Oct. 18, 1960 A. FERRI 2,956,400

INTERNAL-RIBBED EXHAUST NOZZLE FOR JET PROPULSION DEVICES

Filed June 5, 1957 3 Sheets-Sheet 1

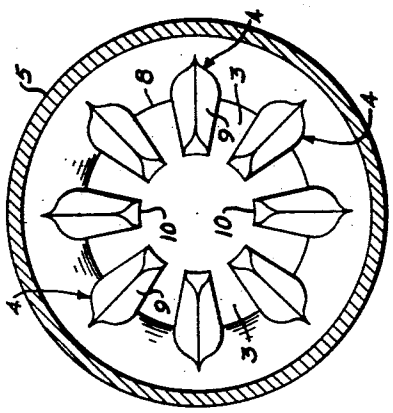


FIG-2

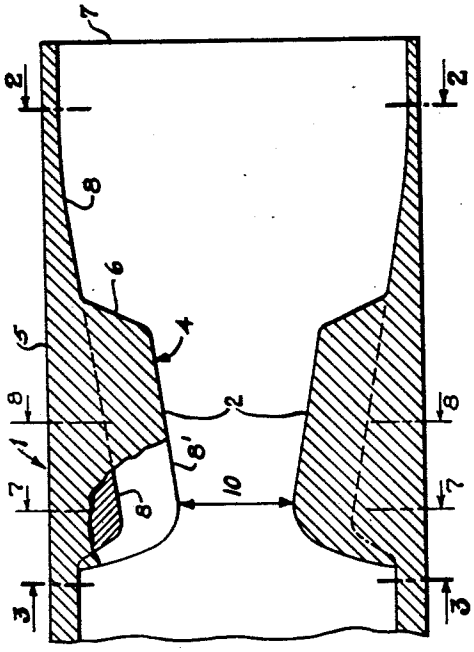


FIG-1

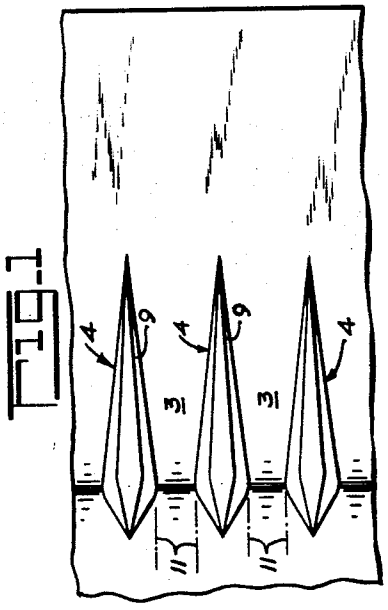


FIG-4

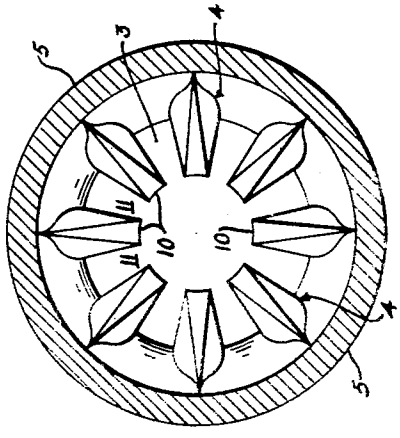


FIG-5

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Oct. 18, 1960 A. FERRI 2,956,400

