United States Patent

[11] **3,570,769**

[72] Inventor **Frederick Freeman**
Derby, England

[21] Appl. No. **782,900**
[22] Filed **Dec. 11, 1968**
[45] Patented **Mar. 16, 1971**

[73] Assignee **Rolls-Royce Limited**
Derby, England

[32] Priority **Dec. 28, 1967**
[33] **Great Britain**
[31] **58860/67**

---

[54] **JET NOZZLE**
8 Claims, 6 Drawing Figs.

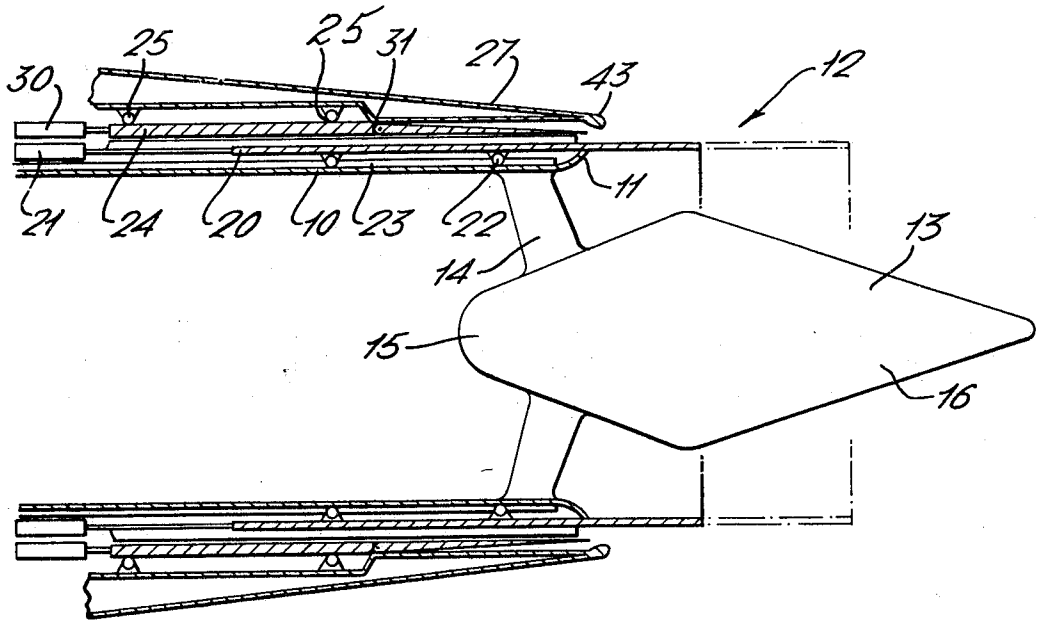
[52] **U.S. Cl.** **239/265.39,** 239/265.13
[51] **Int. Cl.** **B64c 15/06**
[50] **Field of Search** 239/265.39, 265.37, 265.43, 265.13, 265.25; 60/232; 244/52; 181/33.222

[56] **References Cited**
UNITED STATES PATENTS

3,055,174	9/1962	Grotz et al.	239/265.13
3,133,412	5/1964	Westley	239/265.39
3,372,876	3/1968	Colville et al.	239/265.13

Primary Examiner—Lloyd L. King
Attorney—Cushman, Darby & Cushman

ABSTRACT: A jet nozzle comprises a cylindrical member whose downstream end is provided with a plurality of angularly spaced-apart, alternately arranged first and second flaps each of whose adjacent paris of longitudinal edges are interconnected by a plurality of lobe wall members, the flaps and lobe wall members being adapted collectively to provide the nozzle with a plurality of angularly spaced-apart lobes, each lobe wall member being pivotally connected along each of its longitudinal edges to the adjacent longitudinal edge of the adjacent flap or lobe wall member, and means for effecting relative radial movement of the first and second flaps so as to alter the radial depth of the downstream end of each of said lobes.



PATENTED MAR 16 1971

3,570,769

SHEET 1 OF 3

FIG. 1.

