Sept. 17, 1968 C. BARR 3,401,767

ARTICULATED GROUND EFFECT MACHINE SYSTEM

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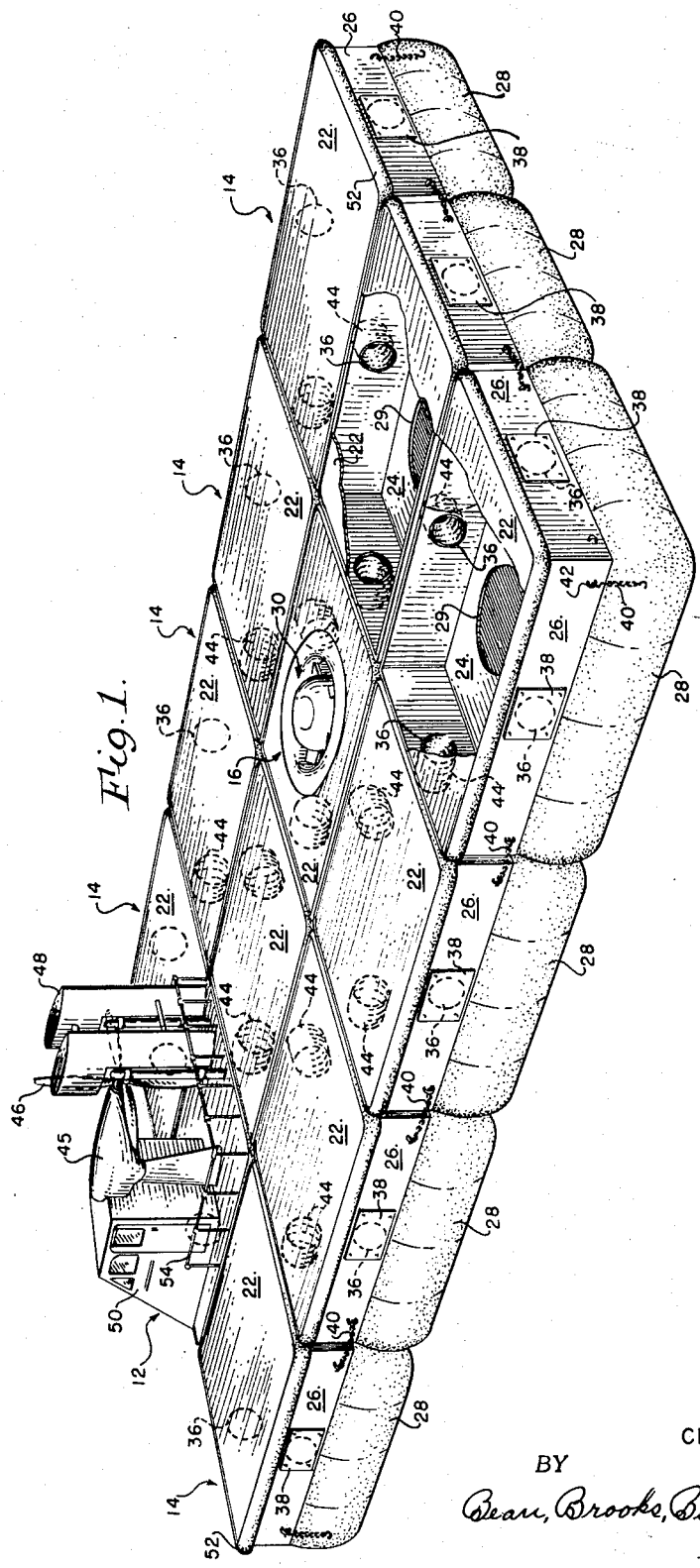


Fig. 1.

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ARTICULATED GROUND EFFECT MACHINE SYSTEM

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Fig. 2.

