Oct. 10, 1961

J. D. JEWELL

3,003,312

EXHAUST NOZZLE FOR JET ENGINES

Filed Aug. 19, 1957

4 Sheets-Sheet 1

Fig. 1

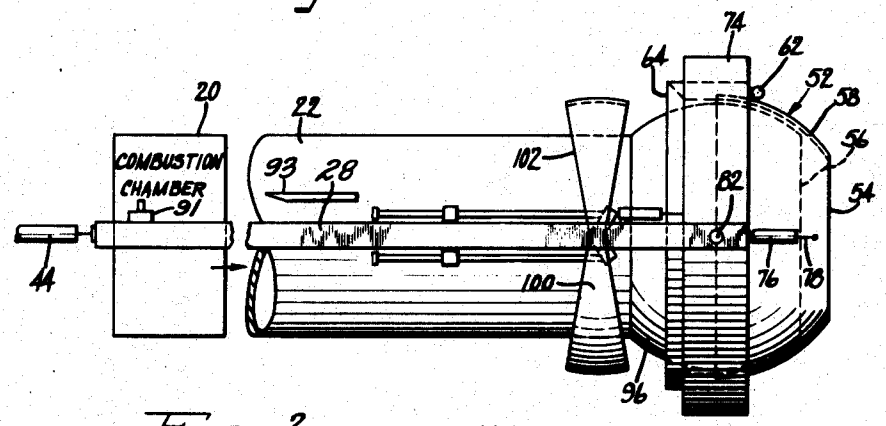


Fig. 2

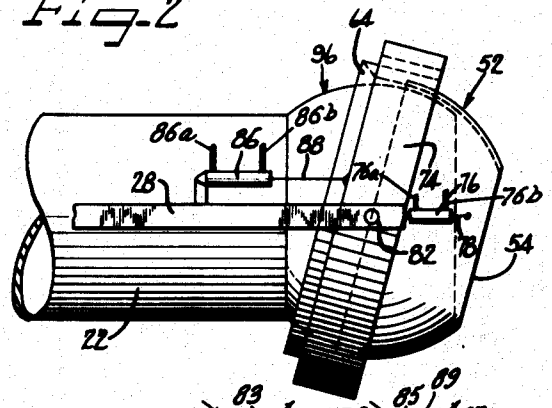
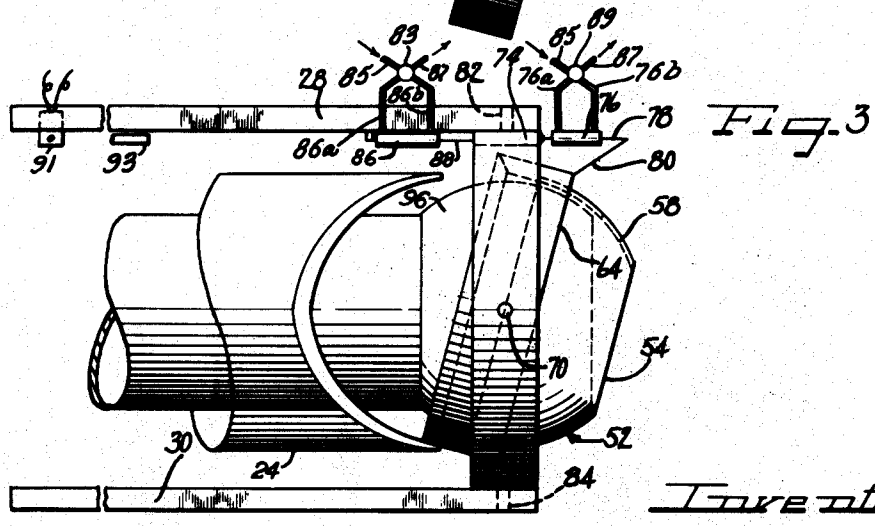


Fig. 3



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Fig. 4

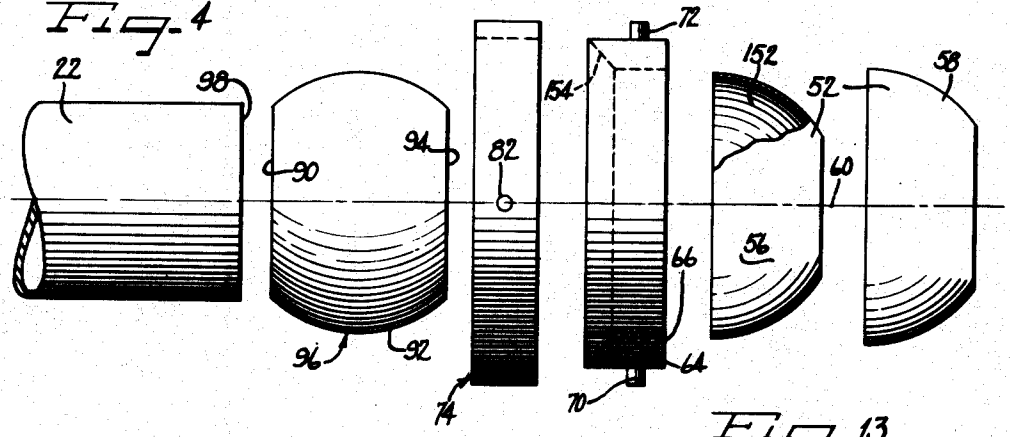
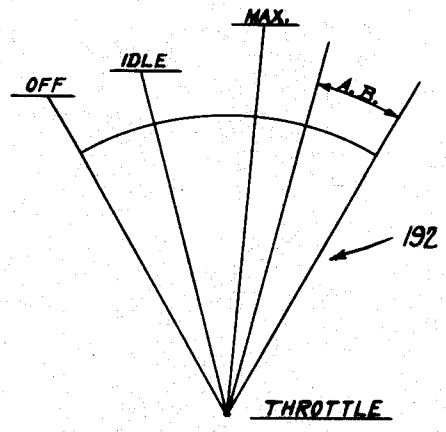


