United States Patent

[11] 3,608,662

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[54] **AIR CUSHION VEHICLE**
22 Claims, 17 Drawing Figs.

[52] U.S. Cl. **180/117,** 180/116, 180/120, 180/126
[51] Int. Cl. **B60v 1/16,** B60v 1/18
[50] Field of Search 180/117, 120, 126, 122

[56] **References Cited**

UNITED STATES PATENTS

2,364,677	12/1944	Warner	180/120 UX
3,066,753	12/1962	Hurley et al.	180/120
3,127,949	4/1964	Harter	180/120
3,150,731	9/1964	Franklin et al.	180/120
3,162,260	12/1964	Cockerell	180/122
3,173,507	3/1965	Wernicke et al.	180/120
3,208,543	9/1965	Crowley	180/121
3,243,003	3/1966	Woltering	180/120
3,259,097	7/1966	Van Veldhuizen et al.	115/15
3,292,721	12/1966	Dobson	180/120
3,322,223	5/1967	Bertelsen	180/120
3,486,577	12/1969	Jackes	180/120
3,262,510	7/1966	Froehler	180/122
3,401,766	9/1968	Laufman et al.	180/120 X
3,467,213	9/1969	Walker	180/120

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ABSTRACT: A single propeller mounted toward the front of the vehicle provides both propulsion and air cushion. Two-point steering is provided by front and rear steering vanes with air channels on each side which direct a portion of the downstream flow of air, under the control of the front vanes, to the rear vanes. The air channels shield the operator from the propeller airblast, and produce air curtains on either side of the operator to shield him from spray and dust. Joint steering of front and rear vanes is provided, with means for changing the relative vane angles to counter crosswinds and side slope on hills.