INTERNAL-RIBBED EXHAUST NOZZLE FOR JET PROPULSION DEVICES

Filed June 5, 1957 3 Sheets-Sheet 2

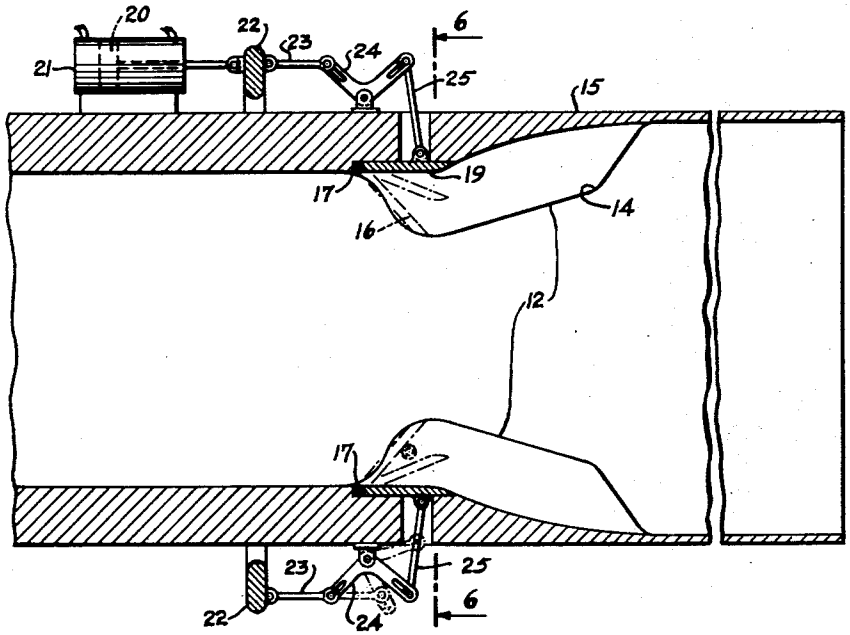



FIG. 5

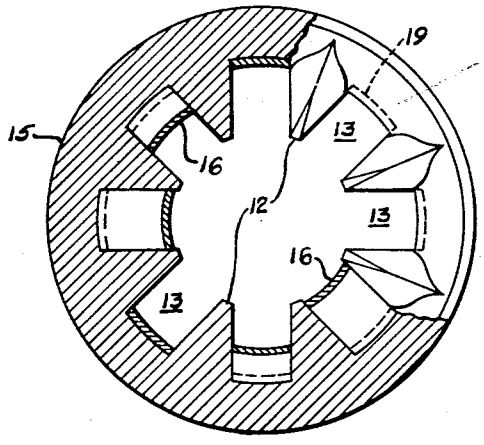



FIG. 6

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INTERNAL-RIBBED EXHAUST NOZZLE FOR JET PROPULSION DEVICES

Filed June 5, 1957 3 Sheets-Sheet 3

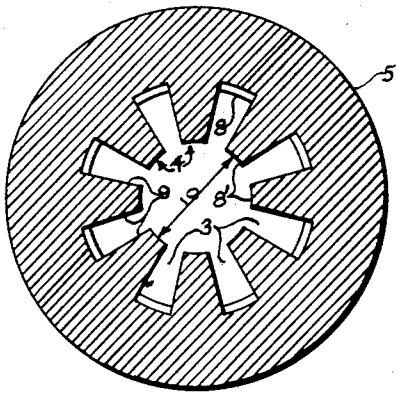



FIG-7

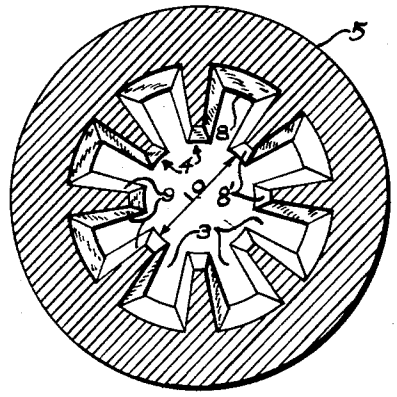



FIG-8

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United States Patent Office 2,956,400
Patented Oct. 18, 1960



2,956,400

# INTERNAL-RIBBED EXHAUST NOZZLE FOR JET PROPULSION DEVICES

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7 Claims. (Cl. 60—35.6)

My invention relates to an exhaust nozzle for jet propulsion devices. More particularly the invention is directed to an internal-ribbed nozzle having particular application to aircraft jet engines.

A prime object of the invention is to provide a suitable jet engine exhaust nozzle which may be constructed in a considerably shorter length than conventionally designed nozzles known in the art.

It is another object of the invention to provide such a nozzle which has variable area means for controlling the amount of expansion within the nozzle.

Other objects and advantages of the invention will become apparent during a reading of the specification.

