United States Patent

Vryland

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[54] GROUND EFFECT MACHINE

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[52] U.S. Cl. 180/120

[51] Int. Cl. B60v 1/14

[58] Field of Search ..... 180/120, 121, 117, 118; 244/12, 23 R, 23 A, 23 B, 23 C, 23 D, 56

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[57] ABSTRACT

A ground-effect machine having a rigid outer plenum chamber which is substantially triangular and has an inverted, cup-shaped form. The two leading sides of the plenum chamber adjacent the bow have inwardly inclined sides which serve to increase stability, provide a slight lift force, and reduce the hydraulic coefficient of discharge, which in turn increases the lift of the vehicle above the ground surface. Three spherical propulsion units are mounted on and extend above the plenum chamber. They are provided with a substantially universal mounting on the plenum chamber and their position is controlled from a cockpit on the plenum chamber.

9 Claims, 9 Drawing Figures

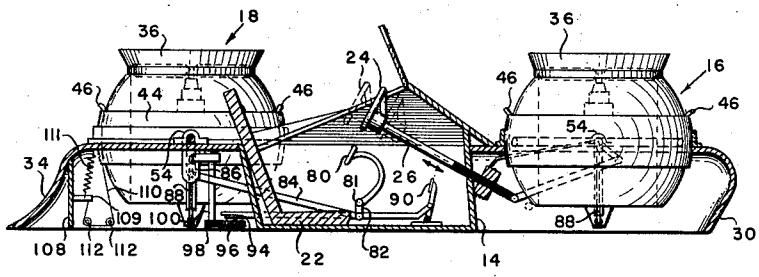
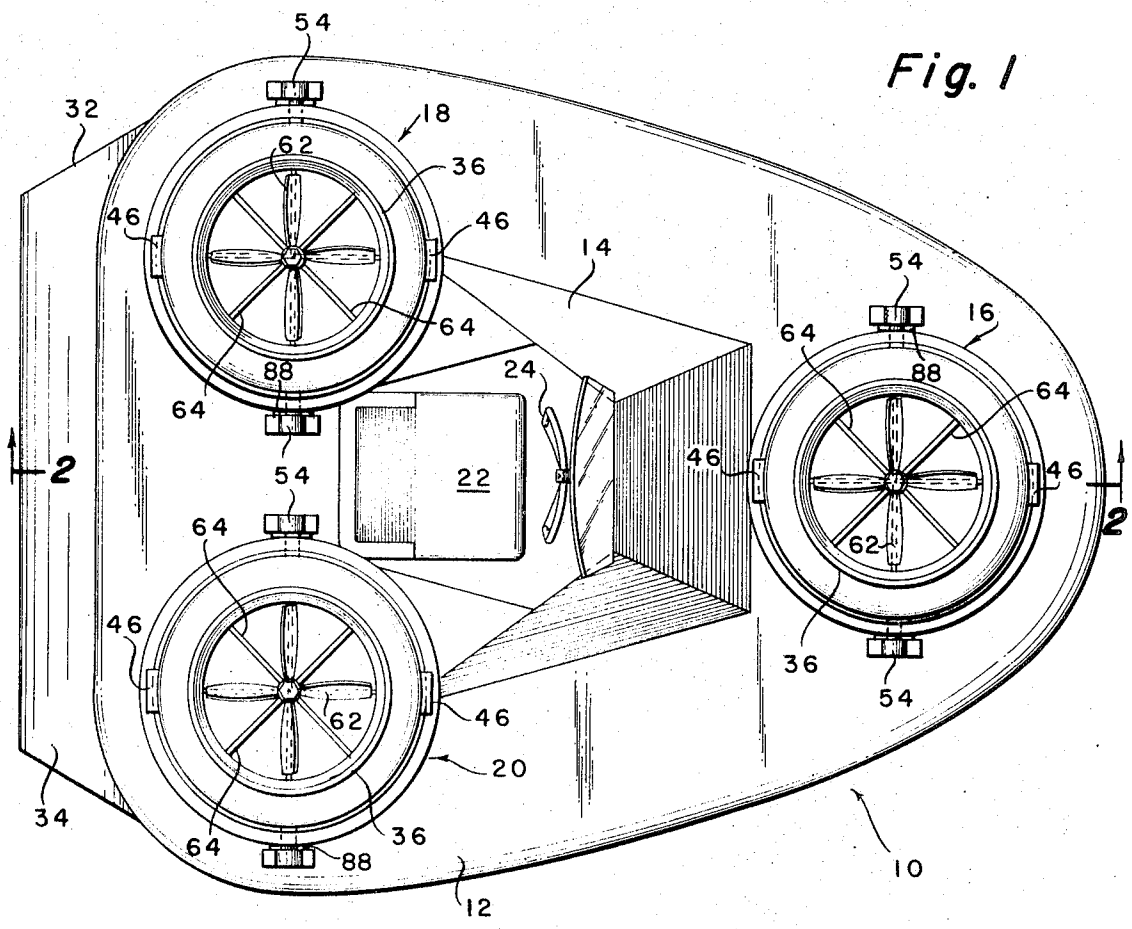


