(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 August 2008 (28.08.2008)

PCT

(10) International Publication Number
WO 2008/103735 A2

(51) International Patent Classification:
B64C 3/20 (2006.01)

(21) International Application Number:
PCT/US2008/054427

(22) International Filing Date:
20 February 2008 (20.02.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/902,726 22 February 2007 (22.02.2007) US

(71) Applicant *(for all designated States except US)*: SNOW AVIATION INTERNATIONAL, INC. [US/US]; 7201 Paul Tibbets Street, Columbus, OH 43217 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: SNOW, Harry, T., Jr. [US/US]; Gahanna, OH (US).

(74) Agent: JOHNSTON, Roger, A.; Fay Sharpe LLP, 1100 Superior Avenue, 7th Floor, Cleveland, OH 44114 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

(54) Title: AIRCRAFT, AND RETROFIT COMPONENTS THEREFOR

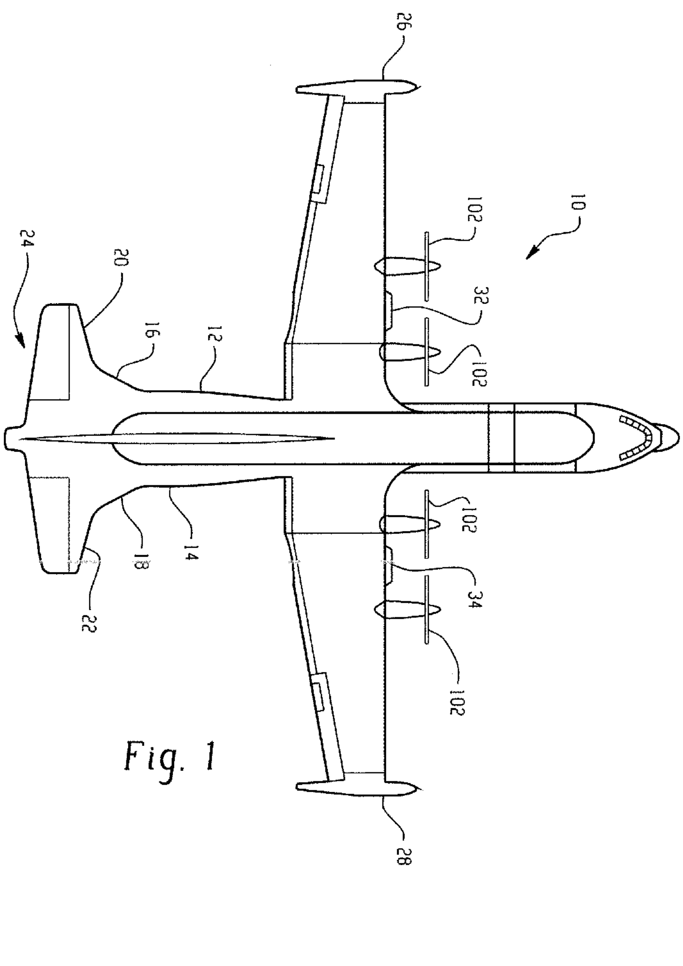

Fig. 1

(57) Abstract: Modification or retrofit components for an aircraft having wing mounted engines. A replacement wing torque box has thickened spar webs machined with raised bosses around holes in the web to lower stress concentration. The spar caps have the vertical web of their T-shape smoothly tapered spanwise to reduce stress concentration. The spar caps are attached to the webs and wing skins with interference fit rivets. An engine mount has a first space frame attached to the front of the wing torque box, or front spar with a first engine nacelle former disposed at the leading edge of first space forward and extending downwardly below the front spar. A second space frame formed of tension compression tubes extends forward from the first former to a second engine nacelle former. A tension-compression strut connects the first former to the rear spar to spread the loading on the torque box. An auxiliary strut stiffens the tension compression strut laterally. The aircraft may be modified to add horsals to the fuselage, which flare aft to connect to the stabilizers for increased pitch stability. A further modification to a high wing, multi-engine turbo-prop aircraft is the addition of eight bladed propellers.

WO 2008/103735 A2

AIRCRAFT, AND RETROFIT COMPONENTS THEREFOR

BACKGROUND

[0001] The present disclosure relates to modifications of propeller driven airplanes and particularly multi-engine aircraft having wing mounted engines, such as, for example high wing type aircraft employing turboprop propulsion systems for cargo carrying service and/or commercial passenger service. Aircraft of this type are known to have a service life of several decades and have found widespread usage for their short field landing and takeoff capabilities in addition to their very large payload with respect to the maximum gross takeoff weight.

[0002] One such aircraft having worldwide acceptance for it ruggedness, long service life and payload capacity is the Lockheed C-130 "Hercules" which has been in service for over 40 years. However, over such an extended period service life, problems have developed with the aircraft structure in part due to more powerful engines. Additionally, it has been desired to improve the flight characteristics of the aircraft to optimize the increased engine power. In particular, aircraft of this type have often employed a wing employing a torque box formed of a front and rear spar with the spar utilizing a sheet web with spar caps riveted thereto and with upper and lower wing skins riveted to the spark caps. The aforesaid type of air craft typically have the wing mounted engines attached to the front face of the torque box by attachment to the front spar and extending in cantilever forward of the wing leading edge. Over the extended service life, problems have been encountered with stress cracking in the spar webs and caps where the aircraft is operated at maximum gross weight for a substantial percentage of the flight time. Problems have also been encountered with stress cracking at the points where the engine mounts are attached to the wing torque box or spar. In addition, the aluminum alloys employed for the spar webs, caps and wing skins such as 7075-T6 aluminum have experienced stress corrosion cracking resulting in shortened fatigue life of the wing structure.

[0003] Thus, it has been desired to provide a way or means of modifying or retrofitting certain structural components of aircraft having wing mounted engines to improve the fatigue life and longevity of the aircraft in service.