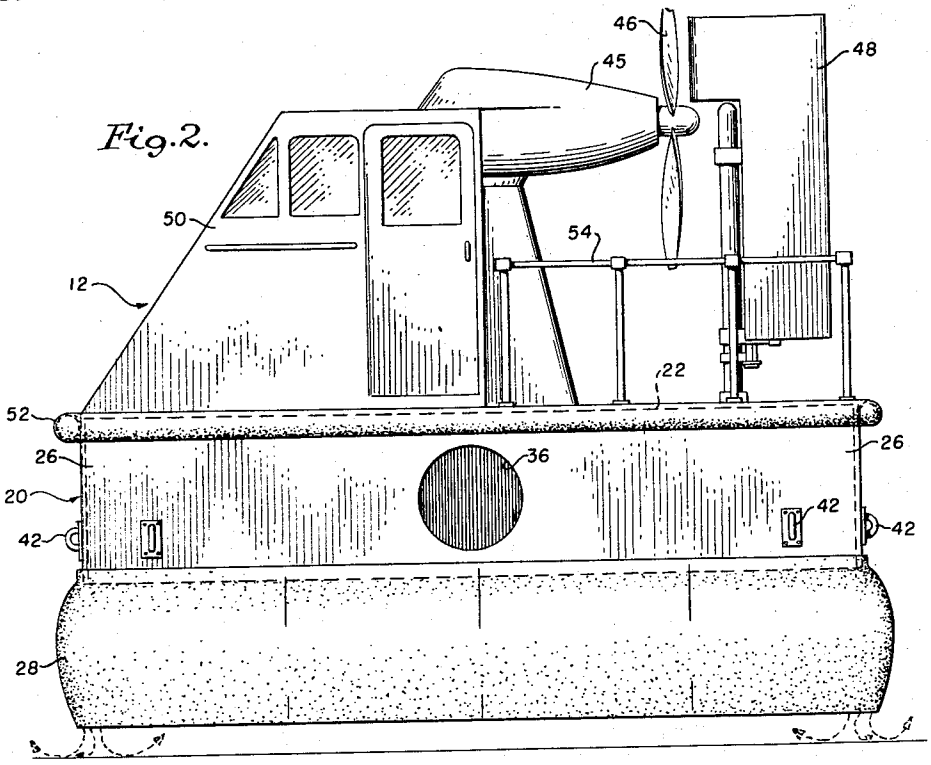
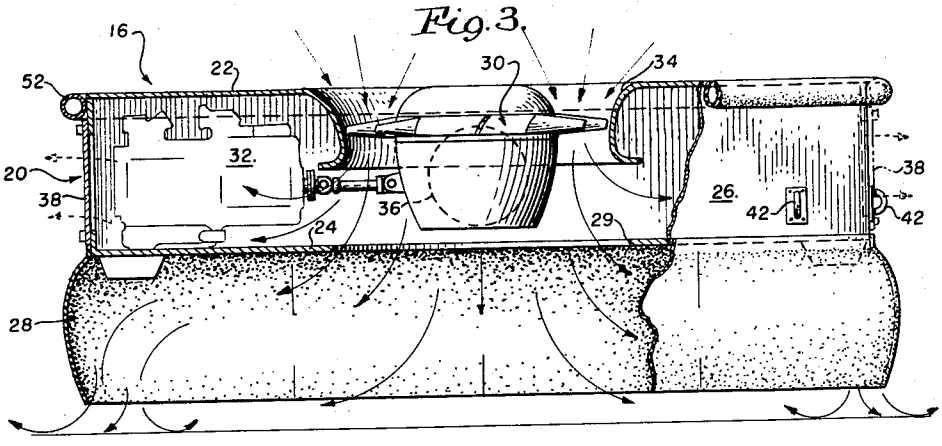


Fig. 3.



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Fig. 4.

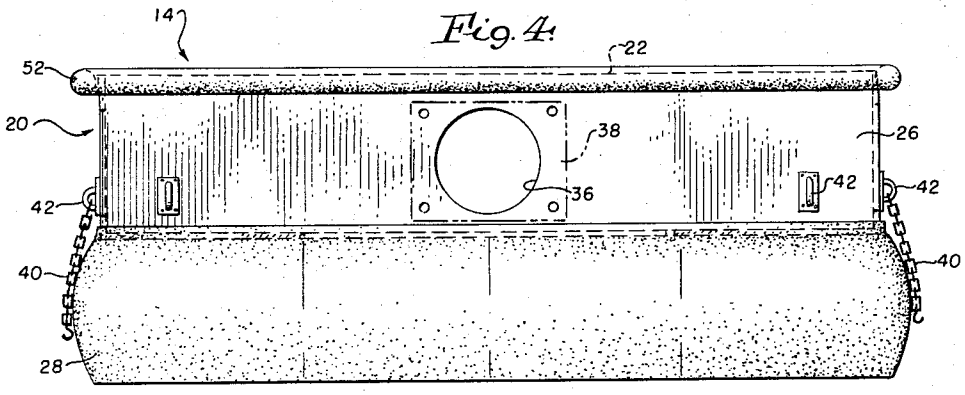
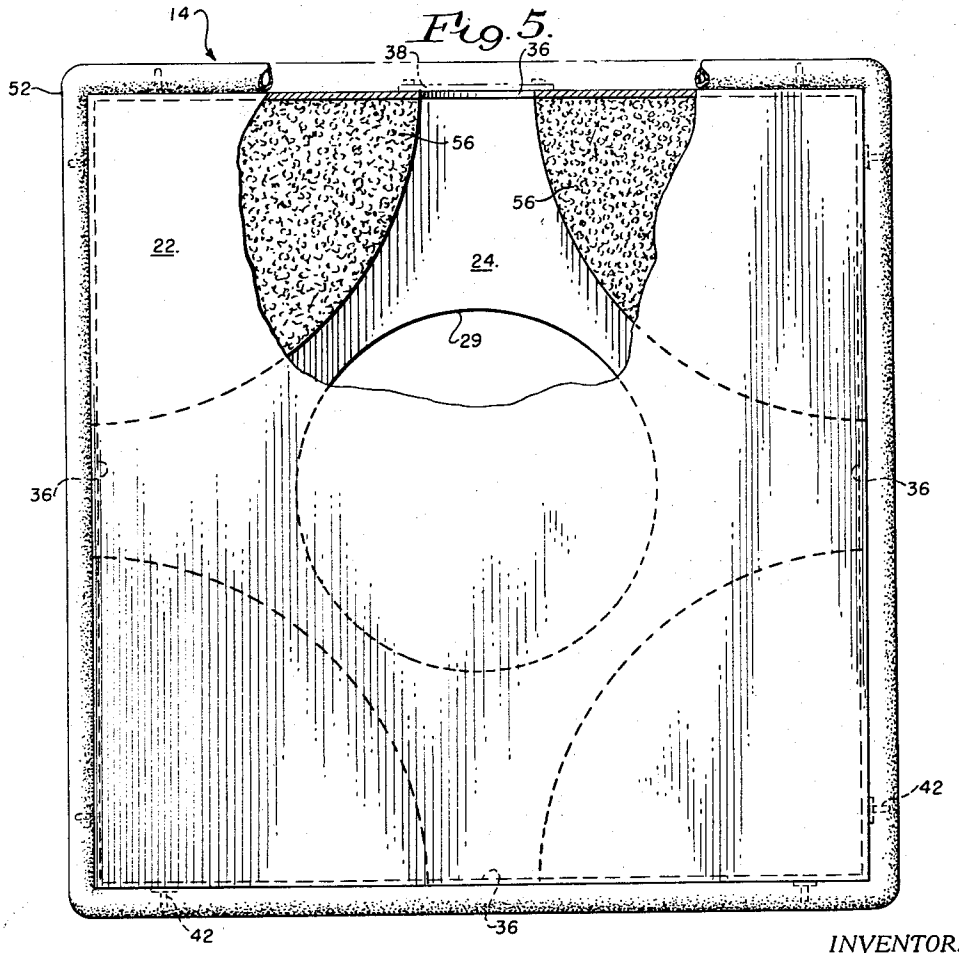


