

May 3, 1960

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2,934,892

VARIABLE AREA PROPULSION NOZZLE

Filed Jan. 31, 1957

4 Sheets-Sheet 1

FIG. 1.

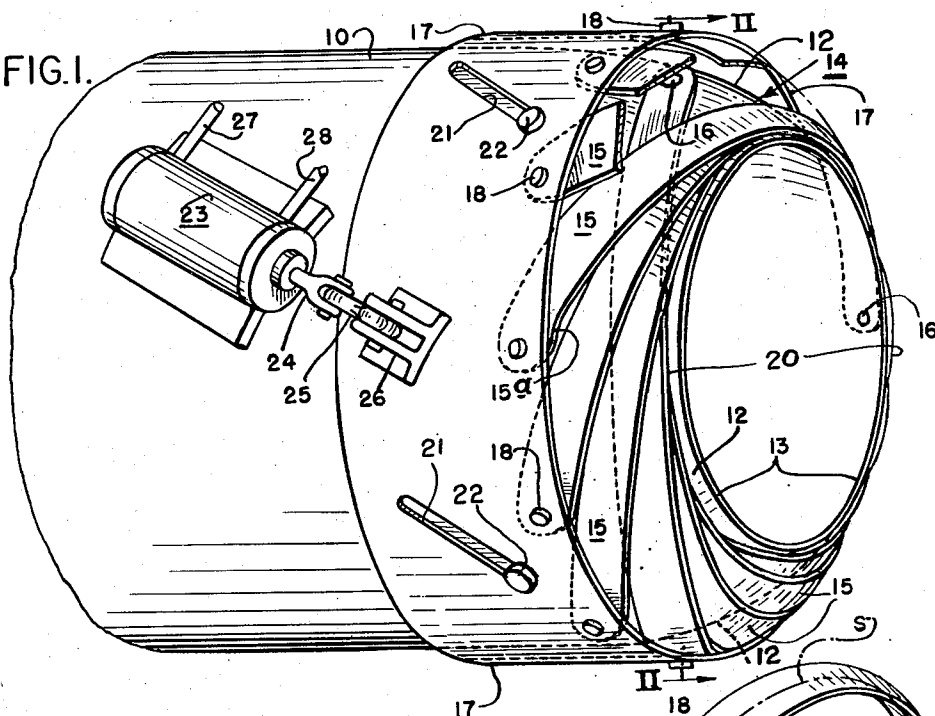


FIG. 2.

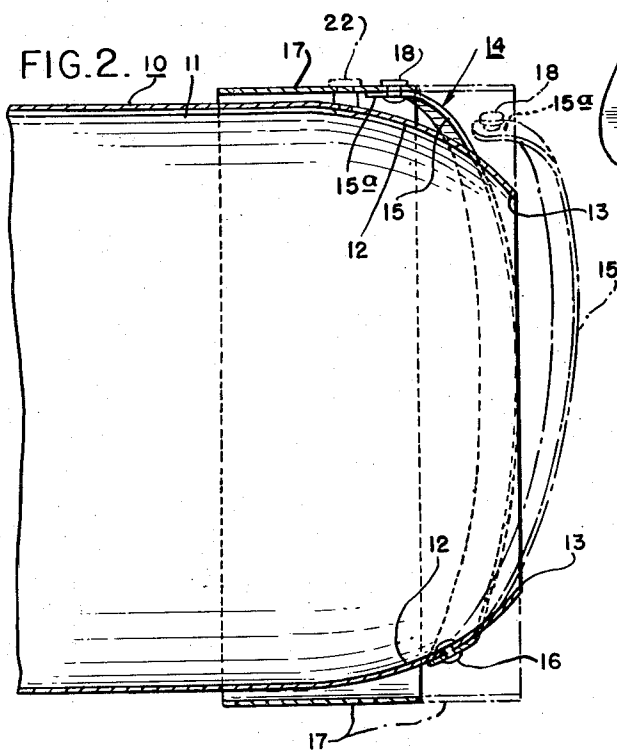
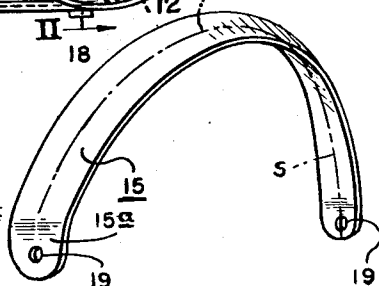


FIG. 3.