BRIEF DESCRIPTION

[0004] The present disclosure presents modifications or retrofits to a multi-engine cargo or commercial airplane of the type having wing mounted engines and particular turbine-propeller powered aircraft. The modifications may be performed to existing aircraft after an extended period in service and are intended to increase the fatigue resistance and increase the service life of the aircraft.

[0005] One modification which may be made to the aircraft wing is replacement of the central and/or outboard torque boxes in the wing with torque boxes having an improved front and rear spar construction and structural elements formed of material with improved fatigue resistance. The front and rear spars may be formed of webs of increased thickness having bosses formed thereon by machining away material surrounding the boss thus leaving integrally formed bosses through which apertures may be formed for passage of fasteners or auxiliary items such as hydraulic tubing in a manner reducing the stress concentration about the aperture. The spar caps are formed with increased radius fillets between the web and flanges of the spar cap; and, the upper and lower wing skins may be riveted to the spar caps and the caps to the webs with interference fit rivets. In addition, vertical stiffeners having a T-shaped cross-section may be employed on the spar web for increased spanwise bending resistance of the spar. In the present practice, it has been found satisfactory to employ solution heat treated aluminum for the spar webs and caps; and, in the present practice 7075-T7351 or 7075-6511 temper material has been found satisfactory. However, other suitable materials may be employed that have greater resistance to stress corrosion cracking than 7075-T6 material.

[0006] In addition, the spar caps of generally T-shaped configuration have the vertical web portion thereof tapered smoothly, and generally linearly, in the spanwise direction to minimize stress concentrations in the areas surrounding the riveted attachment to the spar web.

[0007] The improved engine mount structure of the presently proposed modification for retrofit to the aircraft utilizes a pair of spaced trusses with diagonal bracing forming a first space frame attached to the front face of the torque box or front spar with extending forward therefrom and with a first engine nacelle former or bulkhead attached to the forward edge of the first space frame. A second space frame of tubular tension compression members is attached to the front face of the first nacelle former and extends forward with a second nacelle former attached to the front or leading edge of the second space frame. A tension compression strut is attached to the first nacelle former or the leading edge of the truss; and, the tension compression strut extends aftward and has the aft end thereof connected to the torque box at a location aft of the front spar, such as to the rear spar. A downwardly extending strut may be provided from the front edge of the torque box or the front spar downwardly to the aftward extending tension-compression strut to provide lateral stability to the tension-compression strut. The first and second engine nacelle formers have cutouts therein for receiving the engine. The engine mount structure presented herein thus provides additional strengthening of the attachment to the torque box and reduces the loads and thus stress concentrations at any one of the attachment points.

[0008] A further modification of existing aircraft of the type having wing mounted turbine engines driving the propeller through a speed reducer, particularly the C-130 Aircraft, is the replacement of the four or six bladed propeller with eight bladed propellers for reducing the propeller rotational speed (rpm) and reducing interruption of power pulses from the blades which reduces the disturbance to the airflow over the wing surface and increases the lift. Additionally, the lower speed eight bladed propeller reduces the vibration on the airframe.

[0009] In another aspect of the invention, laterally extending fins are provided between the wing and the empennage extending outwardly from the fuselage and flaring in an aftwise direction to connect with the horizontal stabilizer for providing additional stability of the aircraft about its pitching axis.

[0010] An optional modification which may be employed is relocating the auxiliary fuel tanks from the wing pylons, to the wing tips; and, the wing pylons may then have additional turbine engines attached thereto if desired.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIGURE 1 is a plan view of the aircraft presented herein showing the laterally extending fins or horsals on the fuselage flaring into the stabilizer;

[0012] FIGURE 2 is an isometric view of a portion of the wing torque box of the present modification;

[0013] FIGURE 3 is an enlarged view of a portion of FIGURE 2;

[0014] FIGURE 4 is a section view taken along section indicating lines 4-4 of FIGURE 3;

[0015] FIGURE 5 is a pictorial view of the engine mount modification of the present disclosure;

[0016] FIGURE 6 is a view showing a turbo fan engine mounted to the wing tank pylon;

[0017] FIGURE 7 is a section view taken along section indicating lines 7-7 of FIGURE 3; and,

[0018] FIGURE 8 is a view of the eight bladed propeller modification.

DETAILED DESCRIPTION

[0019] Referring to FIGURE 1, a cargo plane having turbo prop engines mounted on each wing, such as a C-130, is illustrated generally at 10 and has a pair of oppositely disposed laterally outwardly extending fins 12, 14 provided along the fuselage aft of the wings, the fins 12, 14 having flared portions 16, 18 respectively formed thereon which intersect the horizontal stabilizers 20, 22 which form part of the empennage indicated generally at 24. The fuselage fins or horsals 12, 14 with the flared portion 16, 18 are added to the aircraft to increase the stability about the pitching axis of the aircraft.

[0020] With reference to FIGURE 1 and FIGURE 6, the existing wing pylons on the wing, previously utilized for mounting auxiliary fuel tanks, one of which is shown at 30 have optional turbo fan engines 32, 34 as shown in FIGURE 1.

[0021] Referring to FIGURES 2, 3 and 7, the modified torque box for the wing structure is indicated generally at 40 and includes a spanwise extending front spar indicated generally at 42 and a spanwise extending rear spar indicated generally at 44 disposed in fore and aft spaced relationship with upper and lower wing skins 46, 48 attached thereto as will hereinafter be described. The spars 42, 44 each have a web respectively 47, 49 which is formed with increased thickness; and, it has raised bosses such as boss 50 formed integrally thereon by machining away material from the web 47, 49 in the area surrounding the boss. The bosses have apertures such as aperture 52 formed therein for accommodating fasteners and/or auxiliary fittings such as hydraulic tubes and control cables; and, the bosses serve to reduce stress concentrations around the apertures.

