Feb. 28, 1967 H. R. CHAPLIN, JR 3,306,387

INTEGRATED PROPULSION SYSTEM FOR PERIPHERAL JET GROUND EFFECT MACHINES

Filed Oct. 20, 1960

4 Sheets-Sheet 1

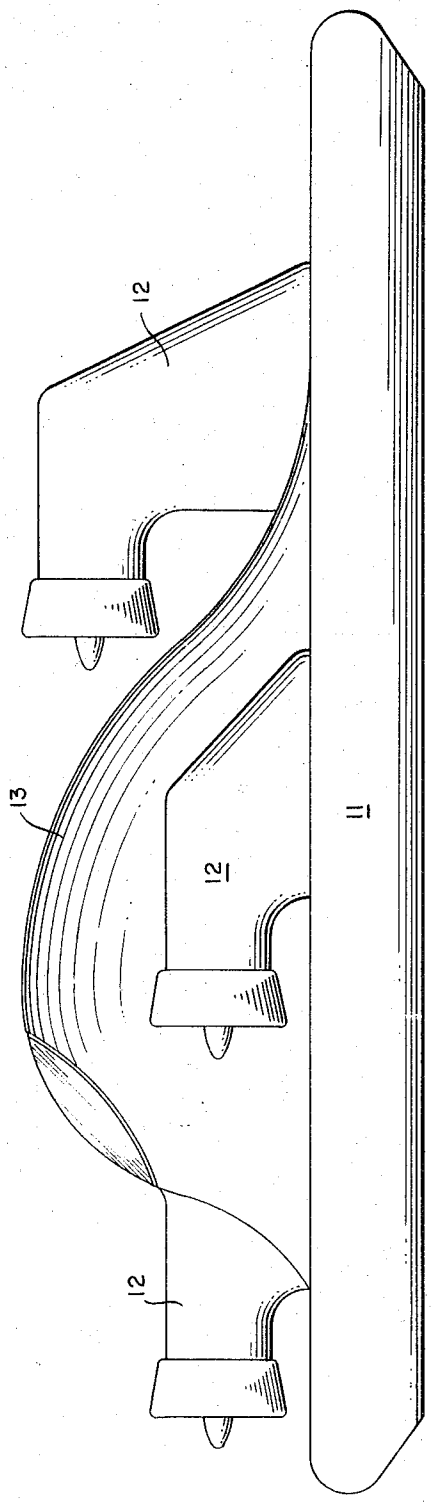


FIG. 1.

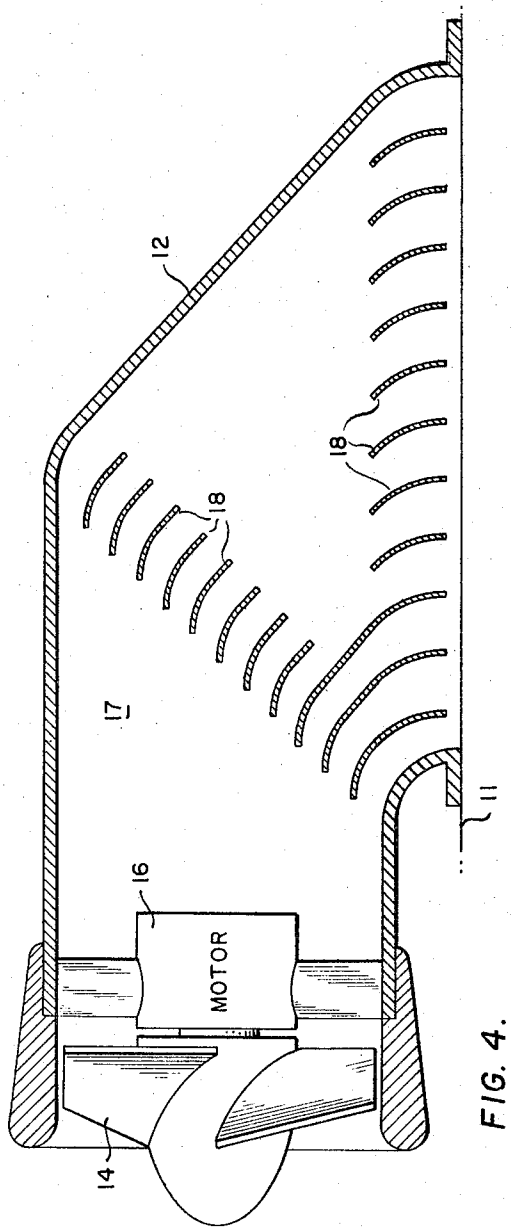


FIG. 4.

