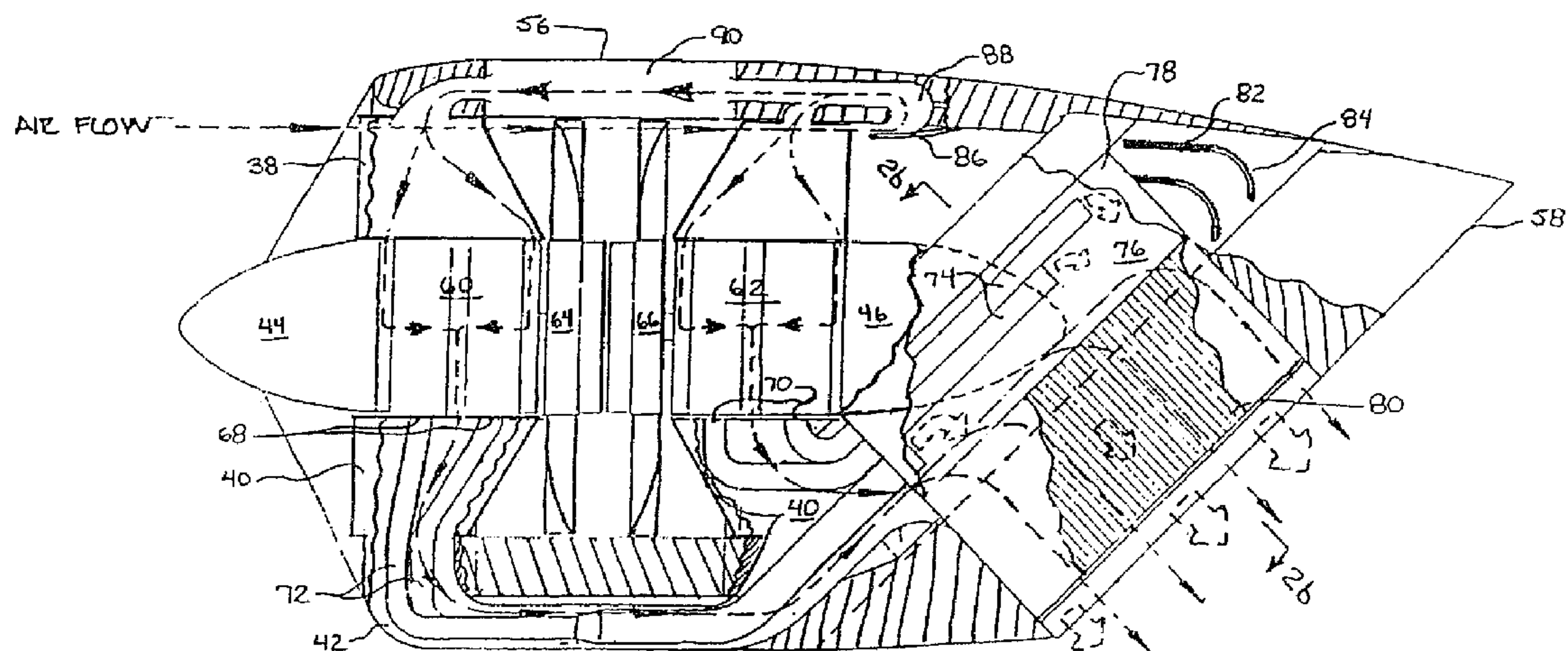




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(54) **APPAREIL ADAV**
(54) **VTOL AIRCRAFT**



(57) Avion à décollage et à atterrissage verticaux comprenant un fuselage (10) présentant quatre nacelles (12, 14, 16 et 18), trois stabilisateurs verticaux (20, 22 et 24) ainsi qu'un stabilisateur horizontal (26) fixés au fuselage (10). Le fuselage (10) et les nacelles (12, 14, 16 et 18) sont des corps de sustentation configurés pour former conjointement un corps de sustentation aérodynamique coopérant avec le stabilisateur horizontal (26) afin de donner à l'avion une sustentation aérodynamique en vol vers l'avant. Chaque nacelle contient deux moteurs rotatifs (60 et 62) entraînant directement des soufflantes correspondantes (64, 66) se faisant face mutuellement et fonctionnant dans des sens de contre-rotation. Chaque nacelle (12, 14, 16 et 18) contient également un système d'aubes (82) situé au niveau de son ouverture arrière (58), ainsi que des dispositifs destinés à étendre et à rétracter les aubes (82). Un système de commande de vol informatisé à triple redondance maintient la stabilité de l'avion lorsqu'il passe d'un régime de vol à un autre, ainsi qu'en vol.

(57) A VTOL aircraft including a fuselage (10) with four nacelles (12, 14, 16, and 18), three vertical stabilizers (20, 22, and 24) and a horizontal stabilizer (26) attached to the fuselage (10). The fuselage (10) and the nacelles (12, 14, 16, and 18) are lifting bodies that are configured to jointly form an aerodynamic lifting body which cooperates with the horizontal stabilizer (26) to provide aerodynamic lift to the aircraft in forward flight. Each nacelle contains two rotary engines (60 and 62) directly driving corresponding fans (64 and 66) which face each other and operate in counter-rotating directions. Each nacelle (12, 14, 16, and 18) also contains a system of vanes (82) located at the rear opening (58) thereof, and devices for extending and retracting the vanes (82). A triple redundant computerized flight control system maintains the stability of the aircraft as it transitions from one flight regime to another as well as in flight.



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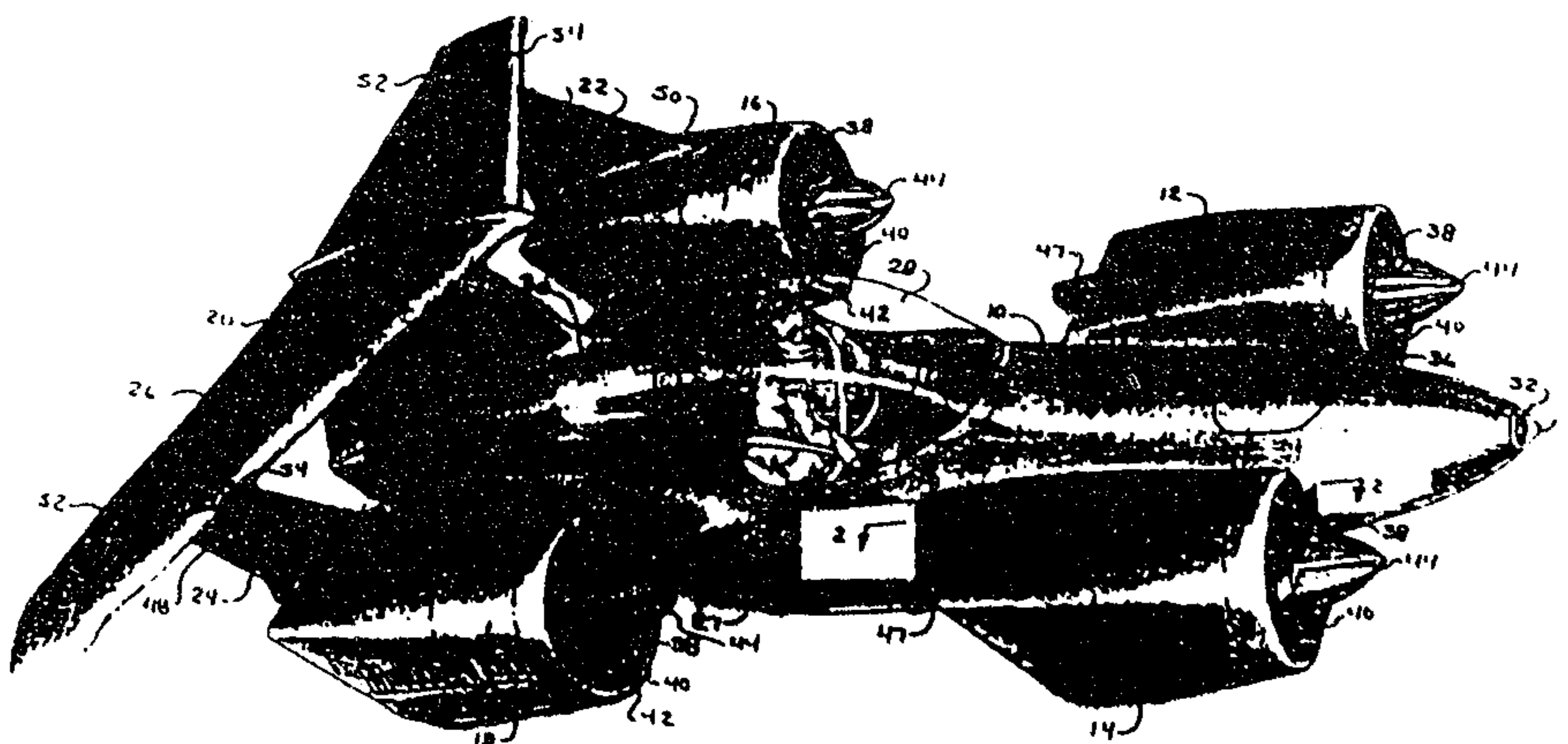
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(54) Title: VTOL AIRCRAFT



(57) Abstract

A VTOL aircraft including a fuselage (10) with four nacelles (12, 14, 16, and 18), three vertical stabilizers (20, 22, and 24) and a horizontal stabilizer (26) attached to the fuselage (10). The fuselage (10) and the nacelles (12, 14, 16, and 18) are lifting bodies that are configured to jointly form an aerodynamic lifting body which cooperates with the horizontal stabilizer (26) to provide aerodynamic lift to the aircraft in forward flight. Each nacelle contains two rotary engines (60 and 62) directly driving corresponding fans (64 and 66) which face each other and operate in counter-rotating directions. Each nacelle (12, 14, 16, and 18) also contains a system of vanes (82) located at the rear opening (58) thereof, and devices for extending and retracting the vanes (82). A triple redundant computerized flight control system maintains the stability of the aircraft as it transitions from one flight regime to another as well as in flight.

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1 Specification

2
3 "VTOL Aircraft"4
5 BACKGROUND OF THE INVENTION6 Field of the Invention

7 The present invention relates generally to VTOL
8 aircraft, and more particularly to an improved VTOL aircraft
9 and ducted fan propulsion system wherein the ducts housing
10 the engines remain stationary with their axial center lines
11 approximately parallel with the center line of the fuselage,
12 and the thrust is selectively vectored by adjustable vanes
13 mounted in the aft portion of each duct.

14
15 Brief Description of the Prior Art

16 Over the past 53 years, inventors have attempted to
17 create a vehicle that could be flown in the air as well as
18 driven on land. According to an article in the February 1989
19 issue of Smithsonian Magazine, more than 30 designs for
20 flying cars have been submitted to the U.S. Patent Office
21 since 1936. These early designs combined elements of the
22 automobile with those of the airplane. Since the fuselage
23 of the craft was large, usually the size of a passenger
24 compartment of a car, a huge, powerful engine and large wings
25 were needed to generate enough thrust and lift to make the
26 craft airborne. On the ground, the huge engine was
27 unnecessary and thus inefficient, the exposed propeller (if
28 one was used) was a safety hazard, and the large wings had

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1 to be removed and stored prior to driving the craft on the
2 road.

3 The present invention is an aircraft that can be used
4 as a land vehicle efficiently and without modification. A
5 major difference between the present invention and the prior
6 car/plane inventions is that the present invention is all one
7 structure so it provides efficiency in the air as well as on
8 the ground. Ducted fans are used instead of exposed
9 propellers so safety is not compromised. Half of the engines
10 can be shut down for fuel conservation and efficient
11 operation of the aircraft while being driven on land.
12 Additionally, the outboard segments of the short wings are
13 hinged to be folded easily, and thus do not have to be
14 removed from the craft prior to driving.

15 Another feature of the present invention is that it is
16 capable of vertical takeoff and landing (VTOL) by vectoring
17 the fan thrust from the ducted fan engines. Previous VTOL
18 efforts have relied on fixed orientation of the duct center-
19 lines vertically for hover and then re-directing their thrust
20 with vanes for transition into forward flight. This method
21 was used with rigid re-directing vanes that would stall the
22 airflow at angles above 15 degrees. This rigid vane
23 approach resulted in a limited ability to generate a
24 significant transverse force for acceleration. The
25 alternative has been VTOL aircraft that have tilted the
26 entire duct or the exposed propeller, whichever was used, in
27 order to vector the thrust. A tiltable duct or propeller
28 requires complex structural, electrical and mechanical

1 connections. Furthermore, the tilting duct or propeller
2 experiences off-axis flow into the inlet during transition
3 into forward flight, resulting in flow separation at the
4 upstream inlet lip. The rotation of the duct or propeller
5 is inherently slow to react and cannot be modulated to
6 provide the fast response time that is required for
7 longitudinal control. Additionally, the tilting duct is not
8 an efficient annular airfoil, and therefore additional wing
9 area must be provided for aerodynamic lift. This greater
10 wing area results in additional drag.

11 U.S. Patent No. 4,358,074 shows a propulsion system for
12 VTOL aircraft having stationary ducts which vector the
13 airflow by utilizing a movable, fixed camber, cascading vane
14 system in addition to a slotted flap system. The airflow
15 within the nacelle is divided into twin airstreams. One of
16 the airstreams is directed downwardly through the fixed
17 camber vane system. The other airstream is exhausted through
18 an aft nozzle at the outlet, against a slotted flap system
19 mounted on a wing located immediately behind the duct. The
20 fixed camber vane system can only direct a limited amount of
21 airflow through very modest angles before the flow separates
22 creating large pressure and thrust losses. The divided
23 airstream system is required because it would be difficult
24 to deflect the full airstream through large angles by
25 utilizing the wing flap system alone.

26 Variable camber flow deflector blades, in which each
27 blade (similar to a vane) is capable of resiliently deforming
28 to affect airflow direction, are the subject of U.S. Patent

1 No. 4,235,397. In this patented invention, the leading edge
2 of the blade is anchored and the trailing edge of the blade
3 is affixed to a mechanism which pulls the trailing edge
4 downward in an arc, so that the blade is effectively bent,
5 thereby re-directing the airflow. This configuration
6 requires that the blade be great enough in width to house an
7 effective leaf spring member and it also limits the materials
8 that the blade skin and filler can be made of. Another type
9 of airfoil variable cambering device is the subject of U.S.
10 Patent No. 4,247,066. Both of these patented inventions
11 utilize mechanical parts that are subject to high stress
12 loads. These complex mechanical devices are slow to react
13 due to the particular interaction of the mechanical parts and
14 cannot provide the fast response times desirable for attitude
15 and altitude control.

16

17 Objectives of the Present Invention

18 It is therefore a primary objective of the present
19 invention to provide an improved ducted fan VTOL aircraft
20 capable of vertical takeoff and hover, forward flight and all
21 regimes of transition between hover and forward flight.

22 Another objective of the present invention is to provide
23 a VTOL aircraft having multiple nacelles, with a powerplant
24 configuration within each horizontal nacelle combining two
25 rotary engines, each driving a fan, with the fans facing each
26 other and counter-rotating.

27 A further objective of the present invention is to
28 provide a VTOL aircraft having multiple nacelles, each of

1 which includes a system of extendable, retractable and
2 flexible vanes capable of selectively deflecting the airflow
3 out of the nacelles downwardly to an angle substantially
4 perpendicular to the lateral axis of the nacelle.

5 An additional objective of the present invention is to
6 provide a general purpose apparatus having a system of vanes
7 capable of redirecting and controlling a large velocity
8 stream of gas or liquid with little actuation power and
9 little thrust or pressure losses.

10 Yet another objective of the present invention is to
11 provide a ducted fan driven VTOL aircraft having an exhaust
12 system that utilizes the dynamic pressure of the air behind
13 the fans to cool the rotors, the exhaust pipes and the baffle
14 structure.

15 A still further objective of the present invention is
16 to provide a multi-engine, ducted fan VTOL aircraft of the
17 type described above, having a triple redundancy flight
18 control system which regulates the thrust of each engine and
19 the amount of deflection of each set of vanes in order to
20 provide a stable platform in all flight regimes.

21

22 SUMMARY OF THE PREFERRED EMBODIMENT

23 Briefly, a preferred embodiment of the present invention
24 includes a fuselage with four nacelles, three vertical
25 stabilizers, and a horizontal stabilizer attached to the
26 fuselage. The fuselage and the nacelles are configured to
27 jointly form an aerodynamic lifting body which cooperates
28 with the horizontal stabilizer to provide aerodynamic lift

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1 to the aircraft. Each nacelle contains two rotary engines,
2 each of which directly drives a fan. The fans face each other
3 and operate in counter-rotating directions. Each nacelle
4 also contains a system of vanes located at the rear opening
5 thereof, and means are provided for extending and retracting
6 the vanes to deflect the airflow over a predetermined range
7 of angles from the horizontal. Each engine utilizes the
8 dynamic pressure of the air behind the fans to cool the
9 engine's rotors and exhaust system. A triple redundant
10 computerized flight control system maintains stability of the
11 aircraft as it transitions from one flight regime to another,
12 as well as in flight.

13

14 Advantages of the Invention

15 An important advantage of the present invention is that
16 it provides an aircraft which smoothly and easily transitions
17 between takeoff or hover modes and forward flight, without
18 any transient decrease in stability.

19 Another advantage of the present invention is that it
20 includes ducted nacelles which are stationary and thus need
21 no complex structural, mechanical and electrical connections.

22 An additional advantage of the present invention is that
23 each nacelle includes a system of vanes which are adjustable
24 to deflect airflow out of the nacelle over a range of more
25 than 90 degrees with only a slight decrease in the airflow
26 cross section, therefore minimizing the loss of thrust in
27 transition from one extreme to another.

1 The use of two engines and fans in each nacelle provides
2 the benefit that failure of one engine will result in only
3 a partial reduction of thrust from that nacelle if the
4 remaining engine is operated near its maximum output.

5 Yet another advantage of the present invention is that
6 the fans face each other and counter-rotate, thereby
7 cancelling the gyroscopic moments which might otherwise
8 interfere with pitch, yaw, and roll control. Also, the swirl
9 in the flow induced by the first fan is cancelled by the
10 second counter-rotating fan so that swirl energy, normally
11 lost, is recovered.

12 It is another advantage of the present invention that
13 one engine in each nacelle can be shut down when maximum
14 speed or power is not required, thereby increasing the range
15 and operating efficiency.

16 Another advantage of the present invention is that the
17 shrouded fans are buried deep in their ducts and
18 counter-rotate, thereby keeping fan noise to a minimum.

19 An advantage gained by the present invention is that it
20 provides a powerplant design having improved rotor and
21 exhaust cooling features needing no auxiliary pump to
22 accomplish the necessary cooling.

23 Another advantage of the present invention is that it
24 includes a computer operated flight control system which,
25 through feedback from inertial sensors and actuator response
26 sensors in the nacelles, keeps the vehicle balanced during
27 flight and implements the pilot's commands for desired pitch,
28 yaw and roll motion.

