Oct. 26, 1943. E. E. WILSON 2,332,543

INTERNAL COMBUSTION ENGINE EXHAUST SYSTEM

Filed Sept. 15, 1932 2 Sheets-Sheet 1

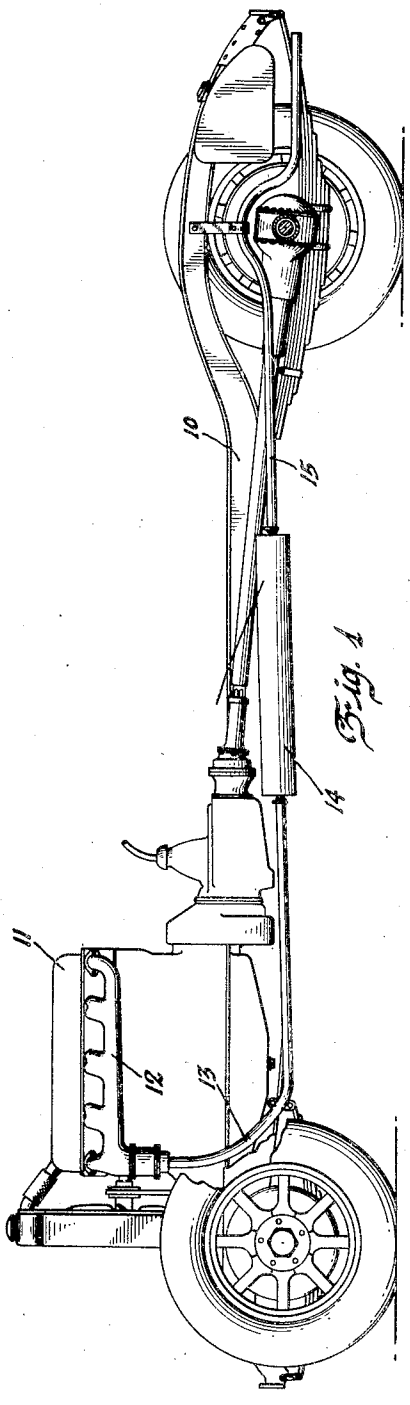


Fig. 1

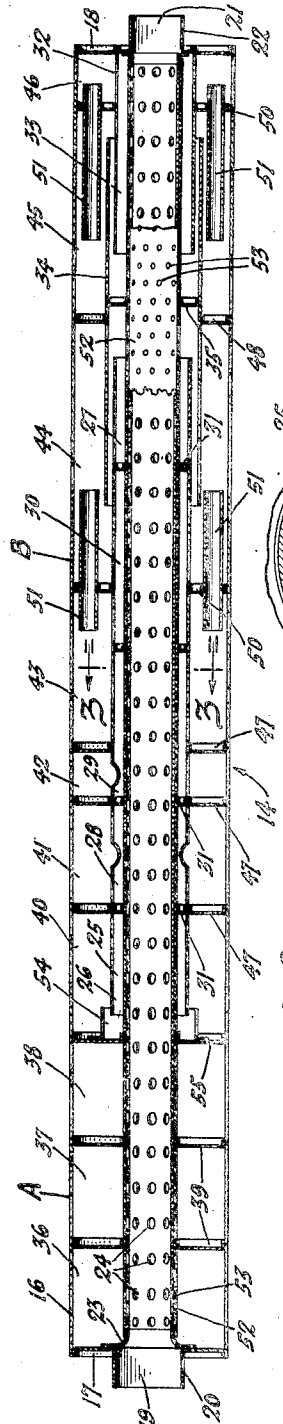


Fig. 2

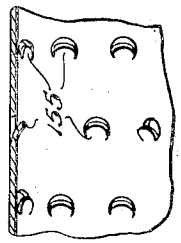


Fig. 9

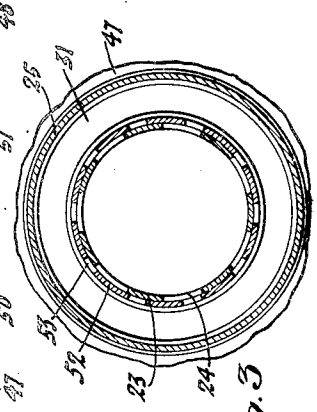


Fig. 5

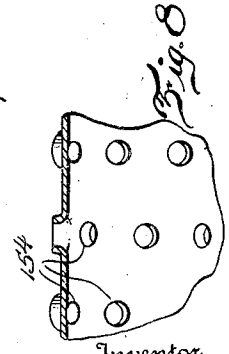


Fig. 8

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INTERNAL COMBUSTION ENGINE EXHAUST SYSTEM

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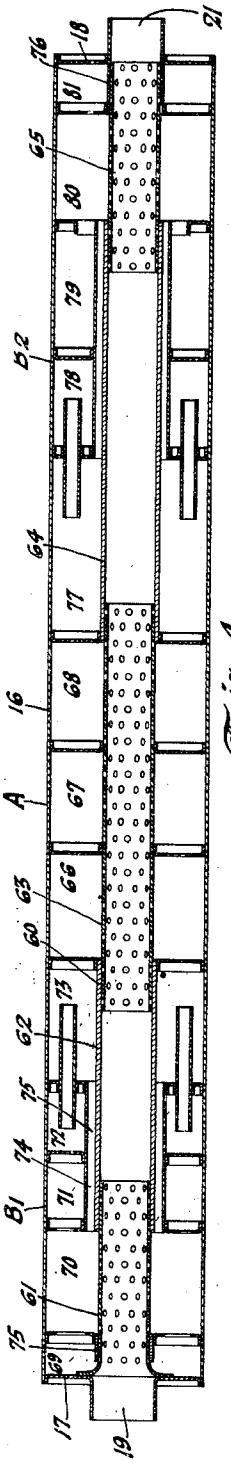