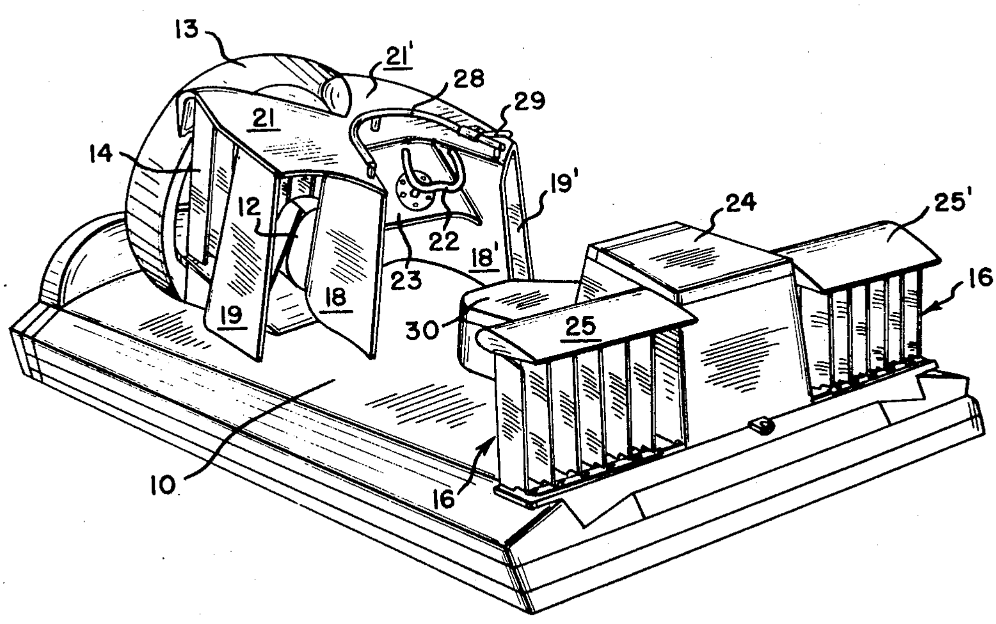

FIG. 1

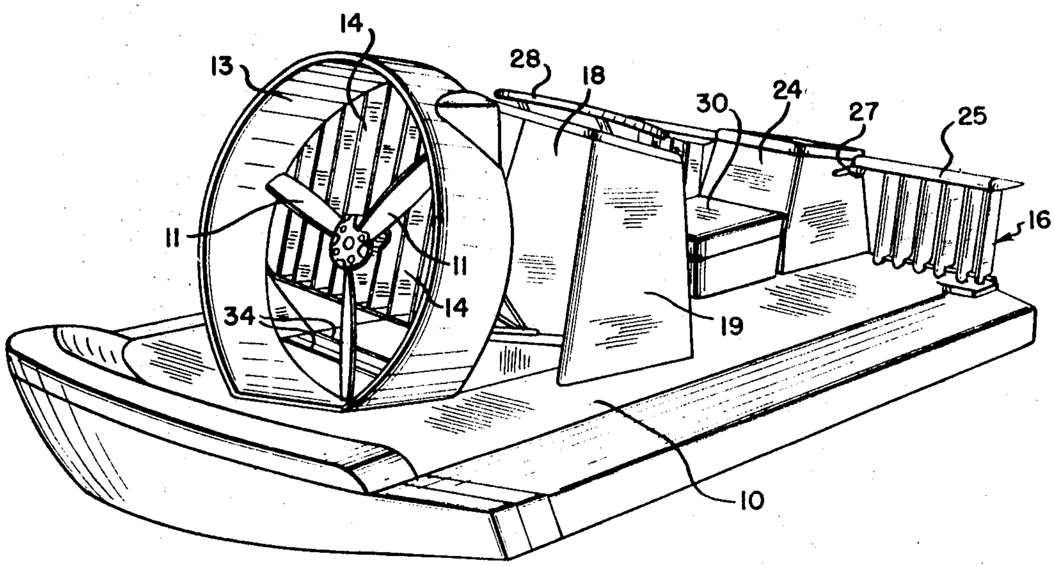

FIG. 2

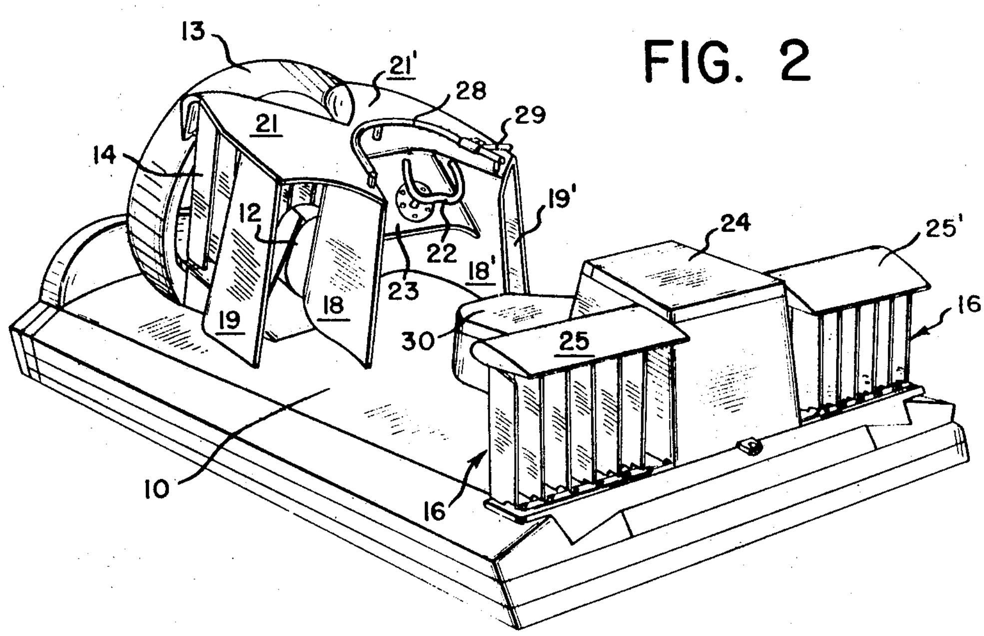

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FIG. 3

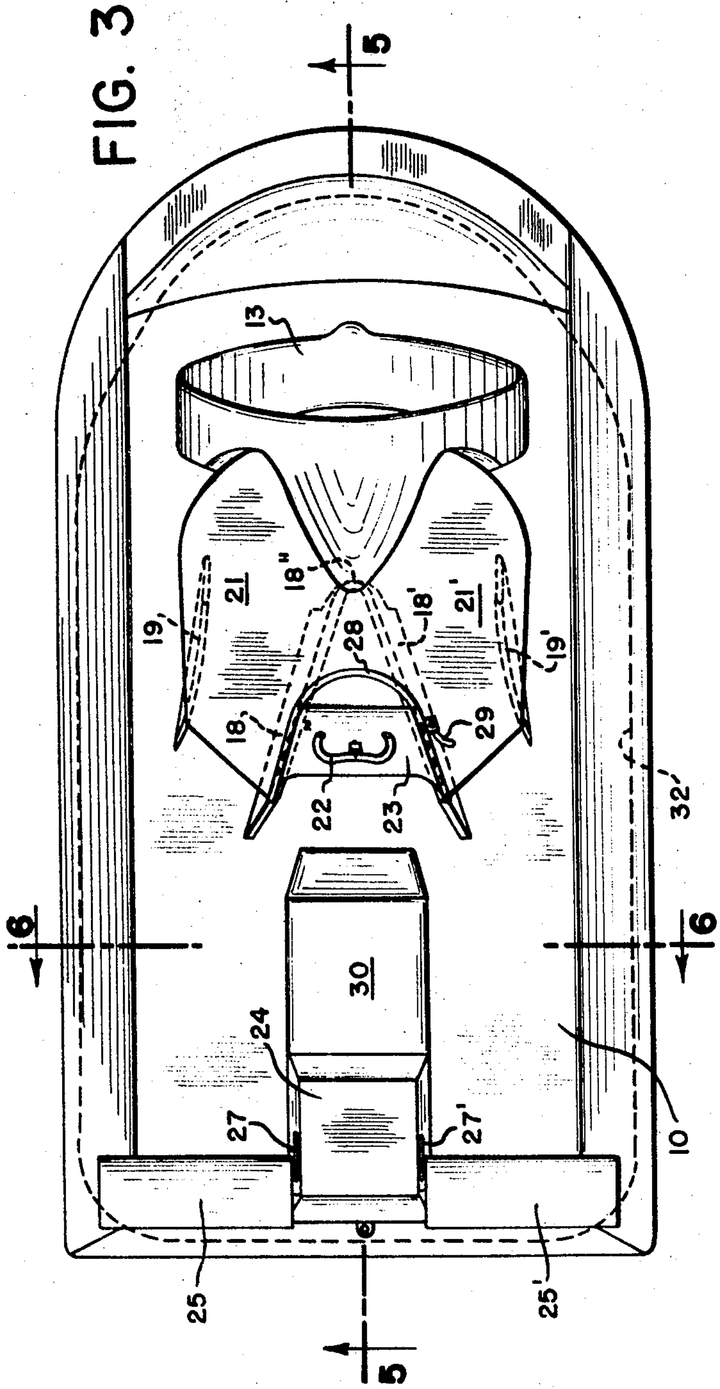

FIG. 4

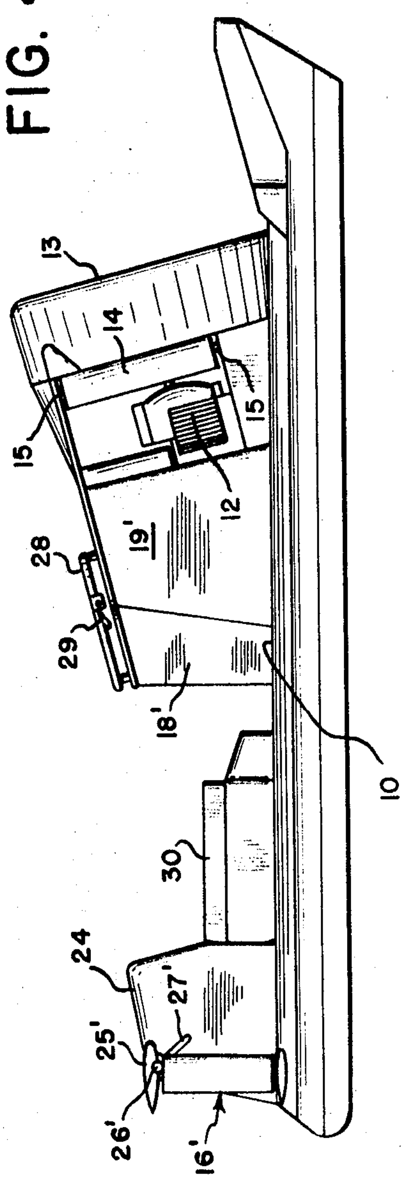

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FIG. 5

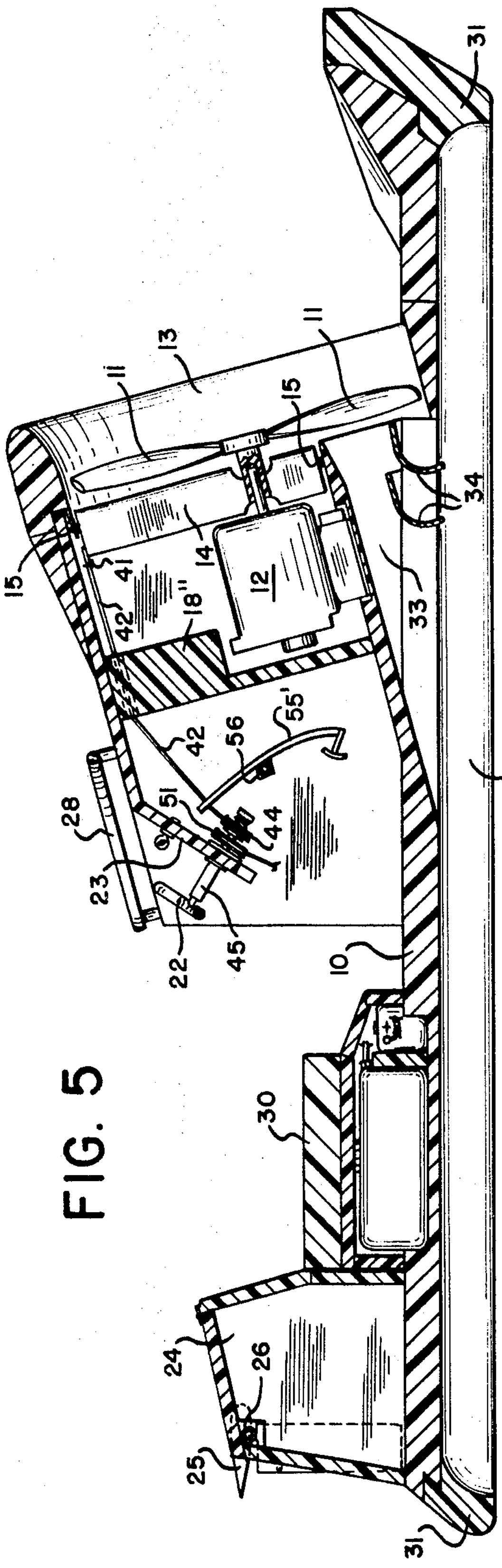
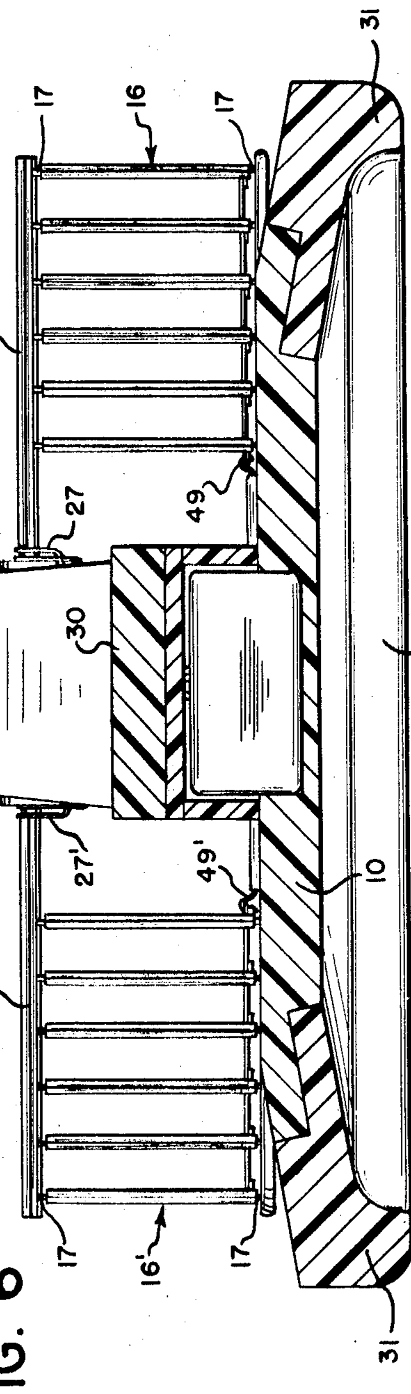