Fig. 1



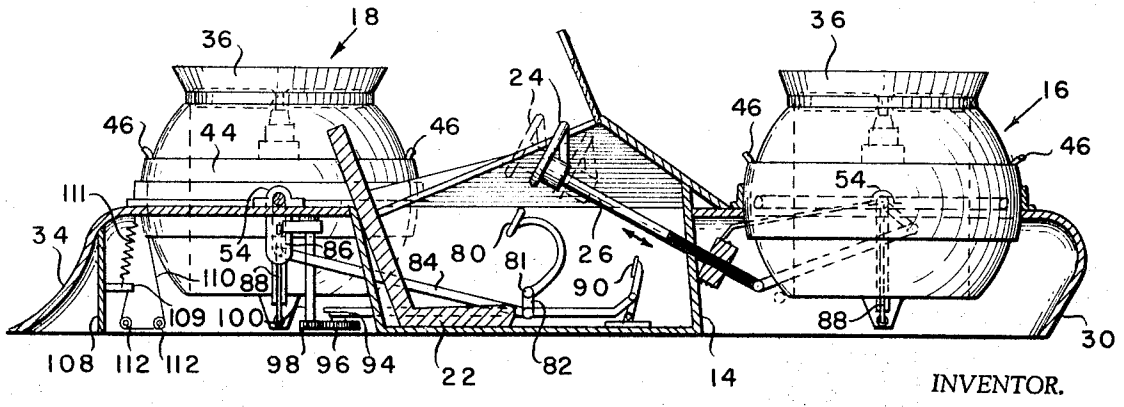
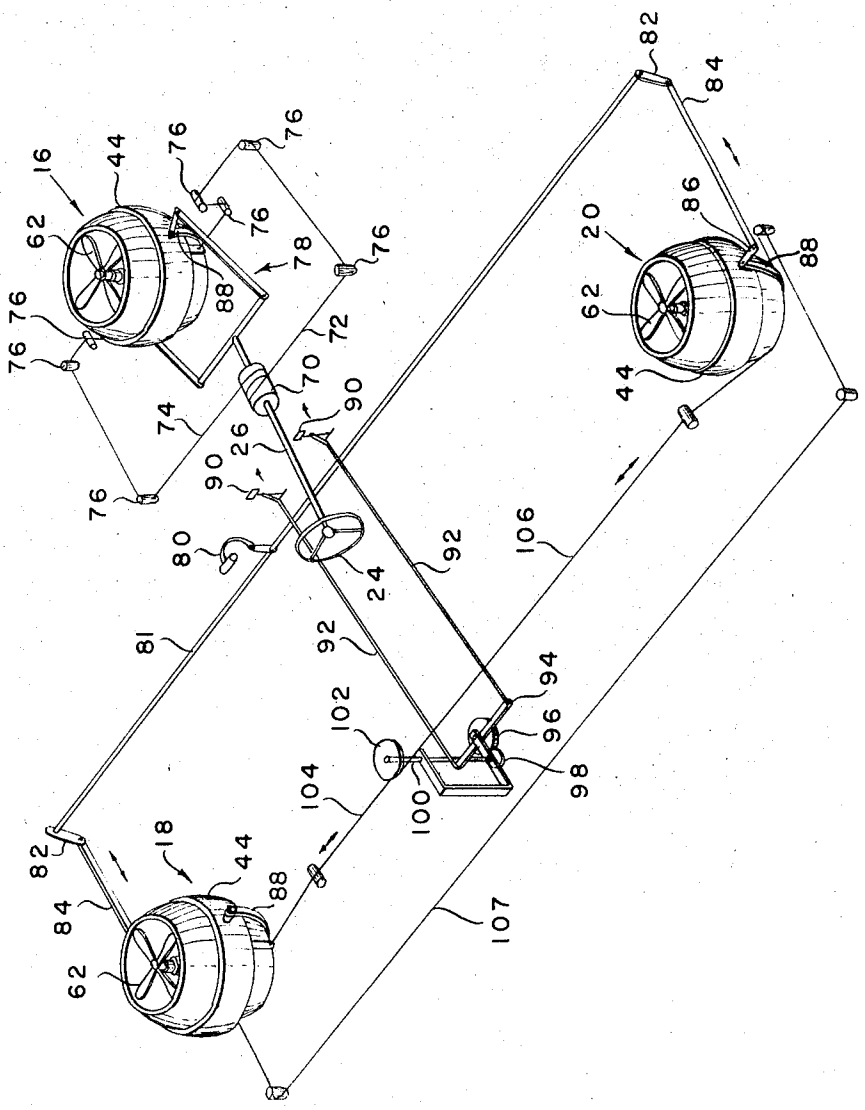


