

Dec. 16, 1958

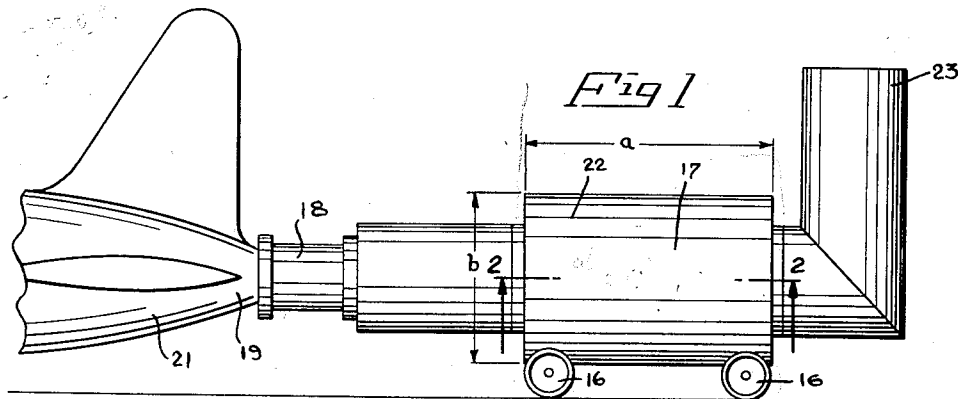
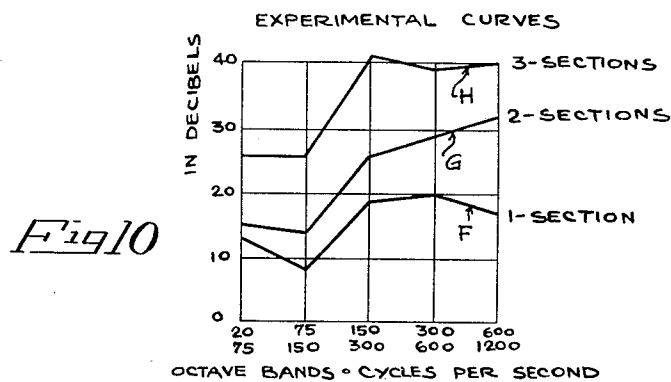
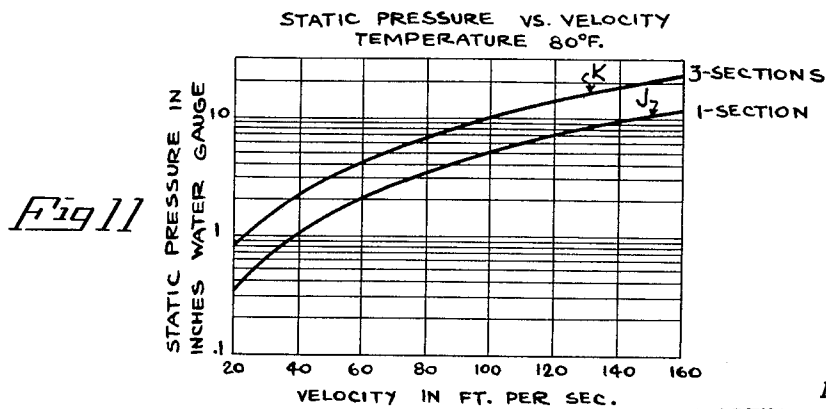
M. HIRSCHORN

2,864,455

EXHAUST NOISE ABATEMENT APPARATUS

Filed April 13, 1955

4 Sheets-Sheet 1



INVENTOR:
MARTIN HIRSCHORN,
BY
Freeman & Marwood
HIS AGENTS.

