

[72] Inventors **Kenneth Greenwood  
Burnley;  
Alban Heaton, Gt. Harwood, near  
Blackburn; Alwin Harrison; Squire Ronald  
Jackson, Burnley, England**  
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[22] Filed **Dec. 11, 1968**  
[45] Patented **May 11, 1971**  
[73] Assignee **Joseph Lucas (Industries) Limited  
Birmingham, England**

[56]

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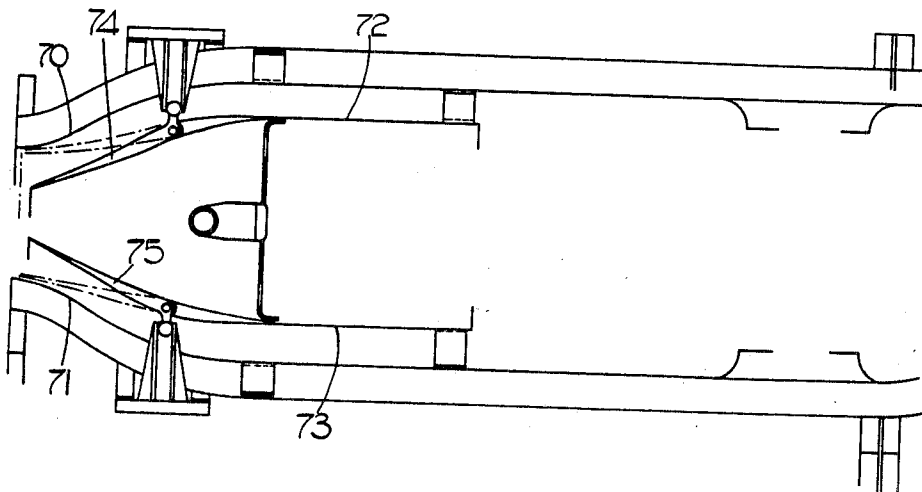
*Primary Examiner*—Douglas Hart

*Attorney*—Holman, Glascock, Downing and Seebold

[54] **FLAME TUBES FOR GAS TURBINE ENGINES**  
**5 Claims, 26 Drawing Figs.**

[52] U.S. Cl. .... **60/39.65,**  
60/39.23, 60/39.29  
[51] Int. Cl. .... **F02c 9/14**  
[50] Field of Search. .... **60/39.65,**  
39.23, 39.26, 39.27, 39.29; 431/351, 352

**ABSTRACT:** A flame tube for a gas turbine engine includes a plurality of primary combustion air inlets, a plurality of secondary combustion air inlets and a plurality of dilution air inlets and variable flow restricting means associated with at least some of the inlets for varying the ratio of primary combustion air to secondary combustion air to dilution air.



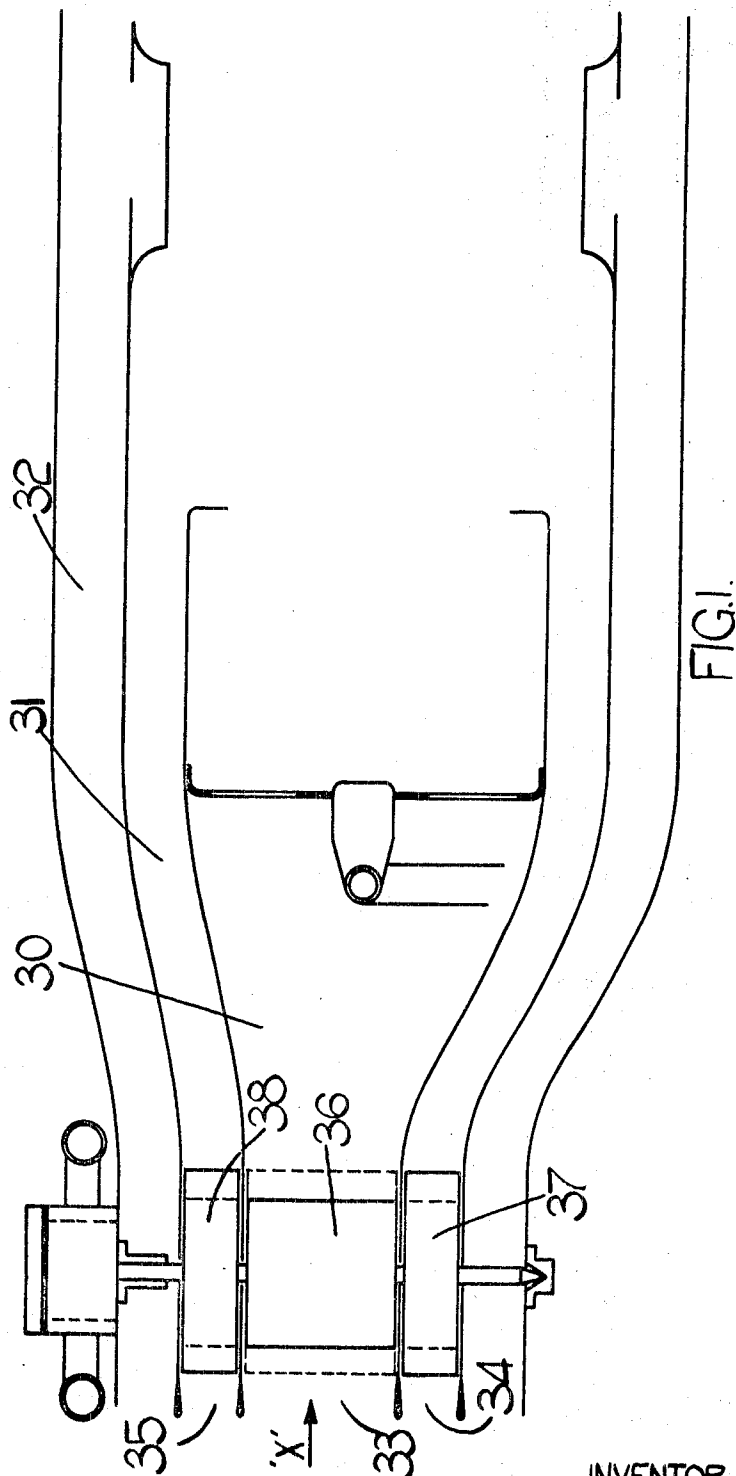


FIG. 1.

*Hennrich Greenwood, Alban Heston, Alwin Harrison & Squire Ronald Jackson*  
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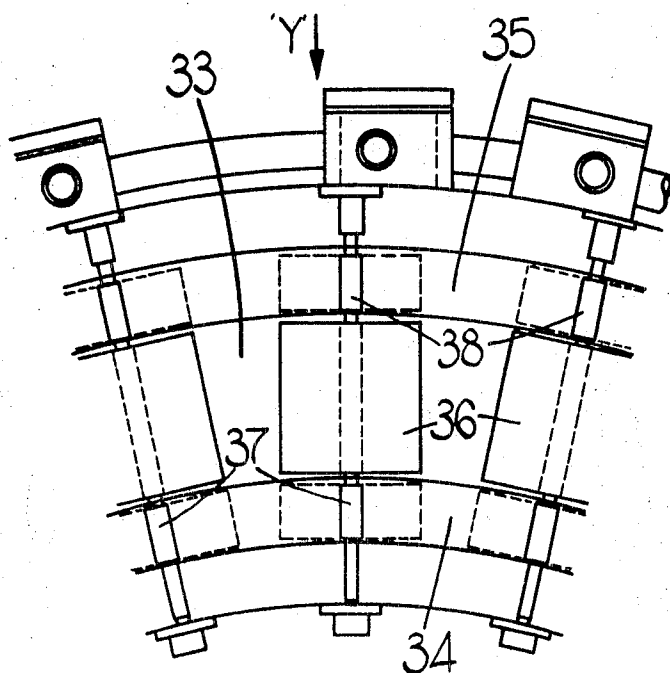


FIG. 2.

