

Oct. 5, 1965

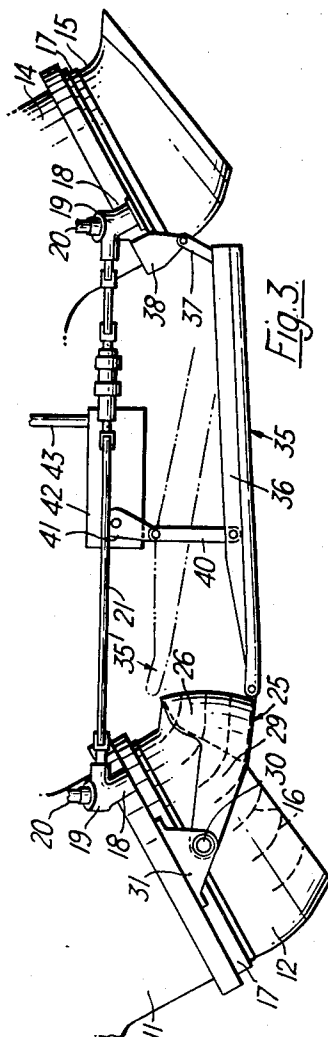
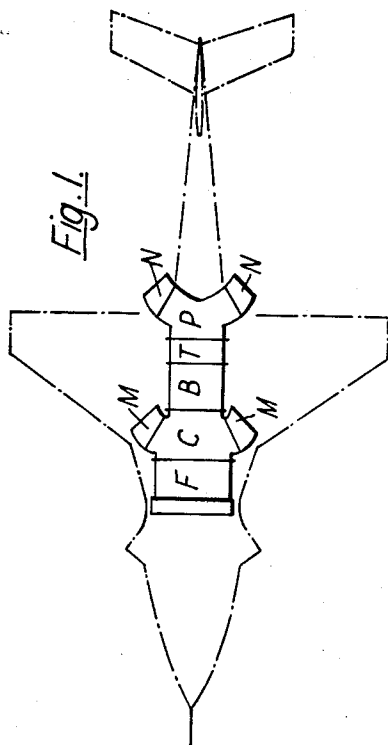
F. C. I. MARCHANT ETAL