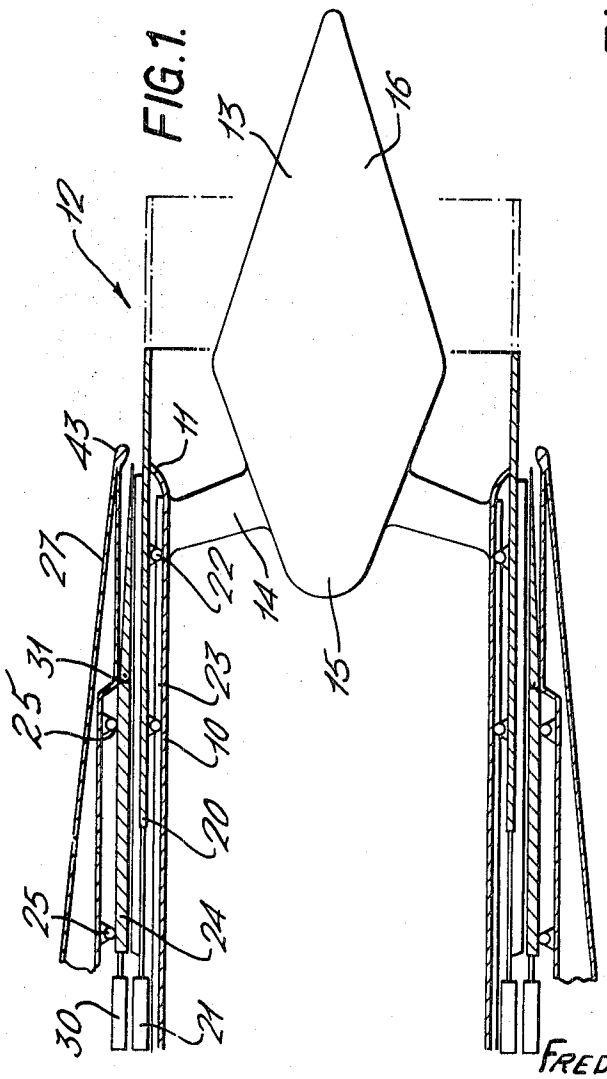
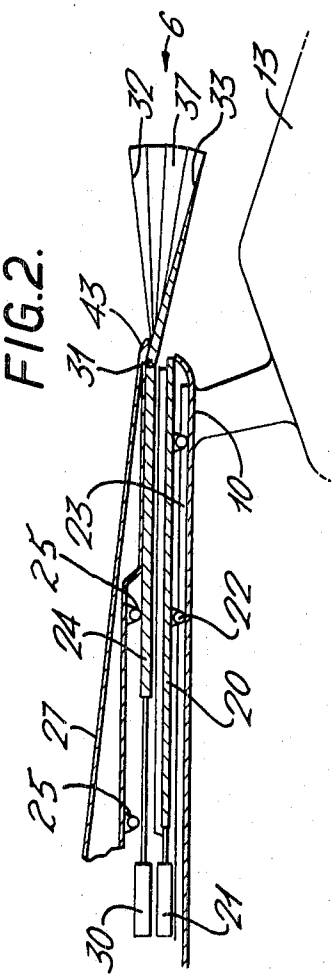


FIG. 2.



INVENTOR:
FREDERICK FREEMAN

By
Cushman, Darby & Cushman
ATTORNEYS

FIG. 3.

