

June 27, 1961

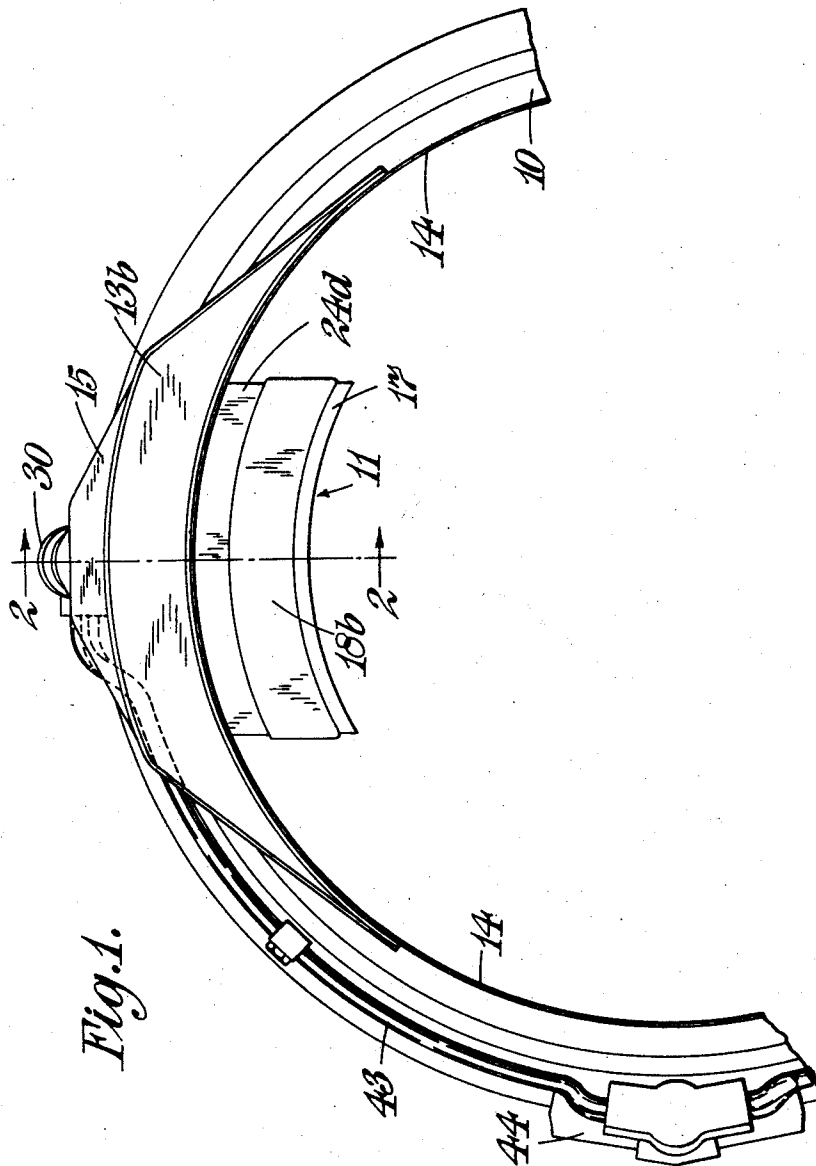
J. M. S. KEEN

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VARIABLE AREA JET PROPULSION NOZZLES

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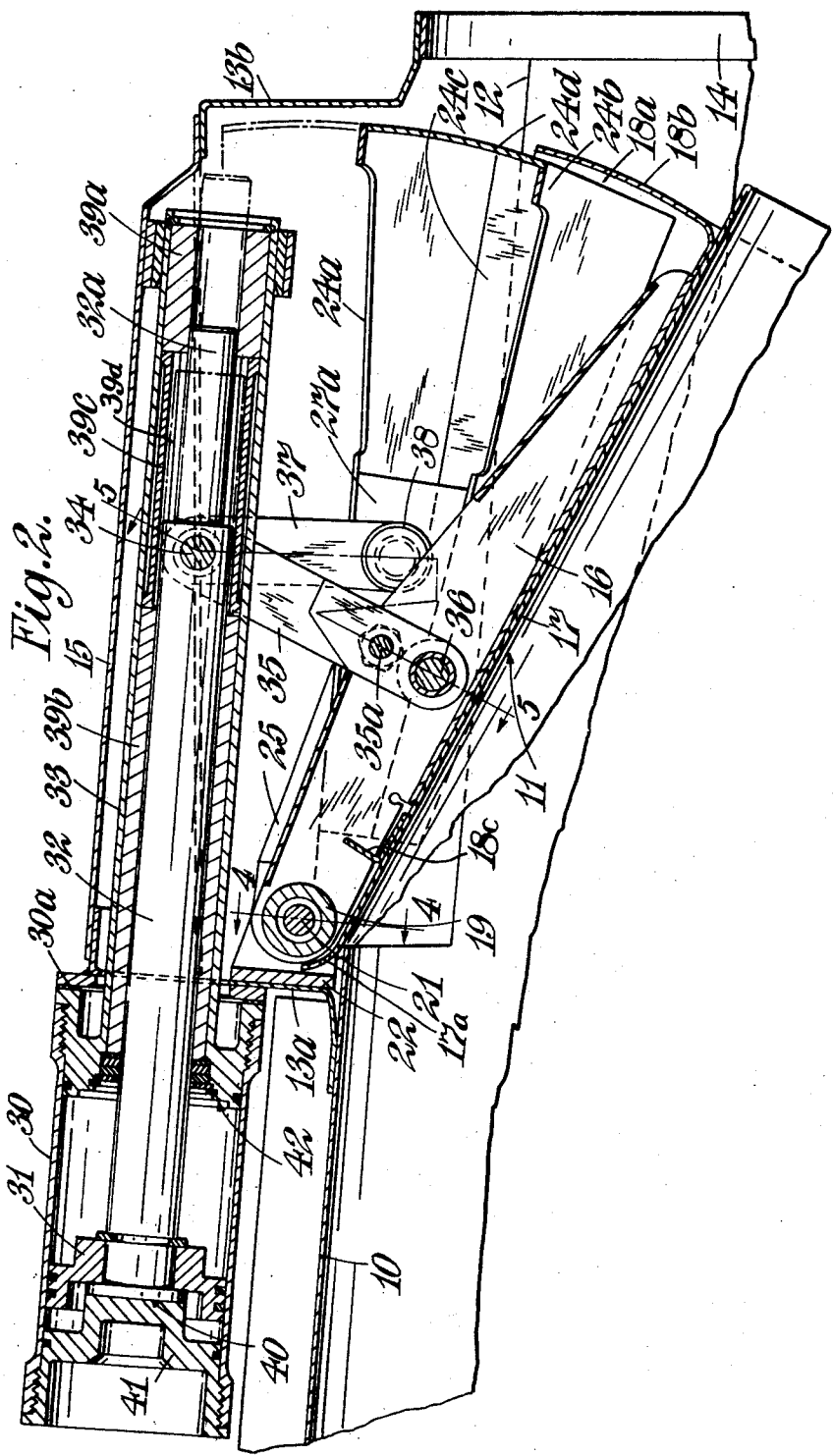
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Fig. 3.

