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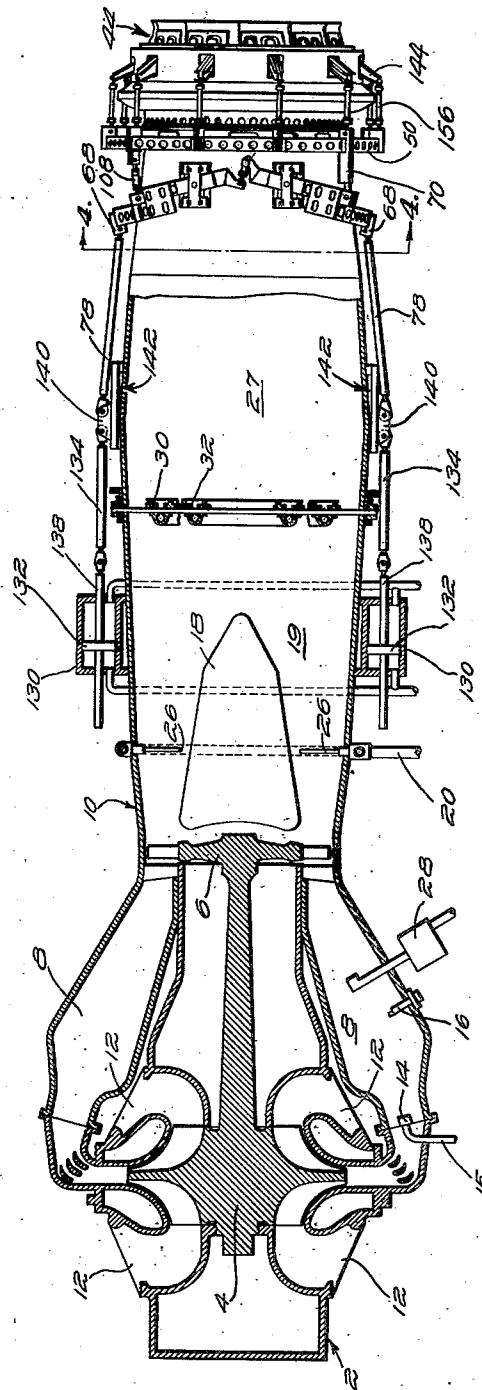
F. L. GEARY ET AL
VARIABLE AREA NOZZLE

2,815,643

Filed June 29, 1951

8 Sheets-Sheet 1

Fig. 1.