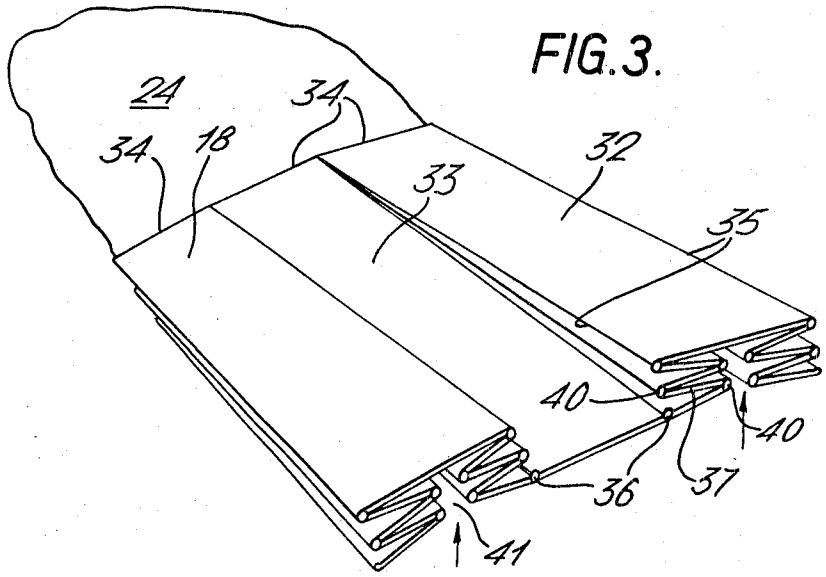
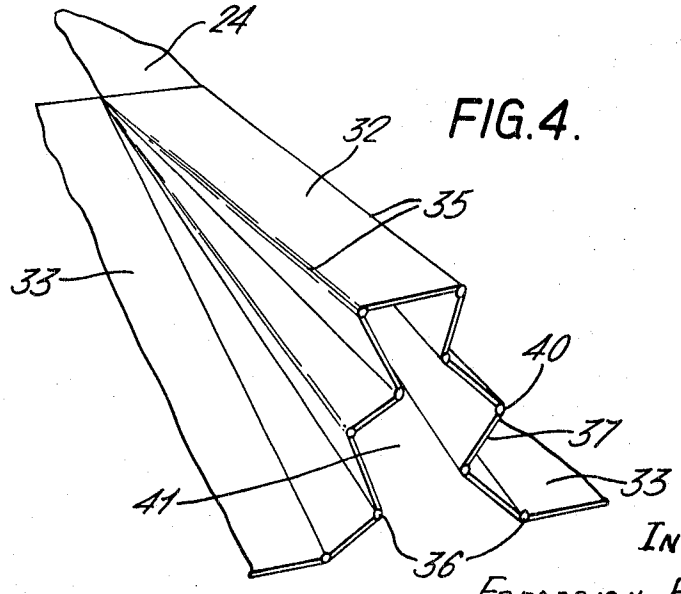


FIG. 4.



INVENTOR
FREDERICK FREEMAN

By
Cushman, Darby & Cushman
ATTORNEYS

FIG.5.

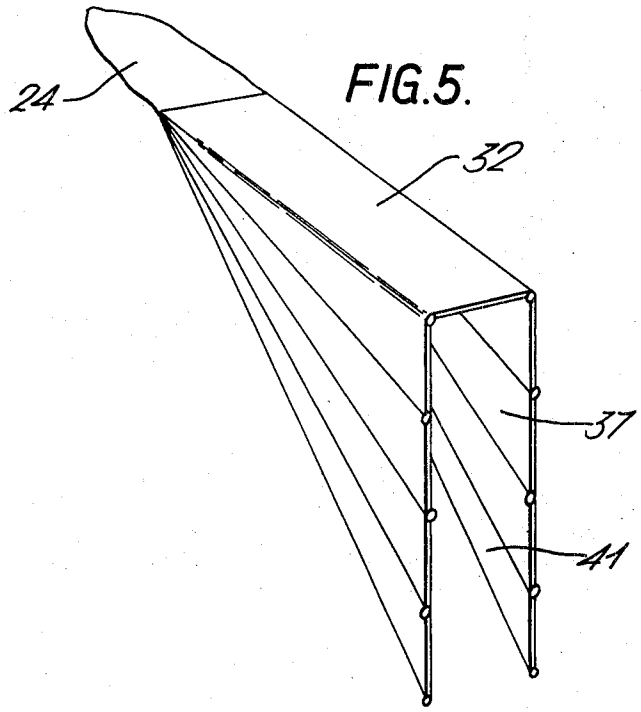
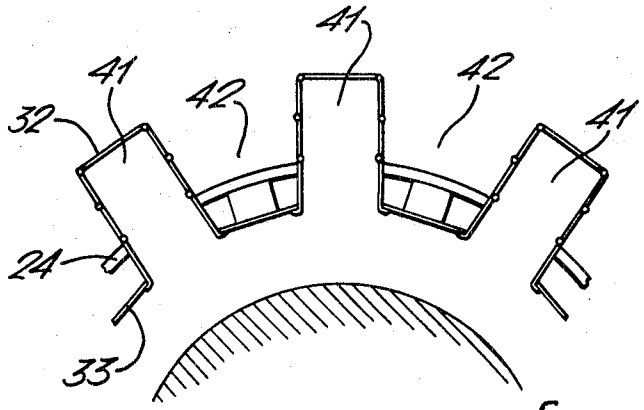


FIG.6.