Fig. 5.



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Fig. 6.

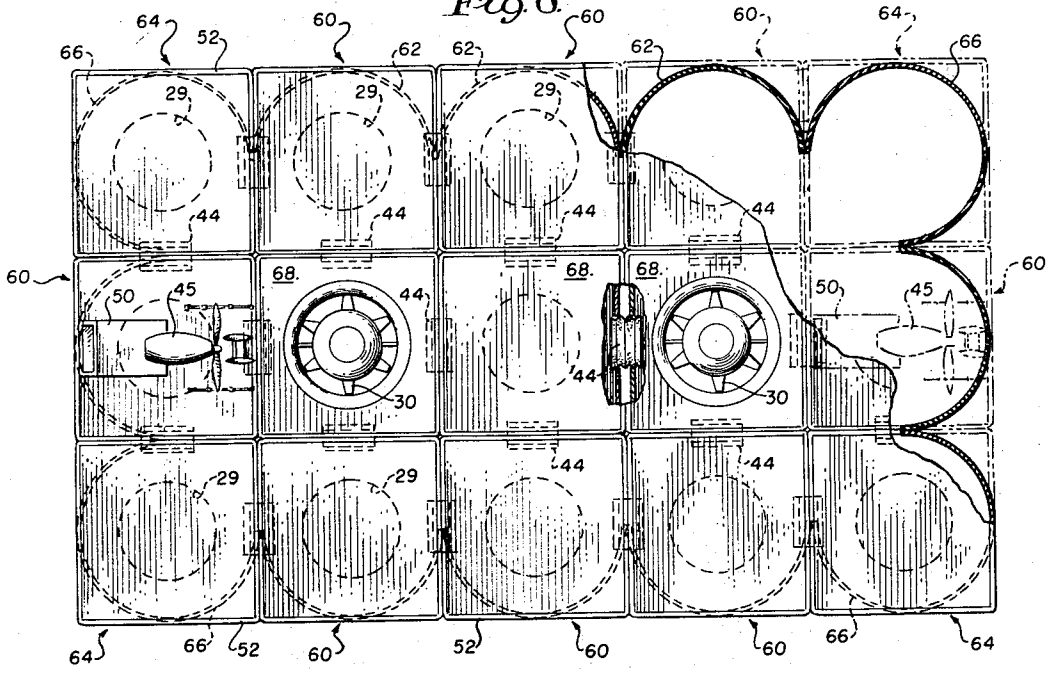
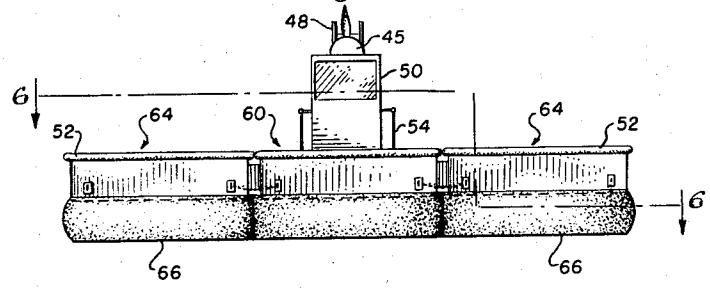


Fig. 7.



