



AU9219995

(12) PATENT ABRIDGMENT **(11) Document No. AU-B-19995/92**
(19) AUSTRALIAN PATENT OFFICE **(10) Acceptance No. 662156**

- (54) Title
PROPULSIVE THRUST RING SYSTEM
- International Patent Classification(s)
(51)⁵ **B64C 011/00**
- (21) Application No. : **19995/92** (22) Application Date : **28.05.92**
- (87) PCT Publication Number : **WO92/22459**
- (43) Publication Date : **12.01.93**
- (44) Publication Date of Accepted Application : **24.08.95**
- (71) Applicant(s)
LEMONT AIRCRAFT CORPORATION
- (72) Inventor(s)
HAROLD E LEMONT
- (74) Attorney or Agent
DAVIES COLLISON CAVE , 1 Little Collins Street, MELBOURNE VIC 3000
- (56) Prior Art Documents
US 4637801
US 2618435
GB 629381
- (57) Claim

1. An apparatus for enhancing the performance of a motor-driven propeller when it is rotated about an axis to establish a flow of fluid from an upstream side towards a downstream side, comprising:

a plurality of rings, at least one of which is located within the axial span of the propeller and another ring being located downstream of said one ring; said rings being so axially-spaced from each other as to form a flow augmenting aperture between said one ring and said downstreamlocated ring with said aperture further being selected to enable propeller generated vortices to augment the fluid flow.

42. A method for enhancing the mass flow from a propeller comprising the steps of:

rotating the propeller so as to move a fluid from an upstream side in a downstream direction while generating tip vortices from the tips of propeller blades; and

during said propeller rotation influencing the flow of said tip vortices to move mass flow from tip vortices into a preselected spaced and sized pumping aperture, which extends at least partially around the propeller, and in a direction so as to convert mass flow from tip vortices into an augmentation of useful mass flow from said propeller.



AU9219995

Y (PCT)

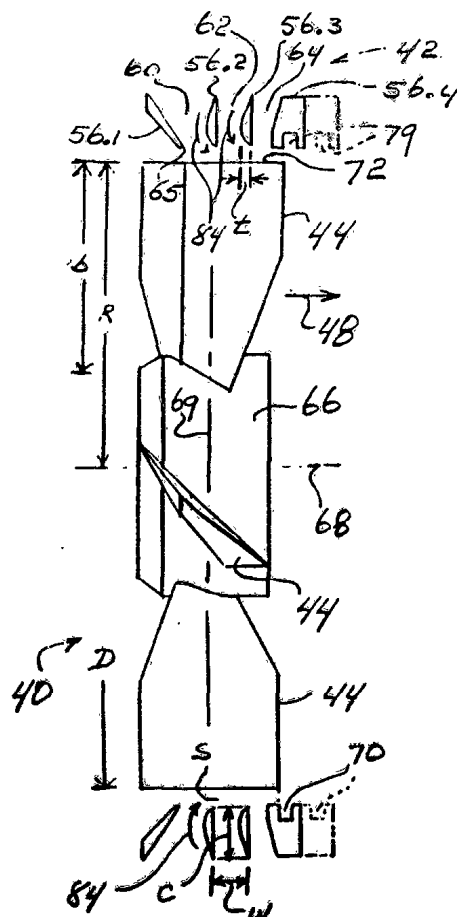
(51) International Patent Classification 5 : B64C 11/00		A1	(11) International Publication Number: WO 92/22459
			(43) International Publication Date: 23 December 1992 (23.12.92)
(21) International Application Number: PCT/US92/04647		(81) Designated States: AT (European patent), AU, BE (European patent), BF (OAPI patent), BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH (European patent), CI (OAPI patent), CM (OAPI patent), DE (European patent), DK (European patent), ES (European patent), FI, FR (European patent), GA (OAPI patent), GB (European patent), GN (OAPI patent), GR (European patent), HU, IT (European patent), JP, KP, KR, LK, LU (European patent), MC (European patent), MG, ML (OAPI patent), MR (OAPI patent), MW, NL (European patent), NO, PL, RO, RU, SD, SE (European patent), SN (OAPI patent), TD (OAPI patent), TG (OAPI patent).	
(22) International Filing Date: 28 May 1992 (28.05.92)			
(30) Priority data: 711,622 5 June 1991 (05.06.91) US			
(71) Applicant: LEMONT AIRCRAFT CORPORATION [US/US]; 350 East Main Street, Ansonia, CT 06401 (US).			
(72) Inventor: LEMONT, Harold, E. ; 117 West Church Street, Seymour, CT 06483 (US).			
(74) Agent: REENS, Louis, H.; St. Onge, Steward, Johnston & Reens, 986 Bedford Street, Stamford, CT 06905 (US).		Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>	

662156

(54) Title: PROPULSIVE THRUST RING SYSTEM

(57) Abstract

A low-aspect ratio propeller system is provided with a multiple ring structure (42) formed with a plurality of circular or non-circular, annular, narrow equivalent air foil rings (56.1, 56.2, 56.3, 56.4) which are held by rails (40) in a predetermined relationship with the propeller blades (44). The upstream ring (56.1) is located downstream from the tip vortex of the propeller (44) within the axial span of the propeller. One or more additional downstream-located rings (56.2, 56.3, 56.4) are used so as to provide at least one annular multiple ring-defined pump aperture (60, 62, 64) through which peripheral vortices generated by the propeller blades (44) or fan blades may enhance the mass flow. These vortices increase thrust because their induction action on the rings (56.1, 56.2, 56.3, 56.4) increase beneficial ring flow circulation. Augmented ring flow reduces the velocities in the expanding wake by increasing the mass flow. The destruction of tip and root vortices reduces noise. The multiple ring structure (42) also serves as a guard.



PROPULSIVE THRUST RING SYSTEMTechnical Field

This invention generally relates to improved fluid moving and mixing by fans and propellers, as well as
5 propeller and fan-driven vehicles, and particularly, to an improved propulsion system to augment and control thrust for boats and all types of aircraft, fans, and other fluid-moving devices.

Background Art

10 Propellers or related rotating forms such as rotors, fans, and screws are an integral aspect in the design of boats and aircraft. Present watercraft screws are of low efficiency, having high noise signatures and are limited by water cavitating effects on
15 blades. Their lack of safety with impact on manatees, people in the water, and submerged objects is frequently reported in the daily press. Proper stopping of small watercraft moving at 60 mph is questionable; no practical braking system presently exists to help
20 avoid running into other crafts, swimmers, and debris. Large propellers rotating at slow speeds are a necessary ship design selection and, because of ship/screw size relationships, have marked flow interferences from the ship body resulting in a lower efficiency.

25 Airplane propellers and helicopter tail rotors, to have acceptable efficiencies, must move large volumes of air with a relatively low induced acceleration of the flow. The sizes of such rotors are relatively limited; therefore, to provide sufficient thrust, these



- 2 -

are driven with high blade tip velocities. Tip vortices produced by high thrust/tip speed conditions add to the noise of the system.

Therefore, there is a need for a structural system which improves performance from propellers by enhancing their thrust, horsepower, and reducing their noise. A need also exists for a cage, which provides safety from impact by the propeller on inert or living objects, and protects the propeller without imposing a penalty on the performance of the propeller. A need also exists to reduce noise levels from the operation of a propeller used on watercraft, aircraft, helicopters and fans.

Previous patents were researched in the fields of propellers, screws, safety devices and for means of increasing propeller thrust with the following results:

U.S. Patent No. 4,689,026 to M.S. Small relates to propeller screws and shows a square tunnel enclosing a screw which system would have excessive water drag and low flow efficiency because of the tunnel corners plus turning losses of the water.

U.S. Patent No. 4,666,411 is for a tubular, ship-wake generator which is also a high drag non-propulsive item.

U.S. Patent No. 4,031,846 to V.W. Tone describes a guiding drive and conical semi-cover

- 3 -

which might act as an anti-ventilation plate but would definitely not be propulsive. As the conical plate covered only the tip of the propeller, it would not act as a safety guard.

5 U.S. Patent No. 3,742,895 describes a rudder in the propeller wake for steering and is not related to my invention.

10 U.S. Patent No. 3,528,382 describes a flow straightener to recover the rotational energy in the water wake by straightening the wake. This represents a small thrust gain at best in that wake velocity measurements indicate skew angles of flow to the shaft axis of rotation of less than 15° at most. This would increase
15 the thrust by 3.5% at most if no drag for the anti-rotation vanes existed; no appreciable positive thrust effects could be expected.

20 U.S. Patent No. 4,580,517 describes a shrouded propeller located in a tube which is a non-propulsive shroud system in forward motion. The tube, which in a static thrust condition improves the thrust, has such a high drag with speed as to force a large penalty in power required for motion.

25 U.S. Patent No. 3,722,454 shows a long, fluid tube adjacent to a propeller. The high skin friction of this device during forward motion precludes its use because of extreme power requirements at all but very low forward
30 speeds.

- 4 -

5 U.S. Patent No. 4,441,163 shows a non-propulsive cage to protect the propeller. This cage, being non-propulsive in nature, causes excessive power to be required at any reasonable operating speed.

U.S. Patent No. 4,078,516 to D.C. Babus shows a non-propulsive cage again with the same high drag characteristics noted above.

10 U.S. Patent No. 3,968,944 to Freidheim Zimmer shows a tapered contracting shroud with a propeller located in the entrance. This again would present a high drag item as the shroud is non-propulsive in nature.

15 It may be noted that most of the above prior art describing shrouds or tunnels do protect personnel and/or sea creatures from propeller contact, but at the expense of efficient performance and with high power requirements because these are high-drag items.

20 My invention achieves the safety provided by a cage but with propulsive thrust augmentation even with reduced input power that can be as little as one-half of normal propeller power required to deliver the same speed.

25 A related Patent No. 4,506,849, Helicopter Rotor Thrust Ring to H.E. Lemont, describes use of a single thrust ring around a tail rotor. Both crossflows from the main rotor and from translational flight are used to enhance thrust from the thrust ring. The area of the single thrust ring required to adopt it for sufficient axial propulsion augmentation would impose too
30

- 5 -

much drag to operate successfully in an axial, high-speed mode.

Townend rings (an early method of streamlining radial aircraft engines) have been used to enclose aircraft propellers to augment thrust. This is an aircraft variant of the shrouds of Patent Nos. 3,722,454 and 3,969,944 mentioned above. The same objections which apply to watercraft also apply to air applications. While these Townend rings boost static ground thrust, at moderate aircraft translational speeds drag soon equals the increased thrust effect to reduce the net effectiveness to zero.

Transport aircraft use propulsive fans which are included within a duct/cowling system for noise control. Thrust enhancement by the distribution of negative air pressures on the cowl lip as well as the elimination of the blade tip vortices when the fan blades are located in the duct are claimed. Variations of duct lip pressures with translational and cross flow cause changes in internal duct air velocities, both in direction and magnitude to effect internal fan face velocity distributions. This upsets the match of the required fan blade twist to the duct internal radial air flow distribution and reduces efficiency. To eliminate the tip vortices, the fan blade tips need to be very close to the duct wall (less than .5% of the radius) with subsequent clearance problems. The small clearance creates a major disadvantage because of the additional weight required to stiffen the duct structure to prevent contact by the fast-moving blades.

Patents that were cited as references against U.S. Patent 4,506,849 use the principle of edgewise cross

flow during translational flight velocity to achieve lift; thus, exhibiting similar limitations as noted for the '849 patent.

According to a first aspect of the present invention there is provided an apparatus
5 for enhancing the performance of a motor-driven propeller when it is rotated about an axis to establish a flow of fluid from an upstream side towards a downstream side, comprising:

a plurality of rings, at least one of which is located within the axial span of the propeller and another ring being located downstream of said one ring; said rings being
10 so axially-spaced from each other as to form a flow augmenting aperture between said one ring and said downstream located ring with said aperture further being selected to enable propeller generated vortices to augment the fluid flow.

According to a second aspect of the present invention there is provided an
15 apparatus for moving fluid comprising:

a motor;

a propeller coupled to the motor for rotation thereby about an axis, said propeller having a relatively low aspect ratio;

a multiple ring cage structure formed of a plurality of rings and placed to
20 surround the propeller, at least one of said rings being located within the axial span of said propeller and another ring being located downstream of said one ring, said rings being so axially-spaced from each other and so located with respect to the propeller as to form at least one flow augmenting aperture entirely within the axial span of the propeller between said one ring and said downstream-located ring, with said rings and
25 aperture further being sized so as to enable fluid tip vortices from the propeller to be effectively converted to useful fluid mass flow.

According to a third aspect of the present invention there is provided a fan for moving air comprising:

30 a motor, a propeller coupled to the motor to be driven by the motor into rotation about an axis, said propeller having a plurality of blades having an axial span along the axis;



a ring cage structure mounted around the propeller, said ring cage structure including a plurality of axially-spaced rings with an annular aperture between said rings, at least one of said rings being within the axial span of the propeller blades and another of said rings being located downstream of said one ring; said rings being so axially spaced from each other and being so selected to provide an air flow augmentation through said aperture from a conversion of propeller generated tip vortices so as to augment the air flow from the propeller.

According to a fourth aspect of the present invention there is provided an airplane engine having a rotating shaft comprising:

10 a propeller coupled to the shaft for rotation thereby and having an axial span and producing gas flow from an upstream direction to a downstream direction;

a ring cage structure mounted to surround the propeller, said ring cage structure having a plurality of axially-spaced rings, at least one of said rings surrounding said propeller by being located within the axial span of said propeller, said rings being axially-separated by an aperture which is at least partially located within the axial span of the propeller and being so sized and located so as to enable propeller generated vortices to augment the gas flow produced by the propeller.

According to a fifth aspect of the present invention there is provided an axial flow propeller system for moving fluid comprising:

an axial flow propeller for rotation about an axis and having a plurality of radially-extending blades; said blades being oriented with an axial span selected to move said fluid in a downstream direction along the axis during blade rotation;

a ring cage structure formed of a plurality of axially-spaced fluid flow enhancing rings located around the axis, with at least one of said fluid flow enhancing rings being axially-located around the blades within their axial spans;

said propeller blades having tips which generate tip vortices during rotation with the shape of the blades being selected to strengthen the tip vortices; the blade tips and the radially-inner edge of said one fluid flow enhancing ring being in sufficiently close proximity and with dimension of said axial fluid flow enhancing rings and their axial spacings being selected to form an aperture through which tip vortices from the blades augment the fluid flow in said downstream direction;



whereby tip vortices can be converted to useful fluid flow for enhanced performance of the axial flow propeller system.

