

- [54] **AIR CUSHION VEHICLE WITH RETRACTABLE SKIRT ASSEMBLY**
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- [73] Assignee: **Global Marine Inc., Los Angeles, Calif.**
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- [51] Int. Cl. **B60r 1/16**
- [58] Field of Search **180/116-130; 104/23 FS; 115/67**

3,550,718 12/1970 Knuth et al. 180/127 X

FOREIGN PATENTS OR APPLICATIONS

1,140,563 1/1969 Great Britain 180/116

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[57] **ABSTRACT**

An air cushion vehicle has a body in which a peripheral skirt assembly is retractable from an operative position, in which the skirt assembly surrounds a space below the bottom of the body, to a retracted position in which the body side surfaces are exposed substantially to the body gunwale. The skirt assembly is provided as a plurality of skirt sections. The skirt assembly is arranged so that the hover height of the vehicle may be increased by movement of the skirt sections through the initial portion of their movement from their deployed positions to their retracted positions.

20 Claims, 6 Drawing Figures

- [56] **References Cited**
- UNITED STATES PATENTS**
- 3,387,685 6/1968 Fresh et al. 180/119
- 3,481,423 12/1969 Winter 180/117
- 3,483,939 12/1969 Maddock et al. 180/127

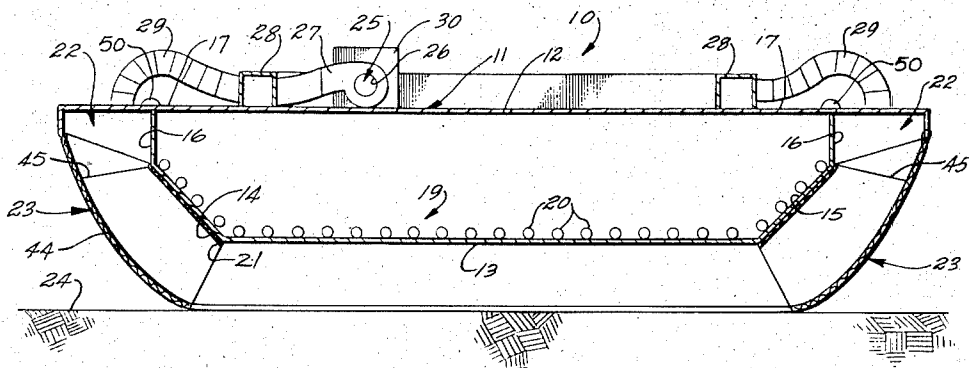


FIG. 1

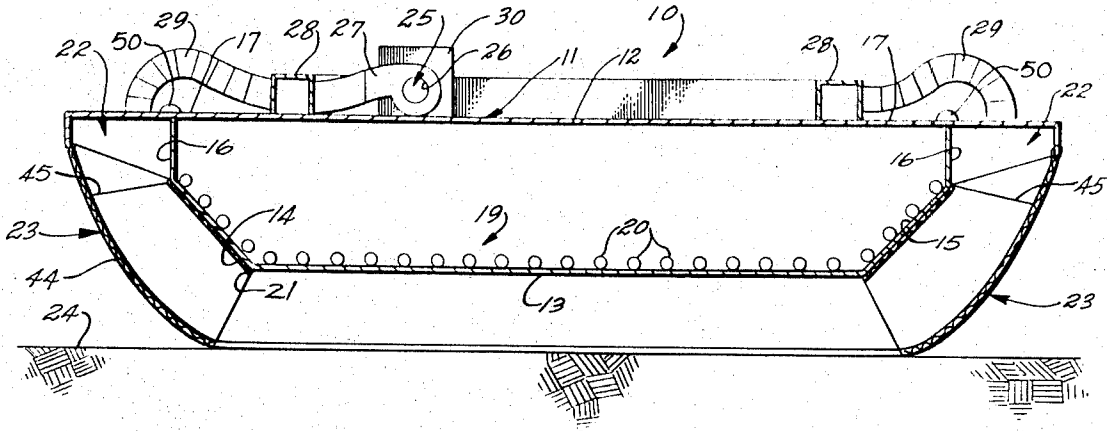


FIG. 2

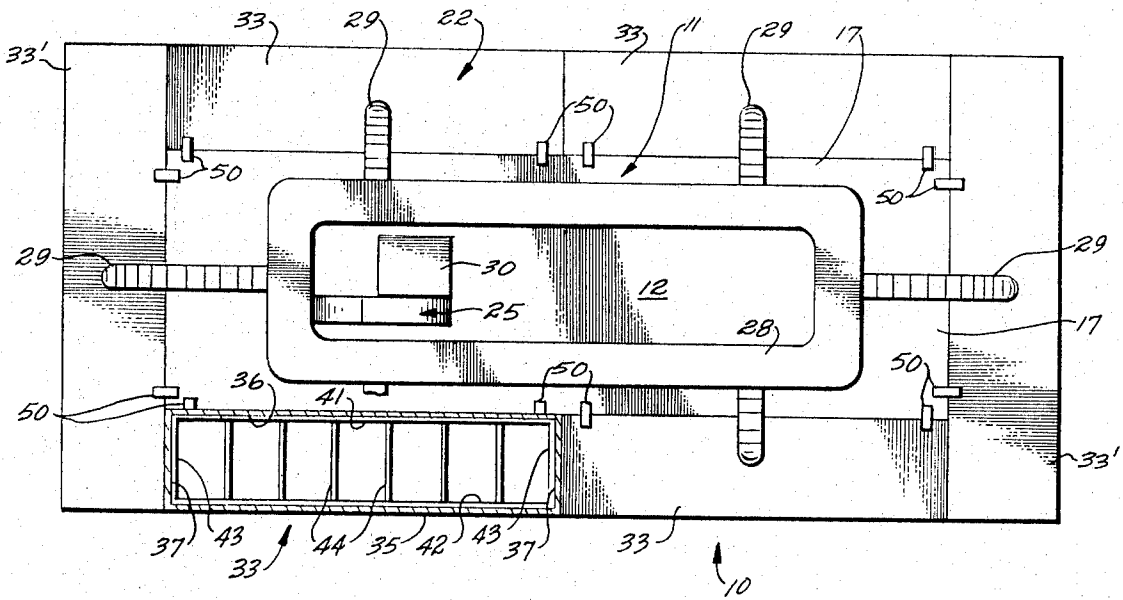
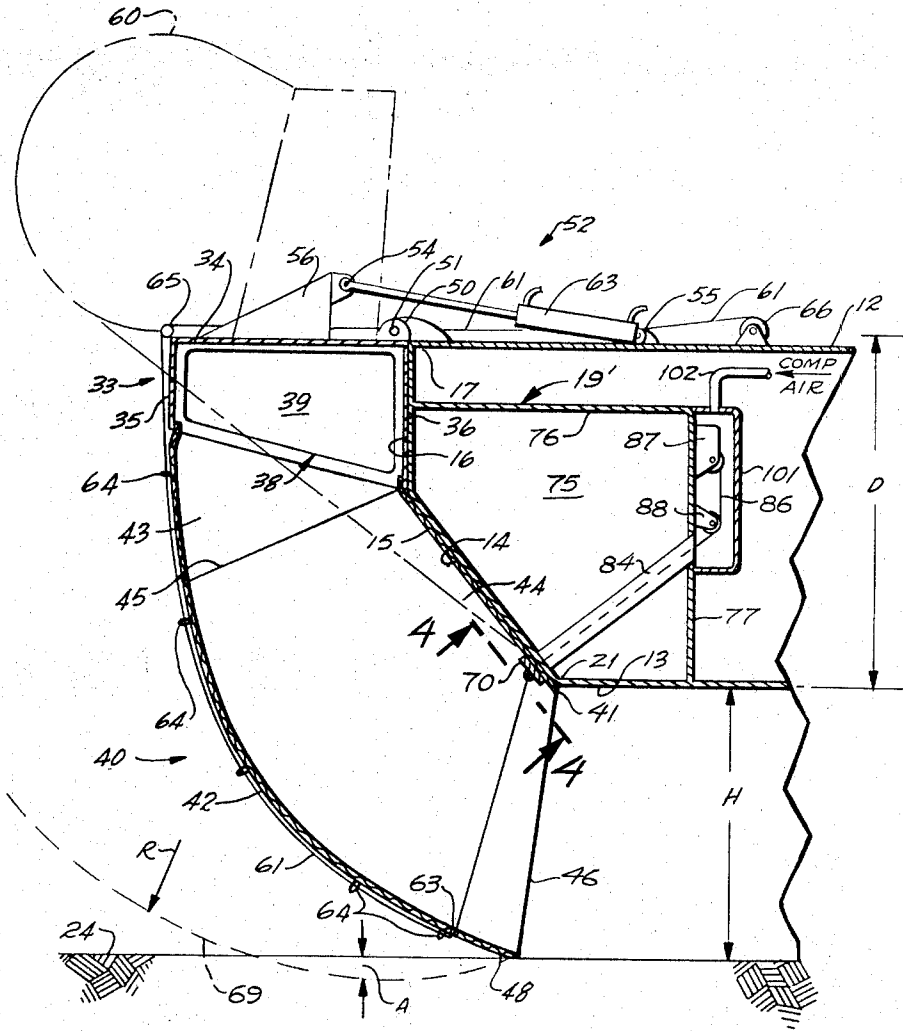


FIG. 3



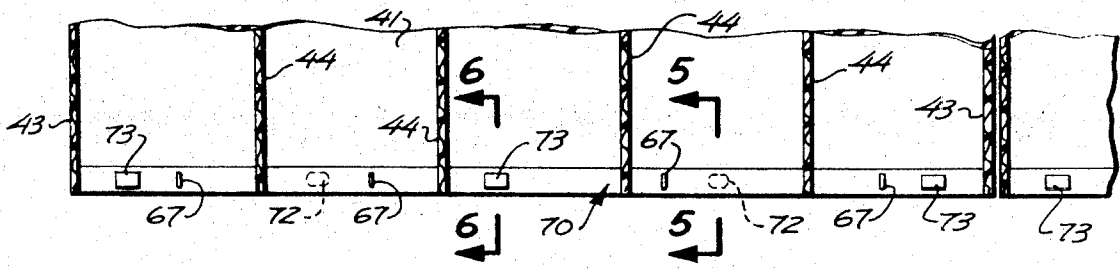


FIG. 4

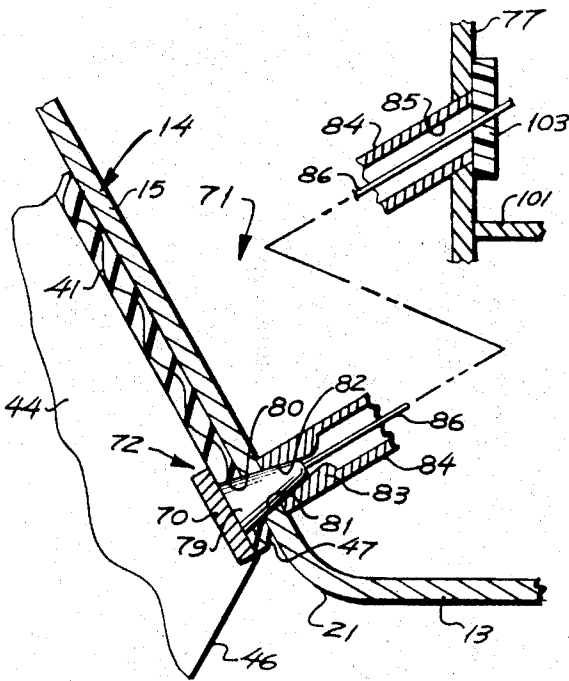


FIG. 5

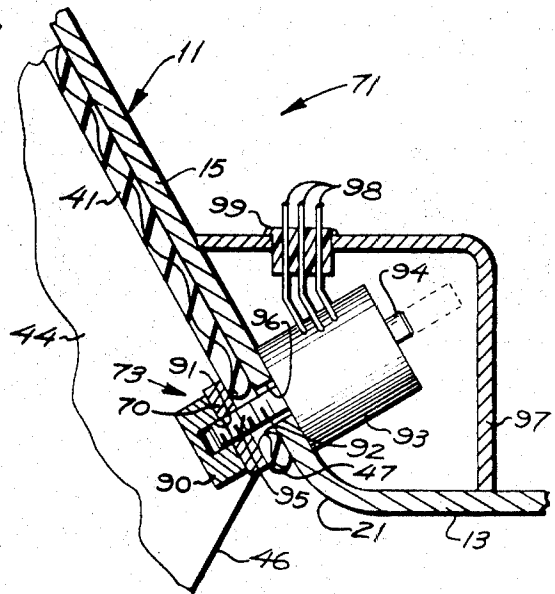


FIG. 6

AIR CUSHION VEHICLE WITH RETRACTABLE SKIRT ASSEMBLY

BACKGROUND OF THE INVENTION

1 Field of the Invention

This invention relates to air cushion vehicles. More particularly, it relates to a skirt assembly for such vehicles which is retractable so that the exterior side surfaces of the vehicle body are substantially fully exposed.