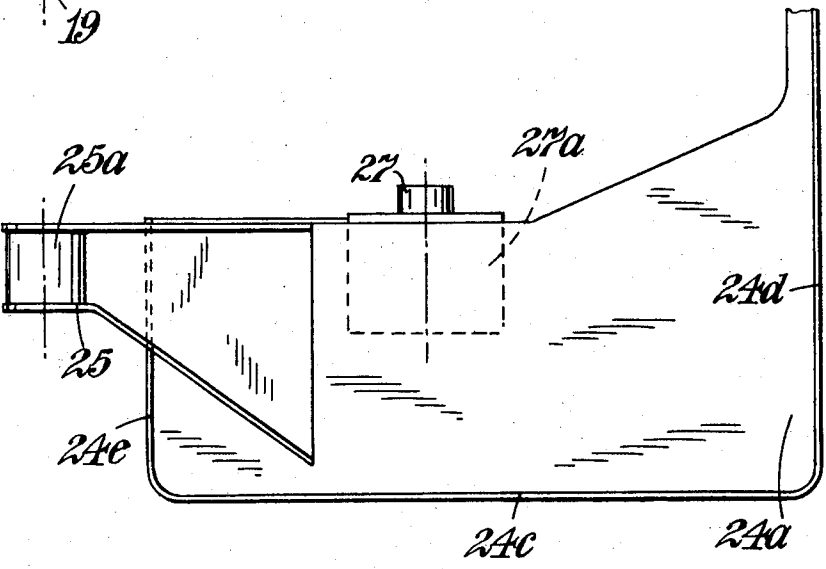
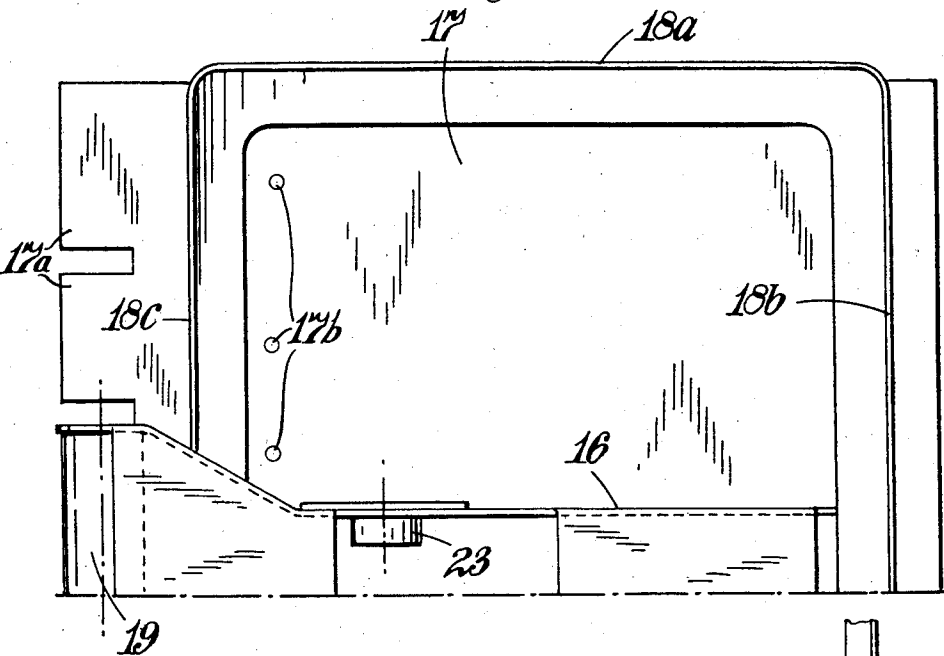


Fig. 3A

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Fig. 4.

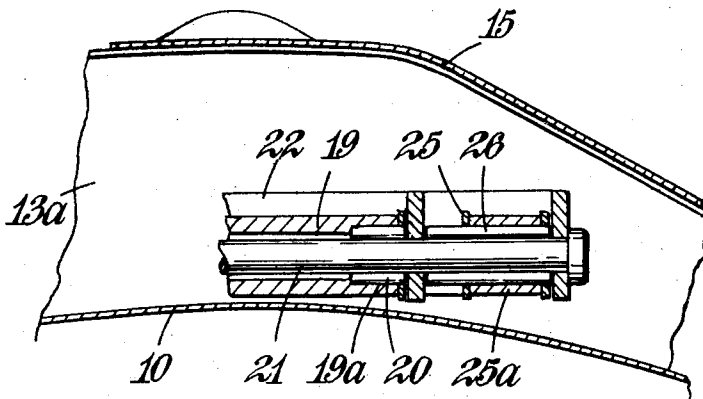
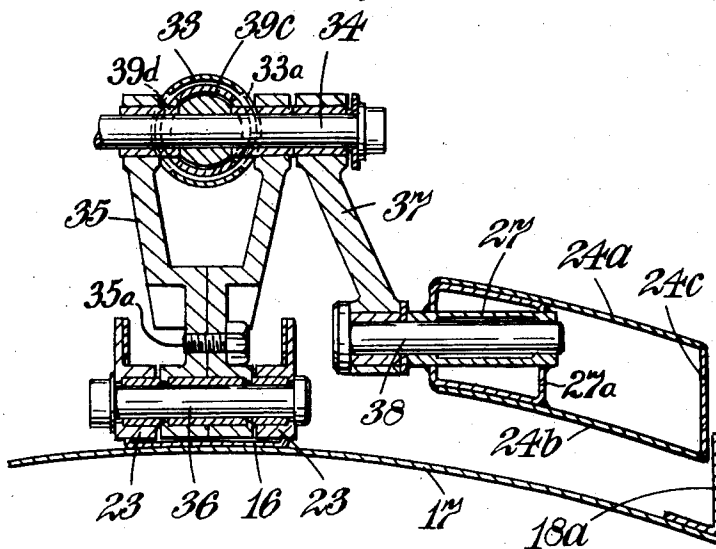