According to a sixth aspect of the present invention there is provided a method
5 for enhancing the mass flow from a propeller comprising the steps of:

rotating the propeller so as to move a fluid from an upstream side in a downstream direction while generating tip vortices from the tips of propeller blades; and

during said propeller rotation influencing the flow of said tip vortices to move mass flow from tip vortices into a preselected spaced and sized pumping aperture, which
10 extends at least partially around the propeller, and in a direction so as to convert mass flow from tip vortices into an augmentation of useful mass flow from said propeller.

According to a seventh aspect of the present invention there is provided an apparatus for enhancing the mass gas flow from a propeller in a fan comprising:

15 a propeller to move a gas from an upstream side in a downstream axial direction while generating tip vortices from tips of propeller blades; and

means for generating a flow augmenting aperture extending at least partially around the propeller, said flow augmenting aperture having a preselected size and is selectively spaced from the tips of the propeller blades so as to convert mass flow from
20 tip vortices into an augmentation of useful axially downstream directed mass flow from said propeller.

With a thrust augmentation device in accordance with an embodiment of the invention, a substantially improved thrust is obtained from a fan or propeller. This is
25 achieved by employing a multiple ring structure wherein a plurality of rings are axially-spaced from each other by a thrust enhancing distance. One thrust ring is located radially opposite the rotating blades with at least one other ring axially-spaced downstream so as to form a ring defined annular pump aperture. Vortices generated by the rotating blades, whether a fan or propeller, are advantageously used to reenter the
30 main fluid flow through the pump aperture between the rings to augment the main flow.



With a thrust augmentation system in accordance with an embodiment of the invention, an increased volume of fluid flow can be achieved for the same horsepower. For example, a free air fan, which is provided with a ring structure in accordance with
5 the invention, may have its mass flow increased as high as five times for the same horsepower.

Substantial noise reductions are obtained with a ring structure of this invention, both in the plane of the rotating blades as well as at 45° from the plane. The ring
10 structure enhances safety for people and water creatures from rotating blades and enables one to obtain enhanced thrust reversal with a controllable pitch blade. The blades can be of economical flat plate low-aspect-ratio construction.

In one embodiment of the invention described herein, a multiple ring structure is incorporated with a small high-speed fan of the type used to ventilate electronic housings enclosing computer circuits or the like. A plurality of rings are located within the axial width of the fan blades so as to provide at least several
5 annular ring-defined apertures located radially opposite of the fan blade peripheral sweep line. The width of the rings, the spacing between them, their shape, orientation, and thickness are selected to provide thrust augmentation from vortices generated by the rotating fan blades. The result of the multiple rings is an enhanced mass flow as a function of input power, and an excellent static pressure versus flow
10 performance.

A multiple ring structure in accordance with an embodiment of the invention is particularly effective with low-aspect-ratio blades, such as encountered in fans, boat propellers, impellers, pumps, turbine engines, blow dryers, heater fans, paint
15 and slurry mixers and the like.

In one axially-extended multiple ring structure in accordance with the invention, at least one ring-defined aperture is radially opposite the rotating blades and one or more ring apertures are located downstream of the blades. This provides
20 an enhanced expanding wake.

With a multiple ring structure in accordance with an embodiment of the invention, much less drag arises than when a single ring is employed. With an appropriate location of the multiple rings, improved thrust augmentation can be
25 achieved resulting in the generation of greater thrust at lower power.

It is, therefore, a preferred object of the invention to improve the thrust obtainable from fans and propellers with less input power than would be obtainable from a conventional fan or propeller of the same size.
30

Other preferred objects and advantages and social benefits of my invention are as follows:

1. Protection of people, marine life and animals from destructive maiming propeller strikes.

2. Provision of a protective ringage which contributes positively to increasing the thrust of the enclosed propeller, rotor, or screw of a vehicle and reduces fuel consumption.

3. Provision of extra vehicle propulsion thrust through the use of otherwise wasted induced power represented by the blade tip and root vortices by a multiple ring action to save fuel, travel faster, and to provide a more efficient vehicle.

4. Better control of thrust magnitudes including reversal with a variable-pitch propeller to brake a vehicle in emergency or other situations.

15

5. Reduction of noise from fan or propeller vortices. Enable the quiet operation of fans, heaters, hair dryers, and the like.

6. Improve the fuel efficiency of a fan or propeller with an economic thrust augmentation system. Significant travel costs savings for boats, ships, aircraft, submarines, and the like can be achieved. Since there are no moving parts in the multiple ring structure of this invention, it will last a long time and its life cycle costs can be expected to be extremely low.

7. The thrust augmentation achieved by my invention can be applied to many types of blades involved in propulsion; air or fluid mixing; pumping of gases, slurries, sludges, and grains; and the movement of air or other media as required such as in fans, heaters, hair dryers, oil burners, transmission pipe line inline pumps, etc.

30

8. Facilitate the separation of major-sized particles in the air or water being moved through the rings.



One embodiment of the present invention comprises a multiple ring structure that can be used in combination with low-aspect-ratio multiblade propellers, fans, impellers, or rotors. The multiple ring structure comprises multiple, axially-spaced rings which form narrow annular airfoils that are separated by an annular ring aperture whose width is expressed as a function of ring chord distance, which in turn is based on the internal to external diameter ratios of the rings. Structure to locate these rings in relation to each other and in the plane of the propeller is a part of the invention. The plane of the first ring being located within the axial length of the propeller and slightly aft of the upstream tip vortices of the propeller. Slight slanting of the forward ring and larger angles of the subsequent downstream rings to the plane of the propeller has beneficial effects for some applications. The propeller has its tip and root vortices associated with the wash increased in strength by the low-aspect-ratio blades, special foil sections, and planform shapes to enhance the thrust action of the ringcage structure. The ringcage converts these vortices into extra thrust by converting their normally-wasted rotative energies as forces acting in the direction of thrust produced by the propeller.

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings in which:-

20

FIGURE 1A are curves of the static pressure of a fan with a multiple ring structure in accordance with an embodiment of the invention and of a conventional slightly larger fan;

25

FIGURE 1B are curves of mass flow as a function of the tip pitch angle for a fan using a multiple ring structure in accordance with an embodiment of the invention and for a conventional fan;

30

FIGURE 2 is schematic representation of a multiple ring structure and a fan with which it is used;

FIGURE 3 is a front view of a fan in accordance with an embodiment of the



invention;

FIGURE 4 is a side view of the propeller portion of the fan shown in Figure 3;

5

FIGURE 5 is a front view in elevation of a fan of an embodiment of this invention;

FIGURE 6 is a side sectional view of the fan of FIGURE 7 taken along the line 6-6 therein;

FIGURE 7 is a side sectional view, like FIGURE 6, of a fan employing a peripheral motor drive;

FIGURE 8 is an elevation view of a boat equipped with a ringcage system in accordance with an embodiment of the invention;

FIGURE 9 is a schematic illustration of the flow of water obtained with a conventional boat screw propeller;

20

FIGURE 10 is a schematic illustration of the flow of water through a propulsive thrust-ring system in accordance with an embodiment of the present invention;

FIGURE 11 is a perspective of a low-aspect-ratio propeller with a ringcage structure in accordance with an embodiment of the invention;

FIGURE 12 is a plot of curves to compare the static thrust produced by a conventional screw alone; a low-aspect-ratio propeller having a diameter that is 75% of the diameter of the screw and a 75% diameter low-aspect-ratio propeller with a propulsion ringcage in accordance with an embodiment of the invention;



FIGURE 13 is a graph with curves to show a comparison of percent thrust horsepower required by a conventional screw with that required by a low-aspect-ratio propeller having a ringcage system in accordance with an embodiment of the invention;

5

FIGURE 14 is a graph of a curve showing the augmentation of vessel speed obtained with a low-aspect-ratio propeller with a ringcage of an embodiment of the invention;

10

FIGURE 15 is a graph of curves showing the noise produced by a low-aspect-ratio air propeller with and without a ringcage of an embodiment of this invention where a microphone is placed both in the plane of the propeller and at 45° to the plane at a distance of 1.50 propeller diameters;

15

FIGURE 16 is an elevational partial section view of a propulsive thrust-ring system;

FIGURE 17 is a plan view of the propulsive thrust-ring system of FIGURE 16;

20

FIGURE 18 are cross sectional views of blade sections suitable for a low-aspect ratio propellers used in an embodiment of the invention;

FIGURE 19 are cross sectional views of rings used in a ringcage system of an embodiment of the invention;

25

FIGURE 20 is an elevation view of an aircraft installation of a ringcage system of an embodiment of the invention with a tractor configuration on a private aircraft; AND

30

FIGURE 21 is an elevation view of an aircraft installation of a ringcage system of an embodiment of the invention with a pusher configuration on a private



aircraft.

With reference to FIGURES 1-5, a fan 40 in accordance with an embodiment
5 of the invention is shown. The fan 40 is provided with a multiple ring structure 42
whereby thrust developed by propeller blades 44 in the direction of arrow 48 is
significantly augmented. FIGURE 1 illustrates two static pressure curves 50, 52.
Curve 50 is for a standard in-tube fan of similar size, but slightly larger (4.41"
diameter), than for fan 40 (4.00" diameter). Curve 52 is for fan 40 with the ringcage
10 structure 42.

Of particular significance is the increased (doubled) mass flow obtained with
fan 40 at the normal operating static pressure of about 0.2 inches of water. The non-
linear dip 54 that is normally present in a static pressure curve for a standard in-tube
15 fan is substantially eliminated with fan 40. Curve 52 is essentially a straight line, but
may vary from that depending on the fan configuration.

This significantly improved performance by fan 40 is achieved with multiple
ring structure 42. This includes at least two rings and in the embodiment a plurality
20 of rings 56.1, 56.2, 56.3 and 56.4 which are radially spaced from the peripheral sweep
line of fan blades 44 and located within the axial distance of propeller blades 46.
Ring 56.1 also serves as a mount for fan 40 to a suitable surface.

The multiple ring structure 42 has three annular ring-defined apertures 60, 62,
25 64, through which air flow mixing with tip shed vortices provides flow augmentation.
The rings 56.2 and 56.3 are annular,

- 14 -

relatively thin air foil structures whose radial width (outer radius less inner radius) or chord, c , and axial spacing, w , are selected to enhance flow augmentation by the ring structure 42. If the ring chord, c , is made too large, the augmentation effect tends to diminish and drag in vehicular application may become too large. If the ring chord is too small, the augmentation effect also tends to diminish. The size for the ring chord, c , can be expressed as a function of the fan radius R and preferably should be in the range from about $.15R$ to about $.59R$. Particularly effective flow augmentation was found at a ring chord dimension of about $.25R$.

Ring thickness t also affects performance with augmentation being reduced when a ring is too thick or too thin. Generally, a ring's thickness is expressed as a function of the chord size c . The ring thickness t preferably is in the range from about $.1c$ to about $.4c$ with augmentation flow generally declining as the ring thickness approaches $.35c$. Ring maximum thickness generally was found to yield maximum static flow augmentation from about $.15c$ to about $.2c$. In one multiple ring structure using four rings with a two-bladed propeller in an eight inch diameter fan, an optimum value for the ring thickness t was $.2c$. Improved mass flow can be obtained even with a ring thickness smaller than $.1c$.

The axial spacings W between rings, i.e. the axial widths, w , of annular ring defined apertures 60, 62, 64 should be sufficient for air flow from vortices to augment the mass flow. If the apertures are widened, flow augmentation gradually reduces. When the aperture width w becomes zero, performance approaches the augmentation obtained with a single ring. Preferably, the

- 15 -

widths, w , of the ring flow apertures are generally selected to be between about half to about four ring chord lengths c , though variations from this range may be encountered with different media such as air and water.

5 In one multiple-ring structure for an eight-inch, two-bladed fan as described above with a ring thickness of .21c and a fan solidity ratio of .2, and with ring spacings of about two chords c , a 40% improvement in mass flow was obtained relative to a fan alone. Mass

10 flow augmentation from the use of a single ring was about 16%.

The axial location of the forward ring relative to the plane of rotation 67 affects the flow augmentation. Generally, the trailing edge 65 of the upstream, or

15 forward, ring 56.1 should not be forward of the tip vortex and preferably is located in the vicinity of the plane of rotation 67. The trailing edge 65 of the forward ring can be forward of plane 69 or downstream. Generally, flow augmentation reduces more rapidly as

20 the position of edge 65 is moved forwardly than rearwardly. Augmentation of the flow was obtained for one fan, using a pair of blades as long as the trailing edge, such as 65, of the forward ring was no further forward from the plane of rotation than about 0.06 of

25 the radius R of the propeller and no further downstream than about 0.2 R . Variations from these locations can be made depending on various propeller factors, such as the strength of the vortices produced by the blades.

FIGURE IB illustrates the significant improvement achieved with a ring cage structure of ^{an embodiment of the} ~~this~~ invention.

30 Curve 70 represents the mass flow as a function of the pitch angle of the tip 72 of a two-bladed, 10-inch diameter fan, having a ring spacing of one chord between three rings 56 and a blade twist angle of 15°. As the



- 16 -

pitch angle increases, the mass flow increases until it reaches a maximum at 74 at about 43° where stall occurs. Further increases in pitch angle result in a reduction as shown at 76. However, at 78, the curve
5 levels off at about 50° and remains that way at least as far out as 60°.

In a conventional fan, the mass flow continues to decrease as shown at 80 until at about 60° pitch angle, there is essentially no axial flow. This illustrates
10 that the ringage structure of this invention is particularly effective in converting the stronger vortices generated at higher pitch angles above stall to useful mass flow.

A particular advantage of the ringage structure 42
15 is that its inner diameter does not have to be closely spaced to the peripheral sweep line of the propeller blades 44. When the clearance, s , is too small, tolerances required of the fan and mounting structures become tight to avoid inadvertent contact with the ring
20 structure 42. If the clearance, s , is too large, then the beneficial effects from the ringage structure 42 reduces and a reverse air flow becomes possible. Generally, a clearance s that is of the order of no more than about 10% of the radius R of the propeller
25 blade is acceptable with about 5% of R being normally used.

