United States Patent

Rausch et al.

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[54] **WAVE INTERFERENCE SILENCER**

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[73] Assignee: **General Motors Corporation,** Detroit, Mich.

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[52] **U.S. Cl.** ....**181/36 B,** 181/44, 181/56, 181/63, 181/67

[51] **Int. Cl.** **F01n 1/12,** F01n 7/08

[58] **Field of Search** ....181/36 B, 44–46, 181/48, 56, 59, 66, 67, 63, 54

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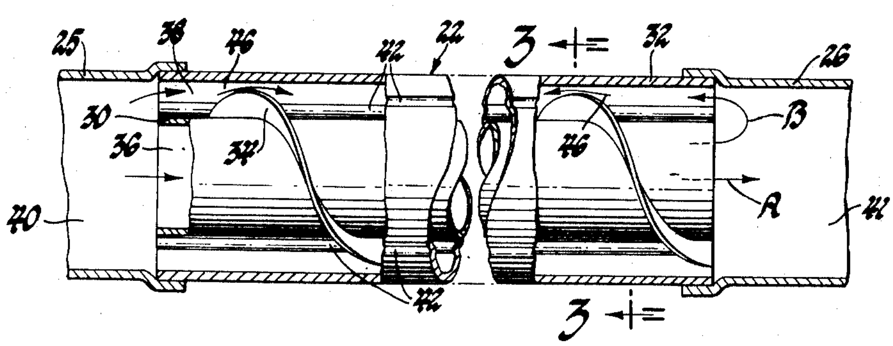
[57] **ABSTRACT**

A wave interference silencer includes a pair of coaxially disposed pipes which are separated by helical baffle and define an axial flow path through the inner pipe and an outer helical flow path between the pipes and the baffle. A plurality of inwardly projecting longitudinal ribs are formed on the outer pipe to radially space the baffle from the outer pipe and define a plurality of frequency independent annular acoustical and fluid leakage paths between adjacent turns of helical flow paths. The leakage paths provide parallel acoustical couplings which are effective upon increasing frequency to attenuate acoustical energy in the helical flow path thereby producing a reduced acoustical pressure at the exit end of the silencer such as the portion of the acoustical energy from the inner pipe reversely flows through the leakage paths for additional attenuation.

5 Claims, 7 Drawing Figures



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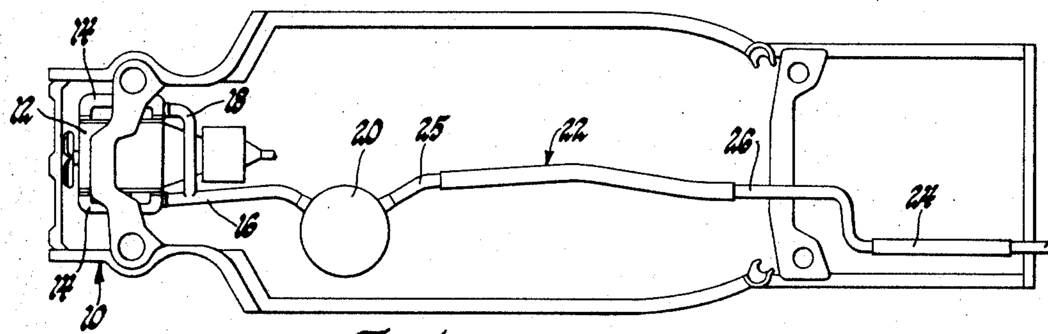