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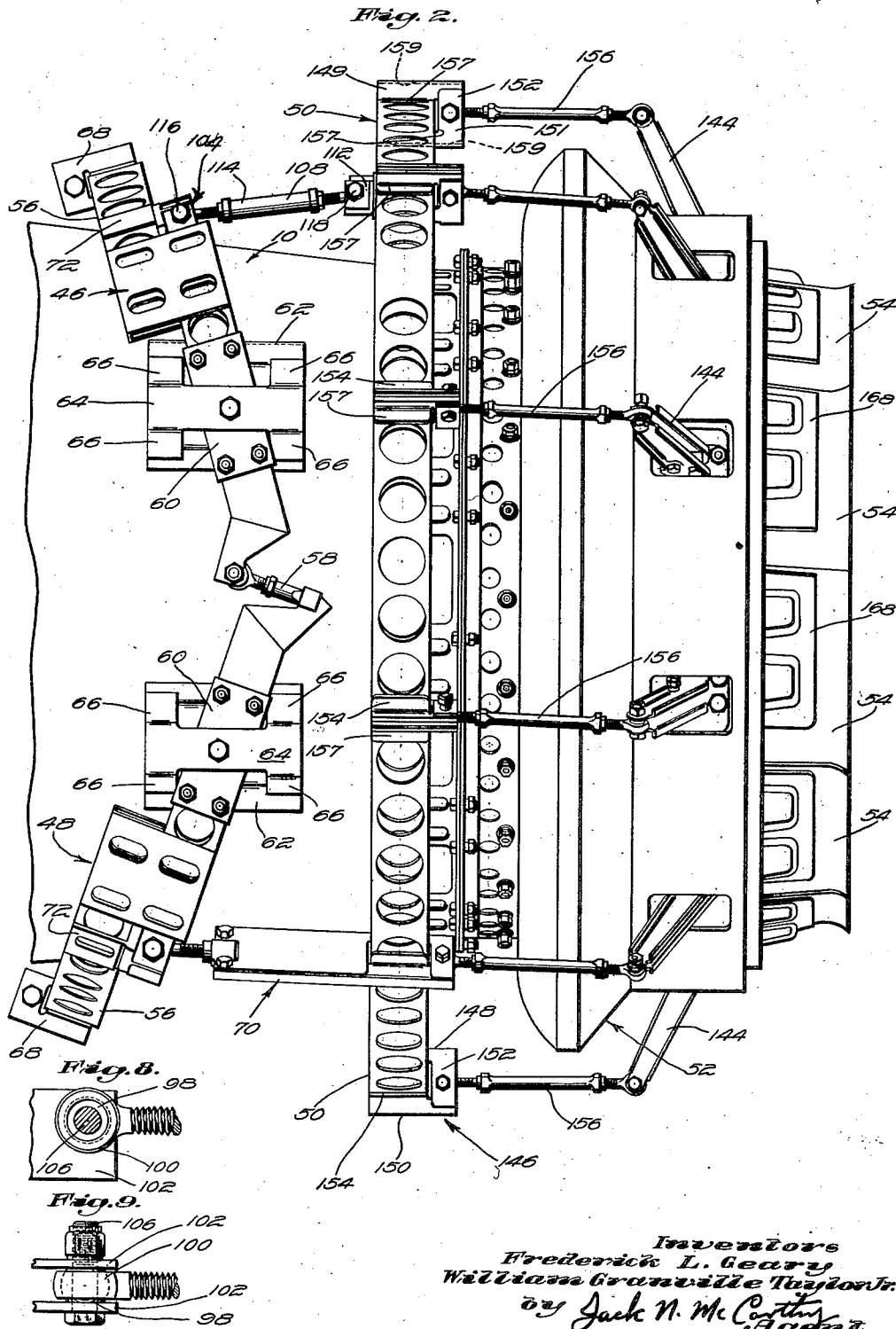
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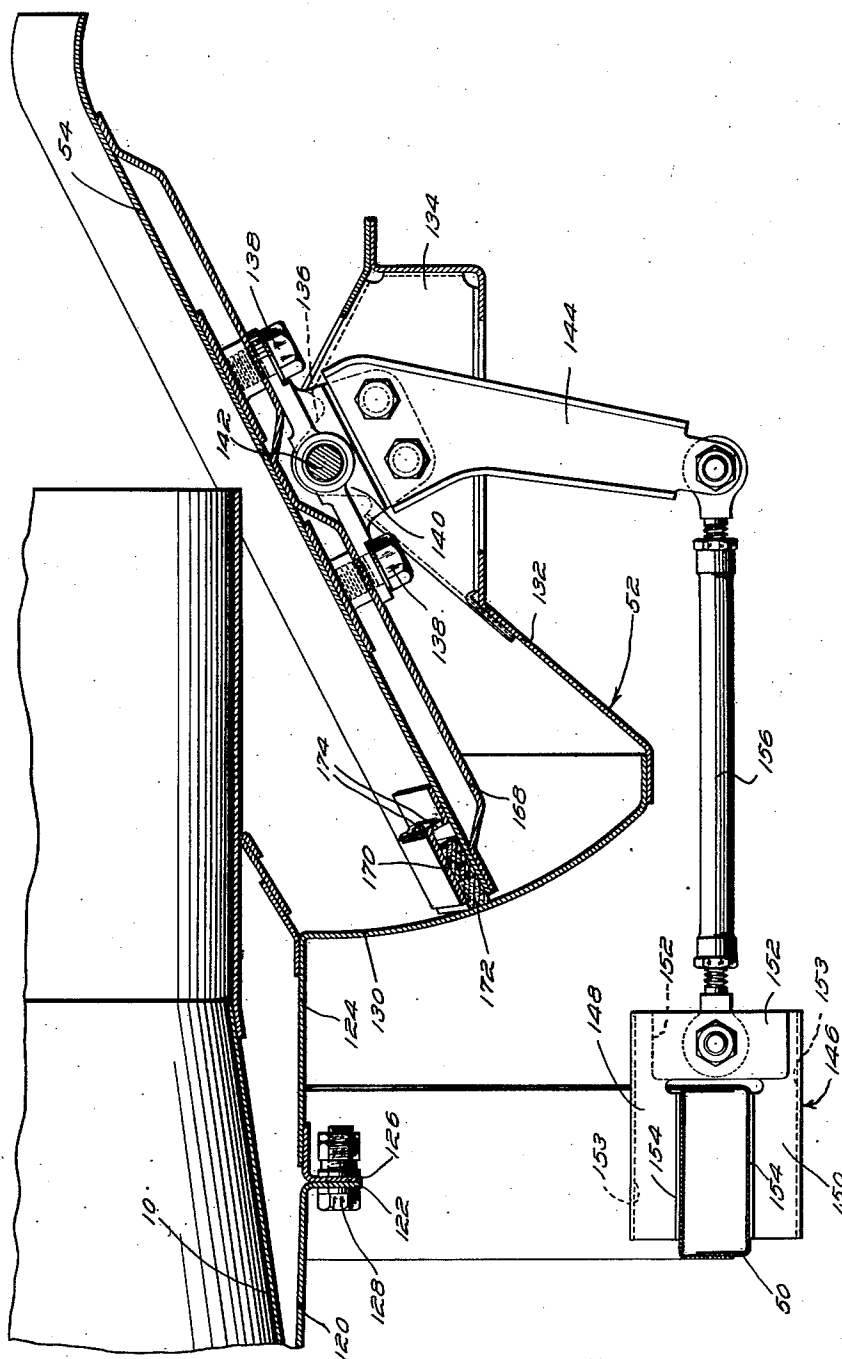
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Fig. 3.