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1 Yet another advantage of the present invention is that
2 two engines are used in each nacelle thereby providing that
3 adequate pitch and roll control can be maintained through
4 power modulation should one engine in a nacelle fail.

5 An advantage of the present invention is that a heavy
6 firewall between the engines and cockpit is not necessary,
7 due to the utilization of engines with a small frontal
8 profile which can be mounted in a nacelle that is attached
9 to the fuselage, rather than having the engines within the
10 fuselage near the cockpit.

11 These and other objects and advantages of the present
12 invention will no doubt become apparent to those skilled in
13 the art after having read the following detailed description
14 of the preferred embodiment which are contained in and
15 illustrated by the various drawing figures.

16

17

IN THE DRAWING

18 Figure 1 is a perspective view of a presently preferred
19 embodiment of a VTOL aircraft according to the present
20 invention.

21 Figure 2a is a longitudinal cross sectional view through
22 the nacelle taken along the line 2-2 of Figure 1.

23 Figure 2b is a partial top view of a nacelle showing a
24 cooling system for the exhaust chamber and baffle structure,
25 which is contained within the dividing strut.

26 Figure 3a is a diagram showing a rear view of the
27 nacelle shown in Figure 2.

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1 Figures 3b through 3d are partial cross-sectional views
2 through the nacelle taken along the line 3-3 of Figure 3a,
3 showing the interior wall of a vane guide containing panel
4 of the nacelle together with the vane control mechanisms and
5 vanes in various control positions.

6 Figures 3e and 3f are side views of a vane guide
7 containing panel taken along lines 3e-3e of Figure 3b.

8 Figure 3g is a side view of a vane showing the vane
9 segments and connecting membrane.

10 Figure 3h is a partial bottom view of a vane with the
11 membrane broken away illustrating details of vane
12 construction.

13 Figure 4 is a top view of the preferred embodiment
14 illustrating the location of the center of gravity of the
15 aircraft and the center of lift of each nacelle in a hover
16 mode.

17 Figures 5a, 5b and 5c are plan, rear, and side views
18 respectively, illustrating details of the horizontal
19 stabilizer of the aircraft shown in Figure 1.

20 Figure 6a is a block diagram illustrating the triple
21 redundant computerized flight control system of the preferred
22 embodiment.

23 Figure 6b is a block diagram representing the various
24 actuators and sensors contained within each nacelle block
25 shown in Figure 6a.

26 Figures 7a through 7d are four side views showing the
27 aircraft of Figure 1 in transition from takeoff through
28 forward flight.

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1 Figure 8a is a perspective view of an apparatus for
2 effecting flow stream directional control.

3 Figure 8b is a diagram showing a vane and bidirectional
4 guide slot assembly.

5 Figures 8c and 8d are partial cross sectional views
6 through the apparatus taken along the line 8-8 of Figure 8a,
7 showing the interior wall of a vane guide containing panel
8 of the apparatus together with the vane control mechanisms
9 and vanes in two extreme positions.

10

11 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

12 Figure 1 shows a perspective view of a preferred
13 embodiment of a VTOL aircraft in accordance with the present
14 invention. As depicted, the preferred embodiment includes
15 an elongated fuselage 10 with four nacelles 12, 14, 16, and
16 18 attached to the fuselage. Two of the nacelles 12 and 14
17 are located on each side of the fuselage 10 forward of the
18 center of gravity of the fuselage, and the other two nacelles
19 16 and 18 are located on each side of the fuselage 10
20 rearward of the center of gravity of the fuselage. The two
21 front nacelles 12 and 14 are attached directly to the
22 fuselage, while the rear nacelles 16 and 18 are each appended
23 to the fuselage by a bridge 27. The preferred embodiment
24 also includes three vertical stabilizers 20, 22 and 24. The
25 center vertical stabilizer 20 is attached to and rises from
26 the rear of the fuselage 10, while each of the two outward
27 vertical stabilizers 22 and 24 is attached to and rises from
28 a rear nacelle 16 and 18. A horizontal stabilizer 26 is

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1 displaced atop the three vertical stabilizers 20, 22 and 24
2 and attached thereto.

3 The fuselage 10 is aerodynamically shaped for maximum
4 lift. A sturdy transparent canopy 28, displaced approximately
5 centrally along the fuselage, covers the cockpit and is
6 pivotable into an open position for pilot and passenger
7 boarding. Just behind the canopy 28 are two passenger
8 windows 30, one on each side of the fuselage 10. Only one
9 passenger window 30 is shown in Figure 1. At the very tip
10 of the fuselage 10 is a headlight 32 surrounded by a
11 transparent plastic headlight cover 34 for protection. The
12 hatch 36 opens to reveal the storage and cargo area in the
13 fore section of the fuselage 10. The aft section of the
14 fuselage houses an emergency parachute, deployable by rocket
15 power, for the unlikely event of a catastrophic engine
16 failure.

17 The parts of the nacelles 12, 14, 16 and 18 that are
18 illustrated in Figure 1 are the engine mounting struts 38 and
19 40, the exhaust shrouds 42, the engine accessory nosecones
20 44, and the dividing struts 47. These parts will be
21 explained in further detail to follow.

22 Attached to the midpoint of the leading edge of the
23 horizontal stabilizer 26 is a pitot-static tube 50 for
24 measuring the air speed of the aircraft. Also shown in this
25 preferred embodiment are the hinges 52 at the folding joint
26 54 of the horizontal stabilizer 26 which allow the outboard
27 segments to be folded.

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1 Figure 2a is a longitudinal cross sectional view of a
2 nacelle. This view is typical of all four nacelles, but for
3 the purpose of this description, a cross section of nacelle
4 14 taken along the lines 2-2 of Figure 1 is shown.

5 Generally, the nacelle housing 56 has an annular airfoil
6 shape transitioning at the rear opening 58 to a more
7 rectangular configuration. The rear opening of the nacelle
8 is angled along a plane whose top is rotated rearwardly
9 relative to normal to the longitudinal axis of the nacelle.
10 The nacelle contains two rotary engines 60 and 62, each
11 capable of producing approximately two horsepower per pound
12 of engine weight, while each nacelle is capable of producing
13 three to four pounds of thrust per horsepower. Each engine
14 directly drives a fan 64 and 66. The fans 64 and 66 face
15 each other and counter-rotate. Each front engine 60 has an
16 engine accessory nosecone 44 and each rear engine 62 has an
17 engine accessory tailcone 46. The nose and tail cones are
18 generally conically shaped with a rounded tip to effectuate
19 a streamlined flow of air through the nacelle. Within these
20 nose and tail cones 44 and 46 is a convenient place to
21 position the engine accessories out of the airflow. The
22 engine accessories include the carburetor, starter and air
23 filter. To hold the engine in place, each engine 60 and 62
24 is bolted to the engine mounting struts 38 and 40 which span
25 the distance between the inside wall of the nacelle housing
26 56 and the engine.

27 Each of the dual exhaust ports 68 of the first engine
28 60 is connected to one end of an exhaust pipe 72. The

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1 exhaust pipes 72 extend radially outwardly through the lower
2 engine mounting struts 40 and then along the base of the
3 nacelle, within the exhaust shroud 42 where they both connect
4 into a single, larger exhaust pipe. The outlet end of the
5 exhaust pipe extends into an exhaust chamber 76 contained
6 within the dividing strut 78. Each of the dual exhaust ports
7 70 of the second engine 62 is likewise connected by an
8 exhaust pipe 74 to the exhaust chamber 76 which contains the
9 exhaust gases and directs the gases into the baffle structure
10 80. The exhaust gases are vented through the baffle
11 structure 80 and exit out the rear opening 58 of the nacelle.

12 The vanes 82 are located in the rear of the nacelle just
13 before the opening. The vanes 82 are placed in a cascading
14 fashion inside the rear opening 58 of the nacelle. Figure
15 2 shows the vanes in their fully retracted position. The
16 guide slots 84, formed in the wall of the nacelle housing 56,
17 define the path that the vanes will travel when they are
18 extended for airstream deflection. Vane actuation will be
19 described in more detail to follow.

20 The unique motor cooling/exhaust system of the present
21 invention uses the dynamic pressure of the air behind the
22 second fan 66 as a source of pressurized air for cooling the
23 engines' rotors, exhaust pipes and baffle structure.
24 Although not specifically shown in the drawing, a portion of
25 this air is also directed to the naturally aspirated
26 carburetor. Pressurized air enters the diffuser 88 through
27 an air intake scoop 86 that extends into the airstream behind
28 the second fan 66. The velocity of the air is then slowed

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1 in the diffuser 88 before entering a plenum chamber 90. The
2 air moves from this plenum chamber 90 through the hollow
3 engine mounting struts 38, into each engine to cool the
4 rotors, and then exits through the lower engine mounting
5 struts 40.

6 The cooling air from the first engine 60 flows through
7 the exhaust shroud 42 and around the exhaust pipes 72, on its
8 way to surround the exhaust chamber 76 and baffle structure
9 80 prior to exiting from the dividing strut 78. The cooling
10 air from the second engine 62 similarly flows around exhaust
11 pipes 74, the exhaust chamber 76 and the baffle structure 80
12 prior to exiting.

13 Figure 2b is a top view of a dividing strut further
14 illustrating the flow of the cooling air around the exhaust
15 chamber 76 and the baffle structure 80. After flowing around
16 the length of both sets of exhaust pipes 72 and 74, the
17 cooling air enters the dividing strut 78 and flows into the
18 space between the inside wall of the dividing strut 78 and
19 the exhaust chamber 76. The disposition of the exhaust
20 chamber 76 and baffle structure 80 within the dividing strut
21 78 forces the cooling air to flow around both of these parts,
22 thereby cooling them, prior to exiting out of the dividing
23 strut 78 at the rear opening of the nacelle 58.

24 The exhaust muffler exit is designed as an air ejector.
25 This means that as the exhaust gases leave the muffler, but
26 while still contained by the side-walls, they entrain (pick-
27 up and accelerate) the cooling gases that have come from the
28 rotor. This generates a suction on the outlet for the

1 cooling air and augments the positive pressure at the inlet,
2 behind the second fan. This entrainment effect contributes
3 to the pumping of the cooling air.

4 The unique vane assembly is capable of re-directing
5 large volumes of air and vectoring large thrust forces with
6 very little actuating power or force required. The vanes and
7 their integration with power level or thrust level allows for
8 replacement of all of the traditional controls of the
9 airplane: i.e. ailerons for roll, elevators for pitch and
10 rudders for yaw. These vanes also allow for replacement of
11 all of the traditional controls of the helicopter: i.e.
12 cyclic rotor pitch control for pitch and roll, collective
13 rotor pitch control for climb and tail rotor pitch for yaw
14 control.

15 Considering the vane assembly in greater detail, Figure
16 3a is a rear view of a typical nacelle. This view shows that
17 there are two independent sets of vanes, one set disposed
18 within the left half of the nacelle exit opening and the
19 other set covering the right half of the nacelle exit
20 opening. Together, the vanes 82 span the width of the rear
21 opening 58 of the nacelle and are mounted within guide slots
22 84 formed in facing wall surfaces and arranged in a cascading
23 fashion inside the rear opening 58 of the nacelle. The vanes
24 are constructed so as to be rigid along their span yet
25 flexible in the airflow direction so that camber may vary
26 through a range of angles.

27 The cutaway portions of Figure 3a expose the vane
28 actuation assemblies for the vanes 82. One pair of drive

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1 motors 92 and 94 is located at the top of a set of vanes, and
2 another pair 96 and 98 is located at the bottom of the set
3 of vanes. The drive shaft 100 and 102 of each pair of motors
4 is connected by a coupler 104 to maintain symmetry in the
5 movement of the vanes. Each motor 92, 94, 96 and 98 is
6 connected to an actuator bar 106 through an actuator arm 108
7 and linkage 109 assembly.

8 Figure 3b is a partial side view through a nacelle taken
9 along the lines 3-3 of Figure 3a. This figure shows the
10 interior wall of a vane guide containing panel of the nacelle
11 with the vane actuation assembly attached. Guide slots 84
12 are formed within the panel, and provide direction for the
13 flexible vanes 82 when they are extended or retracted. The
14 outermost edges of each span of vanes is contained within a
15 guide slot 84 and moves therewithin on rollers. The
16 outermost point of the leading edge of a vane 82 is attached
17 to an actuator bar 106 at an oval slot 107 which allows the
18 actuator bar to be moved at an angle limited by the bounds
19 of the slot, as shown in Figure 3c and further discussed
20 below. Deployment of the vanes is achieved by a drive motor
21 92, 94, 96, 98 and an actuator arm 108 and linkage 109
22 assembly which moves the actuator bar 106. The motor, arm
23 and linkage drive the actuator bar which in turn moves the
24 vanes. The vanes move on the rollers within the guide slots
25 along the path defined by the configuration of the guide
26 slots.

27 The actuator arms 108 are attached to the top and bottom
28 of the actuator bar 106 by linkages 109, the linkage for the

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1 upper actuator arm being attached between the second and
2 third vanes from the top of the bar, and the linkage for the
3 lower actuator arm being attached at the bottom of the bar.
4 This configuration allows the bar to be moved in parallel
5 relationship to the rear opening of the nacelle so that all
6 of the vanes extend and retract simultaneously between the
7 extremes depicted in Figures 3b and 3d. Alternatively, by
8 differentially controlling top pair of motors 92 and 94 and
9 bottom pair of motors 96 and 98, the bar can be moved to an
10 angled position relative to the rear opening so that the
11 vanes at the top of the set are extended more than the lower
12 vanes as depicted in Figure 3c. The oval slots 107 of the
13 actuator bar 106 define the maximum angle that this
14 configuration can achieve.

15 The vanes can be extended to the same degree
16 simultaneously, or can be differentially extended such that
17 the top vane is moved rearwardly while the bottom vane is
18 held in its fully retracted position, and the balance of the
19 vanes are progressively extended from bottom to top as shown
20 in Figure 3c. The purpose of this differential vane
21 extension is to avoid flow separation during transition from
22 one vane setting to another. Similarly, retraction of the
23 lower vanes prior to the upper vanes tends to reduce the
24 occurrence of flow separation in the airstream being
25 deflected by the vanes.

26 Additionally, the coupler 104 will freeze both motors
27 in the pair, in the event that one motor fails. The
28 redundancy of motors is a safety feature. If one motor

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1 should fail, it and its partner would freeze and the other
2 pairs of motors could drive about 75% of all of the vanes in
3 a nacelle for ample deflection of the airflow.

4 In forward flight, the vanes 82 will normally be fully
5 retracted as shown in Figure 3e. In this position, the vanes
6 are essentially horizontal and no air is deflected. The
7 normal position of the vanes 82 for takeoff or hover modes
8 is fully extended as shown in Figure 3f. Here, the vanes are
9 fully extended by being moved rearwardly in the guide slots
10 84 and are thus configured to deflect the airflow
11 perpendicular to the longitudinal axis of the aircraft.

12 The vanes may be extended to any point between these
13 extreme modes as required during the transition between
14 takeoff and forward flight, or just as needed for aircraft
15 balance and stabilization.

16 Figure 3g, a side view of a vane, and Figure 3h, a
17 bottom view with the outermost skin layer of flexible
18 material shown broken away, illustrate the construction of
19 the flexible vanes. Each vane 82 is made of segments 81,
20 journalled to rollers 110 which are displaced within the
21 guide slots 84. The rollers move within the guide slots to
22 allow the segments to be reoriented in relation to each other
23 depending on their collective posture relative to the guide
24 slots. The segments 81 are connected together by a flexible
25 membrane 113 attached to the upper surfaces thereof. Each
26 vane 82 is connected to the actuator bar 106 at its leading
27 edge 83 by a vane pin 111 and grommet 105 assembly, and held
28 in place by a snap ring 85.

1 The use of connected segments in the construction of the
2 vanes allows each vane to be flexible in the airflow
3 direction so that its camber may vary to conform to the
4 curved path of the guide slot, yet maintain rigidity in the
5 span direction in order to deflect the air flowing out of the
6 nacelle.

7 Four common airflow deflection problems have been
8 overcome by the vane design of the present invention: 1) re-
9 directing the exiting flow efficiently over at least 90
10 degrees while not inducing significant pressure and thrust
11 losses; 2) doing this without requiring the use of a large
12 and complex actuation mechanism; 3) constraining the vane
13 with sufficient support to ensure that its varying camber is
14 accurately controlled and stiffened in order to prevent
15 aerodynamic flutter; and 4) ensuring that the vanes do not
16 generate a significant aerodynamic loss when they are in the
17 retracted position for horizontal flight.

18 More specifically, the solution in the instant design
19 includes the provision of one or more variable camber vanes,
20 using graphite fiber-composites which have the strength of
21 steel and the weight of magnesium. As indicated in Figure
22 3e, the guide slot shape is determined by a circularly
23 arcuate section 103 that follows a straight section 101. As
24 depicted in Figure 3f, the straight section is inclined to
25 the upstream flow at approximately 3 degrees. As illustrated
26 in Figure 3g and 3h, the segments are connected together by
27 a flexible membrane 113 attached to the upper surfaces
28 thereof. This design was selected to ensure that

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1 disturbances to the surface will be confined as much as
2 possible to the concave side (bottom side) of the vane where
3 the pressure gradients on the surface are favorable, thereby
4 tending to reduce airflow separation from the top surface.
5 The top (non-grooved) side is kept smooth by the membrane.
6 The vanes are as thin as possible while still retaining the
7 necessary flutter resistance.

8 A further element of the design that reduces the
9 effective duct blockage from the vanes is the staggered
10 relationship of one vane to the other. This means that, as
11 shown in Figure 3c, the airflow is contracting due to one
12 vane surface 93 while it is expanding because the facing
13 adjacent surface 95 is set further ahead in the duct. In
14 forward flight (Figure 3e), the vanes are generally in a
15 horizontal disposition (extended to a 5 to 7 degree
16 deflection angle). On command from the on-board computer or
17 pilot, these vanes can be either extended or retracted within
18 the guide slots. This movement provides the equivalent of
19 aileron or elevator control depending on their individual
20 manipulation.

21 The only force required to actuate the vanes is that
22 required to overcome friction. This is due to the fact that
23 all forces on the vane segments are transmitted at right
24 angles to the vane segment centerlines through the pins and
25 rollers. This means that the large deflection forces are
26 directed normal to and carried by the deflection vane slots
27 and are not directed along the length of the vane slots, i.e.
28 the direction of actuation. This allows a large thrust to

1 be redirected over a wide range of angles without any
2 substantial counteracting control force being required from
3 the vane actuation system. The use of a large number of pins
4 and rollers ensures that the vanes are accurately contoured
5 and uniformly constrained at their ends during their
6 movement, and thereby resist aerodynamic flutter under all
7 conditions.