Dec. 16, 1958

M. HIRSCHORN

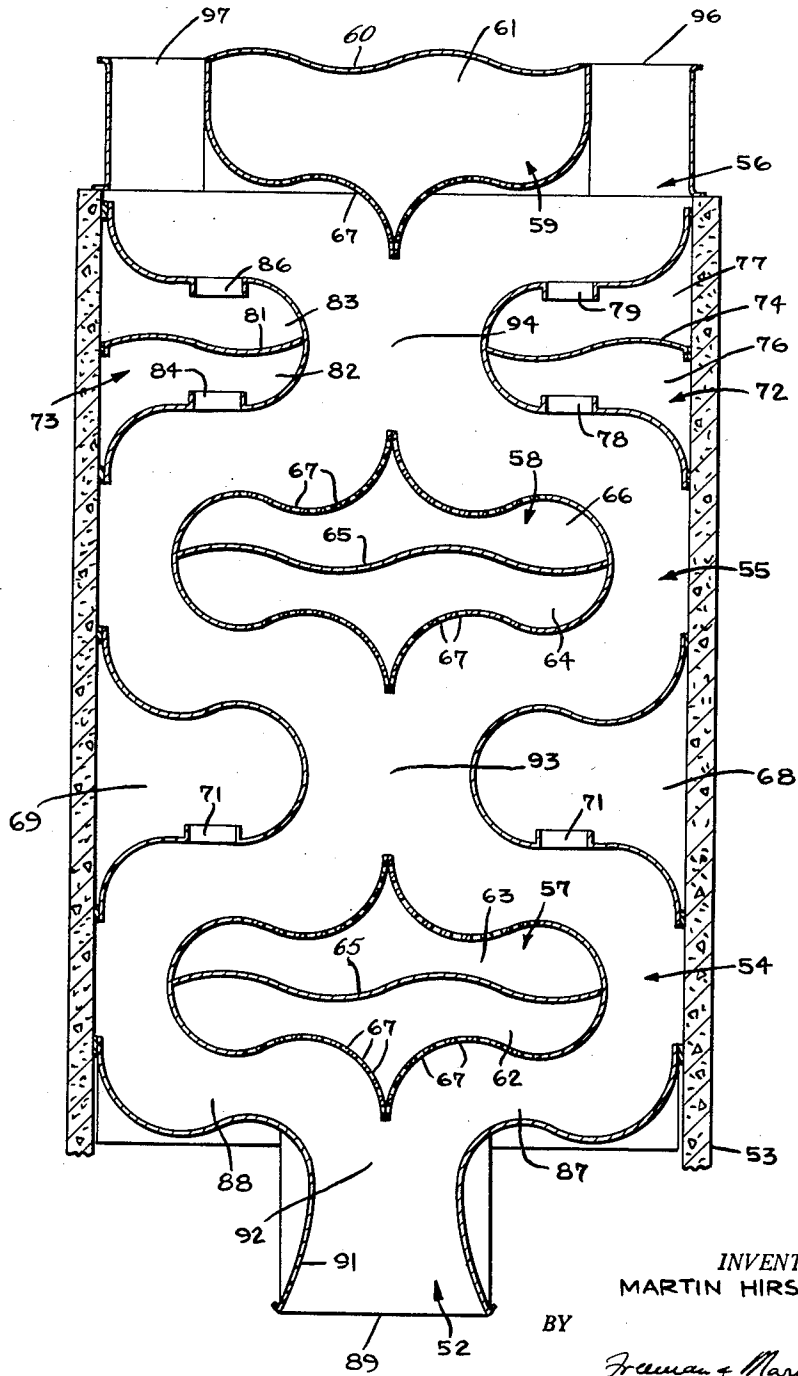
2,864,455

EXHAUST NOISE ABATEMENT APPARATUS

Filed April 13, 1955

4 Sheets-Sheet 3

Fig 6



INVENTOR:
MARTIN HIRSCHORN,
BY
Freeman & Marwood,
HIS AGENTS.

