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J. HEURICH ET AL

2,773,553

MUFFLER

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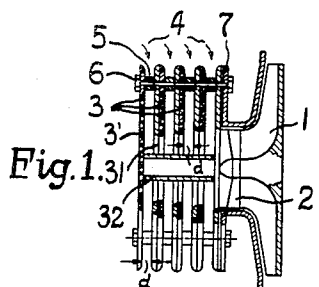


Fig. 1.

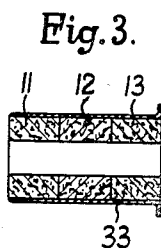


Fig. 3.

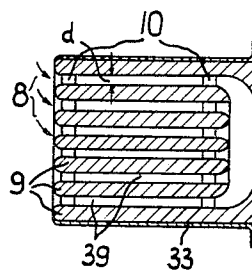


Fig. 2.

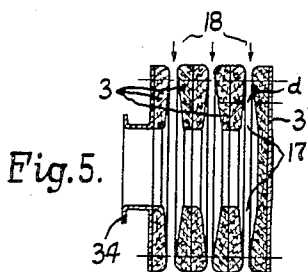


Fig. 5.

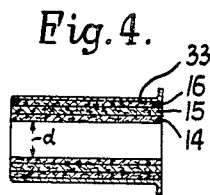


Fig. 4.

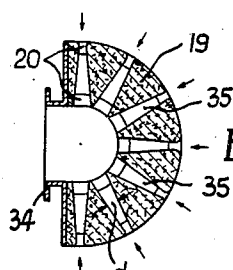


Fig. 6.

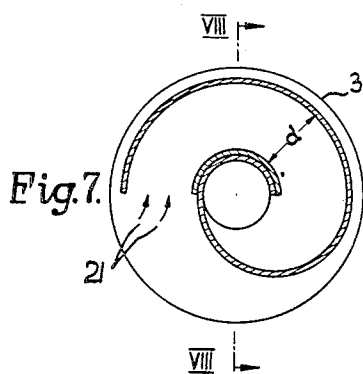


Fig. 7.

Fig. 8.

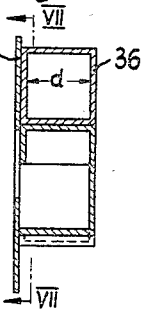


Fig. 9.

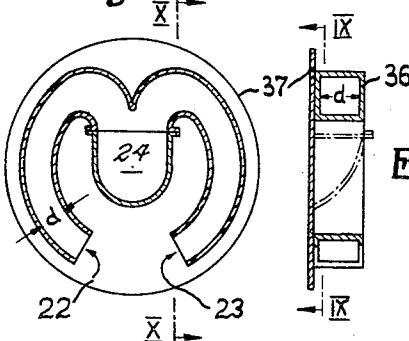


Fig. 10.

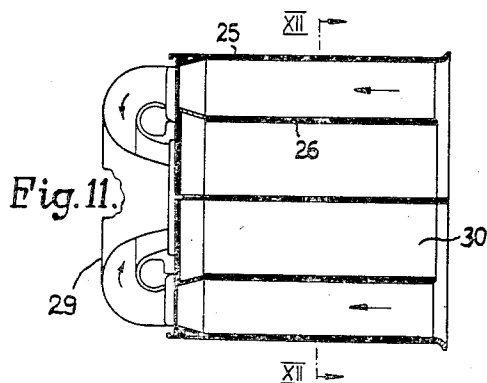


Fig. 11.

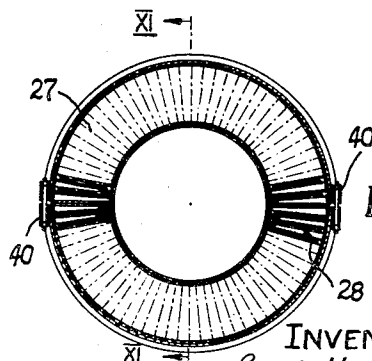


Fig. 12.

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Application February 13, 1953, Serial No. 336,792

26 Claims. (Cl. 181—42)

This invention relates to certain improvements in sound filters of the type known as mufflers or silencers.