3,209,535

THRUST DIRECTION CONTROL MEANS FOR JET PROPULSION ENGINES

Filed July 25, 1962

5 Sheets-Sheet 1



Inventors
Francis Charles Ivor Marchant
Stuart Bertrand Blackman

By
Bailey, Stephens & Hunting
Attorneys

Oct. 5, 1965

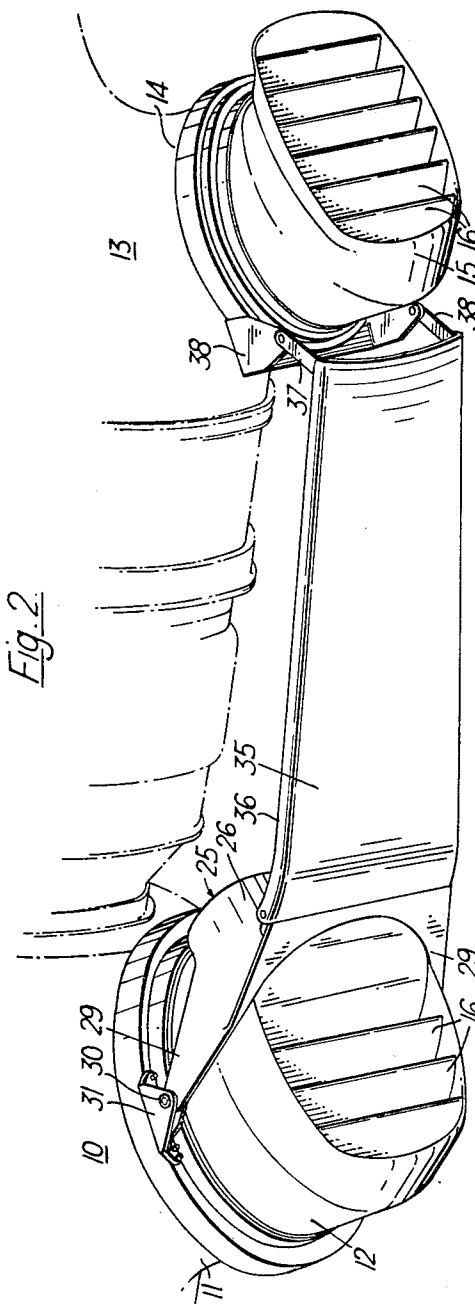
F. C. I. MARCHANT ET AL

3,209,535

THRUST DIRECTION CONTROL MEANS FOR JET PROPULSION ENGINES

Filed July 25, 1962

5 Sheets-Sheet 2



Inventors
FRANCIS CHARLES IVOR MARCHANT
STUART BERTRAM BLACKMAN

By
Bailey, Stephens & Hueltig
Attorneys

Oct. 5, 1965

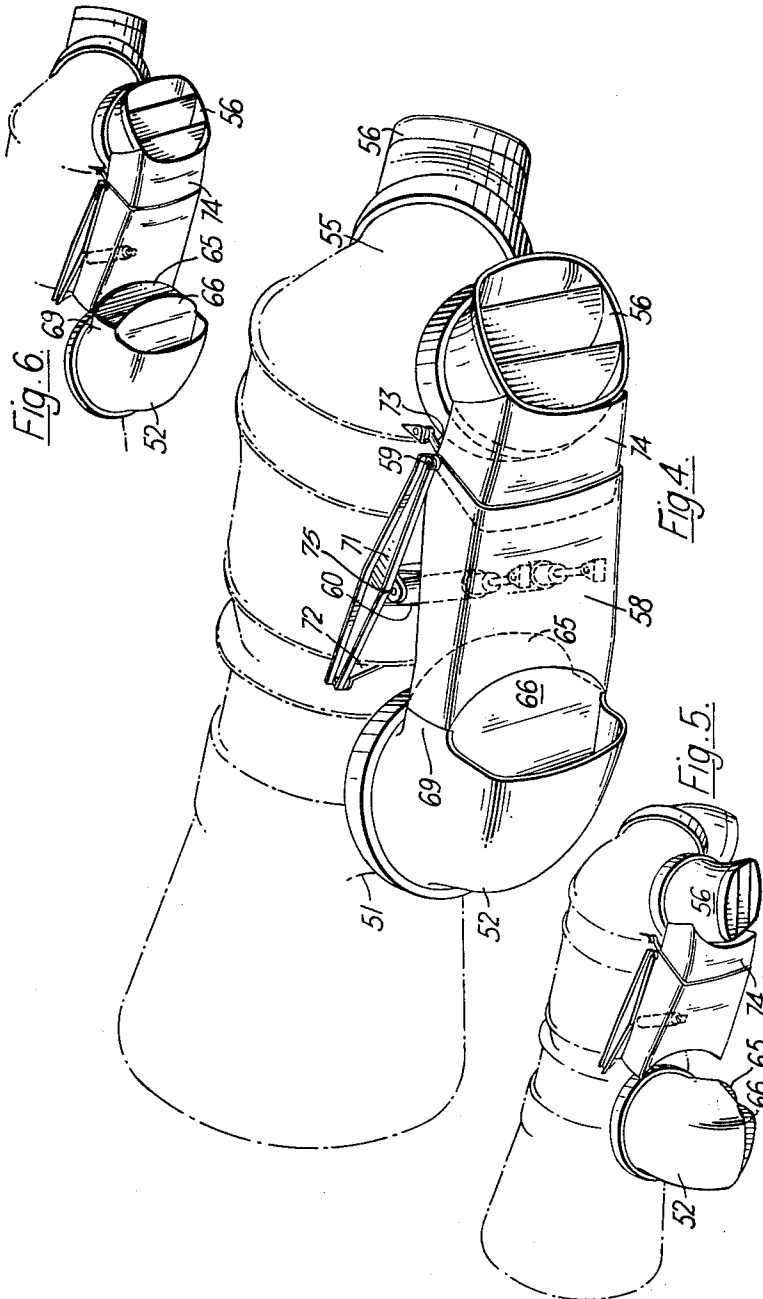
F. C. I. MARCHANT ET AL

3,209,535

THRUST DIRECTION CONTROL MEANS FOR JET PROPULSION ENGINES

Filed July 25, 1962

5 Sheets-Sheet 3



Inventors
Francis Charles Ivor Marchant
Stuart Bertram Blackman

By
Bailey, Stephenson & Huetten
Attorneys

Oct. 5, 1965

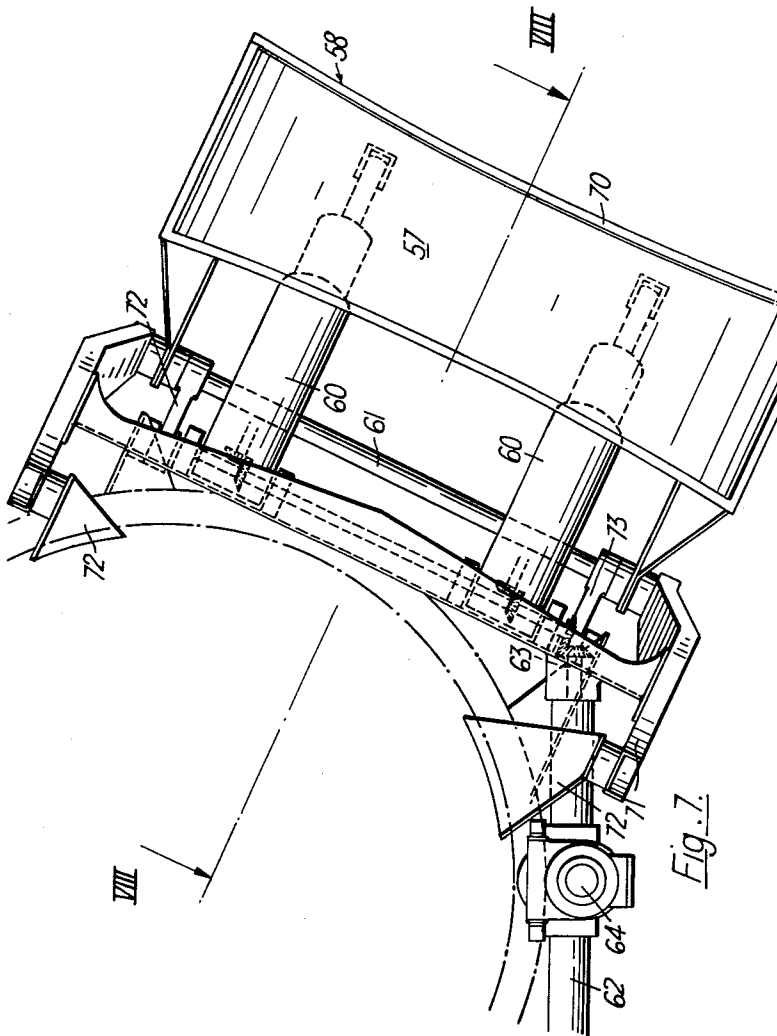
F. C. I. MARCHANT ET AL

3,209,535

THRUST DIRECTION CONTROL MEANS FOR JET PROPULSION ENGINES

Filed July 25, 1962

5 Sheets-Sheet 4



Inventors
Francis Charles Ivor Marchant
Stuart Bertram Blackman

By Bailey, Stephen & Huetting
Attorneys

Oct. 5, 1965

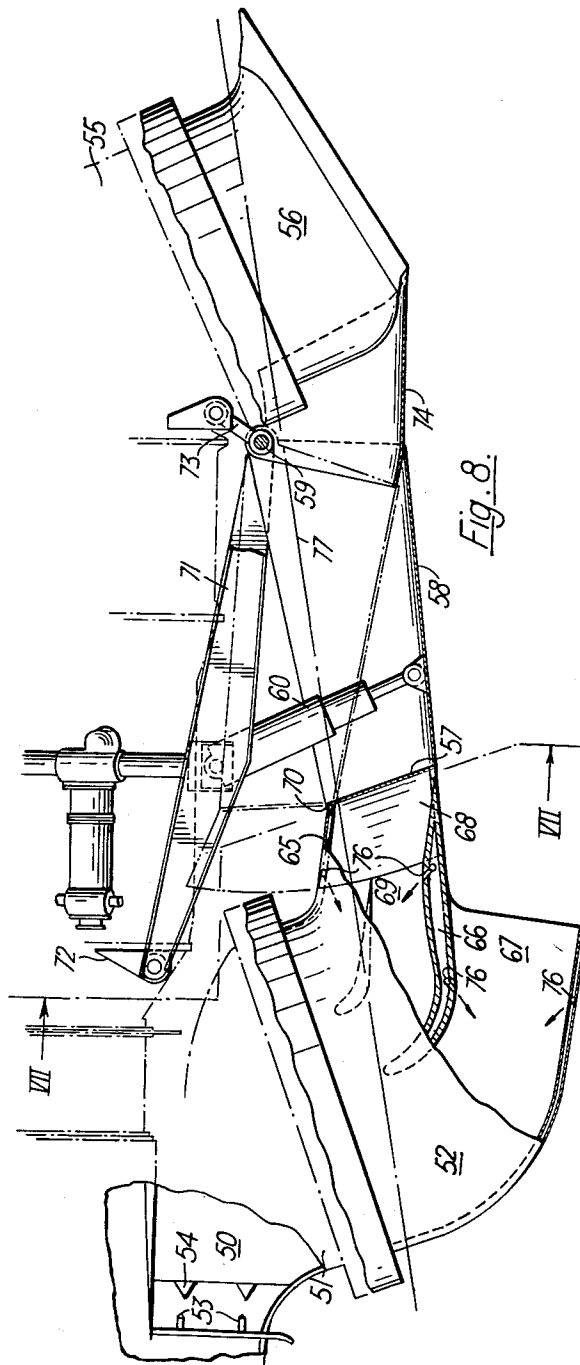
F. C. I. MARCHANT ETAL

3,209,535