Fig. 4

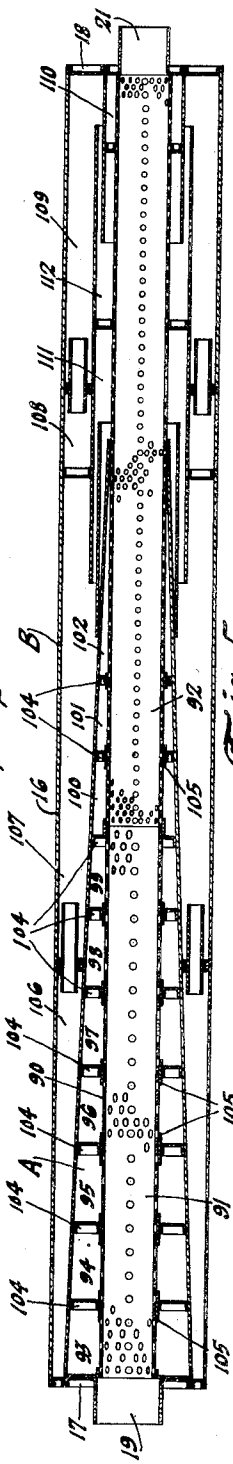


Fig. 5

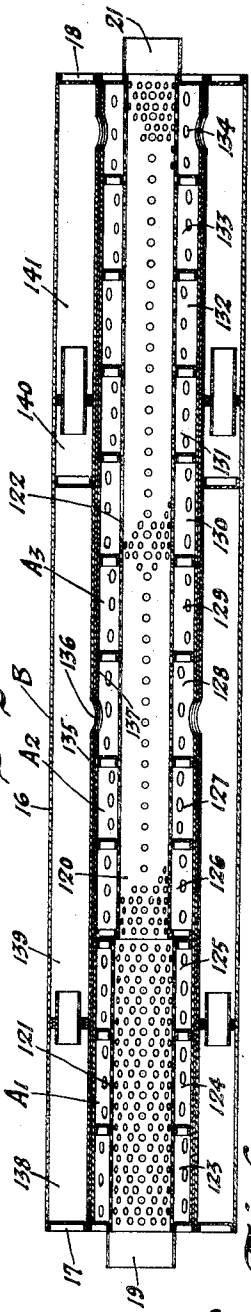


Fig. 6

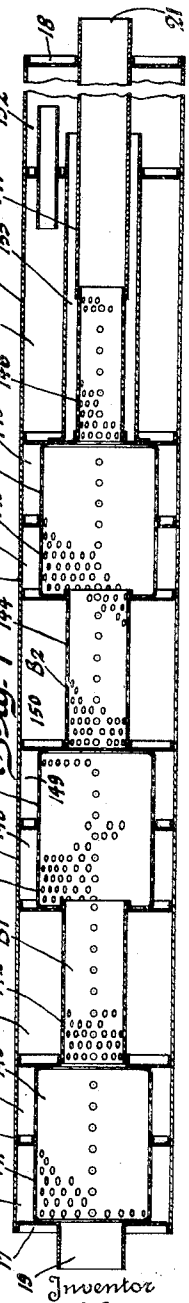


Fig. 7

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INTERNAL COMBUSTION ENGINE EXHAUST SYSTEM

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Application September 15, 1932, Serial No. 633,265

72 Claims. (Cl. 181—48)

This invention relates generally to the attenuation of sound waves, and, particularly, to the attenuation of sound waves in the exhaust systems of internal combustion engines.

In the attenuation of sound waves, I preferably, although not necessarily, employ as the attenuating unit a resonance unit or a plurality of resonance units. The term resonance unit is used herein to mean a resonator or a plurality of resonators which communicate with a sound wave passage or with another resonator or other resonators. As regards the number and arrangement of the constituent resonators, resonance units may be divided into a number of classes. To facilitate the description of the sound wave attenuating units shown in the drawing and hereinafter described, the principal classes will here be named and defined.

A simple resonance unit is one which consists of a single resonator which is adapted to be acoustically connected to a sound wave passage. A multiple-compound resonance unit is one which consists of a plurality of juxtaposed resonators of which each is adapted to be acoustically connected to a sound wave passage independently of the other or the others. A series-compound resonance unit is one which consists of a plurality of acoustically interconnected resonators of which one is adapted to be acoustically connected to a sound wave passage. A complex multiple-compound resonance unit is one which consists of a plurality of juxtaposed simple and/or multiple-compound resonance units and series-compound resonance units of which each is adapted to be acoustically connected to a sound wave passage independently of the other or others.

One of the features of the invention herein disclosed is an improvement in the disposition of sound wave attenuating units with respect to the source of the sound waves on which they operate which is based upon the discovery that the efficiency of sound wave attenuating units, especially resonance units, is markedly affected by their location with respect to the source of the sound waves upon which they operate and of the location at which they operate with maximum efficiency.

Other features of the invention are improvements in the construction of resonance units and the arrangement of resonance units in sound wave attenuating units to the end of increasing the efficiency and minimizing the size of sound wave attenuating units which include resonance units. Among these features are the inclusion in sound wave attenuating units of both multiple-compound and series-compound resonance units which is based upon the discovery that a sound wave attenuating unit in which there are incorporated both a multiple-compound resonance unit and a series-compound resonance unit has decided advantages over a sound wave attenuating unit in which only one of the mentioned types of resonance units is included.

Certain features of the invention herein described and/or illustrated are disclosed in my copending application, Serial No. 470,700, filed July 25, 1930, and this application is, consequently, in part, a continuation of that application.

For a better understanding of the nature and objects of the present invention, reference is made to the following specification in which are described the preferred embodiments of my invention which are illustrated in the accompanying drawings.

In the accompanying drawings:

Figure 1 is a view showing the exhaust system of the internal combustion propelling engine of an automotive vehicle.

Figure 2 is a longitudinal section through the sound wave attenuating unit of the exhaust system illustrated in Figure 1.

Figure 3 is a section taken on the line 3—3 of Figure 2.

Figures 4, 5, 6 and 7 are longitudinal sections through modified forms of sound wave attenuating units.

Figures 8 and 9 are fragmentary views of center tubes for silencers of the type shown in the preceding figures.

In Figure 1 of the drawings there is shown the chassis 10 of an automotive vehicle on which there is installed an internal combustion propelling engine 11 from which the exhaust gases are discharged through an exhaust manifold 12 into the exhaust pipe 13 whence they pass, successively, through the sound wave attenuating unit 14 and the tail pipe 15 to the atmosphere.

The sound wave attenuating unit 14 which is shown in Figures 1, 2, and 3 consists of an imperforate tubular shell 16 whose opposite ends are closed by heads 17 and 18. Through the head 17, there extends an inlet opening 19 surrounded by collar 20 which is adapted to be connected to the exhaust pipe 13 and through the head 18, there extends a discharge opening 21 surrounded by collar 22 which is adapted to be connected to the tail pipe 15. The heads 17 and 18 and the openings 19 and 21 are connected by an unobstructed double-walled tube 23—52 through whose outer wall 52 throughout its length there

extend a multitude of relatively small, closely spaced perforations 53 and through whose inner wall 23 throughout its length there extend a plurality of larger, more distantly spaced perforations 24. An intermediate portion of the tube 23—52 is surrounded by a tube 25 which is imperforate except for the openings connecting chambers 28 and 41 and chambers 29 and 42 and is circumferentially spaced from and secured to the tube 23—52 by annular elements 31 which, in conjunction with the tubes 23—52 and 25, define chambers 28, 29 and 30. The end of the tube 25 nearest the head 17 is surrounded by a tubular element 54 which is circumferentially spaced therefrom and mounted on the annular wall 55 and in conjunction with the adjacent end of the tube 25, the adjacent element 31, the tube 23—52 and the wall 55, defines a chamber 26 which communicates with a chamber 40 through the annular space between the element 54 and the tube 25. The portion of the tube 23—52 adjacent the discharge end of the attenuating unit is surrounded by an imperforate tube 32 which is mounted on the head 18 and circumferentially spaced from the tube 23—52. The juxtaposed ends of the tubes 25 and 32, which are spaced apart axially of the attenuating unit, are surrounded by an imperforate tube 34 which is circumferentially spaced therefrom and is secured to the tube 23—52 by an annular spacer 35. The tube 34, in conjunction with the adjacent end of the tube 25, the adjacent element 31, the spacer 35 and the tube 23—52, defines a chamber 27 which communicates with a chamber 44 through the annular space between the tubes 25 and 34 and, in conjunction with the tube 32, the head 18, the spacer 35 and the tube 23—52, defines a chamber 33 which communicates with a chamber 45 through the annular space between the tubes 32 and 34.

The space between the portions of the tube 23—52 and the shell 16 between the head 17 and the wall 55 is divided into chambers 36, 37 and 38 by imperforate annular walls 39. The space between the tubes 25, 32 and 34 and the shell 16 is divided into annular chambers 40, 41, 42, 43, 44, 45 and 46 by imperforate annular walls 47 and 48 and annular walls 50 through which extend tubular elements 51.

Each of the chambers 28, 29, 30, 36, 37, 38, 40, 41, 42, 43, 44, 45 and 46 constitutes a resonance chamber, and, although the chambers 26, 27 and 33 may be considered as constituting parts of the passages through which the interior of the tube 23—52 is acoustically connected to the chambers 40, 44 and 45, respectively, they are preferably considered as resonance chambers which constitute elements of the series-compound resonance units 26—40, 27—44—43 and 33—45—46, respectively.