The multiple ring structure 42 works particularly well with propeller blades 44 having a relatively low aspect ratio. Aspect ratio (AR) for a propeller blade
30 is defined by the relationship $AR = b^2/A$ where b is the exposed length of the blade outside of the hub 66 and A is the blade area outside of the hub. When the aspect ratio for blades 44 is too high, it lowers the

- 17 -

strength of the tip vortex and thus the benefit of the ringcage structure 42. With low-aspect-ratio propeller blades 44, a stronger tip vortex is generated which can then be converted to useful mass flow and provide
5 better overall efficiency.

Low-aspect-ratios found suitable typically are in the range from about 0.10 to about 3.0, though the invention can work to some extent with propeller aspect ratios that are outside this range.

10 In the fan 40, the leading upstream ring 56.1 is inclined relative to the rotational axis 68. Such inclination angle enables a better air flow and may be also used for other downstream rings such as 56.2 and 56.3. The inclination angle can be of the order of 15° ,
15 though other angles can be used.

The downstream ring 56.4 is shaped with annular inwardly-facing notches 79 which serve to impede reverse air flows that would otherwise impede the flow augmentation obtained with rings 56.1, 56.2 and 56.3.

20 Rings 56.2 and 56.3 have an airfoil cross-sectional shape. This provides a preferential emphasis to a flow as shown by arrows 84 around the rings that enhances the mass flow in the direction 48.

FIGURES 3 and 4 illustrate fan 40 with greater detail. As shown at 92 in FIGURE 4, the rings 56 are assembled together with interlocking brackets 94 and held by a bolt 96 to a suitable frame 98. Frame 98 encloses a space to be ventilated (not shown). Fan 40 is driven by a motor 99 inside hub 66. The use of such
25 brackets 94 is indicative that the rings 56 need not be
30

- 18 -

continuous but can be interrupted at circumferential places while still providing the flow augmentation of my invention.

5 In FIGURES 5 and 6, a fan 100 is shown having a multiple ring structure 102 formed with six rings 103 axially-spaced along the pitch length of the fan blades 104. All of the annular apertures 106 between the rings contribute a positive pumping action whereby significant mass flow augmentation is obtained. Fan 100 can be
10 mounted to one of several suitable frames 108 with a cup-shaped bracket 110. Motor leads 112 are coupled to motor 114 through one of four suitable hollow struts 116 used to support the fan motor 114 and rings 103. Note that where deemed desirable, some or most of the
15 rings 103 can be inclined relative to the rotational axis of the fan blades 104.

FIGURE 7 illustrates a fan 120 which has propeller blades 122 that are rotated by a peripheral motor 124. A multiple ring structure 126 is used to augment the
20 mass flow with the rings 128.1, 128.2 and 128.3 inclined at various angles relative to the rotational axis 129.

FIGURE 8 shows one form of my invention as applied on an outboard motorboat 130 with an outboard motor
25 132. This outboard motor 132 has a conventional throttle and steering lever 136 and is typically mounted in accordance with current practice on the boat transom 134. Parts of the outboard motor 132 may be noted in FIGURE 8 as the anti-ventilation plate 138 and a lower
30 right-angle gearbox casing 140. My invention consists of two major elements; namely, a low-aspect-ratio blade propeller 142 and a ringcage 144 formed of three axially-spaced rings 146.1, 146.2 and 146.3.

- 19 -

Propeller 142 (see FIGURE 10) has short, wide, thin blades 152. Special blade 152 planforms enhance the propeller thrust values at high angles of attack by tip and root vortex action as well as special leading-edge cross-sections to increase boundary layer energies. In contrast, normal screws such as shown in FIGURE 9 try to minimize these vortices to reduce power losses. With a ringcage 144, a conversion of these vortices into useful thrust energy promotes the use of a propeller design with which vortices are strengthened.

In the embodiments shown in FIGURES 2, 4, 6, 7, and 8, three or more rings are used. It should be understood however that the advantages of a multiple ring structure in accordance with the invention can be obtained with a pair of rings which define an annular vortex pumping aperture between them. The aperture should be located at least partially within the axial pitch length of the propeller blades.

In FIGURES 8, 10 and 11, the three rings are shown connected by four angularly-distributed rails 154 which attach to outboard motor 132 and space and support the rings in their proper arrangement in relation to the plane of the propeller 142 to perform their thrust augmentation function. The number of rails 154 may be varied as well as their shape and size. In general, support structure for rings such as provided by rails 154 form a part of ringcage 144 and are located approximately parallel to the waterflow. Rails 154 have cross sections which are shaped to a low drag configuration in accordance with current aerodynamic or hydrodynamic theory as the case may be.

FIGURE 9 shows the waterflow about a conventional screw propeller 160 attached to a drive shaft from an

- 20 -

outboard motor. Its flow is to be compared with the flow in the propulsive thrust ring system of ^{an embodiment of the} the invention, as shown in FIGURE 10, together with a detailed examination of flow about the individual blade and radial inflow about the rings as shown in FIGURE 11.

Propeller 160 of FIGURE 9 has a waterflow represented by horizontal vectors 162. A conventional anti-ventilation plate 138 prevents air leakage from the water surface into propeller 160. Propeller 142 adds additional velocity to the affected tube of water which is normally referred to as "induced velocity". In performing this function, the lower pressure on the top-side and the higher pressure on the lower side cause a vortex to form near the tip of the blade which flows downstream over the blade and is referred to as a "tip shed vortex". This forms with the inboard flow a reduced cross-sectional wake with high rotational speed boundary vortex velocities. Vortex circles 166 with arrow heads represent the direction of vortex rotational flow in a planar-cut normal to the water flow. The shrinking diameter of the wake but not of vortex circles 166 is a result of added induced velocity by propeller 160.

FIGURE 10 shows waterflow of the propulsion thrust ring system 144 as consisting of two parts, one of which is primary flow and the second an induced flow over rings 146. Vectors 170 show primary water flow about the gearcase 140 to propeller 152 and velocity vectors 172 show an induced flow to rings 146. Two sets of vortices are generated by each of propeller blades 152, namely inboard vortices 174 and outboard vortices 176. Flow vectors 172 produce a radial augmentation flow about rings 146 with a mixing with vortices 176.1



- 21 -

and 176.2. This mixing starts at forward ring 146.1 and continues downstream for two to three propeller 142 diameters. The large size of and increase in diameters shown by the outboard vortices 176 and inboard vortices 174 indicate a beneficial conversion of high rotational energy in the vortices when they are small to a slower rotational energy when they are larger. Unlike propeller 142 of FIGURE 9, these propeller vortices disappear downstream by adding their rotational energy and mass to the wake. Final wake vectors 180 show a wake expansion caused by the volume of flow from the induced ring velocity vectors 172 plus primary flow vectors 170.

The bolted attachment 182 ringcage 60 to outboard motor 132 does not lie in the primary path of flow, and their projected areas normal to the flow vectors 170 and 172 have a minimal effect on the wake.

FIGURE 11 is a perspective view of the propulsive thrust ring system 144 and the previously-defined propeller 142. The propeller 142 is a fixed-position, two blade, variable-pitch propeller with adjustability provided by clamping screws 184 for holding front hub 186 to rear hub 188. Blades 152 are flat plate beveled-edge structures which are held by the action of the clamping screws 184 on the butts of the blades. The waterflow action around the blades 152 is represented by three sets of vortices as shown by inboard vortices 190, by outboard vortices 192 and leading edge vortices 194. The angle of attack of a blade 152 is established by vector 170 (see FIGURE 10) and its rotational speed about the axis of shaft 196. The induced velocity created by blades 152 and the augmented velocity flow of vectors 172 result in an orientation as shown in FIGURE 11.

- 22 -

Vortices 190 and 192 created by the positive/negative pressure ratio from the lower to the upper surface, of blades 152 cause the edge vortices shown in FIGURE 11. These vortices flow from the lower surface to the upper surface and then trail off downstream mixing with the induced ring flow. While these are each shown as a single vortex, for the low-aspect-ratio surface of 1.0 or less, more than one vortex may be generated on each side edge of the blade. Vortices such as 194 are a function of the bevel of the leading edge 200, which may be slightly rounded by a 2% chord leading edge radius 200. At a positive angle-of-attack of blades 152, the sharp edges have separated the flow over the bevel. Flow reattaches to blades 152 after the bevel in a chordwise sense and creates a lift bubble. This lift bubble extends span-wise from the vortices 190 to vortices 192 on the beveled part of blades 152. This creates a significant lift on the blades which, with their low-aspect-ratio forms can make a beveled-flat plate section produce a higher lift/unit area than well-profiled airfoil sections.

Two other significant effects are produced by vortices 190, 192 and 194. One is the energizing of the boundary layer on the upper surface of blades 152 to achieve angles-of-attack exceeding 45° (see FIGURE 13) without stalling that would result in a loss of lift and increased drag. Lift values of propeller 142 may exceed twice those of other types. The second effect is that the aforementioned vortices provide a stronger mixing action than a conventional screw propeller 160 (see FIGURE 9). This energy which is lost with screw propeller 160 is converted into usable thrust by my invention.

- 23 -

FIGURE 11 shows induced flow vectors 172 in perspective. These may be noted as starting upstream and parallel to the axis of shaft 196, turning, as a result of the influence of the internal ringcage mixing action (fluid sink action) to flow across the forward surfaces 202 of rings 147, and then proceeding downstream. The inward radial flow across the forward surfaces 202 of the rings 146 generates ring lift with consequent thrust improvement.

FIGURE 12 is a graph of test data of the static thrust of different systems for comparing their thrust-producing capabilities. Thrust in pounds generated by each system is plotted against revolutions per minute (RPM) of the propeller shaft. Curve A is a baseline, three-bladed, standard design, semi-elliptical-planform screw such as 142 in FIGURE 10. Curve C is a three-bladed 75% diameter propeller as 142 without ringcage 60. Dashed Curve D is for a propeller 142 of Curve C with a ringcage 144 using three rings 146. Interpretation of these data is as follows:

1. At 2000 RPM the thrust of Curve C, which is a smaller propeller than the propeller for Curve A, is about 20% less than for the standard propeller of Curve A.
2. At 2000 RPM, the dashed Curve D for a propeller as for Curve C but with a propulsive thrust-ring system 144 produces a slightly greater thrust than the standard propeller system represented by Curve A.

A conclusion to be drawn from the above is that a smaller diameter propeller 142 with a ringcage 144 and

- 24 -

operating at a lower blade tip speed (75% of that of Curve A) will generate the same or slightly greater static thrust. The rings 146 contribute to the total thrust with their induced flow to thus increase the total propulsive force to equal the standard, larger-sized propeller represented by Curve A. A smaller, lower tip speed propeller 142 with a ringcage structure 144 can thus create the same static thrust at a reduced shaft horsepower level as a larger propeller.

FIGURE 13 is a graph of static thrust/horsepower test data on the systems of Curve A and Curve D in FIGURE 12. Plotted are data of the percent horsepower of each system against design thrust. At 100% of design thrust, the propulsive thrust-ring system uses about 50% of the horsepower of the standard screw propeller; this is a significant improvement in efficiency.

FIGURE 14 is a test data graph for a propeller as described with respect to Curve D in FIGURE 12 but with a ringcage 144. Curve D illustrates the percent augmentation achieved as a function of percent cruise speed. Augmentation percent is defined as the thrust T_D , achieved with a ringcage 144 less the thrust, T_A from a propeller alone, divided by T_A , and multiplied by 100. Static thrust augmentation of FIGURE 14 at zero translational velocity is about 24% of the thrust from a propeller 142 alone. At the boat's cruise speed, augmentation has increased to about 60%. This augmentation increase illustrated in FIGURE 14 is obtained with a reduced horsepower requirement as shown in FIGURE 13. Power/energy savings result in high economy, faster, longer-range vehicles for the same fuel usage.

FIGURE 15 shows sound measurements of an air propeller where sound intensities (dBA), thrust, and

- 25 -

horsepower values were taken throughout a range of revolutions per minute. Microphones were placed at distances of 1.5 diameters of a propeller both in its plane of rotation and at 45° to it. Computer-reduced data are plotted in Figure 15 which shows the sound intensity for the percentage of the design thrust of a propeller. Data from both like positions were approximately equal. Curve E shows the dBA values of a propeller alone while Curve F shows the effect of adding a ringcage such as 144 to the system.

The test data for FIGURES 12, 13 and 14 were obtained with a three-bladed propeller system. Force and moment data have been found by four-bladed propeller 44 testing. A parameter defined as "solidity ratio" is the following:

$$\text{Solidity Ratio} = \frac{\text{Total area of the blades}}{\text{Swept disk area}}$$

This parameter has been test evaluated with a varying number of rings and propellers to optimize the selection of components for a range of .06 to over 1.0. When the aspect ratio of an air propeller blade is 3.0, a solidity ratio of 0.20 to 0.35 is appropriate. While for a water use blade, the solidity ratio of 1.0 is a reasonable value. Fans as may be used to cool electronic components, such as in computers, typically have solidity ratios as high as 1.8 to 2.0. Hence, solidity ratios may vary from about .06 to about 3.0 for the various propeller applications of the invention.

At 100% of the design thrust value as may be noted from FIGURE 15, the quieting is about 5 dBA. Ringcage 144 literally swallows the noise by dissipating propeller vortices.

- 26 -

FIGURE 16 is an elevation view of the propulsive thrust-ring system consisting of propeller 142 and ringcage structure 144. A cross-sectioned portion of the propeller hub has been exposed to clarify its method of construction and parts of rings 146 are eliminated for the same reason. Rails 40 may be cast, molded or otherwise fabricated-integrally with plate 138 and the gear case 139 as shown in FIGURES 8 and 16. Intercostals may be used in critical areas to increase safety. Ringcage 144 has thin rings 146 which have an upstream-facing airfoil section. Rings 146 are narrow, circular, and annular with an internal diameter exceeding propeller 142 diameter by about 5.0%. The outer diameter of rings 146 may vary from 120% to 160% of the propeller diameter depending on the vortex strength of propeller 142 and/or other projected use. Rings 146 and rails 154 may be integrally cast or molded of metal, plastics or composites to form a solid joint at their intersections. Alternately, bolted joints may be used to hold the system together. Individual rings 146 may be attached to lugs on rails 154 or to spacerblocks which separate the rings with throughbolts from aft ring 146.3 to gearcase 139.

The selection of the number of rings 146 used in the ringcage 144 is related to the strength of propeller 142 vortices. Two or more rings 146 are needed to achieve the required propulsive force for a particular design situation. Axial spacings between rings 146 may vary from one-half chord to four chord lengths. A chord length is defined as one-half the difference between the inner and outer diameter of annular rings 146.