Fig. 13



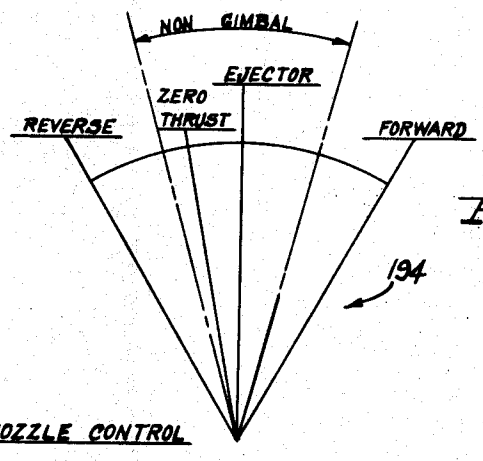


Fig. 14

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Fig. 5

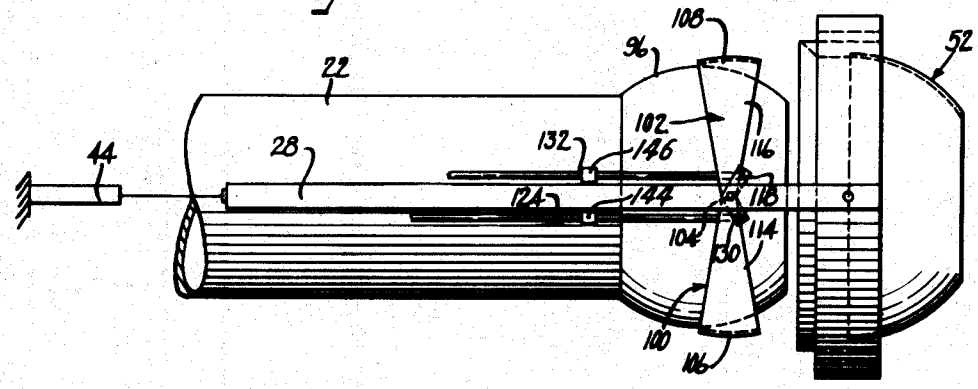


Fig. 6

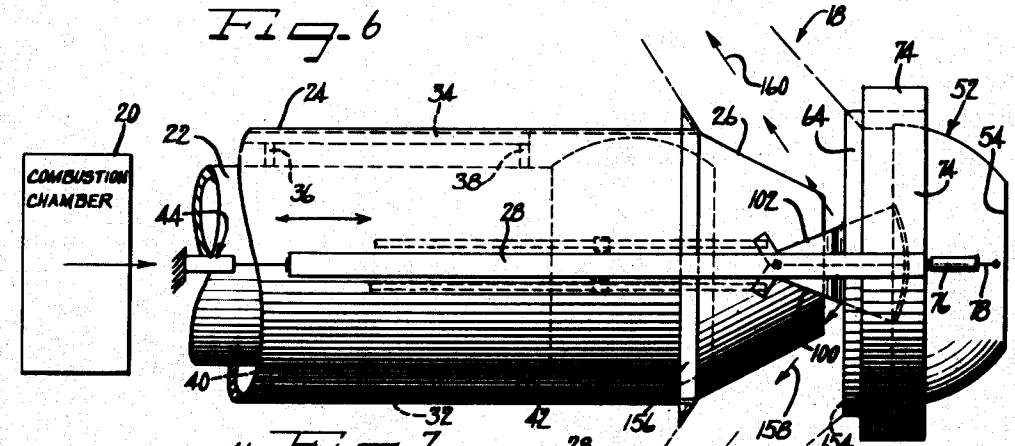
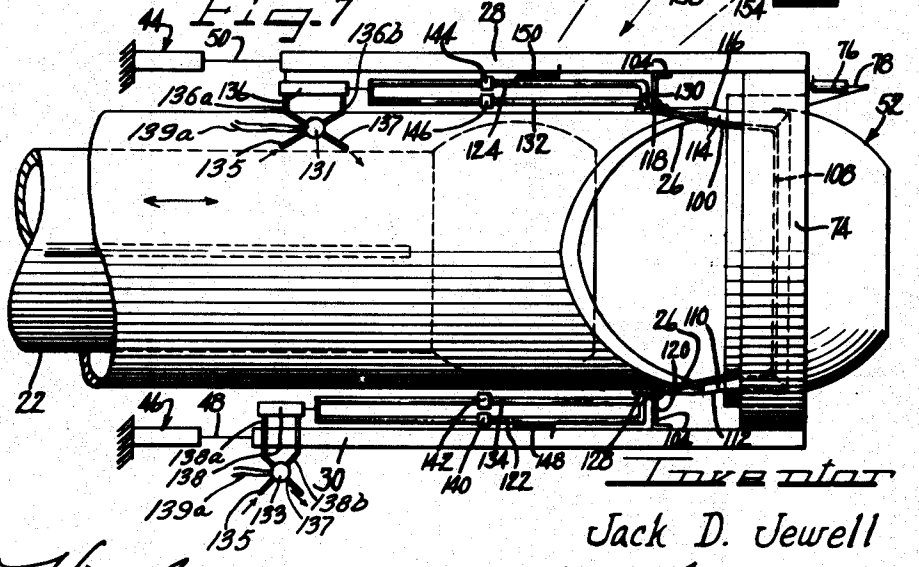