An inspection of the drawings will show that, in the sound wave attenuating unit shown in Figures 1, 2 and 3, the several resonance chambers are so arranged that the sound wave attenuating unit may be considered to consist of two sections, A and B. The section A includes the simple resonance units 36, 37 and 38, and constitutes a multiple-compound resonance unit. The section B includes the simple resonance unit 30 and the series-compound resonance units 26—40, 28—41, 29—42, 27—44—43, and 33—45—46. Either section B, as a whole, or the sound wave attenuating unit, as a whole, may be considered as constituting a complex multiple-compound resonance unit.

Each of the several simple and series-compound resonance units referred to above is so proportioned and dimensioned in the manner set forth in my co-pending application previously referred to that it will resonate to and thus attenuate certain of the sound waves which occur in the exhaust of the engine 11. The multiple-compound resonance unit 36—37—38 is so proportioned and dimensioned that it resonates to and thus attenuates other sound waves which occur in the exhaust. The sound waves of the higher frequencies are attenuated, primarily, by the section A, and secondarily by the sound wave attenuating unit as a whole, functioning as a complex multiple-compound resonance unit. The sound waves of the lower frequencies are attenuated by the section B.

While both simple and series-compound resonance units and multiple-compound resonance units attenuate sound waves by resonance, the mechanics of the process by which a multiple-compound resonance unit attenuates sound waves whose frequencies are higher or lower than that to which it is designed to respond appears to differ from the mechanics of the process by which a simple or series-compound resonance unit attenuates such sound waves. Since a simple or series-compound resonance unit will attenuate almost completely sound waves whose frequency or frequencies are equal to that or those to which it is designed to respond and increasingly less completely sound waves of higher and lower frequencies, it is to be expected that a multiple-compound resonance unit of which the several constituent resonance units are similar will almost completely attenuate sound waves whose frequency or frequencies is equal to that to which the several constituent resonance units, individually, are designed to respond and increasingly less completely sound waves of higher and lower frequencies. However, a multiple-compound resonance unit more completely than one of its constituent resonance units attenuates sound waves whose frequencies are higher or lower than that or those to which the several constituent resonance units, individually, are designed to respond and an increase in the number of constituent resonance units increases the completeness with which it attenuates such sound waves. This appears to indicate that complete attenuation by a multiple-compound resonance unit of sound waves whose frequency or frequencies are higher or lower than that or those to which its several constituent resonance units, individually, are designed to respond is the result of successive partial attenuation of such sound waves by each of the several constituent resonance units. While, theoretically, a sound wave of any frequency may be attenuated by any multiple-compound resonance unit of the type under consideration, irrespective of the proportions and dimensions of the several constituent resonance units, if a sufficiently large number of the constituent resonance units are incorporated therein, it is generally preferable, in order to reduce the number of constituent resonance units to a minimum, so to proportion and dimension, in the manner set forth in my copending application previously referred to, the several constituent resonance units that, individually, they will respond to a sound wave whose frequency is substantially the mean of the maximum and minimum frequencies of the sound waves which it is proposed that the multiple-compound resonance unit shall atten-

uate. Of course, under some circumstances, extraneous factors, such as limitations of space, may render it desirable to employ constituent resonance units of proportions and dimensions other than those which will reduce the number of constituent resonance units to a minimum. Irrespective of what considerations dictate the proportions and dimensions of the constituent resonance units, the number of the constituent resonance units is determined by ascertaining, experimentally or otherwise, the number necessary to reduce the intensity of the sound waves, whose frequencies are within the range with which it is proposed that the multiple-compound resonance unit shall deal, to such an extent that they will be unobjectionable.

It is in place here to mention that the efficiency of resonance units which are connected to a sound wave passage through which a fluid travels with considerable velocity and the tendency of the movement of the fluid through the passage to produce a whistling noise are affected by the number, nature and size of the passages by which the constituent resonance chambers are acoustically connected to the passage. In general, it may be stated that in such an installation a resonance unit is most efficient and the tendency of the movement of the fluid through the passage to produce a whistling noise is minimized if the constituent resonance chambers are connected to the passage by relatively closely spaced perforations of relatively small size extending through a relatively thin wall. I consider it preferable that the wall be of no greater thickness than is necessary to give it the necessary mechanical strength, and that the perforations be approximately $\frac{1}{16}$'' in diameter and spaced apart $\frac{1}{8}$'' from center to center. It should, however, be noted that my experiments indicate that relatively closely spaced perforations of relatively small size are preferable, primarily, not because of their size, but because when perforations of relatively small size are employed the air flowing through the sound wave passage disturbs the vibrating body of air in the perforations and the communicating resonance chambers to a lesser extent than when perforations of relatively large size are employed and, consequently, that perforations of relatively large size may be satisfactorily employed if they are so formed and/or arranged that the air flowing through the sound wave passage cannot substantially disturb the vibrating body of air in the resonance unit. This may be accomplished in any one of several ways, e. g. by providing flanges 154 around the perforations, preferably on the outer side of the walls of the sound wave passage, as shown in Figure 8, by providing in the sound wave passage baffles 155 on the upstream sides of the perforations, as shown in Figure 9, by increasing the thickness of the walls of the sound wave passage through which the perforations extend, or in the special manner shown in Figures 1 and 2 of the drawings, viz., by providing a double-walled sound wave passage in which the perforations which extend through the inner wall are of larger diameter and spaced farther apart (e. g., as shown in the drawing $\frac{3}{16}$'' perforations spaced apart $\frac{1}{2}$'' from center to center) than the perforations which extend through the outer wall. It may here be mentioned that, while as shown in the drawing, the perforations in the walls of the sound wave passage are of uniform size and are uniformly spaced, it may be desirable in order to impart to the several resonance units the desired response characteristics to provide perforations of varying size and/or spacing at different points in the length of the sound wave passage.

From what has been said above, it will be understood that each of the several resonance units which constitute the section B of the sound wave attenuating unit illustrated in Figures 1, 2 and 3 will be so proportioned and dimensioned that it will resonate to and thus attenuate sound waves of one or more of the lower frequencies which occur in the exhaust of the engine 11, and that the resonance units which constitute the section A will be so proportioned and dimensioned and of such number that the multiple-compound resonance unit which the section A constitutes, in conjunction with the complex multiple-compound resonance unit which the sound wave attenuating unit as a whole constitutes, will attenuate all of the objectionable sound waves which occur in the exhaust of the engine which are not affected by the resonance units which constitute the section B.

The passage through which the exhaust gases of an internal combustion engine are conducted to the atmosphere constitutes, in effect, a tube which is closed at the source of sound. Since such a tube responds to and reinforces any sound wave whose frequency is equal to the frequency of the fundamental or any harmonic of the tube, the passage by which the exhaust gases of the internal combustion engine are conducted to the atmosphere will reinforce any exhaust noises resulting from sound waves whose frequencies are equal to the frequency of the fundamental or any harmonic of the passage and may therefore render objectionable some noises which would be unobjectionable if the passage were longer or shorter. My experiments have shown that the reinforcing effect can be counterbalanced and the intensity of noises which result from sound waves whose frequencies are equal to the frequency of the fundamental or a harmonic of a tube reduced by providing an expansion chamber at a nodal point (i. e. a point of maximum pressure change) of the fundamental or harmonic, and, furthermore, that such an expansion chamber will function with maximum efficiency if it constitutes an element of a resonance unit which is so proportioned and dimensioned that it will resonate to and thus attenuate sound waves whose frequency equals that of the fundamental or harmonic at whose nodal point it is located. Although it is a matter of common knowledge, it may be well here to point out that the frequency of the fundamental of a tube of the type here under consideration is determined by the formula:

$$f=\frac{v}{4L}$$

in which

f=the frequency
v=the velocity of sound, and
L=the length of the tube.