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FIG. 4.

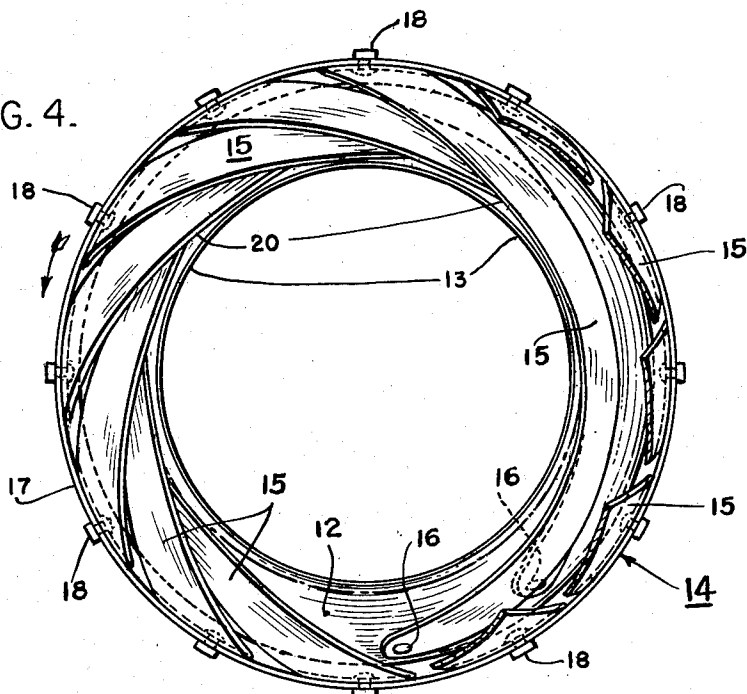
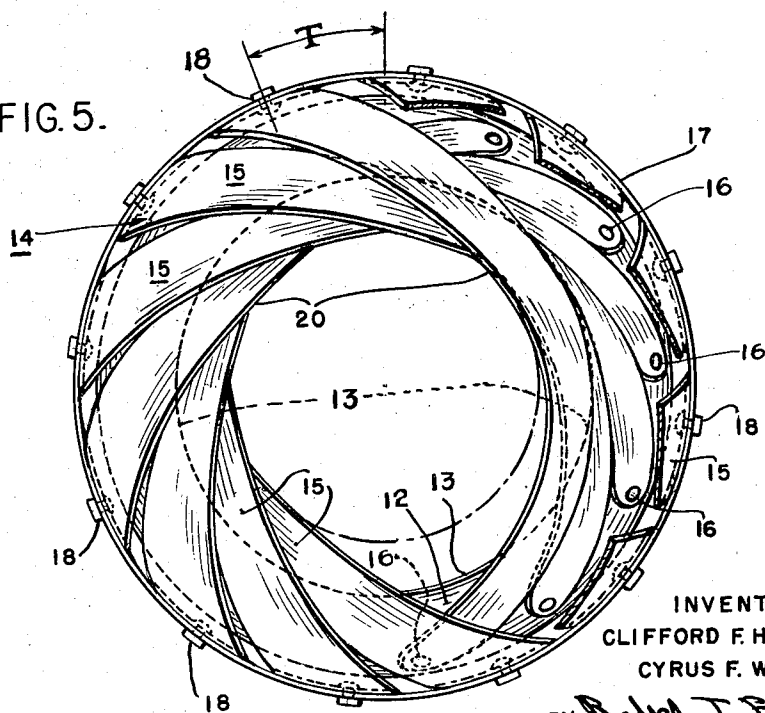


FIG. 5.