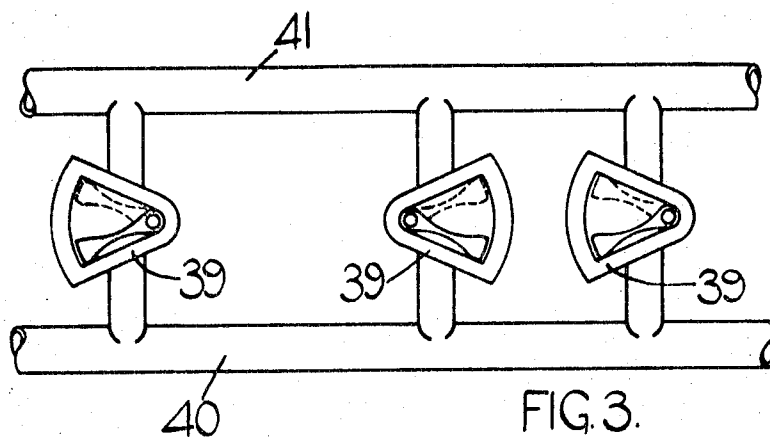
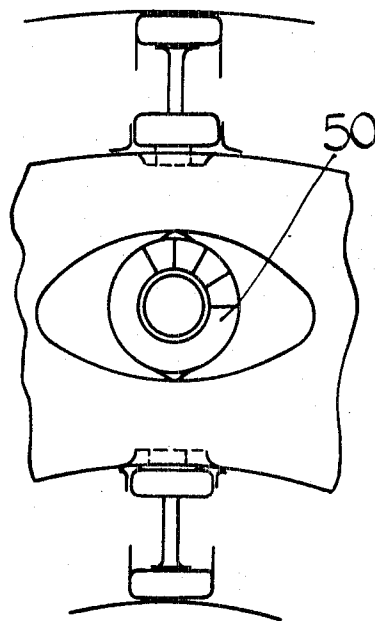
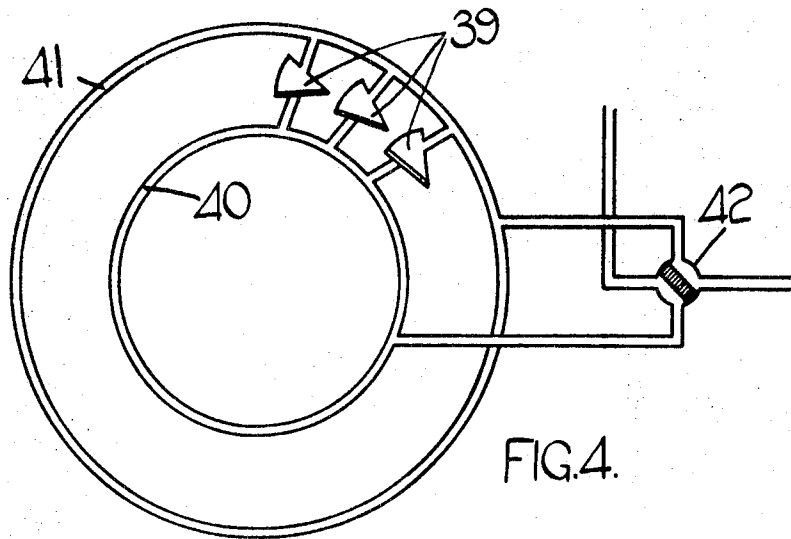


FIG. 3.

*Kenneth Greenwood, Alban Heston, Alvin Harrison & Eugene Ronald Jackson.*  
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 BY  
 ATTORNEY



*Kenneth Greenwood, Alban Heaton, Edwin Harrison & Squire Ronald Jackson*  
INVENTOR  
BY  
ATTORNEY

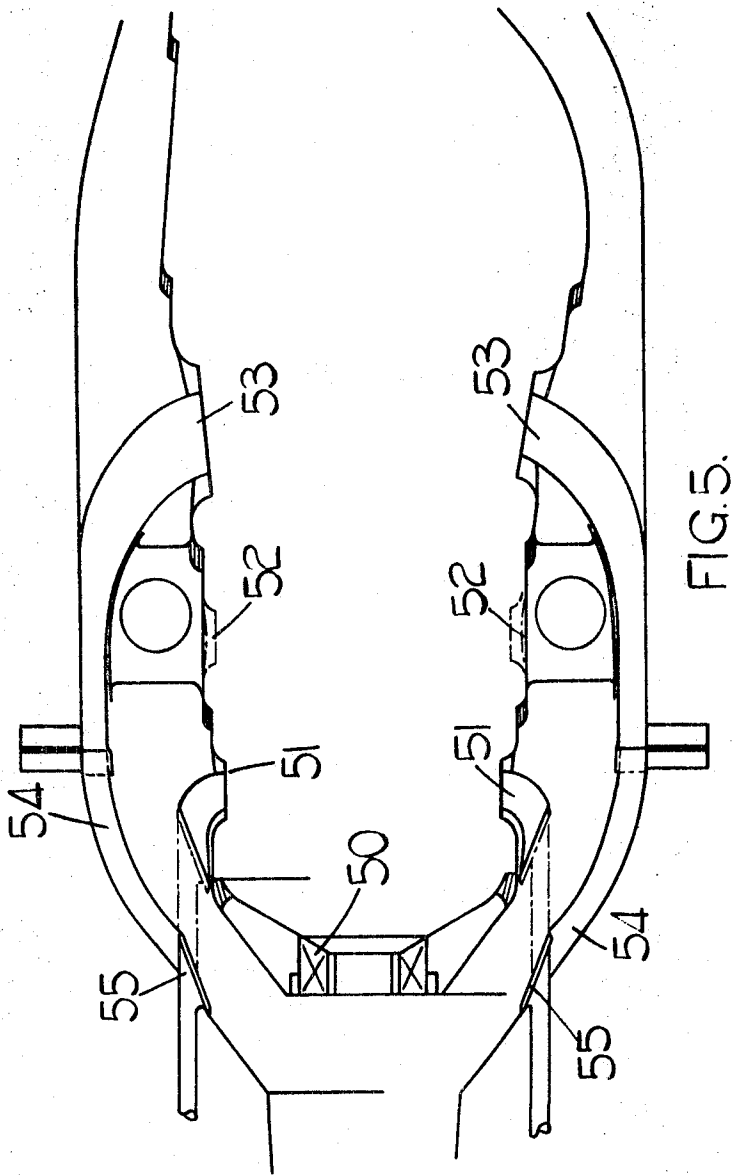
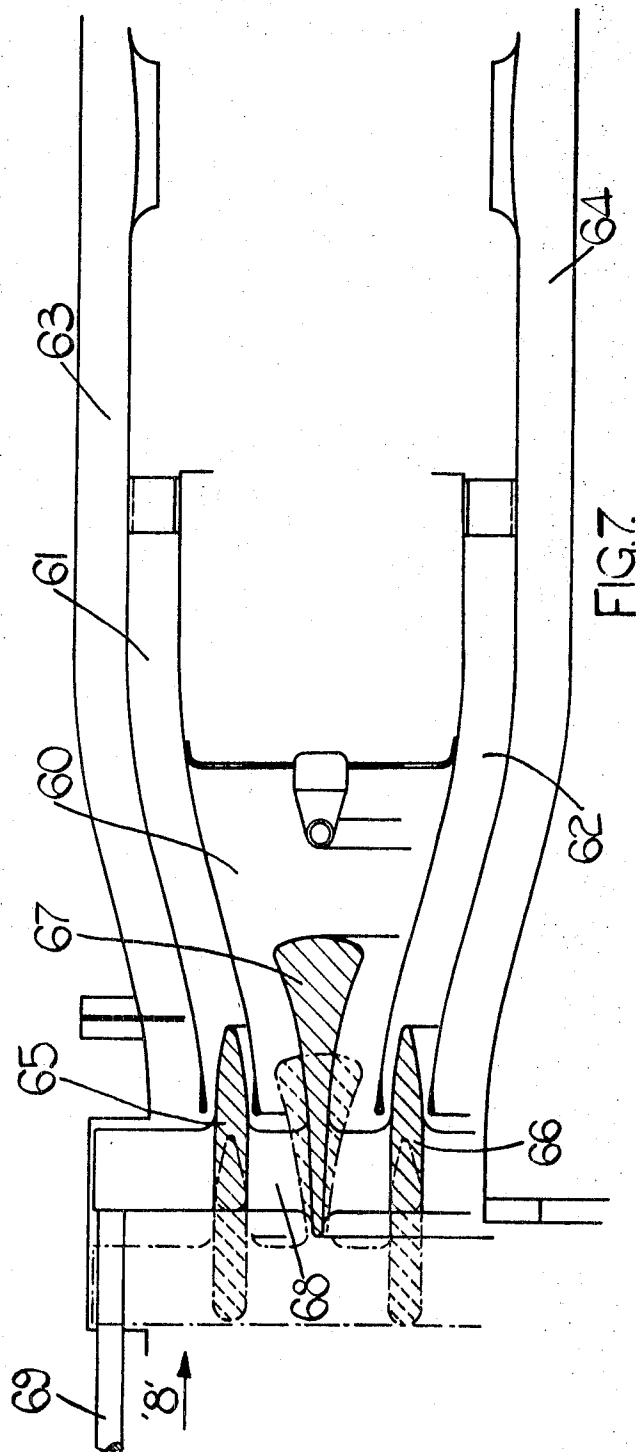


FIG. 5.

Kenneth Greenwood, Alban Heston, Alvin Harrison & Squire Ronald Jackson.  
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BY  
ATTORNEY



INVENTOR  
*Kenneth Greenwood, Alban Heston, Alvin Harrison & Squire Ronald Jackson.*  
BY  
ATTORNEY

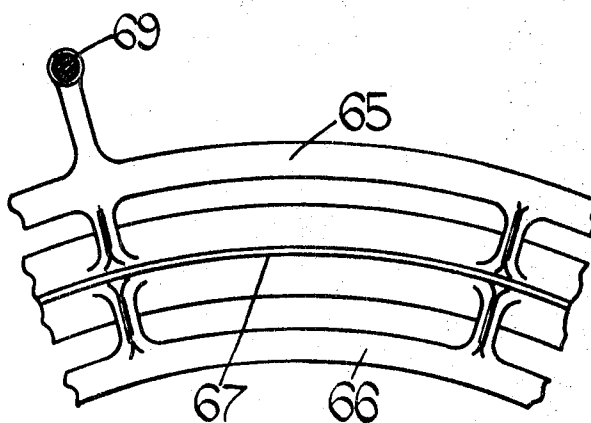


FIG. 8.