FIG. 6



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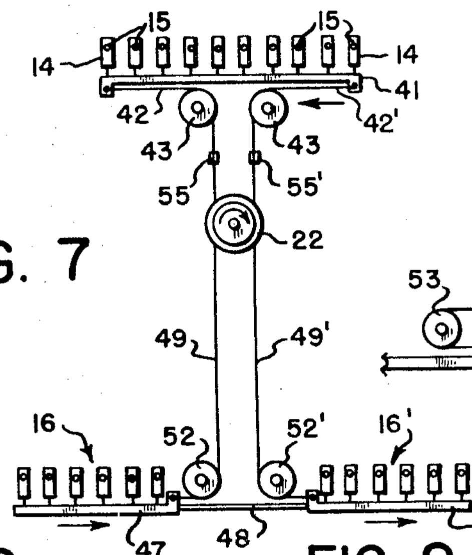


FIG. 7

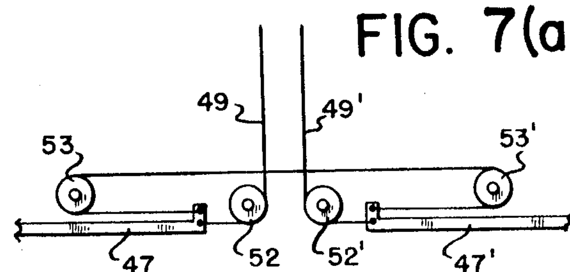
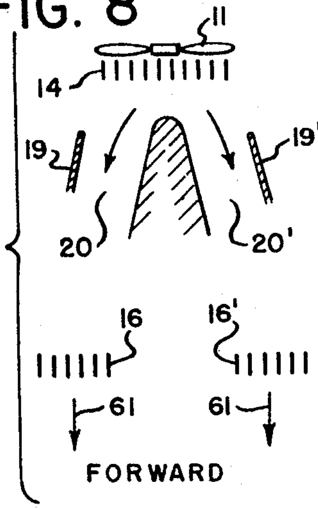


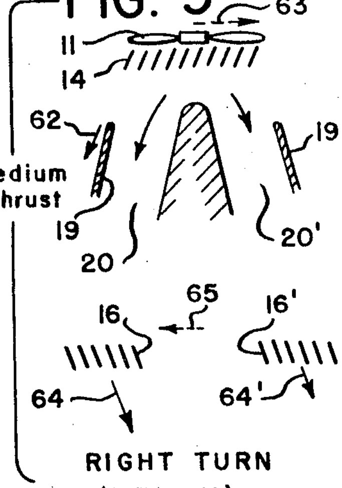
FIG. 7(a)

FIG. 8



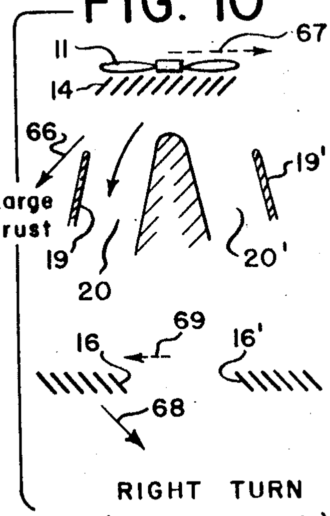
FORWARD

FIG. 9



RIGHT TURN
(MEDIUM)

FIG. 10



RIGHT TURN
(HARD OR SPIN)

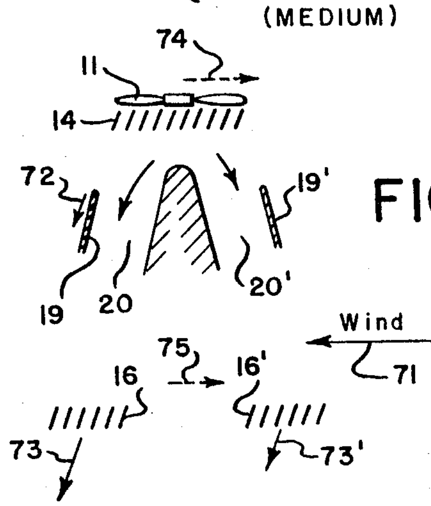


FIG. 11

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FIG. 12

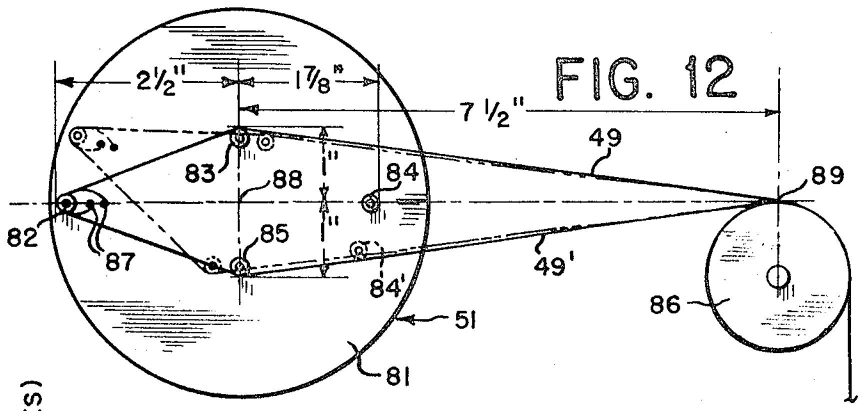


FIG. 12(a)