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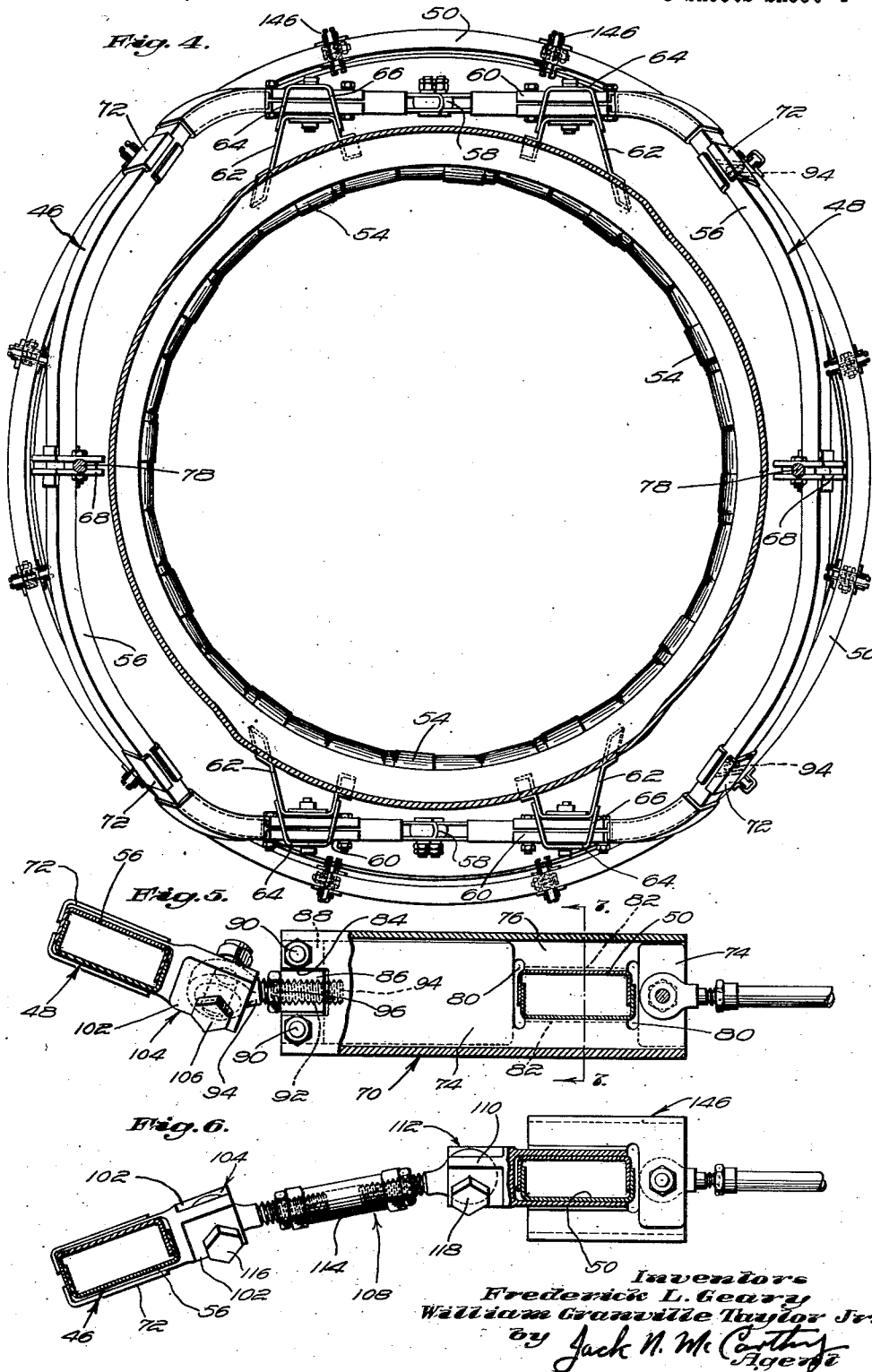
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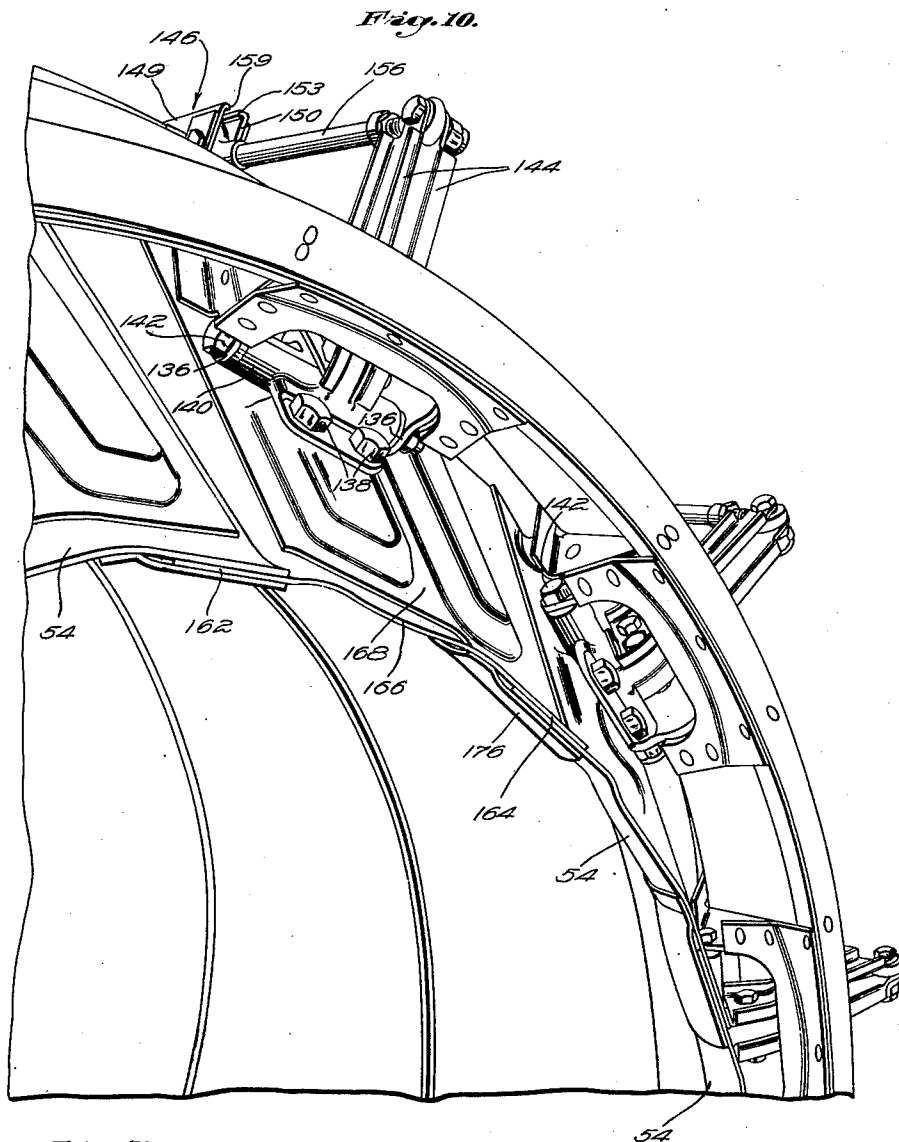
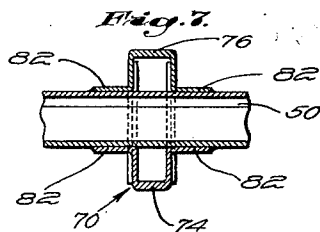
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Fig. 11.