The nozzle of the invention includes a central three dimensional axially symmetric passage and a plurality of other passages, which are preferably substantially two dimensional, surrounding the central passage. The passages located about the central passage are formed by the side walls of a number of rib-like members. Although the central passage and surrounding passages are not physically separated by a dividing wall, nevertheless, the respective passages are defined by the matching of longitudinal pressure gradients. By expanding a portion of the gas flow through the nozzle in the central passage and the remaining portion of the flow in the other passages, the length of the nozzle may be considerably reduced over that required for a nozzle with the same minimum area for the passage of gases having only the usual axially symmetric passage.

Referring to the drawings:

Fig. 1 is a longitudinal sectional view through the nozzle of the invention.

Fig. 2 is a cross-sectional view taken on the plane of the line 2—2 of Fig. 1.

Fig. 3 is a cross-sectional view taken on the plane of the line 3—3 of Fig. 1.

Fig. 4 is a plan development of the inside of the nozzle showing the spoke-like members of the nozzle.

Fig. 5 is a longitudinal sectional view of a spoke-like nozzle provided with closure flaps for varying the throat area of the nozzle.

Fig. 6 is a sectional view taken on the plane of the line 6—6 of Fig. 5.

Fig. 7 is a transverse sectional view taken on the plane of the line 7—7 of Fig. 1.

Fig. 8 is a transverse sectional view taken on the plane of the line 8—8 of Fig. 1.

Reference is made to Figures 1–4 inclusive of the drawings wherein reference character 1 designates a converging-diverging nozzle embodying features of the invention. Such nozzle has a three dimensional central axially symmetric passage 2 and a plurality of other longitudinally extending passages 3 disposed about the central passage between rib-like members 4 projecting from the nozzle wall 5. As shown, the central passage and surrounding passages are converging-diverging in form. Such passages extend throughout only a portion of the overall length of the nozzle. The lengths of the



central and surrounding passages are determined by the lengths of the rib-like members 4, and beyond the ends 6 of the rib-like members the central and surrounding passages merge. The rib-like members 4, and therefore the separate passages, may in theory be extended to the extreme end 7 of the nozzle, however, because of very thin rib sections which would be required at the exit, it is generally desirable to terminate the members 4 short of the end of the nozzle as shown.

With the desicribed construction, gas flow through the nozzle is in part expanded in the central axially symmetrical passage 2, and in part in the other passages 3 about the central passage. As shown the inside surface 8 of the nozzle wall is parallel to the axially asymmetric contour defined by the rib surfaces 8; and as a result the pasages 3 are substantially two dimensional and expansion in such passages take place circumferentially. There are no physical boundaries between the central passages 2 and other passages 3. However, longitudinal pressure gradients between the central and other passages are substantially matched at least over most of the length of the rib members by properly designing the longitudinal extending passages 3 between the rib walls 9 in a well known manner so that there is substantially no expansion of the gas flow in the central passage into the other passages.

The rib-like members 4 of the nozzle terminate a short distance upstream from the throat 10 of the axially symmetric passage. The two dimensional passages have throats 11 located in the vicinity of the throat 10, however, the throats 11 do not necessarily occupy the same longitudinal position in the nozzle as the throat 10. With an axially symmetric passage of a minimum length type, that is, such as to provide a maximum thrust in the shortest possible length, the throats of the two dimensional passages are preferably disposed upstream from the throat 10 of the axially symmetric passage. This is because of an abrupt divergence at the throat of an axially symmertic passage of the minimum length type and a resulting pressure discontinuity. In order to match pressures between the two dimensional passage and axially symmetric passage at the throat of the axially symmetric passage it would be necessary to have a discontinuity in area in each of the two dimensional passages. Such discontinuity in area would cause flow separation. It is therefore preferable to fair the rib contour over the discontinuity thereby placing the throat of the two dimensional passage a short distance upstream from the throat of the axially symmetric passage.