Fig. 2

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Fig. 3



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Fig. 4

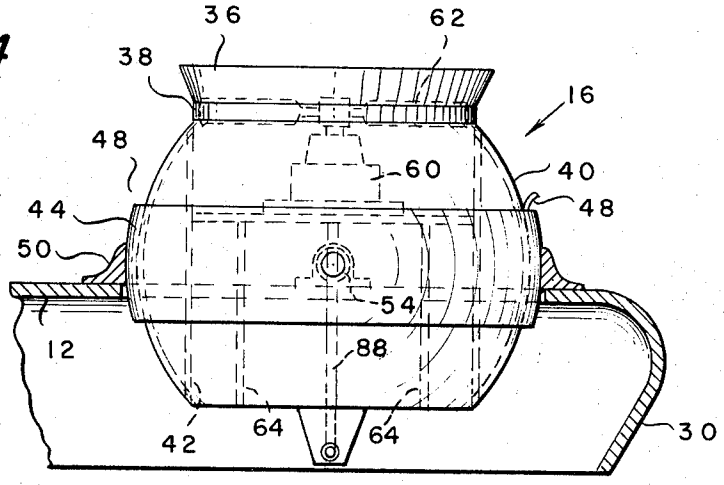
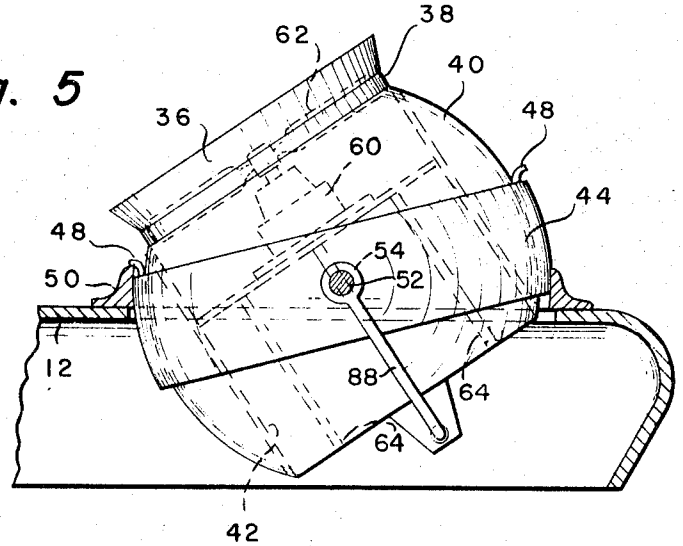
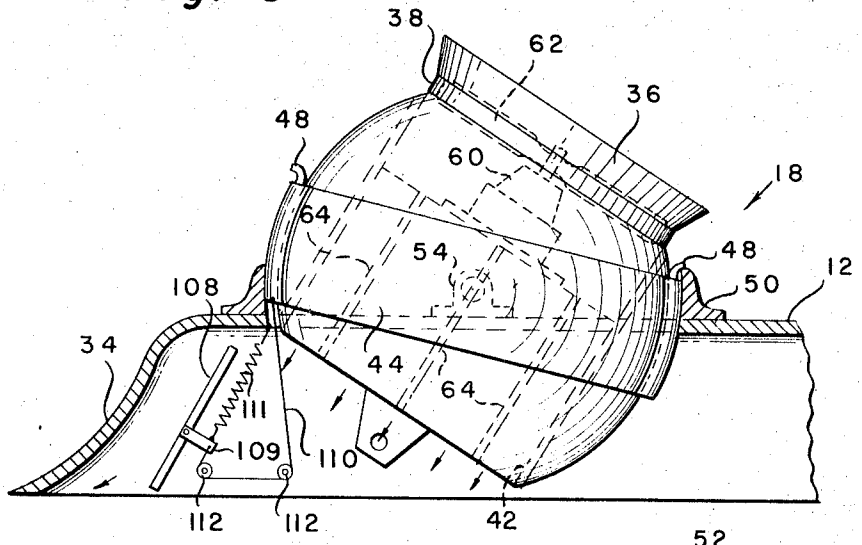