2. Discussion of the Prior Art

Commonly-owned copending application Ser. No. 130,092 filed Apr. 1, 1971, now U.S. Patent No. 3,749,162, describes an air cushion vehicle adapted for use in the arctic for the exploration for and production of oil and gas, among other uses. According to the copending application, the vehicle body is provided in the form of a barge-like floatable structure having a flat bottom and side surfaces. A drilling rig, an oil or gas production facility, or some other desired facility may be mounted to the body. The vehicle is useful on land, in water, or in ice over water. To adapt the vehicle, when equipped with a drilling rig, for example, for use in drilling an underwater well at an ice-covered location, the vehicle body includes means for transferring energy, such as thermal energy, through the side and bottom surfaces of the body. Thus, the body may be floated in a pool of water in an ice sheet during drilling operations, and may hold position within a moving ice sheet over a submerged well by melting its way into the ice; in effect the pool in which the vehicle floats is kept over a submerged location while the ice moves.

The vehicle of the copending application is movable over land, water or ice in an air cushion mode. Therefore, the vehicle includes a peripheral skirt assembly and a system for supplying air at superatmospheric pressure to a space below the vehicle body bounded by the skirt assembly so that the vehicle may be towed or self-propelled on a cushion of air. The skirt assembly is removably connected to the body adjacent the gunwale of the barge-like body. Removability of the skirt is necessary so that the side surfaces of the body may be exposed when the vehicle is used in ice as described above. The presence of the skirt assembly between the ice and the body side surfaces would impair the effectiveness of the energy transfer means to function to hold the vehicle at a fixed position relative to a moving ice sheet.

The skirt assemblies of air cushion vehicles conventionally are fabricated of relatively heavy fabric impregnated with an elastomeric material to be air impervious and wear resistant. Such skirt assemblies are heavy and difficult to handle in the best of circumstances, but in cold weather, as in the arctic, they are considerably more difficult to handle for connection and disconnection to the vehicle body. Emergencies may arise during the drilling of an oil well, or by reason of natural events in the arctic, which make it necessary for the vehicle of the copending application to be removed quickly from its floating state within an ice sheet; such removal requires that the vehicle be operated in its air cushion mode, but that means that the skirt assembly must be reconnected to the body before the vehicle can be moved.

It is apparent, therefore, that retractable rather than removable skirt assemblies would be of great utility in air cushion vehicles intended for use in the situations

described above. To be effective, however, the skirt assembly must be retractable to a position in which the vehicle side surfaces are fully exposed so that the energy transfer means described in the copending application may be used effectively.

Several retractable air cushion skirt arrangements have been described in the prior art, but because of certain limitations and disadvantages present in each of them they do not provide a solution to the problem which has been identified above.

U.S. Pat. No. 3,321,039 describes a skirt assembly which is retractable to above the flat bottom of the body of an air cushion vehicle. The retracted position of the skirt is outboard of the side surfaces of the body. Thus, the use of this form of retractable skirt in the vehicle of the copending application would disable the energy transfer mechanisms provided for the vehicle side surfaces. The retractable skirt assemblies described in U.S. Pats. Nos. 3,387,685 and 3,550,718 suffer from the same disadvantages and limitations.

U.S. Pat. No. 3,379,270 describes another retractable skirt arrangement in which a sponson extends radially outwardly of the vehicle body around the gunwale of the body. The skirt assembly is connected adjacent the outer edge of the sponson and is retractable to engagement with the bottom surfaces of the sponson, thereby exposing the side surfaces of the body below the sponson. This arrangement is not suitable to overcome the problem described above because of the use of the sponsons. Where the vehicle of the copending application is used in ice, it is likely that ice may rise above the gunwale of the vehicle body; a sponson at the gunwale would engage such ice and prevent intimate cooperation between the energy transfer mechanisms and the ice and thereby prevent effective use of the energy transfer mechanism for station-keeping of the vehicle in an ice sheet.

In view of the foregoing, therefore, a need exists for a retractable skirt assembly for an air cushion vehicle capable of being retracted to a position exposing the side surfaces of the vehicle body. When the skirt is retracted, the vehicle should present minimum structure projecting outwardly beyond the body side surfaces.

SUMMARY OF THE INVENTION

This invention provides an improved retractable skirt assembly for an air cushion vehicle. When the skirt assembly is retracted, the side surfaces of the vehicle body are exposed over their entire area. Also, in the retracted position of the skirt, the vehicle provides minimum structure projecting outwardly from the body side surfaces.

The present skirt assembly preferably is arranged so that it may be partially retracted and so that such partial retraction produces an increase in the effective hover height of the vehicle body above an adjacent supporting surface. Also, it is preferred that the skirt material be furled in a retracted condition to obtain maximum protection of the retracted skirt from damage and to minimize the volume occupied by the retracted skirt.

The improved skirt is provided by structure which is rugged, simple, reliable and efficient, and which may be operated quickly to dispose the skirt in a deployed state for air cushion mode operation of the vehicle. The skirt and its associated structure preferably are arranged for efficient use in a vehicle of the type described in Patent No. 3,749,162 but it will be

recognized by workers in the art of air cushion vehicles that the present invention may be used to advantage in other types of air cushion vehicles.

Generally speaking, this invention is provided in the context of an air cushion vehicle which includes a body 5 having a gunwale and side surfaces which extend downwardly from the gunwale to the bottom of the body. A flexible skirt is connected peripherally of the body and extends adjacent the body side surfaces for enclosing a space below the body. Means are provided for supplying 10 air at superatmospheric pressure to the space for supporting the body above an adjacent support surface. In this environment, the improvements provided by this invention comprise a plurality of skirt sections which are arranged to cooperate with each other to define the skirt. Each skirt section is movably mounted to the 15 body for movement of the section from a deployed position in which the skirt sections cooperate with adjacent sections so disposed to define the skirt and to enclose the space. The skirt sections are movable from this operative position to a second position in which they are disposed substantially adjacent the gunwale and the body side surfaces are exposed.

DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features of this invention are more fully set forth in the following detailed description of a presently preferred embodiment of the invention, which description is presented with reference to the accompanying drawings, wherein:

FIG. 1 is a cross-sectional elevation view of an air cushion vehicle, operating in its air cushion mode, equipped with a retractable skirt according to this invention;

FIG. 2 is a top plan view, partially in cross-section, of the vehicle shown in FIG. 1;

FIG. 3 is an enlarged fragmentary cross-sectional elevation view of a portion of the structure shown in FIG. 1;

FIG. 4 is an elevation view taken along line 4—4 in FIG. 3;

FIG. 5 is an enlarged cross-section view taken along line 5—5 in FIG. 4; and

FIG. 6 is an enlarged cross-section view taken along line 6—6 in FIG. 4.

DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

As shown in FIG. 1, an air cushion vehicle 10 includes a body 11 which has a barge-like configuration with a deck 12, a flat bottom 13, and side walls 14. Side walls 14 may have upwardly and outwardly sloping lower portions 15 and vertically disposed upper portions 16 which intersect deck 12 to define a gunwale 17 which extends around the perimeter of vehicle body 11. It is within the scope of this invention, however, that side walls 14 of the vehicle body 11 may be entirely of the sloping type, exemplified by lower portions 15, or of the vertical type, exemplified by vertical sections 16; if the vehicle body is provided with vertical side walls, then it is preferred that the side walls be merged into the flat bottom surface of the body by a rounded bilge, for example.

So that vehicle 10 may be used according to the disclosures of the above-identified copending application, a plurality of energy transfer mechanisms 19 are provided within the vehicle body in association with the

bottom and side wall surfaces of the body. By way of example, energy transfer mechanisms 19 may be provided in the form of a plurality of tubes 20 disposed in intimate engagement with the inner surfaces of the vehicle bottom and side walls and through which a heated heat transfer fluid may be circulated. Accordingly, when the vehicle side walls are exposed to the exterior of the vehicle and the vehicle body is disposed in a pool of water formed in an ice sheet, heated fluid may be circulated through tubes 20 to maintain the water pool within the ice sheet and also to melt the walls of the pool to enable the pool to stay stationary over a submerged location even when the ice sheet moves laterally relative to the submerged location.

In order that vehicle 10 may be operated in an air cushion mode for support of bottom 13 above an adjacent support surface 24, such as ground or water or the top of an ice sheet, vehicle 10 includes an air pressurizing and circulation system. The air system includes a blower 25 mounted to the deck of the vehicle body, for example. Blower 25 has an inlet 26 and an outlet duct 27 through which air is discharged at superatmospheric pressure. This pressurized air is supplied to a space below bottom 13 which is enclosed by a skirt assembly 23 disposed circumferentially of body 11. While pressurized air can be supplied to the enclosed space in many ways, in vehicle 10 such supply is via a plenum structure 22. Plenum structure 22 has an operative position circumferentially of vehicle body 11 adjacent gunwale 17. Skirt assembly 23 is connected to the plenum structure to depend from the plenum structure to an operative position below the bottom 13 of the vehicle body, as shown in FIG. 1. As shown best in FIG. 2, a duct 28 extends around the vehicle adjacent gunwale 17 and receives pressurized air from blower 25 via outlet duct 27. The plenum structure 22 is connected at selected locations around its extent to duct 28 via suitable branch ducts 29. Blower 25 is operated by a diesel engine 30, for example. Accordingly, when blower 25 is driven by engine 30, it discharges air at superatmospheric pressure to plenum structure 22 via duct 28 and branch ducts 29. This pressurized air is applied via skirt assembly 23 to below the bottom 13 of the vehicle. The pressure of the air supplied to the skirt assembly is sufficient that the vehicle body rises above surface 24 by reason of the pressure of the air in a space between vehicle bottom 13 and surface 24 bounded by skirt assembly 23. This is the hover or air cushion mode of operation of vehicle 10 and is illustrated in FIGS. 1 and 3.

As shown best in FIG. 2, it is preferred that the plan configuration of vehicle body 11 be substantially rectangular. Plenum structure 22 is defined by a plurality of plenum sections 33, there being at least one plenum section 33 provided for each of the four sides of the vehicle. FIG. 2 shows that at least two plenum sections 33 may be provided for each of the sides of the vehicle and that a single plenum section 33' may be provided across each end of the vehicle. End plenum sections 33' are of sufficient length transversely of the vehicle to encompass the width of the vehicle and the width of the plenum sections 33 on opposite sides of the vehicle. Thus, when plenum sections 33 and 33' are disposed in their operative deployed positions shown in FIG. 2, the plan configuration of the overall vehicle is substantially rectangular as shown in FIG. 2. Preferably, plenum sections 33 and 33' are arranged so that when they are in

their deployed position there is no fluid flow communication directly between adjacent plenum sections.

As shown in FIGS. 2 and 3, each plenum section includes a top plate 34, an outer plate 35, an inner plate 36 and end plates 37. The top, outer and inner plates are rigidly interconnected and held in position by suitable truss members 38 spaced along the length of the plenum section. The central portions of the truss members are open as at 39 (see FIG. 3), to provide fluid flow communication within the length of each plenum section. As shown best in FIG. 3, the bottom of each plenum section is open in that no closure plate is connected across truss members 33 between the lower margins of outer and inner plates 35 and 36. A branch duct 29 is connected from duct 28 to each of plenum sections 33 through the top plate of the plenum section; because the plenum sections are movable, the branch ducts preferably are flexible and extensible so that air flow communication from duct 28 to the plenum sections is maintained throughout the full range of movement of the plenum sections. Thus, the interior of each plenum section communicates through its bottom to the interior of a corresponding skirt section 40 which is connected at its upper extent to the plenum section.

Each skirt section 40 includes an inner sheet 41, an outer sheet 42, and opposite end sheets 43, each of which is connected at its upper margin to those surfaces of the corresponding plates of the plenum section which open to the interior of the plenum section. Thus, each plenum section functions as a support structure for the corresponding skirt section. For example, inner sheet 41 of skirt section 40 is connected to the surface of plenum section inner plate 36 which opens toward the interior of the plenum section, as shown in FIG. 3. A plurality of partition webs 44 are spaced along the length of each skirt section and are interconnected between the inner and outer sheets of the skirt section. Each partition web 44 has an upper edge 45 which preferably is spaced below the plenum section but which, in a preferred form of the invention, intersects the inner sheet adjacent the connection of the inner sheet to plate 36 of the adjacent plenum section. Each partition web has a lower edge 46 which intersects the lower edges 47 and 48 of the skirt section inner and outer sheets, respectively. Partition webs 44 are provided within the skirt sections to assure that the inner and outer sheets of the skirt section are disposed in a predetermined relationship to each other when air is supplied to the skirt sections during air cushion mode operation of vehicle 10. It is preferred that the lower edge 47 of inner sheet 41, during air cushion mode operation of the vehicle, be disposed adjacent the turn of the bilge 21 of body 11 inwardly of and above the operative position of the lower edge 48 of the outer sheet.