Dec. 16, 1958

M. HIRSCHORN

2,864,455

EXHAUST NOISE ABATEMENT APPARATUS

Filed April 13, 1955

4 Sheets-Sheet 4

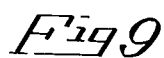
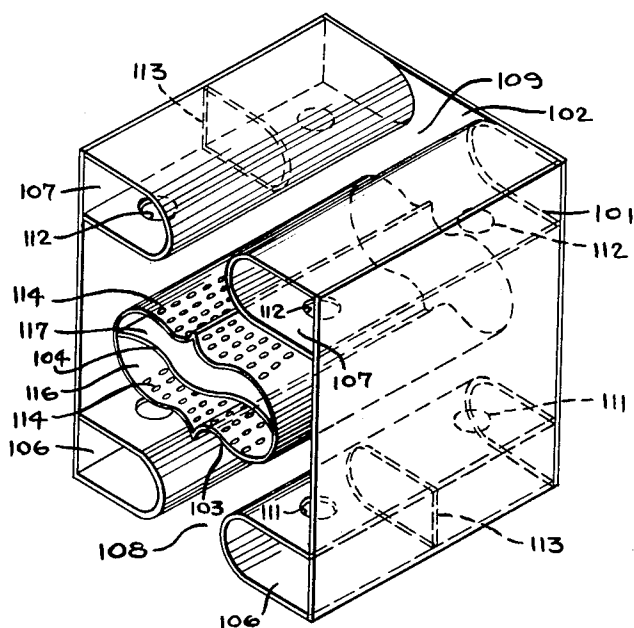
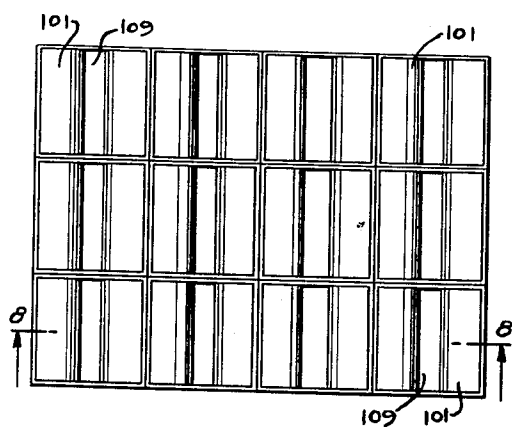
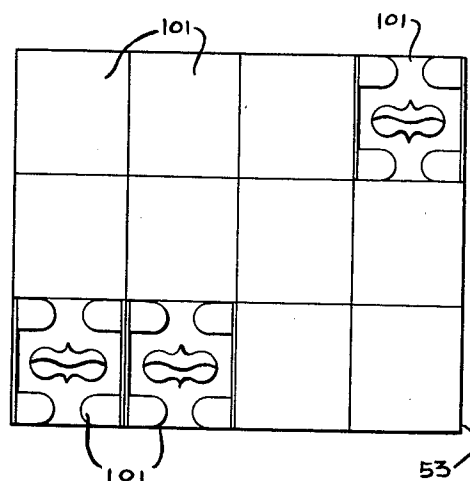


Fig 7

Fig 8

INVENTOR:
MARTIN HIRSCHORN,
BY
Freeman & Marmon,
HIS AGENTS.

1

2,864,455

EXHAUST NOISE ABATEMENT APPARATUS

Martin Hirschorn, New York, N. Y.

Application April 13, 1955, Serial No. 501,100

8 Claims. (Cl. 181—59)

The invention relates to noise abatement, and relates more particularly to acoustic filtering for reducing the noise level of gaseous streams. Still more particularly, the invention relates to acoustic filtering specially for use in connection with jet aircraft for instance on airports.

The main reason for development of the invention was to find an answer to the difficult maintenance problem posed to aircraft manufacturers and users by conventional silencing systems installed in test cell exhaust stacks or ground mufflers.

The acoustic attenuation characteristics of conventional silencing systems depended on the use of sound absorbing material such as fibrous materials, stainless steel shavings, or copperwool. Though good acoustic performance results can be obtained with such materials, they deteriorate rapidly under operating conditions involving elevated temperatures and high velocities. Even though these conventional silencing systems were built with sufficient cooling and open area to provide calculated temperatures and velocities which were proven by laboratory tests to be satisfactory for such silencers, they need to be replaced in many cases within one year. The reasons for this are two-fold. First, velocity distribution is seldom uniform and much higher values than calculated are actually experienced locally. Second, the low operating temperatures are often exceeded by failure of the water cooling system, fires and other abnormally hot operation.

The maintenance problem in splitter type installations has been further aggravated by the common practice of enclosing the loose filler materials in a light weight sheet metal casing varying in thickness from 18 to 14 gauge. As the trend is towards engines with higher mass flows, still higher velocities are to be expected in existing test cells; this would render the maintenance problem with conventional silencers still more acute.

The instant invention represents a departure from conventional silencing systems and provides for an all-plate silencer with high acoustic attenuation characteristics, and with a lifetime that is only limited by the normal wear and tear of heavy plate material.