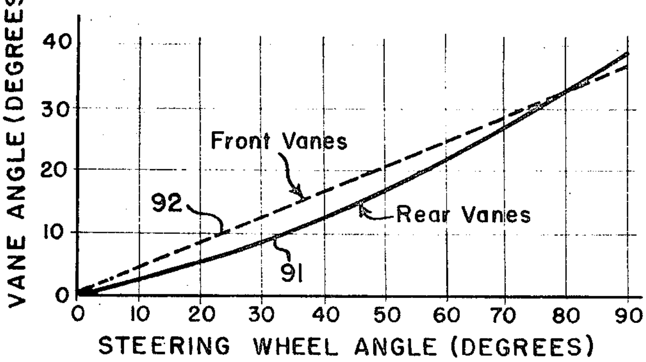


FIG. 13

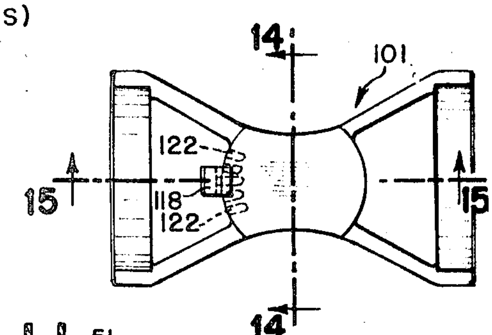


FIG. 14

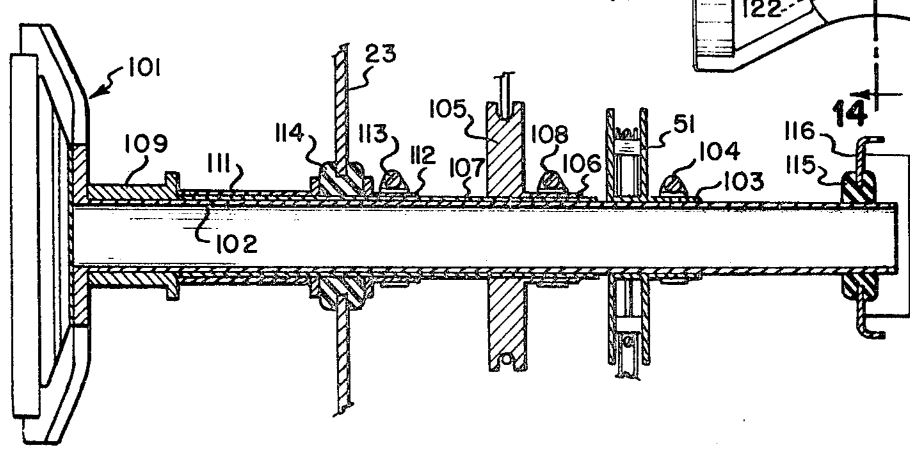
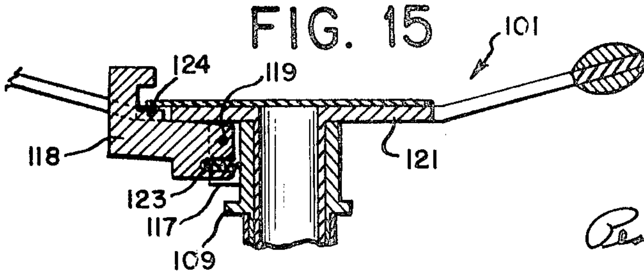


FIG. 15



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AIR CUSHION VEHICLE

BACKGROUND OF THE INVENTION

This invention relates to air cushion vehicles. Although particularly directed to a relatively small and inexpensive vehicle capable of carrying one or two passengers, some of the features may be applied to larger and more elaborate vehicles.

Large air cushion vehicles capable of carrying many passengers, or equivalent cargo, are now in use. Small vehicles capable of carrying one or two passengers are also commercially available. However, the smaller vehicles are quite expensive and have certain drawbacks in performance.

In general, air cushion vehicles utilize an arrangement for producing a cushion of air under pressure beneath the vehicle so as to raise the vehicle a short distance from the supporting surface in operation. The supporting surface may be water, ground, snow, ice, etc. Two principal types of structure are commonly employed for producing the air cushion. One type employs an open plenum chamber beneath the vehicle with a relatively large volume of low-pressure air supplied thereto. The plenum chamber usually is formed by a downwardly extending peripheral wall or skirt which, together with the bottom of the vehicle, forms a chamber which is open at the bottom. The other principal type employs a peripheral slot or jet which procedures a downwardly and inwardly sloping curtain of air under relatively high pressure. The open plenum chamber has the virtue of simplicity. The air curtain type is in general more efficient, in that less air is lost, but involves a much more complicated structure. In either case, sufficient air must be continuously furnished to maintain the pressure under the vehicle to raise it from the supporting surface, and to replace the air exhausted around the bottom periphery of the vehicle.

When raised from the ground in operation, an air cushion vehicle is essentially floating on air and the propelling and steering means must be designed to take this into account. Many means have been provided in the past for creating thrusts in different directions to propel the vehicle forwards, to brake forward motion or produce rearward motion, and to turn the vehicle. In some arrangements vanes in the peripheral skirt are controlled to change the direction of the air issuing therefrom. In others, a supply chamber for delivering pressurized air to a peripheral air curtain is provided with vanes on the sides thereof, and at the front and rear, and the vanes are controlled to produce movement of the vehicle in the desired direction. Vanes inside a plenum chamber have also been suggested for propulsion and control. In vehicles using propellers in the open air, rudders have been used for steering. With a single propeller the rudder is commonly at the rear. With propellers and respective engines mounted fore and aft on the vehicle, individual rudders may be located behind each propeller for steering purposes.

In many vehicles, separate sources of air are employed for the cushion and for propulsion. They may be driven by separate engines, or by a single engine with suitable belting or gearing.

It is highly desirable for proper control of an air cushion vehicle to provide steering forces at both front and rear of the vehicle. This greatly facilitates quick turning about a small radius, reduces skidding, and permits proper control in crosswinds. Although means affording such control have been suggested, in general they require fore and aft propellers with associated rudders, or vanes at various peripheral regions of pressure chambers, etc.

The present invention provides an air cushion vehicle which requires only a single engine and propeller for producing the air cushion, propulsion and steering, while providing both fore and aft steering control, and which has other advantageous features which will be described hereinafter.

SUMMARY OF THE INVENTION

In accordance with the invention, air propelling means is mounted toward the forward end of the vehicle. For the relatively small vehicles particularly contemplated, a single propeller and engine suffice. Means for producing an air cushion under the vehicle is provided, and preferably a portion of the air from the air propelling means is used for the purpose.

In order to provide both fore and aft steering control with a downstream flow of air originating at a forward part of the vehicle, front steering means are provided for changing the direction of the downstream flow of air to lateral angles on either side of the vehicle, thereby providing a steering force toward the front of the vehicle. Air-channeling means spaced downstream of the front steering means is provided for receiving portions of the downstream flow of aid, under the control of the front steering means, and directing the flow of air therethrough to the rear of the vehicle. Rear steering means is positioned toward the rear of the vehicle on each side thereof to receive the downstream flow of air from the air-channeling means and divert the air supplied thereto to lateral angles on either side of the vehicle, thereby providing a steering force toward the rear of the vehicle.

In forward travel over a horizontal surface without a crosswind, the downstream flow of air is generally longitudinal of the vehicle and propels the vehicle forward. In turning, a portion of the downstream flow of air is diverted outside the air-channeling means to provide a turning moment, the amount diverted depending on the sharpness of the turn. The remainder of the air is directed by the air-channeling means to the rear steering means to provide a turning moment thereat. The air-channeling means is designed and spaced from the front steering means so that, under all normal steering conditions, a sufficient amount of air is directed to the rear steering means for adequate control. For normal turns the lateral angles of the front and rear steering means are in opposite directions so that both turning moments are effective and the center of turning is between the two steering means, and advantageously near the center of the vehicle.

For forward travel over a horizontal surface in the presence of a crosswind, or along a sloping surface, the front and rear steering means may be turned to lateral angles in the same direction, so as to prevent skidding. For turning under such conditions, the normal turning lateral angles may be modified to take into account the tendency to skid.

In the specific embodiment described hereinafter, the lower portion of the downstream air from the propeller is supplied to the open plenum chamber beneath the vehicle through an opening in the floor of the body, and the propeller axis is inclined somewhat downwards and rearwards to facilitate supplying air to the open plenum chamber. Fixed vanes are provided in the opening to divert a portion of the air toward the front of the underside of the vehicle, thereby approximately equalizing air pressure over the bottom surface. A set of generally vertically extending vanes is provided immediately behind the propeller and controllable to direct downstream flow of aid generally longitudinally of the vehicle or to lateral angles on either side of the vehicle. A centrally located body structure is provided behind which the operator sits, and suitable controls are placed therein. This body structure is designed to divert the downstream flow of air along the sides thereof. Side members spaced from this body structure on either side thereof, together with top members, form air channels open at front and rear so that the portions of the downstream flow of air entering the channels under the control of the front vanes is directed rearwards. At the rear of the vehicle a set of generally vertically extending vanes is provided on each side of the vehicle to receive air passing through the respective channel.