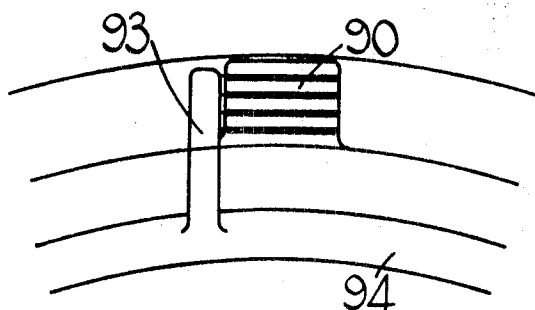


FIG. 12.

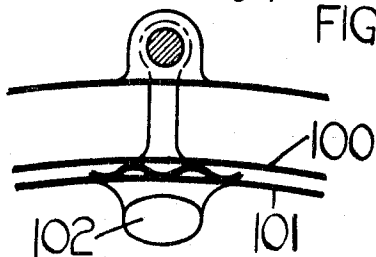


FIG. 14.

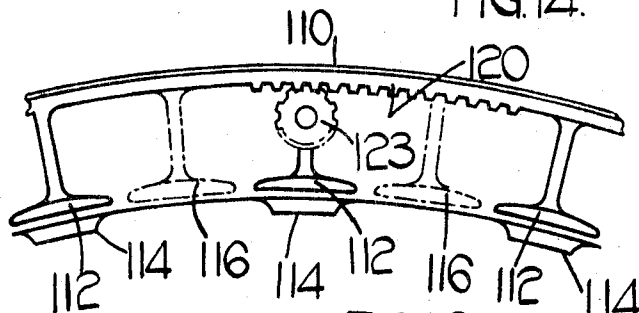


FIG. 16.

INVENTOR  
*Kenneth Greenwood, Alban Heston, Alvin Harrison & Squire Ronald Jackson*  
 BY  
 ATTORNEY

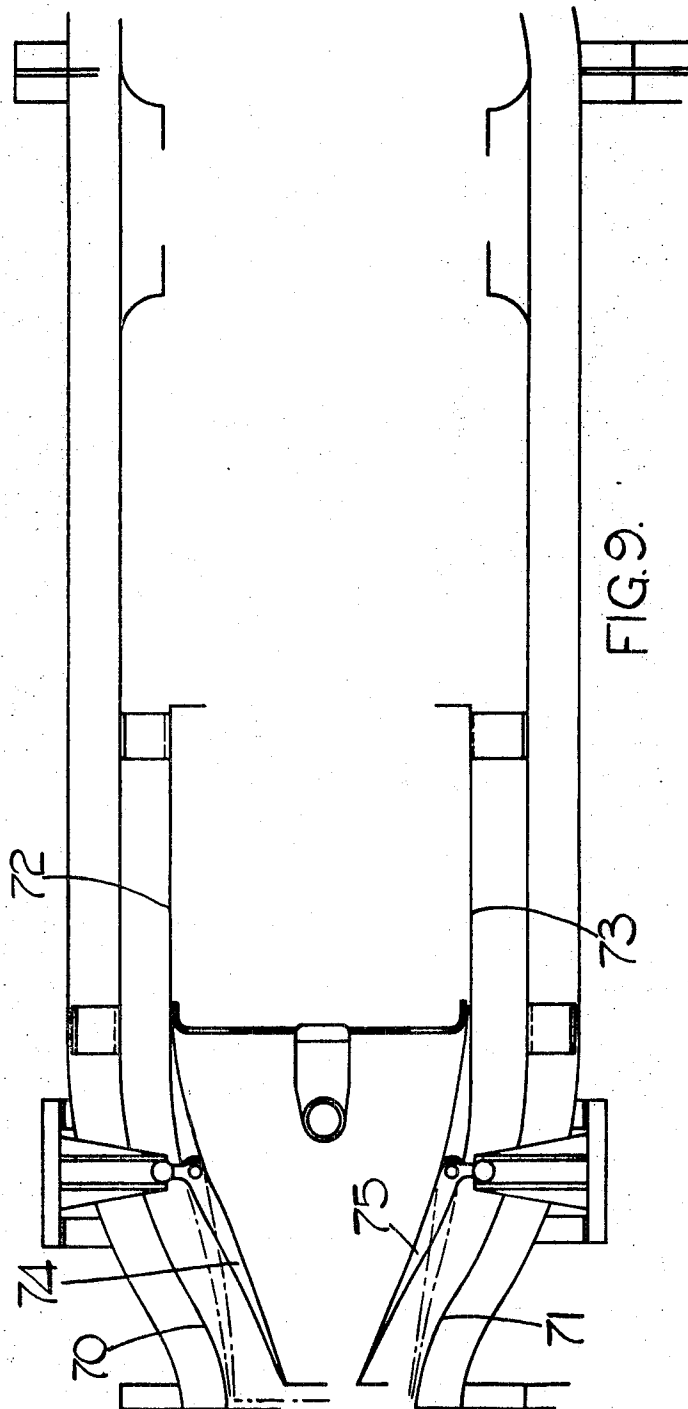


FIG. 9.

*Kenneth Greenwood, Alvan Heaton, Alvin Harrison & Squire Ronald Jackson.*  
INVENTOR  
BY  
ATTORNEY

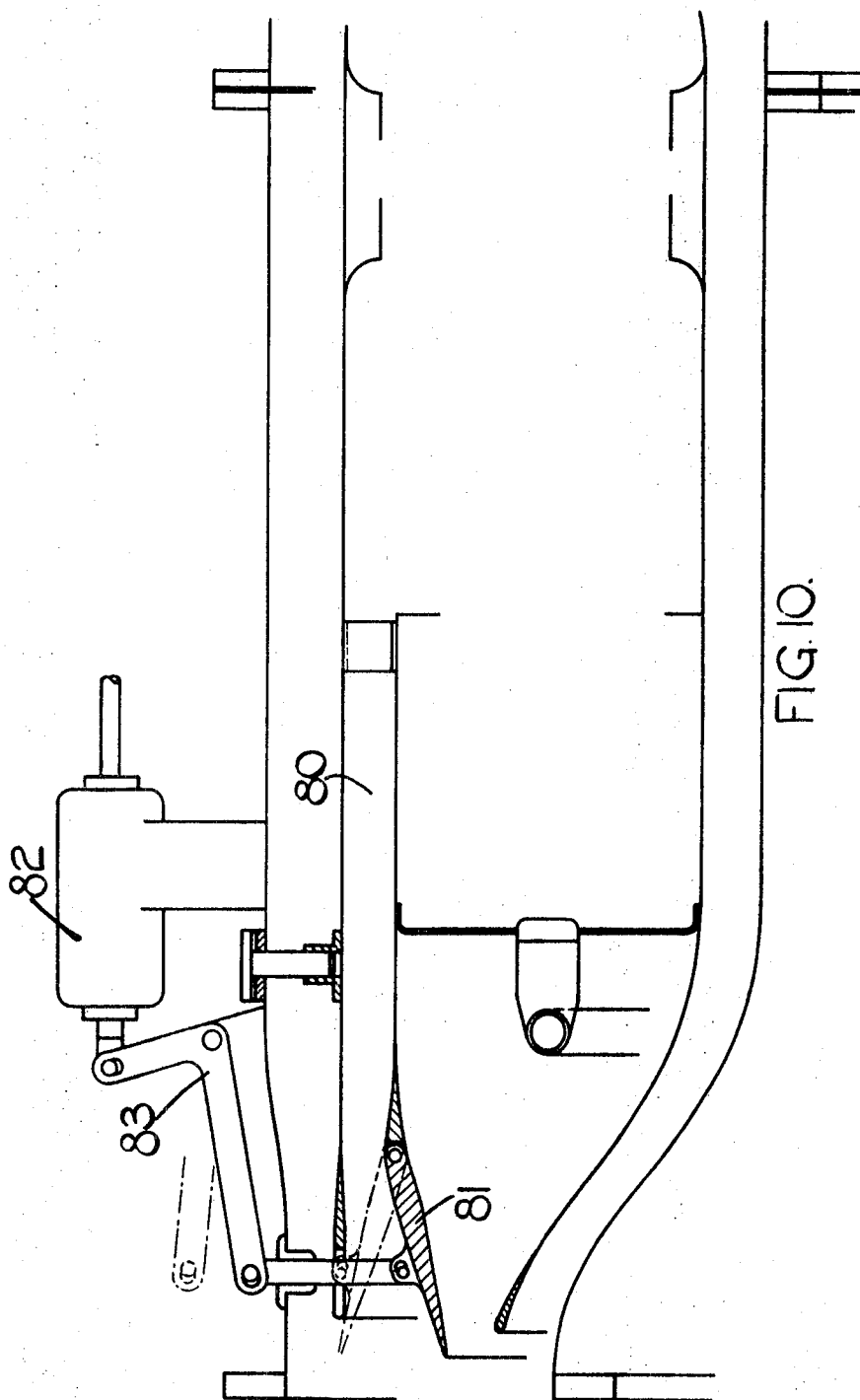


FIG. 10.