THRUST DIRECTION CONTROL MEANS FOR JET PROPULSION ENGINES

Filed July 25, 1962

5 Sheets-Sheet 5



Inventors
Francis Charles Ivor Marchant
Stuart Bertram Blackman

By Bailey, Stephens & Huettig
Attorneys

1

3,209,535

THRUST DIRECTION CONTROL MEANS FOR JET PROPULSION ENGINES

Francis Charles Ivor Marchant and Stuart Bertram Blackman, Bristol, England, assignors to Bristol Siddeley Engines Limited, Bristol, England, a British company

Filed July 25, 1962, Ser. No. 212,407

Claims priority, application Great Britain, July 31, 1961, 27,716/61

9 Claims. (Cl. 60—35.55)

This invention relates to gas turbine jet propulsion engines having a propulsion nozzle of the kind which is rotatable to vary the direction of its discharge between a downward setting for upthrust and a rearward setting for forward thrust. In one type of nozzle of this kind, the rotatable part of the nozzle is bent. In another type, also of this kind, the rotatable part is straight but has a skew upstream end, rotatable on a skew downstream end of a mounting pipe.

It may be desired to increase the thrust at a particular setting above normal by heating (or reheating) the gas before discharge. This invention provides an improved arrangement for varying the effective cross-sectional outlet area of the nozzle to suit these differing operating conditions.

A gas turbine jet propulsion engine according to this invention has a nozzle of the kind described, means for supplying gas to the nozzle for discharge through it to provide a normal thrust, means for heating the gas before discharge to provide a thrust greater than normal, the nozzle having an outlet area to match the discharge when the heating means is operative, and an obturator pivoted to move independently of the nozzle, through a range of positions such that when the nozzle is in its rearward setting it can be progressively partially masked by the obturator to reduce the effective outlet area of the nozzle, but when the nozzle is in its downward setting the obturator does not mask the nozzle in any position in the range, and such that the obturator in any position in the range does not obstruct rotation of the nozzle between the downward and the rearward setting.

There may be a gas deflector which extends downstream from the obturator to form a reaction surface for the gas when discharged from the nozzle in a rearward direction.