INVENTOR.
HARVEY R. CHAPLIN, JR.
BY
Howard W. Hermann
AGENT.

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4 Sheets-Sheet 2

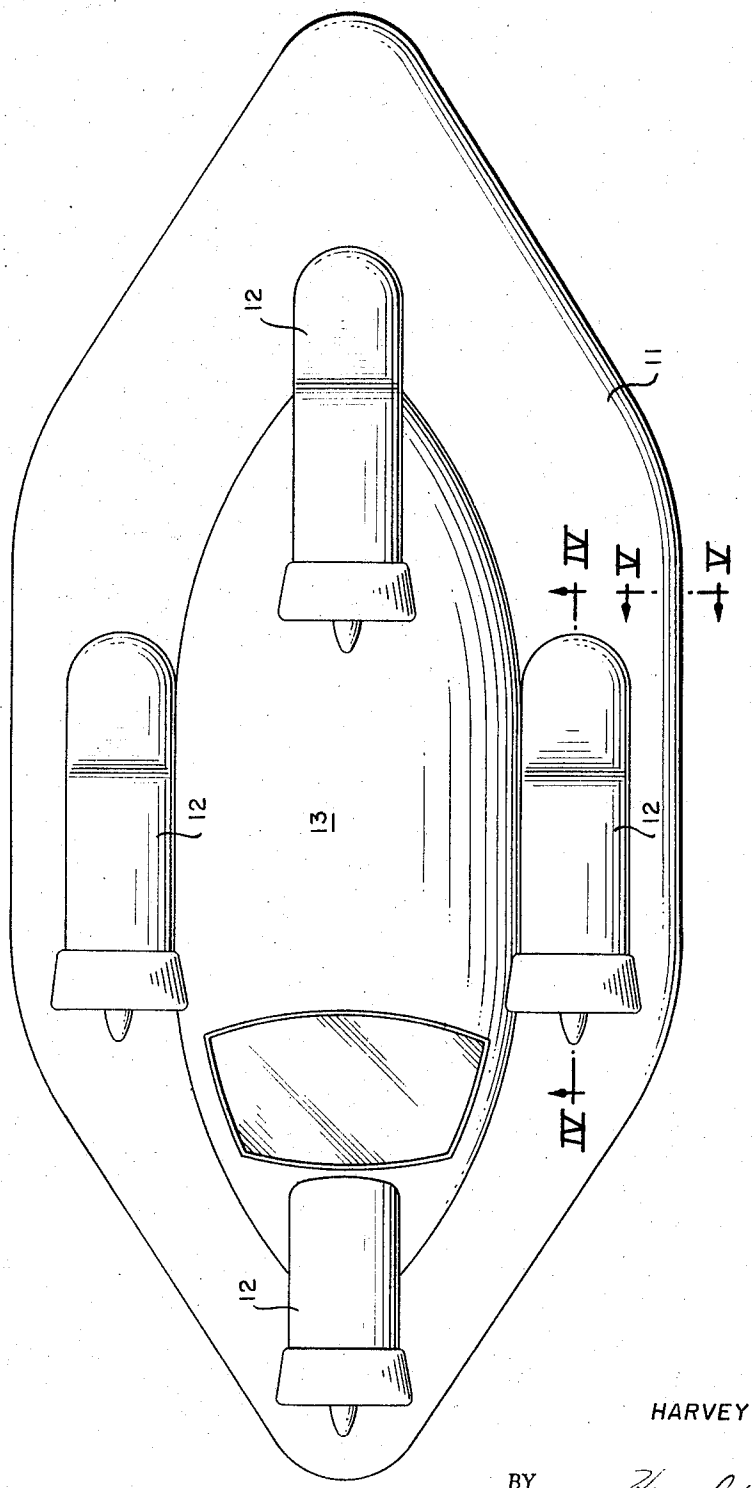


FIG. 2.

INVENTOR

HARVEY R. CHAPLIN, JR.

BY Howard W. Hermann

AGENT.