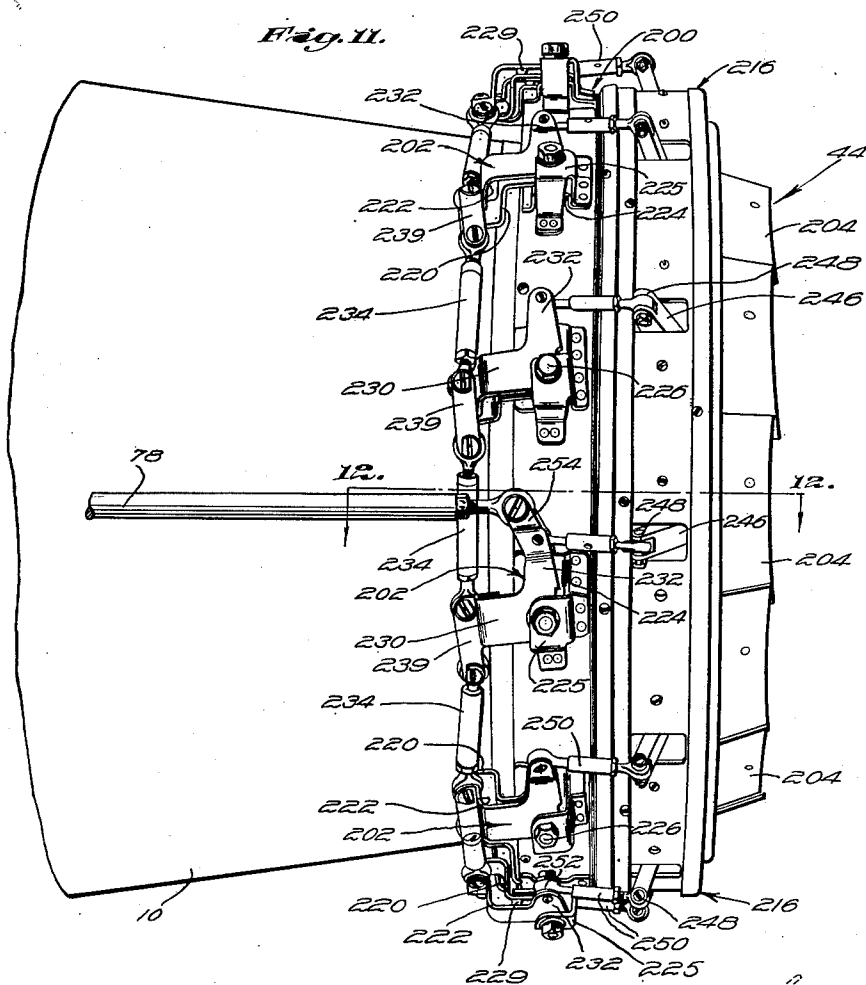
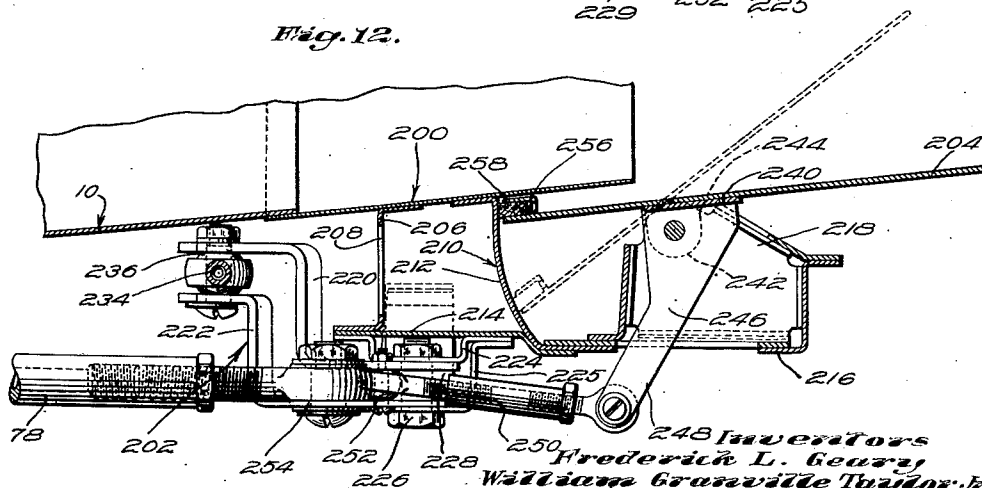


Fig. 12.



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Fig. 19.

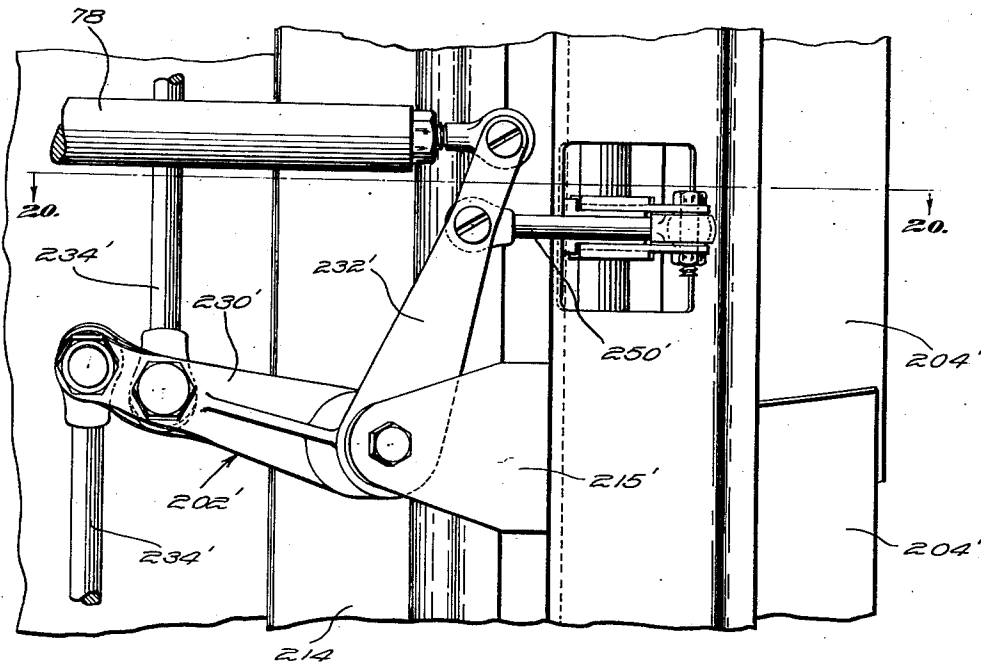
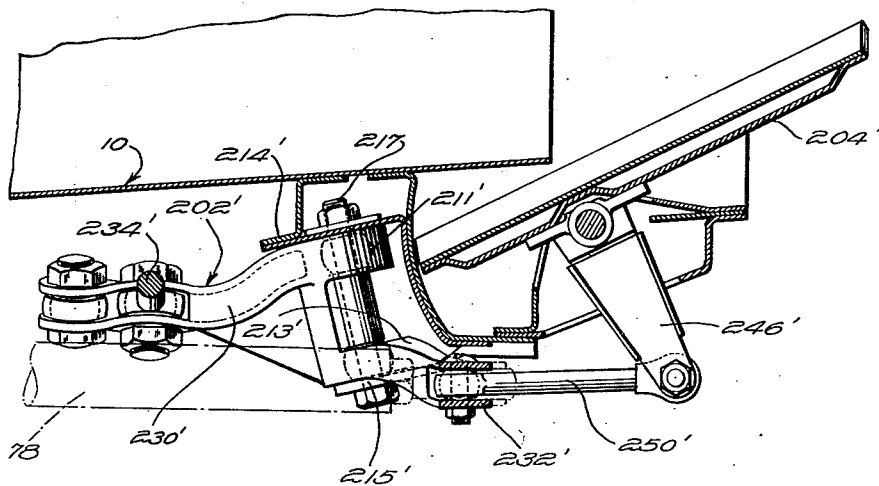