Fig. 7



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Fig. 8

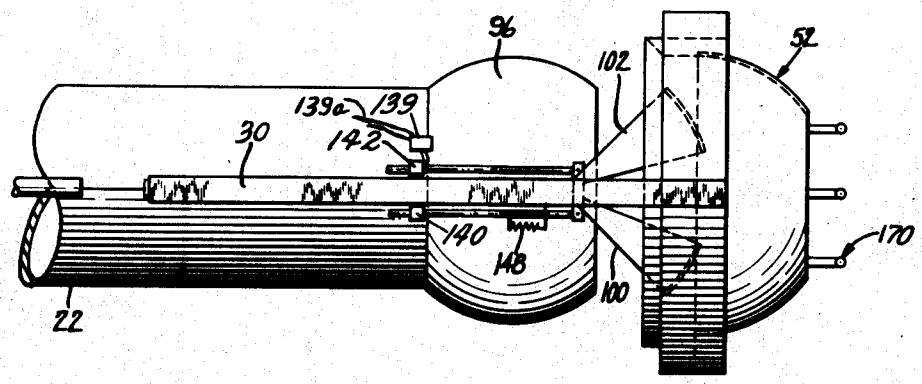


Fig. 9

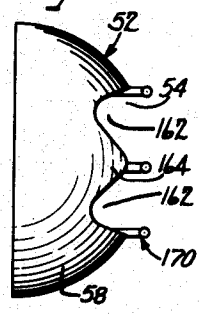


Fig. 10

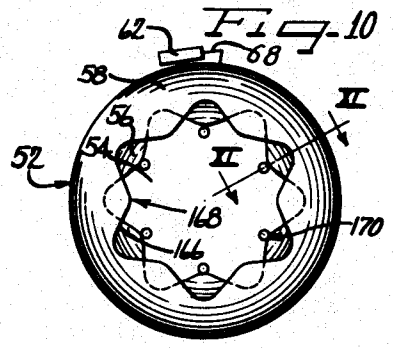


Fig. 11

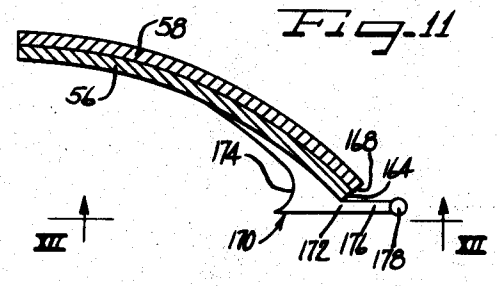
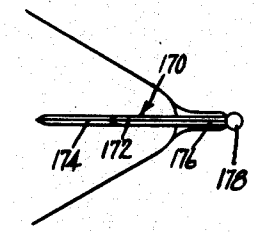


Fig. 12



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United States Patent Office 3,003,312
Patented Oct. 10, 1961

3,003,312

EXHAUST NOZZLE FOR JET ENGINES

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Filed Aug. 19, 1957, Ser. No. 678,915
2 Claims. (Cl. 60—35.54)

The present invention relates to improvements in controllable jet nozzles for jet propulsion units. More particularly, the invention relates to improvements in jet nozzles which are controllable in their various functional factors that control the flow of gas to obtain the thrust power, and especially to improvements in the control of the nozzle to affect the forward thrust, directional control, reversal of thrust, nozzle area, sound attenuation, and operational safety of the nozzle.

The improved nozzle assembly embodying the principles of the invention may be utilized in a jet propulsion engine in an aircraft or the like, and also may be employed for test purposes. The structural features employed in accordance with the principles of the invention mutually contribute to effect an improved operation of the nozzle in areas including each of those referred to above.

Accordingly, it is an object of the invention to provide an improved jet nozzle for the propulsion of hot gases to obtain a controllable thrust which has improved performance features and has an improved controllability over nozzles heretofore used.

Another object of the invention is to provide a controllable jet propulsion nozzle with improved directional control features.

A further object of the invention is to provide a jet propulsion nozzle for use in aircraft or the like, wherein the thrust can be controllably reversed and wherein the directional control nozzle and its associated features contribute to the performance of the thrust reversing mechanism.

A further object of the invention is to provide an improved nozzle wherein the nozzle area is controllably variable, and wherein the area control contributes to the thrust performance of the nozzle, and also obtains improved thrust reversing and improved noise characteristics.

Another object of the invention is to provide an improved jet thrust nozzle having an improved nozzle opening shape for enhancing the performance of the nozzle and improving noise attenuation, and especially for relieving screech conditions at choked nozzle settings.