The plane of front ring 146.1 may be tilted as much as 15° relative to the propeller shaft axis 196 without appreciably affecting the thrust augmentation values.

- 27 -

However, the upstream side of tilted or a non-tilted ring 146 should not be forward of blades 152 vortices 174 and 176 to insure proper pumping action. Downstream rings 146.2 and 146.3 may be tilted up to 45° relative to shaft 196 while maintaining one-side chordal spacing on one axial side without materially affecting the augmentation effect.

Radial offset of rings 146 downstream of first ring 146.1 may be up to one-half of a ring chord c without causing significant augmentation loss values. Tests have shown that maintaining the same internal to external diameter ratio while increasing or decreasing the internal diameter of rings 146 cause only small changes in the augmentation effect. Uniform or non-uniform ring spacings within four chord spacing showed no significant effects on the mass-flow augmentation effect.

Note that at least the leading, forward or upstream ring 146.1 is located opposite propeller 142 and preferably the second ring 146.2 is also so placed. In this manner, each ring 146.1 and 146.2 contributes to vortex conversion and enhances the flow augmentation effect. Additional downstream rings 146 can be used with those such as 146.3 located as an extended ring structure downstream of propeller 142. Such extended rings 146 can be of greater diameter to accommodate the expanding wake.

These considerations also apply to the ringage structures shown in FIGURES 2, 4, 6, and 7 and vice-versa, the design criteria described with reference to the air fans shown in these figures are applicable to the boat propeller and ringage structure.

- 28 -

Rails 154 form a portion of ringage 144 and perform the structural function of supporting and locating, guarding and protecting the structure from impact. The hydrodynamic forces generated by vectors, such as
5 172, FIGURE 10, are resisted by rails 154 and distributed to gearcase 139 to be eventually applied to boat 30. Rails 154 locate rings 146 in relation to each other and to the plane of propeller 142.

On the upstream side, rails 154 are slanted radi-
10 ally and diagonally to the direction of waterflow to deflect objects from propeller 142 and partially from rings 146. FIGURE 16 shows rails 154 attaching rings 146 to gearcase 139 and to anti-ventilation plate 138. This provides a security guard for impact at four
15 points about the periphery of propeller 142. To supplement the guarding and deflecting of objects, animals, and personnel, secondary appropriate intercostal rails 154 may be added to other angular positions between those shown in FIGURE 16 and located
20 forward of the first ring 146.1. The cross-sectional shapes of rails 154 between and along the rings 146 generally are selected to minimize drag, and their cross-sectional profiles have airfoil shapes with their leading edges facing outboard away from the shaft 196.

25 Shaft 196 is a standard outboard motor type with a retainer nut and a Woodruff key hub drive means. Other propeller attachments can be used. The propeller mount consists of three major structures - namely, a forward hub 210, an aft hub 212, and propeller blades 152.
30 Other parts include pins 214 to position blade pitch angles and screw attachment pieces to clamp the hub parts and blades in their appropriate positions. The forward hub 210 has an interior diameter which enables a slide fit on shaft 196 and has an exterior shape to

- 29 -

supplement streamlining. The inner diameter of aft hub 212 also fits on shaft 196 and has a torque-transmitting Woodruff key to carry drive loads from shaft 196 to blades 152.

5 Blades 152 each are of a one-piece structure suitable for a fixed-position, variable-pitch design. Their hydrodynamic, essentially rectangular surface, is an edge beveled-flat plate which at its radial top has a width of 2% to 15% of the chord. The beveled, leading,
10 and trailing edges extend from 10% to 25% of the chord on the radial top surface, as selected by use considerations. As the thrust from blades 152 is mostly influenced by the leading-edge bevel, it may be noted that for some applications, the amount or need for an aft
15 bevel of blades 152 is not critical. The equal beveling of both edges permits blades 152 to be used for either left or right-hand propeller rotation by appropriate pitch angle selection. Left-hand rotation is used in the FIGURES of this application and is defined as an
20 anti-clockwise motion when viewed from a downstream position.

FIGURE 18 shows special propeller blade cross-sectional profiles which can be used in addition to a standard NASA or other aircraft propeller cross-
25 sections. Flat plate beveled-edge section 230 is for a thin airfoil (2%-15%) chord thickness, to impart special hydrodynamic/aerodynamic properties for the propulsive thrust-ring system. Flow at angles of attack to the leading-edge, assumed to be to the left on
30 FIGURE 18, separates at the sharp point and reattaches on the flat, thick portion 232 aft of the bevel. A suction bubble forms between the bevel surface and the free stream flow. This generates a surface lift at an efficiency which permits an effective system to be

- 30 -

designed. Accuracy in contour and surface finish of the profile becomes secondary in that the bubble effect is predominant in lift determination on the upper surface. Lower surface pressures sum up as positive which
5 tend to be insensitive to surface roughness. The bevel surface extends from the leading edge to a minimum of about 8% chord and a maximum of about 30% chord.

Section 234 has a large radius/chord ratio arc forming the upper surface 235 and a thickness ratio
10 range like section 230.

Section 236 has a 25% chord-beveled leading edge 238, a flat bottom 240, and a tapered section aft of the bevel. Section thickness ratios vary like section 230 values.

15 Section 242 has a double-taper which commences at the slanted, dotted line 244 shown in FIGURE 18. This line passes through the top intersection of the tapered surfaces at 25% of the section chord. Its angle to the horizontal which may be as much as 75° fore or aft of
20 the vertical, depending on use, determines the intersection of the front and rear bottom lines at the section. Droop snoots, as commonly used for airfoil sections, may be incorporated to further modify these profiles as may the many types of slots and flaps used
25 in aircraft designs.

FIGURE 19 shows cross-sectional profiles used for rings 248 in a multiple ring structure of this invention. Section 250 is the standard NASA or other equivalent aircraft profile. The leading edge 252 on the left
30 in FIGURE 19 forms the inner diameter of ring 248, and the trailing edge 254 is the outer diameter. This section of ring 248 may be set at an angle to the plane of

- 31 -

ring 248 and corresponds to an airfoil section angle of attack. Ringage flow is from the trailing edge 254 to the leading edge of the section edge which is a 180° difference from normal airplane wing operation. Tests
5 on ring section thicknesses from 9% to 38% chord indicate 15% to 20% chord as the best to maximize static mass flow augmentation.

Section 260 of FIGURE 19 is for a bent-plate ring 248 with a rounded-edge 262 on its inner diameter.
10 This cupping design compensates for a flatplate lack of upper curvature. The shape of section 260 may approximate the top profile line of standard NASA airfoils. The induced velocity in a multiple structure mostly affects this top surface 264 with static pressure occurring on the underside surface. Therefore, the top
15 surface is most important and should be smooth without protuberances or indentations which might adversely change the flow.

Section 270 of FIGURE 19 is a specially designed
20 airfoil for application for a first upstream in a multiple ring structure 272 in FIGURE 20. It consists of a Clark-Y type airfoil section, which is well-known in aircraft engineering, with nose modifications. The top solid and the aft lower solid line plus the dashed line
25 are the original shape of the Clark-Y. A vertical line tangent to the Clark-Y nose radius intersects a forward extension of the normally-flat undersurface of the airfoil. The corner created by the intersection of these lines is blended by a radius equal to that of the
30 Clark-Y leading edge radius. This airfoil section modification appears to give increased augmentation flow to the ringage 272.

- 32 -

FIGURE 20 is the application of a propulsive thrust-ring system 272 to a twin-engine light aircraft 274 as used for private flying. A tractor propeller 276 designed for air use is located on the engine. 5 Ringcage 272 attaches to airplane wing 278 by two spaced-apart extension beams 280 which fasten to rails 154. Supplemental benefits to the basic performance increases are the better field of vision available and the lighter weight landing gear associated with a 10 smaller propeller.

FIGURE 21 is the application of a propulsive thrust-ring system of this invention to a single-engine pusher aircraft 286. Propeller 288 designed for aircraft use is located on the engine in the location of 15 the normal propeller. A ringcage 290 is attached to the fuselage by suitable means.

While my description contains many specificaties, these should not be construed as limitation on the scope of the invention, but that as preferred embodiments thereof. Many other variations are possible. For 20 example, a multiple ring structure as described herein employs circular rings. In some applications somewhat differently-shaped rings may be used without departing from the scope of the invention. The term ring as used 25 herein encompasses such other shapes. Some of the applications of the invention are the following:

1. Thrust Producing Usage

- a. Submarine tow motors for scuba divers,
- b. Electrical power quiet-trolling outboard 30 motors for fishing use,
- c. Flying submarines where air/water propulsion system is common and a small fuel volume is required for submersion,

- 33 -

- d. Lifting circular wings and propellers for STOL aircraft,
 - e. Tilting-propeller aircraft for hovering and conversion to a forward flight configuration with VSTOL operation,
 - 5 f. Tilting-wing propeller vehicle for VSTOL operation,
 - g. Tip propulsion of rotor blades for both small and large aircraft,
 - 10 h. Propulsion of ultra light aircraft,
 - i. Propulsion of ground effect machines and swamp boats,
 - j. Hydrofoils.
2. Air and water moving apparatus:
- 15 a. Leaf blower with light-weight motor mechanism,
 - b. Wind-tunnel-power system for increased velocity or reduced power requirements,
 - c. Water tunnel for aquatic testing for engineering information,
 - 20 d. Water pump for automotive applications,
 - e. Blower for cooling auto radiators,
 - f. Blower for cooling brakes,
 - g. Quite defrosting fans for vehicles, homes, frost-free refrigerator use,
 - 25 h. Pumping of grains,
 - i. Cooling fan for electronic equipment,
 - j. Circulating fans, in ducts, or ductless in offices, factories, or other buildings,
 - 30 k. Snowblowers,
 - l. Vacuum cleaners
 - m. Clothes dryer,
 - n. Dehumidifier by blowing air against a cold plate or inside a cooled tube.
 - 35

3. Heaters and Coolers:

- a. Fans with heating elements and ducts,
- b. Electric furnace hot-air heater,
- c. Steam-heat fans with hollow, steam-filled ringcages,
- 5 d. Heat exchanger with fan cooling of rings,
- e. Air conditioner with expanding freon coolant in the hollow rings to remove heat from the air,
- f. Convection-oven heating fan unit.

10 4. Mixers:

- a. Kitchen mixer for cooking,
- b. Coffee grinder,
- c. Food processors,
- d. Paint mixer,
- 15 e. Chemical products mixer,
- f. Sewer mixing and solid chopper.

Accordingly, the scope of the invention should be determined not by the embodiments illustrated, but by the appended claims.

20

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.



THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. An apparatus for enhancing the performance of a motor-driven propeller when it is rotated about an axis to establish a flow of fluid from an upstream side towards a downstream side, comprising:

a plurality of rings, at least one of which is located within the axial span of the propeller and another ring being located downstream of said one ring; said rings being so axially-spaced from each other as to form a flow augmenting aperture between said one ring and said downstreamlocated ring with said aperture further being selected to enable propeller generated vortices to augment the fluid flow.

2. The apparatus as claimed in claim 1 wherein a plurality of rings are located within the axial span of the propeller to form a plurality of flow augmenting apertures through which propeller generated tip vortices augment the fluid flow.

3. The apparatus as claimed in claim 1 wherein one of said rings is oriented so that it forms an inclined angle of attack relative to the propeller axis of rotation.

4. The apparatus as claimed in claim 1 wherein said rings have a radial chord width and wherein the radial chord width of said rings and the axial spacings between the rings are selected to establish said augmentation of the fluid flow.

5. The apparatus as claimed in claim 1 wherein said rings have a radial chord width and wherein the radial chord width of said rings, the axial spacing between the rings, and the thicknesses of the rings are selected to establish said augmentation of the fluid flow.



6. The apparatus as claimed in claim 1 and further including a heater element located at least within one of said rings.

7. The apparatus as claimed in claim 5 wherein the radial chord width has a dimension c of said rings is in the range from about 15% to about 50% of the radius of said propeller; the axial spacing w between rings is in the range from about one-half to about four chord dimension c ; and the thickness t of said rings is in the range from about 10% to about 35% of a chord dimension c .

8. The apparatus as claimed in claim 7 wherein said propeller has a tip, and wherein the clearance, s , between said propeller tip and the inner diameter of said one ring is in the range from about 3% to about 10% of the radius of the propeller.

9. The apparatus as claimed in claim 1 wherein said rings have cross-sectional airfoil shapes with one side shaped to promote an induced flow of tip vortices fluid around said rings in a direction that augments primary fluid flow from said propeller.

10. An apparatus for moving fluid comprising:
a motor;

a propeller coupled to the motor for rotation thereby about an axis, said propeller having a relatively low aspect ratio;

a multiple ring cage structure formed of a plurality of rings and placed to surround the propeller, at least one of said rings being located within the axial span of said propeller and another ring being located downstream of said one ring, said



rings being so axially-spaced from each other and so located with respect to the propeller as to form at least one flow augmenting aperture entirely within the axial span of the propeller between said one ring and said downstream-located ring, with said rings and aperture further being sized so as to enable fluid tip vortices from the propeller to be effectively converted to useful fluid mass flow.

11. The apparatus as claimed in claim 10 wherein said propeller has blades selected to strengthen tip vortices and with an aspect ratio in the range from about 0.1 to about 3.

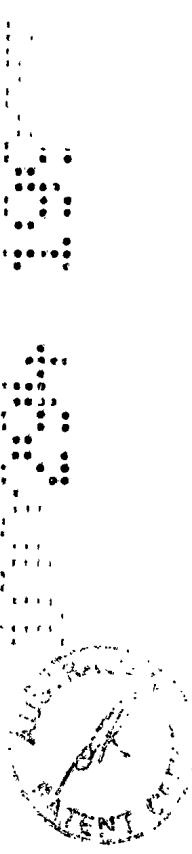
12. The apparatus as claimed in claim 10 wherein the solidity ratio of the propeller is in the range from about .06 to about 1.0.

13. The apparatus as claimed in claim 10 wherein the propeller has a plurality of blades, said blades having a generally rectangular planform.

14. The apparatus as claimed in claim 10 wherein the plurality of rings are located to surround the propeller within its axial span.

15. The apparatus as claimed in claim 10 wherein the rings have a radial chord length selected within the range from about 10% to about 50% of the radius of the propeller.

16. The apparatus as claimed in claim 10 wherein the axial spacings between at least a pair of axially successive rings defines a fluid flow augmenting aperture whose axial width is in the range from about



one-half to about four radial chord lengths and is at least partially located within the axial span of the propeller.