That the frequencies of the harmonics of such a tube is determined by the formula:

$$f=\frac{v(2n+1)}{4L}$$

in which f, v and L have the same significance as in the preceding formula, and in which n is any integer; that the fundamental has a nodal point at the source of sound; that each of the harmonics has a nodal point at the source of

sound and, in addition, one or more nodal points between the source of sound and the end of the passage toward which the sound waves travel; and that the distance between the successive nodal points of any harmonic is equal to one-half of its wave length which may be determined from its frequency by the following formula:

$$\lambda=\frac{v}{f}$$

in which v and f have the same significance as in the preceding formulas and λ is the wave length.

For the purpose of locating nodal points, the exhaust passage of an internal combustion engine may be considered as a tube closed and having its source of sound at the engine end. While it is not entirely clear in all types of exhaust systems just what point in the exhaust passage should be considered as the closed end of the tube to determine the effective length thereof, it seems that generally the effective length of the tube is approximately equal to the length of the passage from its atmospheric end to the discharge end of the exhaust manifold plus a distance equal to the volume of the exhaust manifold divided by the cross-sectional area of the exhaust pipe. In cases in which the indicated method of determining the effective length of the exhaust system considered as a closed tube is not applicable, the effective length may readily be determined by experiment.

Practically, it is not essential that the expansion chamber be located precisely at a node of the fundamental or a harmonic of the sound wave whose intensity it is intended to reduce. As a matter of fact, I have found that it is more essential, in order to obtain satisfactory results, to avoid locating the chamber too near an antinode than to locate it precisely with respect to a node of the fundamental or a harmonic of the sound wave whose intensity it is intended to reduce.

The sound wave attenuating unit illustrated in Figures 1, 2 and 3 was designed for use in the exhaust system of an internal combustion engine whose characteristics were such that the intensity of the fundamental of the exhaust passage was so inconsiderable that it was unnecessary to reduce it to render the resulting noise unobjectionable. It was, however, found that the intensity of the third and fifth harmonics of the passage was so great that they resulted in objectionable noises and therefore that it was desirable to reduce it. To this end there were provided two resonance units **27—44—43** and **33—45—46** which were so proportioned and dimensioned that one of the principal frequencies of the former equaled that of the third harmonic and one of the principal frequencies of the latter equaled that of the fifth harmonic and so located in the sound wave attenuating unit that they communicated with the interior of the tube **23—52** at points separated by a distance equal to that between one of the nodal points of the third harmonic and the adjacent nodal point of the fifth harmonic and the exhaust system was so designed that when the sound wave attenuating unit was installed therein the resonance units **27—44—43** and **33—45—46** would communicate therewith at a nodal point of the third harmonic and a nodal point of the fifth harmonic, respectively.

In the exhaust system for which the sound wave attenuating unit illustrated in Figures 1, 2 and 3 was designed, it was found that of the higher harmonics the intensity was so inconsiderable that it was unnecessary to reduce it, or that the frequency was so high that resonance units located at random sufficiently reduced their intensity.

To attenuate the sound waves whose frequencies were higher than those of the third and fifth harmonics and yet relatively low, there were provided in addition to the resonance units **27—44—43** and **33—45—46**, the resonance units **26—40**, **28—41**, **29—42** and **30** which were so proportioned and dimensioned that they would respond to and attenuate them. To attenuate the sound waves whose frequencies were higher than those which the resonance units mentioned in the preceding sentence were designed to attenuate, there was provided the resonance unit **36—37—38**.

A few general observations will do much to abbreviate the separate descriptions of the sound wave attenuating units illustrated in Figures 4 to 7 of the drawings. These sound wave attenuating units are in general similar to that illustrated in Figures 1, 2 and 3 of the drawings and each includes a section A (or sections A_1 and A_2 or A_1, A_2 and A_3) which is designed to attenuate sound waves of relatively high frequencies, and a section B (or sections B_1 and B_2 or B_1, B_2 and B_3) which is designed to attenuate sound waves of relatively low frequencies which travel through the sound wave passage of which the unit forms a part. Each of the sections A, A_1, A_2 and A_3 consists of a plurality of resonance units so arranged as to form a multiple-compound resonance unit and each of the sections B, B_1, B_2 and B_3 consists of a plurality of simple and/or series-compound resonance units, of which some or all are intended to be located at nodal points of harmonics of the sound wave passage of which the unit constitutes a part.

The sound wave attenuating units illustrated in Figures 4 to 7 are similar to that illustrated in Figures 1, 2 and 3 and to each other in that each includes an imperforate tubular shell **16** whose opposite ends are closed by heads **17** and **18** through which extend, respectively, intake openings **19** and discharge openings **21** connected by an unobstructed tubular element which constitutes a sound wave passage. In details of construction, the sound wave attenuating units illustrated in Figures 4 to 7 differ considerably from that illustrated in Figures 1, 2 and 3 and from each other, but except when the differences are important or the construction is not readily comprehensible from an examination of the drawings, these details will, for the sake of brevity, not be referred to specifically in the descriptions of the units.

In the sound wave attenuating unit illustrated in Figure 4, the tube **60** which connects the openings **19** and **21** is made in seven partly telescoped sections **61**, **62**, **63**, **64**, **65**, **75** and **76**, of which the sections **61**, **63** and **65** are perforated similarly to the tube **52** which is shown in Figures 2 and 3, i. e., preferably with $\frac{1}{16}$'' perforations spaced apart $\frac{1}{8}$'' from center to center, and of which the sections **62**, **64**, **75** and **76** are imperforate. The section A of the unit includes three resonance chambers **66**, **67** and **68** which surround the section **63** of the tube **60**. The section B_1 includes five resonance chambers **69**, **70**, **71**, **72** and **73** of which the chamber **69** surrounds the section **75**, the chamber **70**, the section **61** and the chambers **71**, **72** and **73**, the section **62** of the tube **60**. The resonance chambers **69**, **70**, **71**,

72 and 73 may be considered to constitute elements of a five-chamber series-compound resonance unit but are more accurately described as elements of a three-chamber unit 69—70—71 which communicates with the sound wave passage through the perforations in the section 61 and a two-chamber unit 73—72 which communicates with the sound wave passage through the chamber 70 and the annular passage 75 between section 62 of the tube 60 and the tubular element 74 which forms the inner wall of the chambers 71 and 72. The section B_2 includes five resonance chambers 77, 78, 79, 80 and 81 which surround the sections 64, 65 and 76 of the tube 60 and are arranged in the same relation thereto as the chambers 73, 72, 71, 70 and 69 are arranged in relation to the sections 62, 61 and 75.

In the sound wave attenuating unit illustrated in Figure 5, the tube 90 which connects the openings 19 and 21 is made of two sections 91 and 92 which abut end to end and are perforated similarly to the tubes 23 and 52, respectively, which are shown in Figures 2 and 3. The section A of the unit includes ten resonance chambers 93, 94, 95, 96, 97, 98, 99, 100, 101 and 102 which surround the section 91 and a portion of the section 92 of the tube 90. By reason of the fact that the outer wall of the chambers 93, 94, 95, 96, 97, 98, 99, 100, 101 and 102 is made of frusto-conical shape and the annular walls 104 which separate the several chambers are spaced apart the same distance axially, the chambers 93, 94, 95, 96, 97, 98, 99, 100 and 101 successively decrease in size and have different response characteristics. The inner edges of the annular walls 104 are connected to the sections 91 and 92 through tubular members 105 which surround the sections and close some of the perforations therein and, consequently, reduce the acoustical conductivity of the passages between the several chambers and the sound wave passage. The section B of the unit includes seven resonance chambers 106, 107, 108, 109, 110, 111 and 112 of which the chambers 106 and 107 surround the section A of the unit, the chambers 110, 111 and 112, a portion of the section 92 of the tube 90 which is not surrounded by the section A and the chambers 108 and 109, the chambers 110, 111 and 112 and the portion of the section 92 between the section A and the head 18. The chambers 106, 107 and 111 constitute elements of a three-chamber series-compound resonance unit which communicates with the sound wave passage through perforations in the section 92 of the tube 90. The chambers 108, 109 and 112 constitute elements of a three-chamber series-compound resonance unit which communicates with the sound wave passage through perforations in the section 92 of the tube 90. The chamber 110 constitutes a simple resonance unit which communicates with the sound wave passage through perforations in the section 92 of the tube 90.