At least the outer and end sheets of each skirt section are air impervious and it is preferred that the inner sheet of each skirt assembly also be air impervious. The air impervious sheets of the skirt assemblies may be fabricated of a heavy fabric impregnated with a suitable elastomeric material, such as rubber or the like. Because of the function which they serve within each skirt section, the partition webs may be and preferably are pervious to the flow of air through them.

Each skirt supporting plenum section 33 or 33' is hinged to vehicle body 11, as by a pair of hinge assemblies 50 spaced along the length of each plenum section and interconnected between the plenum section top

plate and the deck of the vehicle at gunwale 17. It is preferred that the hinge axis 51 for each plenum section be located just outboard of the gunwale, as shown in FIG. 3, or at the gunwale line. A retracting mechanism 52 is interconnected between the vehicle body and each plenum section for moving the plenum section about hinge axis 51 between an operative deployed position, shown in solid lines in FIG. 3, and a retracted position, shown in broken lines in FIG. 3. When the plenum sections are in their deployed position, the top plates of the several plenum sections are essentially coplanar with deck 12 of vehicle 10, and the inner plates 36 of each plenum section abut and are supported by the outer walls of vehicle body 11. In their retracted positions, the plenum sections are disposed so that their top plates are disposed at least vertically as shown in FIG. 3, or preferably, are sloped inwardly toward the center of vehicle 10 from adjacent hinge axes 51. An optimum disposition of the plenum assemblies in their retracted position would be a disposition in which the plenum section top plates are disposed substantially parallel to and above vehicle deck 12.

When the plenum sections are disposed in their deployed positions, as shown in FIG. 2, the end plates of side plenum sections 33 abut each other or the adjacent portions of the inner plates of end plenum sections 33'. This intimate cooperation between the adjacent portions of the several plenum sections assures that the corresponding sheets of the skirt sections carried by the respective plenum sections will cooperate with each other, when air is supplied at superatmospheric pressure to the skirt sections, to cause the end sheets and inner sheets of the several skirt sections to abut each other and effectively seal off the lateral boundaries of the space provided below the vehicle body. In effect, then, plenum sections 33 and 33' and the skirt sections carried by them cooperate, when the plenum sections are in their fully deployed position, to function as a unitary plenum structure and skirt extending circumferentially of vehicle body 11.

The retraction mechanism 52 provided for each plenum section may conveniently include a double-acting hydraulic or pneumatic ram assembly 53 pivoted, as at 54 and 55, to a suitable bracket 56 connected to the plenum section top plate and to vehicle deck 12, respectively.

To further assure that the side walls of vehicle body 11 will be exposed to the maximum extent possible when plenum sections 33 are disposed in their retracted positions, vehicle 10 includes means for furling skirt sections 40 relative to each corresponding plenum section. The furled state of the skirt sections is indicated in FIG. 3 at 60, shown in broken lines. The furling mechanism for each skirt section includes a plurality of draw lines 61, only one of which is shown in FIG. 3. A draw line is provided at each of a plurality of stations along the length of the skirt section. Each draw line is connected at its outer end 62 via a suitable connector 67 to a tie-down bar 70 secured to the inner face of inner skirt sheet 41 adjacent its lower edge 47. From this connection, each draw line extends across the interior of the skirt assembly, parallel to the plane of partition webs 44, through an opening 63 provided in the outer sheet adjacent its lower edge 48. Openings 63 preferably are of small diameter to minimize leakage of air from the interior of the skirt through the openings during air cushion mode operation of the vehicle. Each

opening 63 may be defined by a grommet located in the skirt outer sheet and having an inner diameter somewhat larger than the diameter of draw line 62. After passing through opening 63, each draw line 61 extends upwardly along the outer face of outer sheet 42 through a plurality of spaced guide eyes 64 which are affixed at appropriate locations to the outer sheet. Each draw line is passed over a suitable rotatable guide roller 65 mounted to the plenum section at the upper outer corner of the plenum section defined by the joint between the top and outer plates of the plenum section. Each draw line extends from roller 65 via suitable additional guide rollers (not shown) to a winch mechanism 66 which is illustrated to be mounted to deck 12, but which may be mounted in any convenient location within the structure of the vehicle. If desired, all of the draw lines for a given skirt section may be led to a common winch or to individual winches.

It will be apparent that, because of the arrangement of the draw lines relative to the inner and outer sheets of each skirt section, reeling in of the draw lines after the adjacent plenum section has been moved to its retracted position will cause the skirt assembly to be rolled up upon itself to a furled

It will be apparent that, because of the arrangement of the draw lines relative to the inner and outer sheets of each skirt section, reeling in of the draw lines after the adjacent plenum section has been moved to its retracted position will cause the skirt assembly to be rolled up upon itself to a furled storage state indicated at 60 in FIG. 3. Furling of the skirt sections is facilitated by making the skirt sections as flexible as possible, and it is for this reason that it is preferred that partition webs 44 be defined by a fabric which has not been increased in thickness or stiffness by being impregnated with an elastomeric material or the like to render it impervious to the passage of air.

Assume that plenum sections 33 and 33' are in their retracted state and the skirt sections are furled as indicated in FIG. 3. If it is then desired to move the plenum sections to their operative deployed position and to commence air cushion mode operation of the vehicle, retraction mechanisms 52 are operated to move plenum sections to their deployed positions. Air is then applied to the interior of the plenum sections from blower 25. The application of pressurized air to the interior of the plenum section acts upon the furled skirt sections to bias the skirt sections from the furled state to their fully deployed state shown in FIG. 3. Accordingly, draw lines 61 are paid out from winches 66 to permit the skirt sections to unfurl. Control over the rate at which the draw lines are paid out provides control over the rate of unfurling of the skirt assemblies.