8 It has been noted that if the cross-section of the
9 airstream between two adjacent vanes is examined, the area
10 increases quite rapidly (approximately a 40% expansion) over
11 a distance of about 1-1/2 times the distance of the gap width
12 between vanes. This translates into a very rapid expansion
13 (slowing down) of the airflow that could not occur without
14 separation unless the expansion is immediately followed by
15 a contraction. When the vanes are deflecting the airstream
16 through 90 degrees, the expansion is followed by a generally
17 equal contraction, so the overall pressure loss is low.
18 However, when the vanes are all retracted together to 45
19 degrees, the contraction after the expansion disappears and
20 flow separation occurs resulting in a significant pressure
21 loss.

22 In this design, such flow separation has been eliminated
23 by use of an actuation mechanism that retracts the vanes from
24 the bottom first. This ensures that the concave side of the
25 vane does more of the deflection work, and the convex side,
26 which already has adverse pressure gradients on it, is not
27 required to work as hard in deflecting the flow, thus
28 preventing the flow from separating from the convex surface

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1 or downstream side of the vane.

2 The present invention is able to provide a balanced
3 arrangement of lift and thrust generators in hover, a
4 balanced and stabilized aerodynamic configuration when the
5 majority of lift is generated aerodynamically (as in forward
6 flight), and a balanced response to an engine failure. To
7 depict these conditions, reference is made to Figure 4 which
8 shows the arrangement of the nacelles 12, 14, 16 and 18 on
9 the fuselage 10. The centers of lift 112 and 114 of the two
10 forward nacelles 12 and 14 are positioned forward of the
11 center of gravity 120 at the same distance along the
12 longitudinal centerline of the fuselage as the centers of
13 lift 116 and 118 of the two rear nacelles 16 and 18 are
14 positioned rearward of the center of gravity. However the
15 two rear nacelles 16 and 18 are generally placed further
16 outboard of and above the center line of the fuselage as
17 compared to the positioning of the front two nacelles 12 and
18 14, to reduce the slipstream interference between the front
19 and the rear nacelles. All four nacelles are the same size
20 and have the same thrust rating. The level of thrust and the
21 deflection of airflow of each nacelle is independent of the
22 other nacelles to allow the aircraft to be balanced and
23 stabilized in hover and in forward flight. Should one engine
24 in a nacelle fail, the balance and overall thrust level of
25 the aircraft can be maintained by a corresponding increase
26 in thrust from the remaining engine in that nacelle as well
27 as a small decrease in the thrust from the nacelle diagonally
28 opposite the failed engine nacelle. Thrust will increase

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1 somewhat in the other two nacelles. This is automatically
2 caused by the electronic stabilization system.

3 The hinges 52 at the folding joint 54 of the horizontal
4 stabilizer tips 122 are shown most clearly in Figure 4. From
5 the hinge 52 to the tip 122, the horizontal stabilizer 26 can
6 be folded downward and locked in place behind the nacelle,
7 for ground travel and convenience in parking and storage.
8 When the tips 122 are folded, the horizontal stabilizer 26
9 is approximately equal to the width between the outer
10 extremity of nacelles 16 and 18 at their widest point. This
11 distance can be adapted to that required by law to enable the
12 aircraft to operate legally on the highway.

13 Figure 4 also details the relationship between the
14 center of gravity 120 of the aircraft and the center of lift
15 112, 114, 116 and 118 of the nacelles 12, 14, 16 and 18
16 during hover. While the collective centers of lift from
17 vectored thrust of the nacelles during hover is at the center
18 of gravity of the aircraft, during forward flight aerodynamic
19 lift causes the overall center of lift of the nacelles to
20 move substantially ahead of the center of gravity resulting
21 in a dynamic imbalance of lift. This imbalance is
22 compensated for by the unique horizontal stabilizer 26 as
23 shown in Figures 5a through 5c.

24 The horizontal stabilizer 26 of Figures 5a, 5b and 5c
25 has a traditional swept wing design with a novel twist along
26 its span and is downwardly curved at its tips 122. Figure
27 5a is a plan view of the horizontal stabilizer showing the
28 traditional swept wing design. As indicated in Figure 5c,

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1 in the preferred embodiment the horizontal stabilizer has an
2 angle of incidence of 10 degrees at the root 124, and a
3 negative 5 degree angle of incidence proximate the curved
4 tips 122, for a total difference of 15 degrees hence, giving
5 rise to a twist in the horizontal stabilizer along its
6 length. Figure 5b is a rear view further illustrating the
7 horizontal stabilizer configuration. The tip is curved to
8 maximize the effective span while keeping the real span low.
9 The tips are curved downward to minimize the overall height
10 of the aircraft.

11 Figure 6a is a block diagram illustrating the basic
12 components of the triple redundant flight control system of
13 the preferred embodiment. The system stabilizes the attitude
14 of the aircraft in pitch and roll during hover and early
15 transition primarily by modulation of engine thrust levels.
16 During latter transition and full forward flight, the vanes
17 are the primary means of providing control. The aircraft is
18 also capable of maintaining the heading of the aircraft along
19 a flight plan that has been preprogrammed into its computers.
20 The components of the flight control system are the sensor
21 package 126, pilot controls 128, analog computer 130, two
22 digital computers 132 and 134, a supervisor 136 and four sets
23 of nacelle actuators and sensors 138.

24 Inputs into the computers 130, 132 and 134 are signals
25 from the inertial sensors of the sensor package 126, pilot
26 input, and feedback signals from the nacelle sensors 138.
27 In hover, each computer 130, 132 and 134 receives the
28 electrical signals, calculates the thrust level and thrust

1 deflection required in each nacelle, and sends appropriate
2 information to each engine throttle for pitch and roll
3 stabilization and control, and to the nacelle vane actuators
4 for yaw stabilization and control.

5 In full forward flight or transitioning flight, each
6 computer 130, 132 and 134 receives the input electrical
7 signals, calculates the required amount of control actuation,
8 and sends the control information to both the nacelle vane
9 actuators 138 and engine throttle for pitch, roll and yaw
10 control. The pilot can select the desired direction, but the
11 computer will calculate the appropriate balance of speed,
12 rate of climb and attitude.

13 Each digital computer 132 and 134 of the preferred
14 embodiment consists of a 80186 type processor and a plurality
15 of analog-to-digital and digital-to-analog converters. In
16 normal operation, the two digital computers 132 and 134 are
17 alternately accessed by the supervisor 136, so that each
18 controls the flight operation for approximately 10
19 milliseconds. This creates a system of checks for possible
20 malfunction in either computer. Should one digital computer
21 fail, the other digital computer will solely control the
22 flight operation. Should both digital computers fail, the
23 analog computer 130 will adequately control the flight
24 operation.

25 The power supply 144 is made fail-safe for any single
26 electrical fault and most dual faults by its combination of
27 a secure battery bus, electrical fusing, switching regulators
28 and linear regulators.

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1 Figure 6b is a diagram of an enlarged nacelle block
2 (Figure 6a) showing the actuators and sensors within each
3 nacelle. The top row represents actuators which receive
4 signals from the supervisor 136 and in turn drive the
5 appropriate mechanical part. The bottom row depicts the
6 position response sensors within each nacelle. Each sensor
7 generates an output signal which is fed back to each computer
8 giving it the status of each engine and set of vanes.

9 There are two actuators within each nacelle for engine
10 throttle control. This is to say that each engine's throttle
11 is controlled independently. There are also eight actuators
12 within each nacelle for vane deflection control. As
13 previously stated, each nacelle contains two independent sets
14 of vanes and there are four control actuators per set of
15 vanes for safety. Should one actuator pair fail, the other
16 actuator pair could implement partial deflection of the vanes
17 for balanced flight control.

18 For each nacelle, there are two sensors for sensing
19 throttle position (one for each engine in the nacelle), eight
20 sensors for sensing the vane position (four for each set of
21 vanes), and two tachometers for monitoring engine speed (one
22 per engine). The outputs from these sensors are combined
23 into a system of feedback 146 which is routed from each
24 engine to the computers, as shown in Figure 6a. The
25 computers utilize this information in combination with
26 information received from the sensor package 126 to make any
27 necessary adjustments in the positioning of the vanes or
28 level of thrust of the engines in order to keep the aircraft

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1 balanced and stabilized.

2 In addition to the stability provided by the
3 computerized flight control system, roll, pitch and yaw can
4 be controlled by the pilot through the pilot controls 128.
5 This means that both the pilot and the computer have control
6 of roll, pitch and yaw. Under normal conditions, the two are
7 doing different jobs. The pilot gives the aircraft inputs
8 of moderate magnitude to control the aircraft's motion or
9 direction while the computer provides stabilization inputs.
10 More specifically, the pilot lacks the short response times
11 necessary to stabilize the aircraft during hover and most of
12 transition. This is where the computer plays an essential
13 role in stabilizing the aircraft. Its commands are typically
14 of very small magnitude, but with a far shorter response
15 time. These small, quick corrections of the pilot's overall
16 commands result in stabilized hover and transition.

17 The pilot can directly control the static functions
18 suggested by box 142. These functions include operation of
19 the landing gear, opening and closing of the canopy,
20 activation of the motor and worm gear assembly that folds the
21 horizontal stabilizer tips down and locks them into place,
22 and activation of the rockets that deploy the emergency
23 parachute.

24 As previously mentioned, the computerized flight control
25 system primarily functions to stabilize the aircraft. During
26 hover, the vanes are deflecting the airflow out of the
27 nacelle through approximately 90 degrees. Pitch and roll
28 stabilization, using information from the sensors and

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1 feedback, is achieved through thrust level modulation and
2 does not involve vane movement. When the aircraft is
3 hovering over one spot (no wind), the vanes control only yaw.
4 This is accomplished by moving the vanes to a greater
5 deflection on one side of the aircraft (over 90 degrees) and
6 moving them to a smaller deflection (under 90 degrees) on the
7 other side. The deflection of the thrust away from 90
8 degrees will slightly lower the overall thrust, approximately
9 0.3% for a 5 degree deflection. The stabilization system can
10 be designed to hold a desired altitude, so that the overall
11 thrust level would automatically increase to generate this
12 lost thrust during a yawing maneuver. Moving backwards in
13 a strong wind or braking rapidly is achieved by using a
14 backward position of the right hand directional control stick
15 to achieve the required differential thrust level for pitch.
16 To resist side winds or move sideways during hover, the
17 thrust level is increased on the opposite side to the desired
18 direction of motion. Correspondingly, the thrust level will
19 be decreased on the other side by the stabilization system
20 just enough to maintain the average RPM or thrust level. The
21 vanes are not involved in side motion control during hover
22 or low speeds.

23 During transition, the vane position plays an indirect
24 part in roll stabilization and control. With the directional
25 stick neutral, the roll stability is still controlled
26 essentially by power or thrust levels as in hover, but
27 because the vanes are now partially retracted, a computer
28 initiated thrust level change to correct an unwanted roll

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1 will also produce a yaw moment. Utilizing information
2 provided by the yaw sensor, the computer will correct the
3 moment by deflecting the vanes. For example, if the aircraft
4 inadvertently rolls to the right, thrust level on the right
5 side will increase producing a corrective rolling moment to
6 the left and also causing the aircraft to yaw towards the
7 left. This yaw, however, is corrected by slight automatic
8 retraction of the vanes on the left side due to input from
9 the yaw sensor as well as a pre-programmed response to this
10 combination of movements. This simultaneously provides a
11 correcting yaw moment to the right and further increases the
12 corrective rolling moment by reducing the vertical thrust on
13 the left hand side. Ideally, the degree of vane movement
14 used for roll stabilization will be selected to ensure a
15 convergent yaw and roll motion after a roll or yaw
16 disturbance. A similar action takes place when the aircraft
17 is disturbed in yaw. For example, an unwanted yaw to the
18 right would automatically cause the right side vanes to
19 retract and the left side vanes to extend. This would
20 introduce a roll moment to the right which would be corrected
21 by the pre-programmed response and roll sensor increasing the
22 thrust level on the right side, canceling the adverse yaw.

23 If, on the other hand, the pilot wishes to turn to his
24 left, he will move the directional stick to the left which
25 will increase the thrust level on the right hand side
26 simultaneously causing the aircraft to roll to the left and
27 yaw to the left resulting in a turning to the left. This is
28 consistent with a coordinated turn to the left. The pilot

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1 could twist the directional stick which will independently
2 move the vanes to ensure that a coordinated turn is achieved.
3 However, it is far easier to let the computer adjust the vane
4 position automatically so that coordinated turns can be
5 achieved entirely by side motion of the direction stick.

6 Longitudinal control (speed and movement in the
7 longitudinal direction) originates from fore or aft movement
8 of the right hand directional control stick. This stick
9 affects movement or no movement in a horizontal direction.
10 For movement forward or backward, a combination of
11 differential throttle control and nacelle vane position
12 control is available to provide the longitudinal force
13 necessary for such movement. The flight control computer
14 could be programmed to provide the best choice. For example,
15 during take-off and early transition it may be advantageous
16 to operate the aircraft in a nose down position for improved
17 visibility. If this were the case, then pitching the nose
18 down might provide most of the translational force required
19 during early transition. If a rapid acceleration (large
20 force) was required, then the vanes could retract somewhat
21 to vector some of the thrust longitudinally as well.

22 The aircraft has the facility for an automatic altitude
23 hold feature wherein a selected altitude is maintained in
24 response to inputs from a radar altimeter at low altitudes
25 and a barometric altimeter at high altitudes. This ensures
26 that the aircraft maintains altitude while slowing down. The
27 pilot can also pre-select the rate of climb or descent.
28 Therefore, if he desires to slow down and descend, he would

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1 first select a rate of descent and then a new altitude. The
2 thrust level would automatically reduce to achieve that rate
3 of descent. The pilot would then slow the aircraft down by
4 aft movement of the directional stick which would first
5 extend the vanes. The vane position, airspeed and selected
6 rate of descent will cause the flight control computer to
7 adjust the thrust or power level accordingly. At
8 significantly reduced thrust levels, the vanes become drag
9 producers as well as lift generators. This allows a rapid
10 reduction in forward speed, if desired. As transition speeds
11 are entered (speeds less than 125 m.p.h.), the computer would
12 adjust the thrust levels upwardly in order not to exceed the
13 selected rate of descent.

14 For very rapid braking after the vanes are fully
15 extended and the airspeed is low enough that aerodynamic
16 forces are not excessive, the aircraft can be positioned in
17 a nose high attitude to introduce additional drag and a large
18 vectored thrust component in the forward direction. This is
19 achieved by moving the directional stick sufficiently far
20 back.

21 There is also an inflight information computer 148
22 included in this preferred embodiment that does not directly
23 interface with the computerized flight control system. This
24 computer conveys information from certain aircraft sensors
25 such as the engine temperature gauge and the pitot-static
26 tube, etc., and displays them in easy to understand, visual
27 images on the pilot's instrument panel.

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1 Figures 7a through 7d show how lift is generated in four
2 flight regimes from takeoff or hover modes through forward
3 flight.

4 Figure 7a shows an aircraft in the takeoff or hover
5 mode. In this mode, all of the lift is generated by
6 vectoring the fan thrust from the engines through the
7 deflector vanes where the vanes are fully extended for
8 maximum deflection of the airflow. Also, in this mode, pitch
9 and roll are controlled by changes in engine thrust level,
10 and yaw is controlled by changes in the amount of deflection
11 of the vanes, i.e. the position of the vanes within their
12 guide slots.

13 At the start of transition to forward flight, the
14 greater part of the lift is generated by the vectored fan
15 thrust with very little, if any, of the lift being generated
16 by the aerodynamic characteristics of the lifting bodies
17 (nacelle, horizontal stabilizer, fuselage). As transition
18 progresses toward forward flight, as shown in Figures 7b and
19 7c, more of the lift is generated by the lifting bodies and
20 less by the vectored fan thrust until the ratio of
21 aerodynamic lift dominates over the lift from thrust. In
22 both stages, pitch, roll and yaw are controlled by both vane
23 deflection and engine RPM changes.

24 Figure 7d shows an aircraft in a full forward flight
25 mode, where virtually all lift is aerodynamically provided
26 by the lifting bodies. A negligible amount is provided by
27 fan thrust. In this mode, pitch and roll are controlled by
28 vane deflection alone, and yaw is generally controlled by

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1 vane deflection and engine RPM changes.

2 To enter the aircraft, the pilot opens the canopy and
3 seats himself in the cockpit. Once inside, the pilot
4 initializes the computers and sets his flight destination.
5 He uses a small electric motor driving one wheel to move the
6 vehicle out of its parking area. He then starts one engine
7 in each of the rear nacelles, and uses the rearward thrust
8 to drive the craft to an appropriate takeoff site. At the
9 takeoff site, the pilot initiates the computer controlled
10 starting sequence which starts the remaining six engines.
11 To save weight, only one of the two engines in each nacelle
12 has a starter. The other engine is started by using the
13 aerodynamic interaction of the two fans to turn the non-
14 running engine at sufficient speed for starting. Upon
15 ignition of the engines, the flight computer takes control
16 over the flight operation and will execute a pre-flight
17 checklist. The pilot, through his controls, can now select
18 the altitude and rate of climb, and control the speed and
19 direction of the craft. He does not direct the flight
20 management, as this is the function of the flight computer.

21 The flight computer carries a great responsibility in
22 the operation of the aircraft. This is the reason why the
23 triple redundancy flight computer safety feature is so
24 important. The triple redundancy feature operates by having
25 the supervisor constantly check each digital computer for
26 possible malfunction. If one of the digital computers fails,
27 the other takes over complete control of the flight
28 operation. If both digital computers fail, the analog

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1 computer takes over control of the flight operation. The
2 potential utilization of three computers creates the triple
3 redundancy safety feature.

4 In the event of a known or probable computer flight
5 control system failure, it is possible to provide a direct
6 link between the pilot controls and top movement of the
7 outside set of vanes of the front two nacelles. This could
8 give the pilot adequate control of the aircraft in both pitch
9 and roll during full forward flight. This control would then
10 be used to slow the aircraft to an acceptable parachute
11 deployment speed and to direct the aircraft to an appropriate
12 parachute deployment site.

13 Following the computerized pre-flight check, the
14 computer will indicate to the pilot that all systems are
15 functioning normally and that the aircraft is ready for
16 flight. The pilot will initiate takeoff by advancing the
17 altitude select control to the "ground effect hover"
18 altitude. The computer will operate the aircraft into a
19 stable, hover mode and perform a final pre-departure check.
20 In this hover mode, all of the lift is generated by vectoring
21 the fan thrust through the fully deflected vanes. Also, in
22 this mode, the computer controls pitch and roll by varying
23 the respective engine thrust levels, and yaw is controlled
24 by the amount of deflection of the vanes. The aircraft will
25 continue to hover until the pilot selects an altitude and a
26 rate of climb. Once selection is made, the computer
27 calculates the level of engine power needed to achieve the
28 pilot's desires, taking into consideration other factors such

1 as vehicle gross weight, and gets ready to accelerate the
2 aircraft into a controlled ascent.