It is among the objects of the invention to provide silencing apparatus, as well as methods, for effectively attenuating noise in gaseous streams, such as air streams. It is a further object of the invention to provide such apparatus which may be made entirely of plate material and dispenses with all conventional sound absorbing material. It is a still further object of the invention to provide for apparatus of greatly differing dimensions, some large enough for stacks for test cells, others smaller for use with rockets and jets, and still others small enough for automobile exhausts, though all based on one principle disclosed below.

With the above and other objects of the invention in view, the invention consists in the novel methods, constructions, arrangements and combination of various devices, elements and parts, as set forth in the claims hereof, certain embodiments of the same being illus-

2

trated in the accompanying drawings and described in the specification.

In the accompanying drawing,

Fig. 1 is a vertical elevational schematic view showing a silencer apparatus in accordance with an embodiment of the invention illustrating an attachment to the exhaust of a jet aircraft;

Fig. 2 is a large scale sectional view taken on line 2—2 of Fig. 1;

Fig. 3 is a sectional view taken on line 3—3 of Fig. 2;

Fig. 4 is a vertical elevational view similar to Fig. 1, but showing a modification;

Fig. 5 is a vertical elevational schematic view similar to Figs. 1 and 4, but showing a further modification;

Fig. 6 is a sectional view of a silencer in accordance with a modified embodiment, applied to the stack of a stationary test cell;

Fig. 7 is a plan view of an embodiment similar to that of Fig. 6, but including a further modification;

Fig. 8 is a schematic fragmentary elevational view, partly in section taken on line 8—8 of Fig. 7;

Fig. 9 is a schematic perspective view of a unit shown in Figs. 7 and 8, but with a front plate removed; and Figs. 10 and 11 are graphs.

In Figs. 1—4 there are shown several embodiments of a silencer of the muffler type.

These muffler type silencers are supported on wheels 16 for moving about, and are provided with diffusers and watercooling for afterburner operation.

They may be used on airports, on launching areas in connection with airplanes of the turbo-jet or rocket type, or in connection with guided missiles.

In Fig. 1 the wheels 16 carry a muffler silencer 17 that has an intake portion 18 that is shown removably connected to the exhaust 19 of a jet aircraft 21. The muffler includes a silencer portion 22 and an exhaust portion 23.

As best shown in Fig. 2, the silencer portion 22 comprises an enclosure wall 24 that may be of cylindrical shape. On the intake side, the enclosure wall casing 24 forms a conduit or intake tube 26 and on the exhaust side another conduit, namely an exhaust tube 27. The wall 24 defines on the interior a chamber 28. Centrally of the chamber 28 there is suspended on suspension members 30 a divider 29, which may be of circular cross section, and which is disposed axially of the silencer 22.

A structure 31 is formed near the intake tube 26 and another similar structure 32 near the exhaust tube 27. These structures are hollow annular chamber structures that define on their interior, chambers 33 and 34, respectively. The chambers 33 and 34 may be subdivided by radial partitions 35 to break up the chamber continuum.

The divider 29 has a central sine-wave shaped partition 36, and forms on each side of the partition 36 a chamber, namely a chamber 37 that faces the intake tube 26 and a chamber 38 that faces the exhaust tube 27. The walls of the divider are provided with holes 39 and the holes 39 cover about one-fourth of the perforated area. The structure 31 has openings 41 and the structure 32 has openings 42. The holes 39 and the openings 41 and 42 provide for expansion of the gaseous substance of the stream into the chambers 33, 34, 37 and 38, respectively, acting as resonators.

The divider 29, in connection with the intake and exhaust tubes 26 and 27, with the chamber structures 31 and 32, and with the wall 24 acts to force the stream of gaseous substances to flow through the silencer in a mushroom shaped formation, first dividing the incoming stream into separate stream portions or branches, and subsequently uniting them again into a single stream.

The stream enters the silencer through an intake opening 44 of the tube 26, and flows through the intake

3

tube 26 in the direction A in a compact formation. The divider 29 has a pointed part 46 which projects towards the intake tube 26 and faces the incoming stream.

The stream that flows in the direction A will be split up or divided near that point into branches or stream portions, and will be forced to flow through a series of sections of branching circuit or circuits 47.