A further object of the invention is to provide an improved method and apparatus for controlling the forward and reverse thrust of the nozzle and for providing a safety feature wherein forward thrust will be restored in the event of failure of the reverse thrust controls.

A still further object of the invention is to provide improved operational controls for a jet nozzle for obtaining direction control, reversal of thrust, variance of the nozzle area, and adjustment of controlled jet flow for either directional thrust or net forward or reverse thrust.

A further object of the invention is to provide an improved mechanism for operation under certain circumstances as a secondary air ejector to cool the jet exhausts and decrease the sound power.

Another object of the invention is to provide a jet nozzle with a shape which will create small jets in addition to a large jet with means to create a turbulence to separate the small jets from the larger jets, and for decreasing sound power.

Another object of the invention is to provide an improved control for a variable jet nozzle, wherein directional control is automatically prevented during areas of reverse thrust operation.

Other objects and advantages will become more apparent with the teachings of the principles of the invention in connection with the disclosure of the preferred embodiments thereof, in the specification, claims and drawings, in which:

FIGURE 1 is a plan view, shown somewhat in schematic form, with portions removed, of a jet propulsion nozzle embodying the principles of the invention;

FIGURE 2 is a plan view, similar to FIGURE 1, but with parts removed, illustrating the directional control of the nozzle in a horizontal plane;

FIGURE 3 is a side elevational view of the nozzle with parts removed, and illustrating the directional control in a vertical plane;

FIGURE 4 is an exploded view illustrating assembly parts of the nozzle;

FIGURE 5 is a plan view, similar to FIGURE 1, but with the reverse thrust target members included;

FIGURE 6 is a plan view somewhat in schematic form, of the nozzle with substantially all elements included;

FIGURE 7 is a side elevational view of the nozzle of FIGURE 6;

FIGURE 8 is a plan view of the nozzle illustrating the position of the thrust reversing target members in zero thrust position;

FIGURE 9 is a side elevational view of a part of a variable area nozzle;

FIGURE 10 is a rear elevational view of the variable area nozzle illustrating it adjusted to minimum area;

FIGURE 11 is a sectional view taken along line XI—XI of FIGURE 10, but with the nozzle adjusted to maximum area so that the scallop projections coincide;

FIGURE 12 is a sectional view taken substantially along line XII—XII of FIGURE 11, from the inside of the nozzle to illustrate the vortex generator;

FIGURE 13 is a schematic illustration of the throttle control arrangement; and

FIGURE 14 is a schematic arrangement of the nozzle control.

The variable nozzle assembly is most fully shown in FIGURE 6 at **18**, as variably controlling the flow of gas supplied by a combustion chamber **20**, which may include an afterburner.

The propellant, which may be in the form of a fluid or as commonly used with a thrust engine, in the form of hot gases generated in the combustion chamber, flows through a duct **22**, as illustrated in FIGURES 1 and 6. The duct is illustrated as surrounded by a fuselage protecting tube **24**, which coaxially surrounds the duct and which is omitted from the drawing in FIGURE 1. The fuselage protecting tube has rearwardly extending triangular shaped guard extensions **26, 26**, which are located on each side of the rearwardly moving jet stream when the tube **24** and other operational elements carried on transient bars **28** and **30**, are in extended position.

The tube **24** is shown supported for its axial movement in a coaxial position relative to the duct on tube guides **32** and **34**, which are mounted such as by supports **36** and **38** for the guide **34**, and **40** and **42** for the guide **32**, on the duct **22**. The transient bars or rails are carried on the tube and move axially therewith.

Axial movement in the direction of the flow of the jet stream, for the transient rails, is obtained by rail actuator cylinders **44** and **46**, FIGURES 1, 6 and 7. These cylinders are fixedly mounted, and each contains a piston with a piston rod **48** and **50** connected to the piston and secured to the transient rails **28** and **30**. Operation of the pistons within the cylinders **44** and **46** is obtained by the controlled flow of a hydraulic fluid. Hydraulic fluid is supplied from a suitable pressure source, and controlled through nozzle control valves operated by a nozzle control, such as illustrated in FIGURE 14. The control of

FIGURE 14 controls the flow of hydraulic fluid to other operational cylinders which function to position the other operational elements of the nozzle in a manner which will be described.

As illustrated in FIGURES 1 through 4, a control nozzle or nozzle extension assembly **52** is provided. This nozzle is variable in position in a radial direction to give a controlled lateral thrust. The control nozzle **52** is also variable in size so as to regulate the size of a central nozzle opening **54**, which is of the shape illustrated in FIGURE 10.

The control nozzle **52** includes two parts, an inner shell **56** and an outer shell **58**. The inner shell **56** has a shape whereby the inner and outer surfaces form sections of a sphere. The outer shell **58** is similar in shape and somewhat larger, so as to fit over the inner shell in the manner illustrated in FIGURE 1. The outer shell **58** is normally fixed with respect to the inner shell, but at times will be rotated relative thereto about the central axis **60** to change the size of the jet opening **54**. This relative rotation of the outer shell is controlled by a nozzle rotation cylinder **62**, FIGURE 1. The cylinder is mounted on the inner shell support and deflector ring **64**. The inner shell **56** is secured to the rear face **66** of the inner shell support in a concentric position and is supported thereby. The shell rotation cylinder **62**, has a piston to which is secured a piston rod **68** secured to the outer shell **58**. The flow of fluid to the cylinder **62** thus controls the rotational position of the outer shell in a manner which will later be described.