3 When the pilot moves the left hand controls to select
4 altitude and rate of climb, the computer will adjust the
5 power and start vertically rising at the specified rate
6 towards the selected altitude. When the pilot moves the
7 directional stick forward, the aircraft will also begin
8 moving into forward flight toward the desired altitude while
9 maintaining the selected rate of climb. The vanes, which
10 were fully deflected for the hover mode, will be slowly
11 retraced to transition the aircraft into forward flight.
12 During this transition phase, the computer controls pitch,
13 roll and yaw by both vane deflection and engine thrust level
14 changes. As the aircraft gains forward airspeed and the
15 fuselage, horizontal stabilizer and nacelles start to
16 generate lift, the computer automatically adjusts the
17 deflection of the vanes to maintain the appropriate attitude
18 of the aircraft for efficient aerodynamic lift. When the
19 vanes are no longer significantly deflecting the nacelle
20 airflow downward, the aircraft will have completed transition
21 and achieved sufficient flying speed for full aerodynamic
22 flight.

23 In full forward flight mode, where virtually all lift
24 is provided by the lifting bodies, the computer controls
25 pitch and roll by vane deflection, and yaw is controlled by
26 the vanes and thrust level changes. In this mode, no pilot
27 input is necessary due to the pre-programmed flight
28 destination that the pilot initially input into the computer.

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1 However, the pilot may change the heading, altitude, or
2 airspeed if he so desires.

3 The sequence of events for landing the aircraft are the
4 exact opposite of those for takeoff. When the pilot is ready
5 to transition into a descent, he will select the rate of
6 descent and new altitude and then apply back-pressure on the
7 right hand directional control stick. The computer will
8 adjust the engine thrust levels and vane positions to cause
9 the aircraft to descend. When the aircraft nears the chosen
10 landing site, the pilot moves the altitude select control to
11 the "hover" or "land" position. The computer then guides the
12 aircraft into the selected mode.

13 Although a passenger aircraft is utilized in the above
14 example, the present invention can also be used as a vehicle
15 for transporting other payloads from one place to another
16 under automatic control. The present invention is also
17 suitable for use as a drone or any other application normally
18 fulfilled by pilotless aircraft.

19 Furthermore, the vane system and its deployment
20 mechanism can be used (independently of an aircraft) as an
21 apparatus for vectoring airflow, or for effecting fluid
22 stream directional control. For example, the concept of the
23 present invention could be incorporated in a blower of the
24 type used in agricultural applications for keeping frost from
25 forming on crops. Alternatively, the vane system could be
26 implemented in a water jet propulsion system of the type used
27 to power water borne vehicles and the like. The present
28 invention would be particularly effective in the latter

1 implementation because of its low actuating force
2 requirements in an environment in which flow direction of a
3 flow stream having substantial mass is involved.

4 Figures 8a through 8d illustrate an alternative
5 embodiment of a vane system and its deployment mechanism.
6 Figure 8a is a perspective view of an apparatus for effecting
7 flow stream directional control consisting of a housing 150
8 having, at its inlet end 152, a generally annular shape that
9 transitions to a rectangular configuration at its outlet 154,
10 with one pair of opposing sides 156 being of greater length
11 than the other pair of opposing sides 158, and a
12 bidirectional vane system which will be discussed in detail
13 to follow. The sides of lesser length 158 provide clearance
14 for the redirected stream flow.

15 The apparatus is capable of deflecting the exiting flow
16 stream to one side or the opposite side thereof, and in
17 excess of 90 degrees in each direction. Additionally, by
18 rotating the apparatus about its longitudinal axis, the flow
19 plane along which the flow stream can be deflected can be
20 changed.

21 The bidirectional capability of one of the vanes of the
22 vane system of this embodiment is illustrated in Figure 8b
23 by a diagram of a centrally positioned vane and guide slot
24 not depicted in Figure 8a. As illustrated, the vane 160 is
25 in a horizontal, non-deflecting position within the straight
26 section 162 of the guide slot. Following the straight
27 section, there are two circularly arcuate sections 164 and
28 166 of guide slot that branch off in opposite directions.

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1 A dual position slot gate 168, disposed at the junction
2 of the straight and curved sections of the guide slot, is
3 driven by an actuator assembly 170 and operates to block the
4 entrance to one of the two curved sections of the guide slot,
5 so that when the vane is extended, it will follow the path
6 of the guide slot whose entrance is not blocked by the slot
7 gate. The deployment mechanism 173 actuates the movement of
8 the vane within the guide slot. As illustrated, the entrance
9 to the upper curved section of guide slot is blocked by the
10 slot gate, and the dashed line shows the position of the slot
11 gate actuator if the gate were blocking the entrance to the
12 lower curved section of guide slot. Similarly, the dashed
13 lines for the deployment mechanism and vane depict the
14 positioning of those items if the vane were fully extended
15 within the guide slot.

16 Figure 8c is a broken partial side view taken along the
17 line 8c-8c of Figure 8a showing the interior wall of a vane
18 guide containing panel 172 of the apparatus, with the vane
19 deployment mechanism attached. A vane guide containing panel
20 is disposed within each of the opposing sides 156 of the
21 apparatus that have the greatest lengths.

22 Similar to the preferred embodiment, the deployment
23 mechanism for this apparatus consists of a drive motor 174,
24 actuator arm 176 and linkage 178 assembly which moves the
25 actuator bar 180. The leading edge of each vane is attached
26 to the actuator bar at an elongated slot 182 which allows the
27 actuator bar to be moved at an angle limited by the bounds
28 of the elongated slot. The straight portion of the top guide

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1 slot 184 is extended beyond the intersection with the
2 upwardly extending curved portion such that the downwardly
3 extending curved portion thereof is located in a cascaded
4 relationship to the corresponding downwardly curved portion
5 of the central slot 186 and the bottom slot 188. The central
6 slot 186 has a straight portion immediately followed by two
7 curved portions that branch off in opposite directions
8 therefrom. Note that this is the centrally disposed vane and
9 guide slot as described in Figure 8b. The bottom guide slot
10 188, the reciprocal of the top guide slot 184, has its
11 straight portion extended beyond the intersection with the
12 downwardly extending curved portion such that the upwardly
13 extending curved portion thereof is located in a cascaded
14 relationship to the corresponding upwardly curved portion of
15 the central slot 186 and the top slot 188. As previously
16 described in Figure 8b, the slot gate 192 for the central
17 slot is disposed at the junction of the straight and curved
18 sections of the guide slot. In contrast with the central
19 slot, the slot gates 190 and 194, for the top and bottom
20 guide slots respectively, are displaced at the first
21 intersection of the straight section and a curved section,
22 from the upstream end of the guide slot.

23 Figure 8c further illustrates the vanes in a horizontal,
24 non-deflecting mode, and the slot gates blocking the entrance
25 to the downward deflecting guide slots, thereby creating a
26 continuous guide slot path into the upwardly curved slots.
27 The curved portion of the slots bend at a 5 degree angle
28 normal to the longitudinal axis of the apparatus in order to

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1 deflect the flow stream beyond 90 degrees in each direction.

2 Figure 8d illustrates the vane system of Figure 8c in
3 a full deflection mode. The top actuator arm is broken away
4 to better illustrate the cambered vane within the upwardly
5 curved section of the top guide slot 184.

6 Alternately, the vane system can be used to reduce the
7 exit area by having the slot gates block the outwardly
8 curving portions of the guide slots, thereby creating a
9 continuous guide slot path into the downwardly curved slot
10 of the top guide slot, and into the upwardly curved slot of
11 the bottom guide slot. In this configuration, fully
12 extending the vanes would cause the top vane to deflect
13 downward and the bottom vane to deflect upward, thereby
14 directing the flow stream through the very narrow exit
15 opening created by the extended vanes. For this purpose, the
16 direction of the deflection of the central slot is
17 immaterial. Also, if the trailing edges of the extended
18 vanes within the guide slots were sufficiently close
19 together, the exit could in effect be shut off completely.
20 These attributes can be used to reduce noise, to assist in
21 wheel braking during landing, or to shut down an engine if
22 desired.

23 The operation of the bidirectional vane system is
24 identical to that previously described in the preferred
25 embodiment with the exception of the availability of the
26 second curved section of guide slot and the operation of the
27 slot gate. An apparatus containing a bidirectional vane
28 system is operable by input signals from a human operator or

1 a computerized system similar to that described in the
2 preferred embodiment. Additionally, an operating computer
3 can be programmed to extend the vanes to deflect the flow
4 stream in one direction, retract the vanes so that there is
5 no deflection of the flow, extend the vanes to deflect the
6 flow in the opposite direction of the previous deflection,
7 retract the vanes again and so forth, to achieve a flow
8 variably deflected over 180 degrees, without requiring a
9 complex mechanism to pivot the apparatus itself.

10 Although the present invention has been described in
11 terms of specific embodiments, it is anticipated that
12 alterations and modifications thereof will no doubt become
13 apparent to those skilled in the art. It is therefore
14 intended that the following claims be interpreted as covering
15 all such alterations and modifications as fall within the
16 true spirit and scope of the invention.

17

18 What is claimed is:

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A VTOL aircraft comprising:

5 an elongated fuselage configured to develop aerodynamic lift when moved forward in the direction of its longitudinal axis;

at least one vertical stabilizer connected to an aft portion of said fuselage;

10 a horizontal stabilizer connected to said vertical stabilizer;

15 a plurality of fixed nacelles rigidly disposed fore, aft and on both sides of the center of gravity of said fuselage and operative to generate independent streams of airflow for propelling and stabilizing said aircraft, each said nacelle having powerplant means which rotates about an axis substantially parallel to said longitudinal axis and generates a propelling flowstream through the nacelle, each said nacelle including a structure having
20 an inlet portion and an outlet portion, said outlet portion including inner wall means with at least two opposed sides having guide slots formed therein, said guide slots having a straight portion and a curved portion, and a vane structure including at least one vane
25 disposed within said outlet portion, each said vane including a plurality of elongated vane segments linked together and extending in parallel relationship to each other and transverse to said longitudinal axis, the ends of said segments being movably disposed within said guide slots, and means for moving said vane segments relative
30 to said guide slots to vary the camber of said vane in order to direct said flowstream either generally parallel to said longitudinal axis or at an angle relative thereto as said flowstream exits said outlet portion; and

35 control means for controlling the power generated by each said powerplant means and for controlling the positions of the corresponding vanes to cause said flowstream to be directed downwardly to cause said aircraft to rise vertically, and to alternatively be

directed rearwardly to cause said aircraft to move in a forward direction, said control means being operative to cause the power supplied by each said powerplant means and the position of the corresponding vanes to be coordinated to maintain the balance and stability of the aircraft.

2. A VTOL aircraft as recited in claim 1 wherein said nacelles are positioned so that when all airflow is directed downwardly from each nacelle at predetermined powerplant means power settings, the combined center of lift of the aircraft is located proximate the center of gravity of said aircraft.

3. A VTOL aircraft as recited in claim 1 wherein said vertical stabilizer is affixed directly to the aft end of said fuselage and rises immediately thereabove.

4. A VTOL aircraft as recited in claims 1 or 3 wherein said plurality of nacelles includes at least one aft nacelle located on each side of said fuselage.

5. A VTOL aircraft as recited in claim 4 and further comprising second and third vertical stabilizers respectively disposed on opposite sides of said first vertical stabilizer and respectively mounted to one of said aft nacelles.

6. A VTOL aircraft as recited in claim 5 wherein an upper portion of each of said second and third vertical stabilizers is affixed to said horizontal stabilizer.

7. A VTOL aircraft as recited in claim 1 wherein said horizontal stabilizer is comprised of two symmetrical halves, each half being swept and having a predetermined twist from root to tip.

8. A VTOL aircraft as recited in claim 7 further comprising downwardly turned cuffs formed in each tip.

9. A VTOL aircraft as recited in claims 1 or 8 wherein said horizontal stabilizer is articulated to allow the airfoil to be folded to reduce span dimension for ground travel or storage.

5

10. A VTOL aircraft as recited in claim 1 wherein said plurality of nacelles includes a first and second nacelle respectively disposed forward of the center of gravity of said aircraft and on opposite sides of said longitudinal axis.

10

11. A VTOL aircraft as recited in claim 10 wherein said plurality of nacelles includes third and fourth nacelles respectively disposed aft of said center of gravity and on opposite sides of said longitudinal axis.

15

12. A VTOL aircraft as recited in claim 1 or 11 wherein said nacelles have external surfaces configured to develop lift when moved forward in the direction of said longitudinal axis.

20

13. A VTOL aircraft as recited in claim 12 wherein said nacelles have a front opening and a rear opening, said rear opening lying in a plane the upper portion of which is rotated aft relative to a plane normal to the longitudinal axis of said nacelle.

25

14. A VTOL aircraft as recited in claim 11 wherein said at least one vertical stabilizer affixed directly to said external surface of said third and fourth nacelles and rising immediately thereabove.

30

15. A VTOL aircraft as recited in claim 14 wherein said control means further include sensor means responsive to said powerplant means power levels and vane position, and operative to develop powerplant means power level signals and vane position signals for communication to said power control means.

35

16. A VTOL aircraft as recited in claim 1 wherein each said powerplant means includes a pair of engines located along the longitudinal axis of its corresponding nacelle.

5 17. A VTOL aircraft as recited in claim 16 wherein each of said engines directly drives a propeller, said propellers being driven independently of each other, being positioned to face each other, and being caused to counter-rotate with respect to each other.

10 18. A VTOL aircraft as recited in claim 16 or 17 wherein said engines are rotary engines.

15 19. A VTOL aircraft as recited in claim 17 wherein each said nacelle contains a system for routing pressurized air from a point downstream of said propellers through internal cooling passageways in said engines.

20 20. A VTOL aircraft as recited in claim 19 wherein each of said nacelles contains a baffle structure disposed downstream of said propellers and in the airstream flowing through the nacelle to reduce the noise of the exhaust from said engines.

25 21. A VTOL aircraft as recited in claim 20 wherein said baffle structure includes means forming an exhaust port through which said exhaust is passed and further including means forming an additional passageway having an entrance for receiving said pressurized air after it
30 has been routed through said internal cooling passageways and an exit surrounding said exhaust port such that said exhaust causes said pressurized air to be drawn through said additional passageway and to be mixed with said exhaust.

35 22. A VTOL aircraft as recited in claim 1 wherein each said vane system includes a plurality of vanes disposed in the exit orifice of a corresponding nacelle and means for varying the camber of each said vane in order to

direct said airflow.

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5 23. A VTOL aircraft as recited in claim 22 wherein each end of each of said vanes is movably disposed within a curved guide slot formed along an inner wall of said nacelle near said rear opening.

10 24. A VTOL aircraft as recited in claim 22 wherein said plurality of vanes are disposed within said nacelle in a cascading configuration wherein the uppermost vane is positioned substantially aft of the lowermost vane.

15 25. A VTOL aircraft as recited in claim 23 wherein said plurality of vanes are disposed in two sets of vanes which operate independently of each other.

20 26. A VTOL aircraft as recited in claim 24 wherein one set of said two sets of vanes is disposed on one side of said powerplant means axis and the other set is disposed on the opposite side of said powerplant means axis.

25 27. A VTOL aircraft as recited in claim 25 wherein said plurality of vanes are articulated, and the articulated portions thereof move in succession into said first and second positions.

28. A VTOL aircraft as recited in claim 1 wherein said control means include:

30 sensor means for sensing pitch, roll and yaw, and developing pitch signals, roll signals and yaw signals; and

35 power control means responsive to said pitch, roll and yaw signals, and operative to control the power generated by each of said powerplant means, and the positioning of each of said vanes so as to maintain the stability of said aircraft.

29. A VTOL aircraft as recited in claims 22, 23, 24, 25, 26 or 27 wherein each said vane is of a tambour-like

construction.

30. An apparatus for controlling the flow of a gas or fluid stream comprising:

5 means for confining a flow stream and including a structure having an inlet portion with a longitudinal axis along which said flow stream moves and an outlet portion with inner wall means having at least two opposed sides;

10 a vane structure including at least one vane disposed within said outlet portion, said vane including a plurality of vane segments, the ends of which are movably disposed within guide slots formed in said opposed sides, said guide slots having a straight portion
15 and a curved portion; and

means for moving said vane relative to said guide slots to vary the camber of said vane in order to direct said flow stream at an angle relative to said longitudinal axis, as said flow stream exits said outlet
20 portion.

31. An apparatus as recited in claim 30 wherein said means for moving said vane includes motor driven actuator bar means attached to said vane for driving said vane
25 within said guide slots.

32. An apparatus as recited in claim 31 wherein said vane structure includes a plurality of said vanes disposed within a plurality of said guide slots, said
30 actuator bar being attached to each said vane for driving each said vane within the corresponding guide slots.

33. An apparatus as recited in claim 32 wherein each said guide slot includes an additional curved portion and
35 means for selectively coupling said straight portion to one of said curved portions whereby the corresponding vane can be extended into the selected curved portion of said guide slot for directing said flow stream toward the corresponding side of said longitudinal axis.

34. An apparatus as recited in claim 33 wherein said vanes can be extended into the selected curved portion of said guide slot for directing said flow stream through the narrow exit opening created by said extended vanes at said outlet portion.

