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E. M. DE REMER

3,139,153

JET NOISE SUPPRESSOR

Filed April 2, 1961

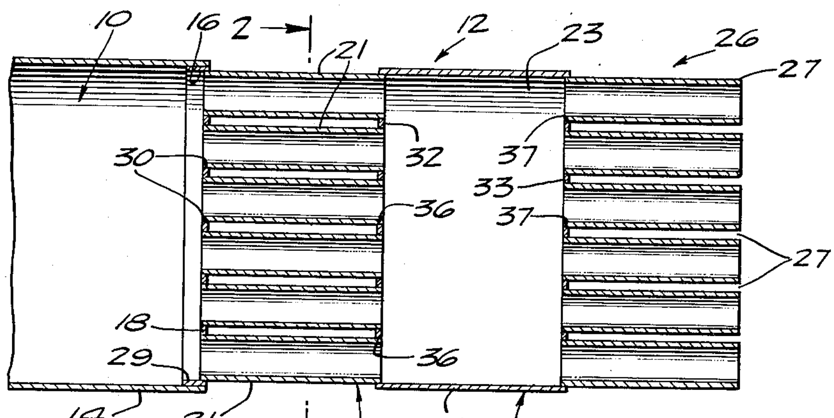

FIG. 1.

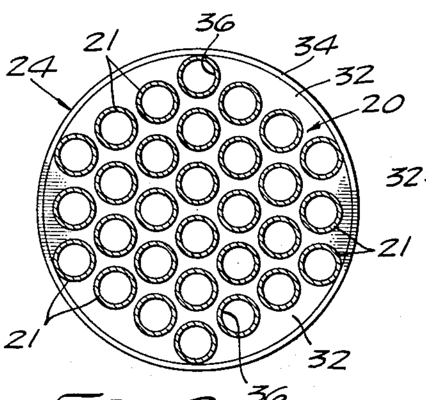

FIG. 2.

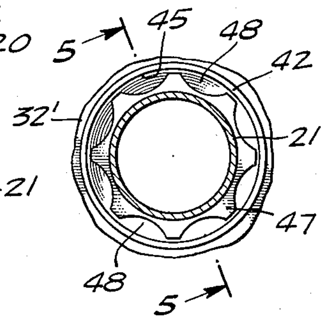

FIG. 4.

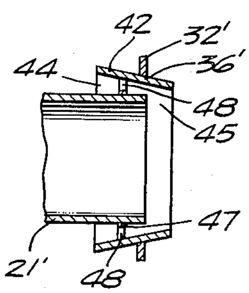

FIG. 5.

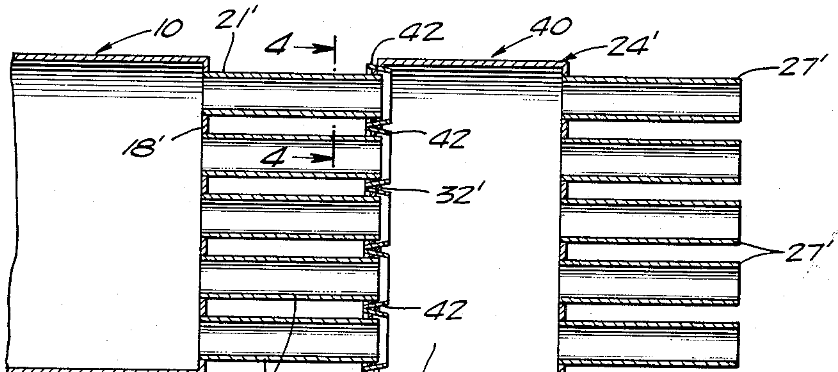

FIG. 3.

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This invention relates generally to reaction motors, e.g., jet engines of the types referred to, for example, in United States Patent No. 2,633,703, and those in United States Patent No. 2,939,279, the invention relating more particularly to the suppression of noise from such jet engines.

The invention finds its greater usefulness when embodied in a jet engine of an aircraft. It has been determined that sound vibrations of a frequency above about 15,000 cycles per second, resulting from the exhaust of an engine of a jet plane are especially annoying to people.

By this invention there is provided an assembly of two groups of tubes and a chamber between the groups, the assembly when connected to the exhaust end of a jet engine and having the dimensions of the tubes or pipes and of the chamber interrelated as is set forth more precisely hereinafter, effecting attenuation of those sound frequencies which are particularly objectionable and irritating to people.