Feb. 28, 1967 H. R. CHAPLIN, JR 3,306,387

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Filed Oct. 20, 1960 4 Sheets-Sheet 3

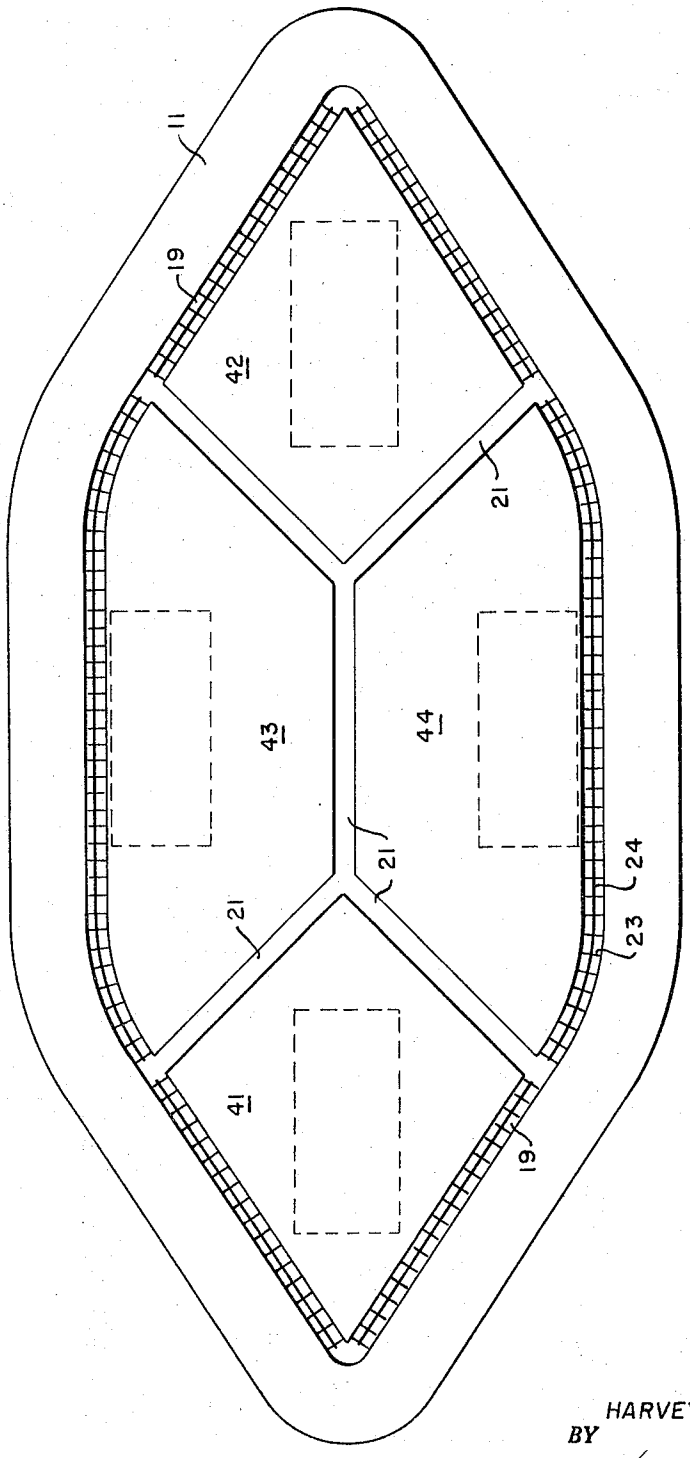


FIG. 3.

INVENTOR.
HARVEY R. CHAPLIN, JR.
BY
Howard W. Hermann
AGENT.

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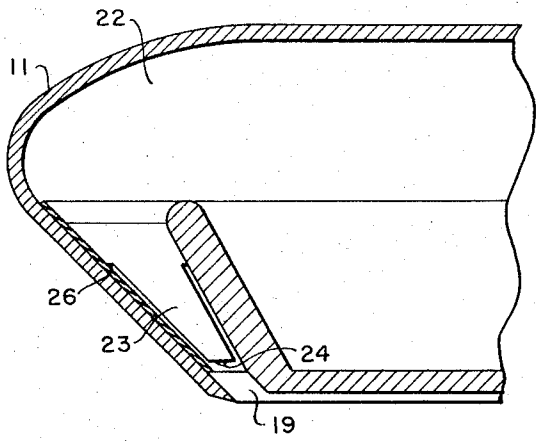


FIG. 5.