The accompanying drawings show examples of engines according to the present invention. In these drawings:

FIGURE 1 is a plan view of a gas turbine jet propulsion engine equipped with four pivotable nozzles, the engine being installed in an aircraft indicated by broken lines;

FIGURE 2 is a perspective view of the outline from the port side of part of a gas turbine jet propulsion engine showing two pivotable nozzles, the forward one of which embodies the present invention;

FIGURE 3 is a plan corresponding substantially to FIGURE 2 but showing operating linkages for the movements of the nozzles and for an obturator associated with the forward port nozzle;

FIGURE 4 is a perspective view of the port side of a second engine;

FIGURES 5 and 6 are diagrams on a smaller scale showing different positions of the components;

2

FIGURE 7 is a fragmentary view of this second engine, looking aft from the line VII—VII in FIGURE 8; and

FIGURE 8 is a section on the line VIII—VIII in FIGURE 7.

FIGURE 1 does not itself illustrate the present invention but has been included to show a form of aircraft propulsion system to which the present invention is applicable. The gas turbine engine of FIGURE 1 comprises a fan F, a high pressure compressor C, a combustor B arranged to receive and heat the air compressed by the high pressure compressor, and a turbine system T which is driven by the combustion gases from the combustor and comprises a high pressure turbine and a mechanically independent low pressure turbine which respectively drive the high pressure compressor and the fan through concentric driving shafts. The turbine exhaust gas is conveyed through a bifurcated jet pipe P to two jet propulsion nozzles N. The delivery from the fan is divided, part of the compressed air entering the high pressure compressor C and the remainder being diverted through two outlet stub ducts for discharge from two jet propulsion nozzles M mounted on the stub ducts. All four nozzles are of pipe bend form and are arranged to rotate about rearwardly and downwardly inclined axes so as to discharge either vertically downwards for upthrust or rearwards for forward thrust.

The engine shown in FIGURES 2 and 3 is similar in general layout to that shown in FIGURE 1, and includes an annular plenum chamber 10 which surrounds the inlet to the high pressure compressor and is provided with a pair of outlet stub ducts 11 supporting a front pair of rotatable propulsion nozzles 12 (corresponding to the nozzles M of FIGURE 1), and a bifurcated jet pipe 13 the branch ducts 14 of which support a rear pair of rotatable propulsion nozzles 15 (corresponding to the nozzles N of FIGURE 1) for discharging the turbine exhaust gas. The four nozzles, which are of pipe bend form and equipped with deflector vanes 16 of aerofoil section, are each arranged to be rotated on their respective supporting ducts by means of the following mechanism, shown in FIGURE 3. A chain substantially encircles each nozzle adjacent the nozzle bearing 17, the ends of the chain being adjustably attached to the rotating inner race of the bearing, and the chain is engaged by a sprocket wheel mounted on the fixed outer race of the bearing. The shafts of the sprocket wheels are enclosed in housings 18 and are connected by bevel gears 19 to driving shafts 20 which are arranged to be driven by air motors operated by compressed air tapped from the high pressure compressor. Coupling shafts 21 fitted with universal joints connect the driving shafts 20. By these means the nozzles 12, 15 are rotated between their illustrated rearward setting for forward propulsion and their downward setting for vertical thrust, each nozzle swinging about its rearwardly and downwardly inclined axis of rotation.

The delivery of the fan is divided into radially inner and outer gaseous streams, the former passing to the high pressure compressor and the latter entering the plenum chamber 10 which delivers it to the two stub ducts 11 which are arranged symmetrically on opposite sides of the vertical plane containing the rotational axis of the engine. In order to increase the thrust from the

discharge of the front nozzles 12, fuel injectors, flame stabilisers and igniters, similar to those shown in FIGURE 8 and described later in this specification, are provided in the plenum chamber 10 and adjacent to the inlets to the stub ducts 11, to heat the air as it enters the ducts on its way to the nozzles 12.

The nozzles 12 are made sufficiently large to match the increased flow resulting from heating the compressed air, but this means that each nozzle 12 will be larger than the optimum size for discharging the gaseous flow when it has not been heated, and if the nozzle cross-sectional area is not reduced, engine efficiency will suffer. Accordingly each nozzle 12 is provided with an obturator in the form of a visor 25, to reduce the effective nozzle area when required, each visor consisting of a part-spherical wall 26 supported by upper and lower arms 29 which are apertured at their free ends to engage pivot pins 30 mounted on brackets 31 secured to the wall of the fixed duct 11.