It is an object of the invention to provide a muffler which can be used especially for suction or gas intake pipes more particularly of supercharging compressors for internal combustion engines, as well as for pressure or exhaust ducts in jet engines, vacuum cleaners, hot air sprayers and the like and which muffler has very low resistance to flow and yet a very intensive silencing effect, especially in the range of the higher acoustic frequencies of, say, 10^3 to 2×10^4 vibrations per second.

Another object of the invention is to provide a sound muffler of the type referred to which is characterized by a simple construction and low cost of production.

With this and other objects in view, this invention consists in the details of construction, combination of elements and mode of operation hereinafter set forth and then specifically designated by the claims.

In order that those skilled in the art to which this invention appertains may understand how to make and use the same, we will describe its construction in detail, referring by numerals to the accompanying drawings forming part of this application, in which:

Fig. 1 is a side view, partly in an axial section, of a sound muffler or silencer in which the air or gas current is split up into a plurality of partial currents perpendicular to the center axis of the compressor on which the muffler is mounted, by means of parallel plates,

Fig. 2 is an axial section through a silencer in which the several damping channels are concentrically arranged parallel to the axis of the compressor,

Fig. 3 is an enlarged fragmentary view in axial section through a silencing channel which is lined with various sound absorbing substances, the single sound-absorbing materials being arranged in series, one behind the other, in the direction of the flow of the noise producing gases therethrough,

Fig. 4 is a section similar to Fig. 3, but showing a modification in which the several layers are concentrically superposed,

Fig. 5 is an axial section through a muffler with conical cross section of the silencing channels,

Fig. 6 is an axial section through a muffler with hemispherical arrangement of the sound-absorbing materials,

Fig. 7 is a section on line VII—VII of Fig. 8 showing a muffler in which the silencing channel is arranged on a spiral curve,

Fig. 8 is a section on line VIII—VIII of Fig. 7,

Fig. 9 is a section on line IX—IX of Fig. 10, showing a muffler with two silencing channels arranged in a heart-shaped or cardioid form,

Fig. 10 is a section on line X—X of Fig. 9,

Fig. 11 is a section on line XI—XI of Fig. 12, showing a muffler in the form of a hollow cylinder with radially arranged plates, and

Fig. 12 is a section on line XII—XII of Fig. 11.

Similar reference numerals denote similar parts in the different views.

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Referring to Fig. 1, it will be seen that the suction opening or inlet 2 of a supercharging compressor, whose impeller is shown at 1, is connected with a sound muffler comprising several parallel silencing plates 3 and an end plate 3' adapted to split up the suction air into a plurality of partial currents 4 and being lined on both sides with sound absorbing materials in the manner as will be described in greater detail with reference to Figs. 3 and 4. The silencing plates 3 are spaced from each other by spacing members 5, clamped together and secured to the flange 7 of the compressor by threaded bolts 6. The sound absorbing materials are arranged either in series, i. e., in the form of concentric rings, or superposed in layers of different thickness. The single currents 4 are deflected on passage through the channels between the silencing plates 3 to be combined through the annular channels 31 formed between a central tubular member 32 and the inner edges of the annular discs 3, and sucked in by the impeller 1 through inlet 2. The clearance "d" between adjacent discs 3 or 3' is $\frac{1}{4}$ to $\frac{1}{2}$ of the most disturbing acoustic wave length of the noise spectrum produced by the gas current passed through the muffler.

For instance, in case of a frequency of $f=6800$ vibrations per second the clear width between the damping walls will be

$$d = \frac{c}{f \cdot 4} = \frac{340}{6800 \cdot 4} = 0.0125 \text{ m. or } 1.25 \text{ cm.}$$

(c being the velocity of sound=340 m./sec.). It will be understood that an optimum silencing effect will be obtained if the sound absorbing material also has its maximum absorbing capacity at the critical frequency. However, it is difficult to find materials meeting fully with this requirement. However, materials having a relatively uniform absorbing capacity over the entire acoustic range have proved to be suitable, such as glass wool, asbestos wool, mineral wool and slag wool, and more especially, felt slabs. Since the density of the sound absorbing materials is important for a high sound absorbing capacity, compressed sound absorbing slabs are preferred. The thickness of the sound absorbing material is also preferably dimensioned according to the above specified formula, i. e. it should be about $\lambda/4$, or 1.25 cm. in the above mentioned example. Where this value cannot be adhered to for constructional reasons, the length of the sound-absorbing channel has to be increased accordingly.