With both front and rear steering vanes in their midposition, the downstream flow of air from the propeller passes through the front vanes and is diverted around the central body section and through the side channels to the two sets of rear steering vanes in approximately equal proportions. Thus, forward propulsion is obtained.

For turning, the angle of the front vanes is changed in the direction of the desired turn, and the angle tending the rear vanes is changed in the opposite direction. This changes the ratio of the air flowing through the two side channels to the respective rear vanes, but sufficient air flows through the channel on the outside of the turn to reach the rear vanes so that an adequate turning thrust is produced, as will be explained hereinafter, in turning the front vanes produce a tilting moment tending to tilt the vehicle into the turn. The rear vanes produce an outward tilting moment which is considerably smaller, so that the net result is to tilt the vehicle into the turn, as is desirable.

In the case of a side wind, both front and rear vanes may be turned in the same direction so as to produce a counteracting side thrust which opposes the side wind.

Due to the channeling of the downstream flow of air to either side of the central body section, the operator is protected from spray, dust, etc. since, in effect, there is a moving air barrier on either side of the operator.

In the specific embodiment the vehicle body is constructed largely of foamed plastic material which provides a simple, inexpensive structure having many desirable qualities including lightweight, rigidity, flotation, bumper protection and vibration absorption.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 are perspective views of an aircushion vehicle in accordance with the invention, from side front and side rear, respectively;

FIGS. 3 and 4 are plan and side elevation views of the vehicle;

FIGS. 5 and 6 are longitudinal and lateral cross sections taken along the lines 5—5 and 6—6 of FIG. 3, respectively,

FIG. 7 is a diagrammatic showing of the steering controls, and FIG. 7*a* shows a partial modification thereof;

FIGS. 8–11 are schematics illustrating steering vane positions and airflow under different operating conditions;

FIG. 12 illustrates a variable ratio pulley construction for the rear steering vanes and FIG. 12*a* is a graph showing the relationship between front and rear steering vane angles as a function of the steering wheel angle;

FIGS. 13–15 illustrate a modified steering arrangement, FIGS. 14 and 15 being cross sections taken along line 14—14 and 15—15 of FIG. 13.

DESCRIPTION OF THE SPECIFIC EMBODIMENTS

Referring to FIGS. 1–6, the vehicle has a body platform 10, advantageously of foamed plastic providing sufficient buoyancy to support the vehicle and passengers in water, even if the vehicle is overturned. Mounted on the body platform toward the front end thereof is an air propeller 11 driven by an engine 12 (FIGS. 4,5). A shroud 13 around the propeller is designed in accordance with known aerodynamic principles to form a short duct which improves the propeller efficiency. In general, the shroud is designed as a ring airfoil. However, the downstream portion of a true airfoil is, in effect, cut off to reduce the length of the shroud.

Immediately behind the propeller is a set of upwardly extending front steering vanes 14 mounted for rotation about upwardly extending axes 15 (FIGS. 4,5) so that, by turning the vanes in either direction, the downstream flow of air from the propeller is directed to lateral angles on either side of the vehicle. Upwardly extending rear steering vanes are mounted near the rear of the vehicle on each side thereof, and are here shown as two sets of vanes 16 and 16′, mounted for rotation about upwardly extending axes 17 (FIG. 6). In addition to enabling front steering control, front vanes 14 also serve to reduce the rotation of the air from the propeller.

Air-channeling means is mounted on the body platform 10 between the front and rear steering vanes. An inner member has upwardly and rearwardly extending laterally spaced walls 18 and 18′ which are joined at the front thereof as indicated at 18″. The upper portion of the front end or nose 18″ is rounded to promote a smooth flow of air. The lower portion may be flat to provide room for engine 12.

Upwardly and rearwardly extending outer walls 19 and 19′ are laterally spaced from respective inner walls 18, 18′ to form respective open-ended laterally spaced channels 20, 20′ (FIGS. 8–11) which receive respective portions of the downstream flow of air from the propeller, under the control of the front steering vanes 14, and direct the flow of air therethrough to respective sets 16, 16′ of the rear steering vanes. The channels are provided with top members 21, 21′ which extend to the upper part of the shroud 13 over the propeller, thereby preventing rearward flow of air from the propeller above the top members. As will be noted from FIGS. 1 and 4, the space between the front steering vanes and the air channels is open laterally to the ambient air and the functioning thereof will be described later.

A steering wheel 22 is mounted on a panel 23 attached to the sidewalls 18, 18′ of the inner channel member, and a seat 30 is provided for the operator. A gasoline tank, storage battery, etc. may be mounted under the seat, as indicated in FIG. 5. A compartment 24 provides a backrest for the operator and support for the rear vane structure, and is advantageously hollow with a hinged cover for storage purposes. A pair of horizontal airfoils 25, 25′ are mounted on horizontal axles 26, 26′, and may be manually angled upwards or downwards by respective handles 27, 27′ to serve as stabilators which take into account different weights of the operator. Detents are provided to retain the stabilators in any position of adjustment, but are not shown in detail.

A railing 28 may be provided in front of the operator's position, and a hand throttle 29 mounted thereon. The latter is spring biased to its closed position.

As best seen in FIGS. 5 and 6, the body platform 10 is provided with a downwardly extending peripheral wall 31 forming an open plenum chamber 32 beneath the vehicle. Air from the lower portion of the propeller 11 is admitted to the plenum chamber through a slotlike opening 33. Curved fixed vanes 34 are provided to direct a portion of the air to the forward part of the plenum chamber 32, so as to approximately equalize the air pressure in various parts of the plenum chamber.

For a skillful operator, provision may be made for separately controlling the front and rear steering vanes, as by using a steering wheel for the front vanes and a foot treadle for the rear vanes, or vice versa. However, for ease of control, particularly with less skillful operators, it is desirable to link the front and rear steering vanes for joint control. In such case it is advantageous to provide means permitting the relative orientation of the front and rear vanes to be changed at will, so as to take care of crosswinds, sidehills, etc.

In the embodiment of FIGS. 1–6, a joint steering control is provided, including override means for changing the relative orientation of front and rear vanes. A connecting link 41 (FIGS. 5 and 7) is pivotally connected to the rear ends of each of the front steering vanes 14, and flexible steering cables 42, 42′ are connected to each end of the connecting link 41, or to suitably spaced points therealong. Pulleys 43 are provided for guiding the steering cables, as indicated in FIG. 7, but are not specifically illustrated in FIG. 5 to avoid confusion in the drawing. Cables 42, 42′ are led back through suitable guide means to a pulley 44 attached to a shaft in the steering wheel column 45, and the ends suitably affixed to the pulley. The steering wheel 22 is attached to the end of the shaft. Similarly, connecting links 47 and 47′ are pivotally connected to the rear ends of each of the set of rear steering vanes 16, 16′ and a rigid member 48 connects the links. Flexible steering cables 49, 49′ are connected to respective links 47, 47′ and are connected at their ends to a pulley 51 on the steering wheel shaft. Guide pulleys such as indicated at 52, 52′ are provided as required.

Instead of using a rigid connection 48, the arrangement of FIG. 7*a* may be employed. Here a pair of pulleys 53, 53′ are mounted on the vehicle. A flexible cable 54 is attached at each end to respective links 47, 47′ so that both links move simultaneously in the same direction.