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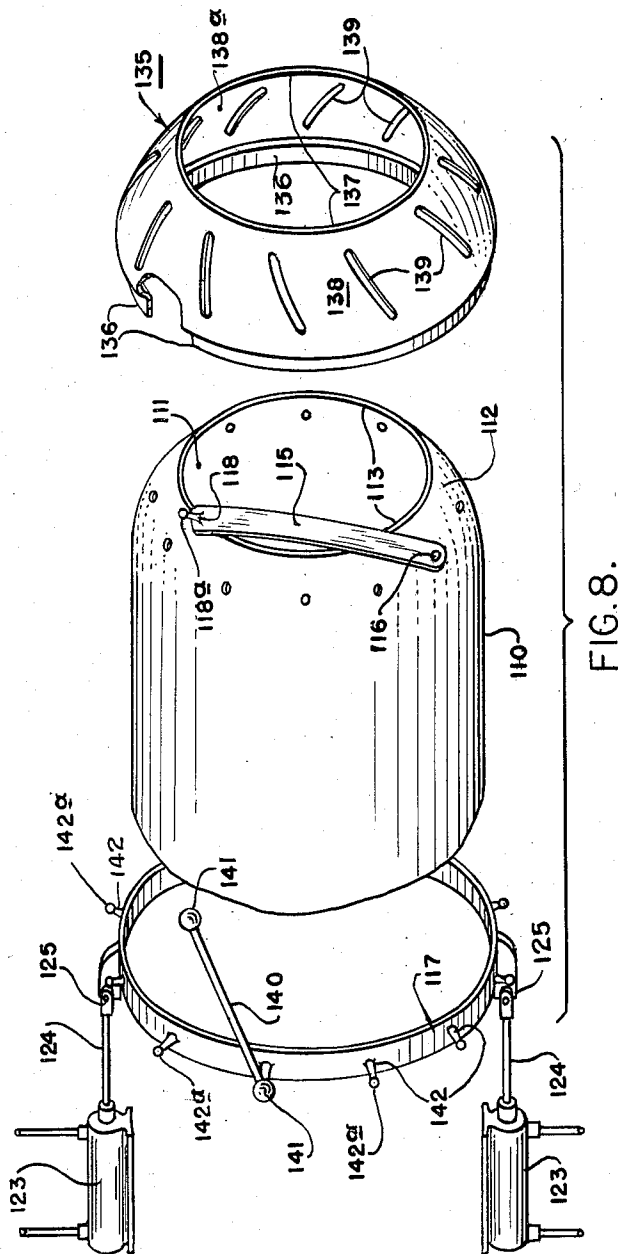
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VARIABLE AREA PROPULSION NOZZLE

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4 Sheets-Sheet 4



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VARIABLE AREA PROPULSION NOZZLE

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Application January 31, 1957, Serial No. 637,460

10 Claims. (Cl. 60—35.6)

This invention relates to jet propulsion power plants, and particularly to variable area nozzle equipment for a power plant of that character.

It is a further object of the invention to provide a variable area nozzle structure for a jet propulsion power plant in which the gas loads are supported by the nozzle structure and are not transmitted to the nozzle actuating system.

A more specific object of the invention is to provide a variable area nozzle of the above type which employs an annular array of mutually overlapping curved iris leaves jointly movable in nozzle area reducing or increasing direction.

Yet another object is to provide a variable area nozzle of the iris type in which each of the iris leaves supports its share of the gas load by tension stress instead of bending stress within the leaf.

In accordance with the invention, there is provided a variable area nozzle of the iris type comprising a plurality of preformed iris leaves of curved shape and arranged in overlapping relation with each other. Each of the leaves is pivoted at one end to the exhaust collector casing and at its other end to an annular actuator or unison ring. The unison ring is mounted on the collector casing for fore and aft movement along the central axis thereof and suitable power actuating structure is harnessed thereto for positioning the unison ring. Thus, when the unison ring is moved in one direction the iris leaves are moved in nozzle area-reducing direction, and when the unison ring is moved in the opposite direction the iris leaves are moved in nozzle area-increasing direction.

The iris leaves impart a spherical shape to the nozzle and each of the iris leaves is preferably curved in a manner to provide a segment of that sphere. More specifically, each of the leaves is preferably so shaped that a line describing the center of stress within the leaf lies on a great circle of the spherical surface defined by the iris leaf array.