The inner shell support and deflector ring **64** is pivotally mounted on trunnions **70** and **72** within the outer gimbal ring **74**. The inner shell support and deflector ring **64** acts as the inner gimbal ring and is pivoted about a horizontal axis on the trunnions **70** and **72** to direct the gases upwardly or downwardly and thereby control the vertical thrust. Pivotal movement of the inner shell support and deflector ring **64** is obtained from a vertical actuator cylinder **76**, which is secured to the outer gimbal ring **74**. The cylinder carries a piston slidable therein to which is connected a piston rod **78**. The piston rod is illustrated diagrammatically in FIGURE 3, connected to an arm **80** on the inner shell support ring **64** to pivot the ring about its trunnions **70** and **72**.

Horizontal variations in thrust are obtained by the outer gimbal ring **74** pivoting about its trunnions **82** and **84**. A rotational force to pivot the outer gimbal ring **74** is obtained by an outer gimbal ring operating cylinder **86** which is mounted on the transient support rail **28**. The cylinder **86** contains a slidable piston with a piston rod **88** connected to the gimbal ring **74** at a point spaced from the trunnions **82** and **84** to apply a torque to the ring **74**. Operation of the cylinder **86** for causing a reciprocation of the piston rod **88** is obtained by a flow of controlled hydraulic fluid, as controlled by the nozzle control shown at FIGURE 14. The cylinder **86** is supplied hydraulic fluid through a pressure supply line **85** and a control valve **83** is connected to the supply line to direct fluid through line **86***a* or line **86***b* which lead to the ends of the cylinder **86**. A fluid return line **87** leads back to a reservoir of a pressurized fluid supply system, not shown. The valve **83** may be electrically operated, and direct pressurized fluid to either end of the cylinder **86** and relieve the other end. The cylinder **76** is also supplied pressurized hydraulic operating fluid from the supply line **85** through a valve **89**. The valve **89** may be electrically operated to direct operating fluid through either line **76***a* or line **76***b* which lead to the ends of the cylinder **76**. Fluid is relieved from the unpressurized end of the cylinder through the return line **87**.

The inner and outer shell **56** and **58** will thus move together with operation of the gimbal rings **64** and **74**. The shells are substantially close together in a gas-tight relationship, and are rotationally slidable with respect to each other. The shell assembly or nozzle extension **52**, is mounted on the support nozzle **96**, as illustrated in FIGURES 1 through 4. The support nozzle has an outer spherical surface **92** in order to receive the inner shell **56** for universal sliding movement thereon. The support nozzle **96** has a nozzle opening **94**, which continues from the opening **98** at the end of the duct **22**. The forward edge **90** of the spherical section which forms the inner support nozzle **92**, is secured, such as by welding, to the edge of the duct **22**, which forms the opening **90** at the rear end of the duct.

The inner shell **56** slidably fits on the spherical surface **92** of the support nozzle **96**, and an adequate space is provided therebetween for bearing and sealing members, which are not shown in detail. These bearing and sealing elements are fixedly mounted to the surfaces in order that the control nozzle **52** may be moved axially outwardly away from the support nozzle **96** to the position illustrated in FIGURE 6.

When the control nozzle **52** is moved to its extended position on the transient rails **28** and **30**, the supporting gimbal rings **64** and **74** for the control nozzle **52** are locked in their neutral position wherein the gas nozzle opening **54** faces directly rearwardly. The controls are so locked that the control nozzle cannot be moved in any direction while in the extended position by the control as shown in FIG. 14. This prevents any accidental upsetting lateral deflective forces from occurring when reverse thrust forces are utilized, as controlled by the engine. Locking of the gimbal rings **64** and **74** is accomplished by locking the control valves **83** and **89**. An electrical control switch **91** is mounted on the transient bar **28** and is actuated by a fixed cam **93**. When the transient bars **28** and **30** move outwardly to extended position, the cam **93** actuates the switch **91** which is electrically connected to the valves **83** and **89** to prevent operation of the valves. If desired, the switch may be connected to insure that the valves will be positioned so that the gimbal rings are in neutral position with the gas nozzle facing directly rearwardly. The electrical circuitry for connecting the switch **91** and the valves **83** and **89** and a control handle will be apparent to those versed in the art, and the circuitry need not be shown in detail. It will also be appreciated by those versed in the art that mechanical interconnections may be used for the foregoing operations.

Reverse thrusts are obtained by a pair of reversing target members **100** and **102**, shown in their inoperative position in FIG. 5, and in their full reverse operative position in FIG. 6. These target members are controllably movable between these two positions and the control of FIG. 14 will be set so that the targets **100** and **102** may be automatically set in any one of three positions, with the first position being the inoperative position of FIG. 5, the second position being a position of zero thrust, as shown in FIG. 8, and the third position being a position of full thrust, as shown in FIG. 6.