Fig. 5



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Fig. 6



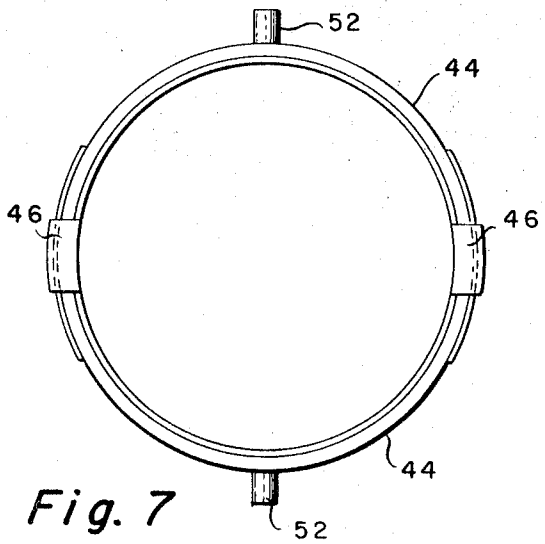


Fig. 7

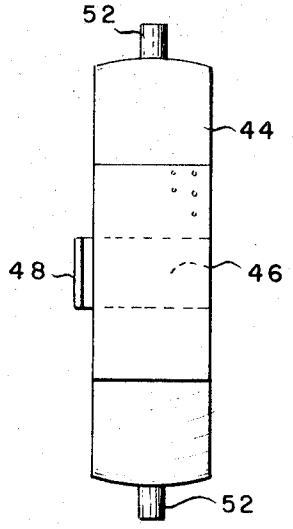


Fig. 8

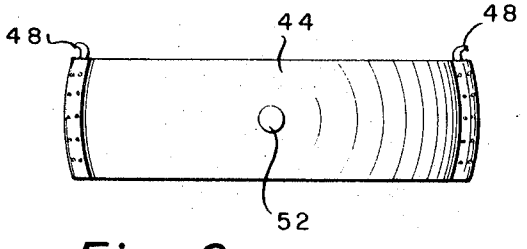


Fig. 9

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GROUND EFFECT MACHINE

This invention relates to a ground-effect machine and more particularly to a ground-effect machine which is provided with a rigid outer plenum chamber having an inverted, substantially triangular, cup-shaped form and spherical propulsion units mounted thereon.