The foregoing and other objects are effected by the invention as will be apparent from the following description and claims taken in connection with the accompanying drawings, forming a part of this application, in which:

Fig. 1 is a perspective view of the exhaust end of a jet propulsion power plant having an iris type variable area nozzle structure made in accordance with the invention;

Fig. 2 is an axial sectional view taken on line II—II, with all but one of the iris leaves omitted for clarity;

Fig. 3 is a perspective view of one of the iris leaves;

Fig. 4 is an end elevational view showing the above variable area nozzle in one operating position; some of the iris leaves being broken away for clarity;

Fig. 5 is a view similar to Fig. 4 but showing the nozzle in another operating position;

Fig. 6 is a perspective view of a variable area exhaust nozzle illustrating a preferred embodiment of the invention;

Fig. 7 is an end elevational view of the exhaust nozzle

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shown in Fig. 6, on a larger scale and with portions cut away or omitted for clarity; and

Fig. 8 is an "exploded" perspective view of the exhaust nozzle of Figs. 6 and 7, but showing only one iris leaf and its associated linkage.

Referring to the drawings in detail, especially Figs. 1 and 2, there is shown a tubular exhaust collector casing 10 of the type provided at the rearward end of an aviation jet engine (not shown), defining a gas passageway 11 and having a converging end portion 12 of frusto-spherical shape defining a discharge opening 13 for the ejection of the hot gases to the atmosphere in a propulsive jet.

In accordance with the invention, variable exhaust nozzle structure generally designated 14 is provided for varying the effective cross-sectional area of the discharge opening 13.

The variable area exhaust nozzle structure 14 comprises a plurality of iris leaves 15 of curved shape arranged in an annular array about the converging ejector casing portion 12. Each of the leaves 15 is pivotally attached at one end to the ejector casing 10 by a pivot member 16 and at the other end to an annular actuating member or unison ring 17 by a pivot member 18.

Each of the iris leaves 15, as best seen in Fig. 3, is of elongated shape and preferably is preformed in a manner to provide a curved surface which is a substantially 180° arcuate segment of a sphere and an offset end portion 16a for smooth abutment with the unison ring 17. Adjacent the end portions of the leaf 15 a pair of diametrically opposed holes 19 is provided for reception of the pivot members 16 and 18, and the leaf is so proportioned that, under the gas load imposed thereon during operation, the line S describing the center of tensile stresses within the leaf lies substantially on a great circle of the sphere.

The iris leaves 15 are disposed in mutually overlapping spiral relation with each other and are uniformly distributed about the converging casing portion 12, so as to provide a substantially gas tight structure of frusto-spherical shape having its center on the central axis of the ejector casing and defining a substantially circular nozzle opening 20, concentric with the discharge opening 13.

The unison ring 17 is movably mounted on ejector casing 10 and is provided with a plurality of skewed slots 21 cooperating with studs 22 extending therethrough and fixed in the casing. The unison ring 17 is actuated by a plurality of power actuators 23 (only one shown) which, as illustrated, may be of the fluid motivated piston and cylinder type having a reciprocable piston rod 24 connected by a link 25 to a bracket 26 fixed to the unison ring. Power actuators of this type, as well known in the art, are supplied with pressurized fluid through a conduit 27 to extend the piston rod 24 and through a conduit 28 to retract the same.

In Figs. 1 and 2, the variable area iris nozzle 14 is shown in its maximum open position, i.e., the area of the nozzle opening 20 is at the maximum value and substantially coincides with the ejector exhaust opening 13.

When it is desired to reduce the area of the nozzle opening 20, pressurized fluid is admitted to the power actuator 24 through conduit 27, thereby extending the piston rod 24 and urging the unison ring 17 to the right, as viewed in Figs. 1 and 2, in a spiral motion as determined by the angle of skew of the slots 21. The resulting spiral motion of the unison ring drives the pivot members 18 counterclockwise as viewed in Fig. 4. Since the pivot members 16 remain stationary, the iris leaf members 15 are rotated counterclockwise about the pivot members 16 as viewed in Fig. 4, thereby moving radially inwardly and causing a constriction of the nozzle opening 20.