In the sound wave attenuating unit which is shown in Figure 6, the tube 120 which connects the openings 19 and 21 is made in two sections 121 and 122 which abut end to end and are perforated similarly to the tube 52 which is shown in Figures 2 and 3. The sections 121 and 122 differ materially only in that the section 121 is of larger diameter than the section 122. The section A_1 of the unit includes three resonance chambers 123, 124 and 125 which surround the section 121 of the tube 120. The section 122 of the tube 120 is surrounded by nine resonance chambers 126, 127, 128, 129, 130, 131, 132, 133 and 134 of which the chambers 126 and 127 constitute the section A_2 of the unit and the chambers 129, 130, 131, 132 and 133, the section A_3 of the unit. The outer wall of the chambers 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133 and 134 is formed by three coextensive telescopically related tubular members 135, 136 and 137 which are, respectively, a tube of sheet metal which is imperforate except for the openings which extend therethrough and through the members 136 and 137 to connect the chambers 128 and 139 and the chambers 134 and 141, a tube of asbestos or other suitable sound absorbing material, and a tube of sheet metal perforated similarly to the tube 52 shown in Figures 2 and 3 which keeps the tube 136 which constitutes a sound absorbing lining for the chambers 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133 and 134 in place against the inner wall of the tube 135. The section B of the unit includes six resonance chambers 138, 139, 128, 140, 141 and 134 of which the chambers 138, 139, 140 and 141 surround the sections A_1, A_2 and A_3 and the chambers 128 and 134 of the section B which are located, respectively, between the sections A_1 and A_2 and between the section A_2 and the head 18. The chambers 138, 139 and 128 constitute elements of a three-chamber series compound resonance unit which communicates with the sound wave passage through the perforations in the portion of the section 122 of the tube 120 which is surrounded by the chamber 128. The chambers 140, 141 and 134 constitute elements of a three-chamber series-compound resonance unit which communicates with the sound wave passage through the perforations in the portion of the section 122 of the tube 120 which is surrounded by the chamber 134. It will be noted that the passages which connect the chambers 128 and 139 and the chambers 134 and 141 pass through the layer of sound absorbing material 136 which reduces their acoustical conductivity.

In the sound wave attenuating unit which is illustrated in Figure 7, the passage 140 which connects the openings 19 and 21 includes six tubular sections 141, 142, 143, 144, 145 and 146 which are perforated similarly to the tube 52 which is shown in Figures 2 and 3, and an imperforate tubular section 147. The sections 141, 143, and 145 are of considerably larger diameter than the sections 142, 144, 146 and 147 and, in effect, constitute expansion chambers. Each of the sections A_1, A_2 and A_3 of the unit, which surround, respectively, the sections 141, 143 and 145 of the passage 140, consists of two resonance chambers 148 and 149. Each of the sections B_1 and B_2 of the unit, which surround, respectively, the sections 142 and 144 of the passage 140 consists of a single resonance chamber 150 which communicates with the sound wave passage through the perforations in the section of the passage 140 which it surrounds. The section B_3 of the unit consists of two resonance chambers 151 and 152 which constitute elements of a two chamber series-compound resonance unit which surrounds the sections 146 and 147 of the passage 140 and communicates with the sound wave passage through the passage 153 and the perforations in the section 146.

The detailed description hereinbefore given of the construction and operation of the sound wave attenuating unit shown in Figures 1, 2 and 3 is believed to render any further description of the sound wave attenuating units shown in Figures 4 to 7 superfluous.

It will, of course, be understood that although I have illustrated and described my invention as embodied in the exhaust system of an internal combustion engine, the principles upon which it is based and many of the features thereof may be utilized in attenuating sound waves in practically any installation in which they occur in an enclosure or travel through a passage of finite dimensions.

I claim:

1. In a sound wave attenuating unit, a resonance chamber provided with a lining of sound absorbing material.

2. In a sound wave attenuating unit, a generally tube-like element which is of larger diameter at one point in its length than at another and through which extend a plurality of perforations, and a plurality of chambers of which one communicates with the interior of the generally tube-like element through perforations in a portion of larger diameter and another communicates therewith through perforations in a portion of smaller diameter.

3. A resonator which includes a chamber and a neck whose walls are formed in part of sound absorbing material communicating with the chamber.

4. In a through type silencer including three nested shell devices providing two annular spaces therebetween, the inner one of which is in communication with a through passage through the inner shell, sound wave attenuating means for each annular space comprising three or more annular diaphragms therefor to provide two or more sound wave attenuating chambers therein, each of the chambers of the outer space being substantially completely closed except for sound wave ingress holes opening thereinto in one zone only thereof, the ratio of length of the zone covered by these holes to the entire length of the chamber being a relatively small fraction so that the chamber will function to attenuate sound waves therein.

5. A silencer wherein gases and accompanying sound waves flow in the same general direction without substantial retroversion of the gases, and providing a central through passage for the gases, the silencer including three relatively nested shell devices providing two annular spaces therebetween, there being openings in the inner shell device communicating the central through passage through the inner shell with the inner annular space, sound wave attenuating means for each annular space comprising three or more annular diaphragms therefor to provide two or more sound wave attenuating chambers therein, each of the chambers of the outer space being substantially completely closed except for sound wave ingress holes opening thereinto in one zone only thereof, the ratio of the length of the zone covered by these holes to the entire length of the chamber being a relatively small fraction so that the chamber will function to attenuate sound waves therein.

6. A through type silencer in which sound waves are attenuated by resonance, including three nested shells providing two annular spaces therebetween, the inner one of which is in communication with a through passage through the inner shell, sound wave attenuating means for the annular spaces including two nested series of annular diaphragms, each series connecting a pair of shells, the outer series including three or more diaphragms cooperating with the outer pair of shells to form two or more chambers in the outer annular space in which sound waves are attenuated by resonance, each of the chambers having sound wave ingress holes opening thereinto and arranged or bunched in a relatively isolated zone, the ratio of the length of the zone to the entire length of the chamber being a relatively small fraction so that the chamber will function to attenuate sound waves therein by resonance.

7. In a silencer, two telescopically related generally cylindrical shells which are spaced radially one from the other, a generally tube-like member which extends through the inner of the generally cylindrical shells and is spaced radially therefrom, transversely extending walls which with the generally cylindrical shells and the generally tube-like member define a substantially blind compartment between the generally cylindrical shells and a compartment between the inner of the generally cylindrical shells and the generally tube-like member, an opening in the wall of the generally tube-like member which connects its interior with the interior of the inner compartment, and an opening in the wall of the inner generally cylindrical shell which interconnects the inner and outer compartments.

8. The silencer specified by claim 7 plus a partition which subdivides the outer compartment into a plurality of chambers, and an opening in the partition which interconnects the mentioned chambers.

9. The silencer specified by claim 7 plus a partition which subdivides the inner compartment into a plurality of chambers.