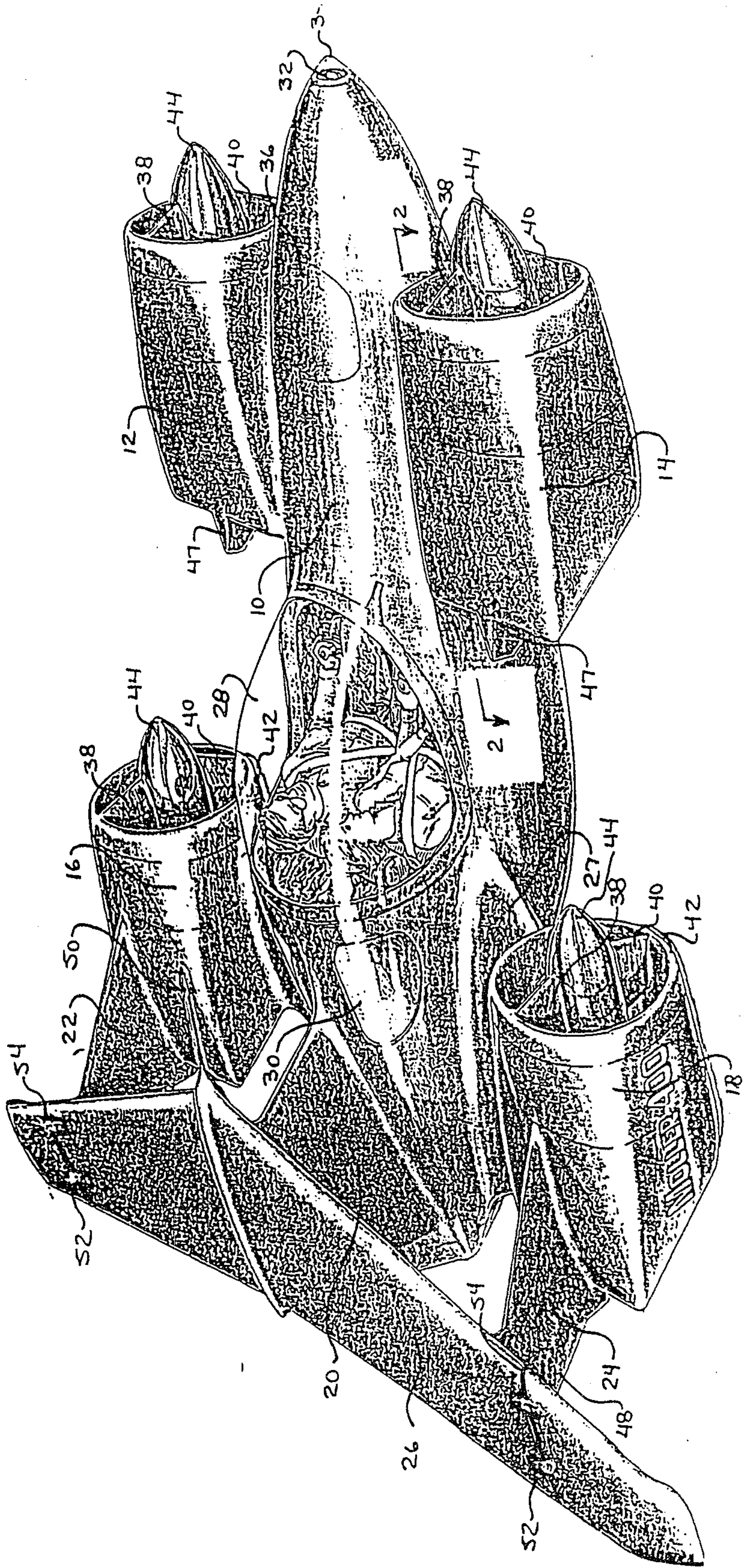
35. An apparatus as recited in claim 34 wherein said plurality of vanes are disposed in two sets of vanes which operate independently of each other.

36. An apparatus as recited in claim 35 wherein one set of said two sets of vanes is disposed on one side of said longitudinal axis and the other set is disposed on the opposite side of said longitudinal axis.

37. An apparatus as recited in claim 36 wherein said plurality of vanes are articulated and the articulated portions thereof move in succession into said curved portions of said guide slots.

38. An apparatus as recited in claim 30 wherein each said vane is of a tambour-like construction.

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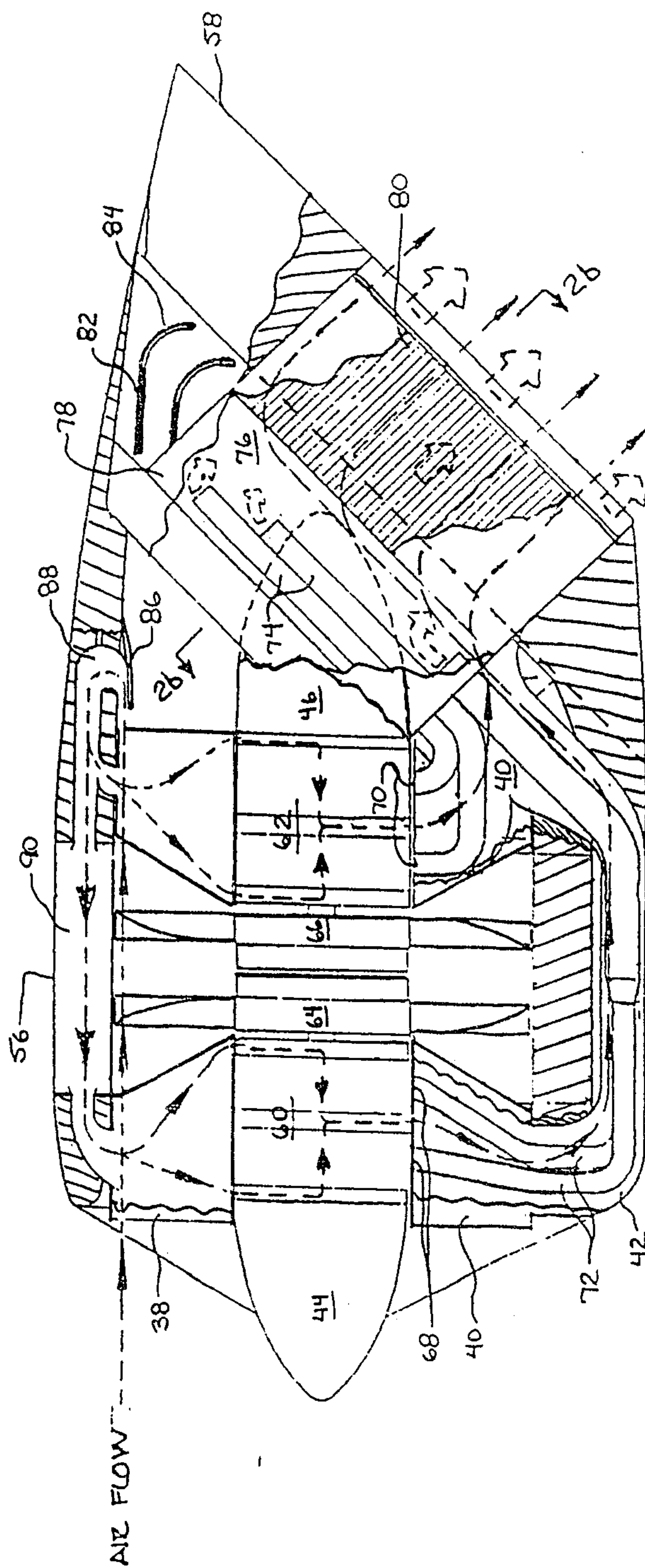
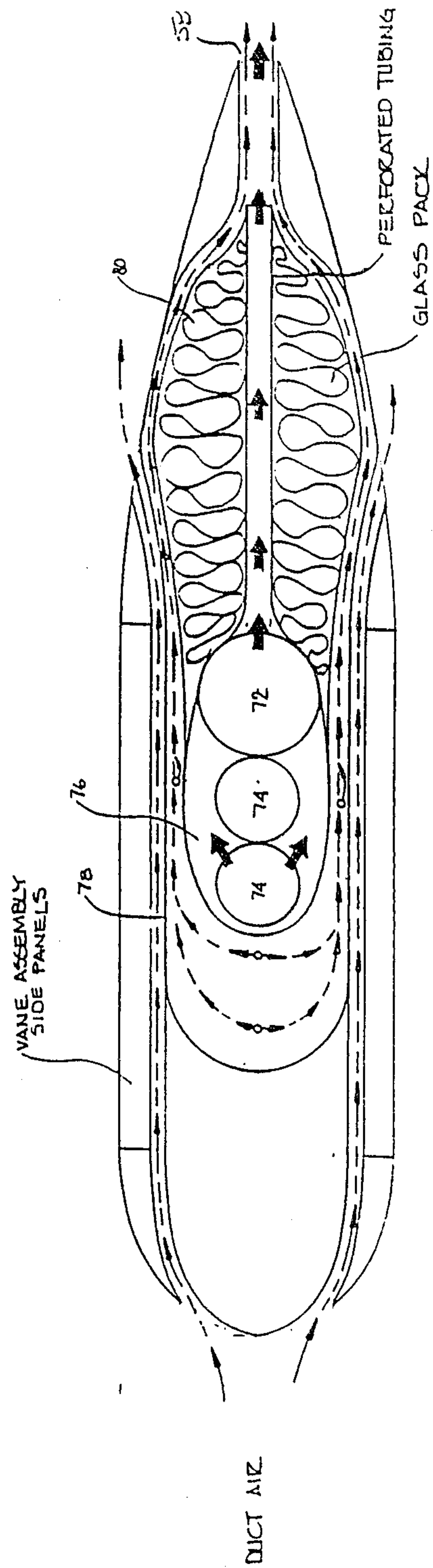


FIG. 2a

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FIG 2b

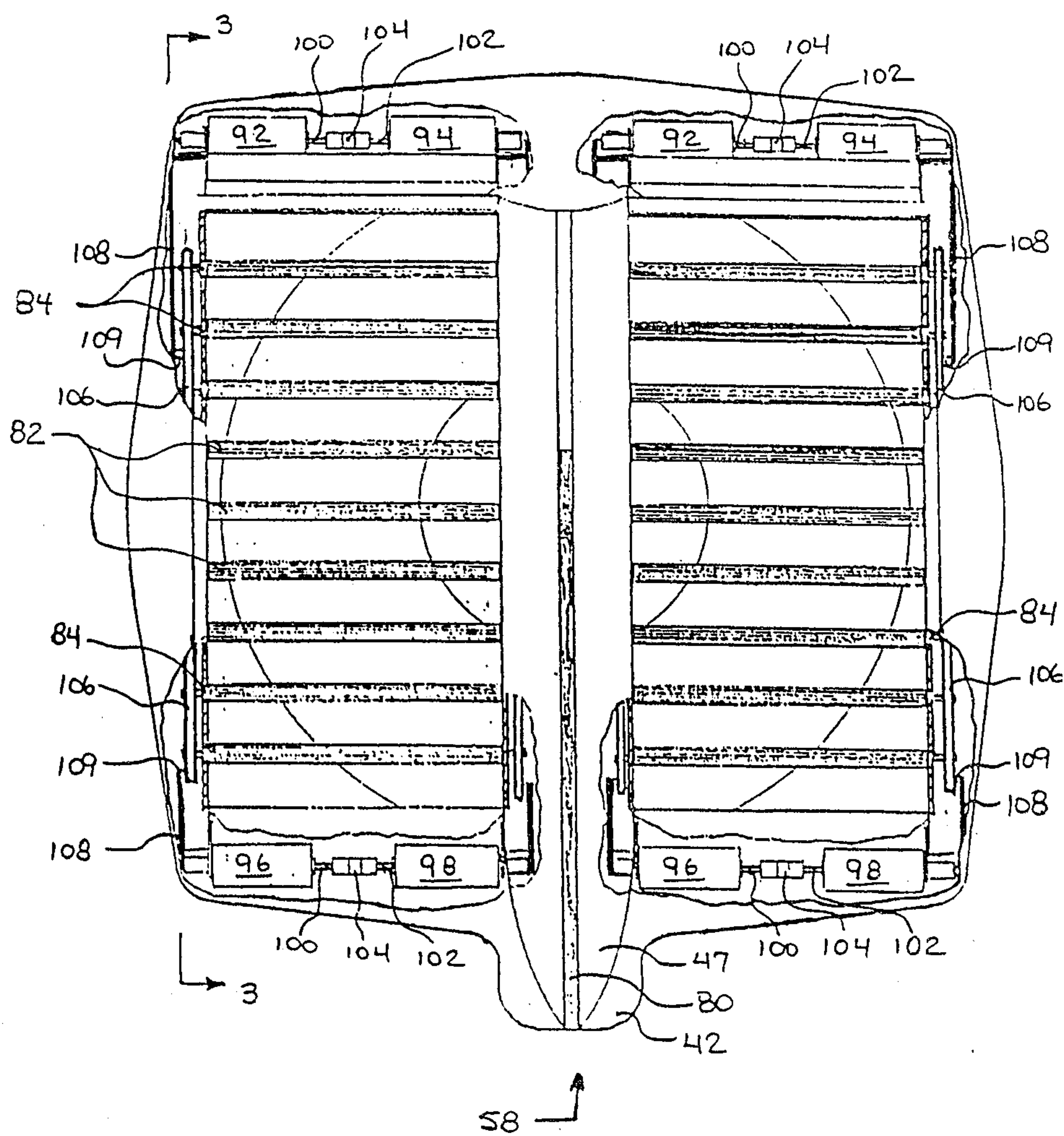


FIG. 3a

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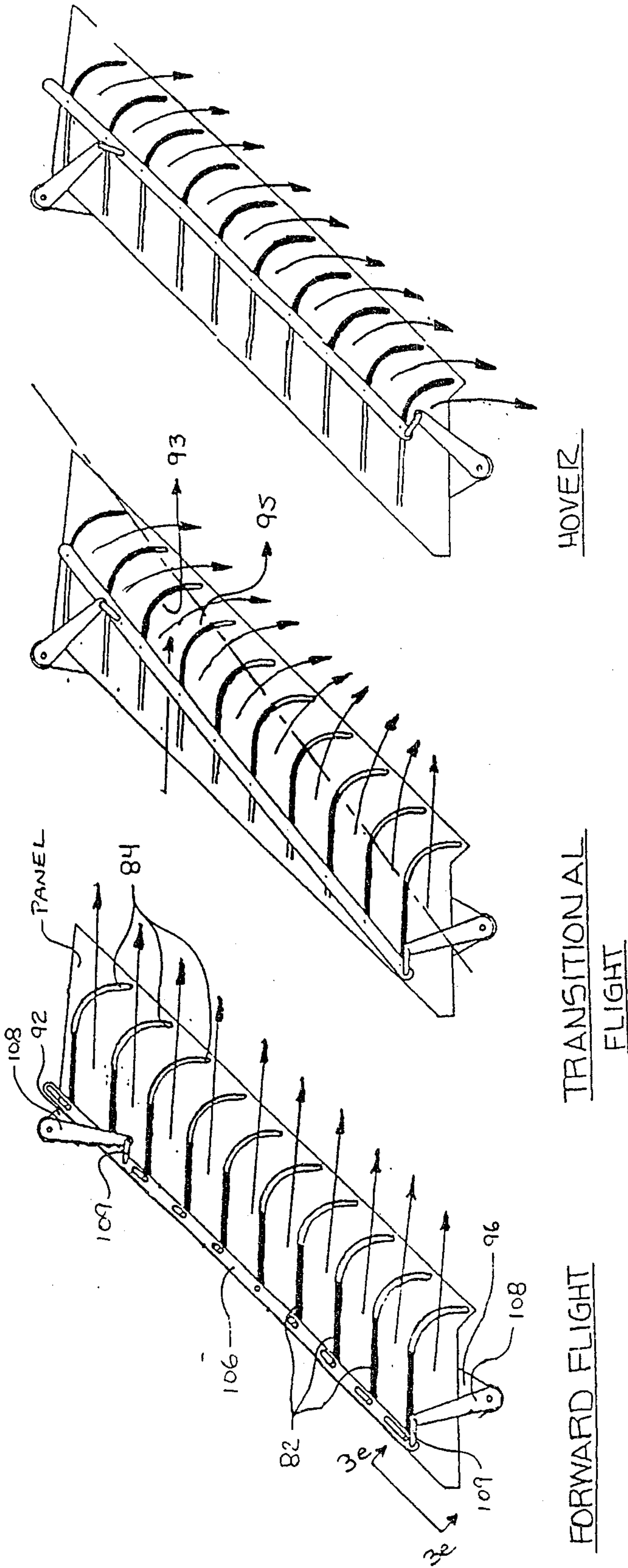
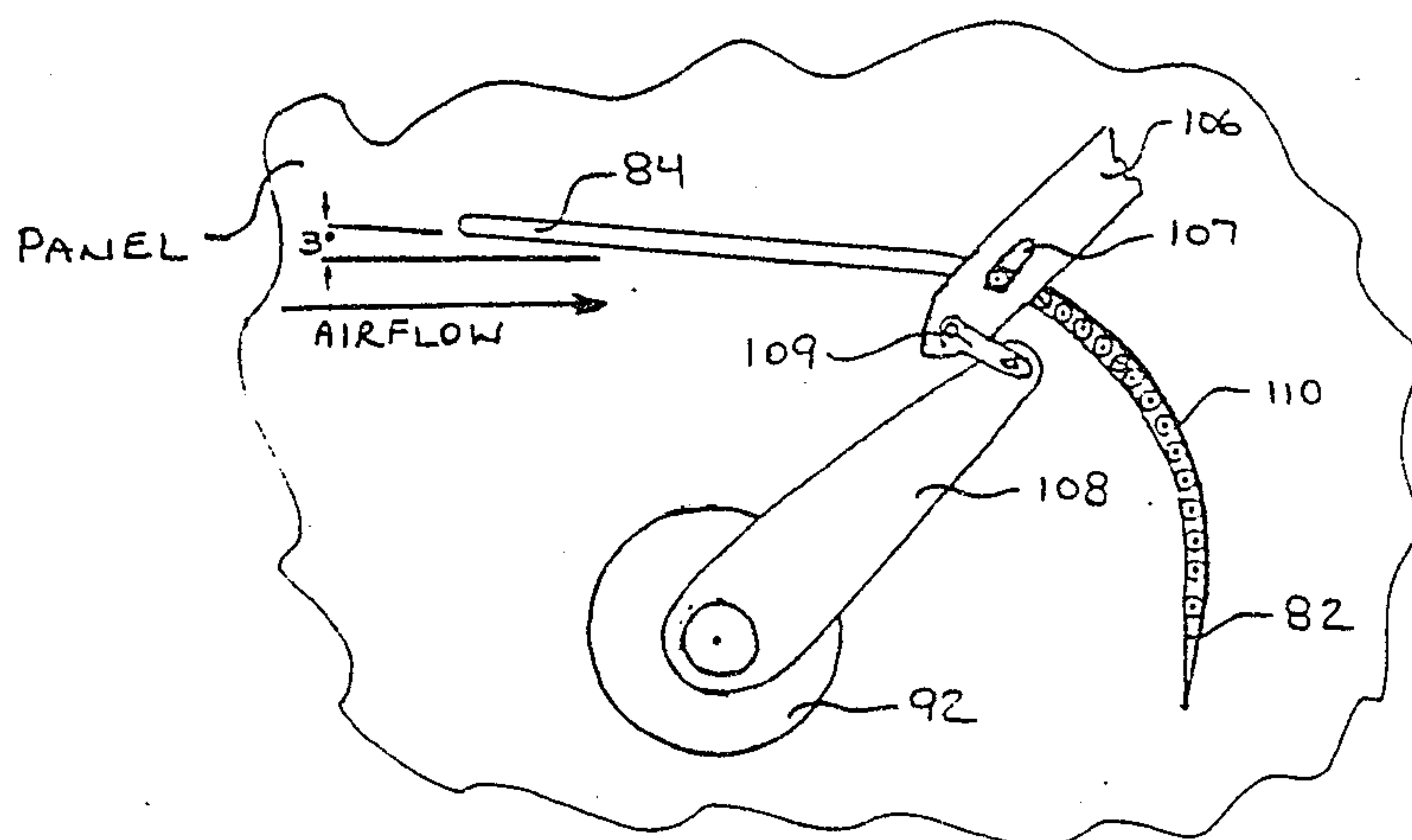
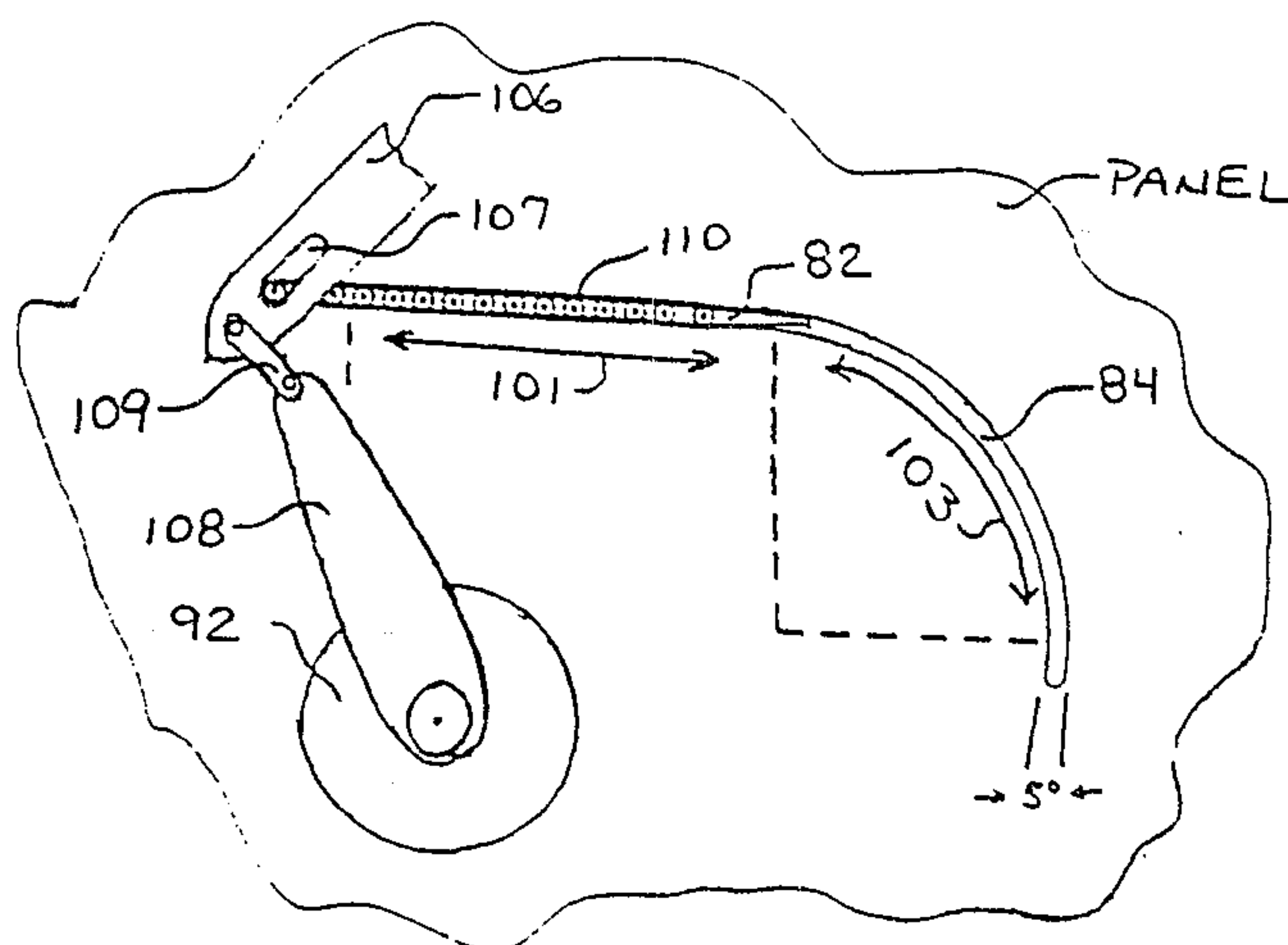