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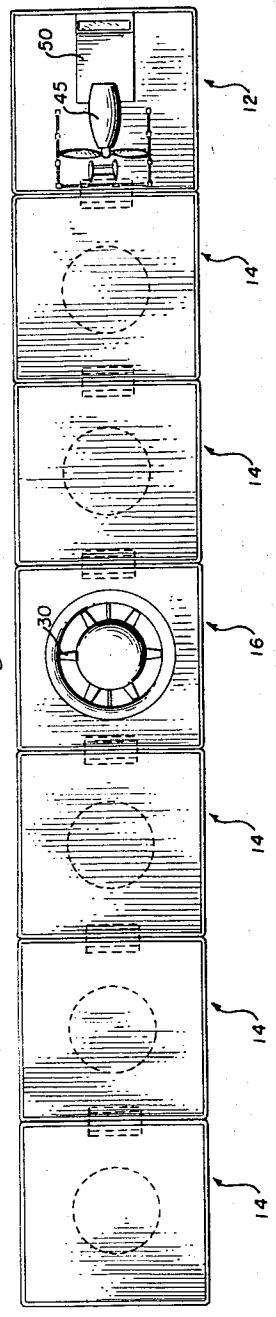


Fig. 8.

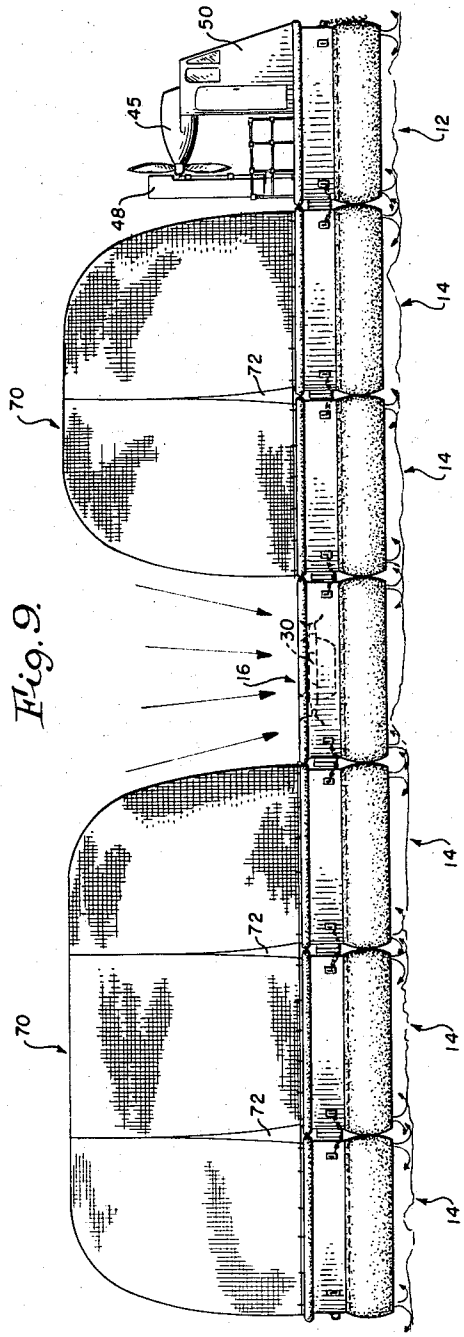


Fig. 9.

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ARTICULATED GROUND EFFECT MACHINE SYSTEM

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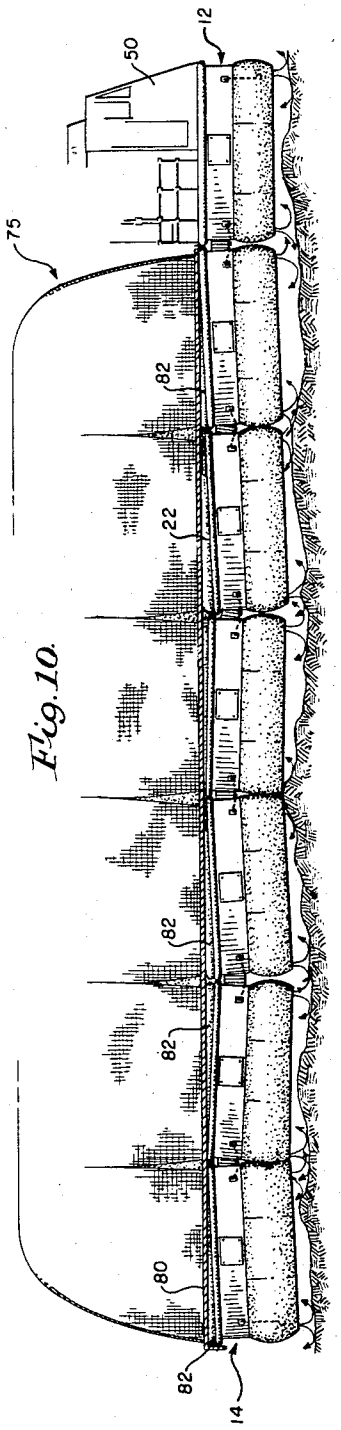


Fig. 10.