The cascade of vanes 16 includes four vanes nearest the visor which are extended downstream beyond the nozzle outlet and are provided with trailing edges of convex shape which follow closely, but with a small clearance, the concavity of the spherical wall 26 of the visor. As a result of the matching shapes of the nozzle wall and its extended vanes 16 on the one hand, and the visor on the other hand, not only may the nozzle be rotated to and from its rearward setting without fouling the visor when the visor is stationary, in any position, but also the visor may be freely moved about its pivot pins 30 so as to cooperate in substantially sealing relationship with any of the extended vanes 16 so as to provide variations in the masking effect of the visor when the nozzle is directed rearwards, and thus provide variations in the nozzle outlet area to suit different degrees of heating in the plenum chamber.

An elongated deflector plate 35 with upper and lower flanges 36 extends between each pair of front and rear nozzles, the upstream end of each plate 35 being hinged to the outer edge of the visor and the downstream end of the plate being connected by a swinging link 37 to a bracket 38 mounted on the exhaust gas duct 14. The shape of the plate 35 changes progressively from being flat adjacent to its hinged connection to the visor to slightly convex at its downstream end. The plate is also supported at an intermediate point in its length by a pair of arms 40, shown only in FIGURE 3, which are rigidly secured at their outer ends to the upper and lower flanges 36 respectively and at their inner ends to lever arms 41 operated through suitable gearing in a housing 42 by means of a drive shaft 43 driven by an air motor, not shown. Thus by pivoting the lever arms 41 towards the engine the plate 35 is caused to swing from the position shown in full lines in FIGURES 2 and 3 until it reaches the innermost position indicated in chain lines 35' in FIGURE 3. Simultaneously, the plate transmits this actuating movement to the visor which is hingedly connected to the plate. The visor is caused to pivot inwards about the pins 30 until it lies between the engine and the nozzle 12, leaving the nozzle completely unmasked.

The plates 35 serve as additional inclined reaction surfaces or nozzle extensions for the propulsion jets when discharged rearwards from the nozzles 12, such pivotable extensions having a convergent or divergent effect according to their inclination relative to the rearward jets from the front nozzles. The plates 35 also serve as heat shields for the aircraft structure downstream of the front nozzles 12.

The four rotatable nozzles are driven by two air motors, not shown, each of which is capable of supplying sufficient power for driving the four nozzles. The two visor and deflector plate assemblies are driven by a separate air motor. This arrangement, together with the

arrangement of the visors and deflector plates already described, ensures that the drive to the nozzles and their freedom to rotate between their rearward and downward positions will be unimpaired by failure of the separate drive to the visor and deflector plate assemblies or by jamming of the latter.

The propulsion system for FIGURES 2 and 3 may be operated in the following manner. For vertical take-off or landing, all four nozzles are rotated to their downward setting, and the thrust from the front nozzles 12 is increased by using the combustion systems in the plenum chamber 10. In this setting, the outlet areas of the front nozzles are unaffected by the visors, and are thus at their maximum effective outlet area to match the increased flow. For transition to forward flight at cruising speed, the visors should be in their innermost positions. Then the nozzles are rotated rearwards and upwards until they reach the rearward setting indicated in the drawings. During or after this transition movement, the combustion systems in the plenum chamber are rendered inoperative by cutting off their fuel supply, and simultaneously the visors are moved outwards to effect a reduction in the effective outlet area of the nozzles. If, however, maximum forward speed is required, the air motor associated with the drive shafts 43 is operated to swing the deflector plates 35 inwards and thereby pivot the visors to their innermost positions in which the effective outlet areas of the front nozzles are no longer reduced by the visors. The combustion systems in the plenum chamber are then brought into operation to increase the forward thrust from the front nozzles.

The construction shown in FIGURES 4 to 8 is a development of that shown in FIGURES 2 and 3. The layout of the engine is again similar to FIGURE 1, including an annular plenum chamber 50, with two outlet stub ducts 51, carrying a pair of rotatable front nozzles 52. FIGURE 8 shows fuel injectors 53 and flame stabilisers 54, by which fuel may be burnt in the plenum chamber when desired, to increase the thrust from the front nozzles 52. A jet pipe 55 carries a pair of rear nozzles 56. The line 77 in FIGURE 8 indicates the line of the outside of the aircraft fuselage.