Fig. 1

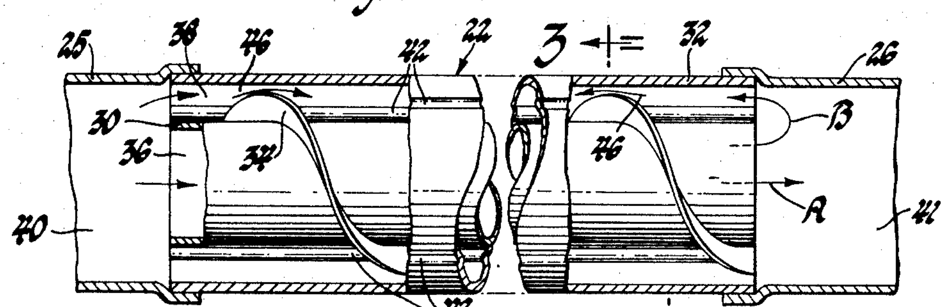

Fig. 2

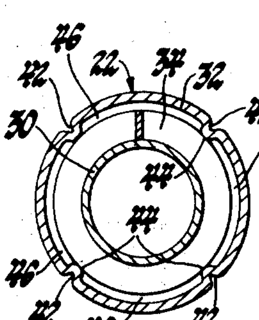

Fig. 3

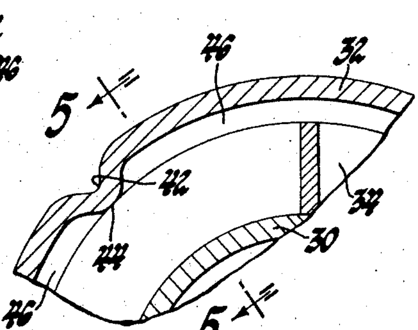

Fig. 4

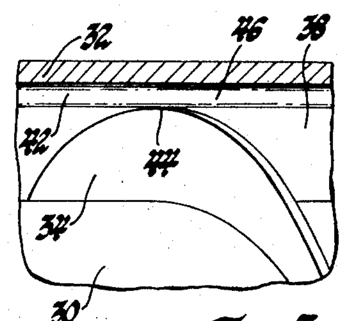

Fig. 5

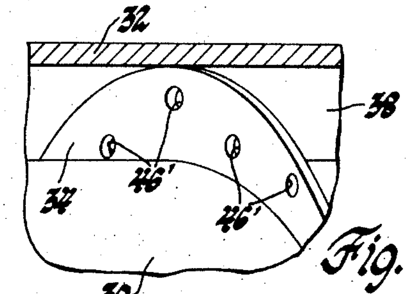

Fig. 6

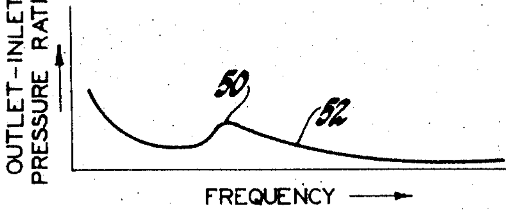

Fig. 7

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WAVE INTERFERENCE SILENCER

The present invention relates to silencing systems and, in particular, to a wave interference attenuating device for a motor vehicle exhaust line that incorporates supplemental acoustical couplings for improving high frequency attenuation.

Exhaust systems using destructive wave interference principles have been proposed for predictably silencing the periodic noises produced by an operating motor vehicle engine throughout the entire noise spectrum of the engine. Generally, such systems employ a plurality of serially connected attenuating sections which are energy and flow compensated to establish actual sound propogational velocities such that the pressure waves traveling separate acoustical paths in the device exit in phase opposition. In this manner, the pressure waves destructively acoustically interfere in a coupling volume adjacent the exit end.

The more prevalent construction for these devices takes the form of a pair of coaxially disposed cylindrical pipes which are separated by a helically wound baffle. The center pipe defines an inner axial flow path and the baffle and the pipes define an outer helical flow path. The ratio of acoustical lengths of the separate flow paths places the pressure waves one-half cycle or 180° out of phase at the exit end of the device at a predetermined fundamental frequency. Inasmuch as these flow paths constitute a conduit having a substantially frequency dependent reactance, the sound energy propagates therethrough without significant attenuation but with a phase shift which increases with frequency. The phase shift will accordingly provide repetitive transmission characteristics.

While such a device will produce limited attenuation on either side of the fundamental frequency and at multiples thereof, normally numerous attenuating sections are needed to obtain complete silencing throughout the noise spectrum, particularly at the lower frequencies. Generally, a pair of relatively long length sections will provide the requisite low frequency attenuation and due to the aforementioned repetitive transmission characteristics also provide nominal high frequency attenuation. However, the engine will normally produce objectionably high frequency noises which are not necessarily multiples of the frequency attenuated by these sections. Therefore, two or three relatively short sections must be provided for these frequencies. Heretofore, five or six such sections have been considered necessary to provide the required silencing.