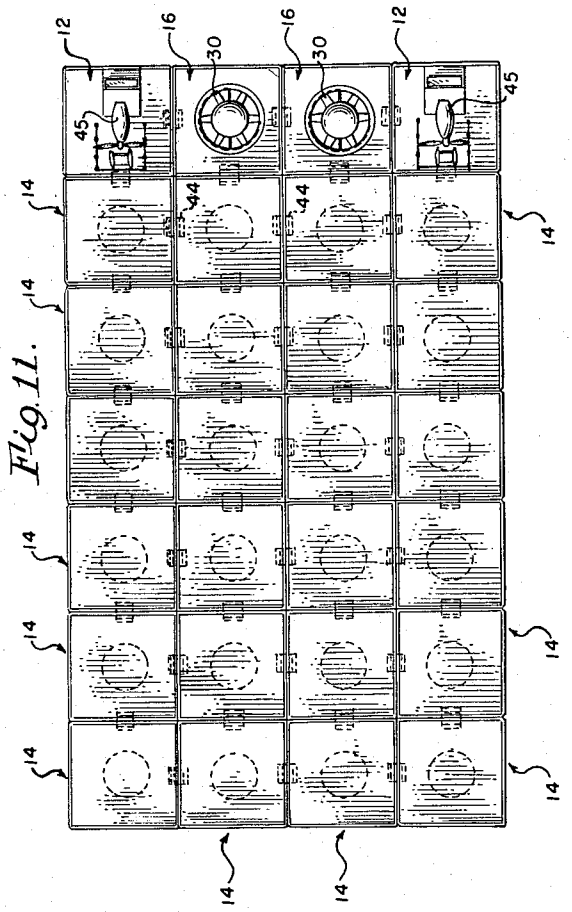


Fig. 11.

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United States Patent Office 3,401,767 Patented Sept. 17, 1968

3,401,767

ARTICULATED GROUND EFFECT MACHINE SYSTEM

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Filed Mar. 17, 1967, Ser. No. 623,867
11 Claims. (Cl. 180—121)

ABSTRACT OF THE DISCLOSURE

A plurality of different type ground effect machine modules are provided with means for interconnecting them in universally articulated relationship in any preferred plan view arrangement, to provide a novel ground effect machine system capable of carrying loads in improved manner over a variety of terrain conditions. The invention features improved overall efficiency of operation and improved versatility with respect to coping with a large variety of transport problems.

Brief summary and background of the invention

This invention relates generally to vehicles of the so-called "ground effect machine" type; and more particularly to a transport system employing, in any desired combination, selected from a large variety of available combinations, pluralities of functionally different vehicle modules. Such systems are particularly useful in conveying commercial or military freight, personnel, supplies, machinery, tools, or the like; over land and water, thin ice, snow, soft or marshy soil, or other terrain or surfaces such as may not for practical purposes be traversed satisfactorily by boats, sleds, wheeled vehicles, or the like.

The typical ground effect machine of the prior art comprises a rigidly integrated unit including a single platform having cushion-air enclosing skirts suspended therefrom and supporting its power plant and air cushion generating fan and propulsion and directional control means, while at the same time also providing a cargo accommodating space. Such machines have proven to be quite useful but in some respects have been found to be disadvantageous because of certain inherent attitude instability problems, as well as a lack of versatility of such machines to adapt to different load and/or terrain situations. The present invention is concerned with improved utilization of "ground effect machine" or "air cushion vehicle" techniques of load levitation and conveyance.

The primary object is to provide a ground effect machine system of improved inherent operational stability; which is particularly useful for example in transport or "ferrying" operations under varying terrain and/or load size-shape-weight conditions. For instance, the invention is particularly suited to the movement of well drilling or mining machinery; mineral ores; lumber; or military equipment or the like; over water, marsh, snow-covered or other wilderness type terrain. The invention is also particularly applicable to situations wherein the length and width dimensions of the loads to be ferried vary substantially.

Heretofore, with a view to saving the time and expense involved in building conventional roadways or the like to accommodate conventional vehicles, efforts have been directed toward the development of special vehicles supported by wheels, tracks, pontoons, skis or the like; with a view to spreading the load over a sufficient area of the surface traversed to attain adequate support. Obviously such devices are extremely limited as to the terrain they can negotiate under load, and such efforts can be effective only under certain limited terrain conditions; and as yet no such devices have been found that will satisfactorily meet

the problem in the base of other more severe and/or different terrain conditions.

Whereas ground effect machines are now of proven practicality, any given machine is of course limited as to the weight, size, shape and type of load it is adapted to transport. For example, a machine designed for carrying one load or type of load will not be dimensionally suited for carrying some other sized or type of load; and although it has been proposed to "gang" up a plurality of such machines when needed to transport a large load, it is obvious that a plurality of such machines would often be required just to provide a suitably sized load support platform, and that such a "gang" system would be inordinately expensive; both from the capital investment standpoint and the operational expense standpoint because the overall available lift and propulsion power of the "gang" system would far exceed the actual need.