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The limits of travel of the unison ring 17 have been illustrated in Fig. 2, wherein the solid line positions of the unison ring 17 and the leaves 15 (only one shown for clarity) denote the maximum nozzle area position, while the dot-dash line positions denote the minimum nozzle area position. These two extremes are also illustrated in Figs. 4 and 5, respectively. The angular degree of travel between the two extreme positions is denoted in Fig. 5 by the double-headed arrow T.

When it is desired to increase the area of the nozzle opening 20, pressurized fluid is admitted to the power actuator 23 through conduit 28, thereby retracting the piston rod 24 and reversing the above outlined movements.

Since the iris leaves 15 are preformed to a spherical shape and are proportioned in a manner to cause the center line of stress S to lie on a great circle of that sphere, each of the leaves supports its share of the loading imparted by the exhaust gases. The gas load places the leaves in tension instead of bending, hence a minimum portion of the load assumed by the leaves is transmitted to the power actuator 23. Also, since each leaf 15 assumes its share of the load, the leaves are uniformly loaded and binding between adjacent leaves is minimized.

When the variable area iris nozzle is in its maximum open position, the leaves 15 are shielded from the direct heating effects of the exhaust gases by the converging ejector casing portion 12.

Referring to Figs. 6-8 inclusive, illustrating a preferred embodiment of the invention, there is shown a tubular exhaust collector casing 110 of jet engine (not shown), defining a gas passageway 111 and having a converging end portion 112 of frusto-spherical shape defining a gas discharge opening 113.

Variable exhaust nozzle structure 114 of modified form is provided for varying the effective cross-sectional area of the discharge opening 113. The variable area exhaust nozzle structure 114 comprises a plurality of curved iris leaves 115 arranged in an annular array about the ejector casing portion 112. Each of the leaves 115 is pivotally attached at one end to the ejector casing by a pivot 116 which is disposed normal to the surface of the casing portion 112 and the leaf, and is provided at its opposite end with an upstanding stud 118 having a ball end 118a.

Each of the iris leaves 115 is of elongated shape and is preferably preformed in a manner to provide a curved surface which is a segment of a sphere. Each of the leaves is so proportioned that under the gas load imposed thereon during operations, the longitudinal centerline of tensile stresses lies on a great circle of the sphere, as described in conjunction with the first embodiment.

The iris leaves 115 are disposed in mutually overlapping spiral relation with each other and are uniformly distributed about the frusto-spherical casing portion 112, in a manner to provide a substantially gas tight structure of frusto-spherical shape having its center coincident with the center of the casing portion 112 and defining a nozzle opening 120 concentric with the discharge opening 113.

An annular sheet metal shroud member 135 having an inwardly directed peripheral flange 136 and a central circular opening 137 encompasses the ejector casing 110 and is rigidly attached thereto at the flange 136 by welding or other suitable fastening means (not shown). The shroud member 135 has a main body portion 138 of frusto-spherical shape but of larger radius than the casing end portion 112 and together therewith forming a frusto-spherical chamber 138a, thereby permitting freedom of movement to the iris leaves 115 confined therein. The shroud is further provided with an annular row of skewed slots or apertures 139 of elongated arcuate shape, through which the studs 118 extend. Each of the slots 139 describes an arc of a circle having its center at the pivot 116 of the associated leaf 115.

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The iris leaves 115 are operatively connected to a unison ring 117 by a plurality of links 140. Each of the links 140 is provided with a spherical socket 141 at each end for attachment to the ball end 118a of its associated iris leaf stud 118 and a similar stud 142 mounted on the unison ring 117. Accordingly, the studs 142 are also provided with ball ends 142a.

The unison ring 117 is operatively connected to a pair of reciprocable power actuators 123 having pistons 124, for movement along its longitudinal axis by suitable pivotal connecting means 125.

In Figs. 6 and 7, the variable area nozzle 114 is shown in its closed position, i.e., the area of the nozzle opening 120 (defined by the iris leaves 115) is at its minimum value.