The present invention, on the other hand, provides an improved construction wherein a low frequency attenuating section contains integrated high frequency silencing means that permit elimination of the conventional high frequency sections. More particularly, the subject attenuating device comprises a pair of concentrically disposed cylindrical pipes which are separated by a helical wound baffle. The center pipe forms an inner axial flow conduit. The space between the pipes and the baffle forms an outer helical flow conduit. In a conventional manner, the baffle establishes a differing acoustical length for the helical flow conduit to place the pressure waves traveling therethrough in phase opposition at the outlet with the pressure waves traveling through the inner conduit thereby attenuating energy at a predetermined low frequency.

High frequency attenuation is integrally provided in the present attenuating section by supplemental acoustical leakage paths in the outer flow conduit. In one form, a plurality of inwardly projecting longitudinal ribs on the outer pipe are radially spaced from the inner surface thereof to establish a circumferential series of annular flow passages between successive turns of the outer flow conduit. The radial spacing, in the order of 0.005 to 0.020 inch, establishes a primarily resistive acoustical impedance which is substantially independent of frequency. In another form, the leakage path comprises small diameter apertures in the baffle. With either construction, sound waves propagating through the outer flow path at low frequencies remain substantially unchanged from the conventional, no leakage constructions. However, as the sound wave frequency increases, the outer conduit reactance increases and forces acoustical energy to flow through the resistive leakage paths. Inasmuch as these paths are relatively independent of the frequency, attenuation and resultant acoustical pressure reduction is provided without an appreciable phase shift. The reduction of sound energy at the outlet of the outer path causes sound energy from the inner conduit to divide into two parts. One part will flow reversely upstream through the helical conduit and the leakage paths providing additional high frequency attenuation. The other part will flow downstream toward the exhaust end of the system. The dividing of the flow energy and loss due to leakage path attenuation greatly improves the high frequency attenuation, particularly above 150 Hz.

The above and other features of the present invention will be apparent to one skilled in the art upon reading the following detailed description, reference being made to the accompanying drawings illustrating a preferred embodiment of the present invention in which:

FIG. **1** is a plan view of a motor vehicle frame having an exhaust system incorporating a wave interference silencer made in accordance with the present invention;

FIG. **2** is an enlarged fragmentary cross sectional view of the silencer shown in FIG. **1**;

FIG. **3** is a view taken along line **3**—**3** of FIG. **2**;

FIG. **4** is an enlarged cross sectional view of a portion of FIG. **3** showing the acoustical and fluid leakage paths between the baffle and the outer pipe;

FIG. **5** is a view taken along line **5**—**5** of FIG. **4**;

FIG. **6** is a view similar to FIG. **5** showing an alternate form of the acoustical and fluid leakage paths; and

FIG. **7** is a graph showing the relationship of the outlet-inlet pressure ratio versus frequency in a device having acoustical and fluid leakage paths.

Referring to FIG. **1**, there is shown a motor vehicle frame **10** on which there is mounted an internal combustion engine **12** having a pair of exhaust conduits **14**. For the illustrated V-type engine, exhaust gases are discharged from the exhaust manifolds to an exhaust line **16** including a crossover pipe **18**. The exhaust line **16** comprises a catalytic convertor **20** and low frequency wave interference silencers or attenuating sections **22, 24**. The convertor **20** and the attenuating section **22, 24** are acoustically coupled in series by coupling conduits **25, 26**. A tailpipe extension **28** is connected to the outlet end of the attenuating section **24** and constitutes the exhaust end of the system.

The above components from the exhaust manifold **14** to the tailpipe extension **28** form an acoustical line through which heated exhaust gases and the resultant pressure waves flow as products of combustion from the engine **12**. During operation, the engine **12** generates pressure pulses and sound waves in the exhaust line **16** having plural frequencies which are a function of engine speed. In the manner hereinafter described, the attenuating sections **22** and **24** provide broad band attenuation throughout the noise spectrum of the engine. The catalytic convertor, which is used in an exhaust emission system, additionally provides an inherent high frequency attenuation and accordingly, supplements the sections **22** and **24**. The convertor **20** is conventional in construction and forms no part of the present invention other than performing the aforementioned high frequency supplemental attenuation.

The attenuating sections **22** and **24** have section lengths for providing attenuation at select low frequencies. For instance, the section **22** is designed to have fundamental attenuating frequency around 25 Hz. The section **24** will be designed to have a fundamental attenuating frequency for around 40 Hz. Additionally, the sections will provide attenuation at multiples of this fundamental frequencies. Except for their lengths, the sections **22, 24** are identical in construction and further details will be given with reference to the attenuating section **22**.