*Kenneth Greenwood, Alban Heaton, Alvin Harrison & Squire Ronald Jackson*  
BY  
ATTORNEY

INVENTOR

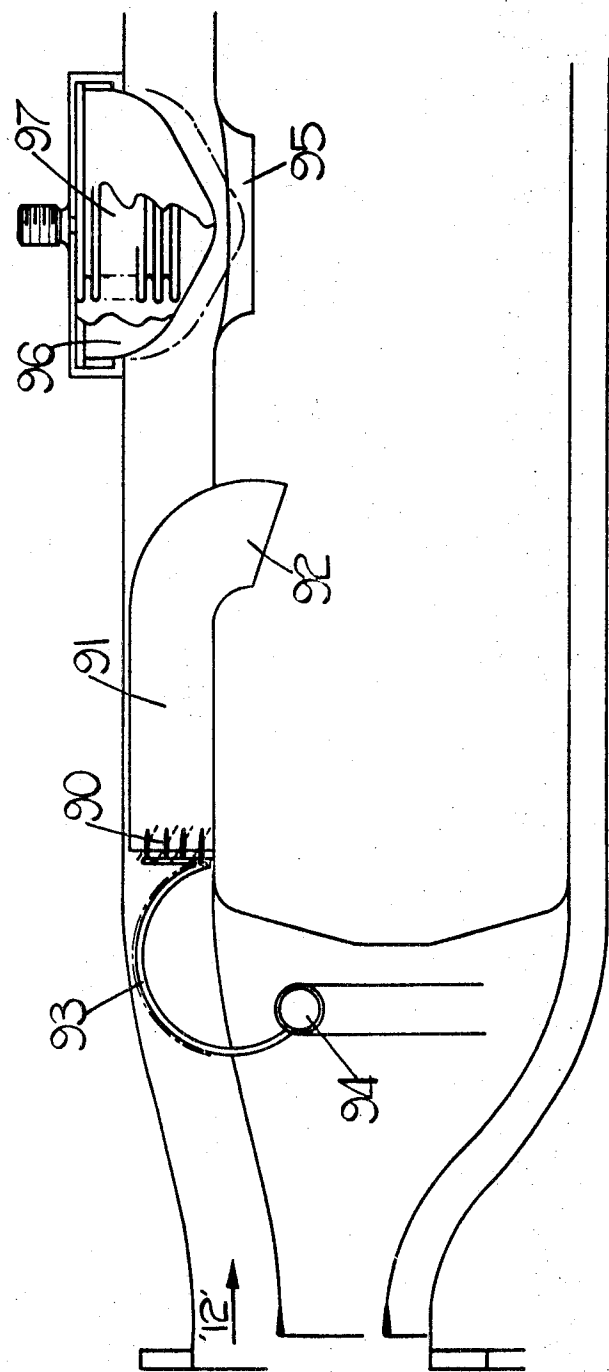


FIG. 11.

INVENTOR  
*Kenneth Greenwood, Alban Heston, Alvin Harrison & Squire Ronald Jackson*  
BY  
ATTORNEY

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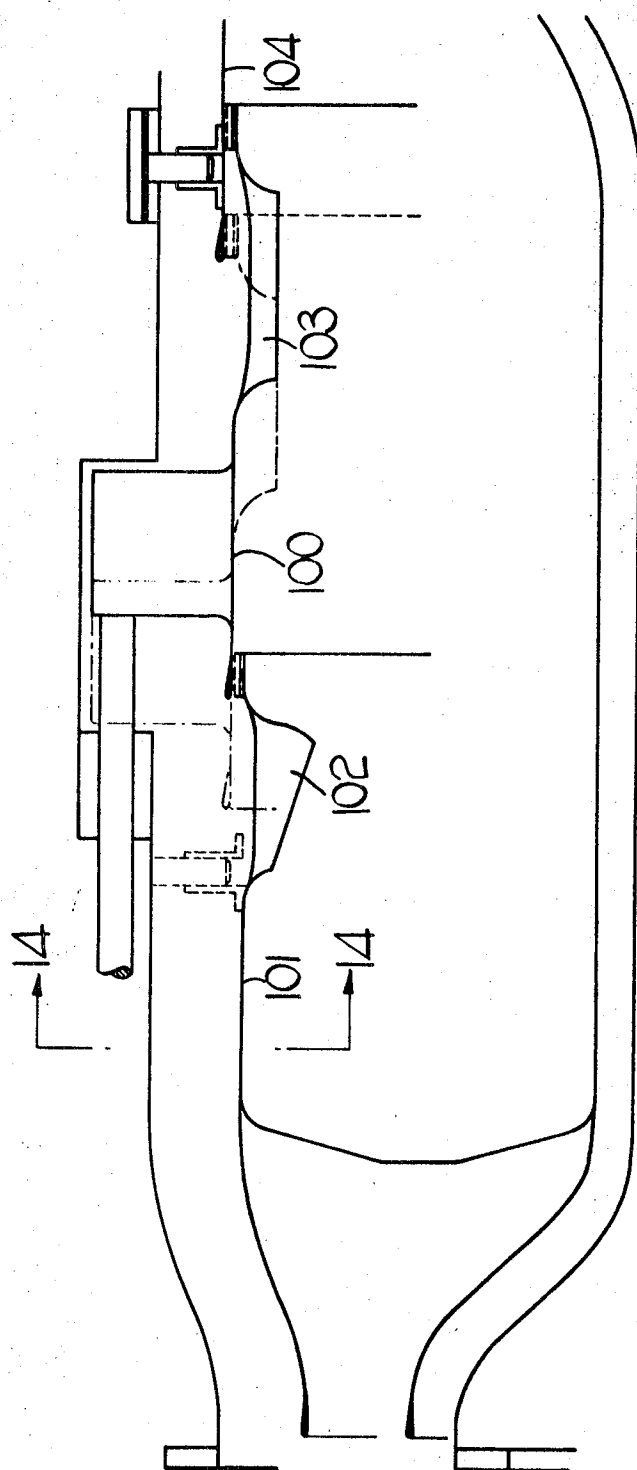
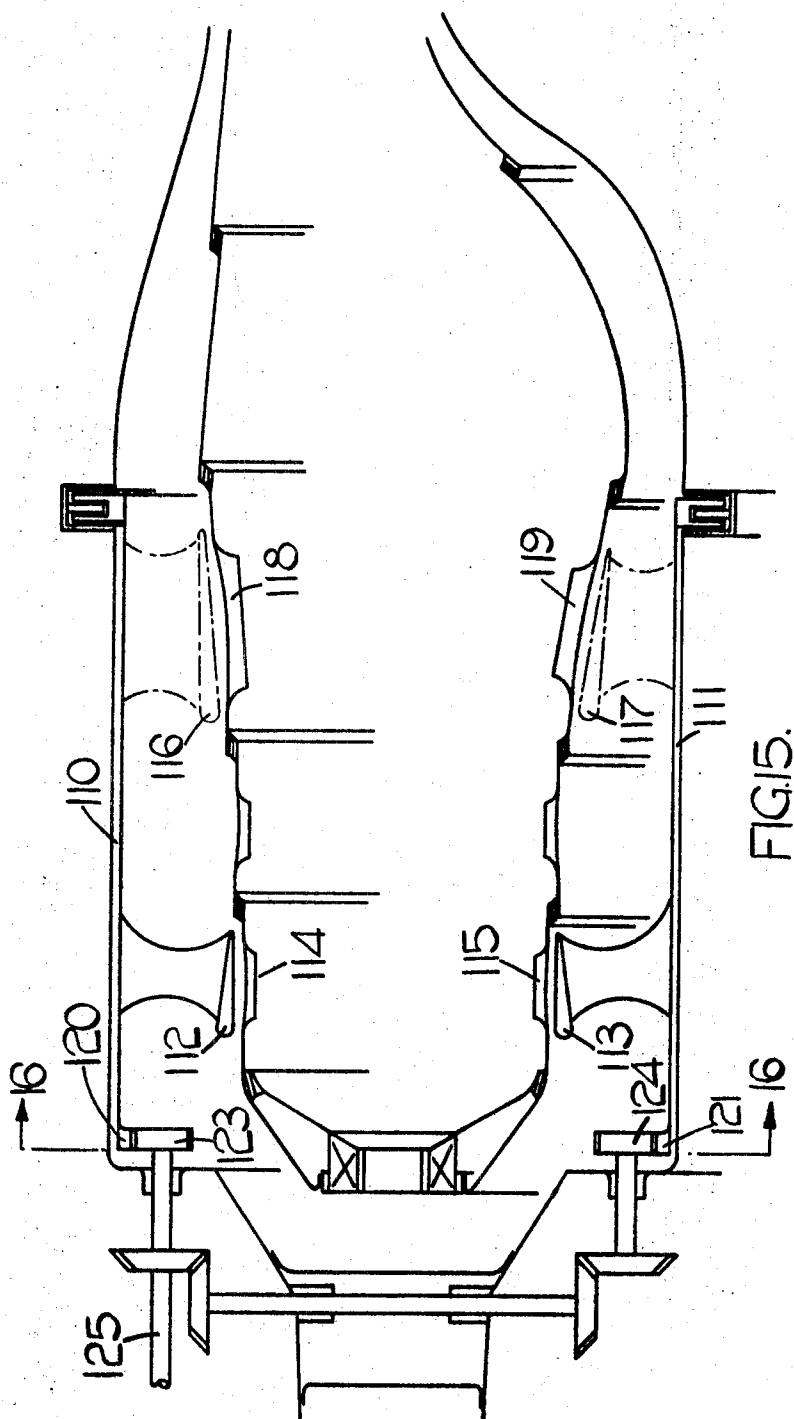