INVENTOR
FREDERICK FREEMAN

By
Cushman, Darby & Cushman
ATTORNEYS

JET NOZZLE

This invention concerns a jet nozzle.

According to the present invention, there is provided a jet nozzle comprising a cylindrical member whose downstream end is provided with a plurality of angularly spaced-apart, alternately arranged first and second flaps each of whose adjacent pairs of longitudinal edges are interconnected by a plurality of lobe wall members, the flaps and lobe wall members being adapted collectively to provide the nozzle with a plurality of angularly spaced-apart lobes, each lobe wall member being pivotally connected along each of its longitudinal edges to the adjacent longitudinal edge of the adjacent flap or lobe wall member, and means for effecting relative radial movement of the first and second flaps so as to alter the radial depth of the downstream end of each of said lobes.

As will be appreciated, when the said lobes have their maximum radial depth, the peripheral boundary between the jet gases and the ambient air will be increased and this will reduce jet noise.

Each of the first and second flaps is preferably pivotally connected at its upstream end to the cylindrical member and is adapted to be urged radially outwardly by the gas forces.

The construction is preferably such that when the said lobes have their maximum radial depth, the downstream ends of the first and second flaps are respectively disposed radially outwardly and inwardly of the downstream end of the cylindrical member so as to increase the nozzle outlet area. Such increase of the nozzle outlet area will reduce the speed of the jet gases and thus effect yet a further reduction in jet noise.

The downstream ends of the second flaps are preferably disposed radially inwardly of those of the first flaps, means being provided for moving the cylindrical member longitudinally into and out of positions in which there is abutment between the second flaps and fixed abutment means, the said abutment causing radial inward movement of the second flaps. Thus the abutment means may comprise internal cam surfaces on a pod within which the cylindrical member is mounted.

The cylindrical member is preferably mounted concentrically about and is movable longitudinally over a fixed jet pipe into and out of a position in which the said flaps are disposed downstream of the jet pipe.

Preferably a sleeve is disposed between the jet pipe and the cylindrical member, and there is a bulbous center body mounted within the jet pipe and extending beyond the downstream end thereof, the sleeve being movable between a first position in which it does not extend beyond the downstream end of the jet pipe, and a second position in which it does so extend and forms a convergent nozzle with the center body.

The sleeve may, moreover, be movable into and out of a third position in which it forms a convergent-divergent nozzle with the center body.

The invention also comprises a jet engine provided with a jet nozzle as set forth above.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:

FIG. 1 is a diagrammatic sectional view of a jet nozzle according to the present invention;

FIG. 2 is a broken-away perspective view of the jet nozzle of FIG. 1 showing the parts thereof in a different position;

FIG. 3 is a broken-away perspective view showing part of the structure of FIGS. 1 and 2 on a larger scale;

FIGS. 4 and 5 are diagrammatic perspective views of different positions of part of the structure shown in FIG. 3; and

FIG. 6 is a view of part of the structure of FIG. 2 looking in the direction of the arrow 6 thereof.

Referring to the drawings, a gas turbine jet engine (not shown) which is adapted for supersonic flight is provided with a fixed jet pipe 10 whose downstream end 11 forms part of a jet nozzle 12.

Mounted within the jet pipe 10 and extending beyond the downstream end 11 thereof is a bulbous center body 13 whose upstream end is supported from the jet pipe 10 by a plurality of angularly spaced-apart struts 14. The center body 13 has axially consecutive conical portions 15, 16 whose area respectively increases and reduces in an axially downstream direction.

Mounted concentrically about the jet pipe 10 is a sleeve 20 which is movable longitudinally over the jet pipe 10 by means of a ram 21, the sleeve 20 being provided internally with rollers 22 which cooperate with axially extending tracks 23 on the external surface of the jet pipe 10.