The target members **100** and **102**, as shown in the plan view of FIG. 5, are mounted for pivotal movement at **104** about a vertical axis. The target members are preferably constructed with an outer concave sector, as shown at **106** for the target member **100**, and at **108** for the target member **102**. As shown in FIG. 7, the target members are mounted on side arms **110**, **112** and **114**, **116**. The target member **100** has pivotal operating arms **118** and **120** connected at its base. Push rods **122** and **124** reciprocate axially to pivot the target member **100**. The other target member **102** has pivotal arms **128** and **130** to which are connected push rods **132** and **134**. The push rods **122**, **124**, **132** and **134** are reciprocated simultaneously and are operated by thrust reversal controlling cylinders **136** and **138**. These reversal controlling cylinders **136** and **138** are mounted on the transient rails **28** and **30** and are connected to the push rods for operating the thrust reversal targets **100** and **102**. The push rods may be provided with stops for accurately positioning the reversing gas targets **100** and **102**. Stops for arms **124** and **132** are

shown at 144 and 146, and stops for rods 122 and 134 are shown at 140 and 142. These stops are in the form of blocks or lugs which may be operative to engage control switches or control valves (not shown) to send a positional responsive signal back to the operational control, as set by the nozzle control mechanism, as shown in FIGURE 1. The stops may also operate to automatically stop the target members in the position set by an operational control handle (not shown). The position in which the targets stop may be overridden by the manual control mechanism to move the targets beyond their stop position. For example, when the control handle is set to move the target members to zero thrust position, the targets in moving from the inoperative position, shown in FIGURE 5, will automatically be stopped in the zero thrust position of FIGURE 8. The manual control handle may be pushed further to override the automatic stop signal and move the targets to zero thrust position, as illustrated in FIGURES 6 and 7, or to some intermediate position. The control handle may be suitably connected to operate valves 131 and 133, FIGURE 5, which are connected to a pressurized hydraulic fluid supply line 135, and are connected to return lines 137 which lead back to a reservoir for the fluid supply which is not shown. The valves direct operating fluid to one end of the cylinders 136 and 138 and then vent the other end, and valve 131 connects to cylinder 136 through lines 136*a* and 136*b* and valve 133 connects to the ends of cylinder 138 through lines 138*a* and 138*b*. The valves 131 and 133 are electrically operated and are connected in circuit with the control handle. Also connected in the circuit is a switch 139 which is mounted in a fixed position to be actuated by the stop lug 142, FIGURE 8. The lug 142 is positioned relative to switch 139 so that when the target members 100 and 102 are in the position of zero thrust, the switch will be actuated to operate the valves 131 and 133 to stop movement of the target members. This zero thrust position can be overridden by movement of the handle. The electrical circuitry for this operation will be apparent to those versed in the art, and, therefore, need not be shown in detail. It will also be apparent that mechanical interconnection may be used instead of electrical circuitry for the above operation. The switch 139, FIGURE 8, is connected by leads 139*a* to the valves 131 and 133, FIGURE 7.

A fail-safe mechanism is provided to prevent the targets from accidentally moving to reverse position on failure of the control operating mechanism. The fail-safe mechanism automatically moves the targets toward inoperative position upon failure of the control mechanism. The outer gas deflecting surfaces 106 and 108 of the targets are shaped so that the stream of gases will force the targets toward the inoperative position of FIG. 5. Further, a target return biasing means is provided in the form of tension springs 148 and 150 which will continually bias the targets toward inoperative position. These springs are connected between the push rods 122 and 124 at either side of the nozzle, and to the transient rails 28 and 30.

It will be noted that the inner surface 152 of the inner shell 56 of the control nozzle 52 is spherical in shape. This spherical surface will combine with the inner concave surfaces of the deflector members 106 and 108 of the targets 100 and 102 for reinforcing the reverse thrust when the control nozzle 52 is at the extended position. The inner gimbal ring 64 has an inwardly beveled forward surface 154 to also aid in deflecting the gases forwardly. Surfaces 154 and 156 are gas deflectors, set at approximately 30° to the axis of the nozzle. The flow of gases is laterally to each side of the nozzle, as indicated by the arrows 158 and 160 in FIGURE 6. It will also be seen in that figure that the triangular extensions 26 of the fuselage gas protecting tube prevent the rearwardly deflected gas from flowing downwardly or upwardly in a vertical direction to engage the aircraft or other mechanism which may be employed to support the nozzle.

In reversing the engine, the transient rails 28 and 30 are moved rearwardly to separate the control nozzle or nozzle extension 52 from the support nozzle 96 and provide a space therebetween. The thrust reversing target members 100 and 102 then pivot laterally into the gas stream to deflect the flow laterally and cause an increasing reverse thrust.

The preferred configuration of the variable area control nozzle 52 is shown in FIGS. 9 and 10, with the nozzle being shown circular in the other drawings for simplicity of explanation. In other figures, with the exception of FIGURES 8 to 12, the vortex generators 170 are also omitted.

The nozzle openings of each of the inner shell 56 and the outer shell 58 are scalloped to form a scalloped edge. This provides axially extending recesses 162 with projections 164 therebetween in the inner shell 56. Corresponding recesses 166 are provided in the outer shell with projections 168. As the outer shell is rotated with respect to the inner shell by action of the shell rotation cylinder 62 to extend the piston rod 64 of the cylinder, the projections 168 of the outer shell move progressively over the recesses 162 of the inner shell to gradually reduce the effective cross-sectional area until a position of minimum area is reached, as illustrated in FIG. 10.