An inspection of FIG. 1 will show that during air cushion mode operation of vehicle 10, it is necessary to constrain inner sheets 41 of skirt assembly 23, at locations on the inner skirt sheets near the bilge 21 of vehicle body 11, from moving outwardly relative to the vehicle body. The lack of such constraint upon the skirt sections during air cushion operation will result in the skirt sections being blown outwardly relative to the vehicle body about the connection of the several skirt sections to plenum sections 33. Such a "blow out" is produced by virtue of the superatmospheric pressure provided within the space bounded by the skirt assembly as blower 25 is operated.

Tie-down bars 70, one of which is provided in association with each skirt section 40, constitute components of a mechanism 71 for releasably constraining the lower margins of inner skirt sheets 41 from moving outwardly relative to body 11 during air cushion mode operation of the vehicle. Referring to FIGS. 3, 4, 5 and 6, a tie-down bar 70 is secured to inner skirt sheet 41 adjacent to and parallel to the lower margin 47 of the inner skirt sheet so as to lie parallel to bilge 21 of vehicle body 11, but slightly above the bilge, when the corresponding skirt section is in its fully deployed position shown in FIG. 3. Preferably, the tie-down bar is secured to the sheet inner face, i.e., the face of the skirt sheet which opens toward outer skirt sheet 42. As shown best in FIG. 4, at least a pair of locating assemblies 72 are associated with each tie-down bar, as are a plurality of latch assemblies 73 and the connectors 67 for the drawlines 61 associated with each skirt section. The positioning assemblies, latch assemblies, and drawline connectors are spaced at desired intervals along the length of the tie-down bar.

FIG. 3, illustrates a different energy transfer mechanism 19' from that shown in FIG. 1. Mechanism 19' takes the form of a hot gas plenum chamber 75 defined peripherally around the interior of body 11 to extend, in cooperation with each side of the body, from adjacent the bilge 21 to the desired elevation on the side wall of the body. Chamber 75 is defined by a suitable enclosure having a top closure portion 76 and a side closure portion 77 cooperating with each other and with the interior of the body side walls and bottom, respectively. Hot gas, such as air warmed by the exhaust of diesel engine 30, for example, may be circulated through chamber 75 for the transfer of thermal energy through the adjacent side walls and bottom of the vehicle for enabling the vehicle to maintain a fixed position within a laterally moving ice sheet during use of the vehicle with the skirt sections in their retracted position, as described above.

As shown best in FIGS. 4 and 5, each of the several positioning assemblies 72 includes a conical projection 79 secured to the outer face of corresponding tie-down bar 70; the outer face of the tie-down bar is the face of the tie-down bar which opens toward the inner face of inner skirt sheet 41. Projection 79 extends through a suitable opening 80 provided in the adjacent inner skirt sheet to cooperate with a mating tapered opening 81 formed in body side wall 15 adjacent bilge 21. Each opening 81 preferably is a component of a seat for projection 79, such seat further being defined by a conical inner wall 82 of an inner boss 83 provided at the lower end of a tube 84. The lower end of the tube is sealed in watertight relation to the inner surface of body wall 15 about opening 81. As shown in FIG. 3, each tube 84 traverses hot gas chamber 75 to an inner end 85 which opens through the vertical closure portion 77 of chamber 75. Each tube 84, one of which is provided in each positioning assembly 72, serves as a passageway for a cable 86 which extends from a connection at one of its ends to the corresponding conical projection 79, through tube 84 and to a winch 87 disposed within the interior of vehicle body 11. A separate winch 87 may be provided for each cable 86 or, preferably, a single winch may be provided for all of the cables associated with a particular skirt section 40. FIG. 3 illustrates that the preferred location of winches 87 is on the vertical closure wall 77 for hot gas chamber 75. To assure that

each cable 86 passes through substantially the center of the inner end of the corresponding tube 84, a guide roller 88 is provided at a suitable location adjacent the inner end of each tube 84, as shown best in FIG. 3.

The several positioning assemblies associated with each skirt section are provided to assure that, as the skirt section is moved from its retracted to its deployed position, those portions of the several latch assemblies which are carried by the tie-down bar of the skirt section are appropriately positioned relative to vehicle body 11 for cooperation with those portions of the latch assemblies which are mounted to body 11.

Each latch assembly 73, as shown in FIG. 6, includes a block 90 affixed to the outer face of tie-down bar 70. An internally threaded hole 91 is formed through the tie-down bar and into block 90 as a component of each latch assembly. An opening 92 is provided through the inner skirt sheet 41 in alignment with each hole 91. A reversible electric motor 93, having a rotatable and reciprocal shaft 94, is affixed to the inner surfaces of body side wall 15 adjacent bilge 21 as a further component of each latch assembly 73. Each motor is so positioned within body 11 that when corresponding tie-down bar 70 has been properly positioned relative to the vehicle body by operation of positioning assemblies 72, the shaft of each motor is coaxially aligned with the corresponding internally threaded hole 91. The outer end of motor shaft is externally threaded, as at 95, to mate with the threads of hole 91. To enable cooperation of the motor shaft with hole 91, an opening 96 is provided through the vehicle body coaxially of each motor shaft. Preferably, the connection of each motor to the inner surfaces of body side wall 15 is a watertight connection about opening 96. It is also preferred that each motor be disposed within a watertight housing 97 with the power conductors 98 for the motor being passed through the housing via a suitable watertight seal assembly 99.

Preferably, each motor shaft 94 is splined within its motor armature so that rotation of the motor armature is transmitted to the motor shaft. The connection of each motor shaft to the armature also includes an axial drive mechanism which is effective to move the shaft axially of the armature in the absence of any substantial resistance to rotation of the motor shaft. These connections of the motor shaft to the motor armature are arranged so that the motor shaft moves linearly into and through opening 96 at the same time as the shaft is rotated in a direction to produce threading engagement between the external thread 95 on the shaft and the internal threads of hole 91. Conversely, when the motor 93 is operated in the opposite direction, threads 95 are disengaged from hole 91 and the motor shaft is moved away from backup bar 70 to its retracted position, shown in broken lines in FIG. 6.

From the foregoing description, it is apparent that the constraining mechanism 71 associated with each skirt section 40 is composed of positioning assemblies 72 and latch assemblies 73.