FIG. 13.

*Kenneth Greenwood, Alban Heaton, Alwin Harrison & Squire Ronald Jackson.*  
INVENTOR  
BY  
ATTORNEY

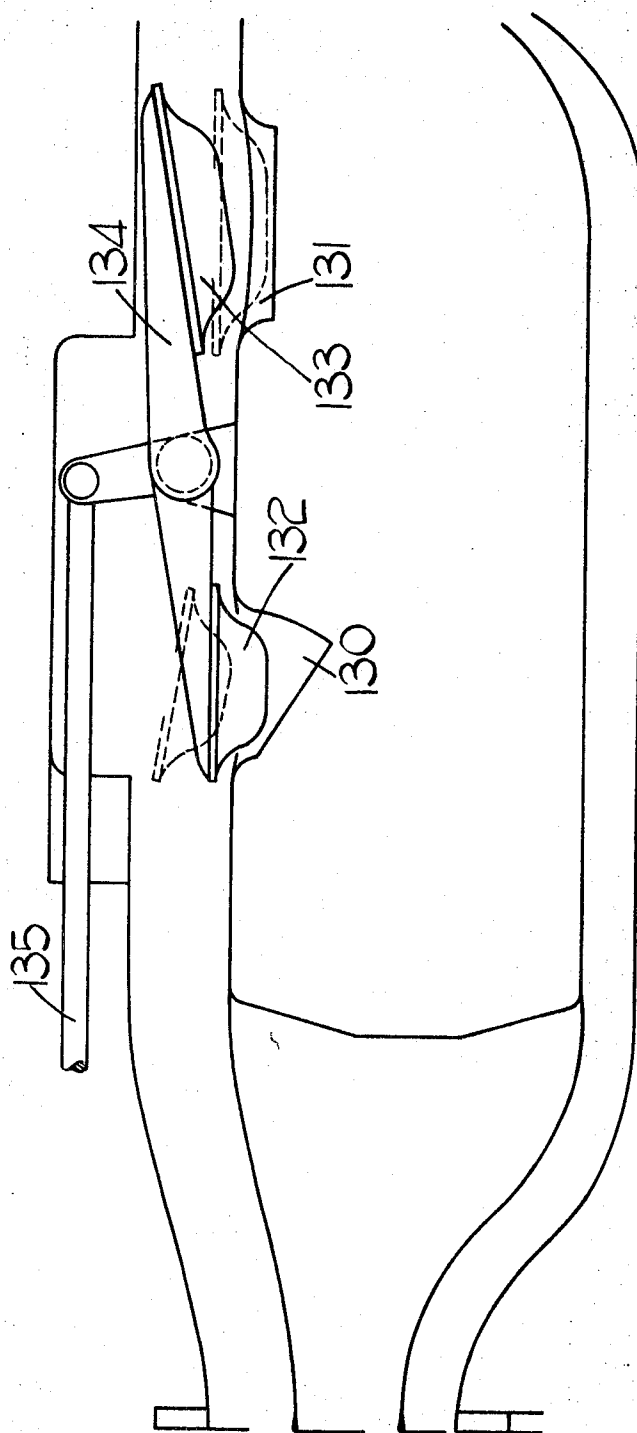


INVENTOR  
*Henneth Greenwood, Alban Heaton, Alvin Harrison & Squire Ronald Jackson*  
 BY  
 ATTORNEY

Patented May 11, 1971

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*Kenneth Greenwood, Alban Heston, Alvin Harrison & Squire Ronald Jackson.*  
INVENTOR  
BY  
ATTORNEY

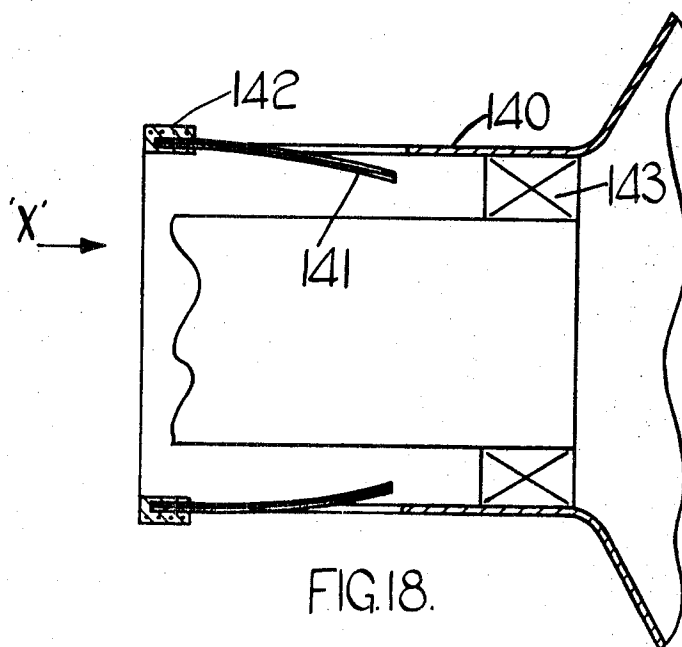


FIG. 18.

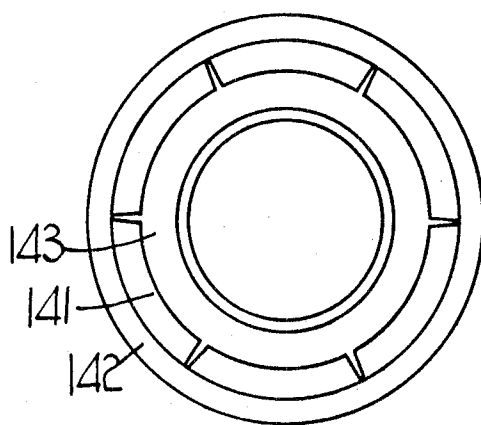


FIG. 19.

*Kenneth Greenwood, Alban Heston, Alvin Harrison & Squire Ronald Jackson*  
INVENTOR  
BY  
ATTORNEY

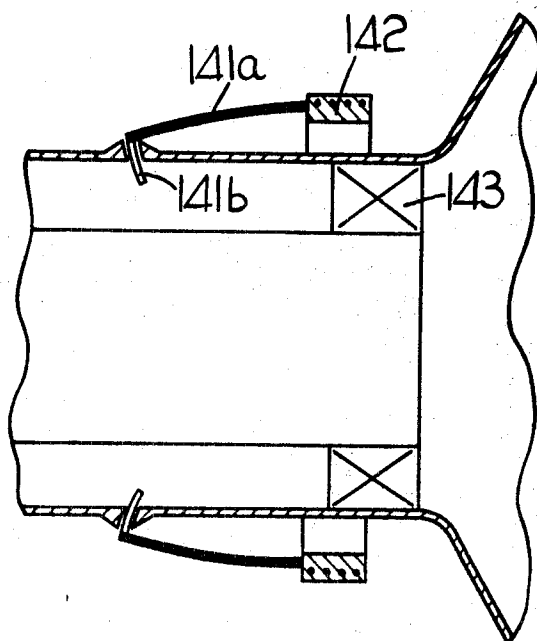


FIG. 20.