[0022] The spars 42, 44 have vertical stiffeners such as stiffener 54 provided thereon in spanwise spaced relationship which are attached to the webs 47, 49 by riveting and which stiffeners have a T-shaped configuration for providing additional stiffness to the spar webs 47, 49.

[0023] It will be understood that the torque box 40 contains spanwise spaced wing ribs for forming the airfoil shape of the upper and lower wing surfaces which ribs have been omitted from the drawing for simplicity of illustration.

[0024] Each of the spars 42, 44 has an upper and lower spar cap denoted respectively 56, 58 and 60, 62 having a generally T-shaped configuration in transverse section and attached thereto along the upper and lower edges of the webs 47, 49 by riveting. The spar caps are formed integrally as a one piece member, such as, for example, by extrusion, and have increased-radius fillets between the flanges of the T-shape and the vertically extending central web portion. The spar caps are subsequently machined as will be further described. For additional reduction of stress concentration and structural strength, the riveting of the spar caps may employ rivets with an interference fit in the range of about .001 to .003 inches (.025-.075mm).

[0025] Referring to FIGURE 3, the upper wing skin 46 is shown as attached to one of the flanges of the upper spar caps 56, 60 by two rows of rivets indicated generally at 62, 64 in the spanwise direction.

[0026] Referring to FIGURE 4, a further aspect of the attachment of the spar caps to the webs is illustrated for the attachment of rear spar cap 60 to the upper skin 46 is shown in enlarged detail wherein the rivets 64 are flush on the upper surface of the skin. The spar cap 60 is attached to the rear spar web 49 by two rows of rivets indicated generally at 66 which may also be in interference fit as described above.

[0027] A downwardly extending integrally formed web portion 68 of the T-shape of the rear spar cap 60 is shown as smoothly tapering in the spanwise direction, such as by linear tapering, as opposed to step wise reduction in the vertical direction in the existing aircraft, particularly the C-130 aircraft. The smooth tapering of the spar cap web 68 thus reduces stress concentration about the rivets 66 and increases the structural strength of the torque box 40. The attachment of the spar cap 56 onto front spar web 47 is similar to that of the rear spar 44.

[0028] Referring to FIGURE 5, the modified engine mount of the present modification or retrofit kit is illustrated generally at 70 and is shown attached to the front face of the wing torque box or front spar 42 and extends forwardly therefrom in cantilever relationship.

[0029] The engine mount 70 includes a pair of trusses 72, 74 which are disposed in spanwise spaced relationship with a first engine nacelle former or bulkhead 76 disposed at the leading end or edge of the trusses 72, 74. The trusses 72, 74 are diagonally braced by tension compression members 78, 80; and, the combination of trusses 72, 74 and the diagonal braces 78, 80 effectively form a first space frame.

[0030] The first engine nacelle former 76 extends downwardly below the spar 42 and has a pair of elongated tension compression members or struts attached thereto, with one such member 82 illustrated in FIGURE 5. The forward or leading end of the tension compression member or strut 82 is denoted by reference numeral 84 and is attached to the first former 76. The aft end of the strut 82 is attached to the wing torque box 40 at a position aft of the front spar 42; and, the strut 82 may be attached to the rear spar 44 at or near its lower edge. A secondary strut 86 has one end attached to the lower edge of front spar 42 and extends downwardly to the strut 82 as denoted by reference numeral 86. The secondary strut 86 may have its upper end attached either to the spar or the truss 74; and, strut 86 and thus provides lateral stability to the strut 82.

[0031] A second space frame indicated generally at 90 is attached to the forward face of the first former 76 and extends forward therefrom in cantilever arrangement to a second engine nacelle former 92 attached thereto. The space frame 90 is comprised of a plurality of tension compression members, such as members 94, 96, 98, 100 on the outboard side of the engine nacelle, it being understood that corresponding set of tubular members are provided on the inboard of the nacelle. In the present practice it has been found satisfactory to form the tension-compression members of the space frame 90 from tubular metal. The first and second engine nacelle formers 76, 92 each have cutouts or voids therein for receiving the aircraft engine therein.

[0032] The engine mount of FIGURE 5 thus provides additional rigidity to the mount and distributes the mounting loads over the front spar and the rear spar and reduces the stress concentrations at the mounting points thereon.

[0033] Referring to FIGURE 8, another modification is illustrated, wherein eight bladed propellers 102 have been installed to reduce the propeller rpm and reduce pressure pulses of air flowing over the wing surface particularly on a C-130 aircraft. This keeps propeller tips below sonic speed, particularly at higher altitudes and thus increases the thrust and propulsive efficiency of the propellers, resulting in higher cruising speeds at higher altitudes. The propeller v blades may have a curved configuration and may be formed of non-metallic composite material with metal strips provided on the leading edge of the blade for protecting the composite material against impact with solid particles.

[0100] The exemplary embodiment has been described with reference to the preferred embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the exemplary embodiment be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

CLAIMS:

1. A torque box for an aircraft wing comprising:

(a) front and rear spanwise extending spar disposed in spaced relationship;

(b) an upper wing skin attached to the upper portion of said front and rear spur;

(c) a lower wing skin attached to the lower portion of said front and rear spar; and,

(d) said front and rear spars each having a vertically disposed web and at least one spar cap attached to the web extending spanwise along the spar, wherein the spar cap has a generally T-shaped configuration in transverse section and is formed integrally as a one piece member with the downwardly extending web portion of said T-shape tapered in the spanwise direction.

2. The torque box defined in claim 1, wherein the spar web has a plurality of integrally formed raised bosses formed integrally therewith as a one-piece member with the bosses each apertured for receiving a member therethrough.