According to Fig. 2 a plurality of concentric tubular members 9 are accommodated in a flanged casing 33, thus forming concentric channels 39 by which the air or gas current is divided into a plurality of concentric partial currents 8, in order to keep the velocity of flow of the air or gas in each single annular silencing channel at a low figure. These partial currents 8 are directed parallel to each other, and coaxially to the axis of the compressor. The cross section of the single channel may be of any suitable (e. g. circular, polygonal) shape, while the clear or unobstructed width d, i. e. the spacing between the coaxial tubular members 9, again is $\frac{1}{4}$ to $\frac{1}{2}$ of the most disturbing acoustic wave length of the noise spectrum produced by the gas or air current passed through the muffler. The concentric tubular members 9 are spaced from each other and held in position by ribs 10. Again, each silencing channel may be lined with one or more sound absorbing substances according as one or several maxima of the sound spectrum are to be damped.

Figs. 3 and 4 exemplify the arrangement of several sound absorbing materials within a single silencing channel 33. According to Fig. 3, the several absorbing materials 11, 12, 13, consisting, e. g., of felt, slag wool, silicate cotton or cinder hair, metal or wood wool, are

arranged in series behind one another, as viewed in the direction of the suction current or flow gas, while according to Fig. 4 they are superposed in concentric layers 14, 15, 16. In both cases, the silencing materials may be provided in layers of varying thickness. It will be understood that such combinations of silencing materials may be arranged in connection with the arrangements according to Figs. 1 or 2. In case of the arrangement shown in Fig. 1 the silencing layers would take the form of concentric rings (corresponding to the principle of Fig. 3) or of superposed rings (corresponding to the principle of Fig. 4).

Fig. 5 shows a further modification, comprising annular discs 3 and an end disc 3', which may be spaced from each other and clamped together in the same way as shown in Fig. 1, but in order to reflect to some extent the sound issuing from the compressor and thus to increase the silencing effect, the annular, or rather cylindrical, cross sectional surfaces 17 or 18 between the discs 3 and 3' are made substantially equal in size between the outer cylindrical surface 18 and the inner cylindrical surface 17, i. e. the clear or unobstructed width d between the members 3, 3' is tapered from 17 towards 18. A flanged end member 34 which is screw-connected to the discs 3 and 3', in the same way as member 7 in Fig. 1, serves to connect the muffler to the compressor or engine.

In the embodiment as per Fig. 6, the suction channels 35 are radially arranged within a hemispherical silencing body 19, in the form of segment-shaped slots, ribs 20 being provided to support and space the sectors 19 in relation to each other. Again, the channels 35 are tapered in an outward direction to obtain a constant cross section.

In order to accommodate the length of the silencing channel or channels required for satisfactory silencing within a small space, the channels may be convolved or compacted in the form of non-bulky curves as exemplified in Figs. 7 to 10.

Referring at first to Figs. 7 and 8, it will be noted that the damping channel 21 in this case is wound about the axis of the casing 36, 37 in a spiral curve.

In the embodiment as per Figs. 9 and 10, two suction channels 22 and 23 are provided in a cardioid curve. The two suction currents terminate in a collecting chamber 24 from which they are centrally supplied to the casing (not shown) of the compressor which is connected to the flanged member 37. The silencing channels of Figs. 7 to 10 are again lined with sound-absorbing material which is not shown in detail in these figures. Again, "d" is dimensioned as hereinbefore described.