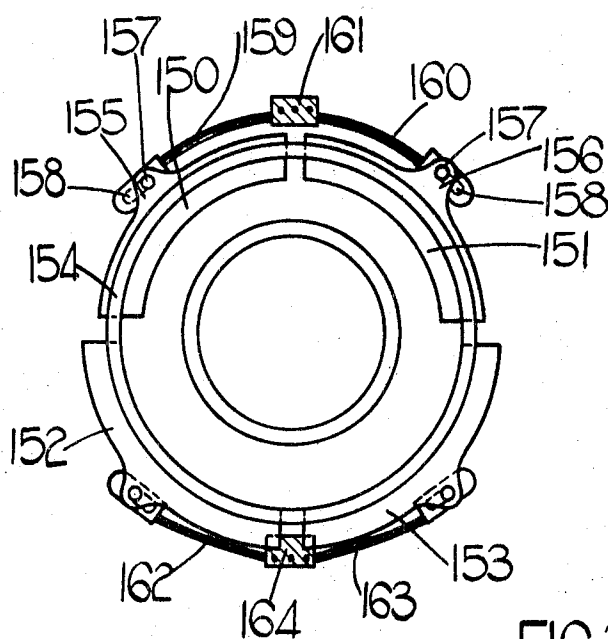


FIG. 21.

*Kenneth Greenwood, Alban Heston, Alvin Harrison & Squire Ronald Jackson*  
 INVENTOR  
 BY  
 ATTORNEY

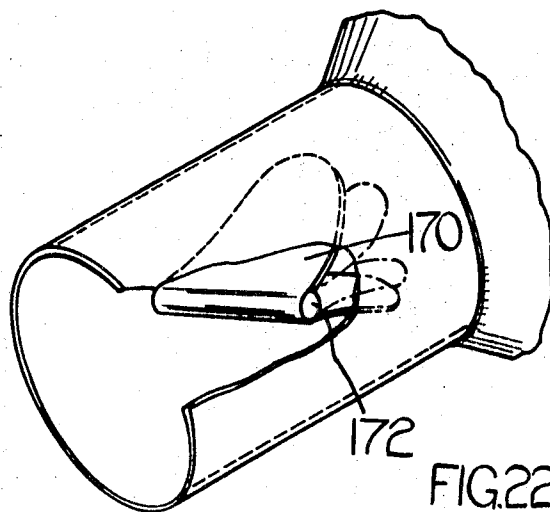


FIG. 22.

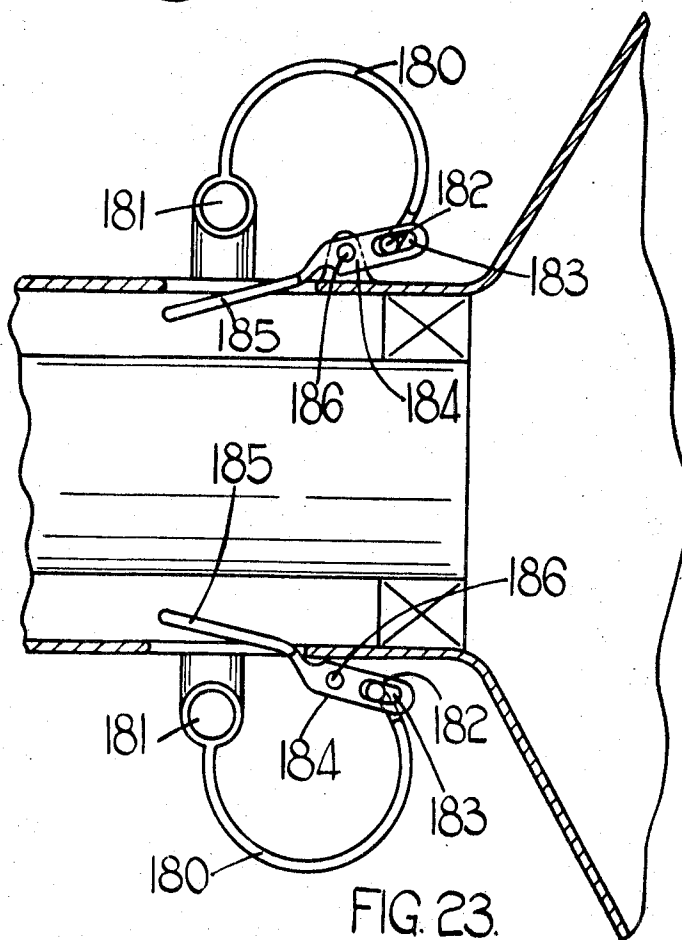


FIG. 23.

*Kenneth Greenwood, Alban Heaton, Alvin Harrison & Squire Ronald Jackson*  
INVENTOR  
BY  
ATTORNEY

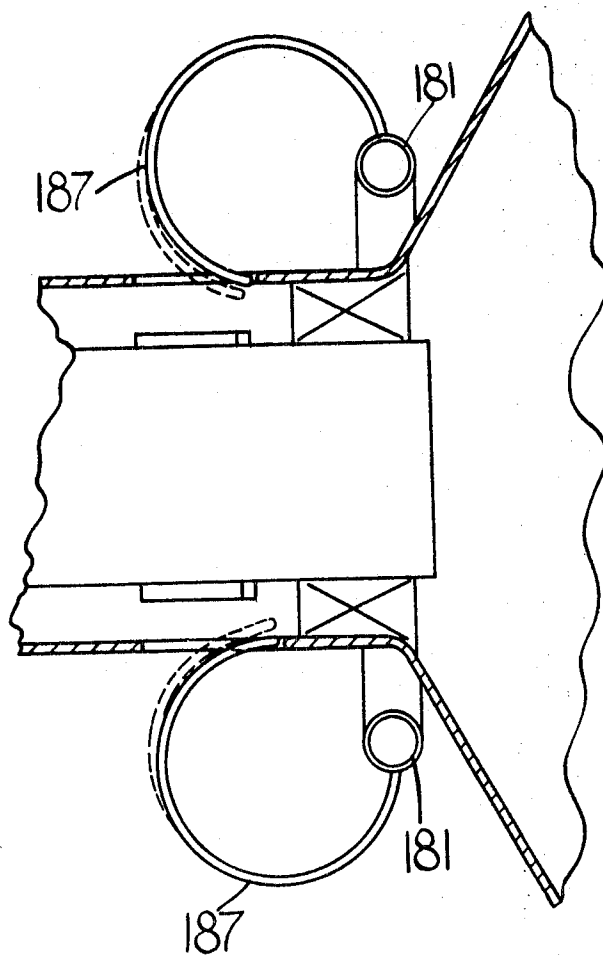


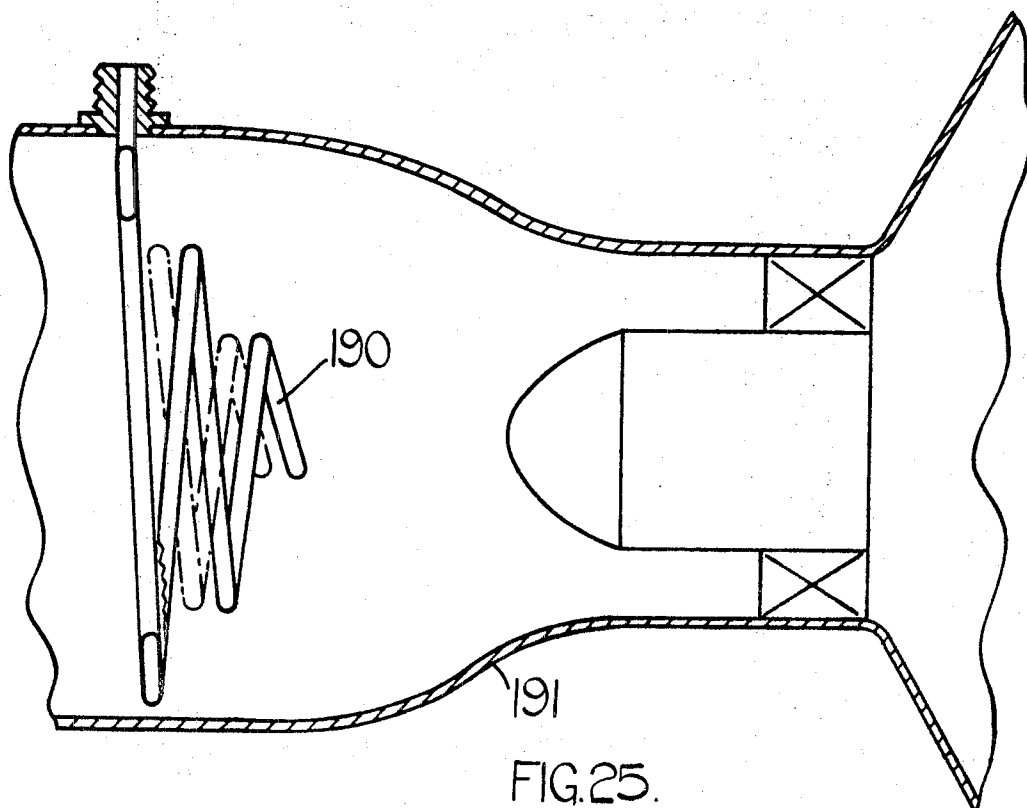
FIG. 24.

