

Aug. 21, 1962

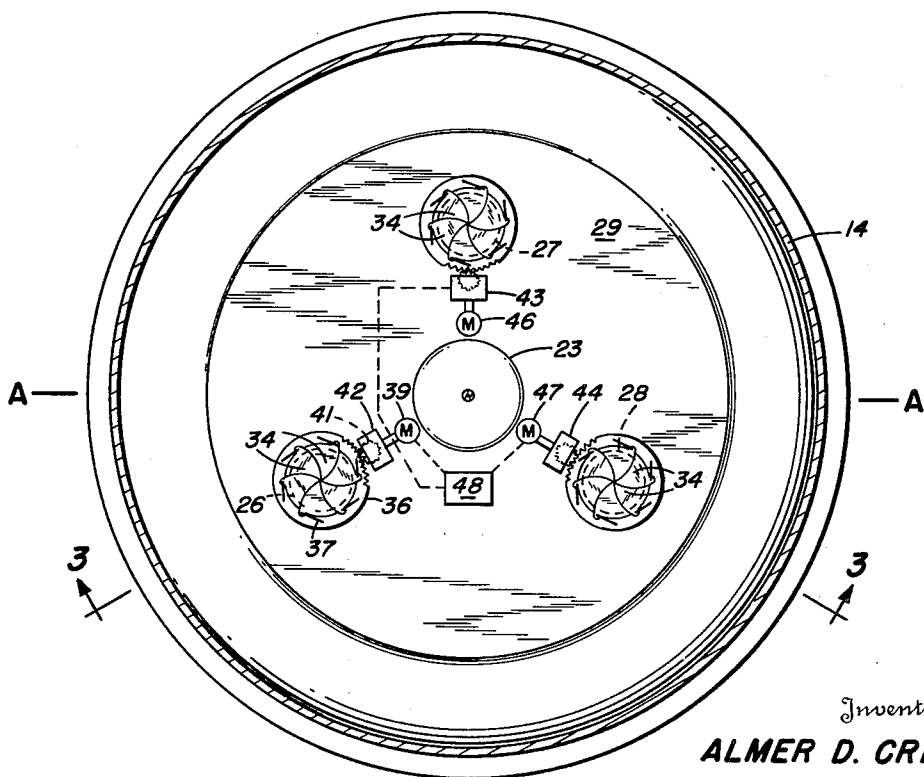
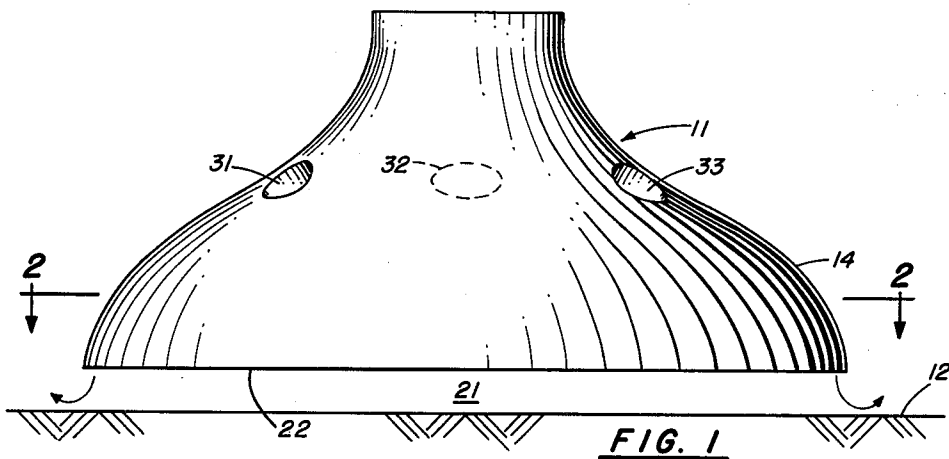
A. D. CRIM