17. The apparatus as claimed in claim 15 wherein the rings have a radial chord
5 length of between about 10% to about 50% of the radius of the propeller; and

wherein at least a pair of axially-successive rings are spaced to form a flow-augmenting aperture whose width is in the range from about one-half to about four radial chord lengths.

10 18. The apparatus as claimed in claim 17 wherein said rings each have a chordal segment and wherein the chordal segment of at least one of said rings is inclined at an angle relative to the axis of rotation of said propeller.

19. The apparatus as claimed in claim 18 wherein the inclination angle of said
15 chordal segment is in the range from about five to about 45 degrees.

20. The apparatus as claimed in claim 10 wherein the propeller has blades which have tip pitch angles in the range from about 15 to 60 degrees.

20 21. A fan for moving air comprising:

a motor, a propeller coupled to the motor to be driven by the motor into rotation about an axis, said propeller having a plurality of blades having an axial span along the axis;

a ring cage structure mounted around the propeller, said ring cage structure
25 including a plurality of axially-spaced rings with an annular aperture between said rings, at least one of said rings being within the axial span of the propeller blades and another of said rings being located downstream of said one ring; said rings being so axially spaced from each other and being so selected to provide an air flow augmentation through said aperture from a conversion of propeller generated tip vortices so as to
30 augment the air flow from the propeller.



22. The fan as claimed in claim 21 wherein a plurality of rings are located within the axial span of said propeller blades.

23. The fan as claimed in claim 21 wherein a plurality of said annular apertures for
5 air flow augmentation are located within the axial span of said propeller blades.

24. The fan as claimed in claim 21 wherein said rings have a ring chord dimension and wherein the ring chord dimension and the axial spacing between said one ring and an axially-successive ring are selected to provide said flow augmentation.

10

25. The fan as claimed in claim 24 wherein the ring chord dimension is in the range between about 10% to about 50% of the radius of the propeller.

26. The fan as claimed in claim 25 wherein the spacing between at least said one
15 ring and an axially successive ring is selected in the range from about one-half to about four ring chord dimensions.

27. The fan as claimed in claim 24 wherein the ring chord dimension, said axial spacing, and said propeller are selected to provide a static pressure versus mass flow
20 curve that is substantially straight.

28. The fan as claimed in claim 27 wherein said propeller blades have a relatively low-aspect-ratio.

25 29. The fan as claimed in claim 28 wherein the propeller blades have an aspect ratio in the range from about 0.1 to about 3.

30. The fan as claimed in claim 29 wherein the propeller has a solidity ratio in the range from about 0.6 to about 3.

30

31. The fan as claimed in claim 30 wherein at least one of said rings is inclined at a desired angle relative to the rotational axis.



32. The fan as claimed in claim 29 wherein the rings forming said annular aperture have cross-sectional airfoil shapes with an airfoil surface facing upstream of said air flow.

5 33. The fan as claimed in claim 32 wherein the ring airfoil surfaces each have a normally blunt leading edge and a normally thick trailing edge, with said blunt leading edge being inboard and said thin trailing edge being outboard, so that airflow from said tip vortices moves from the trailing edges across the airfoil surfaces towards the blunt leading edges.

10

34. An airplane engine having a rotating shaft comprising:
a propeller coupled to the shaft for rotation thereby and having an axial span and producing gas flow from an upstream direction to a downstream direction;

a ring cage structure mounted to surround the propeller, said ring cage structure
15 having a plurality of axially spaced rings, at least one of said rings surrounding said propeller by being located within the axial span of said propeller, said rings being axially-separated by an aperture which is at least partially located within the axial span of the propeller and being so sized and located so as to enable propeller generated vortices to augment the gas flow produced by the propeller.

20

35. An airplane engine as claimed in claim 34 wherein said propeller has a relatively low aspect ratio in the range from about 0.10 to about 3.

36. An airplane engine as claimed in claim 35 wherein the rings have a radial chords
25 width, C, selected within the range from about 15% to about 50% of the radius of said propeller.

37. An airplane engine as claimed in claim 36 wherein the axial spacing w between rings is in the range from about one-half to about four radial chord widths.

30



38. An airplane engine as claimed in claim 37 wherein rings have airfoil surfaces facing upstream and wherein the thickness of the rings is in the range from about 10% to about 35% of a radial chord width.

5 39. An airplane engine as claimed in claim 38 wherein said propeller has a tip and wherein the clearance, S, between said propeller tip and the inner diameter of said one ring is in the range from about 3% to about 10% of the radius of the propeller.

40. An axial flow propeller system for moving fluid comprising:

10 an axial flow propeller for rotation about an axis and having a plurality of radially-extending blades; said blades being oriented with an axial span selected to move said fluid in a downstream direction along the axis during blade rotation;

a ring cage structure formed of a plurality of axially-spaced fluid flow enhancing rings located around the axis, with at least one of said fluid flow enhancing rings being
15 axially-located around the blades within their axial spans;

said propeller blades having tips which generate tip vortices during rotation with the shape of the blades being selected to strengthen the tip vortices; the blade tips and the radially-inner edge of said one fluid flow enhancing ring being in sufficiently close proximity and with dimension of said axial fluid flow enhancing rings and their axial
20 spacing being selected to form an aperture through which tip vortices from the blades augment the fluid flow in said downstream direction;

whereby tip vortices can be converted to useful fluid flow for enhanced performance of the axial flow propeller system.

25 41. The axial flow propeller system as claimed in claim 40 wherein the rings have a ring chord C which is less than about 59% of the radius R of the propeller and wherein the radial clearance between the tips of the propeller blades and an inner edge of said one fluid flow enhancing ring is less than about 10% of said radius R and the axial distance between rings is in the range from about one half to about four ring
30 chords C.

42. A method for enhancing the mass flow from a propeller comprising the steps of:
rotating the propeller so as to move a fluid from an upstream side in a
downstream direction while generating tip vortices from the tips of propeller blades; and
during said propeller rotation influencing the flow of said tip vortices to move
5 mass flow from tip vortices into a preselected spaced and sized pumping aperture, which
extends at least partially around the propeller, and in a direction so as to convert mass
flow from tip vortices into an augmentation of useful mass flow from said propeller.

43. The method for enhancing the mass flow from a propeller as claimed in claim
10 42 and further comprising the step of:
during said propeller rotation influencing the flow of said tip vortices at
successively axially-spaced pumping apertures so as to convert mass flow from tip
vortices into an augmentation of useful mass flow from said propeller at successive
axially-spaced locations.

15 44. An apparatus for enhancing the mass gas flow from a propeller in a fan
comprising:

a propeller to move a gas from an upstream side in a downstream axial direction
while generating tip vortices from tips of propeller blades; and

20 means for generating a flow augmenting aperture extending at least partially
around the propeller, said flow augmenting aperture having a preselected size and is
selectively spaced from the tips of the propeller blades so as to convert mass flow from
tip vortices into an augmentation of useful axially downstream directed mass flow from
said propeller.

25 45. An apparatus for enhancing the mass flow from a propeller as claimed in claim
44 wherein said means for generating said flow augmenting aperture generates a
plurality of said pumping apertures in successive axially spaced locations within the axial
span of said propeller blades, with each of said pumping apertures converting mass flow
30 from tip vortices into an augmentation of useful axially downstream directed mass flow
from said propeller.

46. An apparatus as claimed in claim 45 wherein said means for generating said flow augmenting aperture comprises a plurality of ring elements spaced around the propeller blades.

5 47. An apparatus for enhancing the performance of a motor-driven propeller substantially as hereinbefore described with reference to the accompanying drawings.

48. An apparatus for moving fluid or a fan for moving air substantially as hereinbefore described with reference to the accompanying drawings.

10

49. An airplane engine substantially as hereinbefore described with reference to the accompanying drawings.

50. An axial flow propeller systems substantially as hereinbefore described with
15 reference to the accompanying drawings.

51. A method for enhancing the mass flow from a propeller substantially as hereinbefore described with reference to the accompanying drawings.

20

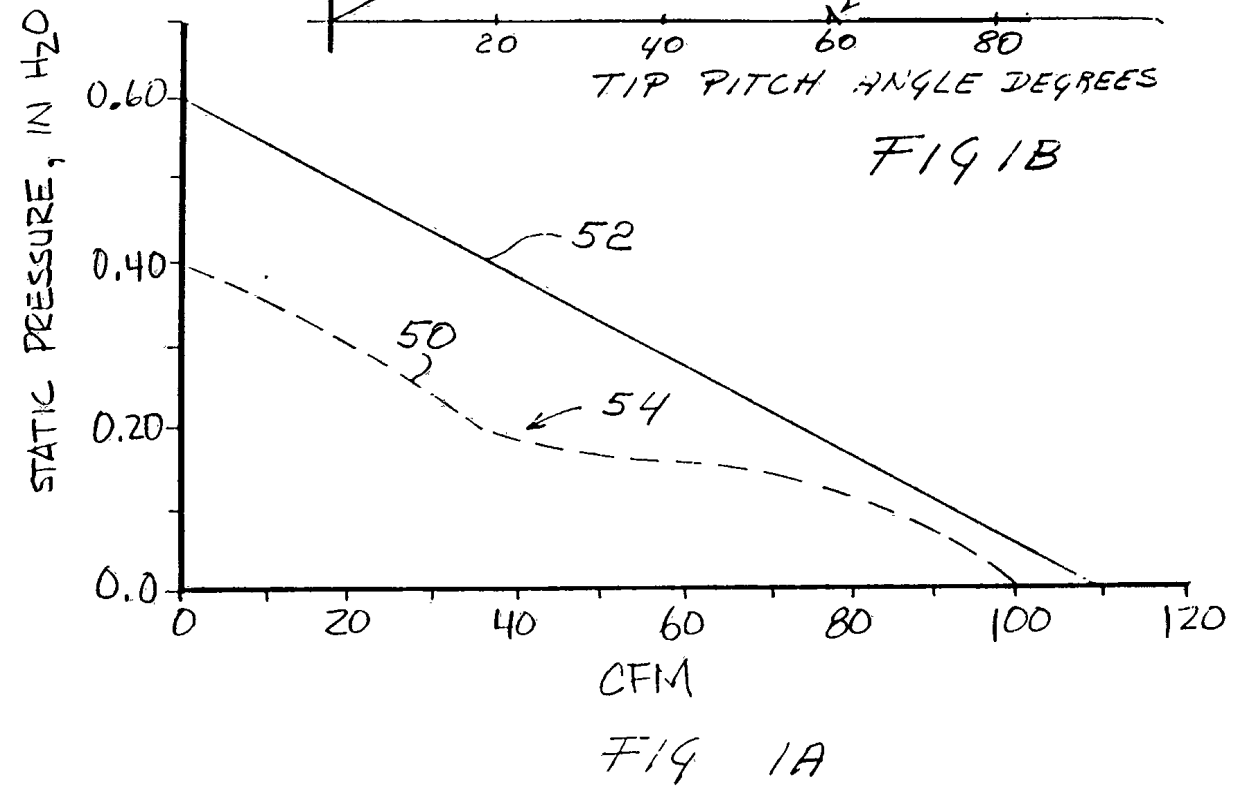
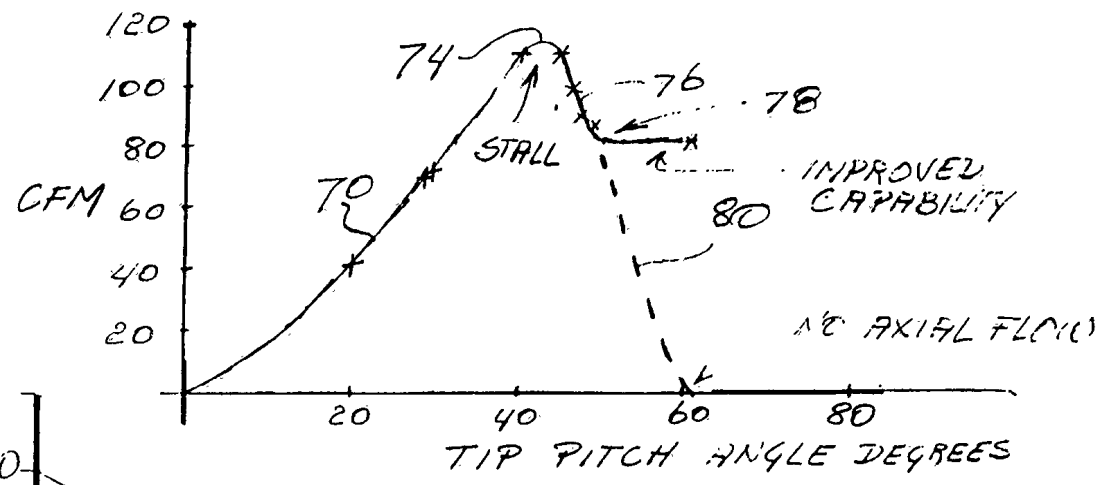
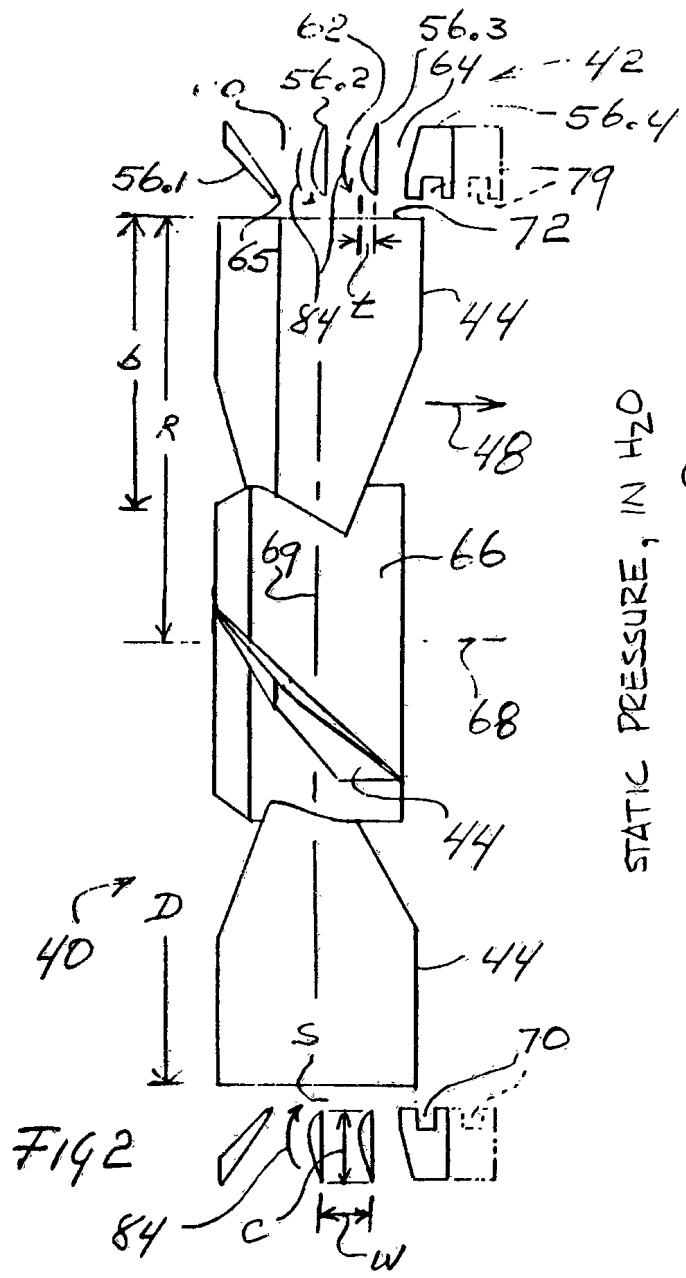
DATED this 29th day of March, 1995