10. In a silencer, a generally cylindrical shell, a generally tube-like member which extends through the shell and is spaced therefrom radially, spaced walls which connect the member and the shell, a partition which divides the space between the shell and the member and the walls into a plurality of compartments, a partition which subdivides one of the compartments into a plurality of chambers, openings in the wall of the member which connect its interior with the interior of one of the compartments and with the interior of one of the chambers in the other compartment, and an opening in the last specified partition which interconnects the mentioned chambers.

11. In a silencer, a generally cylindrical shell, a generally tube-like member which extends through the shell and is spaced therefrom radially, spaced walls which connect the member and the shell, a partition which divides the space between the shell and the member and the walls into a plurality of compartments, partitions which subdivide each of the compartments into a plurality of chambers, openings in the wall of the member which connect its interior with the interiors of the several chambers in one of the compartments and with the interior of one of the chambers in the other compartment, and an opening in the partition in the last mentioned compartment which interconnects the chambers therein.

12. The silencer specified by claim 10 in which the last specified partition extends lengthwise of the silencer.

13. The silencer specified by claim 10 in which the last specified partition extends transversely of the silencer and the member is imperforate opposite one of the chambers in the compartment which is subdivided by the last specified partition.

14. In a silencer, a generally cylindrical shell, a generally tube-like member which consists of

two telescopically related elements which are continuously riddled with openings throughout overlapping portions of their lengths extending through the generally cylindrical shell and spaced therefrom radially, and walls which close the ends of the generally cylindrical shell.

15. In a silencer, a generally cylindrical shell, a generally tube-like member which consists of an inner element and an outer element which snugly embraces the inner element extending through the shell and radially spaced therefrom, walls which close the ends of the shell, openings in the inner of the mentioned elements, and smaller openings in the outer of the mentioned elements.

16. In a silencer, a generally cylindrical shell, a generally tube-like member which extends through the generally cylindrical shell and is spaced therefrom radially, walls which with the generally cylindrical shell and the generally tube-like member define a compartment, an opening in the generally tube-like member which connects its interior with the interior of the compartment, and partly telescoped radially spaced generally cylindrical elements of which each is connected to one and terminates short of the other of the mentioned walls surrounding the generally tube-like member and subdividing the compartment into communicating chambers.

17. In a silencer, a generally cylindrical shell, a generally tube-like member in which there is provided an opening and an imperforate section extending through the shell and spaced therefrom radially, walls which with the shell and the member define a compartment, a generally cylindrical element which surrounds and is radially spaced from the imperforate section of the member, and walls which with the shell and the element define a compartment within and spaced from the ends of the mentioned compartment.

18. The combination, with a duct through which sound waves travel, of a silencer which includes a chamber, a passage which connects the duct and the chamber, and sound absorbing material in the chamber, the acoustical conductivity of the passage and the unoccupied volume of the chamber being such and so related that the silencer attenuates by resonance sound waves of a preselected frequency which occur within the duct.

19. In a silencer, a duct, a chamber, a passage by which the chamber is connected to the duct as a side branch, and sound absorbing material which constitutes a lining for a wall of the chamber.

20. In a silencer, a duct, a chamber, a passage by which the chamber is connected to the duct as a side branch, and sound absorbing material which forms a portion of a wall of the passage.

21. In a silencer, a duct, a chamber, a passage by which the chamber is connected to the duct as a side branch, a body of sound absorbing material which constitutes a lining for a wall of the chamber, and a foraminous member which overlies the body of sound absorbing material.

22. The silencer specified by claim 21 plus a second chamber, and a passage which extends through the foraminous member, the body of sound absorbing material and the wall of the first specified chamber and interconnects the chambers.

23. In a silencer, a generally cylindrical shell, a generally tube-like member which is of greater diameter at one point than at another extending through the shell and spaced therefrom radially, walls and partitions which close the ends of the shell and with the shell and the member define a plurality of compartments, an opening in the larger diametered portion of the member which interconnects its interior and the interior of one of the compartments, and an opening in the smaller diametered portion of the member which interconnects its interior and the interior of another of the compartments.

24. In a device of the class described, a tubular shell, heads closing the opposite ends of the shell, a tubular element which extends through the heads and the interior of the shell and through which objectionable sound waves are adapted to travel, a tubular element surrounding a portion of the first mentioned tubular element and surrounded by the tubular shell and dividing the interior of the shell into intercommunicating resonance chambers which constitute elements of a unit which is so proportioned and dimensioned that it responds to and attenuates by resonance objectionable sound waves which travel through the first mentioned tubular element.

25. In apparatus of the class described, a passage through which objectionable sound waves may travel, and a unit, which includes a resonance chamber which surrounds a portion of and communicates with the passage and a second resonance chamber which surrounds a portion of and communicates with the first mentioned resonance chamber—said unit being so tuned that it responds to and attenuates by resonance objectionable sound waves which travel through the passage.

26. The combination, with a duct in which sound waves occur, of a chamber which communicates with the duct at or near a nodal point of the fundamental or one of the lower harmonics of the duct and constitutes an element of a resonator which is so proportioned and dimensioned that it responds to and attenuates by resonance sound waves whose frequency equals that of the fundamental or the harmonic at or near whose nodal point it communicates with the duct.

27. The combination, with a duct in which sound waves occur, of a chamber which communicates with the duct at a distance from an anti-node of the fundamental or one of the harmonics of the duct and constitutes an element of a resonator which is so tuned that it responds to and attenuates by resonance sound waves whose frequency equals that of the fundamental or a harmonic at a distance from whose anti-node it communicates with the duct.

28. In an internal combustion engine, a duct which communicates with a cylinder of the engine, and a silencer which includes a generally cylindrical shell which encircles a portion of the duct, walls which with the duct and the generally cylindrical shell define a chamber, and an opening in the duct which interconnects the chamber and the duct near a nodal point of the fundamental or one of the lower harmonics of the duct and with the chamber constitutes a side branch of the duct, the side branch being so tuned that it responds to and attenuates by resonance sound waves whose frequency equals that of the fundamental or a harmonic near whose nodal point the opening communicates with the duct.

29. In a silencer, a duct, a shell which encircles and is radially spaced from a portion of the duct, walls which with the duct and the shell define a compartment, a partition which sub-

divides the compartment into chambers, relatively small openings in the duct which establish communication between it and one of the chambers, and a larger opening in the partition which establishes communication between the chambers.

30. In a silencer, a duct, a shell which encircles and is radially spaced from a portion of the duct, walls which with the duct and the shell define a compartment, a partition which subdivides the compartment into relatively large and relatively small chambers, relatively small openings in the duct which establish communication between it and the smaller chamber, and a larger opening in the partition which establishes communication between the chambers.

31. The combination, with a duct in which sound waves occur, of means for attenuating sound waves whose frequency is equal to that of a standing wave in the duct whose frequency and intensity are such as to render it objectionable and whose length is so great that a side branch can be connected to the duct so that it does not communicate with the duct at approximately a nodal point of the standing wave including a chamber which communicates with the duct as a side branch at approximately a nodal point of the mentioned standing wave which is located between the ends of the duct.

32. In a silencer, a generally tube-like member which is continuously riddled throughout a portion of its length with opening equivalent in size to circular openings about three-sixteenths of an inch in diameter or smaller, a generally cylindrical shell which encircles the continuously riddled portion of the generally tube-like member and is spaced therefrom radially, walls which close the ends of the space between the continuously riddled portion of the generally tube-like member and the generally cylindrical shell, and a partition which subdivides the space between the continuously riddled portion of the generally tube-like member and the generally cylindrical shell lengthwise into a plurality of substantially blind resonance chambers which constitute side branches of and communicate with the generally tube-like member through the openings in the continuously riddled portion thereof.