Fig. 5.



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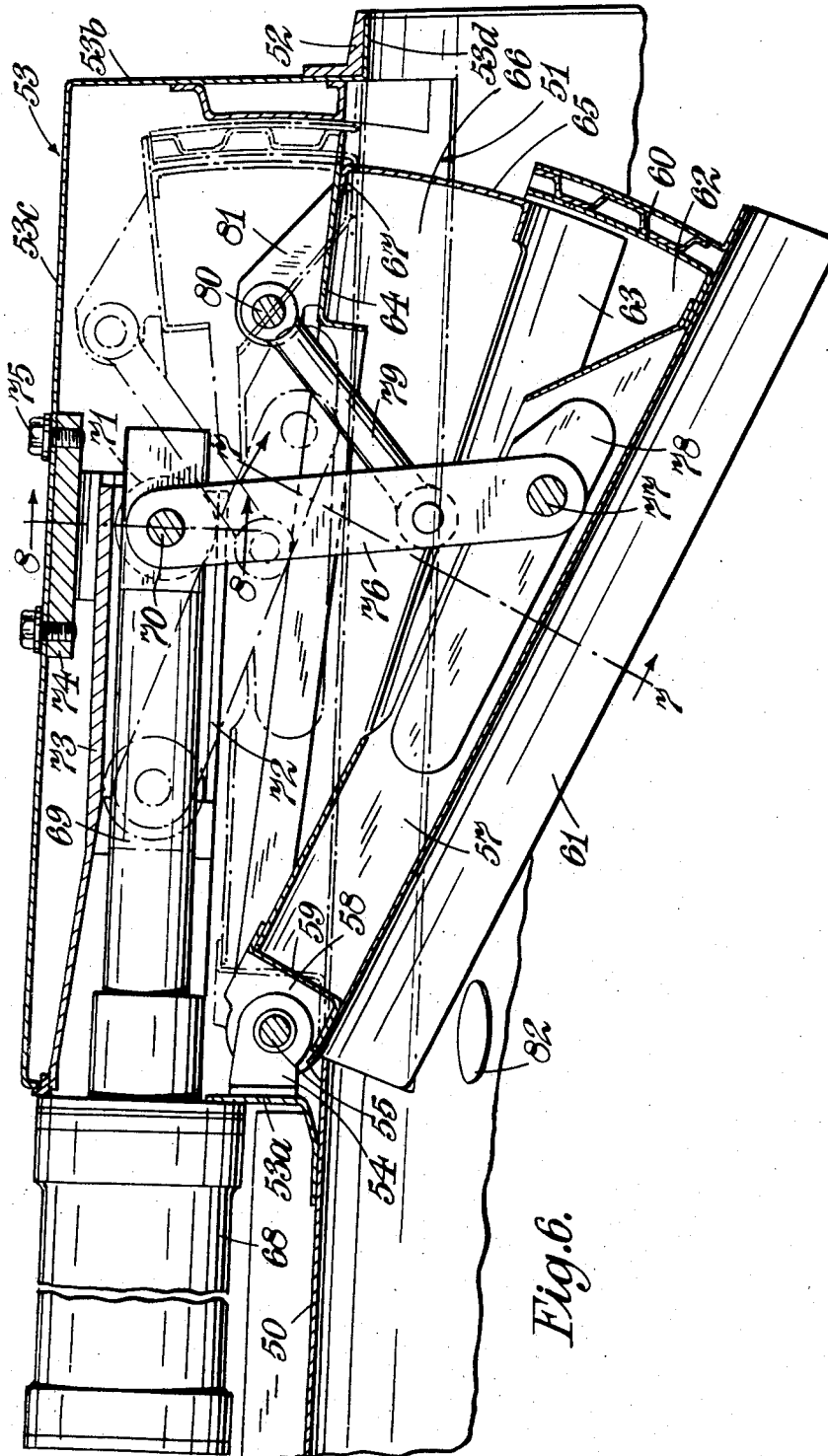


Fig. 6.