Figs. 11 and 12 show a further modification of our novel silencer which is particularly adapted for axial flow compressors. The silencer is constructed in the form of a hollow cylinder comprising an outer wall 25, an inner wall 26 and a plurality of radially arranged partition walls 27 forming a plurality of axially extending silencing chambers 28 having a clear or unobstructed width d of $\frac{1}{4}$ – $\frac{1}{2}$ of the most disturbing wave length. The muffler is advantageously made of two symmetrical halves which are screwed together in suitable manner, as by screws 40. If desired, the axial flow compressor may be arranged in the inner space 30, the air taking a course as indicated by the arrows, owing to the provision of an end cover 29. Again, the chambers 28 are lined with sound absorbing substances (not shown) in the manner as hereinbefore described.

For the purpose of the present specification, the term "gas" is understood to comprise air, fuel, fuel-air mixtures, exhaust gases and any other fluids in gaseous or vapor form.

While the invention has been described in detail with respect to certain now preferred examples and embodiments of the invention it will be understood by those skilled in the art after understanding the invention that various changes and modifications may be made without departing from the spirit and scope of the invention and

it is intended, therefore, to cover all such changes and modifications in the appended claims.

We claim:

1. A muffler device of the character described for application to a machine to reduce the noise of a gas current developed therein, said noise having a component of a predetermined wave length, comprising a plurality of silencing channels disposed in the line of flow of said gas current through said machine for dividing said noise producing current into a plurality of partial currents, a common duct communicating with all said silencing channels and with said machine, and means for attaching said duct to a noise producing element of said machine for directing said gas current through said common duct and said partial currents through said silencing channels, the internal width of each of said silencing channels being approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined noise component wave length.

2. A muffler device of the character described for a machine developing a noise-producing gas current having a noise component of a predetermined wave length, which comprises a plurality of substantially parallel silencing channels disposed in the line of flow of said gas current through said machine for dividing said noise-producing current into a plurality of substantially parallel directed partial currents, a common duct communicating with all of said silencing channels and with said machine, and means for connecting said duct to said machine for conducting said noise-producing current through said common duct and said silencing channels, each of said silencing channels having a substantially unobstructed internal width of approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length of said noise component.

3. A muffler device of the character described for application to a machine to reduce the noise of a gas current developed therein, said noise having a component of a predetermined wave length, comprising a plurality of silencing channels disposed in the line of flow of said gas current through said machine for dividing said noise producing current into a plurality of partial currents, a common duct communicating with all said silencing channels and with said machine, means for connecting said duct to a noise producing element of said machine for directing said gas current through said common duct and said partial currents through said silencing channels, and a layer of sound absorbing material on the internal walls of said silencing channels, said channels and said sound absorbing layers being dimensioned to provide a substantially unobstructed passage between adjacent said layers of a width approximately from $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length.

4. A muffler device of the character described for application to a machine to reduce the noise of a gas current developed therein, said noise having a component of a predetermined wave length, comprising a plurality of silencing channels disposed in the line of flow of said gas current through said machine for dividing said noise producing current into a plurality of partial currents, a common duct communicating with all said silencing channels and with said machine, means for connecting said duct to a noise producing element of said machine for directing said gas current through said common duct and said partial currents through said silencing channels, and a layer of sound absorbing material on the internal walls of said silencing channels, the thickness of said layer and the width of the unobstructed channel between adjacent said layers both being approximately from $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length.

5. A muffler device of the character described for a machine developing a noise-producing gas current having a plurality of noise components of different wave lengths, which comprises a plurality of silencing channels for dividing said noise-producing current into a plurality of partial currents, a common duct communicating with all of said silencing channels and located between said machine and

5 said channels, means for attaching said duct to said machine for conducting said noise-producing current through said common duct and said silencing channels, and a layer of sound absorbing material lining the internal walls of said silencing channels, the free width of said channels internally of said sound absorbing layers being approximately $\frac{1}{4}$ to $\frac{1}{2}$ the length of one of said plurality of noise wave lengths, and said sound absorbing layer including a plurality of different sound absorbing materials adapted to absorb different ones of said plurality of noise wave lengths.