Heretofore it has been known to provide ground-effect machines with separate means for providing lift and separate means for providing change of direction for the ground-effect machine. This has resulted in unsatisfactory directional control characteristics especially at slow speeds. Such prior art devices have also been substantially unable to prevent sliding of the vehicle as high speed turns are made.

Another deficiency noted in many prior art devices is that the means for providing lift for the vehicle are rigidly positioned on the surface of the main plenum chamber whereby, during movement of the vehicle, the air which passes through the lift providing means must be sharply redirected in order to enter the inlet of the lift providing means if mounted vertically, or the air must be sharply redirected after intake if the lift providing means is mounted horizontally and facing the direction of movement.

In accordance with the present invention, the foregoing disadvantages and shortcomings of the prior art are effectively overcome by utilizing the same spherical propulsion units which provide lift for the vehicle also to provide the thrust for directional control of the vehicle.

It is another feature of the present invention that the spherical propulsion units which also provide directional control are tilted into the direction of movement of the vehicle whereby there is a substantially straight-through shot of air entering into and exiting from the spherical propulsion units. Preferably, the spherical propulsion units have a bell-mouthed inlet and are provided with flow straightening means for the air which passes through the spherical propulsion unit.

It is still another feature of the present invention that the rear wall, or stern is slanted outwardly and is equipped with an automatic opening rear door. At hover position or with the two rear propulsion units tilted rearwardly the door remains closed and presents an orifice comparable to the side walls of the vehicle with approximately the same coefficient of discharge and flow restriction to the exiting air. However, with the propulsion units tilted forwardly to drive the vehicle forward, the door is automatically opened to permit the large volume of air delivered by the propulsion units to escape more easily to the rear, under the outwardly slanted wall which has an increased coefficient of discharge and therefore permits a larger quantity to flow through the same size orifice.

The inherent advantages and improvements of the present invention will become more readily apparent upon considering the following detailed description of the invention and by reference to the drawings in which:

FIG. 1 is a top plan view of the ground-effect machine of the present invention;

FIG. 2 is a side elevational view taken in vertical cross section along line 2—2 of FIG. 1;

FIG. 3 is a diagrammatic perspective view showing one suitable means for controlling the spherical propulsion units of the present invention;

FIG. 4 is a fragmentary, elevational view, partially in cross section, showing the mounting of one of the spherical propulsion units and drawn to an enlarged scale;

FIG. 5 is a fragmentary, elevational view similar to FIG. 4, illustrating a different position for the spherical propulsion unit;

FIG. 6 is a fragmentary, elevational view, similar to FIGS. 4 and 5, illustrating another one of the propulsion units in still another position and an automatically operated butterfly-type door across the stern of the inner chamber just aft of the rear propulsion units;

FIG. 7 is a top plan view of a split ring support for the spherical propulsion units of the present invention;

FIG. 8 is a side elevational view of the split ring support member of FIG. 7; and,

FIG. 9 is a front elevational view of the split ring support member of FIG. 7.

Referring now to FIG. 1 of the drawings, a ground-effect machine is indicated generally by numeral 10. Ground-effect machine 10 has a substantially triangular, inverted cup-shaped form which comprises a rigid plenum chamber 12. Mounted substantially centrally of the rigid plenum chamber 12 is a cockpit 14. A first spherical propulsion unit, indicated generally at 16, is mounted in the front or bow of the ground-effect machine 10 while two additional spherical propulsion units indicated generally at 18 and 20 are mounted opposite the bow generally symmetrical with respect to a longitudinal axis of the craft.

Numeral 22 indicates a seat within the cockpit as is a steering wheel 24 on a steering column 26, FIG. 2, which is reciprocally mounted through a forward wall of cockpit 14.

As can be seen in FIGS. 2, 4 and 5, the ground-effect machine 10 is provided with inwardly inclined walls 30 which extend from the bow on both sides of the ground-effect machine 10 completely to the rear of the craft at which point there is a run-out of the inwardly inclined walls at edge 32 of an outwardly flared rear wall 34.