3. The torque box defined in claim 2, wherein said skins are attached to the caps with fasteners received therein in interference fit.

4. The torque box defined in claim 3, wherein the spar caps are attached to the web with fasteners an interference fit.

5. The torque box defined in claim 1, wherein said spar web and bosses are formed of sheet stock machined to final configuration.

6. The torque box defined in claim 1, wherein said spar cap is formed of extruded and solution heat treated aluminum.

7. The torque box defined in claim 1, wherein said spar cap is formed of 7075 aluminum in one of T7351 and T6511 tempered condition.

8. The torque box defined in claim 1, wherein said front and rear spare extend spanwise in generally parallel relationship.

9. The torque box defined in claim 1, wherein said front and rear spar extend in spanwise tapering spaced relationship.

10. The torque box defined in claim 1, wherein said tapered portion of the spar cap T-shape is spanwise smooth tapered continuously.

11. The torque box defined in claim 1, wherein said tapered portion of the spar cap T-shape is linearly tapered.

12. An aircraft comprising:

(a) a fuselage having a forward and aft end with a port and starboard wing extending from the fuselage and located intermediate the fore and aft end;

(b) an empennage attached to the aft end of the fuselage; and,

(c) a port and starboard fin extending laterally from the fuselage intermediate the wing and empennage and flaring in the outboard direction proceeding aftwise and intersecting stabilizer portions of the empennage.

13. The aircraft defined in claim 12, wherein the port and starboard fin are formed as forward extending inboard portions of the stabilizer portions of the empennage.

14. The aircraft defined in claim 12, wherein the port and starboard wing are mounted on the fuselage above the centerline thereof.

15. An engine mount structure for wing mounting an aircraft engine in cantilever from the leading edge of the wing;

(a) a first space frame for mounting to a front spar of the wing;

(b) a first engine nacelle former disposed at the forward end of the trusses;

(c) a second space frame formed of tension-compression members extending forward from the first bulkhead;

(d) a second engine nacelle former disposed at the forward end of the space frame; and,

(e) at least one elongated tension-compression member extending from said first former aftward and adapted for attachment to a rear wing spar.

16. The structure defined in claim 15, wherein said at least one elongated member includes a pair of spaced tubular members.

17. The structure defined in claim 15, wherein the first space frame includes a downwardly extending member connecting to said elongated tension-compression member.

18. The structure defined in claim 15, wherein the at least one tension-compression member of the space frame comprises a pair of spaced tubular members.

19. The structure defined in claim 15, further comprising a lateral stabilizing member extending from the trusses to the at least one tension-compression member intermediate the ends thereof.

20. The structure defined in claim 15, wherein said first space frame includes tubular members.

21. The structure defined in claim 20, wherein said tubular members are connected to a pair of spaced trusses.

22. The structure defined in claim 15, wherein said first and second formers include cut outs out receiving a turbine engine.

23. A method of providing a mount for an aircraft engine on an aircraft wing having a front and rear wing spar comprising:

(a) attaching a pair of forward extending first space to the front spar;

(b) disposing a first engine nacelle former at the forward end of the trusses;

(c) disposing a second space frame extending forward of the first former;

(d) disposing a second engine nacelle former at the forward end of the space frame;

(e) connecting a pair of spaced tension-compression members between the first former and the rear spar.

24. The method defined in claim 23, wherein the step of disposing a second space frame includes forming a space frame of tubular tension-compression members.

25. The method defined in claim 23, wherein the step of connecting a pair to tension-compression members includes connecting one end of a tubular member to the first former and the opposite end of the tubular member to the rear wing spar.

26. The method defined in claim 23, wherein the step of connecting a pair of tension-compression members includes providing a lateral stabilizing strut for the tension-compression members intermediate the ends thereof.

27. The method defined in claim 23, wherein the step of connecting a pair of tension-compression members includes a lateral stabilizing strut between the tension-compression members and the front spar.

28. A method of providing a mount for an aircraft engine or an aircraft wing having a spanwise torque box comprising:

(a) attaching a first space frame to the leading edge of the torque box;

(b) disposing a first engine nacelle former at the forward end of the first space frame;

(c) disposing a second space frame extending forward of the first former;

(d) disposing a second engine nacelle former at the forward end of the second space frame;

(e) connecting a pair of spaced tension-compression members between the first former and a location on the torque box aft of the leading edge thereof.

29. The method defined in claim 28, wherein the step of connecting the tension-compression members aft of the torque box leading edge includes connecting a forward end of the tension-compression members to the first former and an aft end to a rear spar member at the aft edge of the torque box.

30. The method defined in claim 29, further comprising connecting a lateral stabilizing member from the torque box proximate the leading edge to the tension-compression members.

31. The method defined in claim 28, wherein the step of connecting a pair of spaced tension-compression members includes connecting a pair of tubular struts.

32. The method defined in claim 28, wherein the step of disposing a second space frame includes disposing a space frame formed of tubular tension-compression members.

33. A multi-engine, high wing aircraft having wing mounted engines comprising:

(a) forward extending engine nacelles extending in cantilever from the wing; and,

(b) turbine engines mounted in the nacelles, each driving an eight bladed propeller through a speed reducer.