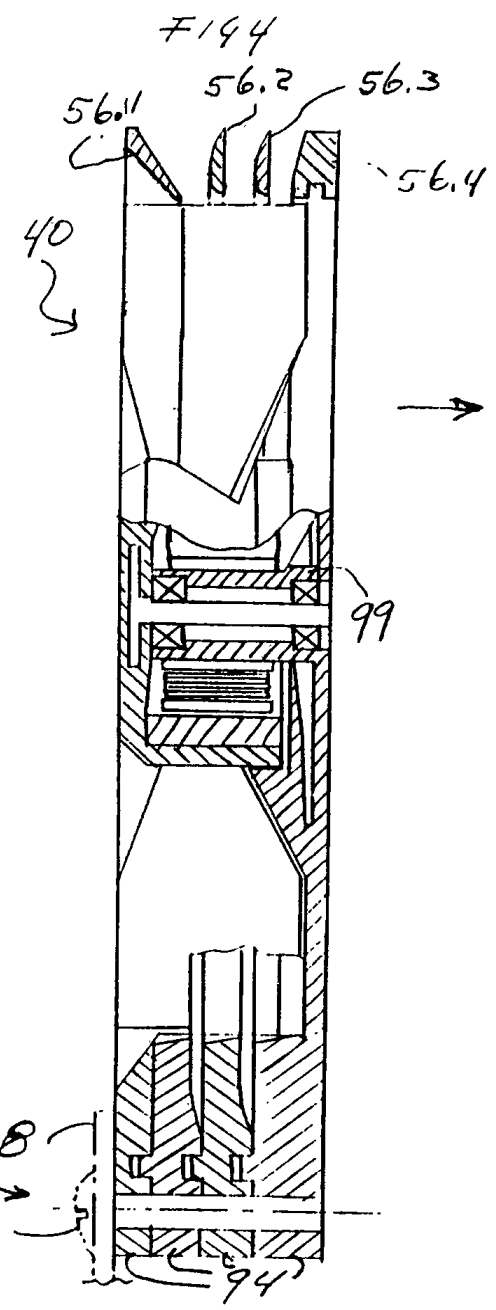
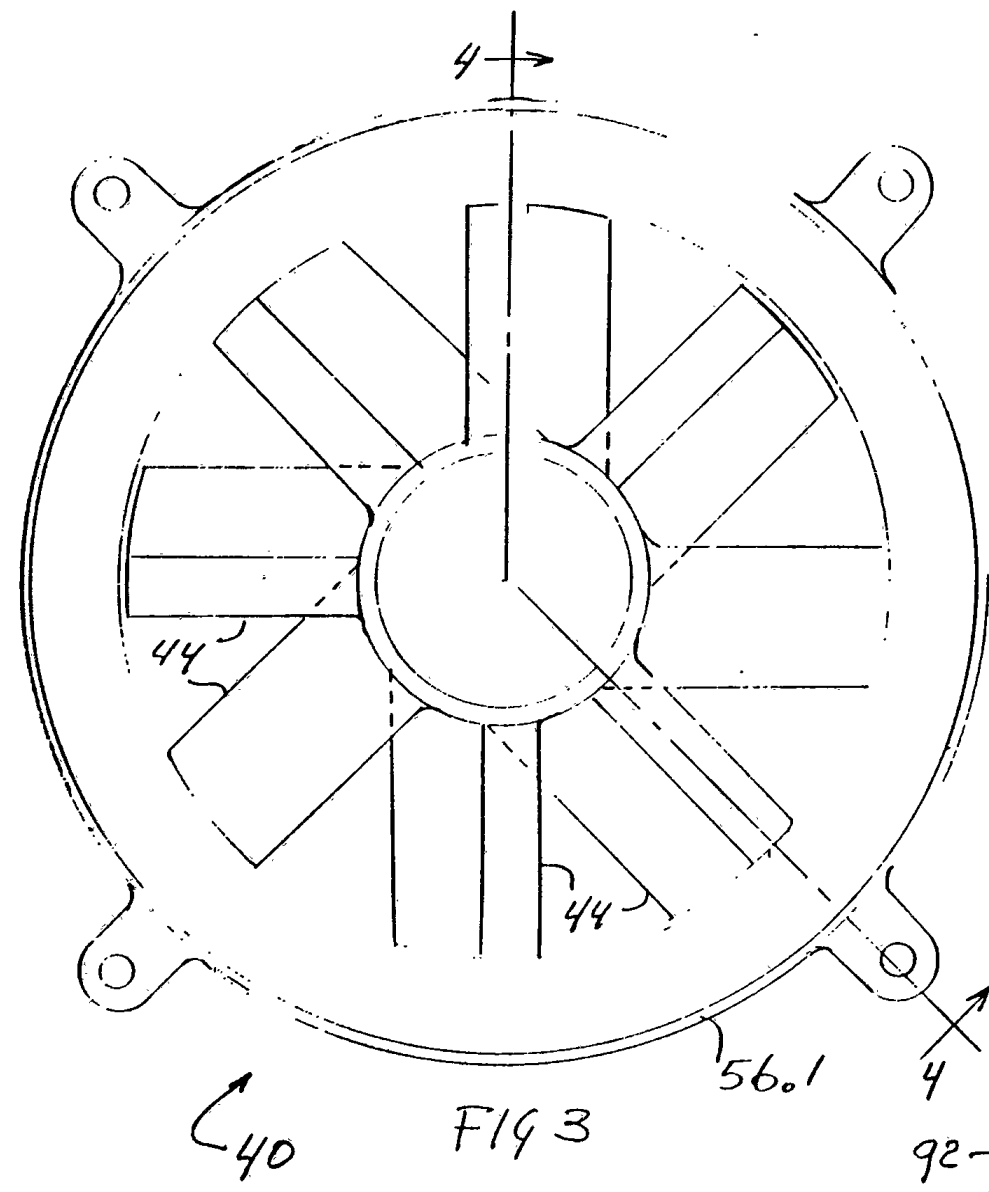
Lemont Aircraft Corporation

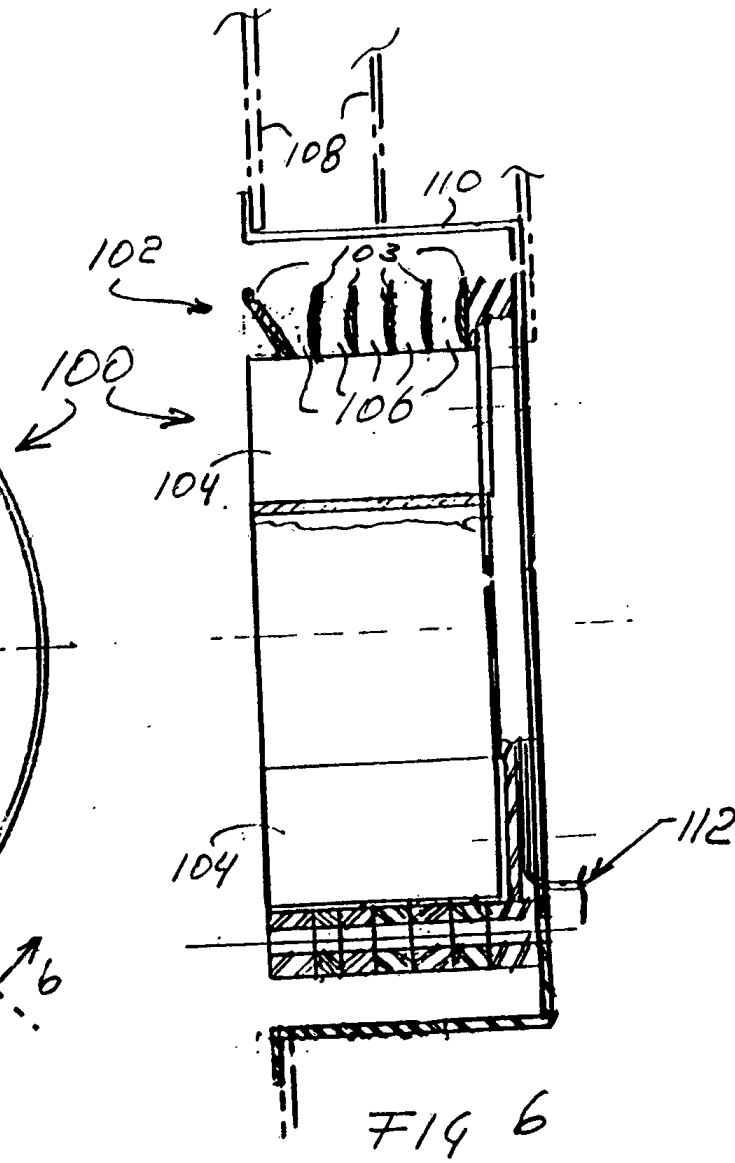
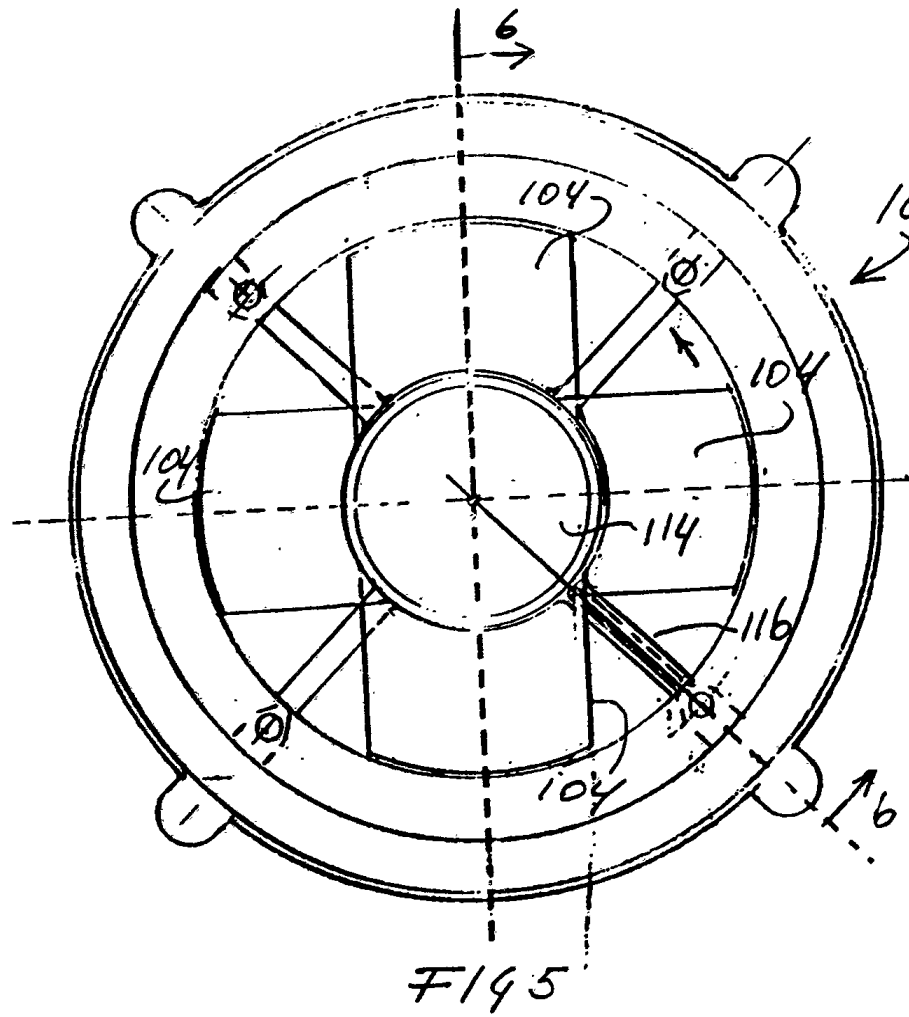
25 By Its Patent Attorneys