Fig. 20.



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2,815,643

VARIABLE AREA NOZZLE

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Application June 29, 1951, Serial No. 234,228

1 Claim. (Cl. 60—35.6)

This invention relates to a variable area propelling nozzle for a turbojet engine.

An object of this invention is to provide a variable area propelling nozzle of the type which can be positioned at any number of positions between two limits.

A further object is to provide a propelling nozzle which for each position of the nozzle will provide a substantially circular opening.

Another object is to provide a nozzle for a turbojet engine which can be opened and closed with a minimum load being placed on the actuating mechanism.

A further object is to provide a nozzle for an exhaust duct of a turbojet engine which for each position of the nozzle will provide an opening which is substantially in one plane perpendicular to the axis of the duct.

Another object is to provide a nozzle having a minimum of weight.

Fig. 1 is a diagrammatic view of a turbojet engine in partial cross section with the nozzle in elevation.

Fig. 2 is an enlarged view of the propelling nozzle shown in Fig. 1.

Fig. 3 is an enlarged sectional view taken through one of the flaps of the propelling nozzle in Fig. 2.

Fig. 4 is a sectional view in a plane through the line 4—4 of Fig. 1 showing the pivotal mounting of the actuating arms.

Fig. 5 is a view partially in section of the fixed hoop bracket between the actuating arm and the hoop.

Fig. 6 is a view of the link hoop bracket between the actuating arm and the hoop.

Fig. 7 is a view taken on the line 7—7 of Fig. 5.

Fig. 8 is a side view of a self-aligning bearing showing the ball and housing.

Fig. 9 is a top view of a self-aligning bearing mounted in a clevis.

Fig. 10 is a perspective view of a part of the propelling nozzle showing the arrangement of the flaps.

Fig. 11 is an enlarged view of a modification of the propelling nozzle.

Fig. 12 is an enlarged sectional view taken on the line 12—12 of Fig. 11.

Fig. 13 is an enlarged view of another modification of the propelling nozzle.

Fig. 14 is a rear view of a part of the propelling nozzle in Fig. 13 showing the arrangement of the flaps with a small portion in section.

Fig. 15 is a view taken along the line 15—15 in Fig. 14 showing the pivotal mounting of the flaps.

Fig. 16 is an end view showing a track and pulley wheel of the modification shown in Fig. 13.

Fig. 17 is an elevational view of a track and pulley wheel showing the spring.

Fig. 18 is a view showing the bracket for attaching the links to the hoop.

Fig. 19 is an enlarged view of a modification of the propelling nozzle.

Fig. 20 is a view taken on the line 20—20 of Fig. 19. Referring to Fig. 1, the turbojet engine 2 has a com-

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pressor 4 which in the arrangement shown is a centrifugal type driven by a turbine 6. Combustion chambers 8 therebetween deliver air from the compressor to the turbine. An afterburner 10 is attached at the turbine outlet to provide a means of increasing the thrust.

The engine 2 has two axially spaced annular intake openings 12 to direct the incoming air into the two oppositely facing annular compressor inlets. Compressed air discharged from the compressor 4 passes to the turbine through the combustion chambers 8 where it is mixed with fuel from fuel nozzles 14. These fuel nozzles 14 receive fuel through conduit 15. The fuel-air mixture is initially ignited within the combustion chambers 8 by spark igniter 16.

From the turbine, the gases pass around a cone 18 into the diffuser section 19 of the afterburner. When the afterburner is operating, fuel from a conduit 20 is discharged into these gases through a plurality of fuel nozzles 26 located in the diffuser section 19. Since the gases leaving the turbine 6 contain a considerable amount of unburned oxygen, the additional fuel introduced by fuel nozzles 26 provides a combustible mixture which may be initially ignited within combustion chamber 27 by any suitable ignition means 28. The ignition means may be of the type shown and claimed in copending application Serial No. 196,402, filed November 18, 1950, now Patent No. 2,780,055, issued February 5, 1957, to Carlton W. Briston, Jr. The burning of this combustible mixture is stabilized in the afterburner combustion chamber 27 by flameholders 30 and 32. The burned gases discharge from the engine through the nozzle 44 whose area can be varied.

The nozzle 44 is the type which can be positioned at any number of positions between two limits. The three nozzles herein disclosed are shown in Figs. 2, 11 and 13. A nozzle actuating system similar to the one shown with this invention is shown and claimed in copending application Serial No. 193,734, filed November 2, 1950, now Patent No. 2,714,285, issued to F. L. Geary on August 2, 1955. The actuating system consists of the cylinder 130, piston 132, connecting control rod 134, nozzle control rod 78, piston rod 138, car 140, and track mechanism 142 for said car.

Referring to Fig. 2, the nozzle shown consists of four main parts, (1) the actuating arms 46 and 48, (2) the hoop 50, (3) the flap supporting ring 52 and (4) the flaps 54. These four parts are closely interconnected by linkages and pivots.

