July 29, 1969 R. B. BENHAM 3,458,008

JET ENGINE NOISE SUPPRESSOR

Filed Dec. 28, 1966 2 Sheets-Sheet 1

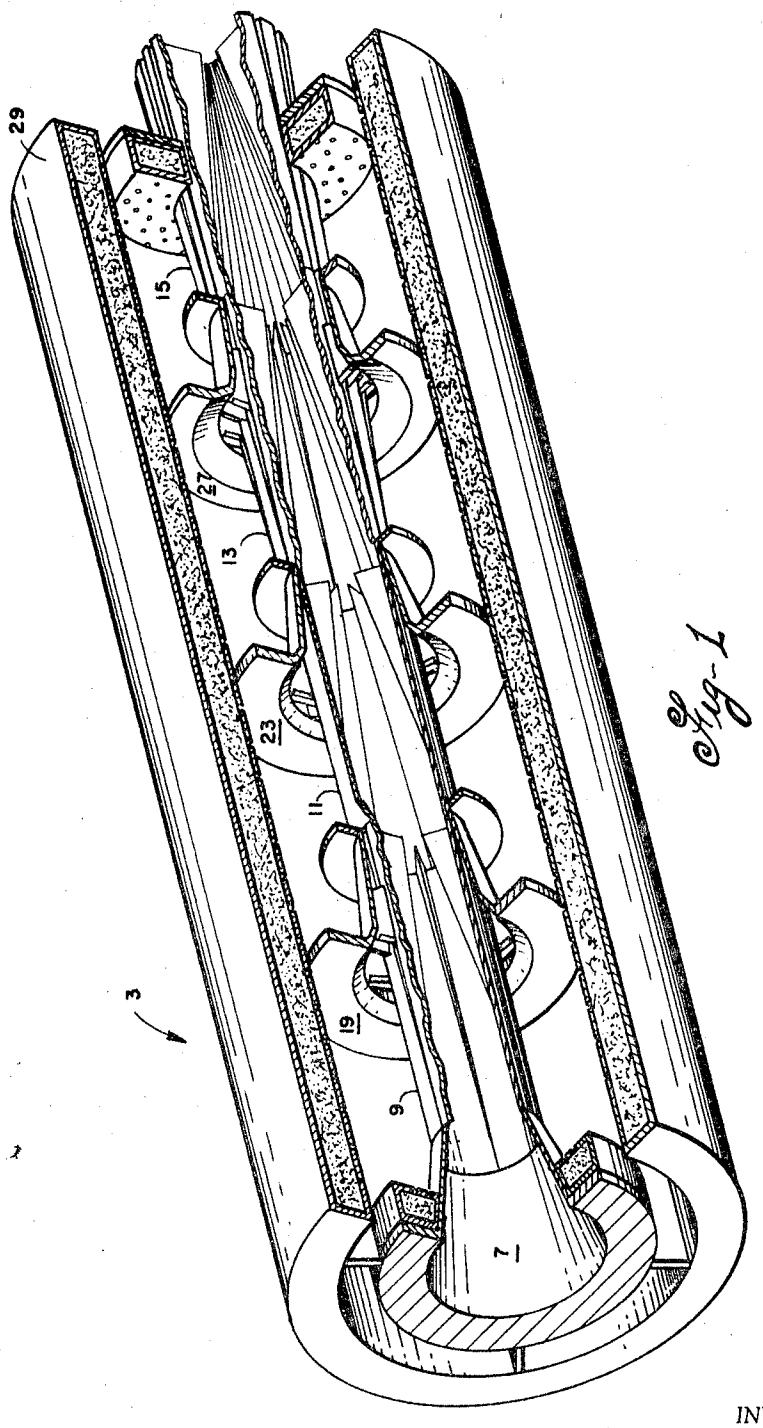



Fig. 1

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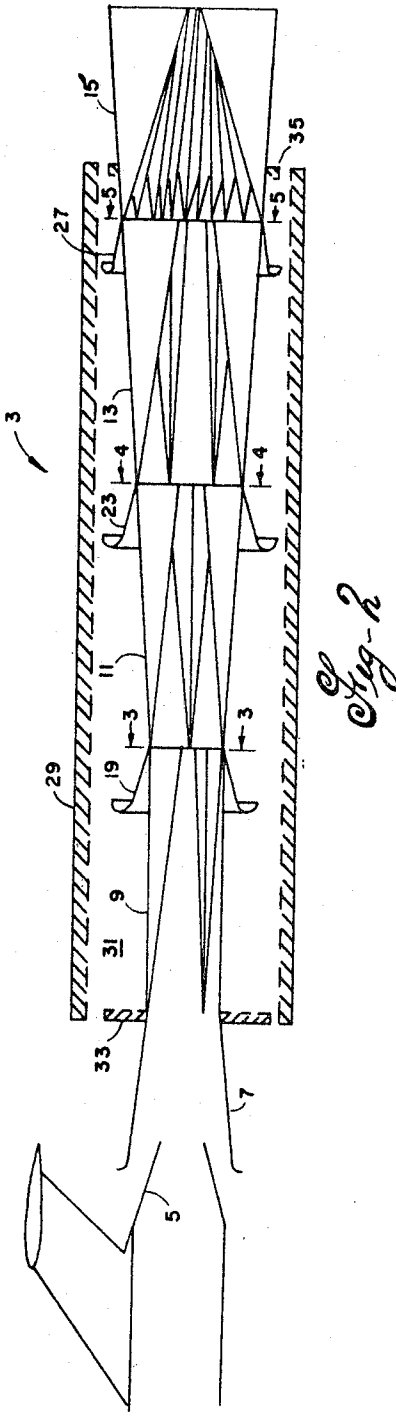



Fig-2

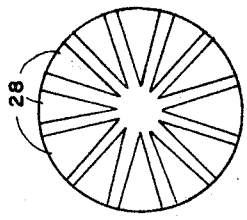



Fig-6

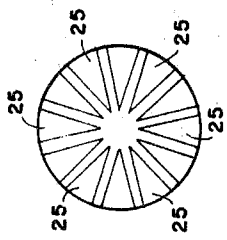



Fig-5

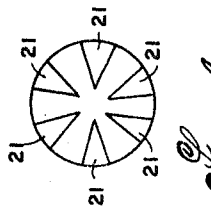



Fig-4

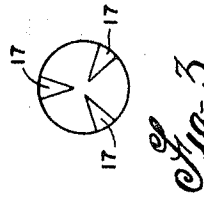



Fig-3

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3,458,008

# JET ENGINE NOISE SUPPRESSOR

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U.S. Cl. 181—43 3 Claims

## ABSTRACT OF THE DISCLOSURE

The present disclosure relates to novel and improved apparatus for suppressing noise created by a high velocity stream of gas that discharges from a nozzle into the ambient atmosphere. The improved apparatus takes the form of a diffuser that is longitudinally disposed opposite the exit end of the nozzle. The diffuser includes a convergent section adjacent the nozzle and a plurality of successive silencing stages into each of which a plurality of chutes conduct air from the area surrounding the exterior of the diffuser. Each diverging silencing stage and its associated intruding chutes are designed so as to maintain a substantially constant area for gaseous flow through the stage and thereby minimize the possibility of separation of flow from the peripheral boundaries of the stage and the generation of secondary noise.

The present invention relates to novel and improved apparatus for suppressing noise created by a high velocity stream of gas that discharges into the ambient atmosphere. More specifically, it relates to novel and improved noise suppressing apparatus for a jet engine with an afterburner during ground run-up testing operations.