33. In a silencer, a generally tube-like member which is continuously riddled throughout a portion of its length with openings equivalent in size to circular openings about three-sixteenths of an inch in diameter or smaller, a generally cylindrical shell which encircles the continuously riddled portion of the generally tube-like member and is spaced therefrom radially, and walls which close the ends of the space between the continuously riddled portion of the generally tube-like member and the generally cylindrical shell and with the generally tube-like member and the generally cylindrical shell define a chamber which with the openings in the generally tube-like member constitute elements of a side branch of the generally tube-like member, the side branch being so tuned that it responds to and attenuates by resonance sound waves of a preselected frequency which occur within the generally tube-like member when the silencer is installed in the environment in which it was designed to be used.

34. In an internal combustion engine, a duct which communicates with a cylinder of the engine and through which gases and sound waves travel while the engine is operating, and means for attenuating sound waves whose frequency is equal to that of a standing wave in the duct whose frequency and intensity are such as to render it objectionable and whose length is so great that a side branch can be connected to the duct so that it does not communicate with the duct at approximately a nodal point of the standing wave including a generally cylindrical shell which encircles a portion of the duct, walls which with the duct and the shell define a chamber, and an opening in the duct which interconnects the chamber and the duct at approximately a nodal point of the mentioned standing wave in the duct.

35. In an internal combustion engine, a duct which communicates with a cylinder of the engine and through which gases and sound waves travel while the engine is operating, and resonators which are arranged as branches of the duct and are so tuned that each responds to and attenuates by resonance the sound waves of a preselected frequency which travel through the duct, each resonator including a compartment and means which establishes restricted communication between the compartment and the duct.

36. In an internal combustion engine, a duct which communicates with a cylinder of the engine and through which gases and sound waves travel while the engine is operating, and similar resonators which are arranged as branches of the duct and are so tuned that each responds to and attenuates by resonance the sound waves of a preselected frequency which travel through the duct, each resonator including a compartment and means which establishes restricted communication between the compartment and the duct.

37. The combination, with a duct through which sound waves travel, of a side branch which communicates with the duct and is so tuned that it responds to and attenuates by resonance sound waves of a preselected frequency which travel through the duct, and sound absorbing material in the side branch.

38. A muffler having an inner shell provided with a plurality of relatively small perforations and having an imperforate portion, an outer imperforate shell having its ends closed, an intermediate shell, said inner and intermediate shells forming between them an inner chamber and said intermediate and outer shells forming between them an outer chamber, said inner chamber receiving gases and sound waves from said inner shell through said perforations, and a passage connecting said inner and outer chambers and formed partly by said imperforate portion of the inner shell, for conducting gases and sound waves from said inner chamber to said outer chamber.

39. A muffler comprising an inner perforate shell forming a passage for gases through the muffler, an outer shell and an intermediate shell surrounding said inner shell and arranged in spaced relation to said inner shell and to each other, heads closing the ends of said outer shell and having openings communicating with said inner shell, baffles forming inner chambers between said inner and intermediate shells and into which sound waves pass through the perforations of said inner shell, and channels between said inner and intermediate shells for conducting sound waves from said inner shell to the space between said outer and intermediate shells.

40. In the art of attenuating sounds in a duct, the expedient which consists of determining the location of antinodes of a standing wave in the duct whose frequency and intensity render it objectionable and connecting a side branch to the duct at a distance from the antinodes of the standing wave.

41. The combination, with a duct through which gases and sound waves travel, of resonators which are arranged as branches of the duct and are so tuned that each resopnds to and attenuates by resonance the sound waves of a preselected frequency which travel through the duct, each resonator including a compartment and means which establishes restricted communication between the compartment and the duct.

42. The combination, with a duct through which gases and sound waves of different frequencies travel, of resonators which are arranged as branches of the duct and are so tuned that each responds to and attenuates by resonance the sound waves of a preselected frequency which travel through the duct, the resonators including a wall which encircles and is radially spaced from a portion of the duct, walls which with the first specified wall and the duct define a compartment, and partition which subdivides the compartment lengthwise into two chambers which independently communicate restrictedly with the duct.

43. The combination, with a passage or other enclosure within which sound waves occur, of a side branch which includes a compartment which communicates with the enclosure and a plurality of compartments which communicate with the first-mentioned compartment independently of the enclosure and of each other and is so proportioned and dimensioned that it responds to and attenuates by resonance objectionable sound waves which occur within the enclosure.

44. The combination, with a conduit in which sound waves occur, of a casing which surrounds a portion of the conduit and defines therewith a compartment, means subdividing the compartment into a plurality of chambers of which two communicate with a third independently of the conduit and of each other, and a passage connecting the third chamber with the conduit—the chambers and the passages being so proportioned and dimensioned that they respond to and attenuate by resonance objectionable sound waves which occur within the conduit.

45. In a silencer, a duct through which gases may travel, a wall which encircles and is radially spaced from a portion of the duct, walls which with the first-specified wall and the duct define a compartment which encircles the duct and is without the path of travel of gases through the silencer, partitions which subdivide the compartment lengthwise into chambers, an orifice which communicates with the duct and enters the intermediate chamber of a series of three chambers, and orifices in the partitions between the intermediate and the end chambers in the series of three which establish communication between the intermediate and end chambers.

46. In a silencer, a duct through which gases may travel, a wall which encircles and is radially spaced from a portion of the duct, walls which with the duct and the first-specified wall define a compartment which encircles the duct and is without the path of travel of gases through the silencer, partitions which subdivide the compartment lengthwise into chambers of which two communicate with the duct independently of each other, and an orifice in one of the partitions which establishes communication between one of the mentioned chambers and a third chamber.

47. In a silencer through which gases travel and sound waves enter: means defining a duct and a chamber which communicates with the duct as a side branch; the mentioned means being so arranged that the gases travel through the duct substantially to the exclusion of the chamber; and means within the duct in advance of the means of communication between the chamber and the duct to deflect gases away from the means of communication and thus avert the production of a whistling noise.

48. In a silencer through which gases travel and sound waves enter: means defining a tube of which a portion is riddled with perforations and a chamber which encircles a portion of the tube which is riddled with perforations and communicates as a side branch with the tube through the perforations in the portion of it it encircles; the mentioned means being so arranged that the gases travel through the tube substantially to the exclusion of the chamber; and means within the tube in advance of each of the perforations to deflect gases away from the perforations and thus avert the production of a whistling noise.

49. In a silencer through which gases travel and sound waves enter: means defining a duct and a chamber which communicates with the duct as a side branch; the mentioned means being so arranged that the gases travel through the duct substantially to the exclusion of the chamber and the side branch being so tuned that it responds to and attenuates by resonance sound waves of a preselected frequency which travel through the duct; and means within the duct in advance of the means of communication between the chamber and the duct to deflect gases away from the means of communication and thus avert the production of a whistling noise.

50. In a silencer, a duct through which travel objectionable sound waves of different frequencies, and means for attenuating a preselected group of objectionable sound waves of different frequencies which travel through the duct, including a plurality of similar chambers disposed successively lengthwise of the duct and independently connected thereto—each of the chambers being so tuned that its natural frequency is higher than the frequency of the sound waves of lowest frequency in the group and lower than the frequency of the sound waves of highest frequency in the group.

51. The combination, with a duct through which travel sound waves of objectionable intensity whose frequency is equal to that of a standing wave in the duct, of means for attenuating the mentioned sound waves including a chamber which communicates with the duct at a side branch at a distance from the antinodes of the mentioned standing wave.

52. The combination, with a duct through which travel sound waves of objectionable intensity whose frequency is equal to that of a standing wave in the duct, of means for attenuating the mentioned sound waves including a chamber which encircles the duct and communicates with it as a side branch at approximately a nodal point of the mentioned standing wave.