The outlet area of each front nozzle 52, when directed rearwards, is controllable by an obturator in the form of the upstream end wall 57 of a gas deflector plate 58 of channel-shaped cross section, with its flanges directed inwards. The plate is pivoted at its rear end on a shaft 59, and can be swung between an outer position, shown in solid lines, and an inner position, shown in FIGURE 8 in chain lines, by means of a pair of screw jacks 60. These jacks, and two similar jacks on the other side of the aircraft, are driven through shafts 61, 62 (FIGURE 7), and bevel gearing 63, from a central air motor 64.

As shown most clearly in FIGURES 4 to 6, the upstream end wall 57 is concave, part-cylindrical. When the plate 58 is in its outer position, see FIGURES 4 and 8, the end wall 57 cooperates with the arcuate trailing edge of the inner wall 65 of the nozzle 52, and with the arcuate trailing edge of a transverse wall 66 which divides the downstream part of the interior of the nozzle into two discharge passages, 67, 68. When the nozzle 52 is directed rearwards, FIGURE 4, the end wall blocks off the inner passage 68, and a seal 70 around the end wall engages the trailing edges of the walls 65 and 66, and of the connecting parts 69 of the side walls. From this position, the nozzle can turn downwards to the position shown in FIGURE 5, the arcuate trailing edges of the walls 65 and 66 being centred on the axis of rotation of the nozzle. Also from the position shown in FIGURE 4, the plate 58 can be moved inwards to the position shown in FIGURE 6. In the position shown in FIGURE 4, the web of the channel plate 58 forms a continuation of the wall 66; in the position shown in FIGURE 6, the web forms a continuation of the wall 65. In both positions, the

5

plate forms a reaction surface for the gas discharged from the nozzle 52.

The transverse wall 66 is cooled internally by means not shown. Not only does it divide the discharge passage and cooperate with the obturator, but it reinforces the nozzle 52 and it acts as a guide vane for the flow through the nozzle with its downstream part in line with the plate 58 when the nozzle is in its rearward setting and the obturator is in its maximum masking position, see FIGURE 4.

The pivot shaft 59 is at a substantial distance outside the nozzle and, to avoid any disturbance of clearances on thermal expansion of the engine casing, the pivot shaft is mounted on an H-shaped frame 71 pivoted at its front end to brackets 72 on the engine casing, and connected at its rear to the casing by links 73. The gap between the plate 58 and the rear nozzle 56 is bridged by a fairing 74 mounted on the links 73. The jacks 60 are pivoted to the frame 71 at 75.

The sequence of operation of the nozzles and obturators in the engine shown in FIGURES 4 to 8 is the same as that already described in relation to the engine shown in FIGURES 2 and 3.

In all engines according to the invention, by arranging that each visor does not interfere with rotation of its associated nozzle, and that in the downward setting the nozzle is clear of all positions of the visor, one ensures that even if the visor should jam, the nozzles can be made fully operative in the downward setting on which a controlled landing depends.

By locating the combustion systems in the plenum chamber, not only is there sufficient volume available for efficient combustion but also the associated propulsion nozzles do not require to be made heavier to accommodate the combustion system. It will also be noted that each visor is not mounted on its associated nozzle and therefore does not add to the weight of the nozzle which has to be rotated, nor necessitate a stronger and heavier nozzle.

The invention is also applicable to the turbine exhaust gas nozzles, in which case re-heat combustion means would be provided in the jet pipe. The visors associated therewith could be actuated either directly, or through deflector plates as described above with reference to the front nozzles.

For aircraft carrier operation, burning additional fuel while the nozzles are directed downwards may not be admissible, and therefore, in engines for such operation, further means are included for reducing the effective outlet area of a nozzle, operable at least when the nozzle is in its downward setting.

If the engine is never to burn additional fuel when the nozzles are directed downwards, then the further means may be a fixed fairing on the aircraft fuselage behind which the nozzle is free to rotate, and a rearward extension of such fairing which extends beneath the nozzle so as to partially mask the outlet of the nozzle when the latter is rotated to its downward setting.

If, however, control is required of the degree of reduction of outlet area, then a system of compressed air jets may be provided, as shown in FIGURE 8. These jets are, when required, directed obliquely upstream into the nozzle from holes 76, and serve to restrict the flow of gas through the nozzle.