Various types of devices have been used in the past to suppress the noise generated by a jet engine during test run-up operations. Elbow devices, for example, have been used where the flow is turned upwardly 60 to 90 degrees to take advantage of the typical jet directivity pattern. Similarly, colander devices have been used to exploit the diffusion characteristics of screens placed across the jet stream. Such mechanisms, however, while suitable at the 1300° F. temperatures of military power, have been found incapable of standing up under the 3000 to 3500° F. temperatures of the afterburning jet. In order to adapt these mechanisms to afterburner operation, it was found necessary to resort to elaborate water or air cooling apparatus. Moreover, these mechanisms have been found to produce relatively high levels of self-generated noise.

It is therefore a principal object of the present invention to provide a novel and improved noise suppressing device which can be used with efficiency with an afterburning jet engine.

It is a further object of the invention to provide a novel and improved noise suppressing device for an afterburning jet engine which requires minimal use of supplemental cooling apparatus and which minimizes self-generated noise.

It is a further object of the invention to provide a novel and improved noise suppressing device for a jet engine which need not be specially stressed to accommodate large aerodynamic loads.

It is a further object of the invention to provide a novel and improved noise suppressing device for a jet engine which produces low drag and no upsetting moment.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:



FIG. 1 is a perspective view of a preferred embodiment of the invention with a portion of the plenum chamber casing cut away;

FIG. 2 is a longitudinal cross-sectional view of the embodiment of the invention shown in FIG. 1;

FIG. 3 is a cross-sectional view along line 3—3 of FIG. 2;

FIG. 4 is a cross-sectional view along line 4—4 of FIG. 2;

FIG. 5 is a cross-sectional view along line 5—5 of FIG. 2; and

FIG. 6 is an end view of the invention shown in FIGS. 1 and 2.

Referring now to the various figures of the drawing, it will be noted that the improved noise suppressing device 3 of the invention is disposed adjacent the discharge gas exit end of the nozzle 5 such that the nozzle 5 and the noise suppressor 3 have a common longitudinal axis. The noise suppressor includes a converging section 7 adjacent the nozzle 5 and four successive silencing stages 9, 11, 13 and 15. The convergent section 7 is contoured and spaced from the end of the nozzle 5 so as to lower the static pressure of the exhaust gases from nozzle 5 and draw air from the surrounding atmosphere to sufficiently cool the interior walls of the section. The first silencing stage 9 of the diffuser 3 is connected to the downstream end of section 7 in any suitable manner and progressively increases in cross-sectional area from its inlet end to its outlet end. Three channels or chutes 17, which are triangular in cross-section, are formed at equally spaced positions about the periphery of the cylindrical wall of stage 9 and project progressively further into the nozzle discharge gas channel such that their cross-sectional areas increase from small apexes at the inlet end of stage 9 to cross-sectional areas of predetermined enlarged size at their outlet end. Stage 9 and its chutes 17 are designed such that the primary fluid flow area through the stage remains constant throughout its length. The bellmouth device 19 is secured to the outer peripheral surface of the inwardly fluted cylindrical wall of stage 9 preferably approximately midway between its inlet and outlet extremities and, as will be more apparent hereinafter, accelerates the secondary flow of air through the chutes of stage 9 into the interior of the diffuser.

Stage 11 of the diffuser 3 is connected to the downstream end of stage 9 in any suitable manner and continues the increase in the cross-sectional area of the gas and air discharge channel initiated by the preceding stage 9. Six channels or chutes 21, which are also triangular in cross-section, are formed at equally spaced positions about the inner periphery of stage 11 and are uniformly staggered with respect to the chutes of stage 9 so as to more readily affect the flow between adjacent pairs of chutes 17 in stage 9. As in stage 9, the chutes 21 of stage 11 project progressively further into the gas flow channel such that their cross-sectional areas increase from small apexes at the inlet end of stage 11 to cross-sectional areas of predetermined enlarged size at the outlet end. Stage 11 and its chutes 21 are designed such that the primary fluid flow area through the stage remains constant throughout its length. The bellmouth device 23 is secured to the outer peripheral surface of the inwardly fluted cylindrical wall of stage 11 preferably approximately midway between its inlet and outlet extremities.