The details of construction and dimensional relationship of component parts of two embodiments of the invention are described hereinafter with reference to the accompanying drawings in which:

FIGURE 1 is a longitudinal section through the exhaust end of a jet engine, and a tail pipe assembly embodying this invention;

FIGURE 2 is a cross-section through the tail pipe assembly taken upon a plane indicated in FIGURE 1 by line 2—2;

FIGURE 3 is a longitudinal section through the exhaust end of a jet engine, and another embodiment of a tail pipe assembly of this invention;

FIGURE 4 is a detail section taken upon a plane indicated in FIGURE 3 by line 4—4; and

FIGURE 5 is a detail longitudinal section taken upon line 5—5 of FIGURE 4.

I have found that a silencer or noise suppressor of this invention attenuates the sound of a jet engine above that frequency (about 15,000 cycles per second) which marks the upper limit tolerable by human beings. In FIGURE 1 of the drawings, reference numeral **10** designates, generally, the tail end portion of the combustion chamber of a conventional jet engine, and numeral **12** designates a noise suppressor or tail pipe assembly of this invention connected to the exhaust end of the combustion chamber.

The combustion chamber is defined by the engine casing **14** which in the illustrated embodiment is cylindrical and circular in cross-section, it being understood that jet engines of any conventional form, besides cylindrical, e.g., of cigar shape form, are herein contemplated. What, without the sound suppressor **12**, would ordinarily be the exhaust end opening for the gases jetted from the combustion chamber is designated by numeral **16**.

Silencer **12** comprises a mounting plate **18**, an upstream group **20** of tubes **21** extending rearwardly of the mounting plate, a plenum chamber **23** defined by a casing **24** and extending downstream of the group of tubes **21**, and a downstream group **26** of tubes **27** extending rearwardly from the chamber casing.

Mounting plate **18** has a peripheral flange **29** telescoped within the tail end of the jet engine casing **14**, and secured as by welding or suitable fasteners not shown. Plate **18** has a plurality of openings **30** into which the forward ends of the tubes **21** of the upstream group are secured. Tubes **21** of the FIGURE 1 embodiment are cylindrical and circular in cross-section and are arranged as close together as good design practice will permit to provide rigidity of connection of the tubes to the plate. It is, of course, obvious that tubes of hexagonal cross-section may be more closely grouped and such hexagonal configuration for the tubes **21**, though not shown, is contemplated by this invention.

The casing **24** which defines plenum chamber **23** between the upstream and downstream groups of tubes comprises a forward or front end wall **32**, a rear end wall **33**, and a cylindrical side wall **34**. Front wall **32** has a plurality of openings **36** into which the rear ends of the tubes **21** of the upstream group of tubes are secured. Rear wall **33** has a plurality of openings **37** into which the forward ends of the tubes **27** of the downstream group of tubes are secured. In the illustrated embodiments, the tubes **27** are equal in number and length to those of the downstream group, and the axial dimension of the plenum chamber **23** (between front and rear walls **32** and **33**) is equal to the length of the tubes. Casing **24** is preferably of a cross-section congruent with the exhaust end opening **16** of the jet engine.

The dimensions of the groups of tubes and plenum chamber are interrelated according to the following formula:

$$\frac{LV}{R^2N}=45.8\left(\frac{c}{f}\right)^2$$

wherein:

L represents the length of the tubes **21** in inches,
R represents the radius of the tubes **21** in inches,
V represents the volume of plenum chamber **23** in cubic inches,
N represents the number of tubes **21**,
c represents the velocity of sound in the exhaust gases, and
f represents the cut-off frequency in cycles per second of sound vibrations tolerable by human beings i.e., 15,000 cycles per second.

When a silencer is used, the component parts of which are dimensionally related in accord with the above formula, it will be found that the extent of transmission of sound frequencies above the cut-off frequency (*f*) is but about five percent of that which is transmitted without a silencer, the percent of attenuation increasing rapidly with increase of frequency up to the cut-off frequency, and from that point leveling off to a relatively steady percent of transmission.

Referring to FIGURES 3–5 there is shown another embodiment of a noise suppressor or silencer of this invention extending rearwardly from engine casing **10**, this silencer being designated generally by reference numeral **40**. The component parts of silencer **40** which correspond to those of silencer **12** of the FIGURE 1 embodiment, are designated by reference numerals corresponding to those used for the FIGURE 1 embodiment, but in the case of the silencer **40**, the reference characters for corresponding parts are distinguished by the addition thereto of a prime. Silencer **40** comprises a mounting plate **18'**, a plurality of tubes **21'** of an upstream group of tubes, a casing **24'** defining a plenum chamber **23'**, and a plurality of tubes **27'** of a downstream group of tubes. In this embodiment the number of tubes **21'** in the upstream group of tubes is less than that in the silencer **12**, and here again the number and length of the tubes **27'** of the downstream group is equal to that of the upstream group of tubes **21'**.