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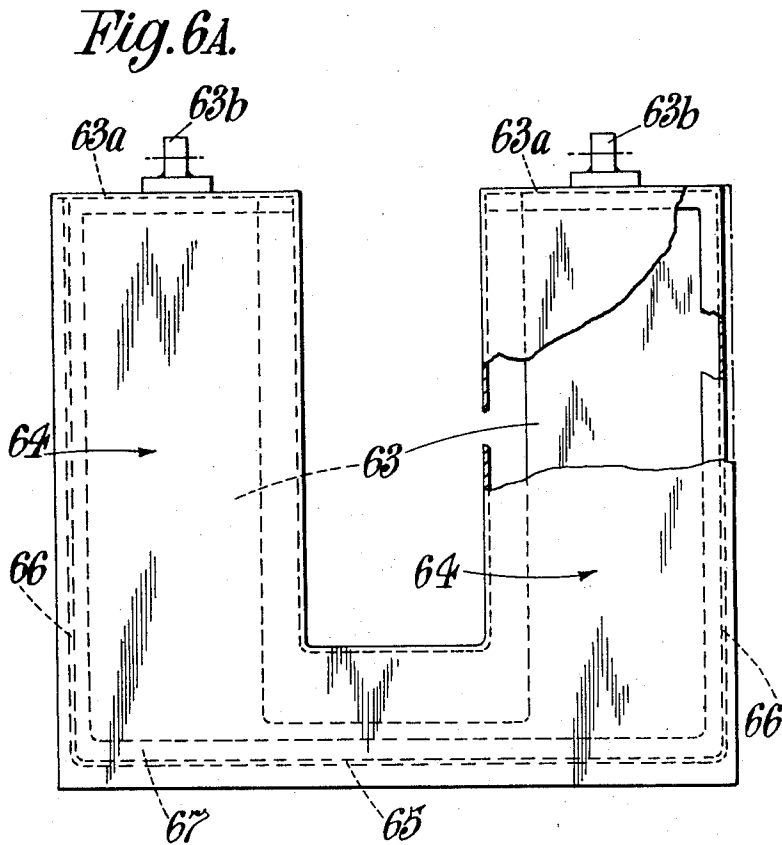
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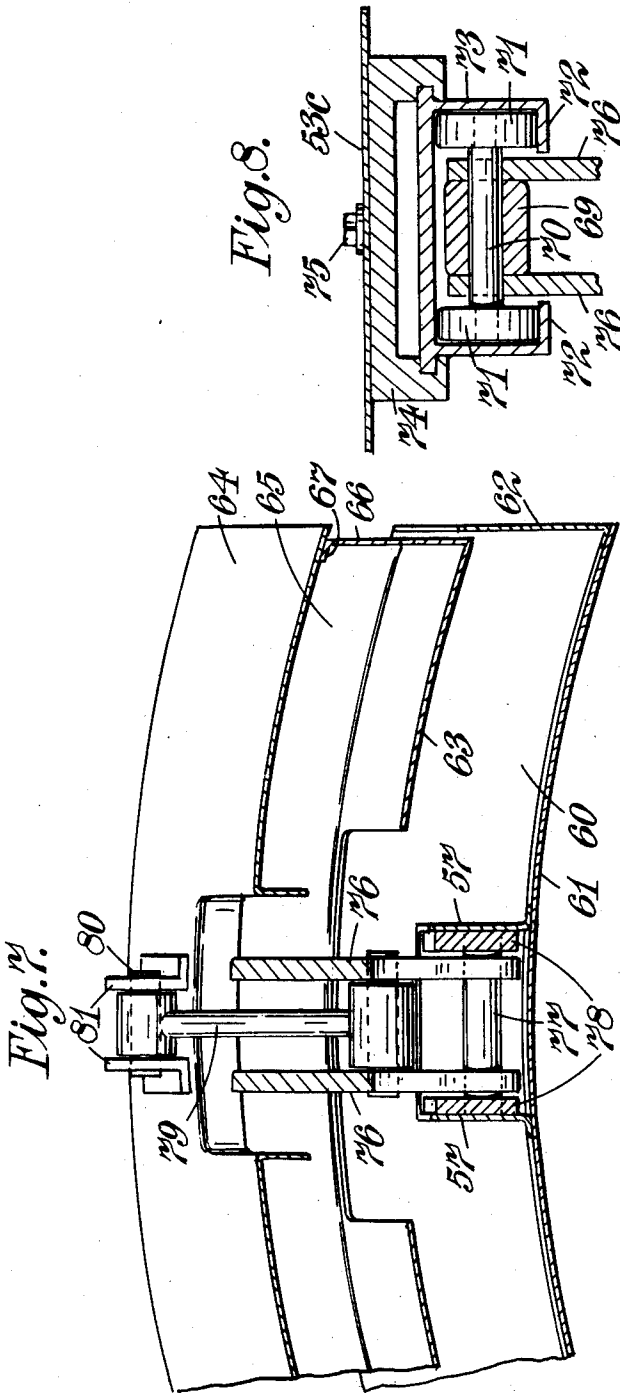
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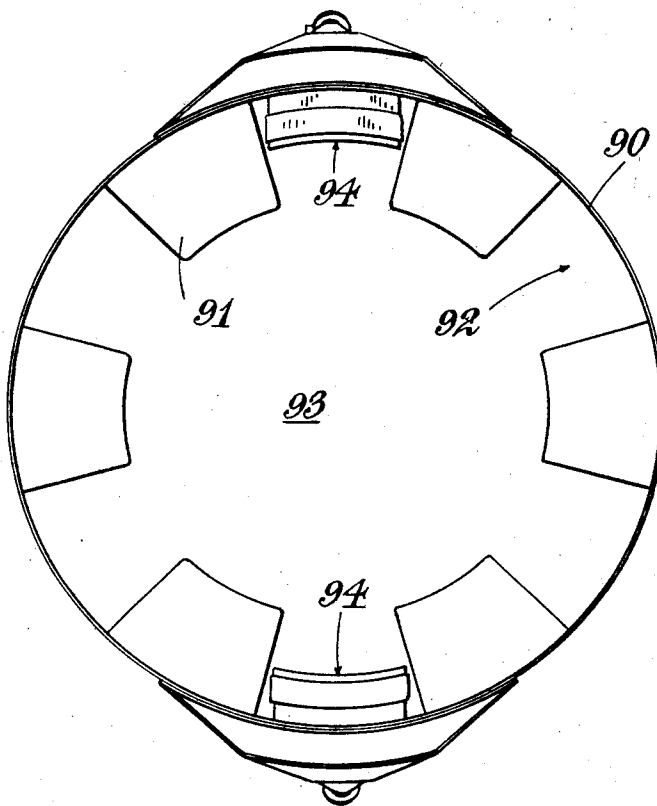
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Fig. 9.