Referring to FIG. **2**, the attenuating section **22** comprises a cylindrical inner pipe **30** and a cylindrical outer pipe **32**, which are separated by a helically wound baffle **34**. The inner pipe **30** forms a flow conduit or axial flow path **36**. The outer pipe **32**, the inner pipe **30**, and the baffle **34** establish an outer flow conduit or helical flow path **38**. The flow paths **36** and **38** are acoustically coupled in parallel between an inlet **40** defined by the coupling **25** at the upstream end of the attenuating section and an outlet **41** defined by the coupling **26** at the downstream end thereof. The flow paths **36** and **38** form acoustical sound transmission paths having reactances substantially the same as a straight pipe. Thus, the reactance, due to the compliance of the flowing gas, increases with frequency. Additionally acoustical energy propagates through the flow paths without appreciable loss, but with phase shift which increases with frequency.

The present invention improves upon this construction by providing supplemental acoustical couplings between adjacent or spaced sections of the outer flow path **38** to provide increased attenuation at the higher frequencies. More particularly, the helical baffle **34** is attached to the inner pipe **30** at its inner diameter and has an outer diameter slightly smaller than the inner diameter of the outer pipe **32**. Four circumferentially spaced inwardly projecting ribs **42** extend longitudinally along the inner surface of the outer pipe **32**. The ribs **42** have apexes **44**, as shown in FIG. **4**, which engage the outer surface of the baffle **34** to radially space the inner surface of the outer pipe **32** from the outer surface of the baffle **34**. The ribs **42** thus establish narrow annular acoustical and fluid leakage paths or passages between the baffle **34** and the outer pipe **32**. Accordingly, parallel acoustical couplings are provided by the leakage paths **46** between adjacent turns of the flow path **38**. Generally, the leakage paths **46** are quite restrictive and in the preferred embodiment the baffle **34** and the pipe **32** have a clearance between 0.005 and 0.020 inch. This sizing will provide a primarily restrictive impedance which is substantially independent of frequency. As shown in FIG. **6**, an alternate form of restrictive leakage can be generated by making apertures or perforations in baffle **34**.

As shown in FIG. **7**, the outlet-inlet pressure ratio in the outer flow path **38** has a low frequency peak **50** around 100 Hz, and a substantially reduced and constant ratio in the higher frequency region **52**. With the above arrangement, the high frequency ratio is in the order of 0.1 to 0.01.

In operation, sound energy will propagate through the exhaust line **16** and through the reactances of the flow paths **36** and **38** substantially unchanged from the no-leakage case at the lower frequencies. In other words, because of the low reactance of the flow path **38**, minimal flow of acoustical energy will be transmitted through the leakage path **46**. However, as the frequency of the pressure waves increases, the reactance in the outer flow path **38** increases. This forces acoustical energy to flow through the leakage paths **46**. Due to the resistive nature of flow passages **46**, this portion of the sound energy is attenuated rather than shifted in phase so as to produce the transmission characteristics illustrated in FIG. **7**. This response establishes a high frequency attenuation contribution of the device, which normally is augmented only at multiples of the fundamental frequency. Inasmuch as the energy at the outlet **41** of the flow path **38** is substantially reduced, an acoustical energy unbalance is established. This unbalance causes a flow through the inner path **36** to be divided in two flows as indicated by arrows A and B. The flow A will flow downstream toward the exhaust outlet. The flow B will flow reversely upstream through the outer flow path **38**. A portion of this flow will then be attenuated by the leakage path **46** as outlined above to thereby provide further high frequency attenuation.

The dividing of the flow and the basic attenuation due to the flow passages **46** provides a substantial and inherent attenuation at frequencies above 150 Hz. Therefore, we have found that broad band attenuation throughout the noise spand of the attenuation can be provided by two basic sections. The first section **22** has a fundamental frequency of around 25 Hz and having a section length of about 64 inches. The second section **24** has a fundamental frequency of around 40 Hz and a section length of about 40 inches length. The high frequency noises from the engine will be attenuated by flow passages with the characteristics outlined above.