FIG 3 b

FIG 3 c

FIG 3 d

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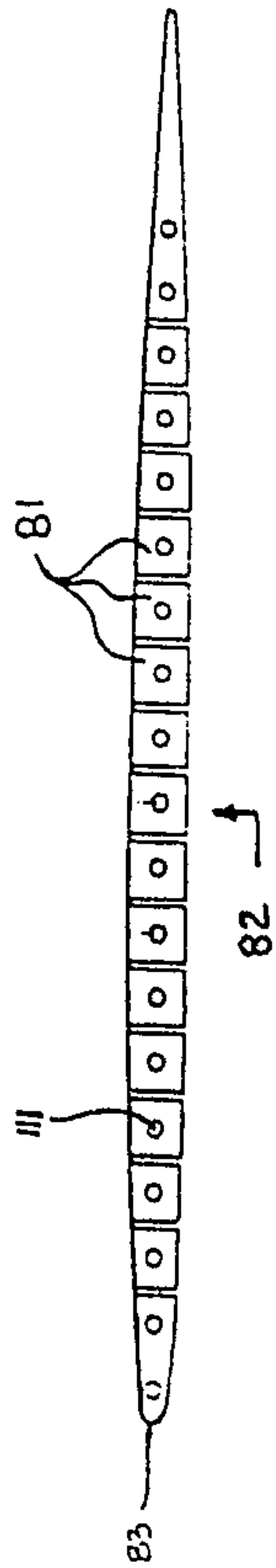


FIG. 3g

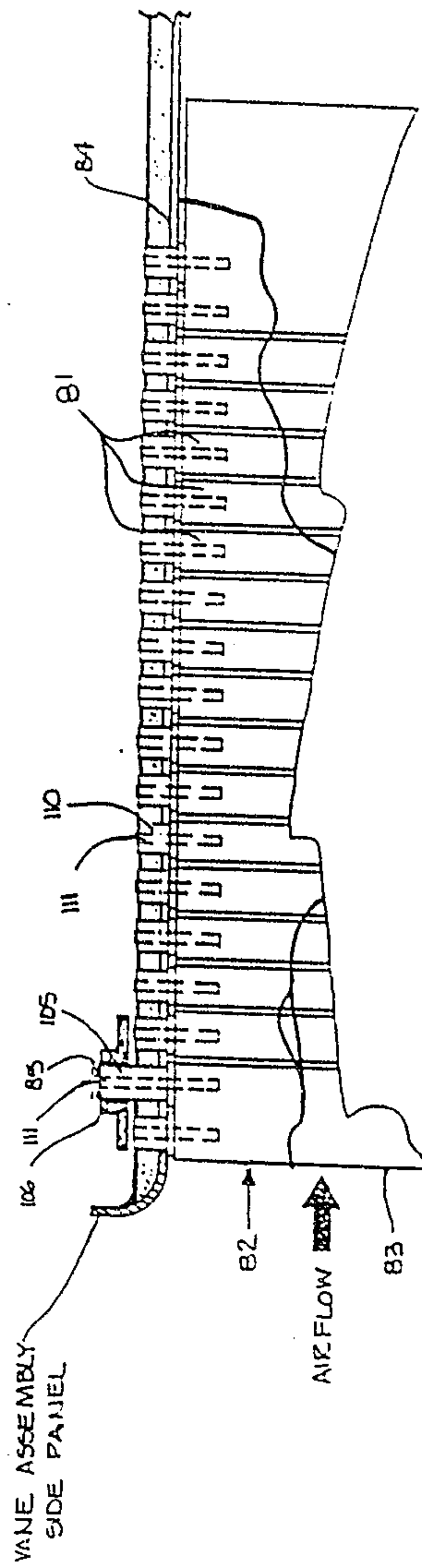


FIG. 3h

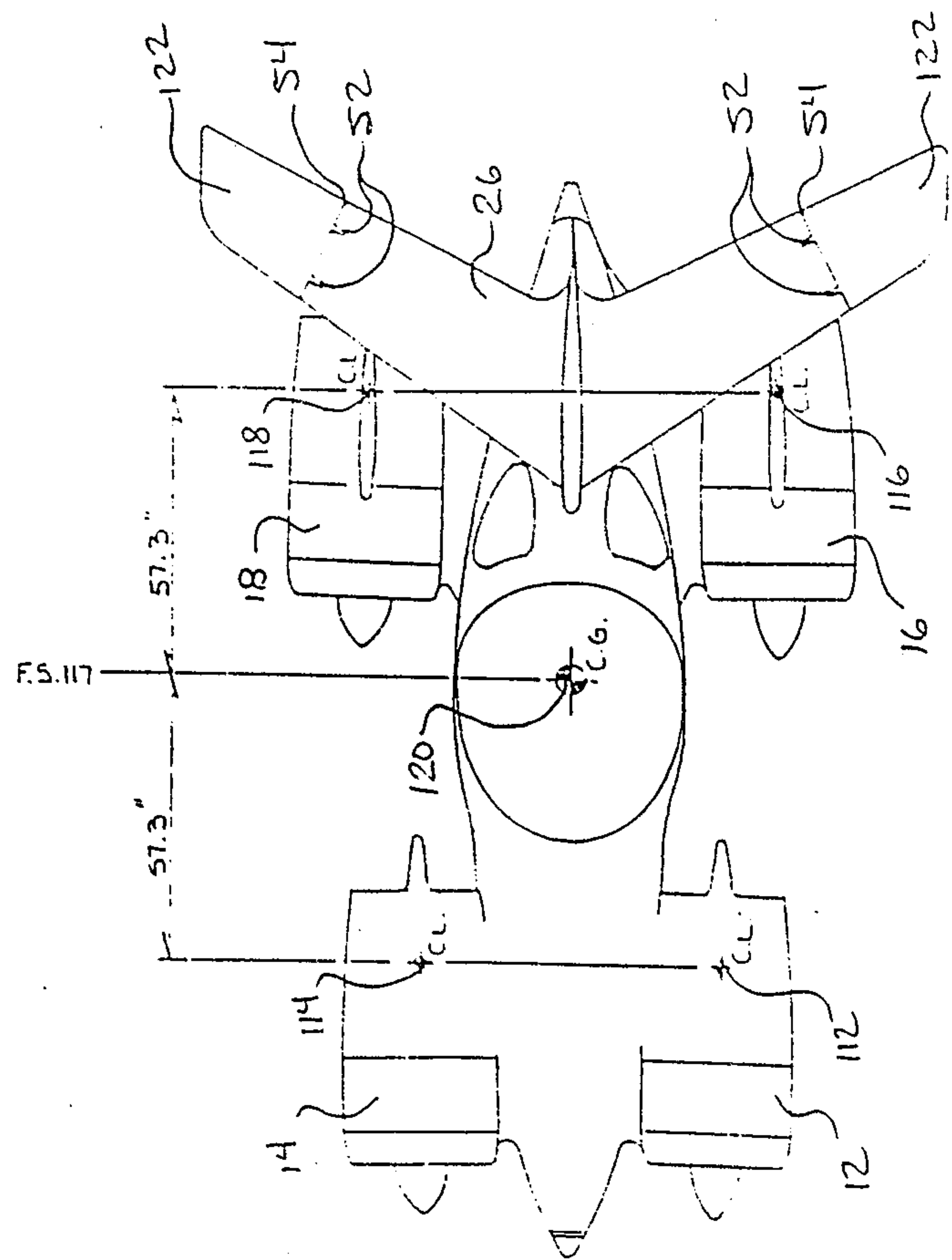
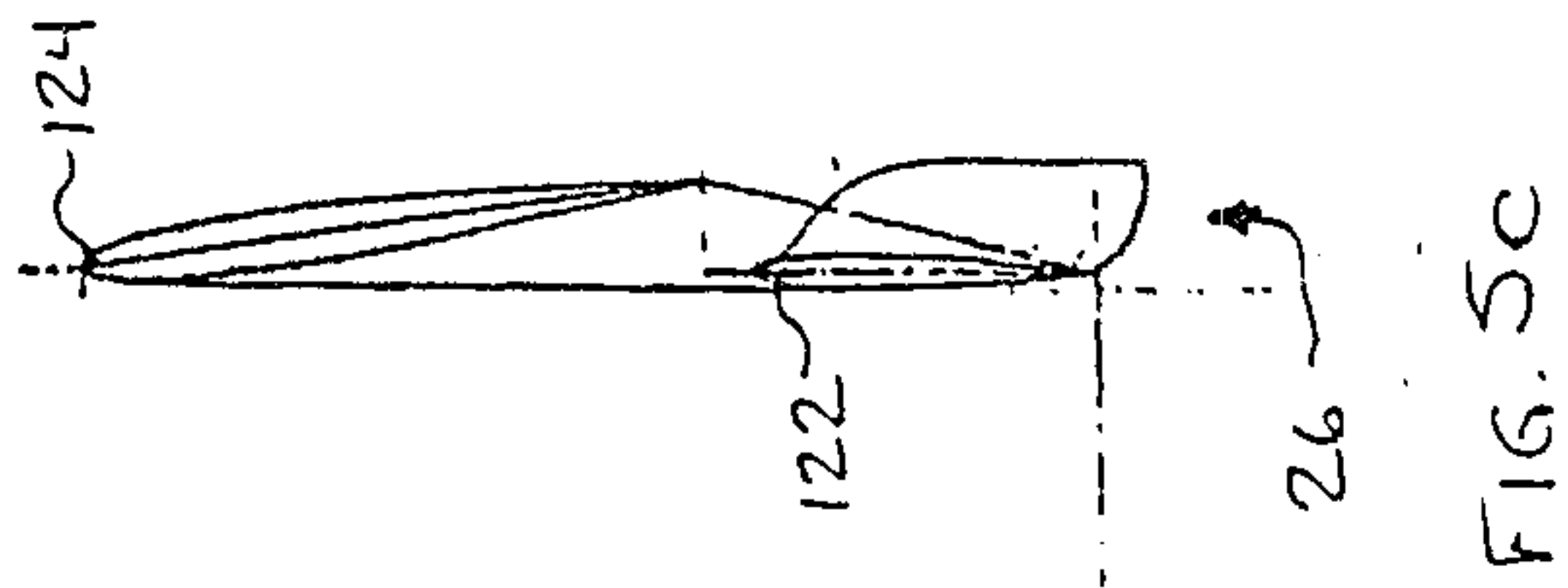
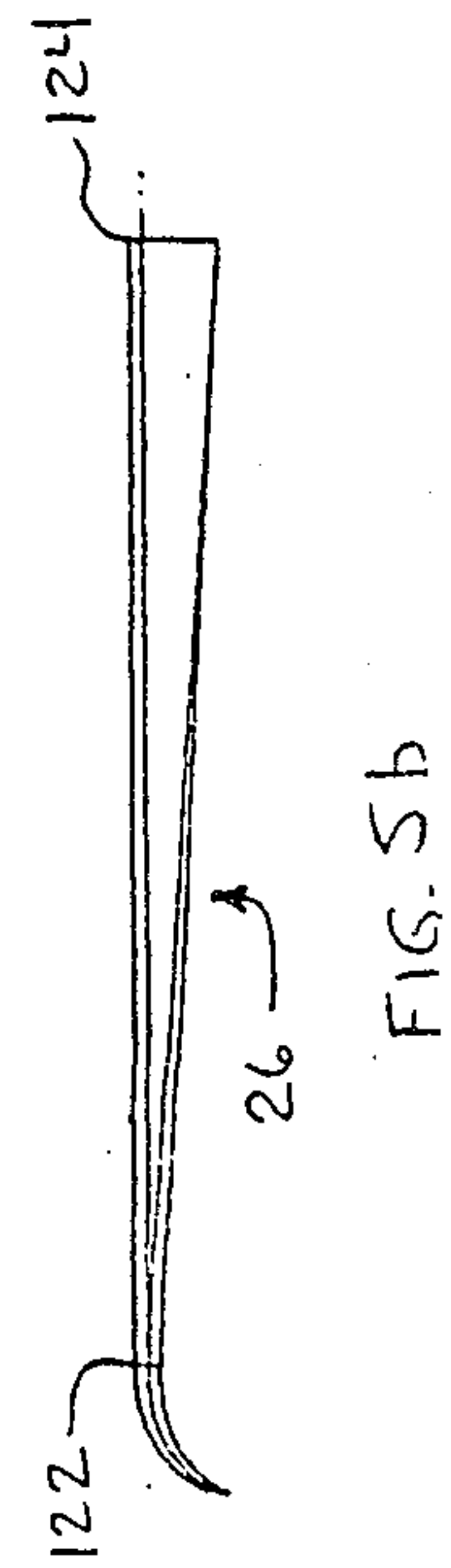
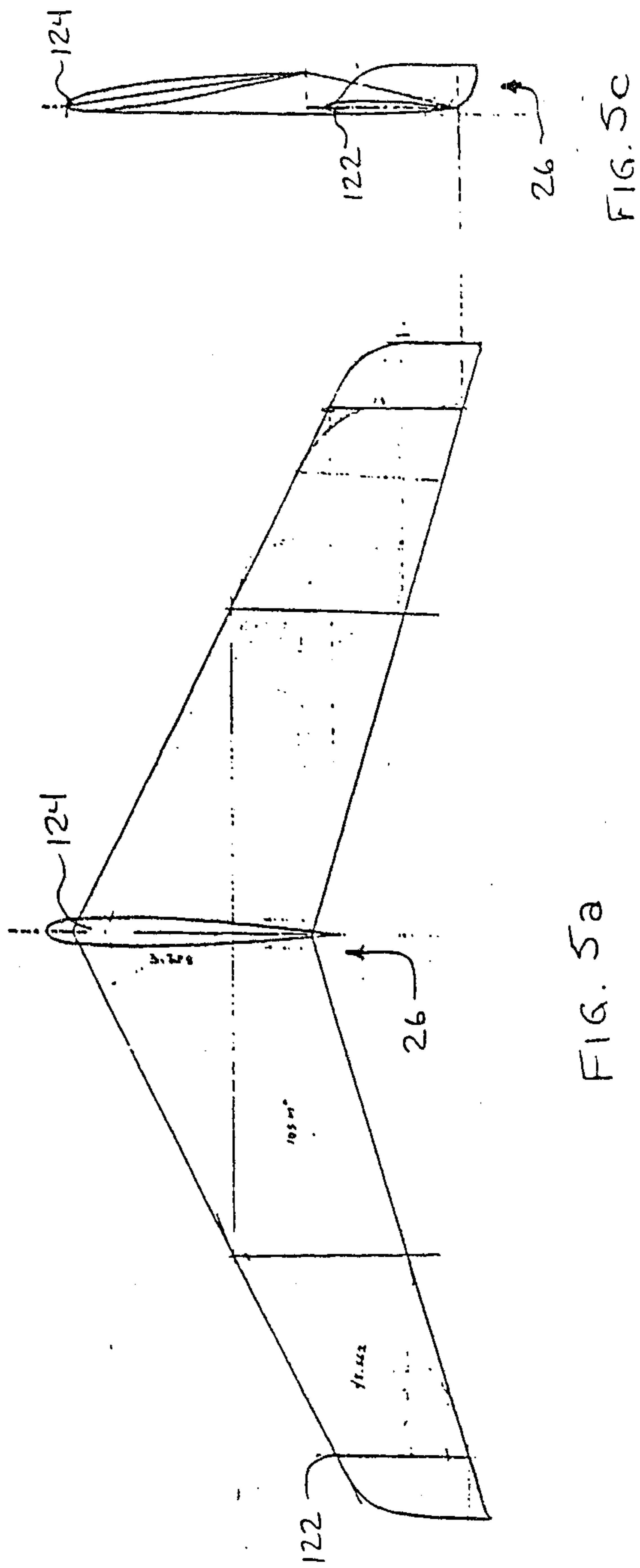


FIG. 4.