34. The aircraft defined in claim 33, further comprising fuel tanks mounted on the wing tips.

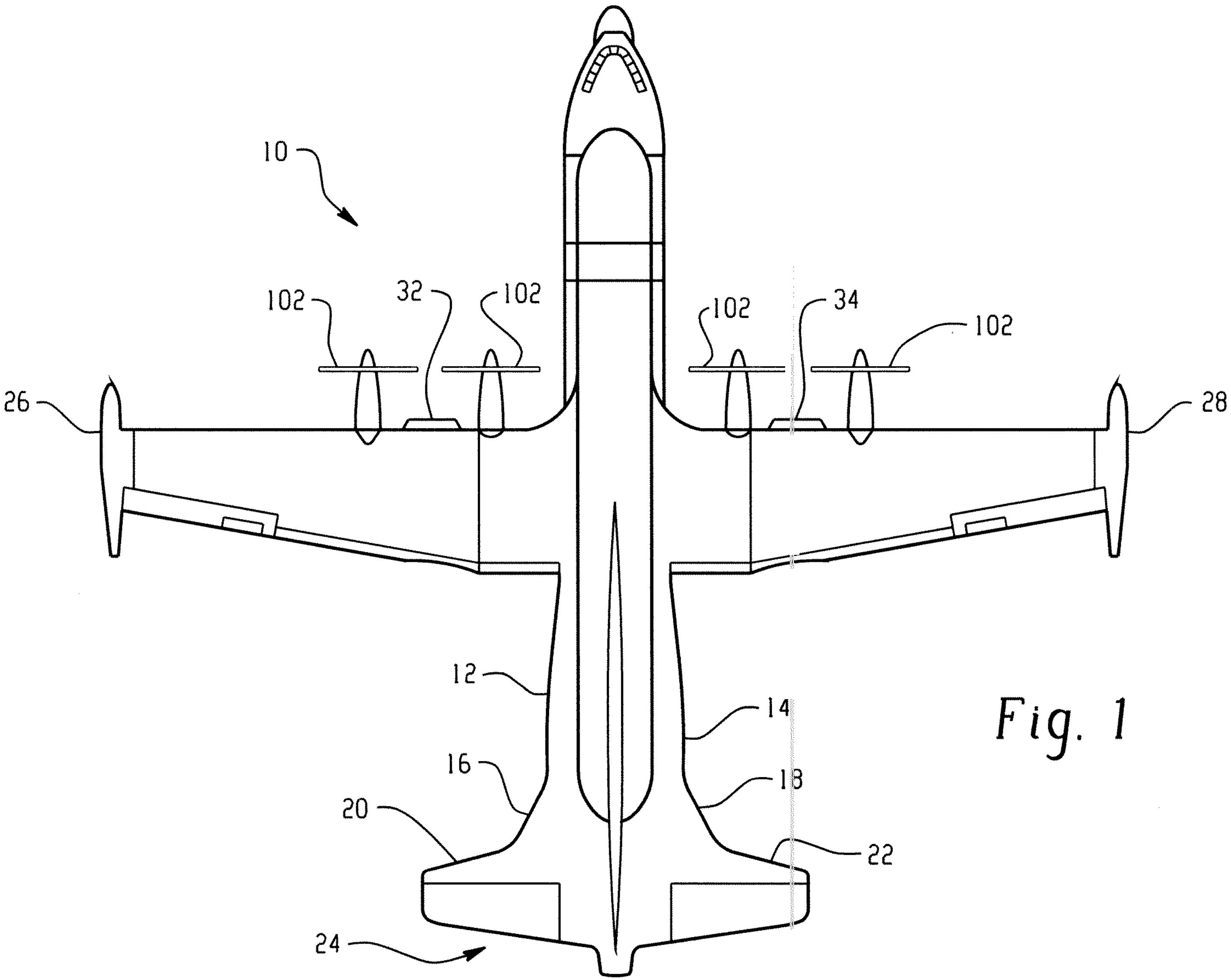

Fig. 1

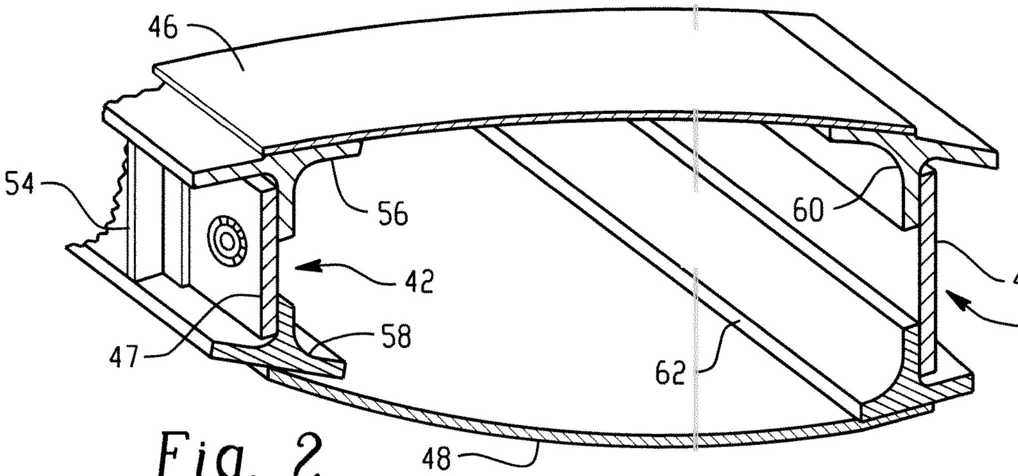
46
40
54
56
60
42
49
44
58
47
62
48

Fig. 2

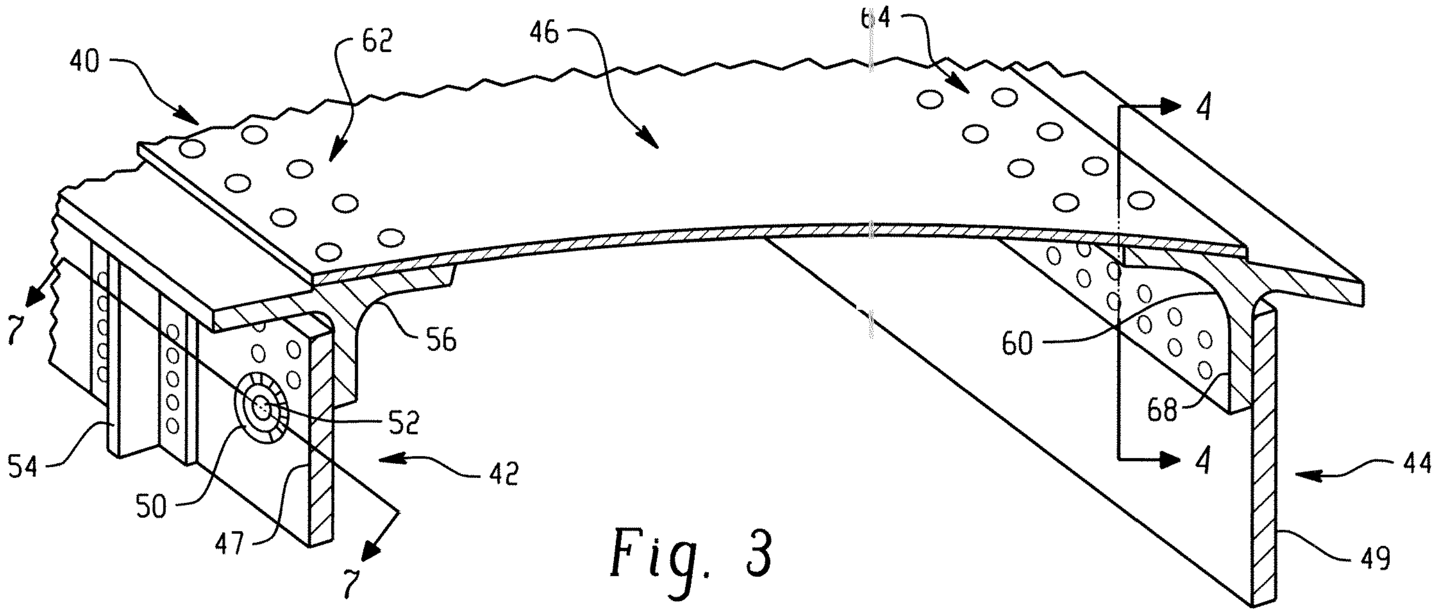
64
62
46
40
4
56
60
7
68
52
54
42
44
50
47
49
7
4