The first sections 48 into which the stream portions are deflected, are formed between the inner wall of the chamber structure 31 and the outer wall of chamber 37. In these sections 48, the stream portions flow outwardly in radial directions B. In deflecting the stream portions to flow through the sections 48, they have been forced through a bend of about 90° from the direction A to the direction B.

Second sections 49 of the circuits 47 are formed between the wall 24 and the divider 29. The stream portions are forced to flow in the sections 49 in an axial direction C parallel to the direction A. In forcing the stream portions to flow through the sections 49, the stream portions have been deflected from the direction B into the direction C through a bend of about 90°.

Third sections 51 of the circuits 47 are formed between the inner wall of the chamber structure 32 and the outer wall of the chamber 38, and in the sections 51 the stream portions are forced to flow inwardly towards each other so that their paths will meet. In forcing the stream portions to flow in radial directions D, they have again been deflected through a bend of about 90°.

Finally, the stream portions are united near a pointed part 50 of the divider 29, that is similar though disposed oppositely to the pointed part 46, and the streamlined shape of which aids in uniting the stream portions to form again a single stream that flows axially in direction E through the exhaust tube 27 in compact formation, and leaves the silencer 22 through the exit opening 45. In uniting the stream portions, they are deflected through a bend of about 90° from the radial directions D into the axial direction E.

Thus, each of the stream portions undergoes four bends totaling about 360°; the stream is divided and forced to flow around a mushroom shaped divider 29 disposed in the chamber structures 31 and 32.

As the stream is split up into portions, the gaseous substance will expand through the holes 39 into the chamber 37, and near the point of uniting, the gaseous substance will expand through the holes 39 into the chamber 38. As the stream portions flow past the openings 41 and 42, the gaseous substance will expand into the chambers 33 and 34, respectively.

As explained in the foregoing, each stream portion is forced through four bends each of about 90°. Depending on the formation of the walls that define the sections 48, 49 and 51, each bend may be exactly at a right angle or less than 90° or more than 90°. It is preferred that each bend is in excess of 90° so that each stream portion is forced to be bent through more than 360° as it passes through a silencer stage. It is believed that the series of bends accounts for the attenuation of the higher frequencies of the noise within the stream. It is believed furthermore, that the expansion in the resonator chambers 33, 34, 37 and 38 accounts for the attenuation of the lower frequencies.

Silencers of this type are designed to attenuate sounds within the range of from 20 cycles to 10 kilocycles.

The silencer 22 may either be of cylindrical shape as shown, or may instead be of rectangular or square cross section. Thus, the wall 24 of the silencer 22 and the chamber structures 31 and 32 as well as the intake and exhaust tubes 26 and 27 may be of circular shape, as shown in Figs. 2 and 3; alternatively, these parts may instead be of rectangular or square shape; or some parts may have one of these shapes and other parts have another of these shapes.

The circuits 47 may be composed of a single passage of

4

mushroom shape, such as of circular or rectangular or square shaped cross section, or may instead be composed of a series of passages arranged about the axis of the silencer 22.

5 The embodiment shown in Figs. 1-3 discloses a single stage silencer. That means that the stream of gaseous substance is forced to divide once and thereafter to unite once into a stream again, so that the stream undergoes a single mushroom shape formation.

10 Two or more silencers may, however, be put in series. In Fig. 4 a silencer 22 is put in series with another silencer 43 along a horizontal axis. In Fig. 5 the silencer 43 is put in series with the silencer 22 but at a right angle thereto. In the embodiment of Figs. 4 and 5 the silencing is carried out in two stages, each of the silencers 22 and 43 providing one stage.

Example 1

20 A unit of the type of Fig. 1 having a single stage was made with the length "a" measuring 10 ft., the diameter "b" measuring 13 ft., and the unit weighed 20,000 lbs. (End of Example I.)

Due to the various acoustical requirements of aircraft test centers it was decided to make each silencer section a separate unit, which can be coupled together or detached as the acoustical requirements dictate. This feature provides maximum utilization of the equipment and minimum cost for adequate silencing.

30 In putting several silencers in series, the entrance opening 44 of a succeeding silencer stage is applied against the exit opening 45 of the preceding silencer stage.

As related in the foregoing, these silencers are equipped with wheels 16, so that the unit (Fig. 1) or units (Figs. 4 and 5) can be towed to any location. The easily assembled sections of the silencer may also be flown to remote sites by means of conventional flying boxcars.