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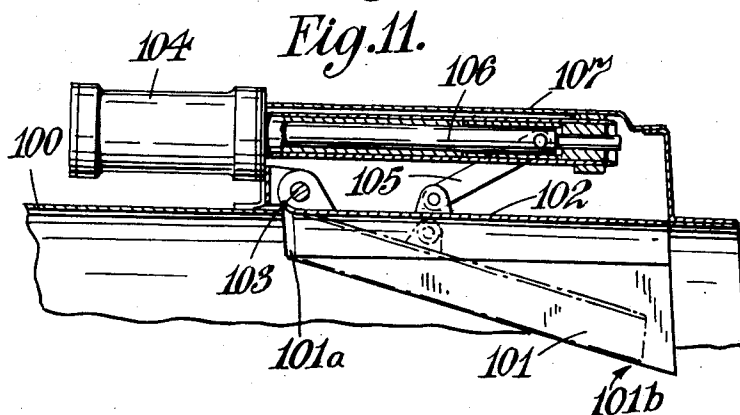
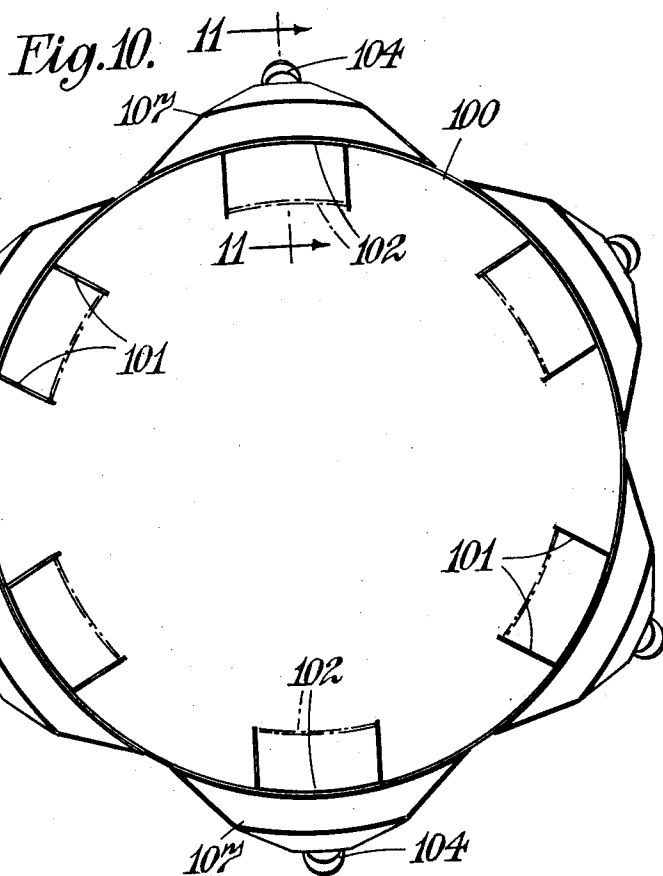
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VARIABLE AREA JET PROPULSION NOZZLES
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8 Claims. (Cl. 181—41)

This invention comprises improvements in or relating to variable area jet nozzles for jet propulsion purposes.

According to the present invention a jet nozzle for jet propulsion purposes comprises a tubular wall member defining a gas passage and having an outlet at one end, and at least one flap member which is adjustable between a first position in which it projects into the gas passage upstream of the outlet to define a first effective area of the nozzle less than the area of said outlet of the tubular wall member, and a second position in which it is retracted and the nozzle has a second effective area greater than said first effective area, and the total peripheral extent of such flap members being a minor proportion of the total peripheral extent of the nozzle outlet.

According to a feature of the invention in the second position of the flap member or members, the second effective area is substantially equal to the area of said outlet.

According to another feature of the present invention each flap member may extend axially of the nozzle and be pivoted to the tubular member to swing about an axis substantially tangential to the tubular member, said axis being at a distance upstream from said outlet greater than the axial extent of the flap member.

According to yet a further feature of the present invention provision is made for substantially equalizing the pressures on each side of the flap member or flap members. The flap member or members may have associated therewith gas sealing structure to prevent the substantial flow of gas around the sides of the flap member or members, while additional gas sealing structure may be provided associated with the downstream end of the flap member or flap members, thereby to provide a closed chamber, provision being made for gas communication from the interior of the tubular wall member into said chamber thereby to substantially equalize the pressures on the two sides of the flap member or flap members.

In preferred embodiments of the invention a flap member or flap members may occupy a cut-out in the tubular member, said cut-out being closed by a blister housing. Further, the tubular wall member may have projecting within it for each flap member a pair of parallel walls which extend substantially parallel to a plane containing the nozzle axis.

In certain preferred embodiments a pair of flap members are provided arranged at diametrically opposite positions around the tubular wall member. In another preferred embodiment about six flap members are provided disposed equi-angularly about the tubular wall member.

In yet another preferred embodiment the tubular wall member is provided with a series of fixed structures angularly spaced around its inner surface and projecting within it to define a series of gas-flow channels, and having such flap members arranged to project within the channels between the fixed structures. In the latter preferred embodiment it will be noted that when the adjustable flap members are in the position in which the area of the nozzle is reduced below the maximum, the nozzle is of corrugated form, the corrugations increasing in depth from the upstream to the downstream end, and accordingly the nozzle will have the property when adjusted to positions other than the maximum area position of re-

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ducing the intensity of noise as more fully described in Rolls-Royce British Patent No. 768,553.

A number of constructions of variable-area jet nozzle will now be described with reference to the accompanying drawings, in which:

FIGURE 1 is an end view in part of one construction of nozzle,

FIGURE 2 is a section to a larger scale on the line 2—2 of FIGURE 1,

FIGURE 3 is a partial plan view of one part of a flap member,

FIGURE 3A is a partial plan view of the other part of a flap member,

FIGURE 4 is a section on the line 4—4 of FIGURE 2,

FIGURE 5 is a section on the line 5—5 of FIGURE 2,

FIGURE 6 is a view corresponding to FIGURE 2 of a second construction of nozzle,

FIGURE 6A is a plan view of a part of the nozzle shown in FIGURE 6,

FIGURES 7 and 8 are sections on the lines 7—7, 8—8 of FIGURE 6,

FIGURE 9 is an end view of another construction of nozzle.