The third silencing stage 13 of the diffuser 3 is connected to the outlet end of stage 11 in any suitable manner and continues the increase in the cross-sectional area of the gas and air discharge channel initiated by the preceding stages. Twelve triangular channels or chutes 25 are formed at equally spaced positions about the inner periphery of stage 13 and are uniformly staggered with

respect to the chutes of stage **11**. As in stages **9** and **11**, the chutes of stage **13** project progressively further into the gas flow channel from small apexes at the inlet end of stage **13** to chutes of predetermined enlarged size at the outlet end. Stage **13** and its chutes **25** are also designed such that the primary fluid flow area through the stage remains constant throughout its length. The bellmouth device **27** is secured to the outer peripheral surface of the inwardly fluted cylindrical wall of stage **13** preferably approximately midway between its inlet and outlet extremities.

The fourth silencing stage **15** of the diffuser **3** is connected to the outlet end of stage **13** in any suitable manner and continues the increase in the cross-sectional area of the gas and air discharge channel initiated by the preceding stages. Twelve triangular channels and chutes **28** are formed at equally spaced positions about the inner periphery of stage **15** and are uniformly staggered with respect to the chutes of stage **13**. As in the preceding stages, the chutes of stage **15** project progressively further into the gas flow channel from small apexes at the inlet end of stage **15** to chutes of predetermined enlarged size at the outlet end. Stage **15** and its chutes **28** are also designed such that the primary fluid flow area through the stage remains constant throughout its length.

The outer casing **29** is positioned in any suitable manner about the exterior surface of the various stages of the diffuser and defines the plenum chamber **31** therebetween. The annular plenum chamber end plates **33** and **35** are secured to and extend radially outwardly respectively from section **7** and stage **15** and are preferably spaced a predetermined small distance from opposite ends of the casing **29** so as to permit unrestricted flow of air between the plenum chamber and the external atmosphere but limit any line of sight sound path between any bellmouth device and the external atmosphere. The casing **29** and the plenum chamber end plates **33** and **35** are lined with "fiber glass" or another suitable sound absorbent material. Although not shown in the drawing, the casing **29** also includes labyrinth openings to further provide unrestricted air inlet but no line of sight sound path between the plenum chamber **31** and the exterior.

In operation, the engine exhaust gases from nozzle **5** enter the converging section **7** of the suppressor **3** and in doing so, draw cooling air from the surrounding atmosphere along the inner walls of section **7**. The size of the flow discharge passage of section **7** at its outlet end is designed so as to pass the afterburner gas flow plus just that amount of cooling air necessary to adequately cool the inner walls of section **7**. The static pressure of the exhaust gases passing through section **7** is subtantially reduced from their ambient value at the junction of nozzle **5** and ection **7** to promote the induction of mixing air from the plenum chamber **31** through the various chutes of succeeding stages of the suppressor. The exhaust gases and cooling air then progress into the first stage of the suppressor. At the inlet end of stage **9**, the chutes **17** begin to protrude into the gas and air flow. Although not shown in the drawing, the walls of stage **9** and its chutes **17** are cooled by thin air films bled from the plenum chamber **31**. The chutes open into the interior of the suppressor at the exit end of stage **9** and in so doing, direct air from the plenum chamber **31** into the primary gas and air stream where they mix and reduce the velocity of the primary stream. The small number of chutes of stage **9** permit the introduction of only enough secondary air to reduce the primary flow velocity a predetermined small amount where mixing shears are high due to the high velocity of the primary flow. The bellmouth device **19** accelerates secondary flow into the chutes and insures maximum momentum recovery. Design of the diverging stage **9** and its protruding chutes **17** so as to maintain a substantially constant area for the primary gas and air flow through stage **9** minimizes the possibility of separation of flow from the peripheral boundaries of stage **9** and the generation of secondary noise.