When it is desired to increase the area of the nozzle opening 120, the power actuators are energized (by means not shown) in a manner to retract the piston rods 124 and thereby urge the unison ring 117 axially to the left as viewed in Fig. 6. Since the iris leaves 115 are pivotally mounted to the ejector casing, they are rotated in counterclockwise direction about the pivots 116 by the links 140 (as viewed in Fig. 8), thereby moving radially outwardly to increase the area of the nozzle opening 120.

The limits of travel of the iris leaves are determined by the length of the slots 139 in the shroud. However, the slots 139 are so proportioned that, when the nozzle structure is in its maximum open position, the nozzle opening 120 coincides with the openings 113 and 137 in the casing 110 and shroud 135, respectively.

Hence, when the nozzle structure is in its maximum open position, the iris leaves are completely enclosed within the casing end portion 112 and the shroud 135 and thus shielded from the heating effects and gas loading forces of the exhaust gases being ejected by the engine.

When it is desired to constrict the nozzle structure, the power actuators are energized for movement in the opposite direction, thereby reversing the direction of motion of the iris leaves and moving them radially clockwise (as seen in Fig. 8) about the pivots 116. Any degree of constriction of the nozzle opening 120 may be obviously attained by suitable regulation of the power actuators 123.

Although in connection with the first embodiment, the iris leaves 15 have been described as being substantially 180° arcuate segments of a sphere with diametrically opposed holes 19, it will be apparent that the leaves may be greater or less than 180° segments and the holes need not be diametrically opposed.

While the invention has been shown in several forms, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof.

What is claimed is:

1. Variable area nozzle apparatus for a jet engine comprising tubular casing structure having an outer peripheral surface and forming a fluid passageway having a circular fluid discharge opening at one end, a plurality of elongated iris leaves of curved shape circumferentially disposed about said casing structure in mutually overlapping relation and jointly defining a substantially circular exhaust nozzle opening in registry with the opening in said casing structure, means including a plurality of first members for pivotally attaching one end of said iris leaves to said outer peripheral surface of the casing structure, said first pivot members being disposed substantially normal to the adjacent surface portions of said casing structure, an actuating member supported by said casing structure, and means including a plurality of second pivot members for pivotally attaching the other end of each of said iris leaves to said actuating member, said second pivot members being disposed substantially normal to the adjacent surface portions of their associated iris leaves, said actu-

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ating member being movable relative to said casing structure in one direction to rotate said iris leaves about said first pivot members in a direction to reduce the area of said nozzle opening and in another direction to rotate said iris leaves in a direction to increase the area of said nozzle opening.

2. Variable area nozzle apparatus for a jet engine comprising tubular casing structure having an outer peripheral surface and forming a fluid passageway having a circular fluid discharge opening at one end, a plurality of elongated iris leaves circumferentially disposed about said casing structure in mutually overlapping relation and jointly defining a substantially circular exhaust nozzle opening in registry with the opening in said casing structure, each of said iris leaves having a spherical surface portion and jointly defining a substantially frusto-spherical surface, means including a plurality of first pivot members for pivotally attaching one end of each of said iris leaves to said outer peripheral surface of the casing structure, said first pivot members extending substantially normal to the adjacent surface portions of said casing, an actuating member encompassing said casing structure, and means including a plurality of second pivot members for pivotally attaching the other end of each of said iris leaves to said actuating member, said second pivot members extending substantially normal to the adjacent surface portions of their associated iris leaves, said actuating member being movable relative to said casing structure in one direction to rotate said iris leaves about said first pivot members in a direction to reduce the area of said nozzle opening and in another direction to rotate said iris leaves in a direction to increase the area of said nozzle opening.