The actuating arms 46 and 48 each consist of a semi-circular half-hoop 56 pivoted at two spaced points on the afterburner 10. The adjacent ends of the two actuating arms are connected by short synchronizing links 58 which are pivoted on the arms and which provide for synchronization of the opening and closing of the nozzle and also permit both arms to be moved in either direction by one actuating system. These links may be adjustable in length, as shown. A similar synchronizing system is used with the two-position nozzle shown in copending application Serial No. 193,734, filed November 2, 1950, now Patent No. 2,714,285, issued to F. L. Geary on August 2, 1955, and is not of itself a part of the present invention.

The pivotal points for actuating arms 46 and 48 each have plates 60 which house self-aligning bearings. Each of the pivotal points is supported between two brackets 62 and 64. Bracket 62 is fixed to the afterburner and bracket 64 extends over a pivotal point and has arms 66 which extend around plates 60 and are fixed to the first bracket 62. A nozzle control rod bracket 68 is fixed on the middle of each actuating arm to receive one end of one of the nozzle control rods 78 which has a self-aligning bearing.

The hoop 50 is a circular member located around the end of the afterburner to the rear of the actuating arms

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46 and 48 and connected to said arms to move therewith. Two fixed hoop brackets 70 on one side of the afterburner and two link brackets 108 on the other side connect hoop 50 to the actuating arms. The hoop brackets are constructed to support the hoop substantially concentrically to the afterburner. The two fixed hoop brackets 70 (see Fig. 5) on one side of the afterburner are rigidly fixed at one end to the hoop 50 and pivotally connected at their other ends to arm brackets 72 which are fixed to the actuating arm 48.

The main body of these fixed hoop brackets 70 is formed from two U-shaped members 74 and 76. Each member has notch 80 through each arm of the U near one end thereof in which the hoop 50 fits when the two U-shaped members are placed together. The U-shaped member 74 is smaller in width than U-shaped member 76 and slides therein to form the rectangular bracket around the hoop. An outwardly extending flange 82 attached to the bottom of each notch rests on the hoop 50 and is fixed thereto (see Fig. 7). While the flange is shown welded to the hoop it may be fixed by any means desired.

The other end of the fixed hoop bracket 70 also has a notch 84 which extends through each arm of both of the U-shaped members 74 and 76. However, this notch 84 extends inwardly from the end of the bracket and receives upper and lower projections 86 of an insert 88 which is fixedly mounted in the end of the fixed hoop bracket 70 by bolts 90. Said insert has an internally threaded hole 92 which receives a bolt 94. A lock nut 96 holds the bolt 94 in place, thus providing for adjusting the length of the connection. The free end of the bolt 94 carries a self-aligning bearing which consists of a ball shaped member 98 mounted in a housing 100 (see Figs. 8 and 9).

The arm brackets 72 have two flat projections 102 extending rearwardly from the arms forming a clevis 104. The projections 102 of the arm bracket extend horizontally therefrom, one over the other. The ball shaped member 98 of the self-aligning bearing of the fixed hoop bracket 70 is held in the clevis 104 by a vertically extending bolt 106.

The two link hoop brackets 108 on the other side of the afterburner provide flat projections 110 extending forwardly of the hoop forming a clevis 112. The projections 110 of the link hoop brackets extend horizontally therefrom, one over the other. The actuating arm 46 on this side of the afterburner has arm brackets 72 identical to the arm brackets on the actuating arm 48 on the other side of the afterburner. Mounted between the clevis 104 on the actuating arm 46 and the clevis 112 on the hoop 50 is an adjustable bolt 114.

The adjustable bolt 114, Fig. 6, has a self-aligning bearing on each end with the ball member of one bearing being held in the clevis 104 by a vertically extending bolt 116 and the ball member of the other bearing being held in the clevis 112 by a vertically extending bolt 118. This connection of the hoop to the actuating arms locates the complete hoop in position but does not interfere with the relative expansion of the afterburner, half hoops, complete hoop or other parts.

Referring to Fig. 3, the flap supporting ring 52 which is fixedly attached to the afterburner consists of several parts. One part, the ring 120, is fixed to the afterburner and has a flange 122 at its free end. A second part, another ring 124, has a mating flange 126 which is bolted to flange 122 by bolts 128. This ring 124 has a curved sealing portion 130 for a purpose to be described later. A third ring 132 is fixed to the outer periphery of said sealing portion and carries the mounting brackets 134 for the flaps.

Each bracket has two mounting bosses 136, Fig. 10, for the flap between which each flap 54 is pivoted.

Each of the flaps 54 has mounted thereon, as by bolts 138, a boss 140 on which each flap pivots. This boss is placed near the center of the flap to balance the loads

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imposed on each end of the flap by the exhaust gases passing from the afterburner. A bolt 142 pivotally connects each boss 140 between mounting bosses 136 on each bracket. The boss 140 on the flaps has a projecting built-up arm 144 for actuating each flap (see Fig. 10). For each flap there is a connection on the hoop.

These connections consist of brackets 146, Figs. 2 and 3, which are formed from two sets of members, members 148 and 150 and members 149 and 151. These members 148 and 150 have projections 152 extending from one end and flanges 154 extending outwardly from the other end. One member 148 is placed on hoop 50 with its flange 154 fixed thereto and its projection 152 extending to the rear of the hoop. The member 150 is placed on the opposite side of hoop 50 with its flange 154 fixed thereto and its projection 152 extending to the rear of the hoop and adjacent the projection 152 of member 148. These two projections are fixed together such as by welding. A small flange 153 extends along the top of the members 148 and 150 in a direction opposite to flange 154. Members 149 and 151 have projections 152 extending from one end and flanges 157 extending outwardly from the other end. One member 149 is placed on hoop 50 near member 148 with its flange 157 fixed thereto and its projection 152 extending to the rear of the hoop. The member 151 is placed on the opposite side of hoop 50 with its flange 157 fixed thereto and its projection 152 extending to the rear of the hoop and adjacent the projection 152 of member 149. These two projections are fixed together such as by welding. A small flange 159 extends along the tip of the members 149 and 151 in a direction opposite to flange 157. Flanges 153 and 159 face each other but do not meet. Members 149 and 148 are interchangeable, as are members 151 and 150.