It is a primary object of the present invention to provide a load transport system which is not subject to the above-mentioned disadvantages of the prior art.

More specifically, it is an object to provide a "ground effect" or "air cushion" support system for transporting in improved manner variously sized loads over all types of terrain or water.

It is another object to provide a system as aforesaid which, while being versatile in respect to the character and magnitude of the loads to be carried thereby, is also economical with respect to the power consumption and capital investment involved.

It is another object to provide a system as aforesaid which comprises a plurality of modules which may be variably interconnected to provide a functionally integrated load platform of variably extended longitudinal and/or lateral planform dimensions; and which automatically adjusts itself to uneven terrain when passing thereover and evenly distributes its loading over the terrain area which is covered by the system.

It is another object to provide a load transport system as aforesaid which is economically self-propelled.

Detailed description

Other objects and advantages of the invention will appear from the following specification and the accompanying drawing in which the invention is illustrated by way of example and in which:

FIG. 1 is a top perspective view, with portions broken away to show interior construction, of a transport system of the invention; comprising a functional combination of three different type modules constructed and assembled in accord with the present invention;

FIG. 2 is a side elevational view, on larger scale, of one type of module utilized in a transport system as shown in FIG. 1;

FIG. 3 is a parti-elevational and vertical sectional view of another type module utilized in a transport system as shown in FIG. 1;

FIG. 4 is a side elevational view of still another type module as utilized in the system of FIG. 1;

FIG. 5 is a top plan view, with portions broken away to show the interior of the module of FIG. 4;

FIG. 6 is a top plan view, with top cover portions broken away as indicated by line 6—6 of FIG. 7, of a transport system employing still different type modules;

FIG. 7 is a front end elevational view of the transport system of FIG. 6;

FIG. 8 illustrates in plan view still another type transport system employing modules of the types shown in FIGS. 1–5;

FIG. 9 is a side elevation view of the system of FIG. 8 and illustrating the application thereto of load protective covering devices;

FIG. 10 is a view corresponding to FIG. 9 but show-

ing the use of a rigid load support platform disposed intermediately of the "ground effect" modules of the system and the load to be transported, and illustrating the terrain-accommodating capabilities of the system while transporting a load in weather-protected manner while avoiding the imposition of shape-changing stresses on the load per se; and

FIG. 11 is a plan view of a transport system such as illustrated by FIG. 10.

As shown at FIG. 1, a transport system of the invention may by way of example be constructed by interconnecting in side-by-side juxtaposed relation any number of three basic type modules, comprising as shown at FIG. 1, a "propulsion" module **12**; a plurality of load "platform" modules **14**; and a "lift" module **16**. The modules **12**, **14**, **16** are illustrated separately at FIGS. 2, 4–5, and 3, respectively. Each of these three basic type modules will be described in detail hereinafter.

As shown in FIGS. 2–5, each of the modules of the system includes a basic structure comprising a rigid chassis or "hard" platform portion **20** which may be conveniently fabricated of sheet metal, wood, or the like into box-like form to include a top plate **22**; a bottom plate **24**; and side wall plates **26**. Each body portion **20** is subtended by a flexible peripherally disposed skirt **28**, and each bottom plate portion **24** is apertured as shown at **29** (FIGS. 1, 3, 5). Thus, it will be appreciated that each box-like structure **20** will comprise a plenum chamber into which air may be pumped for discharge through the aperture **29** into the confines of the flexible skirt portion **28** for generating a levitating air cushion effect thereunder, as will be explained more fully hereinafter.

As illustrated at FIG. 3, the modules **16** enclose within the "hard" structures **20** thereof a downwardly directed fan or compressor device as indicated generally at **30** driven by means of an engine as indicated at **32** to pump air downwardly as through an inlet cowl **34** and through the aperture **29** into the confines of the flexible skirt **28**. Thus, upon operation of the engine **32** the fan **30** will pump air into the plenum chamber interior of the module portion **20**. In addition to the aperture **29** through the bottom plate **24** of the plenum chamber structure, the four side wall portions **26** of the platform structure each includes an aperture **36** provided with a readily detachable cover plate **38**.

The basic modules **14** as illustrated at FIGS. 1, 4, 5 are identical in construction to the module **16** referred to hereinabove except that the top plate portion **22** of the basic modules **14** is continuous across the top surface of the module, and no fan-engine unit is provided therein. However, it will be appreciated that one or more modules of the type designated **14** may be arranged in side-by-side juxtaposed relation with a module of the type designated **16** (FIG. 3) and coupled thereto as by means of flexible chains or cables, or the like as indicated at **40**; the "hard" structures of the modules being provided with suitable eye-brackets **42** or the like to facilitate flexible interconnections of juxtaposed modules as illustrated by way of example at FIG. 1.