35 The silencers of the muffler type of Figs. 1-5 have the further advantage that they terminate in a vertical direction to deflect the hot exhaust gases away from the personnel and aircraft on the airport and away from the ground.

40 It is one of the characteristics of the invention that only heavy plate material is used for the silencer apparatus itself. Depending on the temperatures, the material may be steel plate (for instance for up to 1000° F.), or stainless steel plate (up to about 2000° F.), or a ceramic plate compound such as a stainless steel and ceramic combination (up to about 3000° F.). The thickness of the plates may be from one-quarter of one inch to one-half of one inch or more.

45 Instead of using the silencer as part of a movable muffler on an airport, it may be used in connection with fixed test cells, such as are found in many aircraft engine factories, at airports, and on overhaul bases. In the test cells a silencer may be applied in connection with a muffler to the exhaust of the machine, and/or with the stacks of the test cells. Application of silencers to the stacks of the test cells in general has been shown in my copending application Serial No. 446,926, filed July 30, 1954.

50 The silencer apparatus 52 of Fig. 6 is shown applied to an exhaust stack 53 of a test cell. As evident from a comparison of Fig. 6 with Fig. 2, the silencer in function and principle is similar for both modes of application. Though the principle is the same the dimensions, however, are different. There are also some other specific differences of construction which will be pointed out below.

55 A stack of the type shown at 53 is usually of rectangular cross section, and therefore the silencer 52 will preferably also be of rectangular outline.

60 The silencer 52 has three stages 54, 55 and 56 that are arranged in series. The stage 54 has a divider 57, the stage 55 a divider 58, and the stage 56 a divider 59. As the stage 56 is the last or exhaust stage, the divider 59 has but a single chamber 61. Each of the dividers

57 and 58 has a sine-wave partition 65. The divider 59 has a sine-wave end wall 60. The divider 57 has two resonator chambers 62 and 63 separated by the partition 65, and the divider 58 has also two similarly separated resonator chambers 64 and 66. Each divider 57, 58 and 59 is provided with holes 67 that are similar to the holes 39 of Fig. 2. The holes 67 have a diameter of about five-eighths of one inch, and the holes cover about one-fourth of the perforated area. Between the stages 54 and 55 there are provided two resonator chamber structures 68 and 69 which correspond to the structures 31 or 32 of Fig. 2, the structures 68 and 69, however, are not annular but are straight.

They may be subdivided by vertical partitions (not shown in Fig. 6) similar to the partitioning 35 of Fig. 3. The chambers 68 and 69 have openings 71 for expansion thereinto from the stream portions as they flow in the stage 54.

Between the stages 55 and 56, there are provided expansion chamber structures 72 and 73, each being similar to the structures 68 and 69, but separated into two separate compartments by a partition. Thus, the structure 72 has a partition 74 that separates a chamber 76 from a chamber 77; the chamber 76 has an opening 78 and serves for the expansion of gaseous substance from the preceding stage 55; while the chamber 77 has an opening 79 and serves for the expansion of gaseous substance from the succeeding stage 56. Similarly, the structure 73 has a partition 81 that separates the chamber 82 from the chamber 83; the chamber 82 has an opening 84 and serves for the expansion from the stage 55; and the chamber 83 has an opening 86 and serves for the expansion from the stage 56.

The expansion chambers 62, 63, 64, 66, 61, 68, 69, 76, 82, 77 and 83 vary in size and shape as do the size and nature of the openings leading to the interior of the chambers. For instance, it will be noted that the chambers 61 is larger than the chambers 62, 63, 64 and 66 or the chambers 68 and 69 while these chambers are larger than the chambers 76, 82, 77 and 83. It will also be seen that the chambers 61, 62, 63, 64 and 66 are provided with a plurality of small straight-edged orifices 67 while the chambers 68, 69, 76, 82, 77 and 81 are each provided with a single large opening 71, 78, 79, 84 or 86 having side walls that extend inwardly of the chamber. As will be well understood in the art expansion chambers sized within certain dimensional limitations are, in effect, filters, or resonators, for attenuating the lower audio frequencies. By varying the size and openings of the chambers each chamber is made selective for a particular frequency or frequencies, thus the provision of several selectively "tuned" resonating chambers results in a very effective attenuation throughout the lower range of sound frequencies.