DAVIES COLLISON CAVE

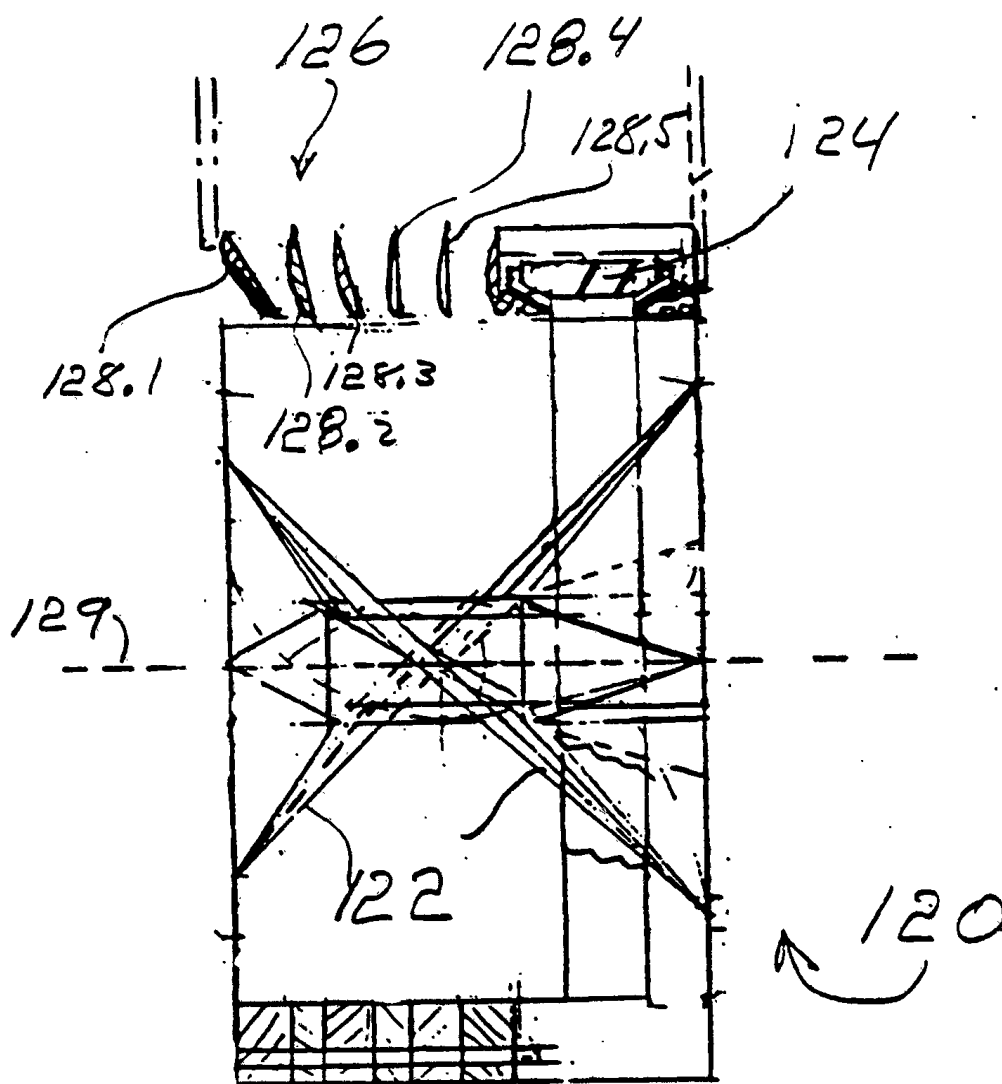
19995192



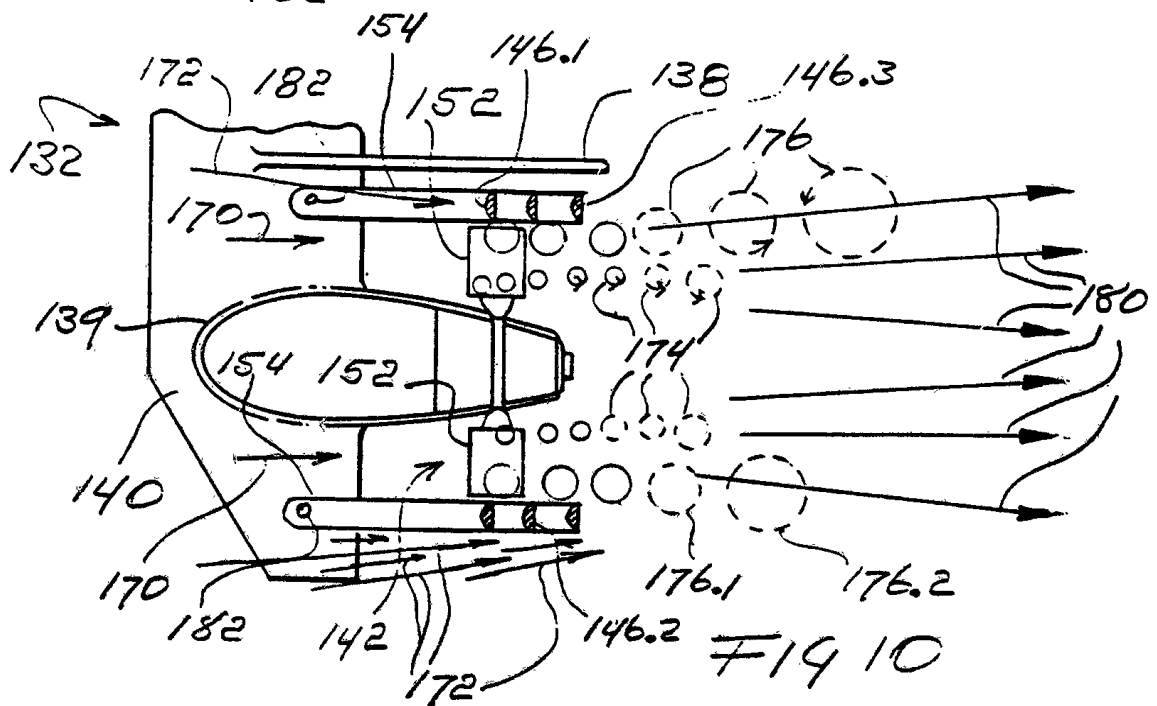
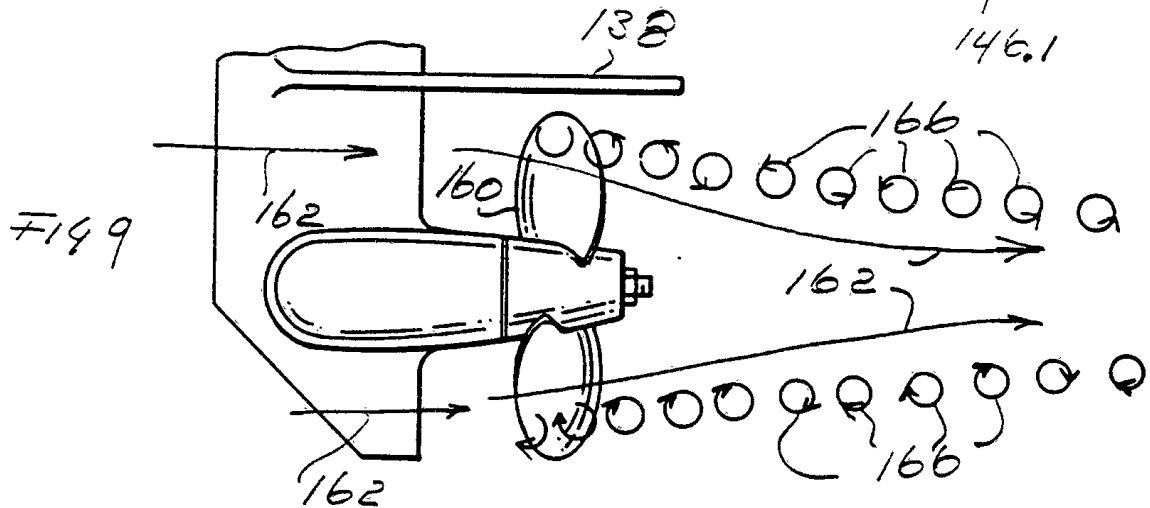
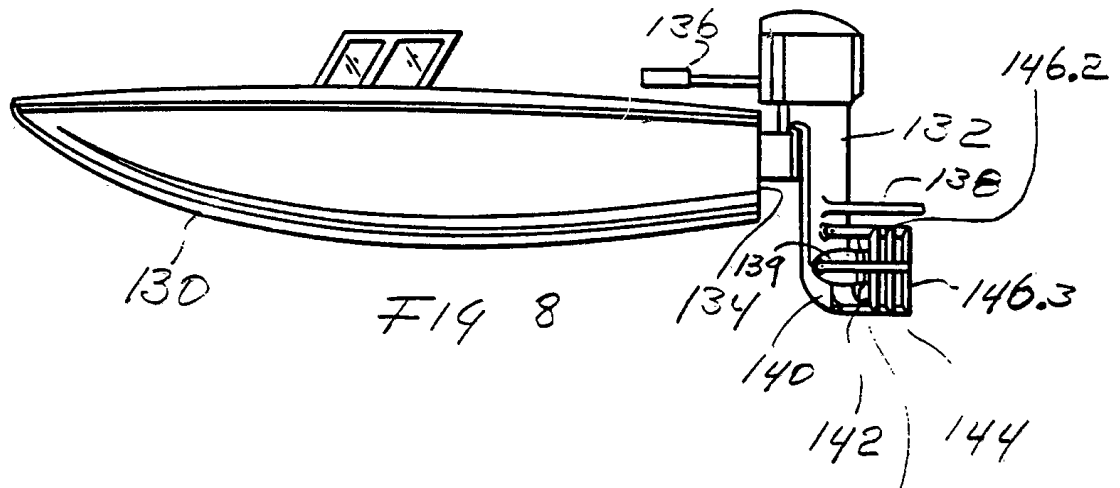


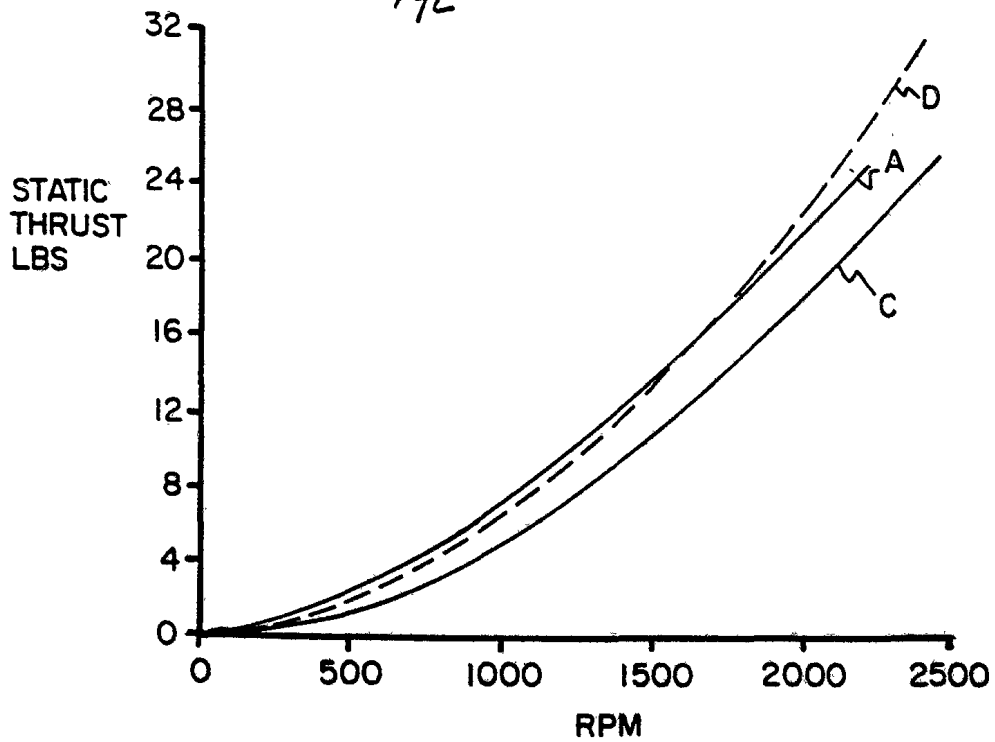
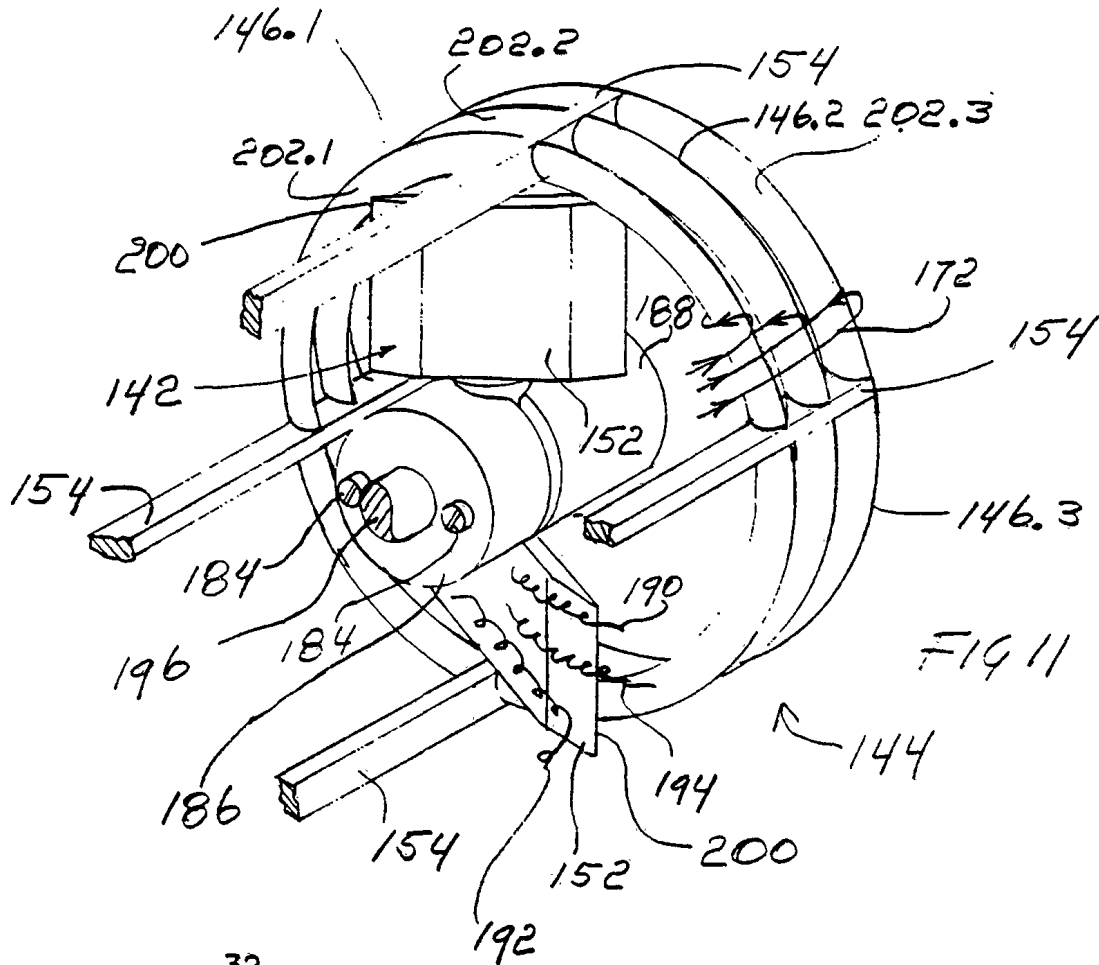