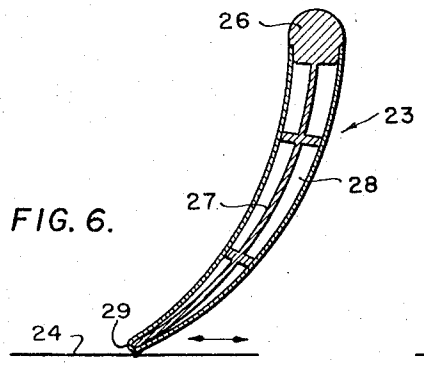


FIG. 6.

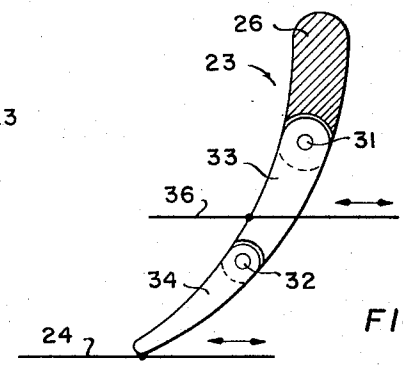


FIG. 7.

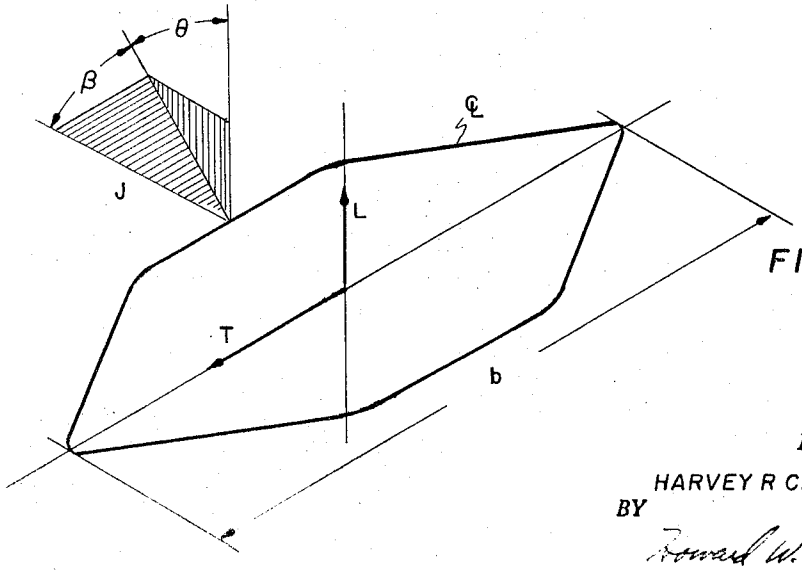


FIG. 8.

INVENTOR.
HARVEY R CHAPLIN, JR.
BY
Howard W. Hermann
AGENT.

United States Patent Office 3,306,387
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3,306,387

INTEGRATED PROPULSION SYSTEM FOR PERIPHERAL JET GROUND EFFECT MACHINES

Harvey R. Chaplin, Jr., 3507 N. Ottawa St., Arlington, Va. 22213

Filed Oct. 20, 1960, Ser. No. 63,935
3 Claims. (Cl. 180—7)

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 air supported vehicles and more particularly to air supported vehicles wherein air jets directed from beneath the vehicle provide both lift and propulsion for the vehicle.

Air supported vehicles, or ground effect machines as they are sometimes known, offer the possibility of travel over land and/or water while clearing many obstacles which would disable or stop conventional land going vehicles and watercraft. Various ground effect machines utilizing various physical principles have been suggested. Although several such devices have been built and proved to be capable of rising above land and water, several serious problems have been discovered.

Ground effect machines, in general, have downwardly directed nozzles which discharge air beneath the hull in a manner to provide a cushion of high pressure air under the hull, thus lifting the craft from the ground. However, the capability of rising above ground is not sufficient by itself to make the craft useful. There must also be a means of propulsion and a system for steering the craft in flight.

Although various means have been suggested for propulsion and steering, none of the known devices obtained optimum efficiency, weight, and useable space.

Further problems appeared when known craft of this type were used over water. The downwardly directed jets caused a considerable amount of spray to be generated. The spray, particularly in salt water, caused many problems on board the craft. The shape, or the planform, of the hull was generally rounded. In rough water it was entirely possible for the nose of the craft to come into contact with the water. The shock of water contacting the broad nose of the airborne craft caused considerable shock to the vehicle and in some instances crippled the craft.