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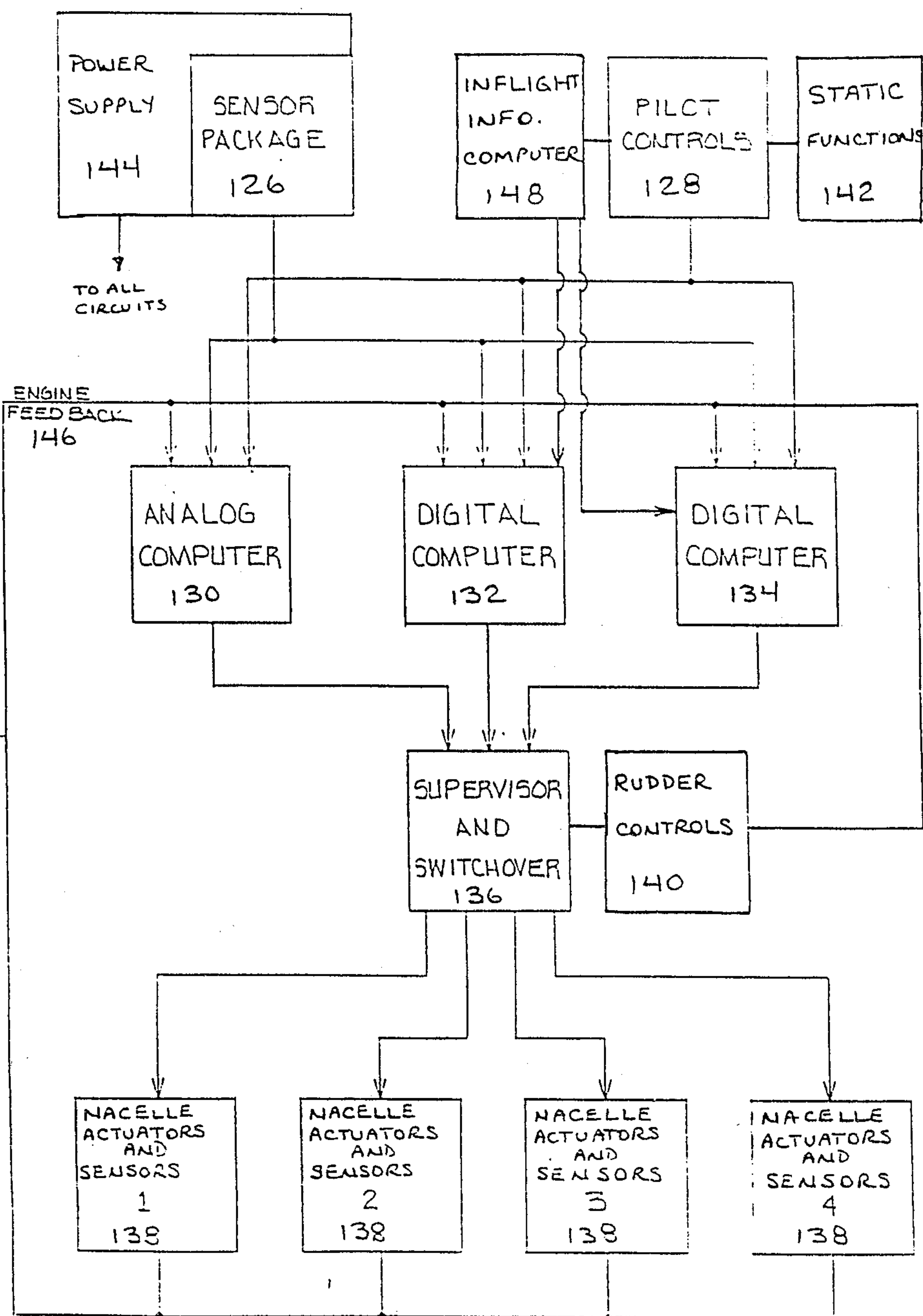
TRIPLE FLIGHT CONTROL SYSTEM

FIG. 6a

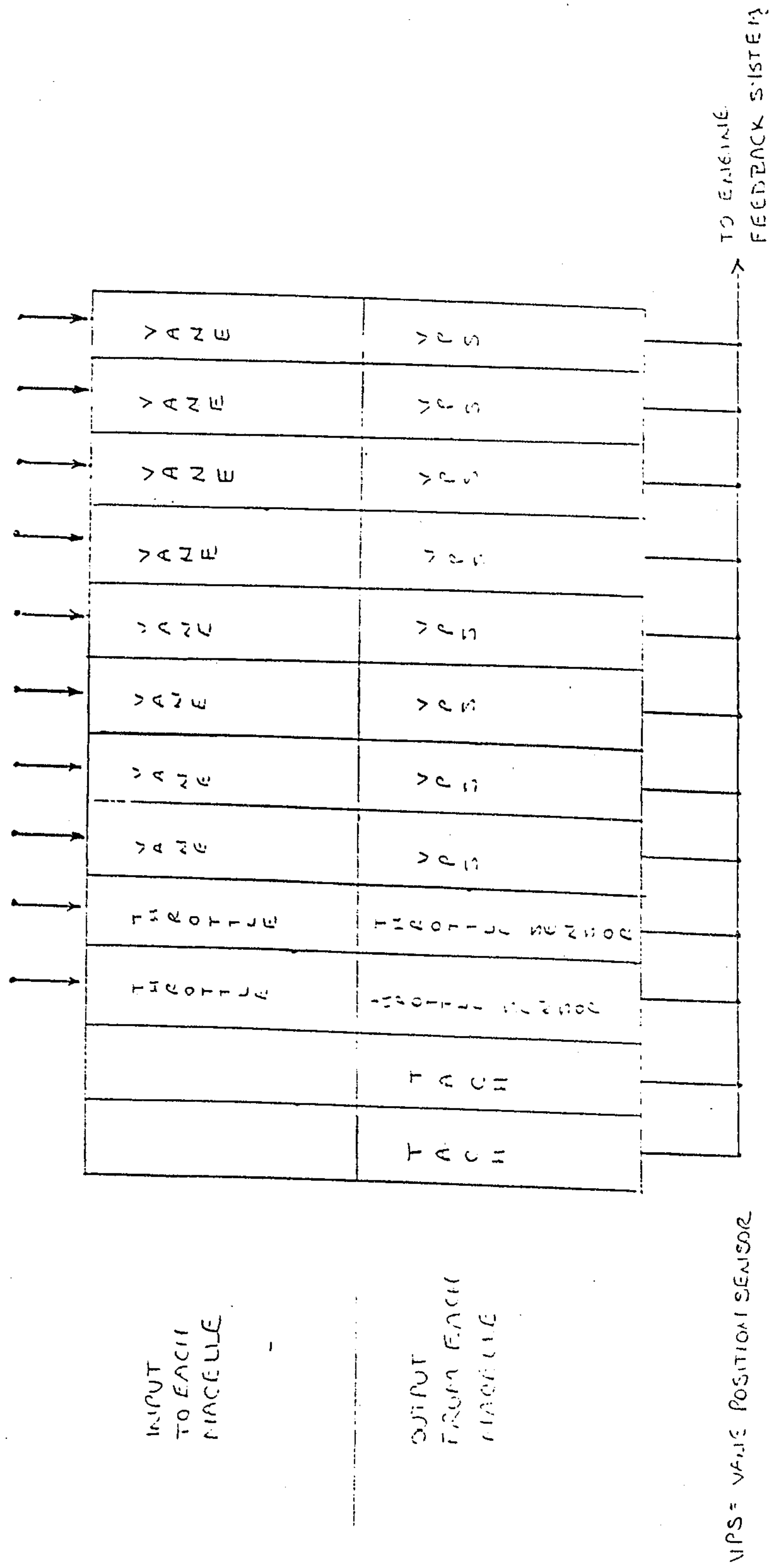
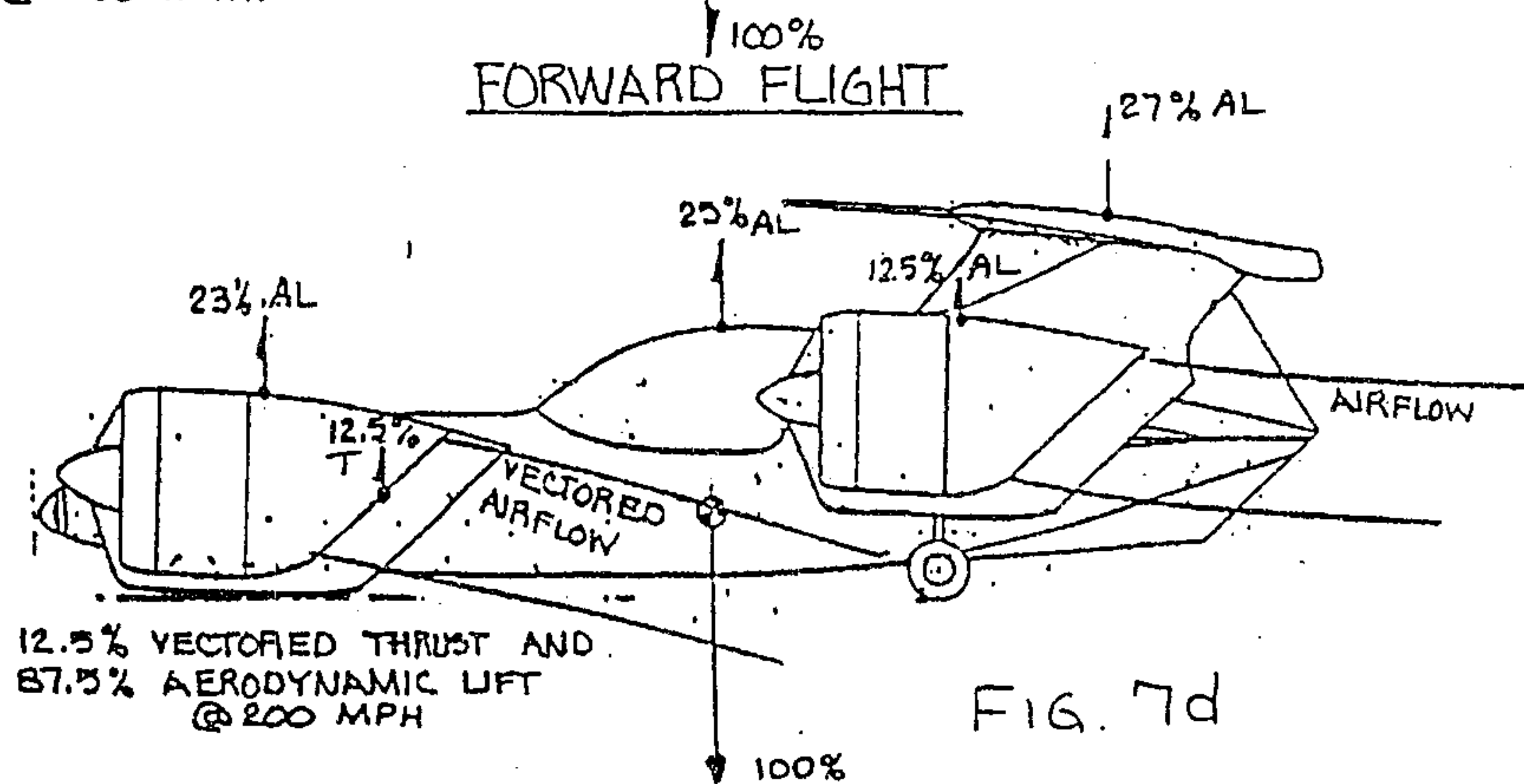
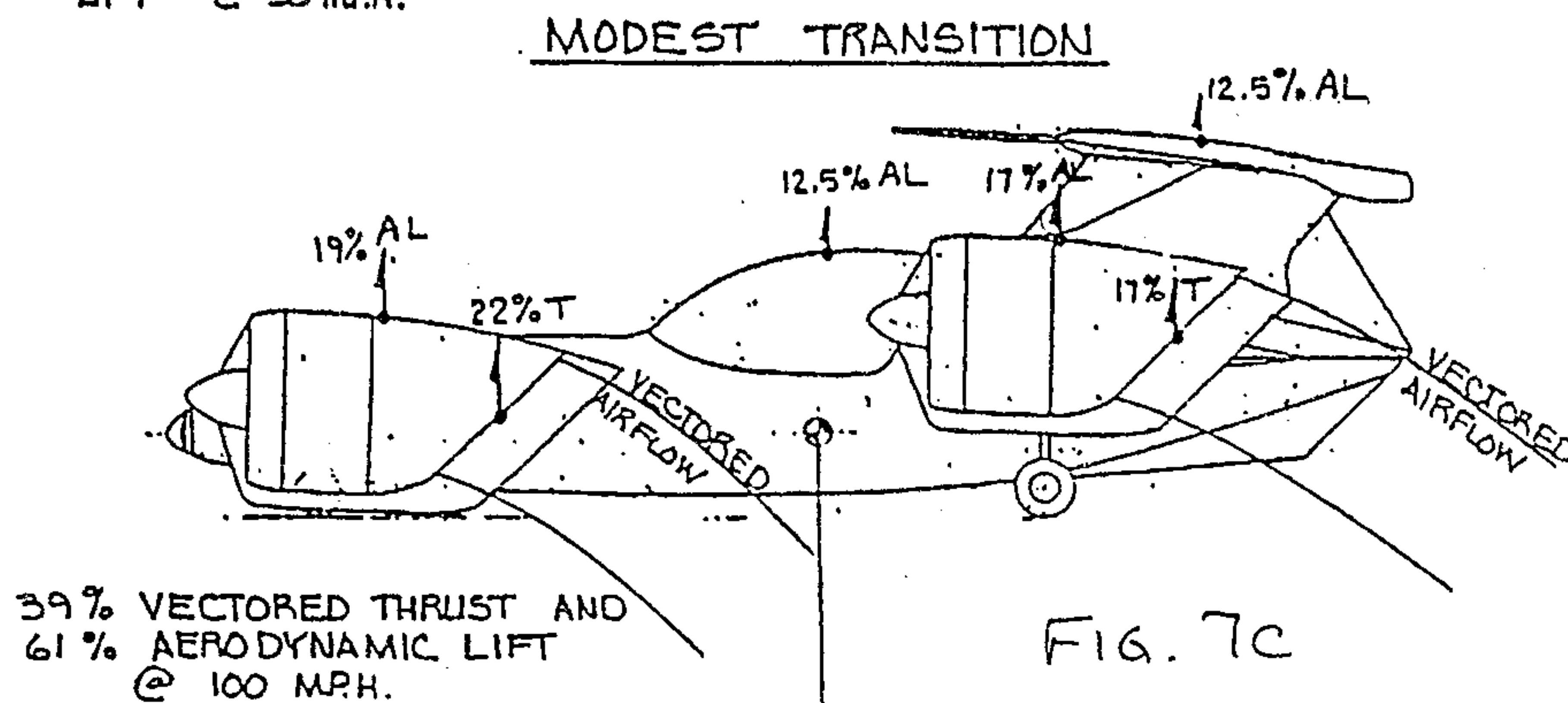
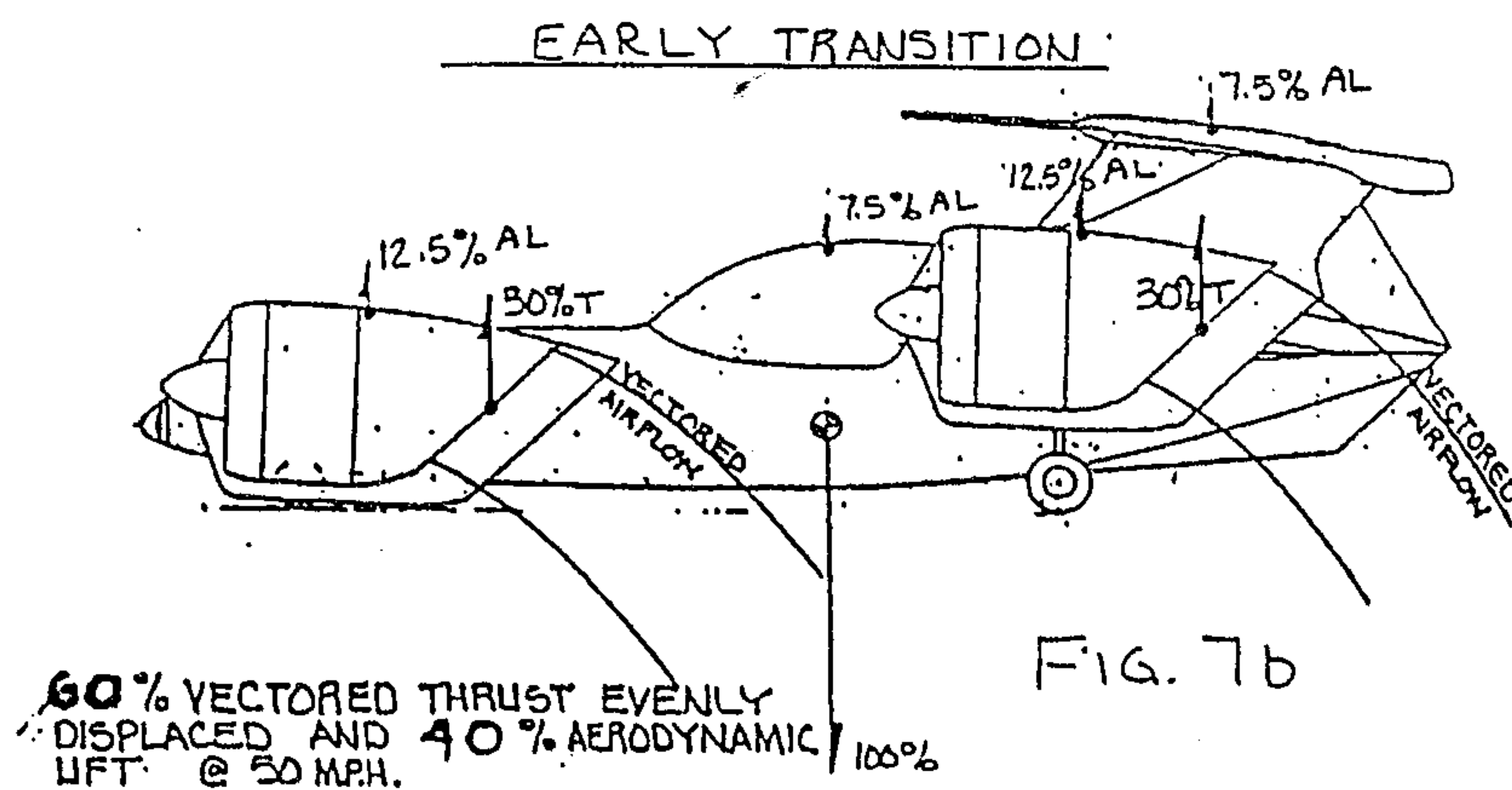
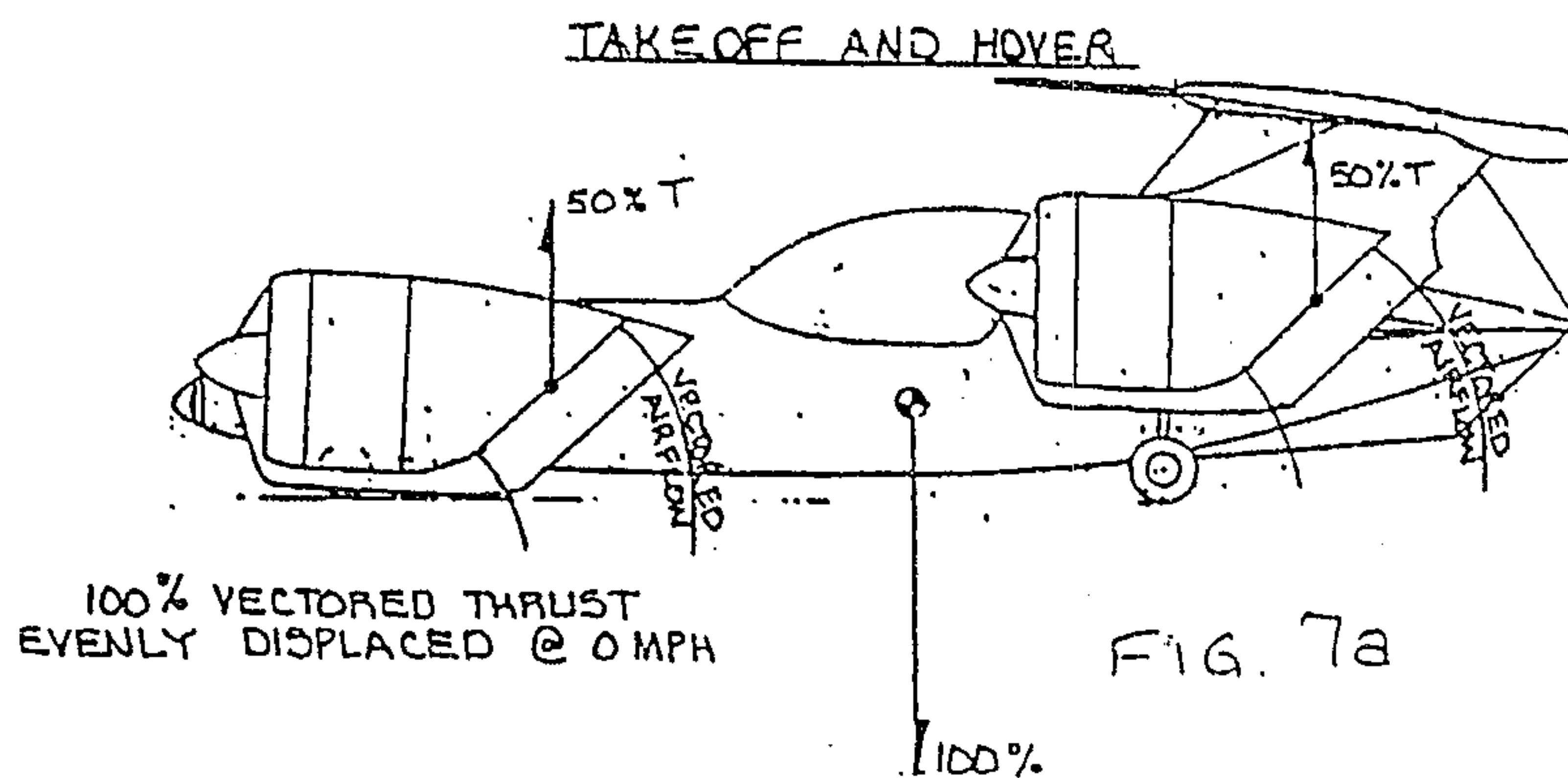