The opposite branch circuits of all the stages are indicated at 87 and 88, respectively. The circuits 87 and 88 are so formed that each bend through which the stream portions are deflected is in excess of 90°, so that in the stage 54, as well as in the stage 55, the branch portions are forced to undergo bending in excess of 360°. In the last stage 56, however, each stream portion is forced to be bent throughout a total of slightly more than 180°.

The stream enters the silencer 52 through the intake opening 89 of the conical intake tube 91. The stream is split up near the narrowmost portion 92 of the tube 91 and is forced to flow in mushroom shape formation through the parts of the stage 54 of the branch circuits 87 and 88. The stream is then reunited in a conduit 93 that is formed between the structures 68 and 69, and is thereafter again split up into branch portions; it is subsequently again united in a conduit 94 that is formed between the structures 72 and 73, and is thereafter again split up into branch portions. One of the portions is finally discharged through the exit opening 96, while the

other is discharged through the exit opening 97, vertically upward.

The function and operation of the silencer 52 is similar to that of the silencer 22, except that the silencer 52 has several stages in series, and is of rectangular build. The dimensions are much larger, as set forth in the following example.

Example II

The stack for the fixed test cell has a cross section of 18 ft. by 20 ft. and is 38 ft. high. The silencer 52 has substantially the same dimensions, and it weighs 70,000 lbs. The silencer is designed to attenuate sounds within the range of from 20 cycles to 10 kilocycles. The stream enters into the intake tube 91 at a speed of up to 400 ft. per second or more, and leaves the exit openings 96 and 97 at a speed reduced as compared to the intake speed to an extent depending on the acoustical considerations and may for instance be a reduction of about 20 percent.

A three-section unit (Fig. 6) was installed in the stack of a fixed test cell installation, and tests made, the results, of which are set forth below.

A full scale installation of a three-section muffler type unit was run and tests made with a J-57 engine with after-burner, having approximately 15,000 lbs. thrust. The data were the following:

Octave bands, C. P. S.-----	37.5 54	75 150	150 300	300 600	600 1,200	1,200 2,400	2,400 4,800	4,800 9,600
EN-1 Attenua- tion, Decibels.	36	45	47	44	49	52	61	64

The water requirements to cool the afterburner exhaust gas from 3000 to 500° F. was about 450 gallons per minute. (End of Example II.)

In Fig. 10 there are shown acoustical attenuation data obtained in an experimental test model. The attenuation is indicated in decibels plotted against cycles per second; it shows a curve F for one stage, a curve G for two stages, and a curve H for three stages.

In Fig. 11 there are indicated pressure drop data obtained at 80° F. The curve J shows the data for one stage, while the curve K shows data for three stages.

Instead of putting a single silencer 52 into the stack 53, a series of smaller size silencers 101 may be assembled in series as well as in parallel in the stack 53. This is shown in Figs. 7, 8 and 9. In that exemplification, a group of silencers 101 are assembled in series and in parallel in the stack 53. Each silencer 101 may be a complete unit of the type shown in Fig. 9 (the front plate that corresponds to the back plate 102 has been omitted in Fig. 9 for clarity of presentation).

Each silencer 101 may have a square cross-section and a height similar to, though preferably in excess of, the width. As best shown in Fig. 9, each silencer 101 may be of a single stage type having a single divider 103 with a sine-wave partition 104, and four resonator chamber structures 106 and 107, respectively. Between the opposite structures 106 there is defined an entrance opening 108, and between the structures 107 an exit opening 109. The structures 106 may be provided with expansion openings 111, and the structures 107 with expansion openings 112. Vertical partitions 113 may be provided in the structures 106 and 107 to break up the chamber continuum. The rear plate 102 and a similar front plate (not shown) complete the silencer 101, forcing the stream that enters through the opening 108 and leaves through the opening 109 to flow in the silencer 101 in a mushroom shape formation. The gaseous substance will be split and reunited, and the stream portions be forced to be bent each throughout 360°, and to expand into the chambers 106 and 107 and through holes 114 into the opposite chambers 116 and 117 of the divider 103.

Means may be provided (not shown) for securing the various silencers 101 to each other in the stack 53. The stream will thus from the start be apportioned among the various parallel silencers 101, and each apportioned part stream will flow upwardly through the series of superposed silencers 101.