By the present invention, there is provided a craft which is designed to optimize power, weight, and space, and to overcome the propulsion and steering difficulties experienced with prior art vehicle of this type.

This is accomplished in accordance with the present invention by the provision of a ship shape or planform having a downwardly and inwardly directed peripheral nozzle in which cascades of controllable camber vanes are utilized to control the direction of the air jets to provide forward thrust and steering. There are also provided a plurality of downwardly directed jets which are designed to divide the space under the craft into a plurality of air cushions separated by air curtains. This sectioning of the air under the craft gives added stability by preventing loss of pressure under the entire craft if air is allowed to escape from under one part of the craft.

Thus it is an object of the present invention to provide an efficient propulsion system for a ground effect machine.

Another object is the provision of a ground effect machine which is capable of flying over water without suffering the detrimental effects of inadvertent contact with the water surface.

A further object is the provision of a ground effect machine with increased stability.

Still another object is the provision of a ground effect machine which eliminates spray problems on board when flying over water.

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 a side view in elevation of a ground effect machine embodying the present invention;

FIG. 2 is a top view of the embodiment shown in FIG. 1;

FIG. 3 is a bottom view of the embodiment shown in FIG. 1;

FIG. 4 is a sectional view of one of the air intake nacelles taken on line IV—IV of FIG. 2;

FIG. 5 is a sectional view through the peripheral nozzle of the embodiment taken on line V—V of FIG. 2;

FIG. 6 is a sectional view of one embodiment of a controllable camber vane;

FIG. 7 is an elevational view partly in section of a second embodiment of a controllable camber vane; and

FIG. 8 is a diagrammatic presentation of the operation of the craft.

Referring now to the drawings wherein like reference numerals designate like or corresponding parts throughout the several views there is shown in FIG. 1 an elongated hull **11** on which are mounted a plurality of faired air intake nacelles **12** and a cockpit **13** from which the vehicle is controlled.

As may be seen in FIG. 4, a propeller **14** driven by a power source **16** is mounted at the entrance of each of air intake nacelles **12**. A duct **17** carries air from propeller **14** into hull **11** of the craft. Interposed in duct **17** are a plurality of guide vanes **18** rigidly positioned to direct the incoming air in a downward direction and assuring even air pressure distribution along the length of the duct.

Referring now to FIG. 5, it will be seen that the interior of the hull **11** is a hollow open only to ducts **17**, peripheral nozzle **19**, and stabilizing nozzles **21** (FIG. 3). As shown in FIG. 5, perpiheral nozzle **19** is directed downwardly and inwardly toward the center of the craft.

In operation, propellers **14**, driven by power sources **16**, draw air into ducts **17** where it is directed downwardly by means of fixed guide vanes **18** into the interior **22** of hull **11** which acts as a duct to carry air to stabilizing nozzles **21** and peripheral nozzle **19**. Stabilizing nozzles **21** allow the air to escape in a vertical direction and cause the space below the craft to be divided into four sections separated by air curtains. Peripheral nozzle **19** allows air to escape in a direction downward and inward from the periphery of the hull around the entire periphery thereof. In FIG. 8 there is shown a diagrammatic presentation of forces acting on the craft. Assuming first that there is no forward component to the air leaving the peripheral nozzle, the entire jet momentum flux J in pounds is directed toward the center of the craft at an angle θ from the vertical. With β, the angle of forward thrust, equal to zero and assuming the flux J to be uniformly distributed around the centerline ℄ of the nozzle, it will be seen that the air ejected from the nozzle will create a lift L tending to raise the craft vertically. The peripheral curtain of air acts as an envelope which encloses a cushion of air beneath the hull and when sufficient air is discharged into the cushion to raise the lifting force L higher than the weight of the vehicle, the vehicle rises.

Lift alone, however, generally has no value in vehicles such as this since some means for propelling the craft must also be provided. In accordance with the instant invention there are provided a plurality of groups or cascades of controllable camber vanes **23**, the vanes in each

cascade being interconnected by a control cable **24** and being (FIG. 3) mounted in peripheral nozzle **19**.