For normal turning, the front and rear steering vanes will be rotated in opposite directions, as indicated by the arrows in FIG. 7. However, when traveling in a crosswind it may be desired to turn both front and rear steering vanes in the same direction. To facilitate this, as well as to provide for other maneuvers, pulley 44 is designed as an overriding clutch, and a pair of foot-operated pedals 55, 55′ are pivoted intermediate their ends about a horizontal axis and their upper ends attached to respective cables 42, 42′ leading to the front steering vanes. Thus, by holding the steering wheel in any given position, and operating the foot pedals, the relative angles of the front and rear steering vanes may be changed. Conveniently, the foot pedals are attached to short tubes which encircle a shaft mounted between the inner walls 18, 18′ of the body structure.

Referring to FIG. 8, the condition of normal forward propulsion on a level surface is shown, in the absence of any appreciable crosswind. The front steering vanes 14 are aligned fore and aft and direct the downstream flow of air from propeller 11 equally to the two laterally spaced air channels 20, 21, as indicated by the arrows. The channels direct the airflow to respective sets of rear steering vanes 16, 16′ which are likewise aligned fore and aft. This produces a forward thrust, as indicated by arrows 61.

FIG. 9 shows the condition for a medium right turn. Here the front steering vanes 14 are turned so as to direct the downstream flow of air at a small lateral angle toward the port side of the vehicle. A portion of the air will be diverted outside the left channel 20, to the ambient air as indicated by arrow 62, and consequently will produce a front steering force toward the right, as indicated by dotted arrow 63. A considerable portion of the downstream flow of air will continue to flow through the port air channel 20, and a somewhat smaller portion will flow through the starboard channel 20′. The portions of the air flowing through the respective channels impinge on rear steering vanes 16, 16′ which are turned at an angle opposite to that of the front steering vanes so as to produce a flow of air at a lateral angle to the vehicle as indicated by arrows 64, 64′. This will produce a rear turning force component toward the left of the vehicle, as indicated by dotted arrow 65, and at the same time a propulsion component. As a result, the vehicle will turn toward the right about a pivot point between the front and rear steering vanes.

FIG. 10 shows a hard right turn wherein the front and rear steering vanes are turned at greater angles. In this case the lateral airflow outside channel 20, to the ambient air indicated by arrow 66, will be greater, thus producing a greater steering force tending to force the front end of the vehicle to the right, as indicated by dotted arrow 67. Considerable airflow will still pass through the port channel 20 to the rear set of steering vanes 16, producing a flow of air in the direction indicated by arrow 68. This will produce a turning component 69, as well as a propulsion component. The airflow in the starboard channel 20′ will be still further reduced and, depending upon the detailed design and the angle of vanes 14, may be negligible. However, sufficient air will still flow through the port channel 20 to produce adequate steering control at the rear.

FIG. 11 shows a condition where it is desired to move the vehicle forward along a straight line, in the presence of a crosswind from the right, as indicated by arrow 71, or to travel along a sidehill. Here the front and rear steering vanes are angled in the same direction so as to provide front and rear thrusts indicated by arrows 72 and 73, 73′. The components of these forces acting laterally are indicated by dotted arrows 74, 75, and are in the same direction to oppose the crosswind 71.

In turning, the side thrust produced by the front steering vanes will be greater than that produced by the rear steering vanes since a portion of the downstream flow of air will have been diverted laterally of the vehicle. The point about which the vehicle turns will depend on a number of factors including the center of gravity of the vehicle (including the operator), wind conditions, uniformity of the air cushion, etc., in addition to the balance between the turning moments produced by front and rear vanes. In the embodiment shown, the resultant turning point is usually in the vicinity of the center of the vehicle, much closer to the front steering vanes than to the rear steering vanes. Thus, the effective lever arm for the rear steering vanes is considerably greater than that for the forward steering vanes, so that the effective turning moment of the rear steering vanes is comparable to that of the front steering vanes for at least moderate turns. Indeed, in the particular embodiment illustrated, for small steering angles the rear steering vanes provide a more sensitive control, that is, the rear steering vanes are more effective in producing a turning force than the front steering vanes. Consequently, it has been found desirable to vary the ratio between the angles of the front and rear steering vanes as a function of the turning angle desired.

In the embodiment here shown, this is accomplished by providing a variable ratio pulley 51 for the rear steering vanes as is shown in FIG. 12. The pulley includes two spaced discs 81, only one of which is shown, between which are four posts 82–85. Cables 49, 49′ from the rear steering vanes pass over a guide pulley 86 and around posts 83, 85 to post 82 where their ends are secured at 87.

As the pulley is rotated from the position shown, say clockwise, the initial arcuate movement is an though the pulley had a radius equal to the radial distance of the outer surfaces of posts 83, 85 from the center 88. When the pulley reaches the position shown by the dotted lines, post 84 has reached a position denoted 84′, and thereafter remains in contact with cable 49′. Shortly after post 84 contacts cable 49′, cable 49 lifts off post 83, and thereafter the cable movement depends on the positions of both posts 82 and 84, yielding the effect of a variable ratio pulley. By graphical methods, the angles of rear vanes 16 produced by the movement of cables 49 for various angles of pulley 51 (and steering wheel 22) can be plotted. With the specific dimensions shown in FIG. 12, curve 91 in FIG. 12*a* shows the result.

The radial positions of posts 82–85 and the distance from the center 88 of the pulley to the point 89 where the cables pass around guide pulleys 86 are selected so that the combined lengths of cables 49, 49′ from post 82 to point 89 is approximately constant as pulley 51 rotates through 90° in either direction from that shown. With the dimensions shown, there is some variation in the combined lengths, but the overall length of cables 49, 49′ to the rear vanes provides sufficient elasticity to accommodate the variation. More perfect results could be obtained with properly shaped cam surfaces, but would be more expensive.

The effective radius of the pulley 44 which controls the front vanes may be selected to yield the desired relative vane angles for each position of the steering wheel. In this specific embodiment the radius was 1⅝ inches, lying between the minimum and maximum effective radii of pulley 51. The dotted line 92 in FIG. 12*a* shows the front vane angle as a function of steering wheel angle. As will be observed from the slopes of the lines, for small steering wheel angles the front vanes turn more rapidly than the rear. As the steering wheel angle increases, the rate of turning of the rear vanes increases until it equals and then exceeds that of the front vanes. Thus, the ratio between the turning angles of the rear and front vanes varies from smaller values at small turning angles to larger values at large turning angles within the turning range.

The particular relative relationship selected will depend on other design factors, and may be chosen to yield the most satisfactory control under all operating conditions expected to be encountered. It may be mentioned that in high-speed travel on a straight course, the lower rate of turning of the rear steering vanes promotes stability.

Referring to FIGS. 13–15, a modified steering arrangement is shown. Here a steering wheel 101 is attached to an inner steering tube member 102. Variable ratio pulley 51, for the rear steering vanes, has a hub 103 which is affixed to tube 102 by clamp 104. Pulley 105, for controlling the front steering vanes, has a hub **106** attached to an outer steering tube member **107** by clamp **108**. A hub **109** is rotatably mounted on tube **102**, and is part of or affixed to the outer tube member **107**. A spacer tube **111** encircles the outer tube **107** and a short tubular section **112** is clamped to tube **107** by clamp **113**. Grommet **114** is mounted in a suitable opening in panel **23** and allows the steering tubes to turn therein. Another grommet **115** is mounted in a structural member **116** to allow rotation of the steering tube **102**.

Hub **109** has a pair of wings **117** between which a detent **118** is pivoted at **119**. An inner plate **121** of the steering wheel has slots **122** formed therein at suitable angular intervals. Detent **118** is biased by spring **123** so that a projection **124** thereof enters one of slots **122**. By pressing downwards on detent **118**, and rotating it, the detent may engage in any one of slots **122**. Inasmuch as the detent is mounted on hub **109**, which in turn is affixed to the front control pulley **105** via tube **107**, the relative angles of the front steering vanes with respect to the rear steering vanes may be manually adjusted to counteract crosswinds, sideslip on the slope of a hill, etc.