FIGURE 10 is a view corresponding to FIGURE 9 of yet another construction of nozzle, and

FIGURE 11 is a section on the line 11—11 of FIGURE 10.

Referring first to FIGURES 1 and 2, the variable-area jet nozzle comprises a frusto-conical wall 10 with its smaller end downstream to form the throat of the nozzle, a pair of longitudinal flap members 11 (one only of which is shown, the second being at a position diametrically opposite the first) by which the area of the throat is varied, and power means to move the members 11. The two flap members have a combined peripheral extent which is a minor proportion of the total peripheral extent of the nozzle outlet.

The wall 10 has cut-outs 12 at the positions of the flap members 11, each cut-out extending upstream from the outlet end of the nozzle, and each cut-out 12 is covered by an external blister housing. The blister housing is formed by a pair of flanged sheet-metal pieces 13a, 13b of which the piece 13a is secured to the wall 10 on the upstream side of the cut-out, and of which the piece 13b is secured to a fully annular strengthening ring 14 which is secured to wall 10 at the outlet end of the nozzle, and by a cover piece 15 which is secured to the outer edges of the walls 13a, 13b and is secured at its circumferentially spaced edges to the wall 10 in such a manner as to be tangential thereto.

Each flap member 11 is formed in two parts which are pivotally mounted on the wall 10 so as to be capable of relative angular movement, the pivotal axis being positioned at a distance upstream of the nozzle outlet greater than the axial extent of the flap member.

The first part comprises (FIGURES 2, 3 and 5) a central girder member 16 having secured to it a sheet-metal piece 17 which affords a longitudinally and circumferentially-extending inner wall of the adjustable member and which is shaped so that in the angular position of the part in which the nozzle area is a maximum, it substantially fills the cut-out 12 and conforms to the curvature of the wall 10. The inner wall piece 17 has secured on its upper surface a rectangular, L-section sheet-metal piece the four upwardly-projecting sides of which form inner portions 18a of a pair of outwardly-extending lateral walls of the flap member 11, an inner portion 18b of a downstream wall of the member and an inner portion 18c of a forward wall. The wall portions 18a, 18b, 18c define a well space. The girder member 16 has secured to it at its upstream end a lug having a bored boss 19, the ends 19a of the bore in the boss being enlarged to receive

needle bearings 20 (FIGURE 4) by which the part is pivoted on a spindle 21 supported in a bracket 22 secured on the forward wall 13a of the blister housing. The girder member 16 also carries at a point intermediate its ends a pair of bored aligned bosses 23 (FIGURE 5), the purpose of which will appear below. It will be seen that the upstream edge 17a of the inner wall 17 is curved outwardly (FIGURE 2) away from the nozzle axis and has a number of tongues (FIGURE 3) to extend between the lugs of bracket 22, and that the downstream edge of this wall projects beyond the downstream wall 18b (FIGURE 2).

The second part is of U-form in plan and comprises spaced top and bottom walls 24a, 24b respectively (FIGURES 3 and 5), side walls 24c which form outer portions of the lateral walls of the flap member 11, a rear wall 24d which forms the base of the U and forms the outer portion of the downstream wall, and forward walls 24e which forms the ends of the limbs of the U. The second part is adapted to be received with a slight clearance in the well space formed by the walls 18a, 18b, 18c. The ends of the limbs of the second part carry brackets 25 with bored bosses 25a at their ends, the bores in the bosses receiving needle bearings 26 by which the part is mounted on the spindle 21 (FIGURE 4). The second part also has secured to it a pair of hollow bushes 27 (FIGURE 5), one in each limb, the bushes being carried in box-like structures 27a welded between the top and bottom walls 24a, 24b, and being aligned with one another.

The power means for moving the flap members comprises a pair of hydraulic or pneumatic rams, one for each flap member. Each ram (FIGURE 2) is mounted on the forward wall 13a of the associated blister housing and comprises a ram cylinder 30, externally of the housing, a piston 31 working in the cylinder 30, a piston rod 32 connected to the piston 31 and extending into the blister housing; a piston rod shroud 33 which is secured to the cylinder 30, extends axially into the blister housing around the piston rod and has at its end remote from the cylinder lateral slots 33a (FIGURE 5) through which extends a crosshead 34. The crosshead 34 is connected by a swinging link 35 to a pin 36 which is engaged in the bosses 23 carried by the girder member 16. The link 35 is in two pieces secured together by a setscrew 35a. The crosshead 34 has also pivoted to it at its ends a pair of swinging links 37, the opposite ends of which engage pivotally on pins 38 mounted in the bushes 27.

The end of the piston rod 32 remote from the piston 31 is reduced in diameter as indicated at 32a and the reduced-diameter portion slidably engages in a bush 39a mounted in the end of the piston rod shroud 33, while the main portion of the piston rod 32 slidably engages in a bush 39b separated from bush 39a by a slotted spacer member 39c formed by a length of tube having a pair of slots 39d in it to permit the passage of the cross-head 34.

The travel of the piston 31 within the cylinder is determined in one direction by abutment of the end of the piston rod 32 on which the piston 31 is mounted, with a projection 40 from the end cover 41 of the cylinder 30, and the travel of the piston in the opposite direction is limited by abutment between the piston and a facing 42 provided on the end of the piston rod shroud 33 which is within the cylinder 30. The extent by which the piston rod can project into the blister housing is varied by providing a shim 30a between the end of the cylinder 30 and the wall 13a. The shim provides the means by which the anti-clockwise swinging of the flap member is adjusted.