As shown in FIG. 6, vane **23** has a leading edge **26** which is fixedly mounted between the peripheral nozzle defining surfaces of hull **11**. Rigidly attached to leading edge portion **26** is a flexible internal support member **27** of spring steel, or the like, around which is molded a flexible filler **28** of resilient material such as rubber. A control cable **24** is attached to the trailing edge **29** and serves, by pulling the trailing edge in one direction or the other, to control the camber of the vane. Control cable **24** is connected to each of the vanes mounted in cascade in the peripheral nozzle and is controllable from cockpit **13**.

An alternative type of controllable camber vane is shown in FIG. 7. In this embodiment there is again a fixed leading edge **26** which is rigidly mounted between the peripheral duct defining portions of hull **11**. Hingedly connected to leading edge portion **26** by means of pivot pins **31** and **32** are a pair of rigid trailing portions **33** and **34**. A control cable **24** is again attached to the trailing-edge and for greater camber control a second control cable **36** may be attached to upper trailing portion **33**. Again the control cable or cables are attached to the vanes mounted in cascade around the peripheral nozzle and are adapted to be controlled from cockpit **13**.

It will be realized that vanes **23** are thus capable of varying the direction of the peripheral jet in a direction parallel to the major axis of the hull. Referring again to FIG. 8, variation of the vane camber varies only the jet deflection angle β, the angle θ being fixed by the design of the nozzle itself. It will be seen that a variation in β provides a thrust component to the jet shown diagrammatically as T and thus provides a propulsive force. Assuming b to be the vehicle base length measured at the nozzle centerline ℄ and C the perimeter of the nozzle measured at the centerline, and assuming J, the total peripheral-jet momentum flux to be evenly distributed around the peripheral nozzle, it has been found that a propulsive force

$$T=\frac{2b}{C}J \sin \beta \tag{1}$$

is produced if the entire jet is deflected through a tangential deflection angle β=constant.

(If J is not uniformly distributed around the nozzle, the form

$$T=\left[\int_0^{c/2}\frac{db}{dc}jdC-\int_c^{c/2}\frac{db}{dC}jdC\right]\sin\beta$$

where j is the local jet momentum flux per unit circumference applies.)

Equation 1 shows that an elongated planform shape, which gives a relatively high value of length to perimeter (b/C), provides more effective utilization of the peripheral jet for propulsion.

If the planform shape is blunt at the nose, uniform positive tangential deflection of the entire peripheral jet produces a divergence in the jet curtain at the nose with a corresponding diminishment of the ground cushion producing effectiveness of the jet curtain. This is avoided by using a planform shape with a pointed nose. With a nose wedge angle of 2γ, divergence will not occur unless β exceeds the value

$$\beta_{max}=\text{arc tan}\left[\frac{-\sin\theta}{\tan\gamma}\right]$$

where θ is the normal jet deflection angle shown in FIG. 8. A pointed stern has a similar beneficial effect in the case of negative β (used for braking or backing up).

Referring now to FIG. 3, it will be seen that controllable camber vanes **23** can also be used to perform control functions as well as provide propulsion. For example, if β is increased in section **41**, a nose down pitching moment results in combination with increased propulsion.

If β is increased in section **42** a nose-up moment results in combination with increased propulsion. Thus pitch trim can be achieved efficiently, by diverting part of the lifting effect of the jet to increased propulsion.

If β is increased in section **43** and/or decreased in section **44** a positive yawing moment results in combination with a negative rolling moment. If power is increased in section **43** (which is possible with the instant invention since a separate power unit is used for each section) and/or decreased in section **44**, a positive yawing moment results in combination with a positive rolling moment. By combining differential power in sections **43** and **44** with differential β in sections **43** and **44**, any desired combination of yawing and rolling moment can be produced. Many other possible control operations will be envisioned by those skilled in the art.

The integrated propulsion-lift system described herein results in greater efficiency than known devices of this type, requiring, at significant forward speed, less power than other systems of the same size and weight at the same height and speed. The total power required is the power to generate the peripheral jet. This requirement increases only slightly with speed thus permitting a much more efficient utilization of engines, compressors, and transmission equipment than is possible with other types of systems wherein the peripheral-jet power decreases with speed while propulsive power increases even more rapidly.

The ship-shaped planform shape permits high utilization of the peripheral jet for propulsion and control. It prevents or diminishes the adverse divergence, which tends to occur at the nose or stern under uniform tangential deflection, and diminishes the adverse induced negative pressure which occurs in the vicinity of the jet curtain during forward flight. When negative induced pressure does occur, a relatively uniform distribution of it is accomplished by the shape.