Fig. 3

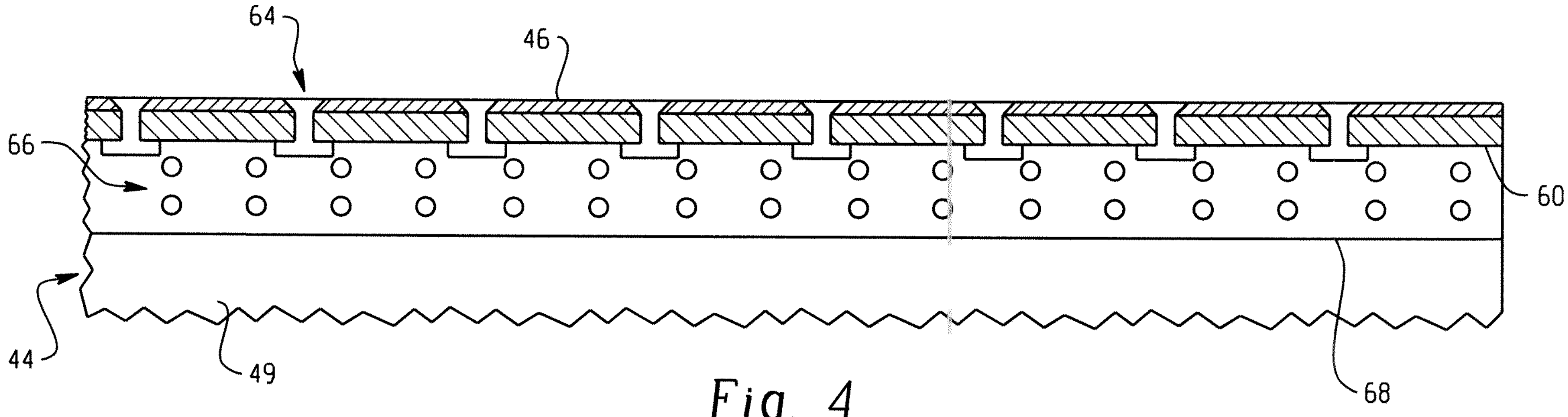

Fig. 4

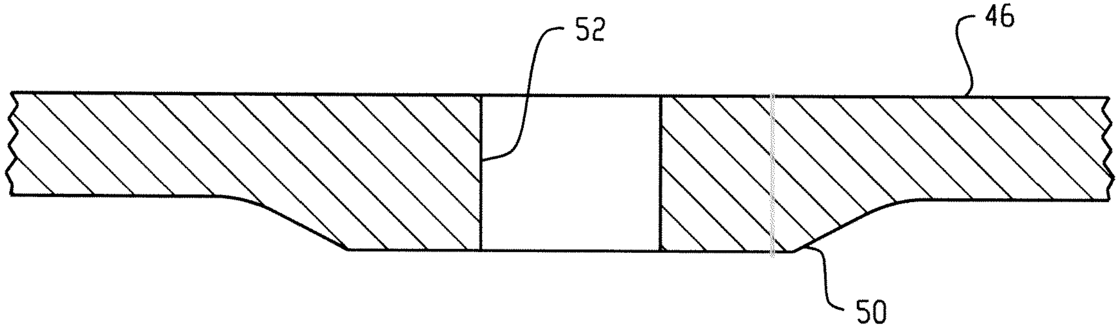

