March 5, 1968 R. C. CHANAUD ETAL 3,371,743

JET EXHAUST SILENCING NOZZLE WITH SUCTION APPLIED AT EXIT WALL

Filed April 29, 1965

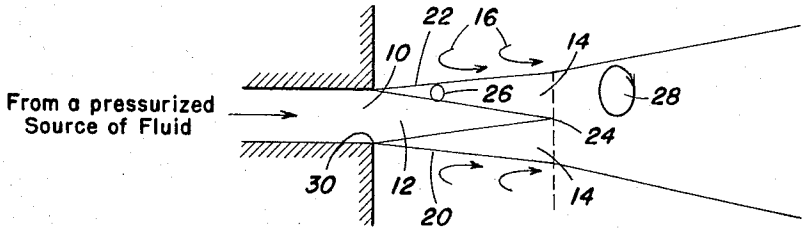


Fig. 1. Prior Art

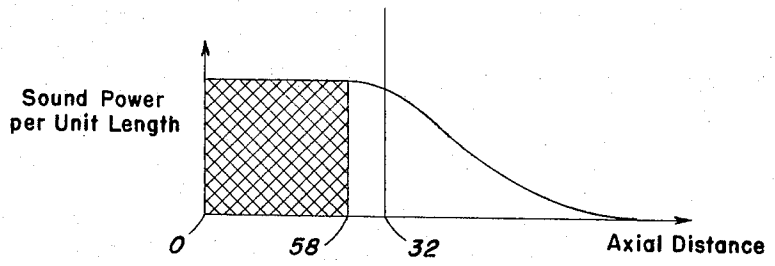


Fig. 2.

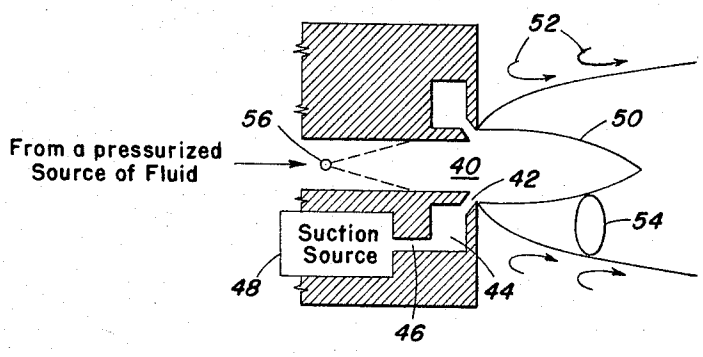


Fig. 3.

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3,371,743

Patented Mar. 5, 1968

3,371,743

JET EXHAUST SILENCING NOZZLE WITH SUCTION APPLIED AT EXIT WALL

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Filed Apr. 29, 1965, Ser. No. 451,714
5 Claims. (Cl. 181—35)

ABSTRACT OF THE DISCLOSURE

This invention relates to a relatively simple and inexpensive arrangement for reducing noise which arises from the expulsion of a high velocity jet of fluid from the nozzle of an aircraft. This is accomplished by applying suction to a narrow slot at the periphery of the nozzle at the very point at which the high velocity jet emerges from the nozzle of the jet engine and enters the free space immediately outside the jet engine. By employing a narrow annular slot making a substantial angle with respect to the direction of the jet expulsion path, there will be a spreading of the jet upon emergence from the nozzle, a rapid reduction in the jet velocity at the exit, an appreciable increase in the size of the eddies, a large reduction in the eddy velocity and a large and significant reduction in the sound power produced beyond the nozzle exit.

This invention pertains to the reduction of the noise associated with high velocity fluid flow and more particularly, to the reduction in the noise generated by a jet of fluid being expelled from a nozzle or orifice.

When fluid is expelled from a nozzle or orifice into a large reservoir the turbulent fluid generates noise. Such noise can be extremely bothersome. A typical instance concerns the noise generated by the jet engines of present day aircraft. It is well known that this noise can be not only a nuisance, but also dangerous. The aircraft industry has recognized this fact and has spent considerable money in developing noise suppressors and/or constructing noise barriers around critical areas of airports. These attempts have produced useful reductions in noise but have either been expensive or have required weight or performance penalties.

It is, accordingly, a general object of the invention to provide an improved method of reducing the noise generated by a jet of fluid which is expelled from a nozzle.

It is another object of the invention to provide a method of jet noise reduction which is simple and inexpensive to practice.

It is a further object of the invention to provide an improved method of reducing the noise generated by a high velocity jet of fluid expelled from a nozzle which requires a minimum of modification of the nozzle.

Briefly, the invention concerns reduction of the noise generated by a jet of fluid emerging from a nozzle by applying suction to the periphery of the nozzle exit.

Other objects, features and advantages of the invention will in part be obvious and will in part appear hereinafter.

The invention, accordingly, comprises the features of processing steps and arrangements which are exemplified

with respect to a particular combination of elements while the scope of the invention will be indicated in the claims.

For a further understanding of the nature and objects and advantages of the invention, reference should be made to the following detailed description read in connection with the accompanying drawings, in which:

FIG. 1 shows a typical prior art nozzle and the pattern of the flow emerging therefrom;

FIG. 2 is a graph of estimated sound power per unit length as the ordinate and axial distance from a nozzle outlet as the abscissa; and

FIG. 3 is a nozzle and the pattern of the flow thereof employing the invention.

Referring now to FIG. 1, there is shown the orifice or nozzle **10** which receives fluid from a pressurized source of fluid (not shown). The fluid as it leaves nozzle **10** has a region of relatively smooth flow **12** and an intense turbulent mixing region **14** which entrains fluid indicated by streamlines **16** from the ambient region. Initially jet spread is approximately linear. The linear spread continues until a point **24** is reached where all the emerging fluid is in the turbulent mixing region **14**.