The drawings show the flap members 11 in the operative position, that is the position in which they are effective to reduce the outlet area of the nozzle, and it will be seen that, in this position of the flap members, the walls 17 diverge from the wall 10 in the downstream direction towards the axis of the nozzle and also that the wall por-

tions 24c, 24d form outward continuations of the lateral walls 18a and downstream wall 18b respectively of the first part of the flap member. On moving the piston 31 to the right as viewed in FIGURE 2, the parts of the flap member 11 are caused to swing upwardly until the inner wall 17 of the first part of the adjustable member lies snugly within the cut-out 12. In this position of the parts, the second part is nested within the first part so that the radial extent of the flap member beyond the outside of the nozzle is substantially less than the extent to which the flap member extends within the gas passage through the nozzle when in the operative position.

It is also arranged that the static pressures on each side of the inner wall 17 are balanced so that a lighter construction of the flap members can be employed and so that the operating loads necessary in moving the flap members to the position shown in the drawings are reduced. The pressure balancing is effected by leaving a slight gap between the upstream edge of the cut-out 12 and the upstream edge of the inner wall 17. If desired as shown in FIGURE 3 small holes 17b may be drilled in the wall 17 for pressure-balancing purposes, the size being such that the flow through them is relatively small.

The ram cylinders 30 of the two adjustable members are coupled together for simultaneous operation. For instance, as shown, the pressure fluid supplied to the cylinders of the two rams may be effected through the pipes 43 (FIGURE 1) leading from a supply control valve 44. The supply to the left-hand ends of the cylinders may be effected through pipes extending from the valve 44 around one side of the nozzle and the supply to the right-hand ends may be effected through pipes lying parallel to the above-mentioned pipes.

Referring now to FIGURES 6 to 8, the nozzle illustrated comprises a tubular wall 50 having a pair of cut-outs 51 (of which one only is shown) located respectively at diametrically-opposite points in the nozzle and also having a flanged machined ring 52 welded to the outlet end of the conical wall. A sheet-metal blister 53 having a front wall 53a, a rear wall 53b and top wall 53c is secured to the external surface of the conical wall 50 around the edge of each cut-out to define a housing space for a pair of flap members for adjusting the outlet area of the nozzle. The rear wall 53b has a flange 53d which fits against the inner surface of the ring 52 and extends circumferentially between the circumferentially-spaced edges of the cut-out 51.

A bracket 54 is secured to the internal surface of each wall 53a and has the respective nozzle area adjusting flap member pivoted thereto by a pivot pin 55.

Each flap member extends longitudinally and is formed in two parts which are capable of relative pivoting to permit adjustment of the parts of the flap member between the full line position shown (in which the nozzle area is a minimum) and the chain line position (in which the nozzle area is maximum).

The first part comprises a central back-bone structure 57 carrying lugs 58 receiving the pin 55, a longitudinally and circumferentially-extending sheet-metal inner wall 61 which is curved to correspond to the curvature of the conical wall 50 so that in the chain line position the wall 61 fits in the cut-out 51, a front wall 59 and rear wall 60, and a pair of side walls 62 extending longitudinally along the side edges of the inner wall 61 and joining the front and rear walls 59, 60. The inner wall 61 projects slightly beyond the rear wall 60.

The second part of the flap member (FIGURE 6a) comprises U-shaped inner and outer walls 63, 64 respectively, front walls 63a carrying lugs 63b to receive the pin 55, a rear wall 65 and side walls 66 extending from the front wall 63a to the rear wall 65. The walls 63, 63a, 65, 66 may be in one piece and the wall 65 may be a separate piece welded to flanges 67 on the front, rear and side walls.

Pivoting of the parts of the flap member is effected by

means of a pneumatic ram whereof the cylinder 68 is externally of the blister housing 53 and is secured to the wall 53a thereof. The ram piston rod 69 projects into the blister housing 53 and carries a cross-pin 70. The pin 70 carries rollers 71 which run on tracks afforded by flanges 72 forming part of a channel member 73. The channel member 73 is supported at one end in a slide bracket 74 secured by studs 75 to the wall 53c of the blister housing 53, and at its other end is secured to the wall 53a through which the piston rod 69 projects. The roller arrangement relieves the piston rod of side loads.

The pin 70 has a pair of links 76 pivoted to it, one on each side of the piston rod 69, and the opposite ends of the links 76 are pivoted on a pin 77 mounted in stiffener bars 78 secured to the backbone structure 57 of the first part of the flap member. Thus, when the piston rod 69 is retracted, the first part of the flap member is caused to swing between the full line and chain line positions.

The links 76 have pivoted to them at points between their ends a further link 79, the opposite end of which is pivoted by a pin 80 in brackets 81 secured to the outer wall 64 of the second part of the flap member. The arrangement is such that, during movement of the first flap part, the second flap part moves, as will be seen from its full line and chain line positions, to a less angular extent than the first part.

In the full line positions, the side walls 66 and rear wall 65 of the second flap part form outward continuations of the side walls 62 and rear wall 60 respectively of the first flap part, and in the chain line positions the second flap part is received snugly in the first flap part and the whole flap member is received in the blister housing thus having a less radial projection externally of the nozzle than the extent of projection of the flap member into the nozzle when the flap member is in its full line position.

The pressure in the blister housing 53 is equalized with that within the nozzle by providing holes 82 in the conical wall 50 which open into the housing.

As in the first-described construction, the combined peripheral extent of the flap members is a minor proportion of the total peripheral extent of the nozzle outlet.

Referring now to FIGURE 9, there is illustrated a nozzle which is constructed not only to have a variable outlet area but also to be silenced in operation.

The nozzle comprises an outer tubular member 90 to the inner surface of which is secured a series of six closed structures 91 defining a corresponding series of angularly-spaced channels 92 for the exhaust gas disposed about a central core 93. The dimensions of the tubular member 90 and structures are selected so that the total cross-sectional area available for flow decreases towards the outlet of the nozzle. The division of the issuing gas, at least peripherally, into a number of streams has the effect of markedly reducing the noise generated in operation of the nozzle, as compared with, say, a plain frusto-conical nozzle.

In order to permit the effective outlet area to be varied between maximum and minimum values, the nozzle is provided at diametrically opposite points with adjustable flap members 94, which may be constructed as described with reference to FIGURES 1 to 5 or FIGURES 6 to 8. It will be seen that the flap members 94 when extended occupy part of a pair of the channels 92. Also the combined peripheral extent of the two flap members 94 is a minor proportion of the total peripheral extent of the nozzle outlet.