The ram 21 is operable to move the sleeve 20 into three positions. In the first of these positions, which is shown in FIG. 2, the sleeve 20 extends up to, but does not extend beyond, the downstream end 11 of the jet pipe 10, and therefore is inoperative in this position. In the second position, however, which is shown in the full lines in FIG. 1, the sleeve 20 does extend beyond the downstream end 11 of the jet pipe 10 and indeed extends to a position in which its downstream end is aligned with the maximum diameter portion of the center body 13. In this position, therefore, the sleeve 20 forms with the center body 13 a convergent nozzle. In the third position, which is indicated by dotted lines in FIG. 1, the downstream end of the sleeve 20 extends downstream of the maximum diameter portion of the center body 13 with the result that the sleeve 20 forms with the center body 13 a convergent-divergent nozzle.

The sleeve 20 is disposed between the jet pipe 10 and a cylindrical member 24 which is also mounted concentrically about the jet pipe 10. A fixed pod 27 within which the cylindrical member 24 is mounted has rollers 25 engaging the exterior of cylindrical member 24. The cylindrical member 24 is thus longitudinally movable by means of a ram 30 with respect both to the jet pipe 10 and to the pod 27.

The downstream end 31 of the cylindrical member 24 is provided with a plurality of angularly spaced-apart radially movable alternately arranged first and second flaps 32, 33. The upstream end of each of the flaps 32, 33 is pivotally connected to the downstream end 31 of the cylindrical member 24 at a circumferentially extending pivot axis 34.

The flaps 32, 33 respectively have longitudinal edges 35, 36, each adjacent pair of longitudinal edges 35, 36 being interconnected by a plurality (e.g. four as shown) of lobe wall members 37. Each lobe wall member 37 has longitudinal edges 40 which are pivotally connected to the adjacent longitudinal edge of the respective flap 32, 33 or to the respective longitudinal edge of the adjacent lobe wall member 37.

The downstream ends of the flaps 33 are, at all times, disposed radially inwardly of those of the flaps 32, so that a plurality of angularly spaced apart lobes 41 are formed collectively by the flaps 32, 33 and by the lobe wall members 37. However, when the parts are in the position shown in FIG. 3, the lobe wall members 37 are collapsed against each other so that the radial depth of the downstream ends of the lobes 41 is at a minimum. As described in greater detail below, relative radial movement may, however, progressively be effected between the flaps 32, 33 so as to move the parts consecutively into the positions shown in FIGS. 4 and 5, and as will be noted the radial depth of the downstream ends of the lobes 41 will thereby be progressively increased.

When the downstream ends of the lobes 41, as indicated in FIGS. 5 and 6, have their maximum radial depth, the downstream ends of the flaps 32, 33 are respectively disposed radially outwardly and inwardly of the downstream end 31 of the cylindrical member 24 so as to increase the outlet area of the nozzle 12 (e.g. by 20 percent). In this particular position, a channel 42 (FIG. 6) is formed between each adjacent pair of lobes 41, and the peripheral boundary area between the jet gases and the ambient air is thereby increased. This has the effect of reducing jet noise. Furthermore, by reason of the previously-mentioned increase in the nozzle outlet area, although there will be an increase in the mass flow through the engine, the jet flow through the nozzle 12 will be somewhat slowed down and this effects a yet further reduction in jet noise without reducing the thrust.

The downstream end of the pod **27** is provided internally with a plurality of angularly spaced-apart fixed cam surfaces **43** which are radially aligned with the flaps **33**. The ram **30** is operable to move the cylindrical member **24** to the position shown in FIG. **1** in which the flaps **32, 33** are disposed upstream of the cam surfaces **43**. The ram **30** is also, however, as indicated in FIG. **2**, operable to move the cylindrical member **24** into the position in which the plurality of cam surfaces **43** are brought into abutment with the flaps **33**.

Both the flaps **32** and the flaps **33** are, in operation, urged radially outwardly by the gas forces. The flaps **32**, which are not engaged by the cam surfaces **43**, will, in the FIG. **2** position, thus be urged radially outwardly of the cylindrical member **24**. The flaps **33**, however, will be at this time be caused by the abutment with the cam surfaces **43** to be moved radially inwardly of the cylindrical member **24**. Accordingly, operation of the ram **30** will alter the radial depth of the downstream ends of the lobes **41** between the minimum position, shown in FIG. **3**, and the maximum position, shown in FIG. **5**. In the said minimum position, of course, the flaps **32, 33** will be disposed as shown in FIG. **1** and will thus be inoperative by reason of the fact that they do not extend downstream of the jet pipe **10**, while in the said maximum position, the flaps **32, 33** will, as shown in FIG. **2**, be rendered operative by reason of the fact that they do extend downstream of the jet pipe **10**.