3. Variable area nozzle apparatus for a jet engine comprising tubular casing structure forming a fluid passageway and having a converging outer peripheral surface portion at one end and defining a circular fluid discharge opening, a plurality of elongated iris leaves circumferentially disposed about said casing structure in mutually overlapping spiral relation and jointly defining a substantially circular exhaust nozzle opening in registry with the opening in said casing structure, each of said iris leaves having a spherical portion and said iris leaves jointly defining a substantially frusto-spherical surface, means including first pivot members for pivotally attaching one end of each of said iris leaves to said outer peripheral surface of the casing structure, said first pivot members being disposed substantially normal to the adjacent surface portions of said casing structure, an actuating member encompassing said casing structure, and means including second pivot members for pivotally attaching the other end of each of said iris leaves to said actuating member, said second pivot members being disposed substantially normal to the adjacent surface portions of their associated iris leaves, said actuating member being movable relative to said casing structure in one direction to rotate said iris leaves about said first pivot members in a direction to reduce the area of said nozzle opening and in another direction to rotate said iris leaves about said second pivot members in a direction to increase the area of said nozzle opening, and said converging casing surface portion underlying said iris leaves when the latter are in the position of maximum nozzle area.

4. Variable area nozzle apparatus for a jet engine comprising tubular casing structure forming a fluid passageway and having a converging peripheral marginal surface portion at one end defining a circular fluid discharge opening, a plurality of elongated iris leaves of spherical surface shape circumferentially disposed about said casing structure in mutually overlapping relation and jointly defining a frusto-spherical surface having a substantially circular exhaust nozzle opening in registry with the opening in said casing structure, said leaves each having opposed end portions and a central portion, the central portions of said leaves jointly defining said circular nozzle opening, each of said iris leaves being so

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formed that a line describing the center of stress there-within lies substantially on a great circle of said spherical surface, means for pivotally attaching one end of each of said iris leaves to said converging surface portion of the casing structure, an actuating member encompassing said casing structure, and means for pivotally attaching the other end of each of said iris leaves to said actuating member, said actuating member being movable relative to said casing structure in one direction to move said central portions of said iris leaves in a direction to reduce the area of said nozzle opening and in another direction to move said central portions of said iris leaves in a direction to increase the area of said nozzle opening, and said converging casing surface portion underlying said iris leaves.

5. In a jet engine, tubular casing structure forming a fluid passageway and having a fluid discharge opening at one end, an adjustable nozzle structure for varying the effective area of said opening comprising a plurality of elongated iris leaves, said casing structure having an outer peripheral surface portion and said leaves being circumferentially disposed about said outer surface of the casing structure, said leaves having spherical surface portions and being in mutually overlapping spiral relation with each other, said leaves jointly imparting a substantially spherical shape to said nozzle structure and defining a nozzle opening concentric with said fluid discharge opening, means for pivotally attaching one end of each of said leaves to said outer surface of the casing structure, a movable actuating member encompassing said casing structure, means for pivotally attaching the other end of each of said leaves to said actuating member, and means for guiding said actuating member along a helical path concentric with the axis of said tubular structure, whereby when said actuating member is moved in one direction said leaves are moved in nozzle area reducing direction and when said actuating member is moved in the opposite direction said leaves are moved in nozzle area increasing direction.

6. In a jet engine, tubular casing structure forming a fluid passageway and having a converging marginal portion at one end defining a fluid discharge opening, an adjustable nozzle structure for varying the effective area of said opening comprising a plurality of elongated iris leaves circumferentially disposed about said casing structure, said leaves having spherical surface portions and being in mutually overlapping spiral relation with each other, said leaves jointly imparting a substantially spherical shape to said nozzle structure and defining a nozzle opening concentric with said fluid discharge opening, said casing structure having an outer peripheral surface, means for pivotally attaching one end of each of said leaves to said outer surface of the casing structure, a movable actuating member encompassing said casing structure, means for pivotally attaching the other end of each of said leaves to said actuating member, and means for guiding said actuating member along a helical path concentric with the axis of said tubular structure, whereby when said actuating member is moved in one direction said leaves are moved in nozzle area reducing direction and when said actuating member is moved in the opposite direction said leaves are moved in nozzle area increasing direction, and said converging casing portion underlying said iris leaves when the latter are in the position of maximum nozzle area.