Another arrangement is shown in FIGURES 10 and 11, in which the nozzle comprises a tubular part 100 (corresponding to the part 10 of the first described construction) with a series of, say six, pairs of parallel walls 101 extending inwardly from the edges of cut-outs 101a. The walls 101 forming a pair are parallel to a plane containing the nozzle axis and the centre line of a flap member 102 of curved section which is disposed between the pair of walls 101 and is mounted on the tubular member

adjacent the upstream ends of the walls 101 by a pivot pin 103. The radial depth of the walls 101 increases in the downstream direction. The flap member 102 is actuated by a ram 104 through a link 105 connected to the ram piston rod 106. The ram is mounted on the exterior of a blister housing 107 and its piston rod 106 projects into the housing 107.

In one position, the flap members 102 occupy the cut-outs 101a in the tubular member 100 and the nozzle area is a maximum, and in a second position the flap members 102 have their edges coincident with the inner edges 101b of the walls 101 and the nozzle outlet area is a minimum. In the second position of the flap members a substantial silencing effect is obtained as compared with an equivalent plain frusto-conical nozzle.

As in the previous constructions, the flap members have a combined peripheral extent which is a minor proportion of the total peripheral extent of the nozzle outlet.

It will be appreciated that the flap members 102 travel over the surface of each of the parallel walls 101 when they are moved from the inoperative to the operative position.

In this case the flap members will be pressure-balanced as described in relation to the first embodiment.

The number of adjustable members may be varied; for example, there may be one or two adjustable members where lightness and simplicity are desired, or there may be say six adjustable members, as shown in FIGURES 10 and 11. In this latter case, when the adjustable members are in the operative position in which the area of the nozzle is reduced below the maximum, the nozzle is of corrugated form, the corrugations increasing in depth from the upstream to the downstream end, and accordingly such an adjustable-area nozzle will have the property, when adjusted to positions other than the maximum area position, of reducing the level of noise produced by the jet stream as more fully described in British Patent No. 768,553.

I claim:

1. A jet propulsion nozzle for a continuous combustion jet propulsion engine, which nozzle comprises a rigid tubular wall member having an outlet at one end and defining a gas passage through which exhaust gases flow from the engine to the outlet, said gas passage having a cross-sectional area which decreases from the upstream end of the nozzle towards the outlet at least over part of its axial length, at least one longitudinally-extending flap member accommodated within the tubular wall member, and pivot means supporting the flap member at its upstream end from the tubular wall member to swing about an axis substantially tangential to the tubular wall member between first and second positions, said flap member including a longitudinally- and circumferentially-extending wall extending axially downstream from said pivot means, which longitudinally- and circumferentially-extending wall in said first position projects into said gas passage and reduces the effective area of the nozzle and which in said second position is retracted flush with the tubular wall member and forms substantially a smooth continuation of said tubular wall member, said tubular wall structure including walls extending externally of the said flap member and defining with the longitudinally and circumferentially-extending wall of the flap member a chamber closed off from atmosphere, said chamber being in communication with the gas passage whereby the pressure within the chamber is substantially equal to the pressure of the gas stream and thus the pressures on each side of said longitudinally- and circumferentially-extending wall are equalized.

2. A jet propulsion nozzle according to claim 1 having said pivot means positioned at a distance upstream of the outlet greater than the longitudinal extent of the flap member.

3. A jet propulsion nozzle for a continuous combustion jet propulsion engine, which nozzle comprises a rigid

tubular wall member having an outlet at one end and defining a gas passage through which exhaust gases flow from the engine to the outlet, said gas passage having a cross-sectional area which decreases from the upstream end of the nozzle towards the outlet at least over part of its axial length, at least one longitudinally-extending flap member accommodated within the tubular wall member, and pivot means supporting the flap member at its upstream end from the tubular wall member to swing about an axis substantially tangential to the tubular wall member between first and second positions, said flap member including a longitudinally- and circumferentially-extending wall extending axially downstream from said pivot means, and parallel walls extending outwards from the edges of said longitudinally- and circumferentially-extending wall, which longitudinally- and circumferentially-extending wall in said first position projects into said gas passage and reduces the effective area of the nozzle and which in said second position is retracted flush with the tubular wall member and forms substantially a smooth continuation of said tubular wall member, said tubular wall structure including walls extending externally of the said flap member and defining with the longitudinally and circumferentially-extending wall of the flap member, a chamber closed off from atmosphere, said chamber being in communication with the gas passage whereby the pressure within the chamber is substantially equal to the pressure of the gas stream and thus the pressures on each side of said longitudinally and circumferentially-extending wall are equalized, said flap member being made in two parts, the first part comprising said longitudinally and circumferentially extending wall and inner portions of the parallel walls, and the second part comprises outer portions of said parallel walls and the parts swing to different angular extents so that, when the flap member is in said second position, the second part is nested within the first part, and that when the member is in the first position the outer portions of the parallel walls form outward extensions of the inner portions.

4. A jet nozzle according to claim 1 wherein in said second position said flap member occupies a cut-out in the tubular wall member, and said walls provided externally of the tubular wall member constituting a blister housing covering said cut-out.

5. A jet nozzle according to claim 1 wherein said flap member comprises parallel walls extending outwards from the edges of said longitudinally and circumferentially-extending wall of the flap member.

10 6. A jet nozzle according to claim 3 wherein each part of the flap member also comprises a rear wall portion joining the downstream edges of the parallel wall portions, said rear wall portions forming continuations one of the other in the first position of the flap member.

15 7. A jet nozzle according to claim 1 comprising a pair of such flap members arranged at diametrically opposite positions around the tubular wall member.

20 8. A jet nozzle according to claim 1 comprising also a series of fixed structures angularly spaced around the inner surface of the tubular wall member and projecting within it to define a series of gas flow channels, and having said flap member arranged to project within the channel between a pair of fixed structures.

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