INVENTOR  
*Kenneth Greenwood, Alban Heston, Alwin Harrison & Squire Ronald Jackson*  
BY  
ATTORNEY

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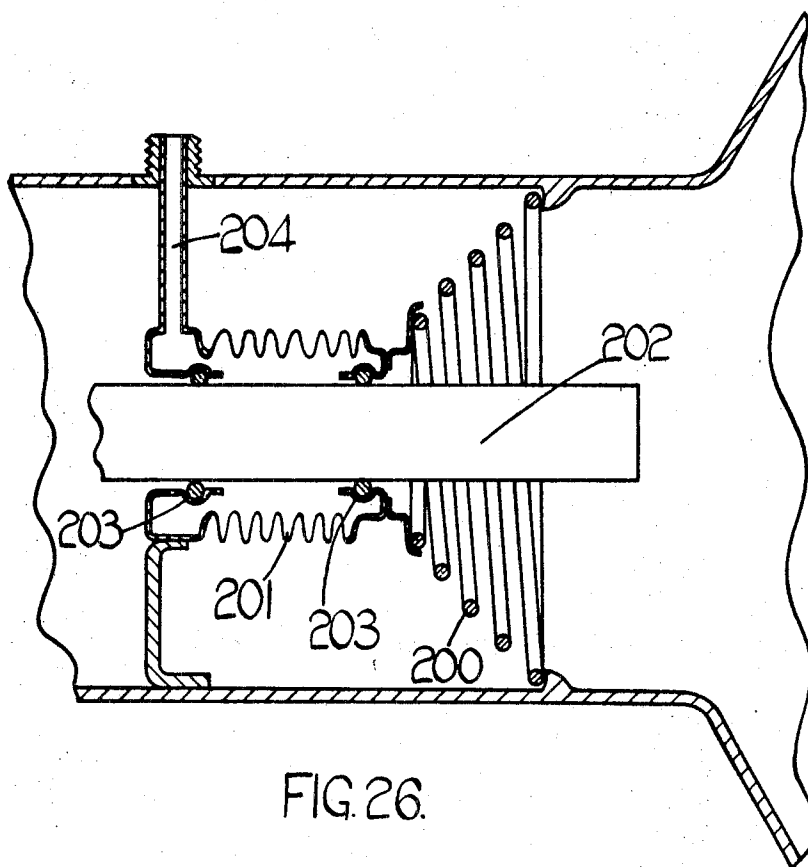


Kenneth Greenwood, Alban Heaton, Alvin Harrison & Squire Ronald Jackson  
INVENTOR  
BY  
ATTORNEY

Patented May 11, 1971

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INVENTOR  
*Kenneth Greenwood, Alban Heaton, Alvin Harrison & Squire Ronald Jackson*  
BY  
ATTORNEY

## FLAME TUBES FOR GAS TURBINE ENGINES

## BACKGROUND OF THE INVENTION

This invention relates to flame tubes for gas turbine engines.

In the flame tubes of such engines, it is the practice for a minor amount of air, about 25—40 percent of the total air intake, to be employed for the combustion of fuel, with the remainder being employed for cooling the flame tube, diluting of the flame and of the products of combustion before the latter are allowed to enter the turbine stage of the engine. The air for combustion purposes is itself normally separated into primary and secondary streams entering along separate paths to the interior of the flame tube. In some engines which are required to operate over a wide range of fuel/air ratios, the combustion and dilution air quantities over some parts of the operating range are incorrect thus impairing combustion and dilution air quantities over some parts of the operating range are incorrect thus impairing combustion efficiency and giving rise to loss of performance over that part of the engine operating range.

The object of the invention is to provide a flame tube for a gas turbine engine in which this disadvantage is overcome or reduced.

In accordance with the invention there is provided a flame tube for a gas turbine engine having a plurality of primary combustion air inlets, a plurality of secondary combustion air inlets, a plurality of dilution air inlets and variable airflow restricting means associated with at least some of said inlets for varying the ratio of primary combustion air to secondary combustion air to dilution air. Reference is now made to the accompanying drawings in which:

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial section through an annular flame tube incorporating one example of the present invention,

FIG. 2 is a view on the arrow X in FIG. 1,

FIG. 3 is a fragmentary view on the arrow Y in FIG. 2,

FIG. 4 is a pneumatic circuit diagram illustrating the manner in which the arrangement shown in FIGS. 1, 2, 3 is operated,

FIG. 5 is a section through an annular flame tube illustrating another embodiment of the present invention,

FIG. 6 is a fragmentary front view of the arrangement shown in FIG. 5,

FIG. 7 is a fragmentary sectionlike FIG. 5 showing another example of the invention,

FIG. 8 is a view on the arrow 8 in FIG. 7,

FIG. 9 is another sectional view through an annular flame tube showing yet another embodiment of the invention,

FIG. 10 is a similar section showing a further embodiment of the invention,

FIG. 11 is a fragmentary sectional view showing yet a further embodiment of the invention,

FIG. 12 is a view on the arrow 12 in FIG. 11,

FIG. 13 is a section of another annular flame tube incorporating yet a further embodiment of the invention,

FIG. 14 is a section on line 14—14 in FIG. 13,

FIG. 15 is a section like FIG. 13 showing yet another embodiment of the invention.

FIG. 16 is a section on line 16—16 in FIG. 15,

FIG. 17 is a sectional view illustrating a still further embodiment of the invention,

FIG. 18 is a section of a primary combustion air inlet variable flow restrictor,

FIG. 19 is a view on arrow 'X' in FIG. 18; and

FIGS. 20 to 26 are views showing alternative forms of primary combustion air inlet variable flow restrictors.

## DETAILED DESCRIPTION OF THE INVENTION

Referring firstly to the embodiment shown in FIGS. 1 to 4 of the drawings, the flame tube incorporates an inner annular passage 30 for the primary combustion air, a surrounding annular passage 31 for secondary combustion air and an outer

annular passage 32 for the dilution air. The passage 30 has an annular intake 33 whereas the passage 31 has a pair of annular intakes 34, 35 disposed respectively inside and outside the intake 33. A row of vanes 36 are mounted in the intake 33 and rows of vanes 37, 38 are likewise mounted in the intakes 34, 35 respectively. The vanes 36, 37 and 38 are on a series of common shafts arranged so that when the vanes 36 lie in planes parallel to the axis of the engine, the vanes 37, 38 are offset and vice versa. Thus when positioned as shown in full lines in FIG. 2 the primary combustion airflow will be restricted while the secondary combustion airflow will be substantially unrestricted.

The vanes, are, however, associated with pneumatic actuators 39 associated with pipework 40, 41 whereby the vanes can be turned to the positions shown in dotted lines in FIG. 2 such that the vanes 36 scarcely restrict airflow into the intake 33 whereas the vanes 37, 38 restrict airflow into the intakes 34, 35. As will be seen from FIG. 3 the actuators 39 are arranged to turn alternate ones of the shafts on which the vanes are mounted in one direction and the remaining shafts in the opposite direction so that no swirl is introduced either into the primary combustion air or secondary combustion air.

FIG. 4 shows how a single valve 42 can be employed to control the supply of compressed air to the pipework 40, 41 and the exhausting of air therefrom to enable all the vanes 36, 37, 38 to be adjusted simultaneously.

Turning now to FIGS. 5 and 6, the flame tube has a series of primary air inlets 50 each provided with swirler vanes which are known per se. Secondary combustion air is introduced via inwardly directed nozzles 51, of which there are two in association with each of the primary air inlets. Dilution air is introduced at two stages in the flame tube, mainly through a first series of nozzles 52 downstream of the nozzles 51 and through a second series of nozzles 53 downstream of the nozzles 52. The nozzles 53 are supplied via ducts 54 which open into intakes upstream of the nozzles 51. The flame tube is provided with axially movable deflector vanes 55 which can be moved from the positions shown in FIG. 5 in which they cover the intakes to the ducts 54, to positions in which they cover intakes to the secondary combustion air nozzles 51.

Referring now to the examples shown in FIGS. 7 and 8, the basic layout of the flame tube is similar to that shown in FIG. 1, that is to say there is an annular primary air duct 60 surrounded externally by a first secondary air duct 61 and internally by a second annular secondary air duct 62. There are also dilution air passages 63, 64 respectively outside the duct 61 and inside the duct 62.

For controlling the proportions of primary and secondary air there are provided three annular flow restricting members 65, 66, and 67. These three restrictors are joined together by means of radial arms 68 so as to be movable axially relative to the flame tube by means of rods like the rod 69. At one limit of the travel, as shown in FIG. 7 the annular restrictors 65, 66 restrict the entry of secondary combustion air to the ducts 61, 62 respectively. In this position the restrictor 67 is deep inside the duct 60 and provides little restriction of the airflow therethrough. It will be noted, however, that the duct 60 diverges markedly from its intake so that when the restrictors are moved to their other position (as shown in dotted lines in FIG. 7) the restrictor 67 will provide a considerable restriction in the intake of the duct 60, whereas the restrictors 65, 66 will have little effect on the airflow into the ducts 61, 62 respectively.