Reference is now made to Figures 5 and 6 showing a rib-like nozzle provided with structure for varying nozzle geometry. The effective throat area of such nozzle includes the throat area of the axially symmetric passage 12 and the throat area of the two dimensional passages 13, formed by the ribs 14 extending from the nozzle wall 15. The throat area of the passages 13 is, however, readily varied as by flaps 16 pivoted in the nozzle as at 17 at the upstream ends of the rib-like members 14, and operable between the ribs. The flaps 16 are operable between closed positions in which they obstruct the flow of gases into the two dimensional passages such that the effective throat area of the nozzle is equal to the throat area of the axially symmetric passage 12, and open positions in which the flaps set in recesses 19 in the nozzle wall to provide a maximum effective throat for the nozzle. The flaps may be disposed between their open and closed positions to provide any intermediate effective throat size for the nozzle. Various positions of the flaps for controlling the effective throat area of the nozzle are shown in Figures 5 and 6. The flap positions may be adjusted in response to control signals by any suitable mechanism which may, for example, include the hydraulically operated piston 20 in cylinder 21, a ring

22 connected to the piston, and linkages 23, 24, and 25 connecting the ring to each of the flaps.

It will now be apparent that I have devised a nozzle of unique design which by permitting expansion through a central axially symmetrical passage and surrounding two-dimensional passages, provides for a nozzle of reduced length. Furthermore, as indicated the nozzle may be readily adapted to vary its geometry, and so provide a nozzle which may be operated efficiently under various conditions. Because of the adjustable feature the nozzle is of course particularly suitable for use on the afterburner of a gas turbine engine of a jet aircraft.

It should of course be understood that this invention is not limited to the specific details of construction and arrangement thereof herein shown and described, and that changes and modifications may occur to one skilled in the art without departing from the spirit of the invention.

I claim as my invention:

1. An exhaust nozzle for a jet engine comprising a nozzle wall having a plurality of rib-like members extending therefrom to define a central axially symmetric converging-diverging passage and a plurality of peripheral converging-diverging passages about the central passage between the rib-like members communicating with said central passage, said peripheral passages being formed with throats disposed upstream from the throat of the axially symmetric passage.

2. An exhaust nozzle for a jet engine comprising a nozzle wall having a plurality of rib-like members extending therefrom to define a central axially symmetric converging-diverging passage and plurality of peripheral converging-diverging passages about the central passage between the rib-like members and communicating with said central passage, the nozzle also having flaps movable in the peripheral passages for varying the nozzle throat area.

3. An exhaust nozzle for a jet engine comprising a nozzle wall having a plurality of rib-like members extending inwardly therefrom defining a nozzle passage having a central converging-diverging portion and a plurality of peripheral converging-diverging portions extending radially from said central portion and communicating therewith and disposed between said rib-like members, said wall extending downstream beyond said central and peripheral portions.

4. An exhaust nozzle as defined in claim 3 wherein said rib-like members are aerodynamically contoured to provide said peripheral portions adapted to substantially match pressures longitudinally at the boundaries of said central and peripheral portions.



5. An exhaust nozzle for a jet engine comprising a nozzle wall of circular cross-section having a plurality of longitudinally disposed rib-like members extending radially inward therefrom a distance less than the radius of said nozzle, said rib-like members having inner faces defining a central passage of first converging-diverging contour and lateral faces defining with said wall a plurality of peripheral passages of second converging-diverging contour and communicating with said central passage, said wall extending downstream beyond said central and peripheral passages.

6. An exhaust nozzle for a jet engine comprising a nozzle wall of circular cross-section having a plurality of rib-like members extending radially inward therefrom a distance less than the radius of said nozzle, said rib-like members having inner faces contoured to define a central converging-diverging passage having a throat, said rib-like members having lateral faces contoured to define a plurality of peripheral converging-diverging passages having throats and communicating with said central passage, the throats of said peripheral passages being positioned upstream from said central throat.

7. An exhaust nozzle as defined in claim 6, wherein there are disposed a plurality of flaps between said rib-like members, said flaps having their upstream ends pivotally mounted to the nozzle wall adjacent to the upstream ends of said rib-like members and their downstream ends arcuately movable between said rib-like members to vary the throat areas of said peripheral passages, and means for imparting arcuate motion to said flaps.

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