FIG. 6b

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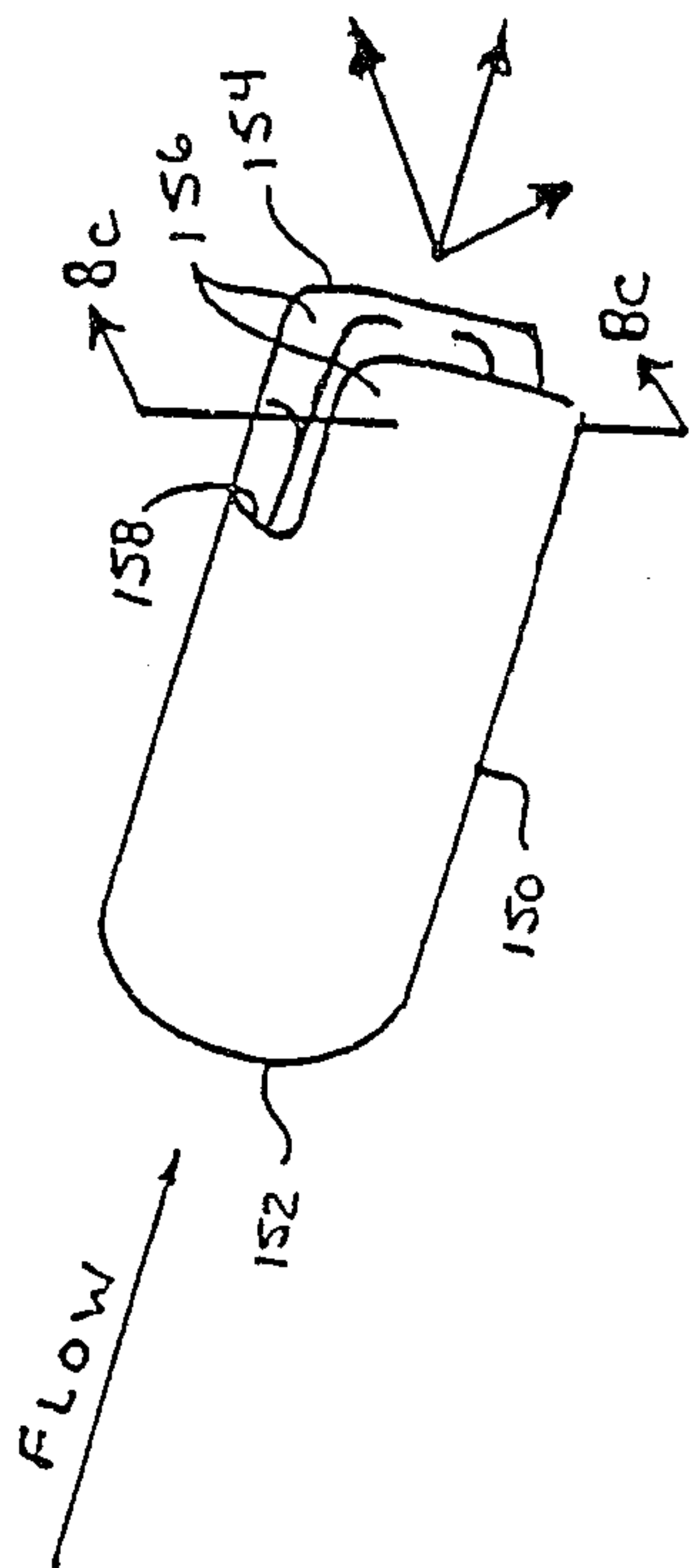


FIG 8a

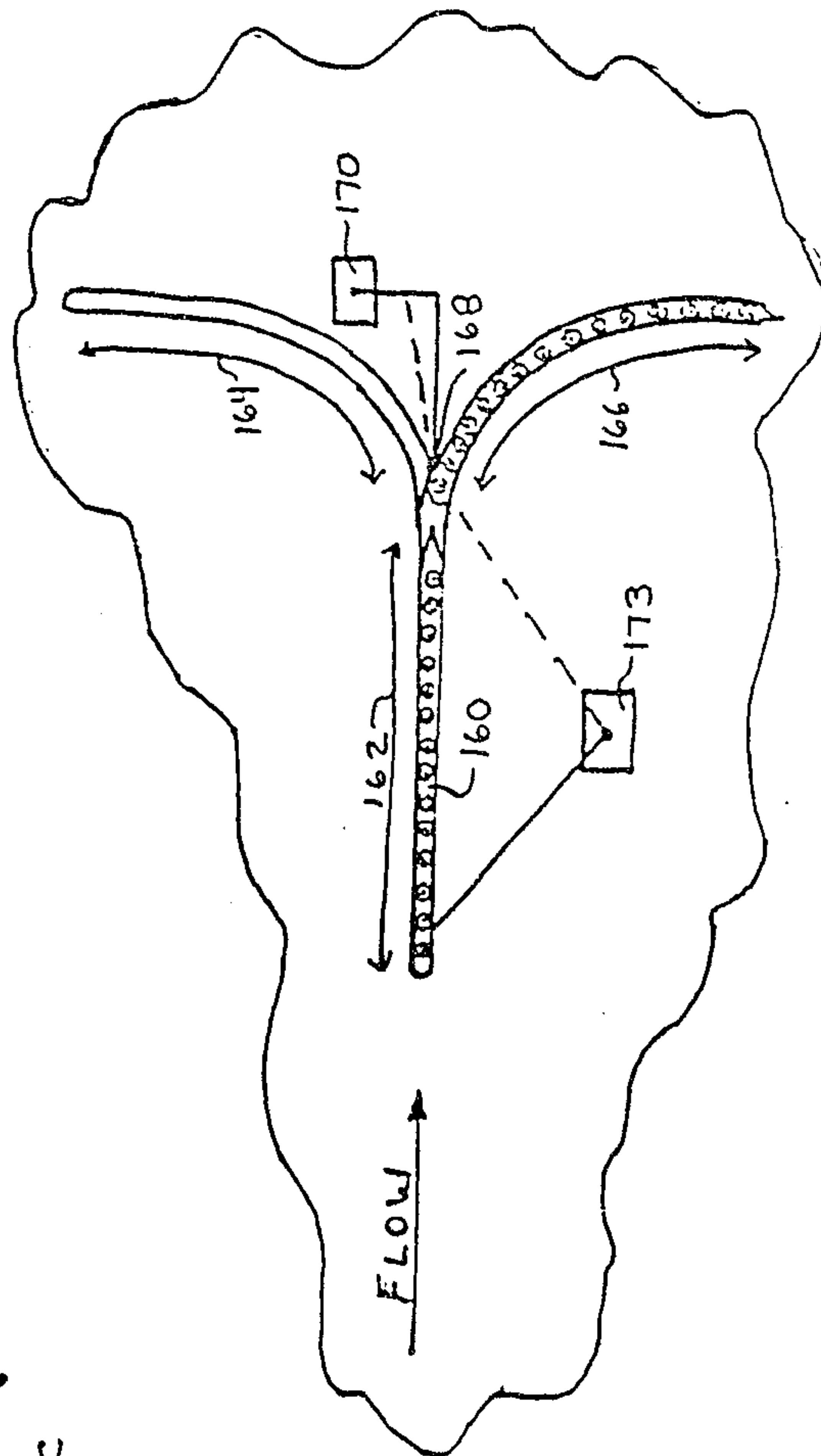


FIG 8b

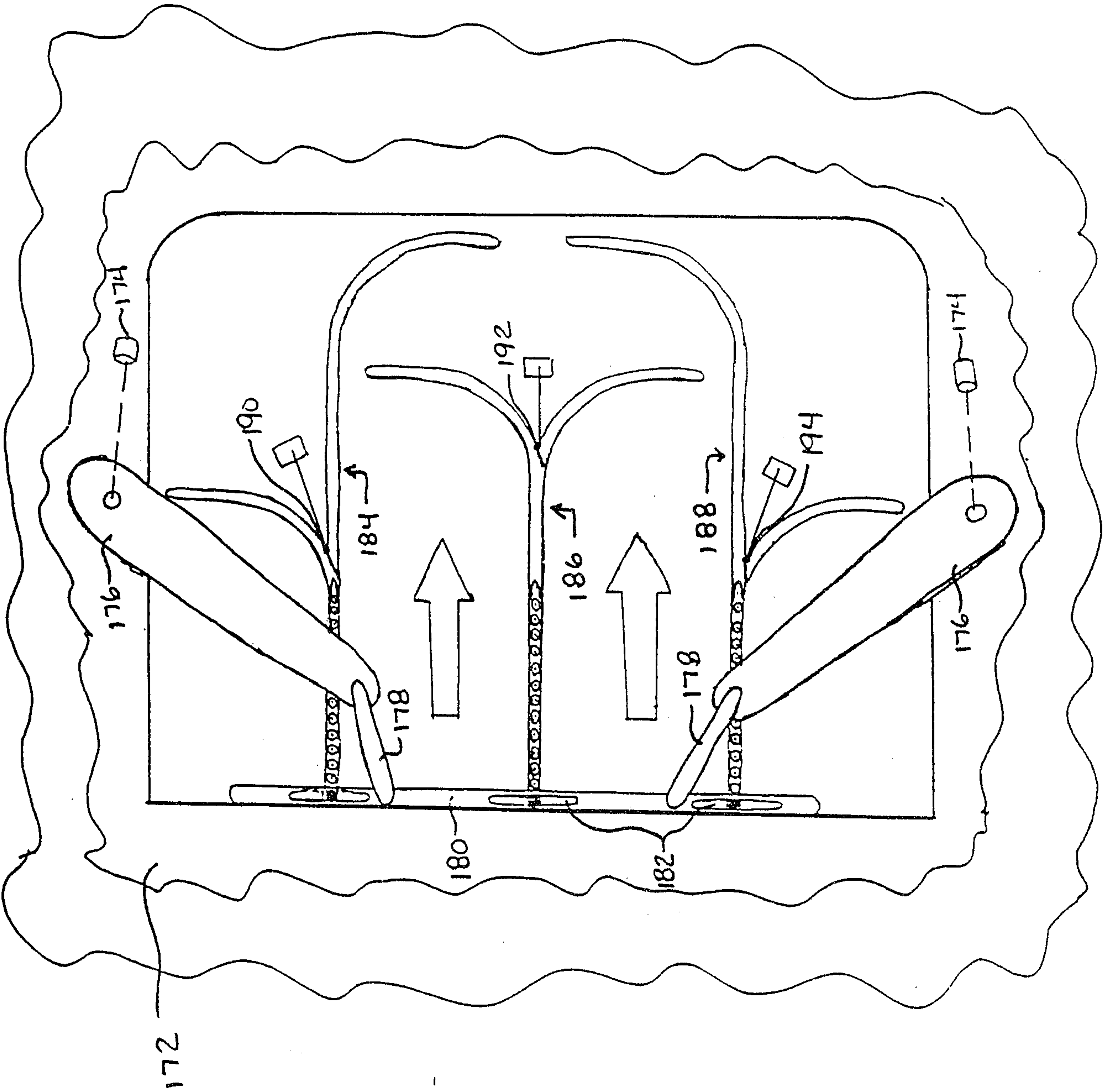


FIG. 8c

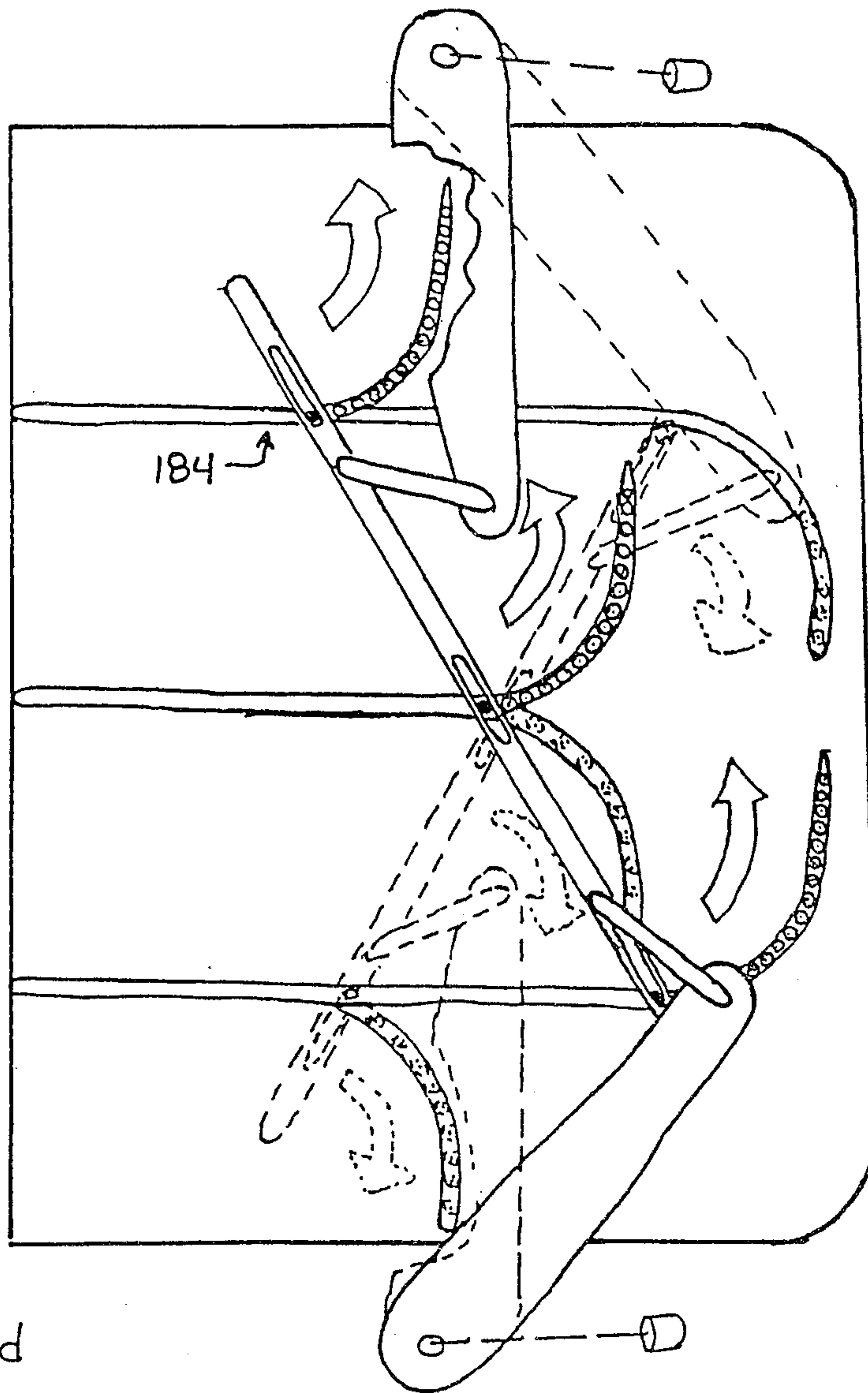


FIG 8d