In the example shown in FIG. 9 the secondary air intake is defined by an outer tube 70 and an inner tube 71. The outer tube 70 lies outside an inner tube 72 forming the outer wall of the primary air duct the inner wall 73 of which is outside the tube 71. The primary/secondary combustion air proportions are varied by means of a pair of annular rows of flaps 74, 75. These flaps are pivoted on tangential axes and when, as shown in FIG. 9 the outer row of flaps 74 are pivoted inwardly and the inner row of flaps 75 are pivoted outwardly there is a minimum area for primary airflow and a maximum area for

secondary airflow. A mechanism is provided for pivoting the flaps 74 and 75 simultaneously by means of an axially movable structure to the dotted positions shown in FIG. 9 in which the secondary airflow is minimized and the primary combustion airflow is at a maximum.

A similar flap arrangement is shown in FIG. 10 but, in this case, all the secondary combustion airflow enters through a single outer duct 80 which is controlled by a single row of annular flaps 81 movable by means of piston and cylinder units 82 and bell cranks 83.

In FIG. 11 an arrangement is shown for varying the secondary airflow by means of a series of louvre-type flow restrictors 90 controlling ducts 91 terminating in nozzles 92 whereby secondary air enters and mixes with the primary airflow and the flame. The louvres 90 are movable by means of a Bourdon tube 93 which receives pressure from a common manifold 94. Dilution air enters the combustion chamber at a position downstream of the secondary air inlet nozzles 92 via nozzles 95 which are controllable by closure members 96 movable into the nozzles 95 by means of pressure operable bellows 97.

In the example shown in FIG. 13 and 14 the flame tube has an axially slidable portion 100 which telescopes with a portion 101 formed with secondary air inlets 102. The portion 100 is formed with dilution air inlets 103. In the position shown in full lines in FIG. 13 the secondary air inlets 102 are fully open whereas the dilution air inlets 103 are restricted by a fixed wall 104. Movement of the portion 100 of the flame tube, however, causes partial closing of the secondary air inlets 102 while the dilution air inlets 103 are fully opened.

Turning now to FIGS. 15 and 16 the flame tube in this case includes an outer rotatable wall 110 and an inner rotatable wall 111. These rotatable walls carry a plurality of valve elements 112, 113 to coact with secondary air inlet ports 114, 115 respectively and may additionally carry further valve members 116, 117 to coact with dilution air inlets 118, 119 respectively. The outer and inner rotatable walls 110 and 111 have ring gears 120, 121 respectively which engage pinions 123, 124 respectively on shafts linked by bevel gear trains to provide reverse rotation of the inner and outer walls on turning an input shaft 125.

In FIG. 17 the secondary air inlets 130 and the dilution air inlets 131 are respectively controlled by valve members 132, 133 on opposite ends of a rockable lever 134 movable by a push rod 135 so that, in the position shown in full lines the secondary air inlets are restricted, whereas in the position shown in dotted lines the dilution air inlets 131 are restricted.

FIG. 18 shows an annular primary air conduit wall 140 having positioned circumferentially thereabout as shown in FIG. 19, a plurality of bimetallic segments 141. The segments 141 each extend into the conduit from outside the wall and the outer end of each segment is connected to an electrically heated retaining ring 142. In operation of the arrangement, the outer ends of the segments are heated in order to effect deflection of each bimetallic element towards the axis of the conduit thereby restricting airflow through the conduit. The flame tube has a series of the conduits 140 opening via swirlers 143 in a common annular combustion space. A burner (not shown) extends into the combustion space through the swirler 143.

FIG. 20 shows an arrangement similar to that shown in FIGS. 18 and 19. In this embodiment, however, the bimetallic strips 141a are wholly outside the primary air conduit wall apart from an angled end piece 141b, with these end pieces being directed slightly in the direction of airflow through the conduit. On heating the bimetallic strips by means of the electrically heated retaining ring 142, the angled pieces 141b are caused to project across the cross section of the conduit in order to restrict airflow to the desired extent.

The embodiment shown in FIG. 21 has a flow restrictor comprising four curved shutters 150, 151 and 152, 153 each of which is movable radially into the primary flow conduit through slots in an annular wall 154. The segments 150, 151 are provided with integral lugs 155, 156 respectively and each

of which has a pin 157 which extends through a slot in an eye 158 secured to one end of a pair of bimetallic strips 159, 160 interconnected to a common electrically heated element 161. The shutters 152, 153 are also connected in similar fashion to double bimetallic strips 162, 163 which are in turn connected to heating element 164. In operation, the heating elements control radially inward or outward movement of the shutters to restrict the flow path for primary air. It should be noted that FIG. 21 shows the shutters 150, 151 closed and the shutters 152, 153 open. This condition does not, of course, occur in actual use.

The flow restrictor illustrated in FIG. 22 comprises a butterfly shaped bimetallic element 170 carried by an electrically heated bar 172 which extends diametrically across the primary air conduit. On applying heat to the heating bar 172 the "wings" of the element 170 diverge to restrict the airflow through the conduit.

The embodiment shown in FIG. 23 comprises arcuate Bourdon tubes 180 connected at one end to a pressure manifold 181. The other end of each tube 180 has a pin 182 which is slidable within a slot 183 in an eye 184 at one end of restrictor segments 185 which extend into the conduit, with the restrictor segments being pivoted at 186. On pressure being applied within the tubes 180, the 180 tend to extend so as to pivot the elements 185 about pivots 186 to remove the elements 185 from the conduit thereby restricting airflow therethrough. On removal of pressure from the tubes 180 the elements 185 are pivoted to extend into the conduit to restrict airflow therethrough. There are a series of the segments 186 about the conduit, each having its own Bourdon tube.

The embodiment of FIG. 24 is a modification of that shown in FIG. 23 with the difference that the separate elements 185 are dispensed with and restriction of the airflow is effected merely by the closed ends of the Bourdon tubes 187.

In FIG. 25 restriction of the primary airflow is effected by a Bourdon tube 190 in spiral form and which extends across a conduit 191. The spiral tube 190 is retractable to the position shown in dotted lines in order to restrict airflow on removal of pressure from the interior of the tube.

The arrangement shown in FIG. 26 is a modification of that of FIG. 25 and embodies a solid spiral restrictor 200. Extension and retraction of the restrictor 200 is effected by a pressurizable bellows 201 slidably mounted on a central spindle 202 through the intermediary of sealing rings 203. The interior of the bellows is in communication with the exterior of the conduit through the intermediary of a pipe 204. In this embodiment, increase in pressure within the bellows 201 causes extension of the bellows which results in closure of the spiral restrictor 200 and hence restriction of the primary air conduit.

We claim:

1. An annular section flame tube for a gas turbine engine comprising an annular chamber having an annular primary combustion air inlet passage and at least one coaxial annular secondary combustion air inlet passage opening into said chamber downstream of said primary combustion air inlet passage, and airflow restricting means at the upstream ends of said passages displaceable in one direction to increase the intake area of the primary combustion air inlet passage and simultaneously to decrease the intake area of the secondary combustion air inlet passage and movable in the opposite direction to decrease the intake area of the primary combustion air inlet passage and simultaneously to increase the intake area of the secondary combustion air inlet passage.

2. An annular section flame tube for a gas turbine engine comprising an annular chamber having an annular primary combustion air inlet passage and at least one coaxial annular secondary combustion air inlet passage opening into said chamber downstream of said primary combustion air inlet passage, and airflow restricting means at the upstream ends of said passages displaceable in one direction to increase the intake area of the primary combustion air inlet passage and decrease the intake area of the secondary combustion air inlet passage and movable in the opposite direction to decrease the

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intake area of the primary combustion air inlet passage and increase the intake area of the secondary combustion air inlet passage, a tubular wall separating said primary combustion air inlet passage from said secondary combustion air inlet passage, said airflow restricting means comprising a plurality of flaps arranged in an annular row at the upstream end of said tubular wall and pivoted on axes tangential to said wall and means for displacing said flaps in one direction across the secondary combustion air inlet passage and in the opposite direction across the primary combustion air inlet passage.

3. An annular section flame tube as claimed in claim 2 in which the secondary combustion air inlet passage surrounds the primary combustion air inlet passage.

4. An annular section flame tube as claimed in claim 3 further comprising an additional annular secondary combustion air inlet passage arranged coaxially within the primary combustion air inlet passage and divided therefrom by a further tubular wall, further flaps arranged in an annular row

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at the upstream end of said further tubular wall and pivotable on axes tangential to said further tubular wall, and further means for displacing said further flaps outwardly across the primary combustion air inlet passage and inwardly across the additional secondary combustion air inlet passage.

5. An annular section flame tube as claimed in claim 4 in which said means for displacing said flaps and said further means for displacing said further flaps comprise the combination of a common axially movable structure, means connecting said structure to said flaps for inward displacement thereof by axial movement of said structure in one direction and outward displacement of the flaps by axial movement of the structure in the opposite direction and means connecting said further flaps to the structure for outward displacement of said further flaps by axial movement of said structure in said one direction and inward displacement of said further flaps by axial movement of said structure in the opposite direction.

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