We claim:

1. A jet nozzle system comprising:

- (a) a fluid supply duct having an outlet end;
- (b) a nozzle forming a continuation of said duct;
- (c) first bearing means supporting the nozzle for rotation relatively to said duct about a first axis passing through the centre of said outlet end;
- (d) the nozzle comprising means for guiding the fluid away from said first axis, and a lip defining an outlet adapted to discharge the fluid in a direction away

6

from said first axis, said lip describing an arcuate track when said nozzle is rotated;

(e) an obturator outside of and separate from said nozzle and having a surface;

(f) second bearing means supporting said obturator for turning about a second axis which is substantially fixed in relation to said fluid supply duct, and actuating means operative to turn said obturator through a limited angular range about said second axis, said range including positions in which said obturator surface overlaps and is in close relation to a part only of said track described by said nozzle outlet lip;

(g) said obturator surface and said nozzle lip having shapes such that, in all such track-overlapping positions of said obturator surface, said nozzle is free to turn into and out of all positions in which said nozzle outlet is overlapped by said obturator surface.

2. A system according to claim 1 wherein said second axis intersects said first axis, and said obturator surface is concave and part-spherical.

3. A system according to claim 1 wherein said second axis is at a substantial distance outside said nozzle, and said obturator surface is concave and part-cylindrical.

4. An engine according to claim 1 in which the downstream part of the interior of the nozzle is divided by a transverse wall into two discharge passages, the obturator is arranged to mask partially the nozzle by blocking one of the two discharge passages, and the downstream edges of all the walls which define the outlet end of that one passage are shaped to fit closely to the cooperating surface of the obturator, said engine including a gas deflector which extends downstream from the obturator to form a reaction surface for the gas when discharged from the nozzle in a rearward direction, the gas deflector serving to transmit actuating movements to the obturator.

5. A system according to claim 1 wherein there is a transverse wall within said nozzle, extending to adjacent said nozzle outlet, and thereby defining two discharge passages in said nozzle, and wherein said obturator actuating means is operative to cause said obturator to block and unblock one only of said passages.

6. A system according to claim 5 including a gas deflector having a surface extending away from said nozzle and means interconnecting said obturator and said gas deflector whereby an edge of said gas deflector surface is adjacent to an edge of said obturator surface.

7. A system according to claim 6 wherein said actuating means is operative to impart movement to said gas deflector, and said gas deflector is operative to transmit such movement to said obturator.

8. A system according to claim 6 wherein said gas deflector is a channel-shaped member, and said obturator is an end wall of said channel.

9. A jet nozzle system comprising:

- (a) a fluid supply duct having an outlet end;
- (b) a nozzle forming a continuation of said duct;
- (c) first bearing means supporting the nozzle for rotation relatively to said duct about a first axis passing through the centre of said outlet end;
- (d) the nozzle comprising means for guiding the fluid away from said first axis, and a lip defining an outlet adapted to discharge the fluid in a direction away from said first axis, said lip describing an arcuate track when said nozzle is rotated;
- (e) an obturator outside of and separate from said nozzle and having a surface;
- (f) second bearing means supporting said obturator for turning about a second axis which is substantially fixed in relation to said fluid supply duct, and actuating means operative to turn said obturator through a limited angular range about said second axis, said range including positions in which said obturator surface overlaps and is in close rela-

tion to a part only of said track described by said
 nozzle outlet lip;
 (g) at least part of said nozzle lip and at least part
 of said obturator surface being close to, but on op-
 posite sides of, an imaginary surface having double
 curvature centred on said first and second axes. 5

References Cited by the Examiner

UNITED STATES PATENTS

2,658,333 11/53 Smalowski ----- 60—35.6 10
 2,734,698 2/56 Straayer ----- 60—35.54 X

2,912,188 11/59 Singleman et al.
 2,944,393 7/60 Fox ----- 60—35.6
 3,048,974 8/62 Bertin et al. ----- 60—35.6 X
 3,080,711 3/63 Connors ----- 60—35.55

FOREIGN PATENTS

1,242,564 8/60 France.
 861,480 2/61 Great Britain.

MARK NEWMAN, *Primary Examiner.*

SAMUEL LEVINE, *Examiner.*