Silencer **40** differs from silencer **12** in that in the case of silencer **40** provisions are made for the introduction of secondary air to the plenum chamber **23'**. Front end wall **32'** mounts a plurality of funnels **42** in its openings

36' respectively, the funnels being of frusto-conical configuration having a large end opening **44** and a small end opening **45**. The funnels encircle the rear ends of the tubes **21'**, the tubes **21'** extending coaxially within the respective funnels. Each funnel has a spider **47** for mounting the rear end of a tube **21'** concentrically within the funnel, the spider having openings **48** for flow of ram air through the funnel around the rear end of its encircled tube **21'** and into the plenum chamber **23'**.

As in the case of the suppressor **12** the dimensions of the tubes **21'** and the plenum chamber **23'** are interrelated according to the above-mentioned formula to effect attenuation of sound frequencies above 15,000 cycles per second, marking the cut-off point of frequencies which are tolerable by human beings. Though in the embodiment **40**, the number and dimensions of the tubes **27'** are equal to those of tubes **21'**, it will be understood, of course, that the tubes **27'** may be more or less in number and of larger dimensions than the tubes **21'** if desired.

While the particular jet noise suppressor herein shown and disclosed in detail is fully capable of attaining the objects and providing the advantages hereinbefore stated, it is to be understood that it is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended to the details of construction or design herein shown other than as defined in the appended claims.

I claim:

1. In combination with the exhaust means of a jet engine, a noise suppressor therefor, comprising an upstream group of open-ended tubes extending in a common direction and connected at their inlet ends to the rear of the combustion chamber of the jet engine, a casing defining a plenum chamber connected to the outlet ends of said tubes, and a downstream group of open-ended tubes connected to said casing whereby gases from said combustion chamber pass through the upstream group of tubes, thence through the plenum chamber, and thence through the tubes of the downstream group, said tubes and said plenum chamber being interrelated according to the following formula:

$$\frac{LV}{R^2N}=45.8\left(\frac{c}{f}\right)^2$$

wherein L represents the length of said upstream tubes in inches, R represents the radius of said upstream tubes in inches, V represents the volume of said plenum chamber in cubic inches, N represents the number of upstream tubes, c represents the velocity of sound in gases from said combustion chamber, and f represents the cut-off frequency of sound vibrations intolerable by human beings, i.e., 15,000 cycles per second.

2. The combination defined in claim 1 characterized in the provision of means for admitting secondary air to said plenum chamber.

3. In combination with the exhaust of a jet engine, a noise suppressor therefor having an upstream group of open-ended tubes arranged side by side and parallel to each other, said tubes being cylindrical and of common length and having means connecting their inlet ends to the exhaust from the combustion chamber of the jet engine, a casing defining a plenum chamber connected to the outlet ends of said tubes, and a downstream group of open-ended tubes connected to said casing whereby gases from said combustion chamber pass through the upstream group of tubes, thence through said plenum chamber and thence through said downstream group of tubes, the downstream group of tubes being equal in number and size and dimensions to the upstream group of tubes, said tubes and said plenum chamber being interrelated according to the following formula:

$$\frac{LV}{R^2N}=45.8\left(\frac{c}{f}\right)^2$$

wherein L represents the length of said upstream tubes in inches, R represents the radius of said upstream tubes in inches, V represents the volume of said plenum chamber in cubic inches, N represents the number of upstream tubes, c represents the velocity of sound in gases from said combustion chamber, and f represents the cut-off frequency of sound vibrations intolerable by human beings, i.e., 15,000 cycles per second.

4. A jet engine having a noise suppressor connected to its exhaust including an upstream group of open-ended tubes extending in a common direction, said tubes having their inlet ends connected to the rear of the combustion chamber of said jet engine, a casing defining a plenum chamber, and a downstream group of open-ended tubes, said casing having a front end wall and a rear end wall, said front end wall having a plurality of openings formed therein, a plurality of frusto-conical funnels in said openings respectively, with the smaller ends thereof being open to said plenum chamber, the upstream tubes extending at their rear ends into the funnels respectively, means for supporting the upstream tubes within the funnels spaced within the funnels for allowing passage of secondary air to flow from around said upstream tubes within said funnels and into the plenum chamber, the tubes of said downstream group being connected to the rear end wall of the casing whereby gases from said combustion chamber pass through the upstream group of tubes, thence through the plenum chamber, and thence through the tubes of the downstream group, said tubes and said plenum chamber being interrelated according to the following formula:

$$\frac{LV}{R^2N}=45.8\left(\frac{c}{f}\right)^2$$

wherein L represents the length of said upstream tubes in inches, R represents the radius of said upstream tubes in inches, V represents the volume of said plenum chamber in cubic inches, N represents the number of upstream tubes, c represents the velocity of sound in gases from said combustion chamber, and f represents the cut-off frequency of sound vibrations intolerable by human beings, i.e. 15,000 cycles per second.

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