7. In a jet engine, tubular casing structure forming a fluid passageway and having a converging peripheral marginal portion at one end defining a fluid discharge opening, an adjustable nozzle structure for varying the effective area of said discharge opening comprising an annular array of elongated iris leaves circumferentially disposed about said converging marginal portion, said leaves having spherical surface portions and being in mutually overlapping spiral relation with each other, said leaves jointly imparting a substantially spherical shape to said nozzle

structure and defining a nozzle opening concentric with said fluid discharge opening, a shroud member encompassing said leaves and said casing and attached at its upstream edge portion to said casing, said shroud member having an annular array of apertures, said casing having an outer peripheral surface, means for pivotally attaching one end of each of said leaves to said outer peripheral surface of said casing structure, a movable annular actuating member encompassing said casing, and means including a stud extending through each of said apertures and attached to the other end of each of said leaves for pivotally connecting said other ends to said actuating member.

8. In a jet engine, tubular casing structure forming a fluid passageway and having a converging peripheral marginal portion at one end defining a fluid discharge opening, an adjustable nozzle structure for varying the effective area of said opening comprising an annular array of elongated iris leaves circumferentially disposed about said converging marginal portion, said leaves having spherical surface portions and being in mutually overlapping spiral relation with each other, said leaves jointly imparting a substantially spherical shape to said nozzle structure and defining a nozzle opening concentric with said fluid discharge opening, a shroud member encompassing said leaves and said casing and attached at its upstream peripheral edge portion to said casing, said shroud member having an annular array of openings, said casing structure having an outer peripheral surface, means for pivotally attaching one end of each of said leaves to said outer peripheral surface of the casing structure, a movable annular actuating member encompassing said casing, and means including a plurality of links and studs for pivotally connecting the other ends of said leaves to said actuating member, said studs extending through said apertures and each of said studs being connected to said other end of an associated leaf and each of said links being connected at one end to one of said studs and at its other end to said actuating member.

9. In an aviation jet engine, tubular casing structure forming a fluid passageway and having a converging peripheral marginal portion at one end defining a fluid discharge opening, an adjustable nozzle structure for varying the effective area of said opening comprising an annular array of elongated iris leaves circumferentially disposed about said converging marginal portion, said leaves having spherical surface portions and being in mutually overlapping spiral relation with each other, said leaves jointly imparting a substantially spherical shape to said nozzle structure and defining a nozzle opening concentric with said fluid discharge opening, a shroud member encompassing said leaves on said casing and attached at its upstream peripheral edge portion to

said casing, said shroud member being of frusto-spherical shape and having an annular array of elongated apertures, said casing structure having an outer peripheral surface, means for pivotally attaching one end of each of said leaves to said outer peripheral surface of the casing structure, a movable annular actuating member encompassing said casing, and means including a plurality of links and studs for pivotally connecting the other ends of said leaves to said actuating member, said studs extending through said apertures, each of said studs being connected to said other end of the associated leaf and each of said links being connected at one end to one of said studs and at its other end to said actuating member, each of said apertures describing the arc of a circle about the associated leaf pivotal means.

10. In a jet engine, tubular casing structure forming a fluid passageway and having a converging peripheral marginal portion at one end defining a fluid discharge opening, an adjustable nozzle structure for varying the effective area of said opening comprising an annular array of elongated iris leaves circumferentially disposed about said converging marginal portion, said leaves having spherical surface portions and being in mutually overlapping spiral relation with each other, said leaves jointly imparting a substantially spherical shape to said nozzle structure and defining a nozzle opening concentric with said fluid discharge opening, an annular shroud member encompassing said leaves and said casing and attached at its upstream peripheral edge portion to said casing, said shroud member having an annular array of apertures, said casing structure having an outer peripheral surface, means for pivotally attaching one end of each of said leaves to said outer peripheral surface of the casing structure, a movable annular actuating member encompassing said casing, and means including a plurality of studs attached to the other ends of said leaves and being received in said apertures for pivotally connecting said other ends to said actuating member, said shroud member and said converging casing portion being of frusto-spherical shape and jointly defining a frusto-spherical chamber confining said annular array of leaves.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,934,892

May 3, 1960

Clifford F. Hurlbert et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 28, for "16a" read -- 15a --; column 4, line 65, after "first" insert -- pivot --; line 66, after "of" insert -- each of --; column 7, line 52, for "on" read -- and --.

Signed and sealed this 31st day of January 1961.

(SEAL)

Attest:

KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON

Commissioner of Patents