53. The combination, with a duct through which travel sound waves of objectionable intensity whose frequency is equal to that of a standing wave in the duct, of means for attenuating the mentioned sound waves including a chamber which communicates with the duct as a side branch at a distance from the antinodes of the mentioned standing wave and constitutes an element of a resonator which is so tuned that it responds to and attenuates by resonance sound

waves whose frequency equals that of the mentioned sound waves.

54. The combination, with a duct through which travel sound waves of objectionable intensity whose frequency is equal to that of a standing wave in the duct, of means for attenuating the mentioned sound waves including a chamber which encircles the duct and communicates with it as a side branch at approximately a nodal point of the mentioned standing wave and constitutes an element of a resonator which is so tuned that it responds to and attenuates by resonance sound waves whose frequency equals that of the mentioned sound waves.

55. In a silencer, a duct through which travel objectionable sound waves of different frequencies, and means for attenuating a preselected group of objectionable sound waves of different frequencies which travel through the duct, including a plurality of similar side branches disposed successively lengthwise of the duct and independently connected thereto—each of the side branches including a chamber which encircles the duct and is restrictedly connected thereto and being so tuned that its natural frequency is higher than the frequency of the sound waves of lowest frequency in the group and lower than the frequency of the sound waves of highest frequency in the group.

56. In a silencer, a duct, a chamber connected to the duct as a side branch, and sound absorbing material with a passage in it into which open voids in the sound absorbing material and through which the chamber communicates with the duct.

57. In a silencer, a shell, a tube which extends through the shell and with it defines a chamber which encircles the tube and is connected with it as a side branch, and a body of sound absorbing material with passages in it into which open voids in the sound absorbing material and through which the chamber communicates with the tube.

58. In a silencer, a duct, a chamber connected to the duct as a side branch, a chamber connected to the first specified chamber, and sound absorbing material with a passage in it into which open voids in the sound absorbing material and through which the second mentioned chamber communicates with the first specified chamber.

59. In a silencer, a duct, a chamber connected to the duct as a side branch, a chamber connected to the first specified chamber, and sound absorbing material in the first specified chamber with a passage in it into which open voids in the sound absorbing material and through which the second specified chamber communicates with the first specified chamber.

60. In a silencer, a tube which is riddled throughout a portion of its length with openings equivalent in size to circular openings about one-sixteenth of an inch in diameter, and a shell which encircles the riddled portion of the tube and with it defines a chamber which encircles the tube and communicates with it as a side branch through the openings in the tube, the acoustical conductivity of the openings and the volume of the chamber being so correlated that the side branch which the openings and the chamber constitute will respond to and attenuate by resonance sound waves of a preselected frequency which enter the tube.

61. In a silencer, a tube which is riddled throughout a portion of its length with openings equivalent in size to circular openings about one-sixteenth of an inch in diameter, a shell which encircles the riddled portion of the tube and with it defines a compartment which encircles the tube, and a partition which subdivides the compartment lengthwise into chambers which communicate with the tube as side branches through the openings in the tube.

62. In a silencer, a tube through which gases travel and into which sound waves enter, a shell which encircles a portion of the tube and with it defines a chamber which encircles the tube, perforations in the tube through which the chamber communicates with the tube, and flanges around the perforations on the outside of the tube.

63. In a silencer, a tubular structure which includes a tubular member and a tubular member of which one end extends into but is radially spaced from the first specified tubular member, a shell which encircles the tubular structure and with it defines a compartment which encircles the tubular structure, a partition which subdivides the compartment lengthwise into two chambers of which one communicates with the interior of the tubular structure through the aperture between the tubular members, and a perforation in the second specified tubular member through which the other of the chambers communicates with the interior of the tubular structure.

64. In a silencer, a duct, a resonator which is so tuned that it responds to and attenuates by resonance sound waves of a preselected frequency which enter the duct, the resonator including a chamber which encircles the duct and communicates with it as a side branch, another resonator which is so tuned that it responds to and attenuates by resonance sound waves of a preselected frequency which enter the duct, the last specified resonator including a chamber which encircles the first specific chamber and communicates with the duct as a side branch.

65. In a silencer, a tubular member, a shell which encircles the tubular member and with it defines a compartment which encircles the tubular member, a partition which subdivides the compartment lengthwise into a plurality of compartments which communicate with the tubular member as side branches, and a partition which encircles the tubular member and is encircled by the shell and subdivides one of the last mentioned compartments into inner and outer chambers.

66. In a silencer, a tubular member which has perforations in it, a tubular member which encircles and is radially spaced from the first specified tubular member and has in it between its ends an aperture, a tubular member which encircles and is radially spaced from the second specified tubular member and overlies the aperture and portions of the second specified tubular member on each side of it, a shell which encircles and is radially spaced from the specified tubular members and constitutes a wall of a compartment which encircles the tubular members, and a partition which extends between the third specified tubular member and the shell and subdivides the compartment lengthwise into two chambers which communicate with the interior of the first specified tubular member through the aperture between the third and second specified tubular members, the aperture in the second specified tubular member, the aperture between the second and first specified tubular members and the perforations in the first specified tubular member.

67. In a silencer, a duct, a chamber which is connected to the duct, and two chambers which

are connected to the first specified chamber independently of each other.

68. In a silencer, a tubular member, a tubular member which encircles and is radially spaced from an intermediate portion of the first specified tubular member, a shell which encircles and is radially spaced from the tubular members, walls disposed beyond the ends of the second specified tubular member which with the shell and the first specified tubular member define a compartment which encircles the tubular members, a partition which subdivides lengthwise the aperture between the tubular members, and a partition which extends between the second specified tubular member and the shell and subdivides the compartment lengthwise into two chambers of which each communicates with the interior of the first specified tubular member through one of the subdivisions of the aperture between the tubular members.

69. In a silencer, a tubular member, a tubular member which encircles and is radially spaced from the first specified tubular member, a shell which encircles and is radially spaced from the tubular members and with them defines a compartment which encircles the tubular members, a partition which extends between the second specified tubular member and the shell and subdivides the compartment lengthwise into two chambers of which each communicates with the interior of the first specified tubular member through the aperture between the tubular members.

70. In a silencer, a tubular member, another tubular member which encircles and is radially spaced from a portion of the first-specified tubular member, a shell which encircles the tubular members and with them defines a substantially blind compartment, and a partition which encircles the first-specified tubular member but not the second-specified tubular member and subdivides the compartment into two chambers of which one communicates with the tubular members as a side branch through the aperture between the tubular members.

71. In a silencer, a tubular member, another tubular member which encircles and is radially spaced from a portion of the first-specified tubular member, a shell which encircles the tubular members and with them defines a substantially blind compartment, and partitions which encircle, respectively, the second-specified tubular member and the first-specified tubular member but not the second-specified tubular member and subdivide the compartment lengthwise into three chambers of which the intermediate chamber communicates with the tubular members as a side branch through the aperture between the tubular members.

72. In a silencer, a duct through which gases may travel, a wall which encircles and is radially spaced from a portion of the duct, walls which with the first-specified wall and the duct define a compartment which encircles the duct and is without the path of travel of gases through the silencer, partitions which subdivide the compartment lengthwise into chambers, an orifice which communicates with the duct and enters the end chamber of a series of three chambers, an orifice in the partition between the mentioned end chamber and the intermediate chamber in the series of three which establishes communication between the two chambers, and a duct which establishes communication between the two end chambers in the series of three.

ERNEST E. WILSON.

CERTIFICATE OF CORRECTION.

Patent No.2,332,543. October 26, 1943.

ERNEST E. WILSON.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 9, first column, line 4, claim 41, for "resopnds" read --responds--; and second column, line 55, claim 51, for "at" read --as--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 4th day of January, A. D. 1944.

Henry Van Arsdale,
Acting Commissioner of Patents.

(Seal)

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