In operation, when an aircraft (not shown) which is provided with the said supersonic engine is progressing down the runway but is not yet actually taking off the ground, the rams **21, 30** are operated (by means not shown) to dispose the parts of the nozzle **12** in the position shown in full lines in FIG. **1**. In this position, the flaps **32, 33** will not extend beyond the downstream end of the jet pipe **10**, and indeed are disposed well upstream of the downstream end of the sleeve **20**, and are therefore completely inoperative. The sleeve **20**, however, in this position forms a convergent nozzle with the center body **13** and the parts are therefore disposed in the position best suited to such progress down the runway. There will of course be no jet silencing at this time, but this is not the time when maximum jet noise occurs.

Silencing is in fact most needed between the time at which the aircraft actually leaves the ground until it reaches its cruise altitude, and during this period the rams **21, 30** are operated so as to move the parts into the position shown in FIG. **2**, i.e. to retract the sleeve **20** and to extend the cylindrical member **24**. The downstream end of the sleeve **20** is, in the FIG. **2** position, radially aligned with that of the jet pipe **10** and in consequence the sleeve **20** is inoperative in this position. The necessary convergent nozzle which is required at this time is, however, provided by the arrangement of the flaps **32, 33** which will at this time extend downstream of the downstream end of the jet pipe **10** and will be in the positions in which the downstream ends of the lobes **41** have their maximum radial depth. As explained above, this will produce substantial jet silencing.

When the cruise altitude is reached, the rams **21, 30** are operated to move the parts to the position shown in full lines in FIG. **1** and this is maintained throughout subsonic flight. When, however, supersonic flight is required, the ram **21** is operated to extend the sleeve **20** to the dotted line position shown in FIG. **1** in which the nozzle is given the necessary convergent-divergent form.

I claim:

1. A jet nozzle comprising a cylindrical member, a plurality of angularly spaced-apart, alternately arranged first and second flaps which are mounted at the downstream end of the cylindrical member and each of whose adjacent pairs of longitudinal edges are interconnected by a plurality of pivotally interconnected lobe wall members, the flaps and lobe wall members being adapted collectively to provide the nozzle with a plurality of angularly spaced-apart lobes which may be radially expanded and contracted like a bellows, each lobe wall member being pivotally connected along each of its longitudinal edges to the adjacent longitudinal edge of the adjacent flap or lobe wall member, and means for effecting relative radial movement of the first and second flaps so as to alter the radial depth of the downstream end of each of said lobes.

2. A nozzle as claimed in claim **1** in which each of the first and second flaps is pivotally connected at its upstream end to the cylindrical member and is adapted to be urged radially outwardly by the gas forces.

3. A nozzle as claimed in claim **2** in which, when the said lobes have their maximum radial depth, the downstream ends of the first and second flaps are respectively disposed radially outwardly and inwardly of the downstream end of the cylindrical member so as to increase the nozzle outlet area.

4. A nozzle as claimed in claim **1** in which the downstream ends of the second flaps are disposed radially inwardly of those of the first flaps, means being provided for moving the cylindrical member longitudinally into and out of positions in which there is abutment between the second flaps and fixed abutment means, the said abutment causing radial inward movement of the second flaps.

5. A nozzle as claimed in claim **4** in which the fixed abutment means comprise internal cam surfaces on a pod within which the cylindrical member is mounted.

6. A nozzle as claimed in claim **4** in which the cylindrical member is mounted concentrically about and is movable longitudinally over a fixed jet pipe into and out of a position in which the said flaps are disposed downstream of the jet pipe.

7. A nozzle as claimed in claim **6** in which a sleeve is disposed between the jet pipe and the cylindrical member, and there is a bulbous center body mounted with the jet pipe and extending beyond the downstream end thereof, the sleeve being movable between a first position in which it does not extend beyond the downstream end of the jet pipe, and a second position in which it does so extend and forms a convergent nozzle with the center body.

8. A nozzle as claimed in claim **7** in which the sleeve is movable into and out of a third position in which it forms a convergent-divergent nozzle with the center body.