6. A muffler device of the character described for a machine developing a noise-producing gas current having a plurality of noise components of different wave lengths, which comprises a plurality of silencing channels for dividing said noise-producing current into a plurality of partial currents, a common duct communicating with all of said silencing channels and located between said machine and said channels, means for attaching said duct to said machine for conducting said noise-producing current through said common duct and said silencing channels, and a layer of sound absorbing material lining the internal walls of said silencing channels, the free width of said channels internally of said sound absorbing layers being approximately $\frac{1}{4}$ to $\frac{1}{2}$ the length of one of said plurality of noise wave lengths, and said sound absorbing layer including a plurality of different sound absorbing materials each adapted to absorb a different one of said plurality of noise wave lengths, said different materials being positioned in said sound absorbing layer sequentially along the direction of flow of said partial currents through said silencing channels.

7. A muffler device of the character described for a machine developing a noise-producing gas current having a plurality of noise components of different wave lengths, which comprises a plurality of silencing channels for dividing said noise-producing current into a plurality of partial currents, a common duct communicating with all of said silencing channels and located between said machine and said channels, means for attaching said duct to said machine for conducting said noise-producing current through said common duct and said silencing channels, and a plurality of superimposed layers of sound absorbing material lining the internal walls of said silencing channels, the free width of said channels internally of said sound absorbing layers being approximately $\frac{1}{4}$ to $\frac{1}{2}$ the length of one of said plurality of noise wave lengths, and each of said superimposed layers including a different sound absorbing material adapted for absorbing a different one of said plurality of noise wave lengths.

8. A muffler device of the character described for a machine developing a noise-producing gas current having a noise component of a predetermined wave length, which comprises in combination a plurality of substantially parallel disks, means for spacing said disks apart by a distance approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length forming a plurality of substantially parallel silencing channels disposed in the line of flow of said gas current through said machine for dividing said gas current into a plurality of substantially parallel directed partial currents, a common duct communicating with all said silencing channels, and means for connecting said duct to said machine to conduct said gas current through said duct and said silencing channels.

9. A muffler device according to claim 8 having on the internal walls of said silencing channels a layer of sound absorbing material and in which the unobstructed width of said channels between said sound absorbing layers is approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length.

10. A muffler device according to claim 8 for a machine in which said gas current produces a plurality of noise components having different wave lengths in which said silencing channels are lined with a plurality of different sound absorbing materials adapted to absorb different ones of said plurality of wave lengths and in which

the substantially unobstructed width of said channels between said layers is approximately $\frac{1}{4}$ to $\frac{1}{2}$ the length of one of said plurality of noise component wave lengths.

11. A muffler device of the character described for a machine developing a noise-producing gas current having a noise component of a predetermined wave length, which comprises in combination a plurality of substantially parallel coaxial disks, means for spacing said disks apart by a distance approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length forming a plurality of substantially parallel annular silencing channels for dividing said gas current into a plurality of partial currents, said disks having in the central portions thereof coaxial openings forming a central chamber communicating with each of said silencing channels, a common duct unobstructedly communicating with said chamber, and means connecting said duct to said machine to conduct said gas current through said duct and said silencing channels, the thickness of said disks increasing from said central chamber outwardly.

12. A muffler device according to claim 11 having on the internal walls of said silencing channels a layer of sound absorbing material and in which the unobstructed width of said channels between said sound absorbing layers is approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length.

13. A muffler device according to claim 11 for a machine in which said gas current produces a plurality of noise components having different wave lengths in which said silencing channels are lined with a plurality of different sound absorbing materials adapted to absorb different ones of said plurality of wave lengths and in which the substantially unobstructed width of said channels between said layers is approximately $\frac{1}{4}$ to $\frac{1}{2}$ the length of one of said plurality of noise component wave lengths.

14. A muffler device of the character described for a machine developing a noise-producing gas current having a noise component of a predetermined wave length, comprising a plurality of substantially concentric tubular members of different diameters, means for spacing said tubular members apart by a distance approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length forming a plurality of substantially coaxial annular silencing channels for dividing said gas current into a plurality of substantially parallel directed partial currents, a common duct communicating with all said silencing channels, and means for connecting said common duct to said machine to conduct said gas through said duct and said silencing channels.

15. A muffler device according to claim 14 having on the internal walls of said silencing channels a layer of sound absorbing material and in which the unobstructed width of said channels between said sound absorbing layers is approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length.