The variable area nozzle is shown in its preferred form with six scallops. I have found that the effectiveness of six scallops obtains advantages in reducing effective noise energy. In the jet noise problem, it has been found that the predominant sound energy produced by a jet shifts to higher frequencies as the dimensions of the jet are reduced. A resulting increased effective noise reduction occurs because of a greater loss of high frequency sound energy in passing through the atmosphere. The highest noise levels from a jet engine are mainly in the 300 to 600 cycle per second range. A nozzle configuration of six scallops or corrugations is effective in the 150 cycle per second to 2,400 cycle per second range. The nozzle design results in an effective nozzle area wherein a main jet is provided in addition to a plurality of smaller jets with the resultant reduced noise effects.

Further, the scallops on the nozzle will encourage jet mixing more rapidly than a circular nozzle because of a larger peripheral area. It has been found that a nozzle shaped in accordance with the principles of my invention relieves the screech conditions at choked nozzle setting. The nozzle has also been found to reduce the overall sound pressure level, without appreciable loss of thrust. To improve the sound attenuation effects, a vortex generator is provided.

The vortex generator is shown at 170 in FIGURES 11 and 12, and is secured at the tip 164 of the scallop on the inner shell 56. The generator consists of an inward radially extending knife blade 172 with the leading edge 174 forming a concave arc. The trailing end 176 of the knife blade 172 carries a spherically-shaped ball 178. This combination of elements which forms the vortex generator separates the small jets created by the scallops from the large jet and a vortex generator is mounted on the inside of each of the scallops. As the gas stream flows rearwardly through the nozzle it first encounters the concave leading edge 174 of the radial knife blade 172, which extends radially inwardly inside the scallops, and radial paths of separation are formed in the gas flow stream. The ends of the scallops and the effects of the knife blade 172 form widened separations in the gas flow stream. The balls 178 form vortexes in the center of the paths separated by the knife blades and at the inner ends of the paths separated by the scallops and this vortex effect tends to reduce the pressure at the center of the vortex and further separate the full flow stream into separate streams separated by radial paths of separation. It is believed that this is the action of the vortex generator which has been found to cause a separation of the main flow stream. The vortex generators are shown in detail

in FIGURES 11 and 12 but are omitted from the rest of the drawings for more clearly describing the other features in connection with the other drawings.

In separating the small jets created by the scallops from the large jets, the total jet stream is divided into a plurality of smaller streams which effectively reduce the noise level.

The controls are shown in FIGS. 13 and 14 in a schematic form. It will be understood that each of the controls may comprise a pivotally movable lever which moves through the positions shown in the diagrams **13** and **14**. The throttle control is shown in FIG. 13 at **192** and controls the output of the combustion chamber **20**, FIGS. 1 and 6. As the control arm is moved in a clockwise direction from the off position, the discharge of thrust gases increases to the point indicated at "Max." whereupon further movement of the throttle lever will move the engine into the afterburner range, as indicated by the symbol "A.B."

The nozzle control may be operated independently when the control is set in the extreme right position of FIG. 14, as indicated by the diagram **194**, a separate control operates the position of the gimbal ring to control the position of the directional control nozzle unit **52**. Moving the control arm from the forward position to the reverse position will move the arm into the "non-gimbal" range. In this position the gimbal rings are locked so that the directional control nozzle is centered axially and no directional components of thrust are obtained. In this range, the reversing targets are brought into the gas stream to reduce the forward thrust and increase the reverse component of thrust.

At a location indicated on the diagram **194**, a point of zero thrust is reached and the reversing targets are shown in this position in FIG. 8. The targets **100** and **102** are maintained in this position with the throttle control set at maximum during landing touchdown conditions during which full power is available with full thrust in a reverse or forward direction being substantially instantaneously available by merely changing the position of the control nozzle elements. For a full reverse thrust, the control **194** of FIG. 14 is moved to the reverse position and for a full forward thrust it is moved to the forward position.

Reviewing the operation of the variable control nozzle, the positional variance of the elements for obtaining horizontally varying lateral thrusts is illustrated in FIG. 2. The outer gimbal ring **74** is turned on its trunnions **82** and **84** by operation of the hydraulic control cylinder **86**, which is mounted on the transient rail **28**. For lateral directional thrust, the rails are drawn in their withdrawn position with the directional control nozzle **52** brought up tightly against the support nozzle **96**.

The variance in position of the control nozzle **52** to obtain vertical components of thrust is shown in FIG. 3. For this purpose, the inner gimbal ring **64** is tilted on its trunnions **70** and **72** by operation of the hydraulic control cylinder **76**. The support rails **28** and **30** remain in their withdrawn position with the control nozzle **52** continuing to be drawn against the support nozzle **96**. It will be recognized that the control nozzle can assume an infinite number of radial positions for radial thrust in any direction. It will also be recognized that the control cylinders **86** and **76** are positioned safely out of the jet stream, and will be out of the jet stream when the unit is in reverse thrust position.

Variance of the nozzle size is obtained by rotating the outer shell **58**, FIG. 10, with respect to the inner shell **56**. This is obtained by operation of the hydraulic cylinder **62** which is mounted on the inner gimbal ring **64**. As the outer shell is rotated its scalloped edges cover the openings in the scalloped edge of the inner shell to reduce the effective nozzle size.