In performing a turn, it is desirable for the vehicle to lean into the turn. In the embodiment illustrated, it will be appreciated that the downstream flow of air from the propeller toward the rear of the vehicle is inclined somewhat downward from the horizontal. Thus the height of the rear steering vanes may be less than that of the front steering vanes, and will still intercept substantially all of the air directed thereto through the channels **20** and **20'**. When the vanes are turned for steering, the front steering vanes produce a force component to the right, as indicated by arrow **63** in FIG. 9. On the other hand, the rear steering vanes will produce a force component to the left, as indicated by arrow **65**.

Both forces will be effective to tilt the vehicle, force **63** tending to tilt the vehicle inwards of the turn and force **65** outwards. However, the effective point of application of the force **63** will be higher on the vehicle than the effective point of application of force **65**, yielding a greater lever arm for the tilting moment (force times distance). Also, the force **63** will be larger than force **65**, since all the downstream flow of air traveling above the vehicle platform will pass through the front vanes **14**, whereas in a turn only a portion will reach the rear vanes, and that portion will become smaller as the turn becomes more severe. This is because the front vanes divert more and more air outside the air channels, as has been explained in connection with FIGS. **8–10**. Consequently the net result will be a tilting moment tending to tilt the vehicle into the turn, and that of the front vanes will predominate more and more as the turn becomes more severe.

As will be observed from FIGS. **2** and **3**, with the operator position located behind the front joining section or nose **18''** of the air channeling means and laterally between the inner walls **18, 18'**, and with the tops **21, 21'** of the channels extending to shroud **13**, the operator is fully protected from the downstream flow of air from the propeller, the velocity of which may exceed 100 m.p.h. For example, in the illustrated embodiment air velocities of 115 m.p.h. from the propeller and 70 m.p.h. at the rear steering vanes have been measured. Further, in travelling on a straight course as in FIG. **8**, airflow through the channels passes on either side of the operator, thereby providing air curtains which reduce or prevent water spray, dust, etc. from reaching the operator. On turns, the air curtain may be reduced on the inside of the turn, but will still be effective on the outside of the turn where it is usually most needed.

Certain design aspects of the specific embodiment may be described more fully. The presence of the opening 33 behind the lower part of the propeller, with the top edge close to the propeller, has an effect on the vertical velocity profile of the downstream flow of air above the opening. With counterclockwise rotation of the propeller as viewed from the front, the velocity on the starboard side is fairly uniform, but on the port side is less just above the opening 33 than at the top. Also, in the engine **12** employed, he head of the engine projects on the starboard side and provides more of an obstruction to airflow than on the port side. Overall, the total thrust is somewhat less on the starboard side than on the port side. To compensate for this, the nose **18''** of the inner walls of the air channels may be moved somewhat toward the port side so that approximately equal thrusts are obtained on both sides when traveling in the forward direction. Also, the front vanes **14, 14'** may be turned at a slight angle for the central position of the steering wheel, to compensate for the difference in thrust on port and starboard sides in travelling straight ahead.

The lateral spacing of the outer walls **19** and **19'** of the air channels is selected so that the downstream flow of air, with the front vanes **14** in their midposition, is slightly inside the walls. The spacing of the outer walls from the front vanes is selected so that, with the front vanes at an angle of 45° to the centerline of the vehicle, approximately one-half of the air is directed outside the channel which is on the side of the vehicle toward which the air is diverted. Thus, in FIG. **8**, the lateral positioning of outer walls **19, 19'** of the channels is such that the high velocity flow of air is slightly inside the walls. With the front vanes at 45° as in FIG. **10**, the airflow indicated by arrow **66** is about one-half the total downstream airflow from propeller **11**. The front edges of outer walls **19, 19'** may be positioned closer to, or farther from, vanes **14** to change the proportion of air directed outside the channels for any given vane angle, as meets the judgement of the designer for optimum steering control.

The tilt of the propeller shaft and the cross section of opening **33** may be selected to provide adequate air for the cushion, and angles of 15° and 11½° from the horizontal have been employed with success. For a given area of opening **33**, the smaller tilt gives a greater propulsion thrust.

The height of the rear vanes and horizontal airfoils **25, 25'** may be selected so that the airstream extends somewhat above the airfoils, thereby enabling effective trim control.

The body platform **10** and the downwardly extending peripheral wall **31** are advantageously formed of foamed material, cemented or otherwise joined together to form a unitary structure. Thus, in one specific embodiment platform **10** was molded of foamed, closed-cell, rigid polyurethane with a tough skin produced by maintaining the mold at a suitable temperature to form the desired skin thickness, in accordance with considerations known in the art. This yields a density of around 4 lbs./cu. ft. in the core, and around 30 lbs./cu ft. in the skin. The peripheral wall is formed of foamed, closed-cell, semirigid polyethylene having a density of about 2 lbs./cu. ft. The wall is conveniently fabricated from sheet material adhered by heat, and then cemented to the body platform. The semirigid wall has sufficient flexibility to avoid serious damage when travelling over rough terrain, and serves as a bumper to avoid damage when striking piers, docks, aboveground objects, etc. Further, the structure has the marked advantage of absorbing vibration from the motor. The body structures mounted on the platform, including walls **18, 18', 19, 19'**, shroud **13**, seat **30**, etc., are also advantageously molded of foamed, closed-cell, rigid polyurethane with a tough skin, similar to platform **10**, thereby yielding a rugged, yet lightweight superstructure.

In the specific embodiment shown, having a length of about 10 feet and a width of about 5½ feet, and a 25-horsepower motor, the overall weight may be kept to about 250–300 lbs. with sufficient flotation to support 1,000 lbs. or more, and capable of carrying a load (including operator) of about 300 lbs.

Accordingly, in a relatively simple, inexpensive structure, many desirable qualities are obtained, including lightweight low center of gravity, rigidity, flotation, bumper protection and vibration absorption.

As will now be appreciated, the invention provides a low-cost air cushion vehicle capable of carrying one or two people, with a single propeller providing both air cushion and propulsion, and with two-point steering control. The steering control can be apportioned between front and rear vanes as desired.

The operator is protected from the blast of air from the propeller, and air curtains are formed on either side of the operator to protect against spray, dust and the like.

It will be understood that certain features of the invention could be employed while omitting others. For example, a separate source of air could be employed for the air cushion, and other than plenum chamber support could be used. Also, the single propeller could be replaced by two or more propellers at the front of the vehicle, with suitable changes in the air channels. The detailed structure may be changed from that shown, as meets the judgement of the designer.

I claim:

1. An air cushion vehicle including a body, and means for propelling and supporting said body on an air cushion including air propelling means mounted toward the forward end of said body and adapted to produce a downstream flow of air in the rearward direction of the vehicle, in which the improvement comprises

a. front steering means for changing the direction of said downstream flow of air to lateral angles on either side of the vehicle,

b. rear steering means positioned toward the rear of the vehicle on each side thereof and adapted to divert downstream flow of air supplied thereto to lateral angles on either side of the vehicle,

c. and air-channeling means spaced downstream of said front steering means for receiving portions of said downstream flow of air under the control of said front steering means and directing the flow of air therethrough to said rear steering means.

2. A vehicle in accordance with claim 1 in which the outer lateral boundaries of said air-channeling means and the spacing thereof downstream of said front steering means are predetermined so that for at least larger lateral angles within the range of the front steering means a substantial portion of the downstream flow of air is directed laterally outside the air-channeling means.