FIG. 6 indicates one method of automatically operating the butterfly-type door which allow the large volume of air delivered by propulsion units 18 and 20 to escape more readily to the rear when the units are tilted fully forward so as to drive the machine in forward flight. The butterfly door 108 hinged preferably below its dimensional center line, is equipped with rigid levers 109 which have elastic "closing" mechanisms or springs 111 and flexible operating cables 110 passing downwardly from levers 109, around guide sheaves 112, and thence upwardly, attaching to the lower rear edge of the split-ring support members 44 of propulsion units 18 and 20. Tilting the propulsion units forward in unison to drive the machine forward pulls cables 110 upwardly and causes levers 109 to be pulled downwardly opening door 108. Returning the propulsion units to the vertical releases cables 110 and the door is closed through the action of the elastic closers 111. This closing of door 108 restricts the flow of exiting air to provide greater lift at hover by providing an orifice with a much smaller coefficient of discharge than that offered by the outwardly flared rear wall 34. It can also be seen that tilting the propulsion units beyond the vertical to the rear will merely allow the flexible cables 110 to go slack and the door 108 will remain closed by action of the elastic closers.

The spherical propulsion units 16, 18 and 20 have a substantial universal mounting on the plenum chamber 12 with various positions thereof being indicated in FIGS. 2, 4, 5 and 6. Each spherical propulsion unit 16, 18 and 20 has a bell-mouthed entrance 36 which flares outwardly outboard of a cylindrically shaped neck 38 and a spherical body 40. Each spherical propulsion unit has a cylindrical inner wall 42 which is in line with the cylindrically shaped neck 38.

As is detailed in FIGS. 7 through 9, each propulsion unit is provided with split ring propulsion supports 44 of tolerances close enough to support the spherical propulsion units but allowing them to rotate within said ring supports. The split rings are joined together by splice plates 46. The latter carry stop ears 48 to limit the movement of the split ring propulsion supports 44 against a two-piece seal ring 50, the ends of which terminate adjacent stub shafts 52 on the split ring propulsion supports 44. Stub shafts 52 are journaled in bearings 54. Each propulsion unit 16, 18 and 20 carries a motor 60 which drives a propeller 62 thereby constituting a fan means. Each motor 60 is mounted atop a series of flow straightening vanes 64 illustrated best in FIG. 1.

The mounting of the spherical propulsion units is such as to permit substantially infinite variation to the direction of a pure jet thrust while still maintaining an effective seal between the pressurized air within the plenum chamber and the surrounding atmosphere. With the plenum chamber itself having sides inclined inwardly at an optimum angle of approximately 60° with respect to the surface of the ground or water, the plenum chamber provides lift and stability in forward flight. The

ground-effect machine **10** also takes advantage of the effect of the inclined sides to force the air downwardly while the machine moves forward. This downward thrust of air resists the outward flow of air from beneath the bottom edge of the plenum chamber **12** and results in the ground-effect machine obtaining a higher lift. As will be explained more fully hereinafter, the rear propulsion units **18** and **20** may be controlled independently from the front propulsion unit. This permits the machine to begin moving forward with the front propulsion unit **16** providing adequate pressure to maintain lift. As forward movement increases, and additional lift is obtained from the inwardly inclined sides, the front spherical propulsion unit **16** may be tilted forward to provide additional thrust. The front propulsion unit **16** is used for normal steering by tilting to the right or left. The rear propulsion units **18** and **20** may be tilted, in unison, at opposing directions to the front unit to provide greater coupling when required for sharper turns. The front and rear propulsion units may all be tilted sideways in the same direction to oppose cross winds or ground slope, while still maintaining forward tilt for thrust. The spherical propulsion units **16, 18** and **20** by virtue of their construction, can be tilted at any angle from the vertical toward the horizontal. The only restriction is the size of the sphere with relation to the propeller tube.

Referring now to FIG. **3**, one suitable steering mechanism for the ground-effect machine **10** is illustrated. Thus the steering column **26** on which steering wheel **24** is mounted is provided with a turn cylinder **70** around which is entrained steering cables **72** and **74**. The latter lead in opposite directions around posts or guides **76** to the front spherical propulsion unit **16** for control about a longitudinal axis. The reciprocable steering column **26** also passes through the turn cylinder **70** to a yoke steering means, indicated generally at **78**, by means of which the spherical propulsion unit **16** may be tilted about a transverse axis.

A separate control lever **80**, within the cockpit, is movable about a transverse axis **81** as indicated by the arrow in FIG. **3** and thereby imparts a rocking motion to rocking levers **82** which motion is transmitted in order to reciprocate rods **84** and levers **86** which are connected to yoke member **88** to tilt the spherical propulsion units **18** and **20** forwardly and rearwardly about a transverse axis. Similarly, either foot-operated control means **90**, also within the cockpit, may be moved in the direction of the arrows in FIG. **3** so as to push or pull on levers **92** which are connected to transverse bar **94** and which carries gear **96** meshing with gear **98** on shaft **100** which in turn carries pulley **102**. A steering cable **104** entrained around pulley **102** imparts reciprocation of the steering cable **104** or **106** in order to tilt the spherical propulsion units **18** and **20** from side to side about a longitudinal axis. Cable **107** is connected to the outboard sides of spherical propulsion units **18** and **20** to complete the reciprocation loop. The foregoing steering means and control means for the spherical propulsion units **16, 18** and **20** is merely illustrative and any suitable steering means may be used to control the spherical propulsion units.

It will be observed from the foregoing discussion that the plenum chamber **12** is provided with inwardly inclined sides, preferably 60° with respect to the horizontal although a range of 45° to 75° is considered to be acceptable. The substantially triangular rigid plenum chamber **12**, with inwardly inclined sides, produces what is considered to be optimum stability for the craft when moving forward. The inclined sides produce an effective cradling action, produce a lifting force because of the inclination or angle of attack of the sides **30** to the air stream through which the ground-effect-machine is moving, and provide a substantial reduction in the hydraulic coefficient of discharge (C_d), thereby increasing the lift of the vehicle above the ground or water surface.

It can be proven mathematically that in the open-plenum chamber type of ground-effect machine the lift of the machine above a ground or water surface is inversely proportional to the magnitude of the coefficient of discharge of the orifice through which the air is exiting. The following derivation is respectfully submitted:

Considering the opening between the outer edges of the plenum chamber base and the ground or water surface as an orifice with one side completely suppressed, the formula for the area of said orifice will be:

$$A_o = C \times H$$

wherein A_o is the orifice area in square feet; C is the dimensional circumference of the base, in feet; and H is the lift, or height above the surface, in feet.

From the hydraulic formula for the actual quantity of fluid (air) discharging from any chamber, under pressure, through an orifice, it follows that:

$$Q_a = C_d A_o v$$

where Q_a is the quantity flow, in cubic-feet-per-minute; C_d is the dimensionless coefficient of discharge, ranging from 0.50 to 0.97; A_o is the area of the orifice, in square feet; and v is the velocity of the exiting air, in feet per minute.

Substituting for A_o in the above formula, this becomes:

$$Q_a = C_d \times C \times H \times v$$

Transposing this in terms of H, or lift, we have:

$$H = (1/C_d) \times (Q_a/C \times v).$$

The term $Q_a/C \times v$ may be considered a constant, K, by virtue of the fact that the quantity of air delivered to the plenum chamber by the propulsion units exactly equals the quantity of air exiting through the orifice described and is constant for any given fan speed setting; the circumference of the base is dimensionally constant; and the velocity of exiting air is constant.

Substituting K for the above items results in:

$$H = K \times 1/C_d$$

and it is proven that the lift of the machine above any surface is inversely proportional to the magnitude of the coefficient of discharge for any given set of conditions.

It can further be shown that the effect of the down-flow of air along and adjacent to the inwardly slanted sides of the hull, occurring when the machine is in forward motion, materially reduces the coefficient of discharge and therefore provides lift for the vehicle otherwise not attainable. The reduction of the coefficient of discharge is accomplished by action of the downwardly flowing external air as it smooths out the normal "broomy" discharge of exiting air under the plenum chamber edges (C_d from 0.86 to 0.64), and additionally exerts kinetic energy on the exiting air to depress the vena contracta below its normal dimension (C_d from 0.64 to as low as 0.50, depending on forward speed and the kinetic energy developed in the downflowing external air).

In accordance with the present invention, the ground-effect machine takes air from the surrounding atmosphere through universally mounted propulsion units and delivers this air to the plenum chamber in a substantially straight-through flow. A small part of the energy of the mass flow is transformed to static pressure for support of the plenum chamber as in conventional machines. However, the horizontal component of the remainder is available for pure jet thrust to produce forward motion (tilted forward), turning moments, (tilted sideways), or any desired combination of these effects. Universal mounting of the entire propulsion unit provides a maximum efficiency in relation to directing the energy of the air stream or thrust force where it is required.

A further advantage of the universal mounting of the propulsion units comes from the inherent feature that as they are tilted forward to produce forward motion, the inlets are automatically positioned facing the relative surrounding air flow so as to take advantage of the ram-air effect available at higher speeds. This ability further increases the efficiency of the machine in forward flight.

The universal mounting of the propulsion units and their location on the plenum chamber allows directional control of the jet thrust of air to an extent that sliding of the vehicle in relatively high speed turns is reduced to a minimum. At hover position or standstill the coupling action of the front and rear propulsion units if tilted sidewards, in opposite directions, produces a spin about the vertical axis through the cockpit.

While presently preferred embodiments of the invention have been illustrated and described, it will be recognized that the invention may be otherwise variously embodied and practiced within the scope of the claims which follow.

What is claimed is:

1. A ground-effect machine comprising

a. a rigid outer plenum chamber having an inverted, substantially triangular, cup-shaped form,

b. one of the apexes of said substantially triangular, cup-shaped form defining the bow of said ground-effect machine,

c. said cup-shaped form having inwardly inclined sides adjacent said bow,

d. a plurality of spherical propulsion units mounted on and extending partially above said cup-shaped form,

1. said spherical propulsion units having fan means to force air therethrough to provide thrust for direction of said machine and having an air exit within said cup-shaped form to provide both lift and propulsion to said ground-effect machine,

e. substantially universal joint supporting means for said plurality of spherical propulsion units to support said propulsion units and to provide substantially universal motion between said propulsion units and said rigid plenum chamber,

f. a cockpit on said plenum chamber,

g. and control means secured to said propulsion units and said supporting means and extending into said cockpit for controlling the position of said spherical propulsion units from said cockpit.

2. A ground-effect machine as defined in claim 1 wherein said control means permits one of said spherical propulsion units to be controlled independently from said other spherical propulsion units.

3. A ground-effect machine as defined in claim 1 wherein said cup-shaped form is provided with an outwardly flared side opposite said bow and an automatically operated butterfly-type door across the stern of the inner chamber.

4. A ground-effect machine as defined in claim 1 wherein said spherical propulsion units are provided with bell-mouthed entrances.

5. A ground-effect machine as defined in claim 4 wherein said spherical propulsion units are provided with substantially cylindrical passageways adjacent said bell-mounted entrances.

6. A ground-effect machine as defined in claim 5 wherein a major portion of said cylindrical passageways contain flow straightening means.

7. A ground-effect machine as defined in claim 1 wherein said spherical propulsion units are provided with vanes to provide flow straightening of air passing through said spherical propulsion units.

8. A ground-effect machine as defined in claim 1 wherein said control means includes means to tilt all of said propulsion units in the direction of forward movement of said ground-effect machine thereby taking advantage of the ram-air effect at high speeds.

9. A ground-effect machine as defined in claim 1 wherein said spherical propulsion units mounted on said cup-shaped form provide the sole lift and direction control for said ground-effect machine.

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