Although only two forms of this invention has been shown and described, other forms will be readily apparent to those skilled in the art. Therefore, it is not intended to limit the scope of this invention by the embodiments selected for the purpose of this disclosure but only by the claims which follow.

What is claimed is:

1. A wave interference attenuating device, comprising: means defining first and second flow paths having frequency dependent acoustical reactances, said second flow path having an inlet and an outlet acousti-

cally coupled in parallel with the first flow path, said flow paths having conduits differing in acoustical lengths for placing sound waves traveling therethrough in phase opposition at said outlet; acoustical fluid leakage means between spaced sections of said second flow path having a frequency independent acoustical resistance, said leakage means providing parallel acoustical couplings between said spaced sections for attenuating the sound waves flowing through the second flow path without an appreciable phase shift thereby producing a reduced acoustical pressure at said outlet.

2. In a wave interference attenuating device having a pair of conduits acoustically coupled in parallel between an inlet and an outlet, one of the conduits including baffle means having multiple turns which defines a helical flow path and establishes differing acoustical lengths between the conduits so as to place the sound waves traveling through the conduits in phase opposition at the outlet wherein said helical flow path has a substantially frequency dependent reactance,

the improvement comprising:

acoustical and fluid leakage paths in the baffle means acoustically connecting successive turns of said helical flow path to provide parallel acoustical couplings, said leakage paths having frequency independent acoustical resistances whereby said leakage paths are effective upon increasing frequency to attenuate acoustical energy flowing through said helical flow path thereby producing a reduced acoustical pressure at said outlet such that a portion of the acoustical energy from the other of said conduits flows reversely through said leakage paths for additional attenuation.

3. A broad band wave interference device comprising: a cylindrical inner pipe; a cylindrical outer pipe concentrically disposed with respect to said inner pipe; a helical baffle between said pipes, said baffle being connected to one of said pipes and having a clearance with respect to the other of said pipes, said pipes forming an inner axial flow path through inner pipe and an outer helical flow path between said pipes and said baffle, said helical flow path having an acoustical reactance substantially dependent on frequency; inlet means and outlet means fluidly and acoustically coupling said flow paths in parallel; connecting means structurally connecting said other of said pipes to said baffle and forming annular acoustical leakage passages between spaced sections of said helical flow path, said passages having an acoustical resistance substantially independent of frequency and being effective upon increasing sound wave frequencies for attenuating sound waves flowing through said helical flow path thereby producing reduced acoustical pressure at said outlet means.

4. A broad band wave interference device comprising: a cylindrical inner pipe having an axial flow path; a cylindrical outer pipe concentrically disposed with respect to said inner pipe; a multiple turn helical baffle between said pipes, said baffle being connected to said inner pipe and having a diametral clearance with respect to said outer pipes, said pipes and said baffle forming outer flow paths having multiple turns and a substantially frequency dependent acoustical reactance; an inlet and an outlet fluidly and acoustically coupling said flow paths in parallel; a plurality of longitudinally extending inwardly projecting ribs formed on the outer pipe, said ribs engaging said baffle and forming annular acoustical leakage passages between adjacent turns of said outer flow path, said passages having a substantially frequency independent acoustical resistance and being effective upon increasing frequency to attenuating sound waves flowing through said outer flow path thereby producing reduced acoustical pressure at said outlet such that a portion of the acoustical energy from the axial flow path flows upstream through said leakage paths for additional attenuation.

5. A broad band wave interference silencer comprising: a cylindrical inner pipe; a helical baffle connected to the inner pipe; a cylindrical outer pipe concentrically disposed with respect to said inner pipe and connected to said baffle, said pipes forming an inner axial flow path through inner pipe and an outer helical flow path between said pipes and said baffle, said helical flow path having an acoustical reactance substantially dependent on frequency; inlet means and outlet means fluidly and acoustically coupling said flow paths in parallel; acoustical and fluid leakage apertures formed in said baffle establishing acoustical couplings between spaced sections of said helical flow path having an acoustical resistance substantially independent of frequency, said apertures being effective upon increasing sound wave frequencies for attenuating sound waves flowing through said helical flow path thereby producing reduced acoustical pressure at said outlet means and a pressure imbalance between said flow paths whereby a portion of the acoustical energy from the axial flow path is conducted upstream through said apertures for additional attenuation.

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