Fig. 7

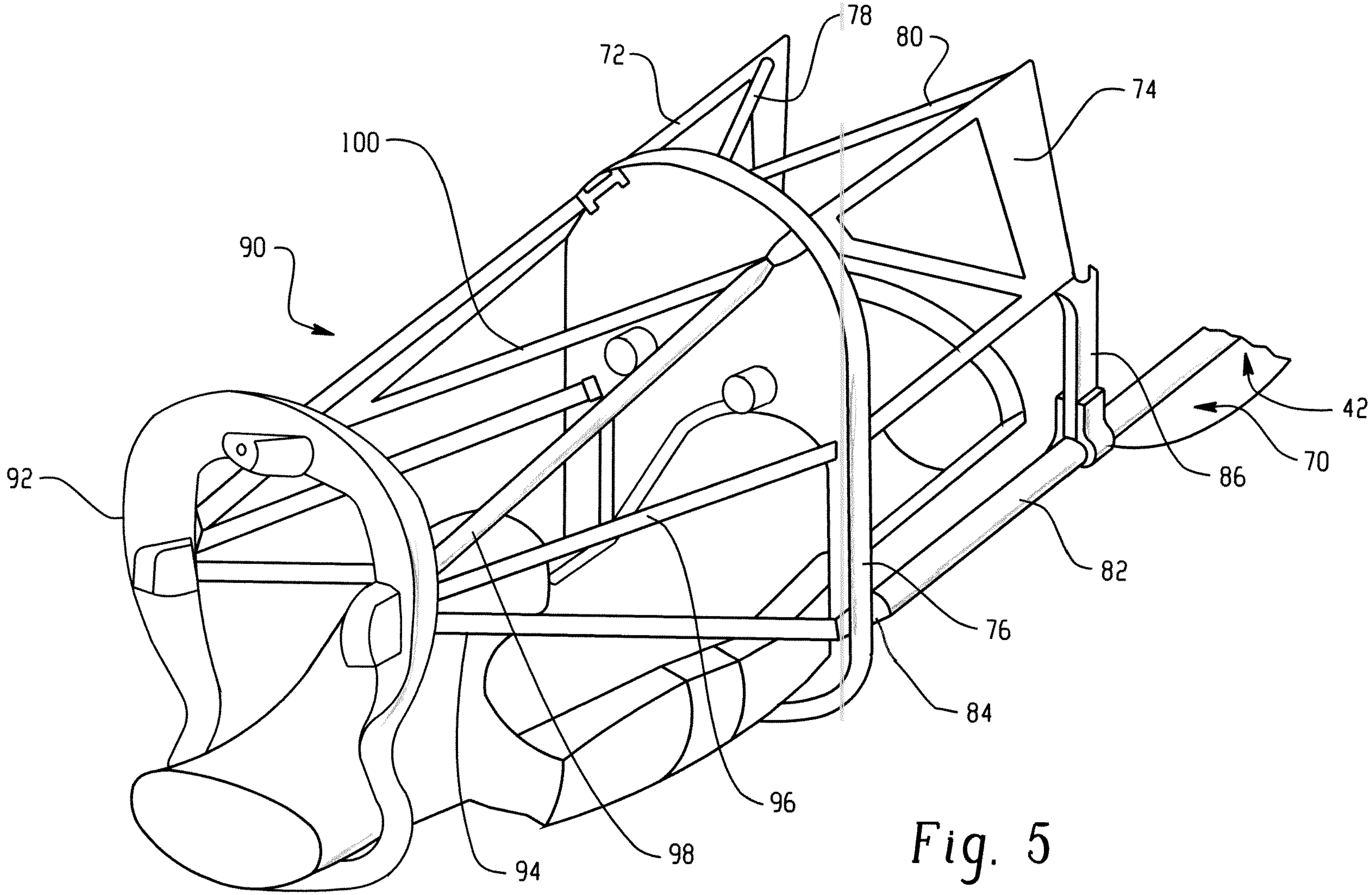

Fig. 5