The connections from the hoop to the flaps are equally spaced around the hoop. In the arrangement shown in this application there are twelve (12) flaps. Four (4) of these brackets fall at the same point on the hoop as the hoop brackets. In this case the ends of the two fixed hoop brackets 70 which extend rearwardly of the hoop are used in place of the brackets 146, and the brackets 146 are merely placed over the holding band of the link hoop brackets 108 for the other two points. Two brackets 146 are equally spaced between each of the points on the hoop at which the hoop brackets are fixed. An adjustable link 156 having self-aligning bearing on each end extends between each connection on the hoop and the ends of each built-up arm 144 of each flap. The link 156 has the ball member of the self-aligning bearing of one end held in the bracket 146 on the hoop and the ball member of the self-aligning bearing of the other end held between the ends of the built-up arm 144 of the flap.

The flap itself is a plate having end portions 162 and 164 angularly displaced inwardly from a center portion 166 (see Fig. 10) and is reinforced by a plate 168 on the center portion 166 and end portion 164. The end of the flap which mates with the sealing portion of ring 124 has a flange member 170 fixed thereto on the inner side in which a sealing strip 172 is mounted. Holes 174 are placed in the flange 170 to allow pressure from the afterburner to act against one side of the sealing strip to press it against the sealing portion of ring 124. However, where the adjacent flaps overlap, this flange is located on the outer side with the holes to allow pressure from the afterburner to act against the sealing strip being located in the flap.

Along the inner side of end portion 164 of each flap which carries part of the reinforcing plate there extends an overlapping plate 176 which is attached to said flap. The end portion 162 of the adjacent flap is received in the opening formed by the first mentioned flap and said plate 176. This arrangement provides for sealing between the flaps themselves.

Operation of the modification shown in Figs. 1-10

Assuming the device to be in the position shown in Fig. 1, when the piston 132 is moved to the right, or rear, this action in turn moves the connecting control rods 134 in the same direction. Each connecting control rod 134 is connected to its associated car 140 on its track mechanism 142 and moves the car to the right along the track. The nozzle control rods 78 are pushed by their respective cars 140 to the right, or rear, to pivot each actuating arm around its pivotal point. This action moves hoop 50 through fixed hoop brackets 70 and link hoop brackets 108. This movement of the hoop in turn pivots each flap simultaneously through built-up arms 144 on the flaps and the connecting adjustable links 156 between said arms and the hoop. This pivoting of the flaps is in a closing direction thereby reducing the area of the exhaust nozzle. If the nozzle is to be opened the piston 132 is moved to the left, or front, and through a sequence of operation, the reverse of that described above, the flaps are moved in an opening direction.

Referring to Fig. 11, the nozzle shown consists of three main parts, (1) the bell crank lever and flap supporting ring 200, (2) the bell crank levers 202 and (3) the flaps 204. These three parts are closely interconnected by linkages and pivots.

Referring to Fig. 12, the flap supporting ring 200 which is fixedly attached to the afterburner 10 consists of several parts. One part, a ring 206, having holes 208, is fixed to the end of the afterburner and extends as a radial flange. A second ring 210 extends similarly from the afterburner and has a curved sealing portion 212 for a purpose to be described later. A third flat ring 214 extends around the afterburner and is attached at each side to the free end of the two rings 206 and 210 and supports the bell crank levers 202. A fourth built-up ring 216 is fixed to said sealing ring and carries the mounting brackets 218 for the flaps.

The bell crank lever 202 consists of two members 220 and 222 similarly shaped which are placed one over the other and pivoted between two brackets 224 and 225 by a bolt 226. A spacer 228 is located around the bolt 226 between the members 220 and 222. These bell crank levers are mounted around the third ring 214. A spacer 229 is fixedly mounted between the members 220 and 222. They have two levers 230 and 232. Lever 230 is offset downward at its free end and is connected to each adjacent lever 230 by links 234 having a self-aligning bearing on each end. Each link 234 has the ball member 236 of the self-aligning bearing of one end held between the free ends of the parts of the members 220 and 222 forming lever 230 of a bell crank lever and the ball member of the self-aligning bearing of the other end held between projections 239 extending from the free ends of the parts of the members 220 and 222 forming lever 230 of the adjacent bell crank lever.

Each of the flaps 204 has mounted thereon a bracket 240 having a boss 242 at each end which is placed between two bosses 244 on the mounting brackets 218 on the flap supporting ring 200. Also mounted on the flap is a built-up arm 246 which has a clevis 248 at its free end. An adjustable link 250 having a self-aligning bearing on each end is connected between the free end of each lever 232 of the bell crank levers 202 and the clevis of the built-up arm of the flap which it is to actuate. The link 250 has the ball member 252 of the self-aligning bearing of one end held between the ends of the parts of the members 220 and 222 forming lever 232 and the ball member of the self-aligning bearing of the other end held in the clevis 248 of the built-up arm 246 of the flap.

The bell crank lever on each side of the afterburner has an extension 254 on the lever 232 which permits the nozzle control rod 78 to be connected thereto to actuate the nozzle 44. The flaps themselves are formed in a manner similar to those shown in Fig. 10. A U-shaped member 256 is fixed on the end of the flap 204 which

mates with the sealing portion of ring 210 in which a sealing strip 258 is mounted. Like the flap shown in Fig. 3, where adjacent flaps overlap this U-shaped member is located on the outer side with the holes to allow pressure from the afterburner to act against the sealing strip being located in the flap.

A modification of this nozzle is shown in Figs. 19 and 20 having the same main parts. However, the bell crank lever 202' is of a different construction and is mounted at an angle to the centerline of the afterburner.