The side wall apertures **36** of all of the modules are positionally located so as to come into communicative registry with corresponding apertures of other modules when a plurality of such modules are brought together into nested relation such as illustrated at FIG. 1. Hence, it will be readily understood that when a transport system as shown for example by FIG. 1 is being assembled, the sidewall ports **36** of contiguous modules are readily interconnected by means of flexible hoses or conduits as indicated at **44** (FIG. 1). Hence, when a group of such modules, including one or more engine-fan containing modules **16**, are relatively assembled as shown for example at FIG. 1, the air pumped into the system by means of the fan or fans **30** will be distributed through the conduits **44** throughout the plenum chamber portions of the modules and thence downwardly into the confines of their

flexible skirt portions; whereby each module will be "air-cushion" energized to rise above the reaction surface therebelow, as illustrated diagrammatically for example at FIGS. 2, 3.

The modules of the type designated **12** are illustrated in better detail in FIG. 2 wherein it will be seen that each such module is identical in construction to the basic module **14** except that pilot accommodation and directional control and propulsion means are carried on the top deck plate **22** thereof. The propulsion mechanism as shown by way of example in the drawing herewith comprises an engine enclosed by a nacelle **45** driving a propeller **46** accompanied by a directional control rudder system **48**. The pilot accommodation cabin is illustrated at **50**. It is to be understood that whereas the engine-propeller unit **45–46** is of the pylon-supported and directionally pivotable type as shown for example in U.S. Patent No. 3,205,960, it may be of any other preferred type, such as for example a radial engine-driven propeller or a turbine or jet engine arrangement.

In any case, by virtue of the mechanical interconnections between the relatively assembled modules, operation of the propulsion engine **45** will drive the entire transport assembly in the desired direction as controlled by the pilot. Hence it will be appreciated that, as typified by the arrangement in FIG. 1, a transport unit of the invention may be readily fabricated by assembly into any preferred planform arrangement any required number of basic "load" modules of the type illustrated at FIG. 4, in combination with any preferred number of "lift-fan" modules as shown at FIG. 3, and any desired number of pilot-propulsion modules as illustrated at FIG. 2. The lift-fan and propulsion modules may be positioned at any preferred plan view location in the assembly, in order to attain the desired lift effect distribution and maneuvering control of the system.

As illustrated at **52**, the upper perimetral edge of each module "hard" structure is preferably margined by an elastic gasket device, such as an inflated rubber tube or the like; so that when the modules are operatively assembled as shown for example in FIG. 1 the gasket devices **52** cooperate to substantially air-seal the spaces between oppositely disposed "hard" wall portions of contiguous modules. Thus, air escaping from beneath the bottom edges of contiguously disposed skirt devices will be substantially trapped by means of the gasket devices **52**, thereby increasing the overall efficiency of the air cushion system.

It is to be understood that incidental to assembly of a transport mechanism as illustrated and hereinabove described, arrangements will be made whereby all of the lift fan and propulsion propeller drive engines and directional control systems of the assembly may be under control of a centrally located pilot, such as may be accommodated in one of the cabins **50**. Such controls may be arranged for either mechanically or electrically, or by means of radio control devices. Preferably, as shown at **54**, a protective railing will be mounted on the deck of each propulsion module **12** to protect personnel from propeller accidents. Also, note that as illustrattd at **56** (FIG. 5) the interior corner portions of the "hard" structures **20** may be filled with "flotation" material, such as any suitable foamed plastic or the like, to increase the buoyancy characteristics of the system.

FIGS. 6, 7, illustrate another form of transport system of the invention wherein the modules of the system are of somewhat different construction. In this case, "basic" modules as indicated at **60** are provided which are generally similar in construction to the modules **14** of FIGS. 1, 4, except that the "hard" structures thereof are subtended by only simicircular flexible skirts as indicated at **62**. Generally similar modules **64** are provided to occupy the four corner portions of a system assembly as shown in FIG. 6; the modules **64** being similar in construction except that they are subtended by three-

quarter circular skirts **66**. Other modules suitable for location centrally of the assembly as indicated at **68** (FIG. 6) are provided of similar construction except that they need no flexible skirt devices depending therefrom, inasmuch as the skirt devices of the modules **60**, **64** cooperate when relatively assembled as shown in FIG. 6 to provide, in effect, a continuous perimetral enclosure for the entire assembly. Pilot-controlled propulsion mechanisms and lift-fan-engine units will of course be carried by one or more of the modules as shown in FIGS. 6, 7, for purposes explained hereinabove.

FIGS. 8, 9, illustrate how a varied assortment of modules may be interconnected to provide a train-like system comprising a line of load modules **14** led by a control module **12** and having a lift module **16** disposed in the line. FIG. 9 illustrates the assembly of FIG. 8 in side view and also depicts how the cargo carrying modules of the system may be weather-protected as by means of air inflated shelters **70—70** which may, for example, be of the type disclosed in Birdair Structures, Inc., Patent 3,116,746. Note that as indicated at **72**, the inflatable envelope fabric is preferably pleated to provide extra fullness in the areas immediately above each zone of abutment between adjacent modules, whereby to permit one module to rock relative to the other (as when negotiating uneven terrain) to avoid subjecting the air-shelter fabric to undesirable stress concentrations.