Noise level attenuation in connection with jet aircraft motors is not a question of convenience or comfort. It is an absolute necessity. Persons subjected to the usual extremely high noise level of such engines are liable to get sick, to become crazed, and even to die.

The safety of the personnel, and of the surrounding communities have made it necessary to deal effectively with the problem of noise abatement. The instant invention solves the problem, by subjecting the stream either to one or to repeated splitting up followed by reuniting with resonators interposed, and with repeated bending of the branches through the split up portions of the stream flow in mushroom shape. Effective attenuation is achieved for the low as well as the high frequencies. The stream leaves the silencer with only slightly diminished speed, but at comfortable noise level.

The silencing by the instant methods and apparatus is obtained by means of acoustic filters including inductance and capacitance means by constriction and volume arrangements, respectively.

It will be apparent to those skilled in the art that the novel principles of the invention disclosed herein in connection with specific exemplifications thereof will suggest various other modifications and application of the same. It is accordingly desired that in construing the breadth of the appended claims they shall not be limited to the specific exemplification of the invention described herein.

Having thus described the invention, what I claim as new and desire to be secured by Letters Patent is as follows:

1. In a silencing system for a gaseous stream, in combination, a first conduit for guiding said stream, a branching circuit connected to said conduit and operable to divide said stream to assume a formation of mushroom shaped cross-section, a second conduit spaced from the first conduit, said branching circuit leading into said second conduit for uniting said divided stream portions into a stream, and means disposed between opposite parts of said circuit including a hollow wall structure having perforations defining on its interior a resonator chamber for expanding therein some of said gaseous stream.

2. In a system, as claimed in claim 1, said resonator chamber having a partition, said perforations being disposed on opposite sides of said chamber, whereby gaseous substance will enter said chamber upon entering and upon leaving said branch circuit.

3. Sound attenuation apparatus comprising an en-

closure forming a conduit for a sound bearing gaseous stream, dividers in the conduit shaped to force the gaseous stream into two separate streams, said dividers being hollow to form resonating chambers for the gaseous stream, side resonating chambers extending inwardly of the conduit and the dividers intermediate adjacent dividers to force the two separate gaseous streams to unite, and openings in the resonating chambers in communication with the conduit for the gaseous streams to permit said gaseous streams to expand thereinto, said resonating chambers being variously sized.

4. Sound attenuation apparatus as set forth in claim 3 in which the openings in the resonating chambers are variously sized.

5. Sound attenuation apparatus as set forth in claim 3 in which the dividers are provided with a plurality of small openings and each side resonating chamber is provided with a single large opening.

6. Sound attenuation apparatus as set forth in claim 5 in which the dividers and the side resonating chambers are shaped to force the two separate gaseous streams to make at least four 90° bends.

7. Sound attenuation apparatus comprising an enclosure of substantially uniform cross-section forming a conduit for a sound bearing gaseous stream, said enclosure also defining at periodic intervals opposite inwardly extending, variously sized resonating chambers, and, intermediate the inwardly extending resonating chambers, centrally positioned hollow dividers forming additional resonating chambers, said chambers and enclosure forming a tortuous passageway for the gaseous stream of alternate constrictions and expansions.

8. Sound attenuation apparatus comprising an enclosure forming a conduit for a sound bearing gaseous stream, at least one divider in the conduit shaped to force the gaseous stream into two separate streams, said divider being hollow to form resonating chambers for the gaseous stream, side resonating chambers extending inwardly of the conduit and the divider to force the two separate gaseous streams to unite, and openings in the resonating chambers in communication with the conduit for the gaseous streams to expand into the chambers, said chambers being variously sized.

References Cited in the file of this patent

UNITED STATES PATENTS

1,984,707	Sommer	Dec. 18, 1934	181-524
1,997,298	Hathorn	Apr. 9, 1935	181-524
2,017,744	Bourne	Oct. 15, 1935	181-524
2,519,160	Tucker	Aug. 15, 1950	181-524
2,727,584	Marx	Dec. 20, 1955	181-524

FOREIGN PATENTS

678,344	Great Britain	Sept. 3, 1952	181-524
---------	---------------	---------------	---------

1,246,154

Nov 13, 1917 181-524