4/9



F197





7/9

Fig 13

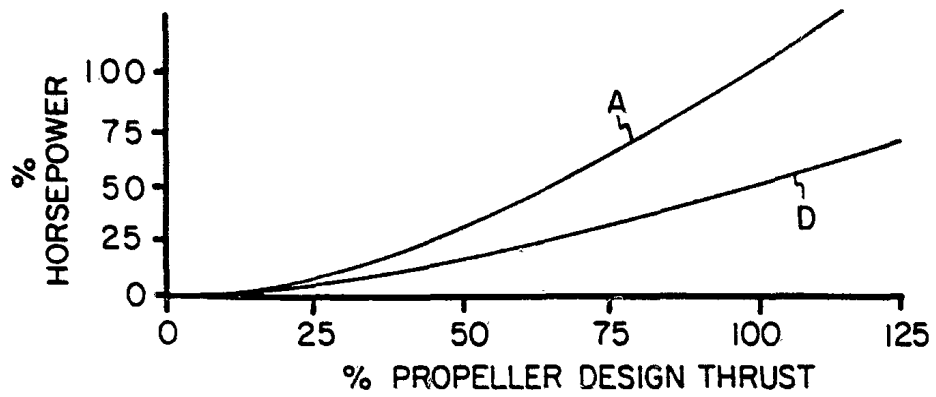


Fig 14

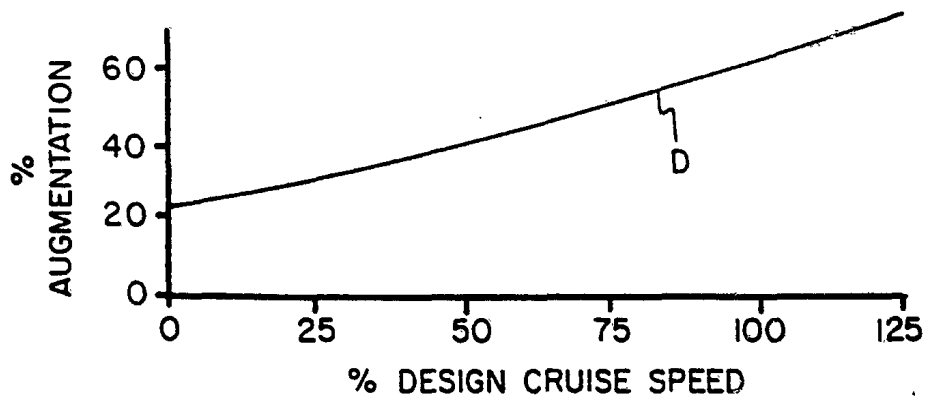
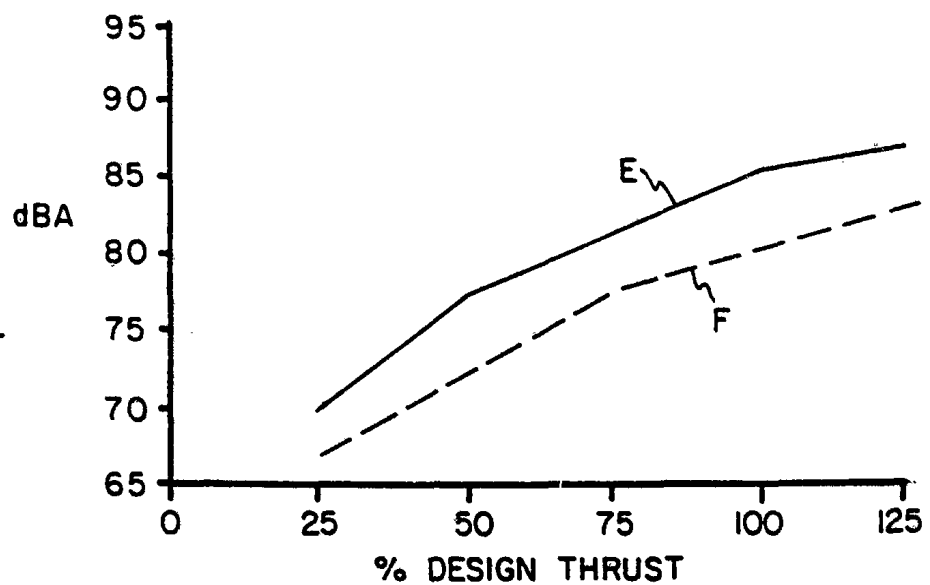


Fig 15



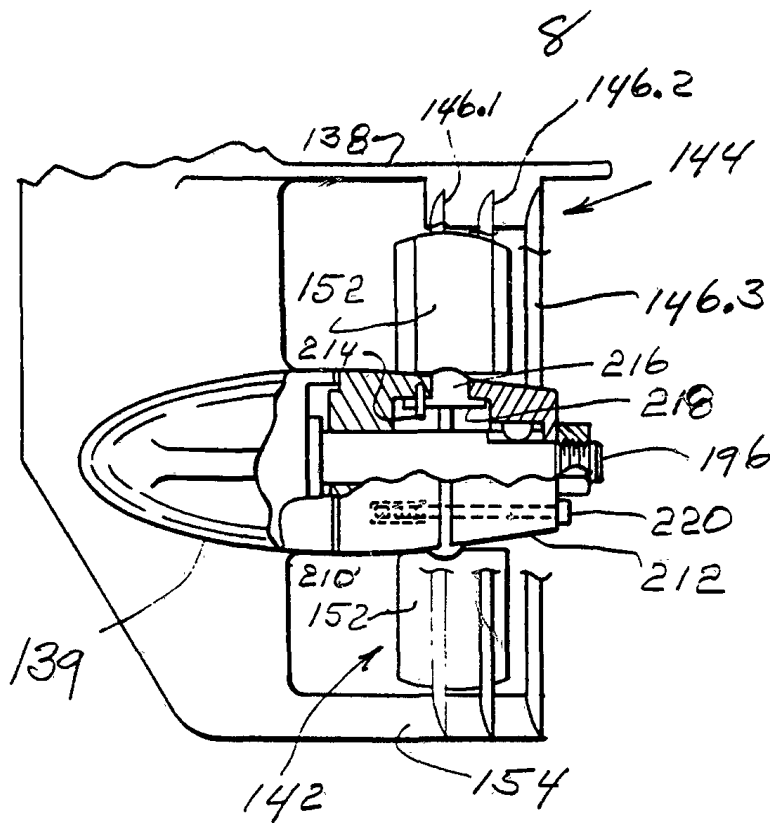


FIG 16

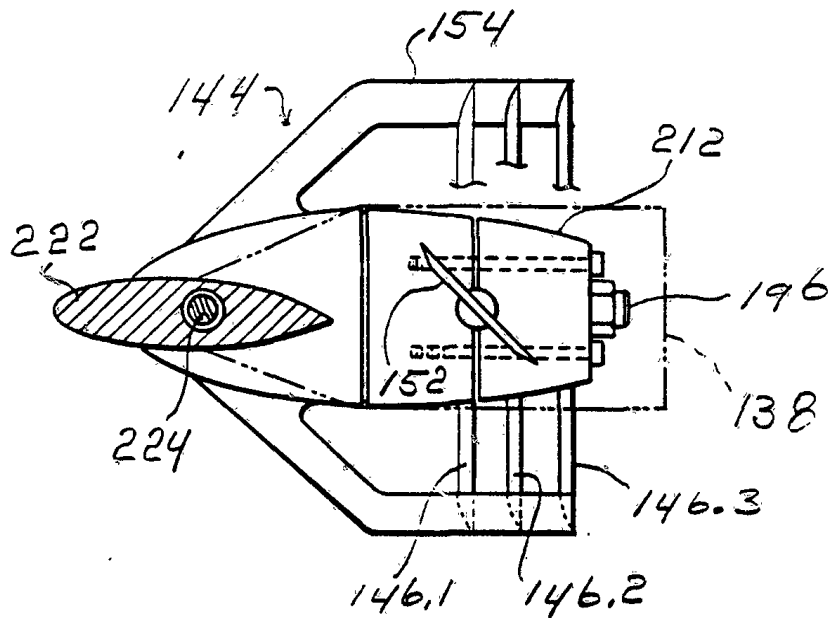


FIG 17

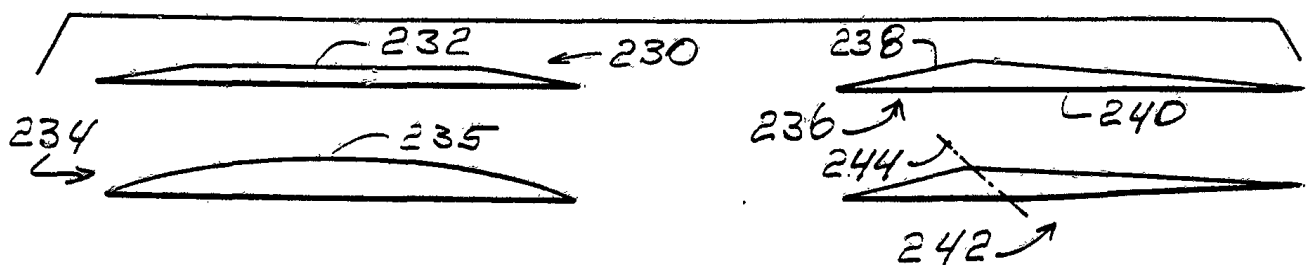
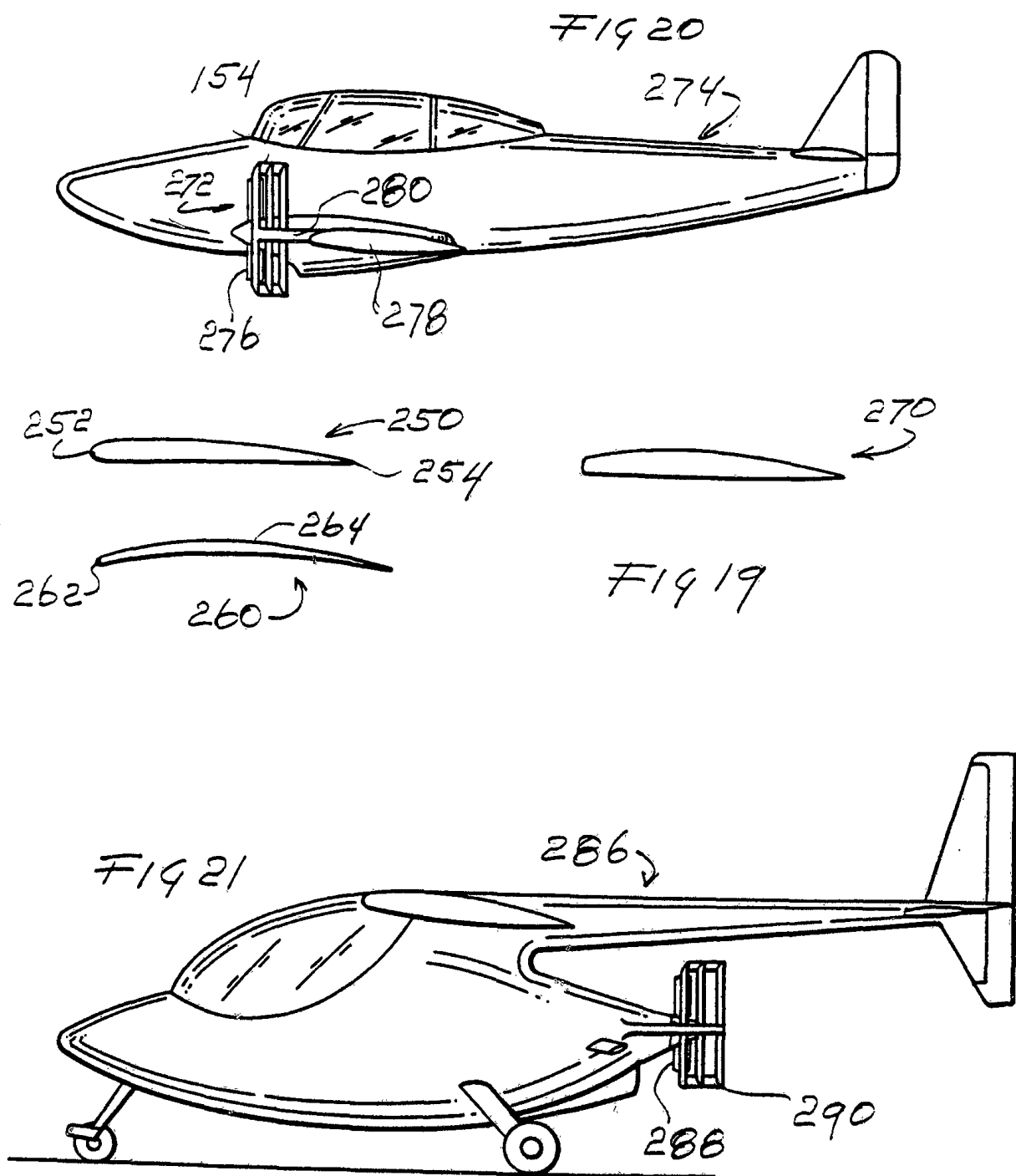


FIG 18



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US92/04647

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :B64C 11/00

US CL :244/065

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 244/12.2.; 440/66,67,71,72; 416/247

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 3489,374 (MORCOM) 13 January 1970, See entire document.	1,3-5,9,10, 35,41,43,44
X	GB, A, 629,381 (FUKAL) 19 September 1941, See entire document.	1-5,10,14, 16,18,21-24, 41,43,44
X	US, A, 4,637,801 (SCHULTZ) 20 January 1987, See entire document.	1-5,9,10, 14,41,43, 44
X	FR, A, 737.957 (FERRAL) 19 December 1932, See entire document.	1,3-5,9,10, 41,43,44

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A document defining the general state of the art which is not considered to be part of particular relevance	*X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
*E earlier document published on or after the international filing date	*Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Z document member of the same patent family
*O document referring to an oral disclosure, use, exhibition or other means	
*P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

13 NOVEMBER 1992

Date of mailing of the international search report

25 NOV 1992

Name and mailing address of the ISA/
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Authorized officer

THOMAS J. BRAHAN

Facsimile No. NOT APPLICABLE

Telephone No. (703) 308-1113

INTERNATIONAL SEARCH REPORTInternational application No.
PCT/US92/04647**C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 2,618,435 (KOCH) 18 November 1952, See entire document.	1-3,5,9,10, 14,21-24,41, 43,44
X	US, A, 2,056,547 (WEBER) 06 October 1936, See entire document.	1-3,5,9,10, 14,21-24