FIGS. 10, 11, illustrate still another system arrangement such as may be readily assembled in accordance with the invention by appropriately interconnecting (in the desired planform) a suitable number of load modules **14** and an appropriate number of control modules **12** and lift modules **16**; it being understood of course that the plenum chamber portions of all of the modules will be interconnected by flexible conduits **44** as explained hereinabove. FIG. 10 provides further illustration of how a single air inflated shelter designated **75** may be arranged to cover all of the load carrying modules. Also, FIG. 10 illustrates how the flexible interconnections between adjacent modules permits them to rock, one relative to the other, as when traversing rough terrain.

Furthermore, FIG. 10 illustrates the provision of a substantially flat and rigid load carrying pallet designated **80**, which is carried upon and spans the tops of the modules **14** to provide a substantially rigid support such as for an elongate load object which requires to be shielded from flexing stresses. As indicated at **82**, flexible cushions, such as air inflated pillows or toroidal shaped cushions or the like are preferably disposed between the tops of the modules **14** and the bottom surface of the load pallet **80**; thereby providing uniform pressure support under all parts of the load pallet while avoiding any inteference with freedom of rocking of one module relative to another and to the load support pallet.

It will of course be understood that the compressed air supply required for maintaining the cargo covering structure **75** illustrated at FIG. 10, and the cushion air supply requirements for the assembly may be furnished by the same source. In fact, during operation of the assembly there may well be sufficient leakage of air from below the platforms upwardly through the junctions of adjacent modules and into the interior of the covering structure **75** to assist in this respect. In any case, the pressure of air within the envelope **75** will be automatically controlled by means of a pressure-responsive regulator, thereby insuring at all times adequate inflation of the covering structure **75** and avoidance of excessive pressurization thereof.

A conventional type single structure ground effect machine (of given planform dimensions) is inherently propense to rolling and pitching gyrations when encountering uneven terrain or sea conditions. However, in the case of the present invention, an assembly having the same overall planform dimensions as a conventional machine will be free from such characteristics. This is because of the novel cooperational effects of contiguously interconnected modules; producing a system wherein attitude shift tendencies of the modules are automatically damped by restraining forces imposed thereon through the interconnections between adjacent modules. Because the individual modules are much smaller (in planform) than the overall planform of the machine of the invention, they individually have much lower magnitudes of instability, and the individual modules are free to participate in terrain accommodating gyrations (see FIG. 10) while each imparting to the total machine only a small fractional resultant of the angular movements of the individual module. In fact, under typical operating conditions the angular motions of the individual modules will usually be cancelled out relative to each other, so that no cumulative perturbance effects on the total machine will result. Thus, the problem of instability such as met with in operation of the single unit type ground effect machine is avoided; and a vehicle assembly of the present invention will simply undulate over an irregular terrain or rough water or the like, while maintaining a generally level course and without requiring any pilot-attention to the pitch-roll attitudes of the machine.

What I claim as my invention is:

1. A ground effect machine system comprising, in combination, a plurality of individual modules including selected numbers of modules from at least three different types thereof assembled in side-by-side relation; each of said modules having rigid platform structures and a flexible cushion-air retaining skirt depending therefrom, said platform structures each having a deck portion and side wall portions, each side wall portion thereof having an air transfer port therethrough, an air exit opening through the bottom of each said platform structure, coupling means carried by each of said platform structures universally articulating pluralities of said modules in juxtaposed connected relations, and conduit means interconnecting the air transfer ports of adjacently disposed modules, the platform structure of at least one of said modules mounting system propulsion and maneuvering control means, the platform structure of at least one other of said modules mounting an air pump means and drive means therefor whereby upon operation of said air pump means a supply of air under pressure is delivered into the interiors of said modules through said conduit means to provide air-cushion effects under said modules, the platform structure of at least another one of said modules providing a load carrying surface.

2. A ground effect machine system as set forth in claim **1** wherein said modules are externally of like shapes and dimensions.

3. A ground effect machine system as set forth in claim **2** wherein said modules are of generally box-shaped form.

4. A ground effect machine system as set forth in claim **1** wherein said air pump means is submerged below the top level of the platform structure of said module.

5. A ground effect machine system as set forth in claim **1** wherein a plurality of said modules mounting propulsion and maneuvering control means are included in the system combination, and wherein the controls thereof are centralized.

6. A ground effect machine system as set forth in claim **1** wherein a plurality of said modules mounting air pump means are included in the system combination.

7. A ground effect machine system as set forth in claim **1** wherein an air inflated covering structure is disposed to enclose the load-carrying space provided by said module platform structures.

8. A ground effect machine system as set forth in claim **7** wherein the supply air for inflating said covering structure is furnished by leakage of air-cushion air from below and around said module skirts and upwardly between said modules.

9. A ground effect machine system as set forth in

claim **7** wherein air supply for inflating said covering structure is furnished by a source independent of said air pump means.

10. A ground effect machine system as set forth in claim **1** wherein gasket devices are provided perimetrally of said module platform structures to retard escape of air therebetween.

11. A ground effect machine system as set forth in claim **10** wherein said gasket devices are of elastic nature and function also as cushion bumpers for said module platform structures.

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