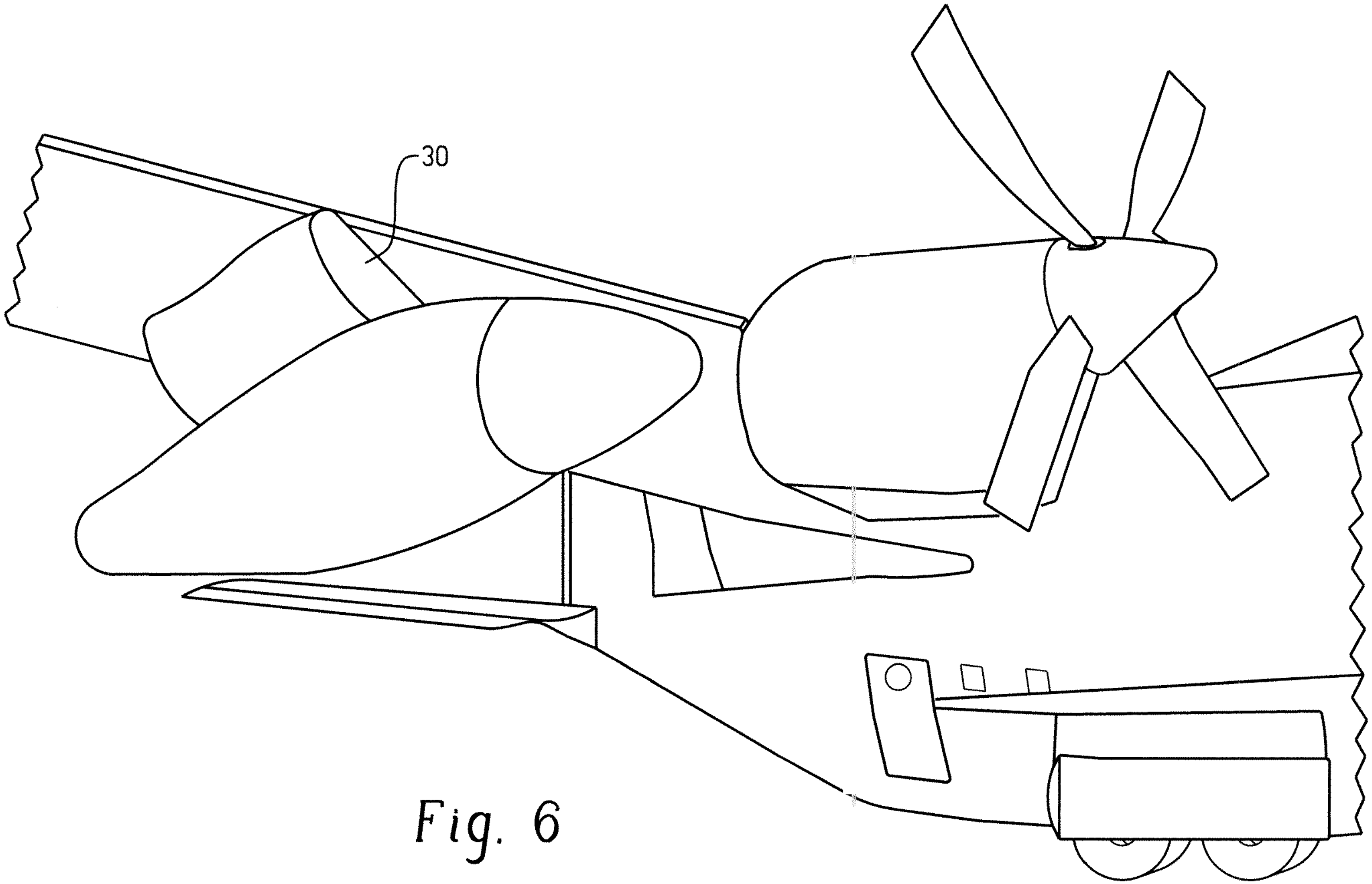

Fig. 6

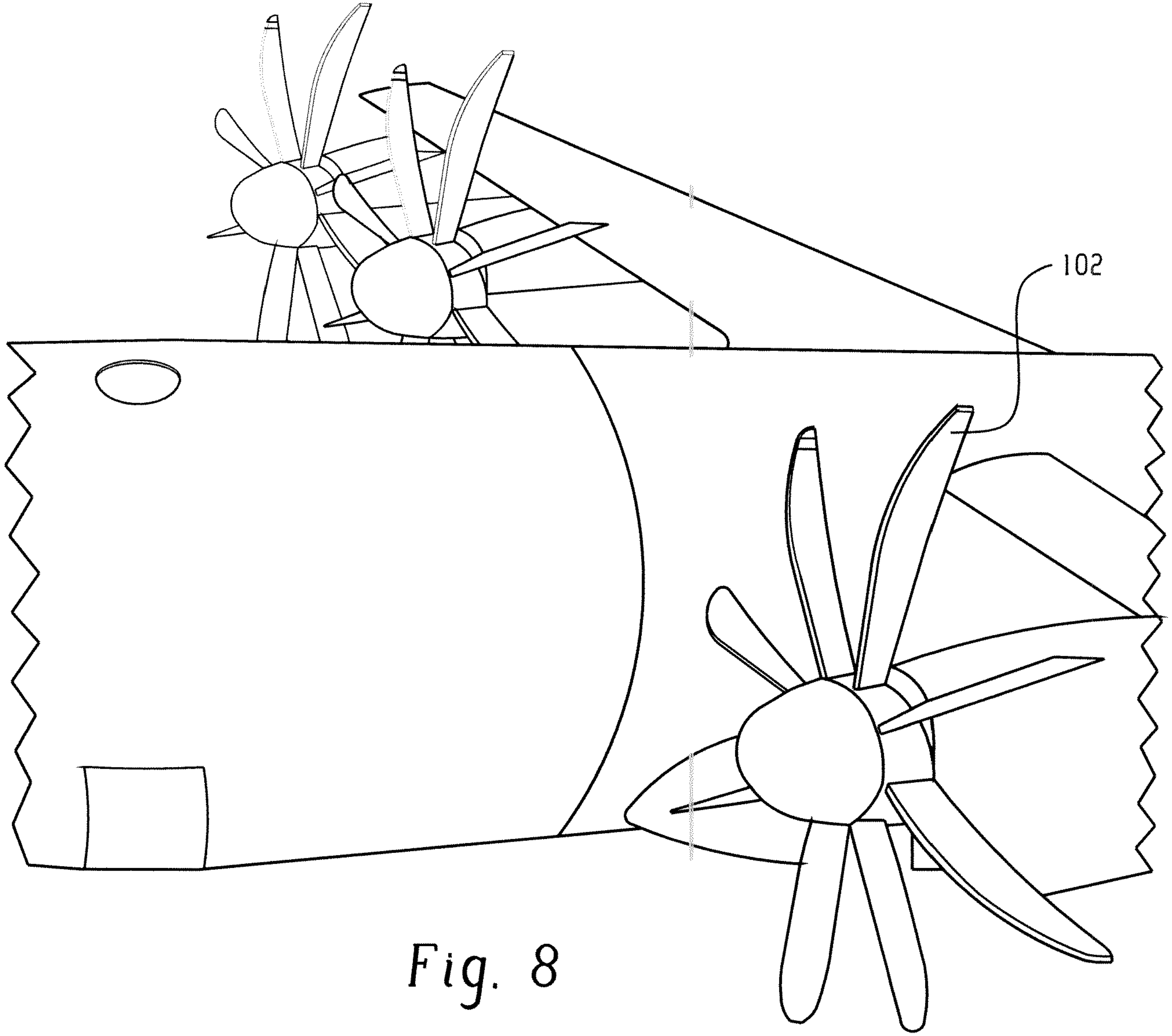

Fig. 8