To adjust the nozzle to reverse thrust position, the transient rails **28** and **30** move the control nozzle **52** rearwardly a distance spaced from the support nozzle **96**. The reversing targets **100** and **102**, as illustrated in FIG. 8, in their zero reverse thrust position are carried rearwardly on the transient rails **28** and **30**. As the target members **100** and **102** are pivoted inwardly toward the jet stream the component of reverse thrust increases until a zero thrust position is reached as shown in FIG. 8. Continued movement will reach a position of maximum reverse thrust, as shown in FIG. 6. The targets are so designed that the targets tend to move toward a position of zero reverse thrust to avoid accidental attainment of increased reverse thrust due to failure of the operating mechanism.

The control nozzle is operative to reduce the noise level in a still further way by moving the reversing targets to a partial reverse position out of the gas stream with the nozzle actuated to its maximum area. In this position of the elements, the unit operates as a secondary air ejector. The air will cool the jet exhaust and decrease the sound power by a very significant amount which is valuable during taxi and engine check runs.

In the extended position of the control nozzle **52**, the fuselage gas blocking tube **24** moves rearwardly. This prevents any of the propellent gas from entering the fuselage and tail section of the plane, if used on a plane, and the tubes ties together the lower and upper transient rails **28** and **30** to help eliminate binding which would occur if two actuators were used for the rails. This also permits using a single actuator, although two are shown at **44** and **46**.

When the control nozzle **52** is in the extended position and the reverse targets are used, the outer shell **58** is preferably rotated to a position of minimum nozzle area. Since both shells are spherical in shape, this provides the maximum spherical backing for the reverse thrust target members **100** and **102**.

The directional control for operating the directional control nozzle **52** is preferably provided with a double actuator for moving the nozzle in each axis. This will assure a positive neutral position. The overall nozzle control, as shown in FIG. 15, in moving from the forward position to the reverse position, will move through the control areas as follows: forward thrust, non-directional control, ejector, zero thrust, directional control and reverse with directional control. The variable area nozzle may be automatically tied in the nozzle control and when the unit goes into reverse the variable area nozzle will close to increase the hemispherical area.

Thus, it will be seen that I have provided an improved variable nozzle which meets the objectives and advantages hereinbefore set forth. The nozzle is capable of complete and effective control of the flow of jet thrust fluid, and may be controlled for rapid, effective and powerful control and accurate operation of the aircraft vehicle on which it is used.

It will be observed that the nozzle construction is comprised of elements which operate interdependently, and which require a minimum number of elements, thus reducing the complexity of the control operational mechanism required. With the use of non-complicated efficient complete control of the thrust, gases can be obtained for directional control thrust in an infinite number of lateral directions, as well as complete control of the thrust in a forward and reverse direction.

The nozzle improves the sound attenuation and greatly reduces the noise level which is an important factor in aircraft use.

I have, in the drawings and specification, presented a detailed disclosure of the preferred embodiments of my invention, and it is to be understood that I do not intend to limit the invention to the specific form disclosed, but intend to cover all modifications, changes and alternative constructions and methods falling within the scope of the principles taught by my invention.

I claim as my invention:

1. A jet propulsion nozzle for aircraft or the like comprising an exhaust duct with a gas discharge opening at the end for the expulsion of a propellant to obtain a forward propulsive thrust, a nozzle extension positioned at the opening of the duct and having a central gas discharge opening, said extension nozzle having a scallop-shaped nozzle edge, an adjustment member rotatable relative to the nozzle extension and also provided with an opening with a scalloped edge whereby rotation of the adjustment member will decrease or increase the total effective nozzle area, transient rails movable parallel to the flow of gas and supporting the nozzle extension whereby the extension may be moved axially outwardly away from the opening at the end of the exhaust duct, a gimbal ring support for the nozzle extension for movement in a universal direction, operating members mounted on the transient rails for tilting the nozzle extension on its gimbal ring support to obtain lateral components of thrust for directional effects, means mounted on the gimbal ring support for operating the nozzle adjustment member, a pair of opposing target members pivotally mounted on the transient rails and movable between an ineffective position out of the gas flow stream and a position of reverse thrust in the gas flow stream, means for pivotally positioning the target members, means urging the target members to a position of decreased reverse thrust, means for axially moving the transient rails to adjustably position the thrust reversing targets and nozzle extension in an axial direction, a tubular shaped aircraft fuselage gas protecting tube surrounding the duct and connected to move with the transient rails whereby the protecting tube moves into place as the target members are moved into location beyond the end of the duct, and a knife edge member with a ball at the end mounted at the end of the projections of the scalloped edges of the nozzle to separate the individual jet streams formed by the scallops.

2. A nozzle assembly for a jet propulsion engine comprising a nozzle member having a fluid conducting opening through which a propellant fluid may flow and be emitted through the opening, a nozzle end positioned over the opening, support means for the nozzle end operative to extend the nozzle end a distance spaced from the opening, adjustment means whereby the size of the nozzle end can be varied to increase or decrease the flow area for fluid therethrough, a pair of opposed target fluid deflectors movable laterally toward the gas stream

at a location between the nozzle extension and extended nozzle, and control means operable to move the targets to partial reverse position out of the gas stream and to adjust the extended nozzle to maximum area whereby the unit will operate as a secondary air ejector to cool the jet exhaust and decrease the sound power.

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