Assume that a given skirt section 40 and its plenum section are in their furled and retracted positions shown in broken lines in FIG. 3; in order for the skirt section to be so disposed, it is apparent that cables 86 associated with that skirt section must be paid out from corresponding winches 87, and this is represented by a broken line in FIG. 3. Assume further that it is desired to dispose the skirt section in its deployed position for

air cushion mode operation of vehicle 10. Plenum section 33 is moved into its deployed position and skirt assembly 40 is unfurled as air is supplied to the interior of the plenum section from blower 25 in the manner described above. As the plenum section is moved to its deployed position, and as the skirt section is unfurled from the plenum section during this process, cables 86 for that skirt section are reeled in via winches 87 so that, as the skirt completely unfurls, conical projections 79 of the several positioning assemblies 72 are moved into snug mating engagement with their seats, as shown in FIG. 5. This reeling in of cables 86 during the unfurling of skirt section 40 may be relied upon to assist in the unfurling process such that the commencement of the supply of pressurized air to the skirt section can be delayed until the skirt section is completely unfurled and latched down to the vehicle body. In any event, snug mating of each of the several projections 79 carried by the tie-down bar of the skirt section is assured by the tensioning on cables 86 from winch 87, and such positioning assures the proper coaxial alignment of internally threaded holes 91 of the same tie-down bar with the several motors 93 of the associated latch assemblies. Once the tie-down bar has been properly positioned relative to the vehicle body as shown in FIG. 5, the motors 93 of the respective latch assemblies are operated to cause the motor shafts to be advanced outwardly from the vehicle body toward the tie-down bar. Such operation of the motors causes the externally threaded outer end of each motor shaft to thread itself into the corresponding internally threaded hole 91. The torque imposed upon the motor shafts during this process is sufficient to assure that the lower margin 47 of inner skirt sheet 41 is securely clamped between the tie-down bar and the vehicle body as each motor shaft reaches the limit of its axial movement outwardly of the vehicle body. When all of the skirt sections have been deployed and releasably connected adjacent their lower margins to the vehicle body in the manner described above, the vehicle may be operated in its air cushion mode during which the skirt assembly maintains its proper position relative to the vehicle body.

It will be apparent that, to enable retraction of the skirt and plenum sections, and to enable furling of the skirt sections on the retracted plenum sections, all that is necessary is that motors 93 for the respective skirt sections be operated in reverse to cause motor shafts 94 to unscrew from internally threaded holes 91 and that winches 87 be operated to pay out cables 86 as winches 66 are operated to reel in drawlines 61. The disposition of a portion of cables 86 adjacent the exterior surfaces of body 11 when the several skirt sections are in their retracted and furled positions does not provide any significant impediment to the operation of the energy transfer mechanisms carried by vehicle 10. Thus, the energy transfer mechanisms carried by the vehicle may be operated effectively to permit the vehicle to maintain a desired position over a fixed submerged location for the purposes described in the previously mentioned copending application.

When the skirt assembly and plenum structure are fully retracted relative to the vehicle body to permit the vehicle to be operated as described in the copending application, the lower ends of cable tubes 84 are disposed below the waterline at which the vehicle body floats. To prevent leakage of water through the guide tubes into the interior of the vehicle, it is preferred that

winches 87 and cable guide rollers 88 be mounted within an airtight housing 101 to which compressed air is applied via a suitable duct 102 at a pressure somewhat greater than the hydrostatic pressure of water at the lower end of the tube. In this manner, air is caused to leak from the inside of the vehicle outwardly, rather than to allow water to leak into the interior of the vehicle. As shown in FIG. 5, leakage of air out of the vehicle, or the leakage of water into the vehicle via tubes 84 is further inhibited by a suitable seal assembly 103 at the inner end of each tube 84 and through which the corresponding cable 86 passes. A suitable seal assembly may be a soft rubber block having a hole there-through sized for snug cooperation with the outer diameter of cable 86.

It is desired that the hinge axis 51 by which each plenum section 33 or 33' is movably connected to vehicle body 11 be disposed outboard of the body from the position at which the lower edge 48 of skirt outer sheet 42 is disposed when the plenum and skirt sections are in their fully deployed positions; this condition is shown in FIG. 3. Accordingly, when vehicle 10 is operated in its air cushion mode, the bottom 13 of the vehicle body is disposed above support surface 24 by a distance H which is the normal hover height of the vehicle. The precise value of hover height H will be dependent upon the effective weight of the vehicle, the pressure of the air supplied to the space between the vehicle and support surface 24 within the confines of skirt 23, and the area of body 11 upon which such air pressure may act vertically. The inboard disposition of outer sheet lower edge 48 from hinge axis 51, however, in combination with the movability of plenum sections 33 relative to the vehicle body, provides vehicle 10 with the capability to increase hover height H by an amount A. Distance A is equal to the height of the chord defined by the intersection of support surface 24 (assuming the vehicle is operated at its normal hover height H) with the arc 69 (having radius R from hinge axis 51) swept by the bottom edge of outer sheet 42 about hinge axis 51 as the plenum section is hinged relative to the vehicle body during air cushion mode operation of the vehicle. In other words, if the depth D is the vertical distance of vehicle bottom 13 below hinge axis 51, then $R = D + H + A$.

It was noted above that the several plenum sections cooperate intimately with each other in their fully deployed state; and that the several skirt sections also cooperate intimately with each other when the plenum sections are fully deployed. This intimate cooperation is maintained through the initial stages of movement of the plenum sections from their fully deployed to their retracted positions due principally to the flexibility and limited expansibility of the skirt sections. That is, the skirt sections are so defined that they tend to balloon somewhat from their normal operative configurations in which the end and inner sheets of each skirt section are constrained by engagement with the side walls of the vehicle body or with the end sheets or inner sheets of adjacent skirt sections. It is apparent, therefore, that one or all of the plenum sections may be hinged about axes 51, through the initial portions of their total hingeable movement relative to the vehicle body, and still maintain an effective circumferential seal on the pressurized space provided between support surface 24 and the vehicle during air cushion mode operation of the vehicle. Accordingly, the maximum hover height capa-

ble of being realized in vehicle 10 is normal hover height H plus additional height increment A. This variability in the hover height of vehicle 10 is achieved at constant air pressure under the vehicle. Since the plenum sections are separately movable, the vehicle may maintain an even keel while moving over a slope, or it may step up over an obstruction on surface 24.