This bell crank lever 202' has two levers 230' and 232'. Lever 230' extends in a manner similar to lever 230' of the modification shown in Fig. 11, however, the links 234' are connected to the lever 230' adjacent each other at the end of the lever. This end of the lever is bifurcated and twisted so as to receive the ends of adjacent links 234' at different angles. Lever 232' extends in a manner similar to 232 of the modification shown in Fig. 11 and is connected to a built-up arm 246' of a flap 204' by a link 250' to actuate the flap. The center part of the bell crank lever 202' has two bosses, 211' and 213' each having a hole for pivotally mounting said lever between ring 214' and flange 215' by a bolt 217'. This pivotal mounting is arranged so that the axis of the bolt 217' is at an angle to the centerline of the afterburner, the end of the bolt nearest the afterburner being located forward of the other end of the bolt. This arrangement maintains the distance between the free ends of adjacent levers 230' substantially constant as the bell crank levers are rotated.

Operation of the modification shown in Figs. 11, 12, 19 and 20

Assuming the nozzle to be in the position shown in Fig. 11, when the nozzle control rods 78 are moved to the left, or front, the bell crank levers 202 connected to said control rods are moved about their pivots with levers 230 moving the adjacent bell crank levers through links 234. Each other bell crank lever 202 is moved by its adjacent lever 230. The motion of the links is transferred to the flaps through links 250 and built-up arms 246. This pivoting of the flaps is in an opening direction thereby increasing the area of the exhaust nozzle. If the nozzle is to be closed, the nozzle control rods 78 are moved to the right, or rear, and through a sequence of operation, the reverse of that described above, the flaps are moved in a closing direction.

Referring to Fig. 13, the nozzle shown consists of four main parts, (1) the hoop 300, (2) the hoop tracks 302, (3) the flap supporting ring 304 and (4) the flaps 306. These four parts are closely interconnected by linkages and pivots.

Referring to Figs. 13, 14, 16, 17 and 18 the hoop 300 is a circular tube located around the end of the afterburner and mounted for axial movement on tracks 302. A plurality of these tracks 302 are mounted around the afterburner. They are formed from a plate and have a single rail with flanged out parts 308 being fixed to the afterburner. For each track 302 there is a bracket 310 located on the hoop on which there is mounted two pulley wheels 312. The bracket 310 consists of two plate members 314 fixed to the hoop and extending front and rear thereof. A pulley wheel 312 is rotatably mounted on each end by a bolt 316. These wheels support the hoop 300 and permit axial movement.

The flap supporting ring 304 consists of two circular members 318 and 320 which are fixed to the end of the afterburner. Circular member 318 has a flange 322 which extends radially therefrom and circular member 320 has a similar flange 324 which extends radially therefrom. These two flanges are located adjacent each other and form a single flange projecting radially from the afterburner. Brackets 326 are bolted to said flanges 322 and 324, by bolts 328. These brackets have a boss 330 on each end, each with a hole for pivotally mounting the flaps

306 in a manner to be hereinafter described. A plurality of these brackets 326 are located around the flap supporting ring 304.

The flap itself is a plate 332 with a hinge plate 334 and sealing plate 336 fixed thereto. The hinge plate 334 is flanged up at 338 to strengthen the flap and flanged up at 340 to provide hinge points for the flap 306. These flanged portions 340 are placed between the end bosses 330 of adjacent brackets 326. A bolt 342 extends through each hole in a hinge plate and its mating hole in the boss of the bracket 326.

Each flap has an arm 344 for actuating it. These arms 344 consist of two members 346 spaced apart and fixed to the flap by flanges 348. For each flap 306 there is a connection on the hoop 300.

These connections are brackets 350 fixed to the hoop. Each bracket consists of two rearwardly extending bosses 352 fixed to said hoop and having a hole through the outer ends thereof. These brackets 350 are equally spaced around the hoop. An adjustable link 354 having a self-aligning bearing on each end extends between each bracket 350 on the hoop and the end of the arms 344 of the flap which it actuates. The ball member of the self-aligning bearing of one end of a link 354 is held between the bosses of a bracket 350 by a clevis pin 353 and the ball member of the self-aligning bearing of the other end of the link is held between the free ends of the two members of an arm 344 by a clevis pin 355. On each side of the afterburner the bracket 350 has two forwardly extending bosses 356. The end of the nozzle control rod 78 on each side of the afterburner is held between the bosses 356 located on that side.

A seal is formed between the afterburner and nozzle 44 by having a channel 357 extend around the end of the afterburner over the hinge points of the flaps 306. A sealing member 358 is placed within said channel and extends around the afterburner. The part of plate 332, forming a part of the flap 306, which is located over the hinge points is bent at 360 to mate with the sealing member 358 as the flap moves to any position.

Brackets 362 on the hoop 300 are mounted on opposite brackets 364 on the flap supporting ring 304. A spring 366 is located between said brackets, one end of said spring being fixed to bracket 362 and the other end of said spring being fixed to bracket 364. This construction biases hoop 300 to the rear for a purpose to be described hereinafter.

Operation of the modification shown in Figs. 13-18

Assuming the nozzle to be in the position shown in Fig. 13, when the nozzle control rods 78 are moved to the left, or front, the hoop 300 is moved in the same

direction. This movement of the hoop in turn moves each link 354 to the left turning flaps 306 simultaneously by arms 344. This action is against the force of spring 366 but with the aid of the exhaust gas against the inner side of the flaps. If the nozzle is to be closed, the nozzle control rods 78 are moved to the right, or rear, and through a sequence of operation, reverse of that described above, the flaps are moved in a closing direction. It is to be noted that in closing the flaps the spring 366 is arranged so that its force aids in this movement, this is to counteract the force of the exhaust gases acting against the inner side of the flaps.

Although specific embodiments have been shown and described herein for the purpose of illustration, it will be evident to those skilled in the art that the invention is capable of various modifications and adaptations within the scope of the appended claim. Another variable area nozzle of the multiple flap type is shown and claimed in copending application Serial No. 234,256, filed June 29, 1951.

We claim:

In combination, a duct having an outlet, a plurality of flaps pivotally mounted to vary the effective area of said outlet, said flaps being spaced outwardly from said duct to form a space between the outlet of said duct and said flaps, said flaps having their pivots located inwardly from their ends, each flap having a section projecting forwardly of said pivot and a section projecting rearwardly of said pivot, sealing means extending around said duct and being in contact therewith, each flap having its forwardly projecting section engaging with said sealing means, duct and flaps, said chamber being in communication with said space and thereby with the outlet of said duct to receive pressure fluid therefrom.

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