16. A muffler device according to claim 14 for a machine in which said gas current produces a plurality of noise components having different wave lengths in which said silencing channels are lined with a plurality of different sound absorbing materials adapted to absorb different ones of said plurality of wave lengths and in which the substantially unobstructed width of said channels between said layers is approximately $\frac{1}{4}$ to $\frac{1}{2}$ the length of one of said plurality of noise component wave lengths.

17. A muffler device of the character described for a machine developing a noise-producing gas current having a noise component of a predetermined wave length, comprising a substantially hemispherical silencing body, a plurality of radial silencing channels in said body for dividing said gas current into a plurality of radially directed partial currents, the unobstructed width of said silencing channels being approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length, a chamber at the central portion of said hemispherical body communicating with all said silencing channels, a common duct communicating with said chamber, and means for connecting said duct to said

machine to conduct said gas current through said duct and said silencing channels.

18. A muffler device according to claim 17 having on the internal walls of said silencing channels a layer of sound absorbing material and in which the unobstructed width of said channels between said sound absorbing layers is approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length.

19. A muffler device according to claim 17 for a machine in which said gas current produces a plurality of noise components having different wave lengths in which said silencing channels are lined with a plurality of different sound absorbing materials adapted to absorb different ones of said plurality of wave lengths and in which the substantially unobstructed width of said channels between said layers is approximately $\frac{1}{4}$ to $\frac{1}{2}$ the length of one of said plurality of noise component wave lengths.

20. A muffler device of the character described for a machine developing a noise-producing gas current having a noise component of a predetermined wave length, comprising a substantially hemispherical silencing body, a plurality of radial silencing channels in said body for dividing said gas current into a plurality of radially directed partial currents, the unobstructed width of said silencing channels being approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length, a central chamber at the central portion of said hemispherical body communicating with all said silencing channels, a common duct communicating with said chamber, and means for connecting said duct to said machine to conduct said gas current through said duct and said silencing channels, the width of said channels decreasing from said central chamber outwardly such that the annular cross section of the inner and outer ends of said channels are substantially equal.

21. A muffler device according to claim 20 having on the internal walls of said silencing channels a layer of sound absorbing material and in which the unobstructed width of said channels between said sound absorbing layers is approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length.

22. A muffler device according to claim 20 for a machine in which said gas current produces a plurality of noise components having different wave lengths in which said silencing channels are lined with a plurality of different sound absorbing materials adapted to absorb different ones of said plurality of wave lengths and in which the substantially unobstructed width of said channels between said layers is approximately $\frac{1}{4}$ to $\frac{1}{2}$ the length of one of said plurality of noise component wave lengths.

23. A muffler device of the character described for a machine developing a noise-producing gas current having a noise component of a predetermined wave length, comprising an outer tubular casing, an inner tubular cas-

ing, substantially concentric with said outer tubular casing, means for mounting said inner casing within said outer casing in spaced relation thereto, means at one end of said casings for conducting said gas current from the space between said casings into said inner casing, a plurality of radial partitions between said inner and outer casings, means for spacing said partitions apart by a distance approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length forming a plurality of substantially parallel silencing channels for dividing said gas current into a plurality of substantially parallel directed partial currents, and means for connecting said inner casing to said machine to conduct said gas current through said inner tubular casing and said silencing channels.

24. A muffler device according to claim 23 having on the internal walls of said silencing channels a layer of sound absorbing material and in which the unobstructed width of said channels between said sound absorbing layers is approximately $\frac{1}{4}$ to $\frac{1}{2}$ said predetermined wave length.

25. A muffler device according to claim 23 for a machine in which said gas current produces a plurality of noise components having different wave lengths in which said silencing channels are lined with a plurality of different sound absorbing materials adapted to absorb different ones of said plurality of wave lengths and in which the substantially unobstructed width of said channels between said layers is approximately $\frac{1}{4}$ to $\frac{1}{2}$ the length of one of said plurality of noise component wave lengths.

26. A muffler device according to claim 23 in which said inner and outer tubular members are each formed of a pair of semicylindrical halves and having means for detachably interconnecting said semicylindrical halves of each said member.

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