Those skilled in the art pertinent to air cushion vehicles and the design of skirts for such vehicles will appreciate that vehicle 10 may be given some inherent pitch and roll stabilization properties by arranging skirt sections 40 so that the outer sheet 42 of each skirt section is disposed at an acute angle relative to support surface 24 adjacent the lower edge 48 of the outer sheets. The more acute the included angle between the outer surface of outer sheet 42 and support surface 24, the greater is the roll or pitch compensating characteristic of vehicle 10. It will be apparent, therefore, that when plenum sections 33 or 33' are moved outwardly about hinge axes 51 relative to vehicle body 11 for the purposes of increasing the effective hover height of the vehicle above surface 24, this increase in effective hover height is attained at the expense of a partial sacrifice in the pitch and roll compensating characteristics of the vehicle. This is true because such movement of the plenum sections about hinge axes 51 produces an increase in the value of the included angle between support surface 24 and the outer surfaces of the outer sheets of the skirt sections.

Constraining mechanisms 71 are operable to provide the necessary constraint of the lower margins of inner skirt sheets 41 from undesired movement away from body 11 during movement of the plenum and skirt sections through the initial portion of their path from deployed to retracted states. That is, the constraining mechanism can be used to maintain proper deployment of the skirt sections as the skirt sections are moved to increase the hover height of the vehicle. If an increase in hover height is desired, over and above hover height H, latch assemblies 73 are operated to disengage motor shafts 94 from tie-down bars 70 during air cushion mode operation of the vehicle. Cables 86 are paid out by winches 87 to the desired extent, and the cables themselves provide the desired constraint against blow-out of the skirt sections.

The above-described hover height variation is possible in vehicle 10 because each plenum section is sealed from the adjacent plenum sections by end plates 37; the air flow arrangement from duct 28 to the several skirt sections is a parallel flow arrangement. If desired, the several plenum sections may be arranged so that their interiors communicate with each other when the several sections are in their deployed state. Where the plenum sections intercommunicate, suitable seals (not shown) are provided for the sections to seal the plenums to each other at their ends when deployed, but the seals must also permit the several sections to be hinged into their retracted positions. If the seals are arranged to maintain pressure within the plenum sections during the initial portions of retraction of the plenum sections from their deployed positions, then the above-described hover height variability will be attained.

The invention has been described above with reference to a single illustrative but presently preferred embodiment of the invention. It will be appreciated that structural arrangements other than those described above may be used to practice the advances made by

this invention without departing from the scope of the invention. For example, the use of a hinge connection between the skirt sections and the vehicle body is only one type of connection which may be used to mount the skirt sections for movement between deployed and retracted positions. Accordingly, the foregoing description should not be regarded as restricting the scope of the invention.

What is claimed is:

1. In an air cushion vehicle including a body having a gunwale and side surfaces extending downwardly from the gunwale to the bottom of the body, a flexible skirt disposed peripherally of the body and extending adjacent the body side surfaces for enclosing a space below the body, and means for supplying air at superatmospheric pressure to the space for supporting the body above an adjacent support surface, the improvement comprising a plurality of skirt sections arranged to cooperate with each other to define the skirt, and means mounting each skirt section to the body for movement of the sections between a deployed position below the gunwale in which each section cooperates with adjacent sections so disposed to enclose said space and a retracted position in which the skirt sections are disposed substantially adjacent the gunwale and the body side surfaces are exposed.

2. Apparatus according to claim 1 including support means for each skirt section to which the skirt section is essentially permanently mounted, and wherein the means mounting each skirt section to the body includes means mounting the support means to the body for movement relative to the body between positions corresponding to the deployed and retracted positions of the skirt sections.

3. Apparatus according to claim 2 wherein the support means comprises a part of the air supplying means.

4. Apparatus according to claim 1 wherein the air supplying means includes plenum means around the body substantially at the gunwale, and wherein the skirt sections are arranged to cooperate with the plenum means in their deployed position for supply of air via the skirt sections to the space.

5. Apparatus according to claim 4 wherein the plenum means includes a plenum section for each skirt section, and including means mounting each plenum section to the body for movement with the corresponding skirt section between its deployed and retracted positions.

6. Apparatus according to claim 5 wherein the air supplying means is arranged for air flow connection to the plenum structure throughout movement of the plenum sections between the deployed and retracted positions of the corresponding skirt sections.

7. Apparatus according to claim 5 wherein the air supplying means is arranged for parallel flow of air to the skirt sections via the respective plenum sections.

8. Apparatus according to claim 7 wherein each skirt section is arranged to receive air at superatmospheric pressure only from the corresponding plenum section.

9. Apparatus according to claim 5 wherein each skirt

section is connected at its upper extent to the corresponding plenum section for movement with the corresponding plenum section relative to the vehicle body.

10. Apparatus according to claim 5 wherein the plenum section mounting means comprises hinge means mounting the plenum sections to the vehicle body.

11. Apparatus according to claim 10 wherein each skirt section is so arranged that when the corresponding plenum section is in its deployed position the lower margin of the corresponding skirt section is disposed inwardly of the vehicle from the hinge axis for the plenum section.

12. Apparatus according to claim 1 wherein the skirt sections and the air supplying means are cooperatively arranged for operation thereof for air cushion support of the vehicle throughout a selected initial portion of the movement of the skirt sections from their deployed position to their retracted position.

13. Apparatus according to claim 12 wherein the skirt sections are arranged for increasing the effective hover height of the vehicle in response to movement of the skirt sections through said selected initial portion of movement from their deployed position during air cushion mode operation of the vehicle.

14. Apparatus according to claim 1 wherein the vehicle includes means in association with the side surfaces of the body for transferring energy through the side surfaces from internally of the vehicle.

15. Apparatus according to claim 14 wherein the energy transferring means is arranged for transferring thermal energy.

16. Apparatus according to claim 1 including means releasably engageable between the vehicle body and each skirt section adjacent the bottom of the body for constraining the skirt section from movement from the deployed position of the skirt section in response to superatmospheric pressure within the space.

17. Apparatus according to claim 16 wherein the constraining means includes releasable latching means having components carried by the skirt section and components carried by the vehicle body which cooperate with each other when the skirt section is in a predetermined position relative to the body, and means for positioning the skirt section in its predetermined position relative to the body.

18. Apparatus according to claim 17 wherein the positioning means is operable to at least partially control movement of the skirt section from its retracted position to its deployed position.

19. Apparatus according to claim 16 wherein the constraining means is operable to provide said constraint upon the skirt section both in the deployed position of the skirt section and during the initial stages of movement of the skirt section from its deployed position toward its retracted position.

20. Apparatus according to claim 1 including means for at least partially furling the skirt sections when the skirt sections are in their retracted positions.

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