3,050,146

CONTROLS FOR VEHICLES UTILIZING THE GROUND EFFECT PRINCIPLE

Filed Oct. 30, 1959

4 Sheets-Sheet 1



Inventor
ALMER D. CRIM

By *R. I. Tompkins*
Attorney

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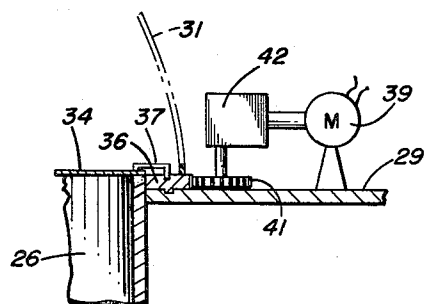
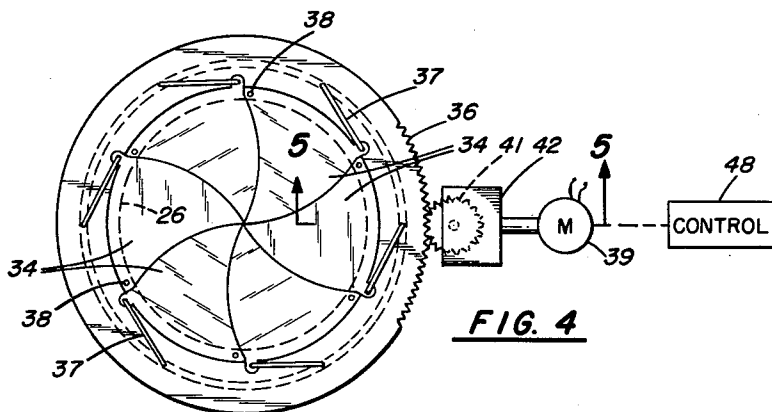
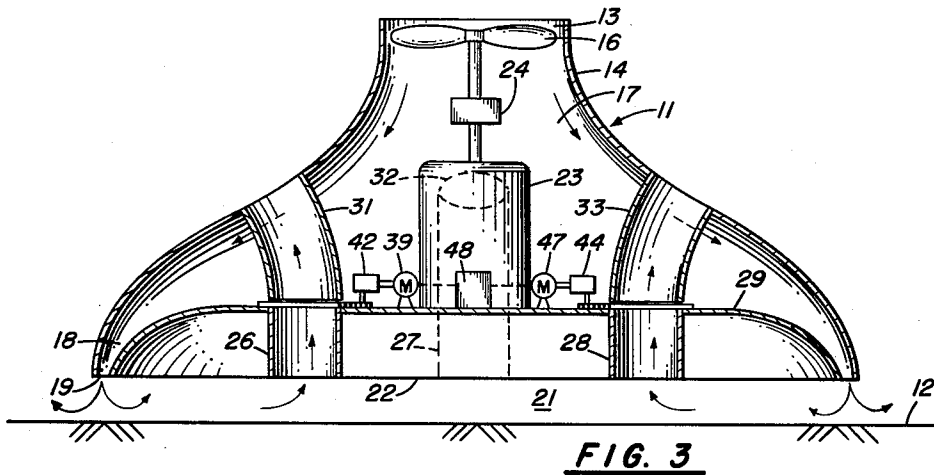
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4 Sheets-Sheet 2



Inventor
ALMER D. CRIM

By *R. J. Tompkins*

Attorney

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A. D. CRIM

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4 Sheets-Sheet 3

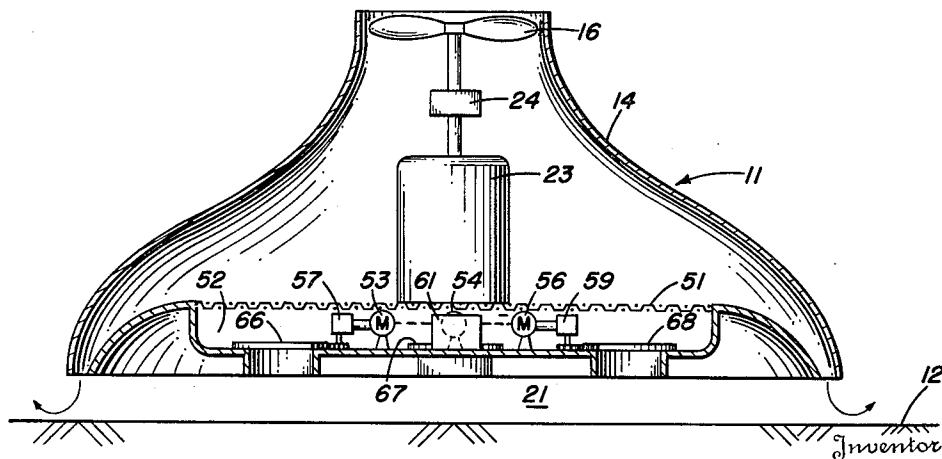
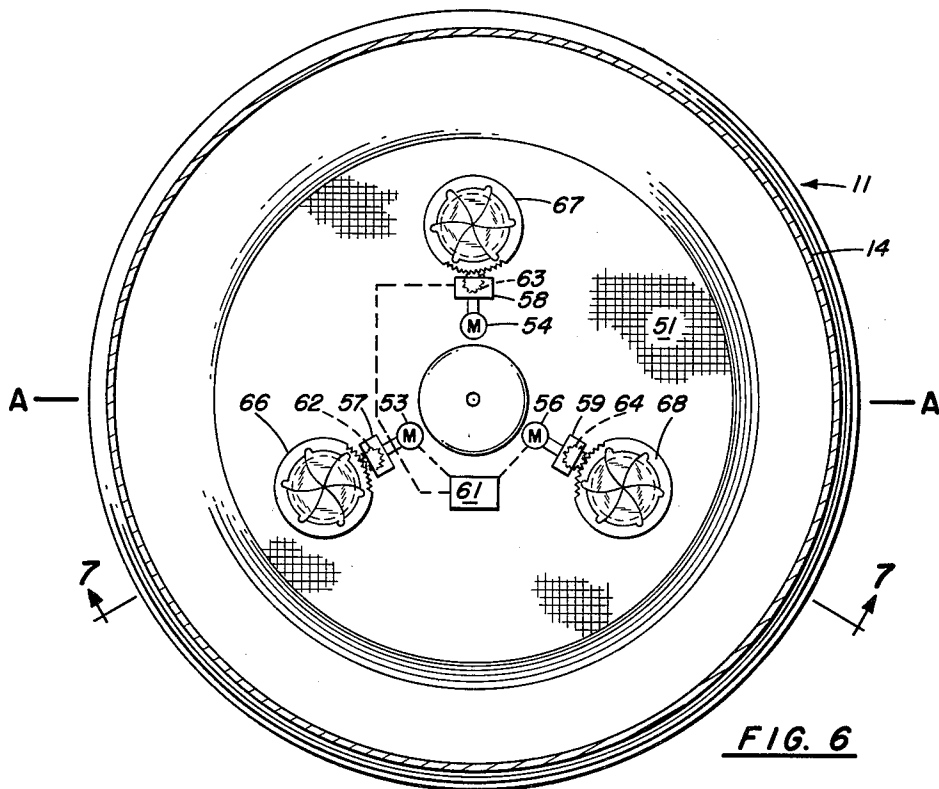


FIG. 7

ALMER D. CRIM

By *R. J. Tompkins*

Attorney

Aug. 21, 1962

A. D. CRIM

3,050,146

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4 Sheets-Sheet 4

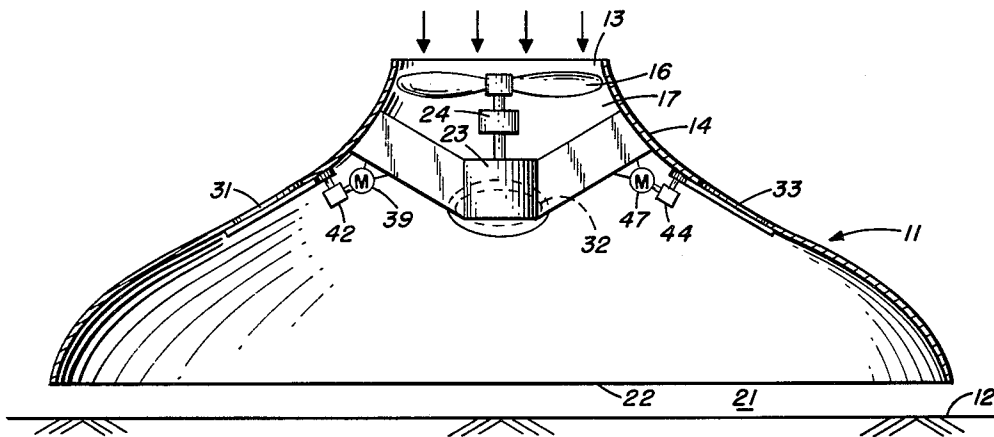


FIG. 8

INVENTOR
ALMER D. CRIM

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CONTROLS FOR VEHICLES UTILIZING THE
GROUND EFFECT PRINCIPLEAlmer D. Crim, Falls Church, Va., assignor to the United
States of America as represented by the Secretary of
the Navy

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5 Claims. (Cl. 180-7)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to ground-effect machines and more particularly to the application of forces and moments to ground-effect machines for exercising control thereof.

The general concept of a conventional ground-effect machine is not new. Broadly, a ground-effect machine is a device designed to utilize the phenomenon of "ground-effect." This "ground-effect" phenomenon is based upon the fact that when an annular jet is discharged downwardly from the base of a device in relatively close proximity to the ground, a lift force greater than the jet reaction force will be realized. This added lift is a product of the creation of a high-pressure air bubble beneath the base of the device. In this manner the device or machine actually rides on a cushion of air.

It should be readily appreciated that operation in proximity to the surface of the ground or water (or ice or snow) is a prime requisite for any device designed as a ground-effect machine. The jet discharge need not be truly annular so long as it is in the shape of a closed plane curve or even polygonal in shape.

A ground effect vehicle, therefore, obtains its lift from positive air pressures reacting upwardly upon the base thereof. By providing openings or vents in the undersurface or base with means for opening and closing such vents the pressure force over separate portions of the undersurface can be increased or decreased by increasing or decreasing the area available for the action thereon by the pressure beneath the vehicle. In this manner a source of force and/or moment variation is provided readily applicable for controlling the attitude of tilt or altitude of the vehicle.

Therefore, an object of the present invention is the provision of control forces and moments on devices using the ground-effect principle.

Another object is to provide simple, positive means for applying control forces and moments to such devices.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is an elevation view of a ground-effect machine embodying the present invention;

FIG. 2 shows a section taken on line 2-2 of FIG. 1 and discloses one embodiment of the present invention;

FIG. 3 is a section taken on line 3-3 of FIG. 2 showing one embodiment of the control means;

FIG. 4 is an enlarged view of the control means shown in FIG. 3;

FIG. 5 shows an enlarged section taken on line 5-5 of FIG. 4;

FIG. 6 is a section similar to FIG. 2 showing an alternate embodiment;

FIG. 7 is a section taken on line 7-7 of FIG. 6; and

FIG. 8 is an elevation view of the present invention as applied to a ground effect machine of the plenum chamber type.

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Referring now to the drawings, FIGS. 1 and 2 show a typical ground-effect machine 11 hovering over surface 12. In operation, air is drawn through intake or duct 13 into exterior housing 14 by ducted fan 16 and is pumped down through vertical well 17 to be discharged from annular nozzle 18 as indicated by the arrows.

Annular jet 19 serves the dual function of creating and maintaining a ground cushion regime in the region 21 beneath base 22. Although jet 19 tends to entrain air both from region 21 and from the ambient air, when the jet impinges on the surface 12, part of the jet air is fed back into region 21 replacing the air lost therefrom due to entrainment. In this way a ground-cushion of air is contained by jet 19 to support machine 11. FIG. 3 shows a simple machine with only one fan 16 and one engine 23 (with clutch and reduction gear unit 24) however, the same discussion applies to a larger machine using a multiplicity of fans and engines.

In order to provide a simple positive control for the attitude of machine 11 relative to surface 12, base 22 is provided with vents or openings as defined by the tubular sections 26, 27, 28 shown passing through interior housing 29 and in communication with the atmosphere through ducts 31, 32, 33. Further, these vents 26, 27, 28 are provided with means for opening and closing same. The means shown for effectuating this opening and closing comprise a shutter resembling the iris diaphragm of a camera. Multiple leaves 34 shown in FIG. 4 may be moved to any position between a position closing off vents 26, 27, 28 and a position in which these vents are substantially unobstructed. To effectuate a change in size of the vent opening ring gear 36 is rotated about vent 26 to act upon rods 37 which are rotatably attached to leaves 34 and ring gear 36, thereby causing leaves 34 to pivot about pin 38, which holds leaves 34 to the end of vent 26. Rotation of ring gear 36 is accomplished by activating electric motor 39 which can then be made to rotate pinion gear 41 through the intermediary of conventional clutch and reducing gear assembly 42. This arrangement is repeated at each of vents 27 and 28 using clutch and reducing gear assemblies 43, 44 and motors 46, 47. Control means 48 is a conventional switching arrangement enabling individual, coupled or simultaneous actuation of motors 39, 46, and 47. Thus, flexibility is obtained whereby the area available for the actuation thereupon by the pressure in region 21 can be increased or decreased in different portions of base 22. In turn this will result in the creation of moments about some appropriate axis in the base when vents 26, 27, 28 are opened to varying degrees. Should vents 26, 27, 28 be opened or closed simultaneously a change in vertical force can be obtained.

Obviously other conventional means can be employed to open or close the vents and other means such as servomotors can be employed to actuate the closure means.

Also, although the preferred embodiment of the present invention provides for communication of vents 26, 27, 28 with the atmosphere through ducts 31, 32, 33 other forms of the invention are possible. For example, in a larger device than the one described herein venting to another part of the ground-effect machine through a duct or ducts is feasible. Also, vents 26, 27, 28 may simply open into the interior of machine 11. Such an embodiment is shown in FIGS. 6 and 7 wherein the same closure means are employed but there are no ducts for venting to the atmosphere. Grating 51 is employed to cover well 52 wherein the motors 53, 54, 56, clutch and reducing gear assemblies 57, 58, 59, control means 61, pinions 62, 63, 64 and closure devices 66, 67, 68 are arranged.

In operation of the preferred embodiment if it is desired to tilt machine 11 about axis A-A the area of vent 26 can be increased or decreased or if an increased moment is wanted, the areas of vents 27 and 28 can be varied as

a pair either with vent 26 remaining unchanged or varying in area in some inverse relationship to the change in vents 27 and 28. By changing the area to either side of axis A—A which is available for effective action thereon by the pressure beneath base 22 the pressure distribution is altered and the balance of pressure forces to either side of axis A—A is upset. In this manner a moment can be obtained about axis A—A causing machine 11 to tilt in the desired direction. In this manner, machine 11 can be made to tilt about any axis through base 22. In the event a change in altitude is to be effected then control 48 must be set to cause the simultaneous change in size of vents 26, 27, 28.

The operation of the alternate embodiment of FIGS. 6 and 7 is similar to that described above.

As disclosed the present invention employs three vents since this is the most practical arrangement for effecting changes in a stable manner. However, it is conceivable that either a smaller or a larger number of vents may be provided.

Further, although attention has been focused herein on the ground-effect machine utilizing the peripheral jet the control means of the present invention is equally applicable to the plenum chamber type of ground-effect vehicle as illustrated by FIG. 8. Such a structure in cross section would have a housing similar to outer housing 14 but would lack the inner housing 29 since no nozzle such as nozzle 18 is required for such a vehicle. Ducts 31, 32, 33 would also be lacking. Engine 23 with clutch and reduction gear 24 and ducted fan 16 would, of course, be suspended from the housing 14 by struts. For control of such a device the iris diaphragm and drive means therefor would be arranged over holes in housing 14 located in the approximate positions in which ducts 31, 32, and 33 are shown opening to the atmosphere.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In a ground-effect machine supported on an air bubble in the immediate proximity of the ground comprising in combination an exterior housing shaped essentially like the frustrum of a cone and having a lower edge lying in a common plane, an interior housing arranged within and circumferentially spaced from said exterior housing, said interior housing being formed as a surface which is disposed concave downwardly and curving upward from said common plane into the exterior housing and away from the lowermost edge of the exterior housing and including a solid surface opposite to and spaced from the ground and which is supported on said ground cushion, a downwardly directed nozzle in the shape of a closed plane curve, said nozzle being formed by the interior housing and the lowermost edge of the exterior housing to emit air normal to the ground, air inlet means in said exterior housing, means for pumping air from said inlet means to exhaust said air from said nozzle so that a portion of the air is confined below the machine creating said air bubble beneath said inner housing, and attitude-controlling means penetrating said inner housing surface and comprising a plurality of independently controllable means for varying the area of said inner housing surface available to one side of some axis lying in the plane of said inner housing surface whereby a control moment is created about said axis from the altered pres-

sure distribution acting upon said inner housing surface.

2. A ground-effect machine as described in claim 1 wherein the attitude-controlling means includes independently operable motor means actuating said independently controllable means for varying differentially the area of the inner housing surface whereby a moment is created to tilt said machine.

3. A ground-effect machine as described in claim 2 wherein when the area of said inner housing surface is varied at fewer than the total number of positions a control moment may be created and when the area of said inner housing surface is varied equally at the total number of positions a change in the force acting upwardly on said inner housing surface results.

4. In a ground-effect machine supported on a ground cushion in the immediate proximity of the ground comprising in combination an exterior housing shaped essentially like the frustrum of a cone, an interior housing arranged within and circumferentially spaced from said exterior housing and including a solid surface opposite to and spaced from said ground and which is supported on said ground cushion, a downwardly directed nozzle in the shape of a closed plane curve, said nozzle being formed by the interior housing and the lowermost edge of the exterior housing to emit air normal to the ground, air inlet means in said exterior housing, means within said inlet means for pumping air from said inlet means to exhaust said air from said nozzle so that a portion of the air is confined below the machine creating said ground cushion beneath said solid surface of said inner housing, attitude-controlling means comprising a plurality of vents extending through said inner housing, a plurality of ducts, each of said ducts being connected to a separate vent at the inner end thereof and passing through said exterior housing and communicating with the atmosphere surrounding said exterior housing whereby at selected points the ground cushion below said lower surface may be placed in communication with the atmosphere, and means arranged in each vent for controllably and independently varying the size of the openings of the respective vents to vary thereby the extent of communication between the ground cushion to one side of some axis in the plane of the underside of the inner housing about which it is desired to effectuate moment control and the atmosphere.

5. In a ground-effect machine an attitude-controlling device as described in claim 4 wherein control means are included to simultaneously actuate the means for varying the size of the openings of the vents whereby a change in the upward-acting force results.

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