The pointed nose alleviates shock occurring from inadvertent contact with the surface during over-water operation. The pointed nose also aids in protecting the craft from spray in that any spray generated by the jet tends to be thrown to the sides.

The controllable camber cascades of guide vanes are mechanically simple, allowing differential tangential deflections between different sections of the peripheral jet. Since the leading edges of the vanes always point directly into the air approaching the cascade, the air flow through the cascade is smooth and relatively free of energy dissipation.

It will be realized that various modifications of the invention could be made by those skilled in the art. For example, an auxiliary propulsion system could be added to give greater forward speeds with a minimum of extra power.

In place of the controllable camber vanes, fixed camber vanes having controllable incidence could be used. The camber would be chosen to give efficient operation in the range of β encountered for long periods. Of course, the efficiency would be reduced at other angles but in some applications this might be tolerable for short periods of time.

The shape, of course, is not specifically limited to that shown in the present embodiment. The significant requirements are that the hull be elongated in the direction of flight, have rounded sides to minimize the induced negative pressures and promote a relatively uniform distribution thereof, and have a nose width significantly narrower than the maximum width of the planform. The pointed stern is less essential and may be dispensed with if other considerations dictate a preference for a blunt stern.

It will also be realized that the principles of this invention are also applicable to ground effect machines which exhaust water or other fluids through their peripheral nozzles.

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. An air cushion supported vehicle comprising a hull having an elongated planform with a pointed forward end, a first nozzle in the bottom of said hull extending around the entire periphery thereof, a plurality of stabilizing nozzles dividing the bottom of said hull into a plurality of sections, air intake means on said hull, power means for driving said air intake means, a plurality of ducts connected between said air intake means and said first and stabilizing nozzles, a plurality of fixedly mounted deflection vanes in said ducts for insuring proper distribution of air to said nozzles, and a plurality of variable camber deflection vanes in said peripheral nozzle for controlling the direction of air ejected from said peripheral nozzle, said plurality of variable camber vanes being mounted in cascade and connected by a plurality of control cables, said variable camber vanes each including a fixed leading edge mounted across said first nozzle and a plurality of hingedly interconnected trailing sections pivotally connected to said fixed leading edge, one of said control cables being attached to the trailing edge of said trailing section; a second control cable being connected to an intermediate section of said hinged trailing sections.

2. An air cushion supported vehicle comprising a hull having an elongated planform with a pointed forward end, a peripheral nozzle in the bottom of said hull, a plurality of stabilizing nozzles dividing the bottom of said hull into a plurality of sections, air intake means on said hull, a plurality of ducts connected between air intake means and said nozzles whereby air entering said intake means is forced out of said nozzle, a plurality of variable camber deflection vanes for controlling the direction of air ejected from said peripheral nozzle, and control means for varying the camber of said deflection vanes, said plurality of deflection vanes being mounted in cascades, and said variable vanes each including a fixed leading edge and a plurality of hinged, interconnected sections pivotally connected to said fixed leading edge, said control means including a first means and a second means, said first means interconnecting the trailing edges of said variable vanes, said second means interconnecting said variable vanes at a point on a hinged section intermediate the fixed and trailing sections.

3. An air cushion supported vehicle comprising a hull having an elongated planform with a pointed forward end, a peripheral nozzle in the bottom of said hull, a plurality of stabilizing nozzles dividing the bottom of said hull into a plurality of sections, air intake means on said hull, a plurality of ducts connected between said air intake means and said nozzles whereby air entering said intake means is forced out of said nozzle, a plurality of variable camber deflection vanes for controlling the direction of air ejected from said peripheral nozzle, said vanes consisting of a plurality of hinged sections, and a plurality of control means for varying the camber of said deflection vanes, said plurality of deflection vanes being mounted in cascades, the vanes of each cascade being interconnected by said control means, each of said variable vanes including a fixed leading edge to which is attached a flexible trailing portion, one of said plurality of control means being attached to the trailing edge of the trailing section of said hinged sections, the other of said plurality of control means being connected one each to each of the intermediate hinged sections of the said variable camber vanes.

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A. HARRY LEVY, *Primary Examiner.*

PHILIP ARNOLD, *Examiner.*