The primary gas and air stream then passes through the second stage of the suppressor. The chutes **21** begin to protrude into the primary stream at the inlet ends of stage **11** and open into the stream at their exit ends. Air from the plenum chamber **31** directed into the primary stream by the chutes **21** mixes with the primary stream and further reduces its velocity. The increased number of chutes of stage **11** introduces increased amounts of air from the plenum chamber **31** and effects a greater reduction in the velocity of the primary stream. The bellmouth device **23** accelerates secondary flow into the chutes **21** and insures maximum momentum recovery. Design of the diverging stage and its protruding chutes **21** to maintain a substantially constant area for the primary gas and air flow through stage **11** again minimizes the possibility of separation of flow from the peripheral boundaries of stage **11** and the generation of secondary noise.

The primary gas and air stream then passes through the third stage of the suppressor. Air from the plenum chamber **31** which is directed into the primary stream by the chutes **25** that open into the stream at the exit end of the suppressor, mixes with the primary stream and still further reduces its velocity. The bellmouth device **27** accelerates secondary flow into the chutes **25** and insures maximum momentum recovery. The uniformly staggered relationship of the chutes of stages **9**, **11** and **13** assures thorough mixing of the primary and secondary streams throughout the entire radial field of flow and increases the efficiency of the velocity reduction and noise silencing process. As the number and cross-sectional areas of the chutes increase and the mixing channels narrow in stages **9**, **11** and **13**, the mixing turbulence is damped out and a fairly uniform velocity profile is produced when the flow is exited through the ambient exit daisy nozzle of stage **15**.

Ambient air is supplied to the plenum chamber **31** through the openings between the ends of casing **29** and the plenum chamber end plates **33** and **35** and through labyrinth openings in casing **29** not shown in the drawing. The inner walls of the casing **29** and end plates **33** and **35** are lined with a suitable material to absorb sound radiated from the various component stages of the suppressor. End plates **33** and **35** block line-of-sight sound paths between the bellmouth devices **19**, **23** and **27** and the exterior.

Although the invention has been described hereinabove as having specified numbers of chutes in each stage and a specific number of stages in the diffuser, it is to be understood that any greater or lesser number of chutes and/or stages could be designed into the diffuser depending on desired noise suppression requirements without departing from the spirit or scope of the invention.

What is claimed is:

**1.** Apparatus for suppressing noise of a high velocity stream of gas issuing from a nozzle, said apparatus comprising:

(a) a diffuser which is positioned adjacent the exit end of the nozzle such that the nozzle and the diffuser have a common longitudinal axis, said diffuser including a convergent section adjacent the nozzle and at least three successive silencing stages, each said silencing stage having a plurality of chutes that conduct air from the area surrounding the exterior of the diffuser into the diffuser primary gas stream, each of the said chutes being generally triangular in section across the longitudinal axis of the diffuser and projecting progressively further into the nozzle discharge gas stream as the gas moves downstream, the effective cross-sectional area of the diffuser throughout the length of each of its first, second and third silencing stages being substantially equal to the cross-sectional entrance area of its respective stage;

(b) means for forming a plenum chamber about the exterior surface of the diffuser from which the air directed through the chutes is supplied;

(c) and individual bellmouth structures for the chutes of the second and third stages that open into the plenum chamber.

2. The apparatus substantially as described in claim 1 wherein the means for forming a plenum chamber includes a circumferential cylindrical structure, the inner peripheral wall of which is lined with a sound absorbent material.

3. The apparatus substantially as described in claim 2 wherein the means for forming the plenum chamber further includes sound absorbent lined end walls that prevent a line of sight sound path from either bellmouth structure and the exterior of the plenum chamber.



**References Cited**

UNITED STATES PATENTS

2,974,744 3/1961 Wade.

FOREIGN PATENTS

889,688 2/1962 Great Britain.

ROBERT S. WARD, JR., Primary Examiner

U.S. Cl. X.R.

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