The mixing region **14** is set up by the fluid near the nozzle wall which undergoes an intense amplification of internal disturbances. The result is a very disturbed shear layer. The shear layer includes a variety of eddy sizes but the eddies such as **26** and **28** increase in size with the thickness of the shear layer. Associated with small eddies such as eddy **26** are high frequencies and with large ones are low frequencies. The particular kind of aerodynamic sound generator found in jet flows is the quadrupole. The sound power of the quadrupole is a function of the fourth power of the frequency. Therefore, small eddies generate high sound power and the sound power rapidly decreases with increase of eddy size.

In FIG. 2, there is shown a graph of sound power per unit axial length of the jet as a function of distance from the nozzle. It should be noted that FIGS. 1 and 2 are horizontally aligned so that the origin 0 of the graph is directly below the peripheral edge **30** of nozzle **10**. It will be noted that the amplitude of the sound power is substantially constant and at a high level until the point **32** on the abscissa is reached. Point **32** is equivalent to the point **24** of FIG. 1. Thereafter, the sound power rapidly falls off.

In FIG. 3, there is shown a method of reducing this noise by applying peripheral edge suction to the nozzle. The result is that there is an initial rapid spreading of the jet, a rapid reduction of jet velocity, some increase in effective eddy size and a large reduction in eddy velocity.

In particular, nozzle **40** along its peripheral edge is provided with an annular slot **42**. Slot **42** communicates with annular chamber **44** which is connected via conduit **46** to a source of suction **48**. Therefore, as fluid flows axially through the nozzle **40** and outward therefrom, a small portion of the fluid is drawn off into annular slot **42**.

At low subsonic Mach numbers, suction applied at a rate of between one and five percent of the flow rate causes the jet to rapidly expand as it leaves the nozzle **40**. The mixing layer **50** between the entrained fluid indicated by streamlines **52** and the relatively smooth flow region grows rapidly, producing eddies, typically represented by eddy **54**, which are of greater diameter. In

effect, the application of peripheral edge suction eliminates the usual initial high shear regions and the jet can be visualized as emerging from an imaginary orifice **56** upstream from the actual output of nozzle **40**.

In order to show the effectiveness of noise reduction, the nozzle **40** of FIG. 3 is horizontally aligned with the graph of FIG. 2. The imaginary orifice **56** is directly below the origin 0 of the graph. The noise generated by the jet emerging from nozzle **40** is represented by the portion of the curve to the right of point **58** which is aligned with the peripheral edge of nozzle **40**. Therefore, the cross-hatched region to the left of point **58** represents the amount of noise power eliminated by the application of peripheral edge suction to a jet of fluid emerging from a nozzle.

There has thus been shown a method of reducing the noise generated by a jet of fluid emerging from a nozzle or orifice. In particular, the application of peripheral edge suction to a jet of fluid causes the rapid spreading of the jet and its associated shear layer. The size of the eddies is increased by a given factor and consequently the sound power is approximately reduced by the fourth power of that factor.

It should be noted that although the invention has been described with respect to a circular nozzle it is equally applicable to "rectangular" nozzles.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. The combination of a nozzle for discharging a jet of fluid through an unobstructed path along the longitudinal axis of the nozzle, means for reducing the noise generated by the discharging jet of fluid, said means comprising an annular slot substantially defined by an exit wall of the nozzle which is normal to said longitudinal axis, said slot having a width which is a fraction of the width of said nozzle at the exit wall, and means for applying suction to said slot to spread the emerging jet of fluid as it leaves the nozzle.

2. The combination of a nozzle for discharging a jet of fluid through an unobstructed path along the longitudinal axis of the nozzle, means for reducing the noise generated by the discharging jet of fluid, said means comprising an annular slot substantially defined by an exit wall of the nozzle which is normal to said longitudinal axis, said slot having a width which is a fraction of the width of said nozzle at the exit wall, a conduit, and means for applying suction through said conduit to said slot to spread the emerging jet of fluid as it leaves the nozzle.

3. An apparatus for discharging a high velocity stream of fluid, comprising a nozzle providing an unobstructed path for the discharge of said stream of fluid along the longitudinal axis of said nozzle with a reduction in the amount of noise generated by the discharging stream, said apparatus also comprising an annular slot substantially defined by the exit wall of said nozzle and having a width which is a fraction of the width of said nozzle at said exit wall, said exit wall being substantially normal to the longitudinal axis of said nozzle, and means for applying suction to said slot for laterally drawing off a portion of the stream of fluid as it leaves said nozzle.

4. Apparatus for reducing the noise generated by a jet of fluid being discharged by a nozzle of substantially circular cross-section providing an unobstructed path for said jet of fluid along the longitudinal axis of said nozzle, said apparatus including an annular slot substantially defined by the exit wall of said nozzle, said slot having a width which is a fraction of the width of said nozzle at said exit wall, said exit wall being substantially perpendicular to said longitudinal axis, and means for applying suction to said slot to spread the emerging jet as it leaves said nozzle.

5. Noise reduction apparatus for a substantially circular nozzle discharging a jet of fluid providing an unobstructed path for said fluid along the longitudinal axis of said nozzle, comprising a peripheral slot substantially defined by the exit wall of said nozzle, said slot having a width which is a fraction of the width of said nozzle at said exit wall, said exit wall being substantially perpendicular to said longitudinal axis, and means for applying suction to said slot to spread the fluid as it emerges from said nozzle.

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