3. An air cushion vehicle which comprises a body platform,

b. means for producing an air cushion support for said body platform,

c. air propeller means mounted on said body platform toward the forward end thereof for producing a propelling downstream flow of air in the rearward direction thereof,

d. upwardly extending front steering vanes mounted vanes mounted in the downstream flow of air near said propeller means,

e. upwardly extending rear steering vanes mounted near the rear of the vehicle on each side thereof,

f. steering means for turning said front and rear steering vanes to change the direction of airflow therefrom to respective lateral angles on either side of the vehicle,

g. and air-channeling means mounted on said body platform between said front and rear steering vanes having upwardly and rearwardly extending inner laterally spaced walls with a front joining section, and upwardly and rearwardly extending outer walls laterally spaced from respective inner walls, said walls forming respective open-ended laterally spaced channels for receiving portions of said downstream flow of air under the control of the front steering vanes and directing the flow of air therethrough to the rear steering vanes on the respective sides of the vehicle.

4. A vehicle in accordance with claim 3 in which the spacing between said front steering vanes and the outer walls of said channels and the lateral spacing of the outer walls are predetermined so that for at least larger lateral angles within the turning range of the front steering vanes a substantial portion of the downstream flow of air is directed outside the channel which is on the side of the vehicle toward which the air is diverted.

5. A vehicle in accordance with claim 4 including a shroud over at least the upper portion of said propeller means, and top members extending over said channels between respective inner and outer walls thereof, said top members extending to said shroud, whereby downstream flow of aid from said propeller means above said top members is substantially prevented.

6. A vehicle in accordance with claim 5 in which said top members are inclined downward from front to rear and said air propeller means is inclined backward to produce a downstream flow of air to the rear steering vanes which is inclined downward from the horizontal, and the height of the upper ends of the rear steering vanes is substantially less than the height of the upper ends of the front steering vanes.

7. A vehicle in accordance with claim 6 in which said steering means includes joint control means for simultaneously turning said front and rear steering vanes in opposite direction, and including variable ratio means coupling said joint control means to said front and rear steering vanes for changing the ratio between the turning angles of the rear and front vanes from smaller values at small turning angles to larger values at large turning angles within the turning range, and means for changing the relative angles of the front and rear steering vanes controlled by said joint control means.

8. A vehicle in accordance with claim 7 in which said means for producing the air cushion includes an opening in said body platform behind the lower portion of said air propeller means for directing air from said lower portion to the space beneath said body platform, and vane means in said opening for directing a portion of the air flowing therethrough to the forward part of said space.

9. A vehicle in accordance with claim 8 including a peripheral wall adhered to said body platform to form a unitary structure therewith and extending outwardly and downwardly thereof, said body platform being formed primarily of a foamed, closed-cell, rigid plastic and said peripheral wall being formed primarily of a foamed, closed-cell, semirigid plastic.

10. A vehicle in accordance with claim 3 including a shroud over at least the upper portion of said propeller means, and top members extending over said channels between respective inner and outer walls thereof, said top members extending to said shroud, whereby downstream flow of air from said propeller means above said top members is substantially prevented.

11. A vehicle in accordance with claim 10 including an operator position located behind said front joining section of the air-channeling means and laterally between the laterally spaced channels provided thereby, whereby air flowing through said channels to the rear steering vanes on respective sides of the vehicle provides air curtains on either side of an operator in said operator position.

12. A vehicle in accordance with claim 10 in which said top members are inclined downward from front to rear thereof to produce a downstream flow of air to the rear steering vanes which is inclined downward from the horizontal.

13. A vehicle in accordance with claim 12 in which the height of the upper ends of the rear steering vanes is substantially less than the height of the upper ends of the front steering vanes.

14. A vehicle in accordance with claim 12 in which said air propeller means is inclined backward from the vertical to produce a downstream flow of air approximately parallel to said top members.

15. A vehicle in accordance with claim 14 in which said means for producing the air cushion includes an opening in said body platform behind the lower portion of said air propeller means for directing air from said lower portion to the space beneath said body platform, and vane means in said opening for directing a portion of the air flowing therethrough to the forward part of said space.

16. A vehicle in accordance with claim 3 including a peripheral wall adhered to said body platform to from a unitary structure therewith and extending outwardly and downwardly thereof, said body platform being formed

primarily of a foamed, closed-cell, rigid plastic and said peripheral wall being formed primarily of a foamed closed-cell, semirigid plastic.

17. A vehicle in accordance with claim 16 in which said rigid plastic is polyurethane with a tough skin formed thereover, and said semirigid plastic is polyethylene.

18. A vehicle in accordance with claim 3 in which said steering means includes joint control means for simultaneously turning said front and rear steering vanes in opposite directions, and means for changing the relative angles of the front and rear steering vanes controlled by said joint control means.

19. A vehicle in accordance with claim 3 in which said steering means includes joint control means for simultaneously turning said front and rear steering vanes in opposite directions, and variable ratio means coupling said joint control means to said front and rear steering vanes for changing the ratio between the turning angles of the rear and front vanes from smaller values at small turning angles to larger values at large turning angles within the turning range.

20. A vehicle in accordance with claim 3 in which said means for producing the air cushion includes means for directing a portion of the air from said air propeller means to the space beneath said body platform.

21. An air cushion vehicle which comprises

a. a body,

b. means for propelling and supporting said body on an air cushion including air propelling means mounted toward the forward end of said body and adapted to produce a downstream flow of air in the rearward direction of the vehicle,

c. front steering means for changing the direction of said downstream flow of air to lateral angles on either side of the vehicle,

d. rear steering means positioned toward the rear of the vehicle on each side thereof and adapted to divert downstream flow of air supplied thereto to lateral angles on either side of the vehicle,

e. a pair of laterally spaced air channels positioned rearwards of said front steering means for receiving portions of said downstream flow of air under the control of said front steering means and directing the flow of air therethrough to said rear steering means,

f. the space between said front steering means and said air channels opening laterally to the ambient air,

g. the rearward position and lateral spacing of said air channels being predetermined so that, over a substantial portion of the steering range of the front steering means, an increasing lateral angle of the downstream flow of air from the front steering means on either side of the vehicle produces an increasing airflow laterally outside the air channel on the respective side and a decreasing airflow to the air channel on the other side while maintaining airflow to the air channel on said respective side.

22. An air cushion vehicle which comprises

a. a body,

b. means for propelling and supporting said body on an air cushion including air propeller means mounted toward the forward end of said body and adapted to produce a downstream flow of air in the rearward direction of the vehicle,

c. upwardly extending front steering vanes mounted in the downstream flow of air near said propeller means for changing the flow of air to lateral angles on either side of the vehicle,

d. upwardly extending rear steering vanes mounted near the rear of the vehicle on each side thereof for diverting downstream flow of air supplied thereto to lateral angles on either side of the vehicle, and

e. a pair of laterally spaced air channels positioned rearwards of said front steering vanes for receiving portions of said downstream flow of air under the control of said front steering vanes and directing the flow of air therethrough to the rear steering vanes on respective sides of the vehicle,

f. the space between said front steering vanes and said air channels opening laterally to the ambient air,

g. the rearward position and lateral spacing of said air channels being predetermined so that, over a substantial portion of the steering range of the front steering vanes, an increasing lateral angle of the downstream flow of air from the front steering vanes on either side of the vehicle produces an increasing airflow laterally outside the air channel on the respective side and a decreasing airflow to the air channel on the other side while maintaining airflow to the air channel on said respective side.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,608,662 Dated September 28, 1971

Inventor(s) HUGO S. FERGUSON

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 2, lines 13 and 56, "aid" should read -- air -- .

Col. 6, line 26, "an though" should read -- as though -- .

Col. 9, line 39, "comprises a" should read -- comprises a. a -- .

Col. 10, line 3, "aid" should read -- air -- .

Signed and sealed this 21st day of March 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents