United States Patent

Markakis

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[54] **STABILIZED FLOATING STRUCTURE**

[72] Inventor: **Costas E. Markakis,** 12 Aravantinou St., Athens, Greece

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Related U.S. Application Data

[63] Continuation of Ser. No. 751,463, Aug. 9, 1968, abandoned.

[52] **U.S. Cl.** **14/27,** 114/125

[51] **Int. Cl.** **E01d 15/08**

[58] **Field of Search** 114/121, 122, 125; 14/27

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Primary Examiner—Jacob L. Nackenoff
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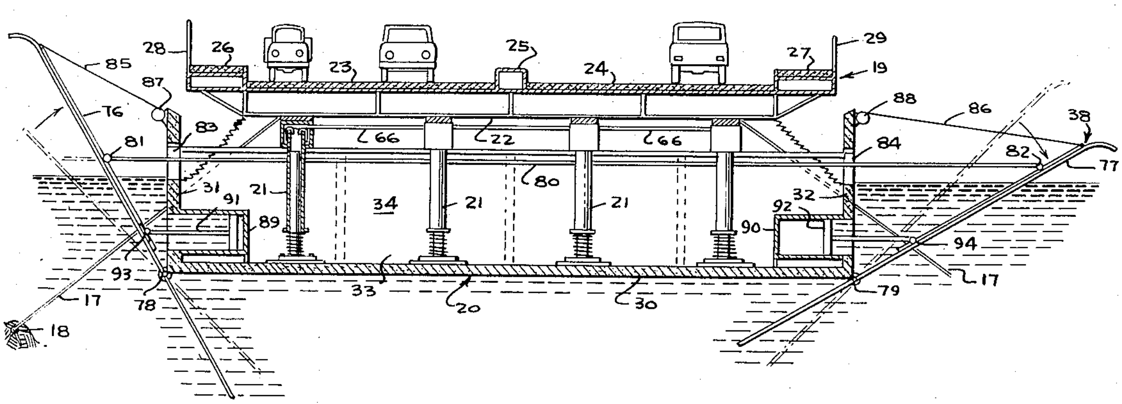
[57] **ABSTRACT**

A floating structure adapted to maintain a predetermined orientation including a floating body at least partially immersed in a fluid, means mounted in the body at selected loci for varying the buoyant forces acting on the selected loci, means responsive to displacements of the floating body relative to the predetermined orientation for actuating the means for varying the buoyant forces whereby the buoyant forces are varied at selected loci to produce counteracting forces tending to return the floating body to the predetermined orientation and the actuating means including means for sensing displacements of the floating body relative to the predetermined orientation.

28 Claims, 23 Drawing Figures



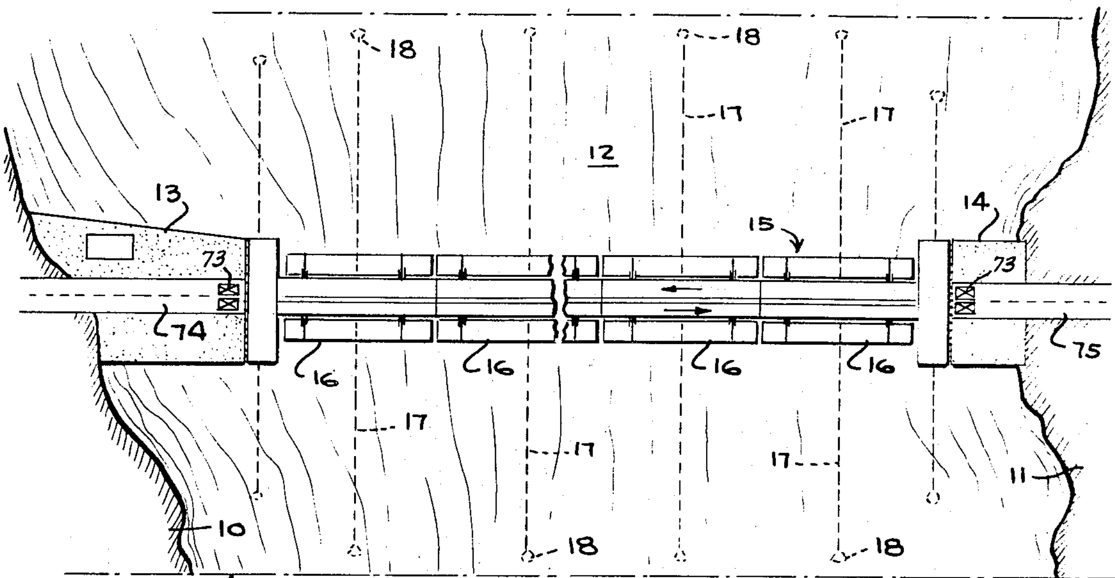


Fig-1

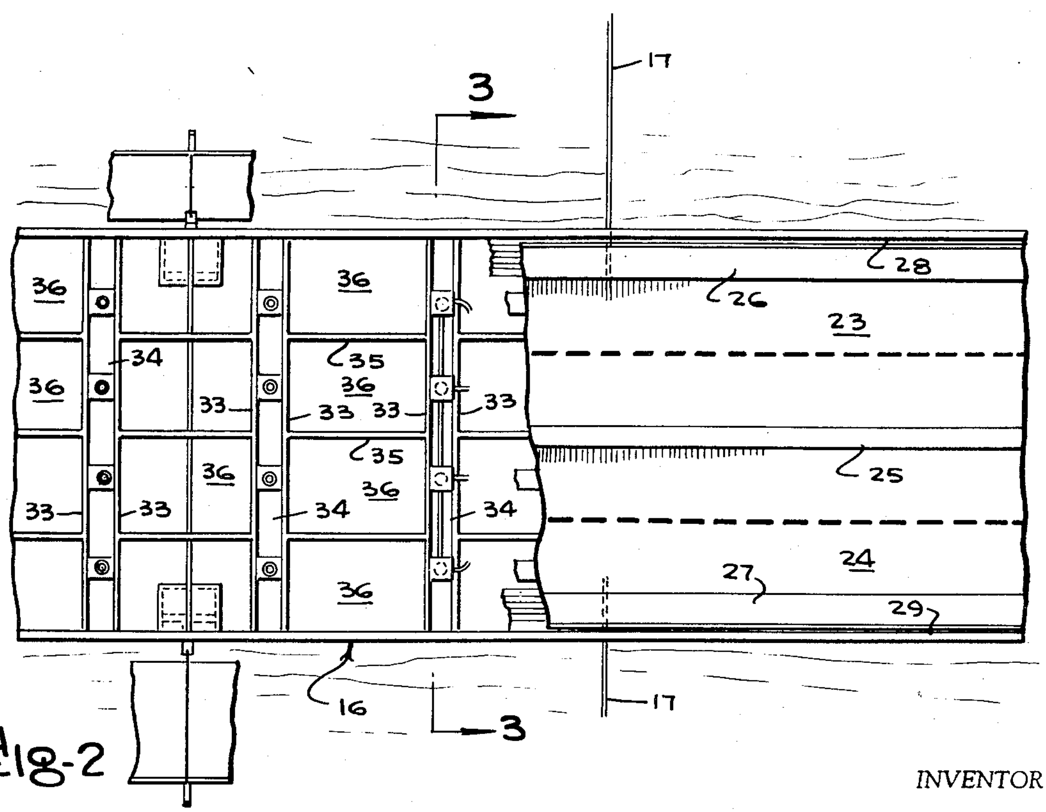


Fig-2

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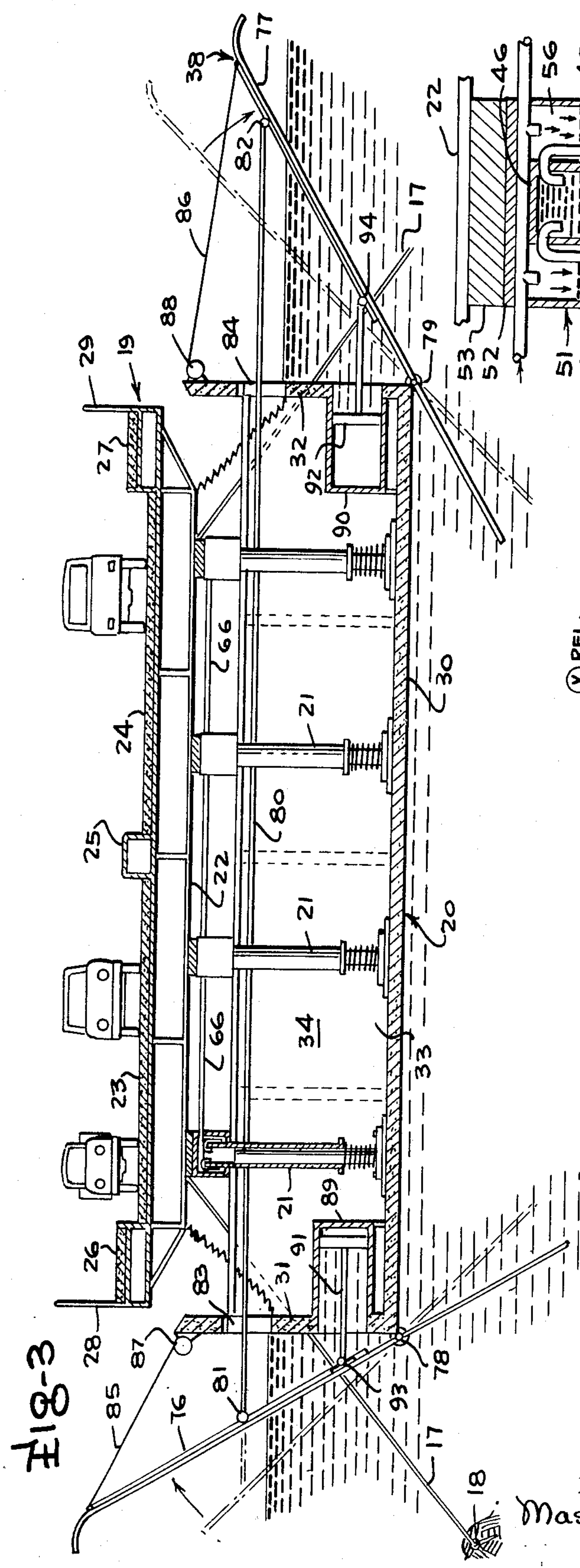

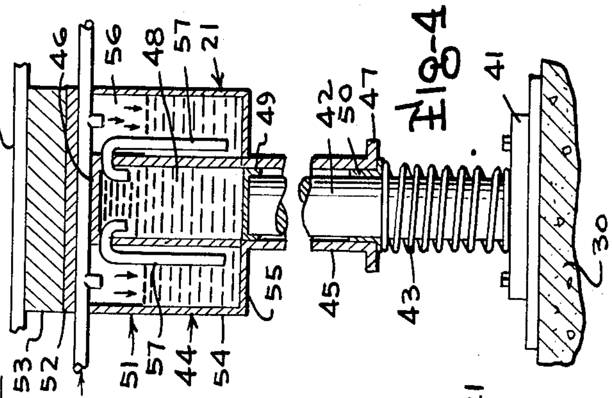

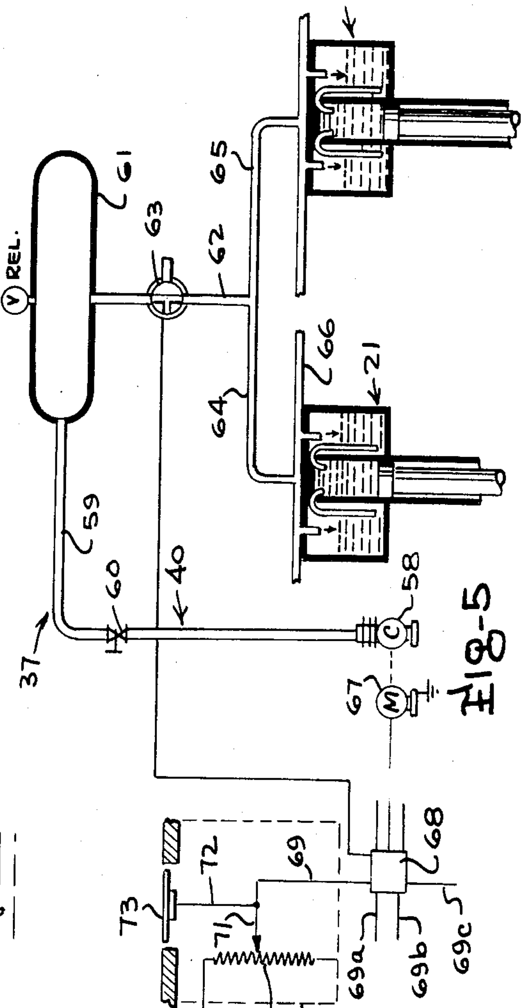

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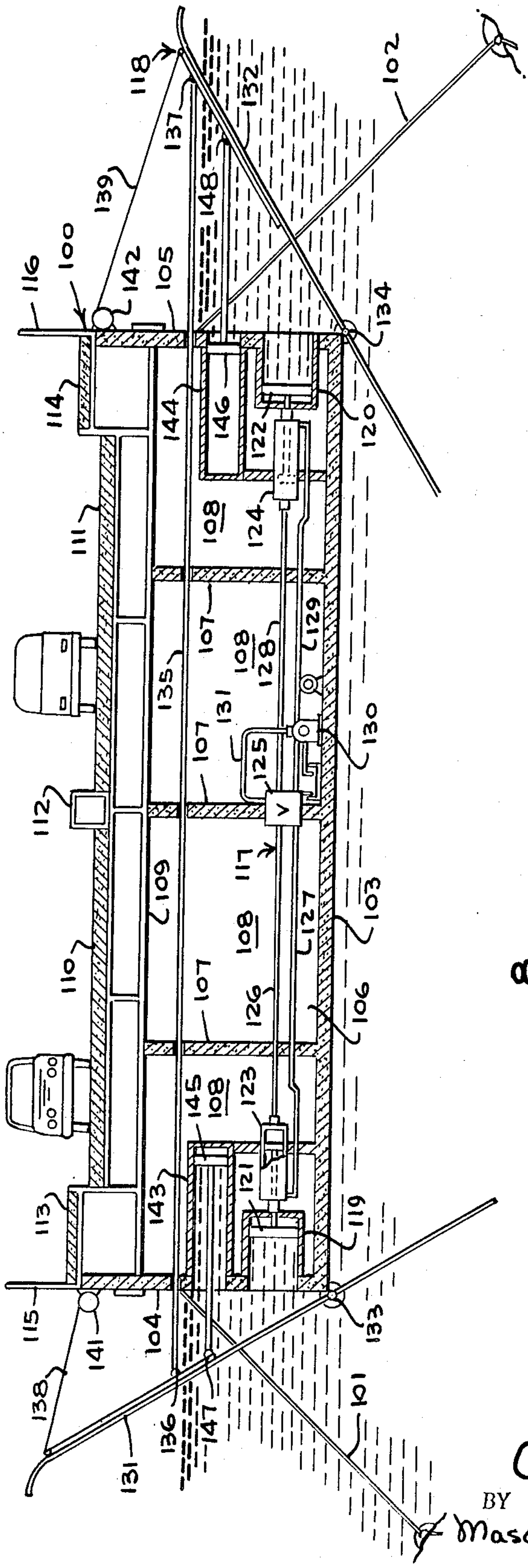

Fig-6

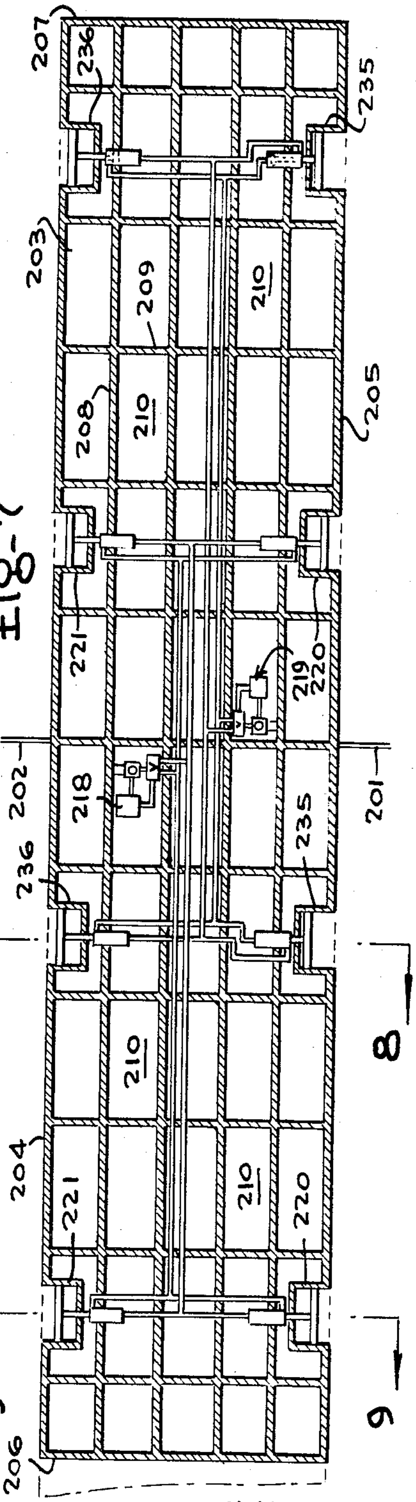

Fig-7

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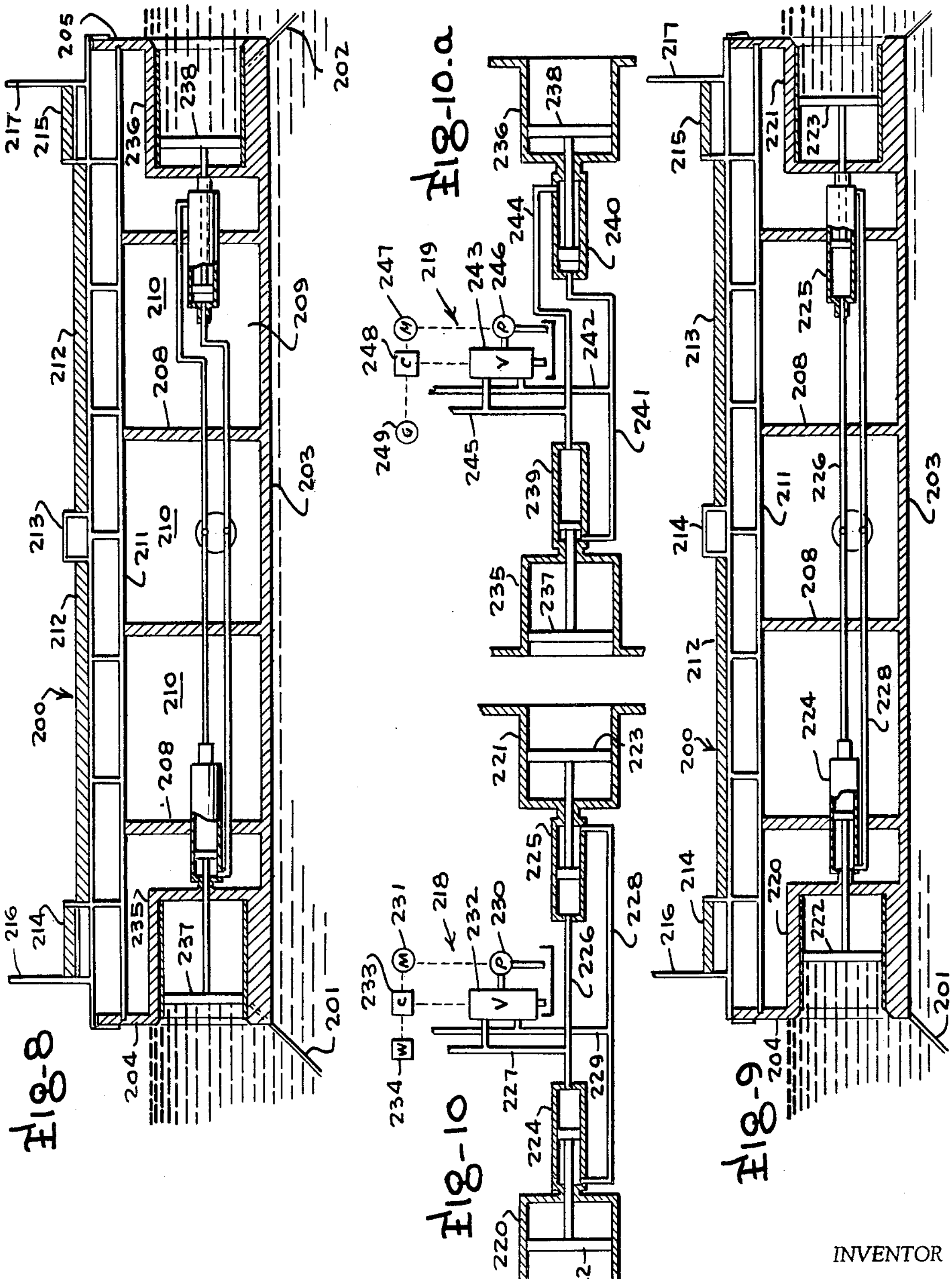

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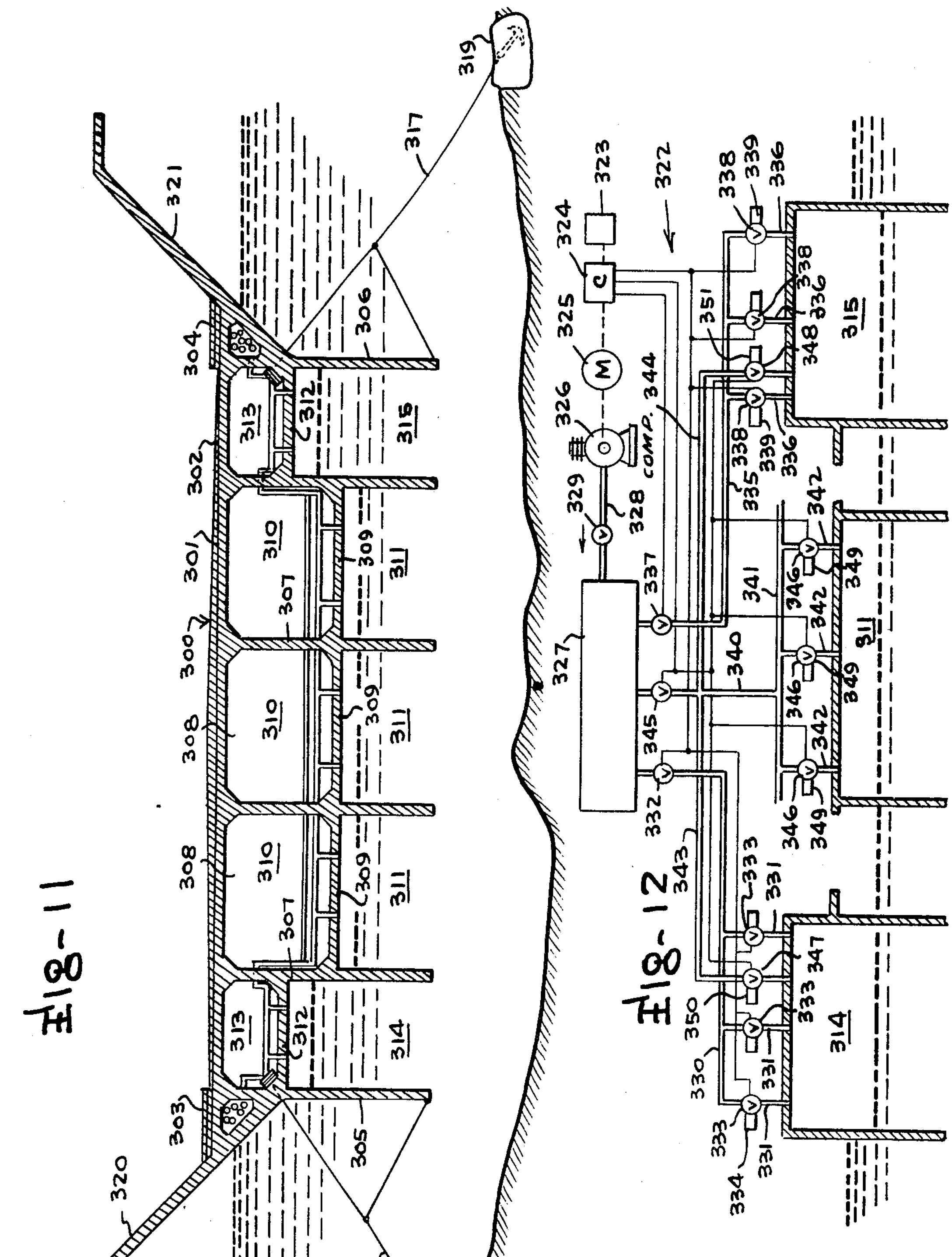

FIG-11

FIG-12

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Fig-13

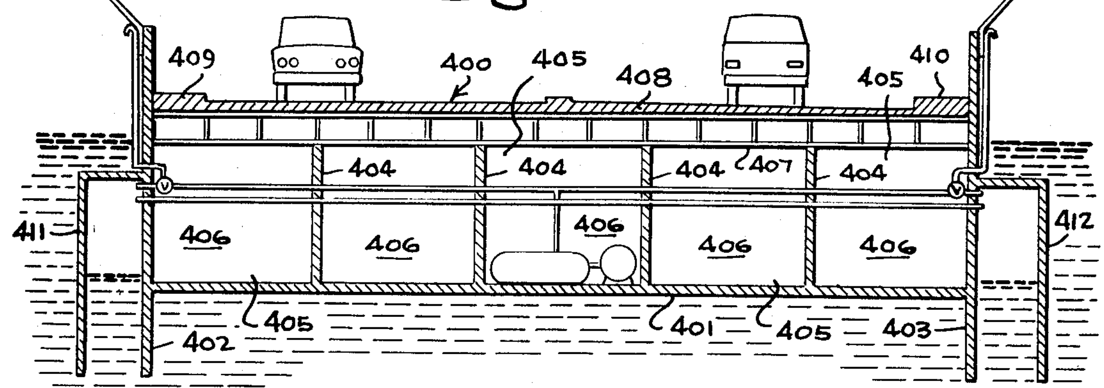
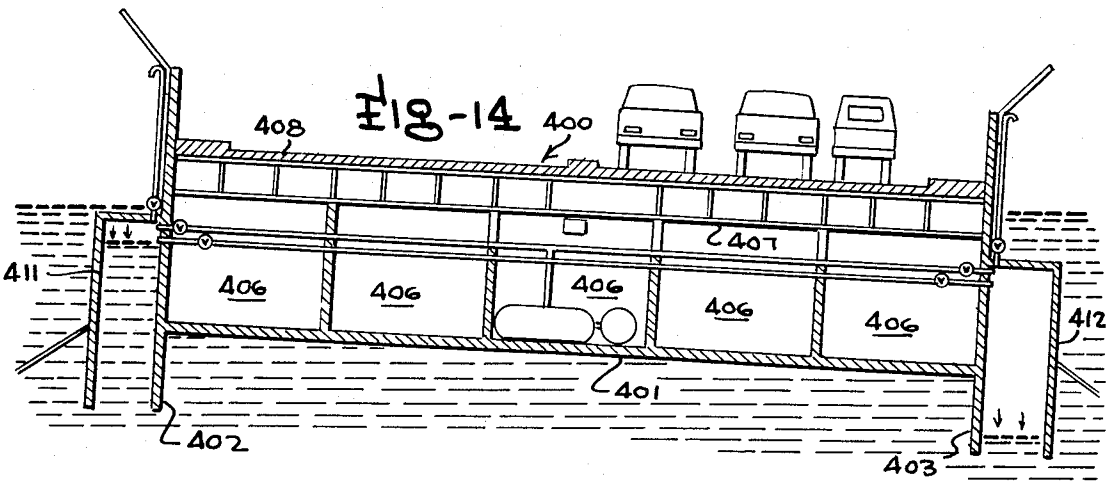


Fig-14



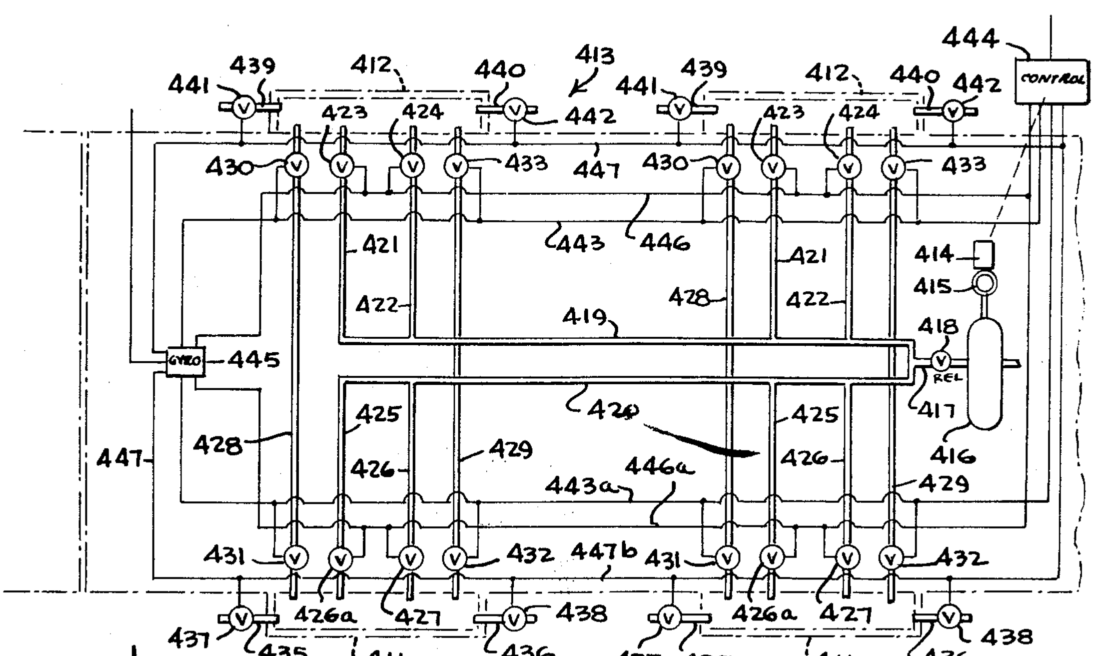


Fig-15

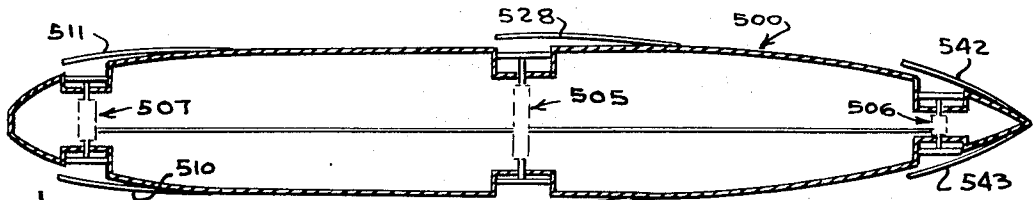


Fig-16

Fig-17

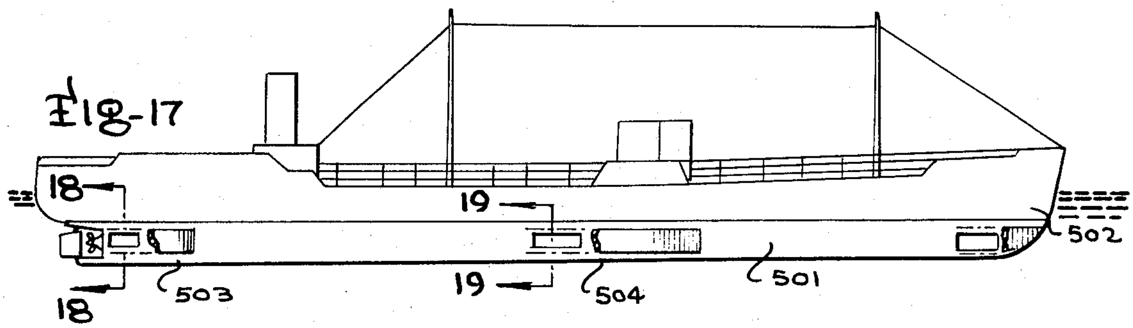


Fig-18

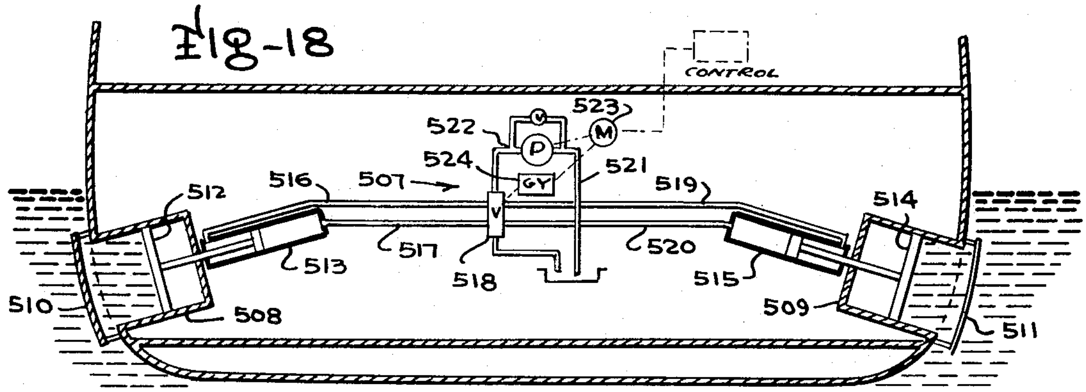
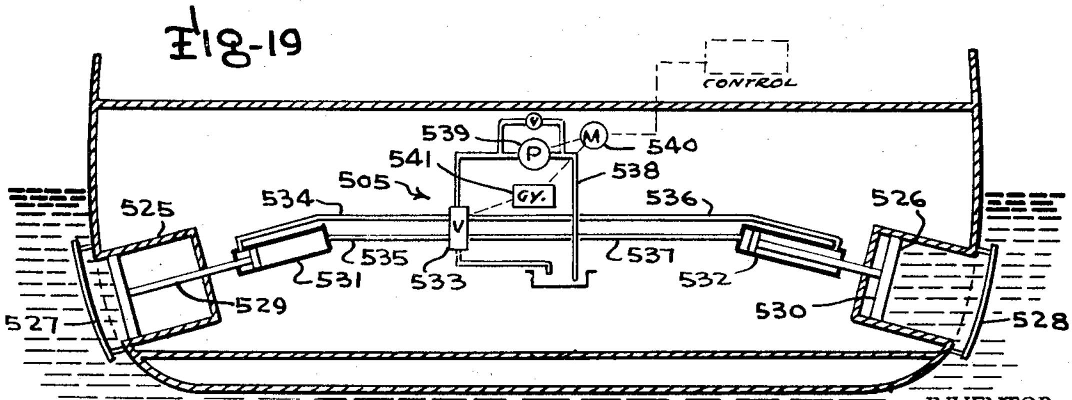


Fig-19



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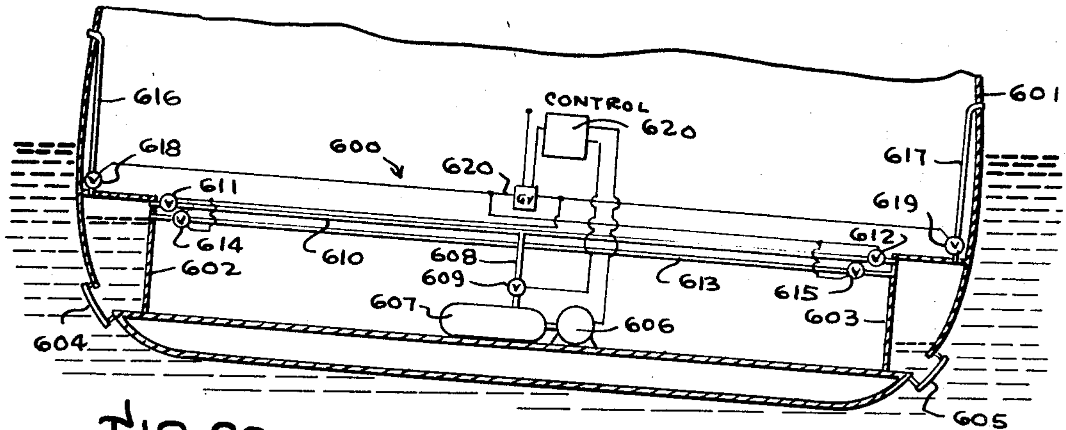
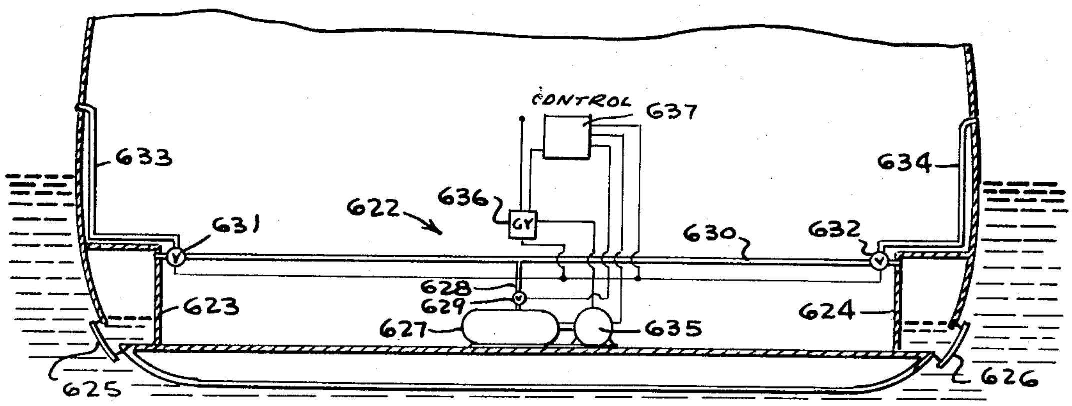


Fig-20

Fig-21



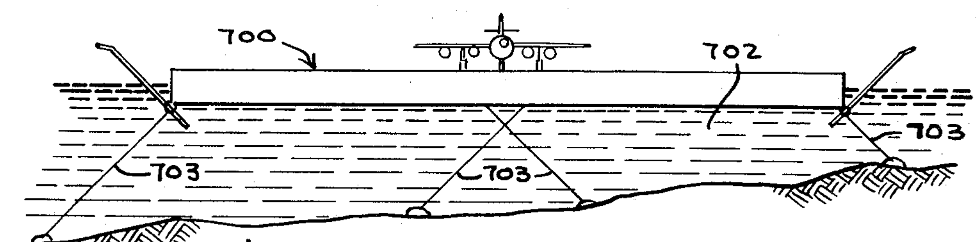


Fig-22

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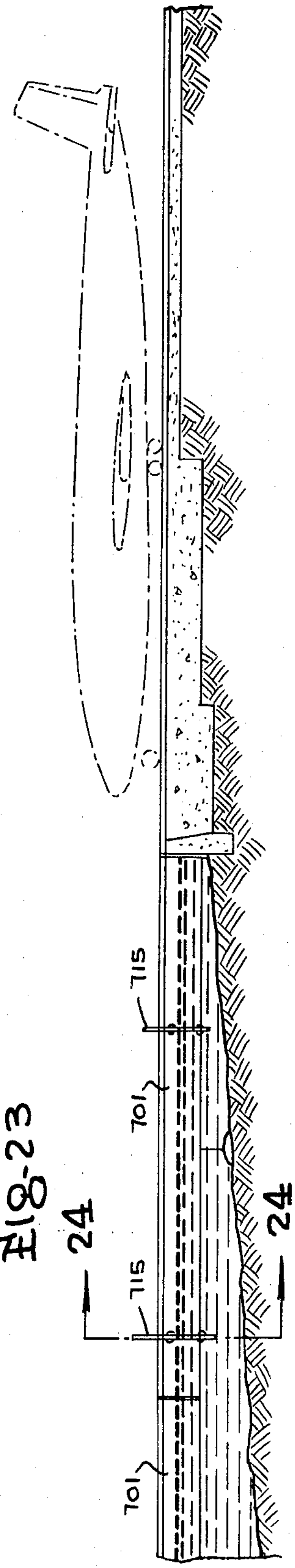

Fig-23

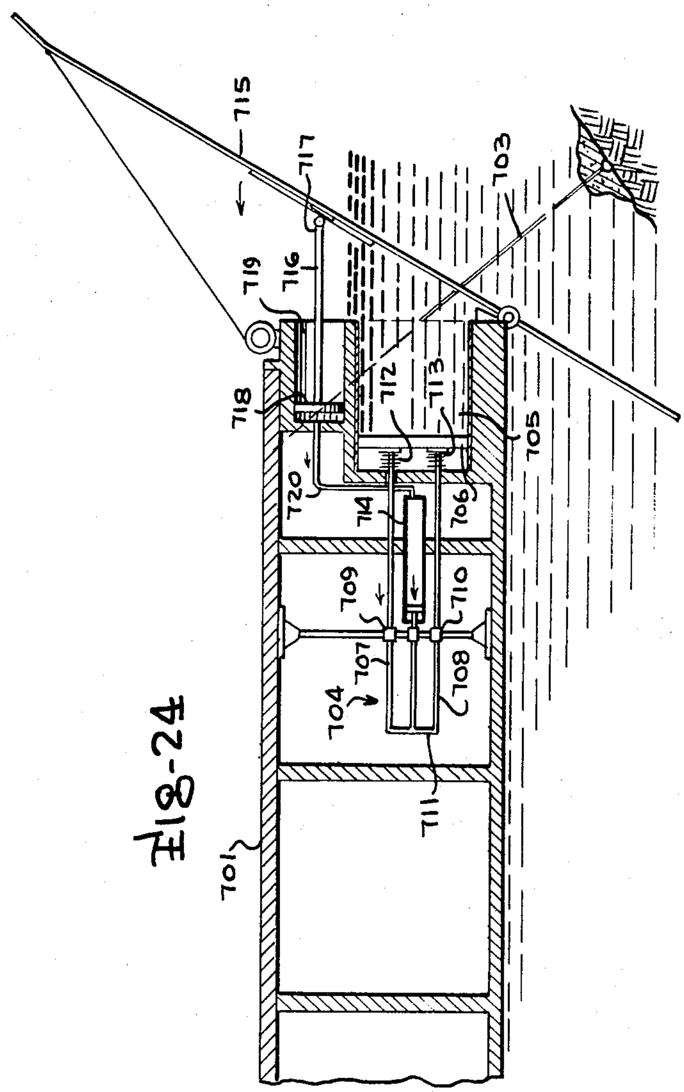

Fig-24

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STABILIZED FLOATING STRUCTURE

This application is a continuation of application Ser. No. 751,463 filed Aug. 9, 1968 and now abandoned.

This invention relates to an improved floating structure and more particularly to a novel floating structure which is adapted to be stabilized under adverse environmental conditions. The invention further contemplates novel floating bridges, vessels and aviation landing decks having stabilized characteristics.

In the use of conventional floating structures such as floating bridges and marine vessels, it has been found that the stability of such structures is affected considerably by the effects of environmental conditions. The stability of conventional floating bridges commonly is affected by the effects of traffic loads, tides and the upsetting forces of winds, waves and seismic disturbances. Similarly, the stability of conventional marine vessels commonly is affected by the effects of upsetting forces of winds and waves.

The instability of conventional floating structures has had the effect of retarding the development of various types of structures such as floating bridges and aviation landing decks. The few existing installations of floating bridges have been limited to geographic regions where the environmental conditions tending to produce upsetting or disturbing forces are minimal. It thus has been found to be desirable to provide a floating structure which is stable under any adverse environmental conditions.

Accordingly, the principal object of the present invention is to provide an improved floating structure.

Another object of the present invention is to provide a stabilized floating structure.

A further object of the present invention is to provide a novel floating structure which may be stabilized under adverse environmental conditions.

A still further object of the present invention is to provide an improved floating structure which will be stabilized when subjected to the upsetting or disturbing forces of winds and waves.

Another object of the present invention is to provide a novel floating structure which will remain stabilized when subjected to the upsetting or disturbing effects of variable traffic loads, tides and seismic phenomena.

A further object of the present invention is to provide a novel, stabilized floating bridge.

A still further object of the present invention is to provide a novel, stabilized floating vessel.

Another object of the present invention is to provide a novel, stabilized floating aviation landing deck.

A further object of the present invention is to provide a novel, stabilized floating structure which is comparatively simple in construction, relatively easy to construct and install and inexpensive to maintain.

Other objects and advantages of the present invention will become more apparent to those persons skilled in the art to which the present invention pertains, from the following description taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a top plan view of an embodiment of the invention;

FIG. 2 is an enlarged fragmentary view of the embodiment illustrated in FIG. 1, having a portion thereof broken away to expose the interior construction thereof;

FIG. 3 is an enlarged cross-sectional view taken along line 3–3 in FIG. 2;

FIG. 4 is an enlarged vertical cross-sectional view of an actuating unit utilized in the embodiment illustrated in FIGS. 1 through 3;

FIG. 5 is a schematic diagrammatic view of the control system and the actuating units utilized in the embodiment illustrated in FIGS. 1 through 3;

FIG. 6 is a vertical cross-sectional view of a second embodiment of the invention;

FIG. 7 is a horizontal cross-sectional view of a third embodiment of the invention;

FIG. 8 is an enlarged cross-sectional view taken along line 8—8 in FIG. 7;

FIG. 9 is an enlarged cross-sectional view taken along line 9—9 in FIG. 7;

FIGS. 10 and 10a are schematic diagrammatic views of the control systems and actuating units employed in the embodiment illustrated in FIGS. 7 through 9;

FIG. 11 is a vertical cross-sectional view of another embodiment of the invention;

FIG. 12 is a schematic diagrammatic view of the control system and actuating units of the embodiment illustrated in FIG. 11;

FIG. 13 is a vertical cross-sectional view of another embodiment of the invention;

FIG. 14 is a view similar to the view shown in FIG. 13, illustrating the embodiment subject to upsetting forces;

FIG. 15 is a schematic diagrammatic view of the control system and actuating units for the embodiment illustrated in FIGS. 13 and 14;

FIG. 16 is a horizontal cross-sectional view of a further embodiment of the invention;

FIG. 17 is a side elevational view of the embodiment illustrated in FIG. 16;

FIG. 18 is an enlarged cross-sectional view taken along line 18—18 in FIG. 17;

FIG. 19 is an enlarged cross-sectional view taken along line 19—19 in FIG. 17;

FIG. 20 is a partial vertical cross-sectional view of a modification of the embodiment illustrated in FIGS. 16 through 19;

FIG. 21 is another partial, vertical cross-sectional view of the modification illustrated in FIG. 20;

FIG. 22 is a front elevational view of still another embodiment of the invention;

FIG. 23 is a side elevational view of the embodiment illustrated in FIG 22, having a portion thereof broken away; and

FIG. 24 is an enlarged cross-sectional view taken along line 24—24 in FIG. 23.

Briefly described, the present invention relates to a floating structure adapted to maintain a predetermined orientation generally comprising a floating body at least partially immersed in a fluid, means mounted in the body at selected loci for varying the buoyant forces acting on the selected loci, means responsive to displacements of the floating body relative to the predetermined orientation for actuating the means for varying the buoyant forces whereby the buoyant forces are varied at selected loci to produce counteracting forces tending to return the floating body to the predetermined orientation and the actuating means including means for sensing displacements of the floating body relative to the predetermined orientation. More specifically, the means mounted at selected loci for varying the buoyant forces acting on the floating body comprise immersed variable volume chambers communicating with the fluid in which the body is immersed, and the sensing means includes means for detecting external forces applied to the floating body tending to disturb the predetermined orientation of the body.

Referring to FIGS. 1 through 5 of the drawings, there is illustrated a first embodiment of the invention. FIG. 1 specifically illustrates a pair of land bodies **10** and **11**, a body of water **12** between the land bodies, a pair of aligned pier structures **13** and **14** connected to the land bodies and a floating bridge structure **15** interconnecting the two pier structure. The bridge structure **15** consists of a plurality of aligned floating bridge spans **16** which are secured together in end to end relation and which also are anchored by a plurality of transversely extending lines **17** moored to the bottom of the body of water, as shown at **18**. The lines **17** function to prevent transverse movements of the bridge structure when lateral forces are applied, and permit vertical movement of the spans while limiting their upper displacement.

As best illustrated in FIG. 3, each component span consists of an upper platform section **19** whose position or orientation is sought to be stabilized when subjected to external disturbing forces, and a lower stabilizing section **20** which is at least partly immersed in the body of water **12**. The sections **19** and **20** are movable relative to each other and are interconnected by a plurality of transversely and longitudinally spaced actuating units **21**. The upper platform section **19** includes a frame structure **22** seated on the upper ends of the actuating units **21**, a pair of roadways **23** and **24** disposed on the frame structure **22** and separated by a divider wall **25**, a pair of pedestrian walkways **26** and **27** extending longitudinally along the outer sides of the roadways **23** and **24**, and a pair of guard rails **28** and **29** extending along the outer sides of the walkways **26** and **27**.

The lower immersed section **20** includes a bottom wall **30** on which the actuating units **21** are mounted, a pair of side walls **31** and **32** and a pair of end walls (not shown), defining a partially immersible, floating section having an open upper end. As best illustrated in FIG. 2, the lower immersed section **20** is provided with a plurality of transversely extending partition walls **33** forming transversely disposed compartments **34** in which the actuating units **21** are mounted. The lower section **20** further is provided with a plurality of longitudinally extending, transversely spaced walls **35** interconnecting spaced transverse walls **33**, defining a plurality of compartments **36**. The plurality of longitudinal and transverse partition walls **33** and **35** define a compartmental immersed section **20** which affords structural water tight integrity to each bridge span.

In the embodiment illustrated in FIGS. 1 through 5, it is intended to maintain the upper platform section **22** in a predetermined orientation, i.e., in a horizontal position at a predetermined level when the bridge structure and its component spans are subjected to exterior forces such as traffic load, and the effects of tides, waves and winds applied at various points. This is accomplished by sensing the disturbing forces and adjusting the buoyant forces acting on the partially immersed lower section **20** of each span **16**. Vertical loads resulting from traffic traversing the bridge structure tending to cause the upper platform section **22** to lower, are sensed and counteracted by a plurality of control systems **37** as illustrated in FIG. 5, which includes the actuating units **21**. External forces such as those caused by winds and waves, tending to cause upsetting moments, are sensed and counteracted by a plurality of compensating units **38**.

Each control system **37** includes a sensing unit **39** and a pneumatic system **40** connected to a plurality of actuating units **21**. As best illustrated in FIG. 4, each actuating unit **21** consists of a base plate member **41** bolted to the bottom wall **30** of a partially immersed lower section **20**, an upstanding piston member **42** rigidly mounted at its lower end on the base plate member **41**, a compression spring **43** mounted around the piston member **42** and seated on the base plate member **41**, and a fluid housing **44** which is adapted to receive the upper end of the piston member **42** in sliding relation therewith, and be seated on the upper end of the compression spring **43**.

The housing member **44** includes a cylindrical section **45** having the upper end closed with a wall **46** and the lower end open for receiving the upper end of the piston member **42**. The lower end of the cylindrical section **45** is provided with an annular flange **47** which is seated on the upper end of the compression spring **43** to support the entire housing member **44**. The upper end of the cylindrical housing section **45** provides a fluid chamber **48** which is sealed from the exterior of the unit by means of a pair of seals **49** and **50** disposed between the piston member **42** and the lower end of the cylindrical housing section **45**. It will be appreciated that the cylindrical housing section **45** will slide vertically relative to the piston member **42**, depending upon the fluid pressure in the chamber **48**, typical of conventional hydraulic cylinder assemblies.

The housing member **44** further includes an upper rectangular shaped housing section **51** which is rigidly mounted on the upper end of the cylindrical housing section **45**. The housing section **51** includes an upper wall member **52** on which there is provided a mounting plate **53** for seating the frame structure **22** of the upper platform section **19**, side walls **54** and a bottom wall **55** defining a fluid chamber **56** disposed about the upper end of the cylindrical housing section **45**. Intercommunicating the fluid chambers **48** and **56** are conduits **57**.

The pneumatic system **40** comprises a compressed air system which is adapted to supply air under pressure to the fluid chambers **56** of the actuating units **21**. The system includes a compressor **58**, a compressed air supply line **59** having a cut-off valve **60**, a compressed air tank **61**, an air supply line **62** having a two-way valve **63** and connecting to branch lines **64** and **65**, and a manifold line **66** having outlets communicating with the upper portions of the fluid chambers **56** in the actuating units **21**. It will be appreciated that when the two-way valve **63** is in the position of as illustrated in FIG. 5, and the compressor **58** is operating, air under pressure will be supplied to the fluid chambers **56** of the actuating units **21**, forcing the liquid in such chambers through the conduits **57** into the fluid chambers **48**, thus displacing the housing members **44** and, correspondingly, the upper platform section **22** of the component span, relative to the piston members **42** and, correspondingly, the partially immersed lower section 20 of the component span. It further will be appreciated that the valve 63 can be operated to vent the upper portions of the housing sections 51 to the atmosphere, thus permitting the liquid from the fluid chambers 48 to flow back through the conduits 57 into the fluid chambers 56, causing the housing members 44 and, correspondingly, the upper platform section 19, and the piston members 42 and, correspondingly, the lower section 20 to move toward each other.

The compressor 58 is driven by a motor 67 which is operated by a computer device 68. The selector valve 63 also is operated by the computer device responsive to input signals from the sensing units 39.

Each sensing unit 39 includes an electrical input circuit 69 connected to the computer 68 which is provided with a variable rheostat 70. The rheostat 70 has a movable contact 71 actuated by a link 72 rigidly secured to a weighing platform 73. As best illustrated in FIG. 1, a plurality of weighing platforms 73 are employed on the roadways 74 and 75 on the pier structures 13 and 14. A pair of weighing platforms 73 is mounted on each pier structure adjacent the floating bridge structure, one in each lane of the roadway. Computer device 68 is adapted to receive signals from input circuits 69, 69*b* and 69*c* of sensing units 39 including the weighing platforms 73, compute corrective signal outputs and transmit corrective signals to one or more motors 67 and selector valves 63 to operate the fluid systems controlling the actuator units in the component spans.

The unit 38, adapted to sense exterior disturbing forces of wind and waves, includes detecting vanes 76 and 77 disposed on opposite sides of the component span and pivotally connected to the lower ends of the side walls 31 and 32 of the lower section 20 as at 78 and 79. The vanes 76 and 77 have large plane surface areas extending above and below the water line which are adapted to be engaged by winds and waves normally applying upsetting forces to the component span. The vanes are adapted to pivot in a vertical plane and are interconnected by a rigid linking member 80 which is pivotally and slidably connected at its outer ends to the vanes as at 81 and 82. The interconnecting member 80 extends through suitable openings 83 and 84 in side walls 31 and 32 in the lower section 20, which are disposed above the water line. The upper ends of the vanes are connected to the upper ends of side walls 31 and 32 by cables 85 and 86 which are operatively connected to take-up reels 87 and 88.

Mounted within the lower section 20 on the side walls 31 and 32 substantially below the water line, are aligned cylinders 89 and 90 which communicate with the body of water. Disposed in the cylinders 89 and 90 are piston members 91 and 92 which are provided with rods pivotally and slidably connected at their outer ends to the vanes 76 and 77 as at 93 and 94. It will be noted that whenever a lateral force is applied to the component span, such force will be detected by a vane 76 or 77 and will cause the vane to move toward the component span and simultaneously to cause the other vane to move away from the component span. As the vanes pivot in such manner, the pistons 91 and 92 also will move, thus varying the displaced volumes of water on opposite sides of the component span. The variations in the displaced volumes of water will vary the buoyant forces acting on opposite sides of the component span, thus producing counteracting forces tending to oppose the upsetting moment caused by the later forces applied to the span.

In the operation of the embodiment illustrated in FIGS. 1 through 5, for stabilizing the position of the upper platform section 19 horizontally and at a predetermined level, the buoyant forces acting on the lower section 20 are varied selectively to counteract the disturbing effects caused by the varying vertical load placed on the upper platform section 19 by the vehicles traversing the bridge structure, and the lateral loads applied to the component spans by waves and wind. It will be appreciated that the upper movement of the platform section 19 is limited by the anchor lines 17 which are secured at their upper ends to the platform section. Vertical loads tending to alter the vertical position of the upper platform section 19 are counteracted by the system illustrated in FIG. 5. Asymmetrical loads applied to the component span are counteracted by the system 38 including the sensing vanes 76 and 77.

It will be appreciated that as vehicles enter upon and are removed from the floating bridge structure, the vertical loads applied to the component spans of the bridge will vary. These variations are sensed by the weighing platforms 73 located on the roadways on the pier structures 13 and 14 as the vehicles enter and exit the bridge structure. As previously mentioned, the vertical movements of the weighing platforms 73 are sensed by electrical sensing units 39 which transmit signals to computer 68. The computer is adapted to compute a correction for the displacement caused by the vertical load and transmit signals to motors 67 and valves 63 of the component spans to vary the supply of air to the actuating units 21. The variations of air supplied to the actuating units will vary the displacement between the upper platform section 19 and the lower section 20 of each component span. The variation in the displaced volume of water by the lower section 20 of each component span will alter the buoyant forces acting on the lower sections 20 of the component spans, thus counteracting the variations in vertical load applied to the bridge structure by traversing vehicles.

The detecting vanes 76 and 77 normally are in the positions illustrated by the phantom lines illustrated in FIG. 3. Assuming the component span illustrated in FIG. 3 is subjected to winds or waves from the port side, such forces would tend to cause the span to list to starboard. To counteract this lateral force applied to the span, the lateral component of force is detected by the vane 76 which is caused to pivot about its pivotal connection with the lower section 20 to the position as shown by solid lines in FIG. 3. Upon such pivotal movement, the vane 77 is caused to move from its position shown in phantom lines to the position shown in solid lines in FIG. 3. Simultaneous with the pivotal movements of the vanes 76 and 77, the pistons 91 and 92 will be caused to move to starboard to decrease the volume of displaced water in the cylindrical chamber 89 and correspondingly increase the volume of displaced water in the cylindrical chamber 90. This action will have the effect of decreasing the buoyant force acting on the port side of the span and increasing the buoyant forces acting on the starboard side of the span. The cumulative effect of the decrease and increase of the buoyant forces acting on opposite sides of the span, will be to create a righting force opposing the lateral forces of the wind or waves applied to the span, tending to return the span to its predetermined level orientation.

FIG. **6** illustrates a vertical cross-sectional view of a component span **100** comprising a second embodiment of the invention. The component span **100** is similar to the span described in connection with the first embodiment. The span **100** differs from the span **16** of the first embodiment, in that it comprises an integral structure and utilizes alternate means for counteracting the variations in vertical load applied to the span. As illustrated in FIG. **6**, the span **100** is adapted to be partially immersed in a body of water and is anchored by means of suitable anchor lines **101** and **102**. The span consists of a bottom wall **103**, a pair of side walls **104** and **105**, end walls (not shown), a plurality of transversely disposed partition walls **106**, and a plurality of longitudinally disposed partition walls **107**, providing a plurality of water tight compartments **108**. Rigidly supported on the upper ends of the partition walls and the side walls **104** and **105** is a frame structure **109** supporting a pair of roadways **110** and **111** separated by a divider **112**, and a pair of walkways **113** and **114** provided with guard rails **115** and **116**.

Variations in vertically applied loads are counteracted by a system **117**, while component lateral forces caused by winds or waves applied to the side walls of the span, tending to cause upsetting moments about the longitudinal axis of the span, are counteracted by a system **118**. The actuating system **117** includes a plurality of chambers **119** and **120** disposed within the span **100** below the water line on the side walls **104** and **105**. The chambers **119** and **120** communicate with the body of water and are provided with pistons **121** and **122** which are movable within the chambers **119** and **120** to vary the displaced volumes of water in the chambers and, correspondingly, the buoyant forces acting on the span at the locations of the chambers.

The piston members **121** and **122** are actuated by hydraulic cylinder assemblies **123** and **124** which are connected to a distributor valve **125** by fluid supply lines **126** through **129**. The valve **125** is supplied with a working fluid under pressure by means of a pump **130** and a fluid supply line **131**. It will be appreciated that the valve **125** will distribute fluid under pressure to the hydraulic cylinder assemblies **123** and **125** to move the pistons **121** and **122** in the chambers **119** and **120** to vary the displaced volume of water in the chambers. The valve **125** is operated by a computer (not shown) which is adapted to receive signals from a vertical load detecting device such as described in connection with the first embodiment, compute counteracting forces sufficient to alter the buoyant forces acting on the span, thus varying the vertical displacement of the span, and transmit a signal to the control means for the valve **125** to supply predetermined amounts of working fluid under pressure to the hydraulic cylinders **123** and **124**. It will be seen that whenever a vertical load is applied to the bridge structure, causing the spans to displace downwardly, the control system will operate the valve **125** to supply fluid under pressure through supply lines **126** and **128**, moving the pistons **119** and **120** outwardly. The increase in the displaced volume of water in the chambers **119** and **120** will increase the buoyant forces acting at such points, thus causing the entire span to move upwardly to its predetermined position.

Similar to the system described in connection with the embodiment illustrated in FIGS. **1** through **5**, the system **118** includes a pair of detecting vanes **131** and **132** mounted on opposite sides of the span. The vanes are pivotally connected to the lower ends of the side walls **104** and **105** as at **133** and **134**, and are disposed both below and above the water line so as to enable them to detect lateral forces applied to the span by waves or winds. The upper ends of the vanes are interconnected by a rigid linking member **135** which extends through aligned openings in side walls **104** and **105** and is pivotally and slidably connected to the vanes as at **136** and **137**. The upper ends of the vanes are urged into their normal positions by cable **138** and **139** which are operatively connected to take-up reels **140** and **141**.

The component span **101** also is provided with a pair of variable volume chambers **143** and **144** which communicate with the body of water below the water level and adjacent the vanes **131** and **132**. Slidably mounted in the chambers **133** and **134** are piston members **145** and **146** having connecting rods pivotally and slidably connected to the adjacent vanes as at **147** and **148**. It will be seen that as the vanes **131** and **132** pivot about their pivot points **133** and **134** the pistons **145** and **146** will move correspondingly to vary the displaced volume of water in the immersed chambers **143** and **144**.

In the operation of the system **118** to counteract the effects of wind or waves tending to disturb the stability of the component span, whenever the vane **131** is subjected to a lateral force of winds or waves, it will pivot to starboard, causing the vane **132** to pivot in the same direction. The movement of the vanes will cause pistons **145** and **146** to move to starboard, thus decreasing the displaced volume of water in chamber **143** and, correspondingly, increasing the displaced volume of water in chamber **144**. Such variations in displaced volumes will have the effect of decreasing the buoyant force acting on the port side of the span and increasing the buoyant force acting on the starboard side of the span. The combination of the increased and decreased buoyant forces acting on opposite sides of the span will have the effect of providing a righting force counteracting the lateral force of winds or waves applied to the span, thus tending to maintain or return the span to its predetermined level position. It will be appreciated that the systems **117** and **118** are adapted to operate simultaneously to maintain the component span in a stabilized condition.

A third embodiment of the invention is illustrated in FIGS. **7** through **10**. Specifically referring to FIG. **7**, there is illustrated a horizontal cross-sectional view of a component span **200** of a floating bridge structure similar to the bridge structure shown in FIG. **1**. The component span **200** consists of a floating body anchored to the bottom of a body of water by means of anchor lines **201** and **202**, and includes a bottom wall **203**, side walls **204** and **205**, and end walls **206** and **207**. The interior of the span is provided with a plurality of longitudinally disposed partition walls **208** and a plurality of transversely disposed partition walls **209** defining a plurality of watertight compartments **210**.

Rigidly mounted on the side and partition walls is a frame structure **211** which supports a pair of roadways **212,212** separated by a divider **213**. Also mounted on the frame structure along the outer sides of the roadways are pedestrian walkways **214** and **215** provided with guide rails **216** and **217**.

As best illustrated in FIG. **7**, the span is provided with two systems **218** and **219** which are adapted to maintain the component span stabilized in a predetermined orientation under the influence of loads applied to the component span by traffic traversing the span and external forces such as winds and waves also tending to disturb the stability of the span. The system **218** is adapted to counteract vertical displacements of the component span caused by vehicles traversing the span and includes a plurality of pairs of variable volume chambers **220** and **221** disposed on opposite sides of the span, below the water line and communicating with the body of water. The variable volume chambers **220** and **221** are provided with sliding pistons **222** and **223** which are actuated by a pair of hydraulic cylinders **224** and **225**. As best illustrated in FIG. **10**, the rear ends of the cylinders **224** and **225** are interconnected with a fluid line **226**, which communicates with a fluid supply line **227**, and the front ends of the cylinders are interconnected with a fluid line **228** which communicates with a fluid supply line **229**. Fluid under pressure for actuating the hydraulic cylinders **224** and **225** is provided by a pump **230**. The pump is operated by a motor **231** and supplies fluid under pressure to fluid supply lines **227** and **229** through a distribution valve **232**. The operations of the motor **231** and the distribution valve **232** are controlled by a computer **233** which computes output signals for the motor valve as a result of input signals provided by the weighing platforms **234** located on the roadways of the piers adjacent the opposite ends of the floating bridge structure.

The system **219** includes a plurality of pairs of variable volume chambers **235** and **236** disposed on opposite sides of the span below the water line which communicate with the body of water. The chambers **235** and **236** are provided with pistons **237** and **238** which are actuated by hydraulic cylinders **239** and **240**. As best illustrated in FIG. **10***a*, a fluid line **241** interconnects the front end of hydraulic cylinder **239** and the rear end of hydraulic cylinder **240**, and communicates with a fluid supply line **242** connected to a distributor valve **243**. Similarly, a fluid line **244** interconnects the rear end of hydraulic cylinders **239** and the front end of hydraulic cylinder **240**, and communicates with a fluid supply line **245** which also is connected to the distributor valve **243**. Fluid under pressure is supplied to the fluid supply lines **242** and **245** through the distributor valve **243** by means of a pump **246** which is driven by a motor **247**. The operations of the motor **247** and the distributor valve **243** are controlled by output signals from a computer **248**. The computer is adapted to receive input signals from a gyroscopic device **249** sensing a variation of position due to the effects of winds or waves, and transmit command signals to the distributor valve **243** and the drive motor **247**.

In the operation of the system **219** illustrated in FIG. **10**a, whenever the component span **200** is subjected to the forces of wind or waves from the port side, the span will tend to list to starboard, causing the port side to rise unless restrained by the anchor line **201**. Such variation in position will be sensed by the gyroscopic device **249** which will transmit a signal to the computer **248**. Upon receipt of the input signal from the gyroscopic device, the computer **248** will compute the appropriate correction and will energize the motor **247** and set the distributor valve in the proper position. Under such circumstances, fluid under pressure will flow through supply line **242** and fluid line **241** to the front end of hydraulic cylinder **239** and the rear end of hydraulic cylinder **240** to cause the pistons to move to starboard. The movement of the pistons to starboard will have the effect of decreasing the displaced volume of water in variable chamber **235** and increasing the displaced volume of water in variable chamber **236** and, correspondingly, decreasing the buoyant force acting on the span at the point of the chamber **235** and increasing the buoyant force acting on the span at the point of the chamber **236**. This alteration of the buoyant forces acting on the span at opposite sides thereof will have the effect of producing a counteracting righting force opposing the forces of the winds or waves applied to the port side of the span.

It is to be noted that the systems **218** and **219** function concurrently to counteract the disturbing effects of vertical loads applied to the span by traversing vehicles and the lateral loads applied to the span by winds or waves. It further will be seen that the effects of tides which may vertically displace the span may be sensed by any suitable sensing device which would transmit a signal to the computer **233** which in turn will transmit a command signal to the distributor valve **232** to alter the buoyant forces acting on the span, thus counteracting the effects of tides tending to vertically displace the span.

Another embodiment of the invention is illustrated in FIGS. **11** and **12**. In this embodiment, pneumatic means are provided for altering the buoyant forces acting on a span **300** at selected points to counteract the effects of vertical loads, tides, winds and waves acting on the span and tending to upset it. The component span **300** consists of a framework including an upper wall **301** on which there is provided a roadway **302** and pedestrian walkways **303** and **304**, a pair of side walls **305** and **306** and a pair of end walls (not shown). The span further is provided with a plurality of longitudinal partition walls **307** and transverse partition walls **308**. The inboard walls are provided with bottom walls **309** providing a plurality of closed chambers **310** and a plurality of chambers **311** communicating with the body of water. The outboard sections of the transverse walls **308** are provided with bottom walls **312** providing closed chambers **313** and outboard chambers **314** and **315** which communicate at their lower ends with the body of water.

The upper and lateral movement of the component span **300** is limited by means of a pair of anchor lines **316** and **317** anchored to the bottom of the body of water as at **318** and **319**. The component span also is provided with a pair of upwardly and outwardly projecting vanes **320** and **321** which are utilized to detect forces of wind and waves applied to the span tending to upset it from its normal position.

Generally, the span illustrated in FIG. **11** is stabilized by varying the amount of air under pressure supplied to the variable volume chambers **311**, **314** and **315** to counteract the effects of vertical displacement of the span due to vehicle loads applied to the bridge, and tides. It will be appreciated that by supplying or exhausting air under pressure to the variable volume chambers the displaced volume of water and, correspondingly, the buoyant forces acting on the span, can be varied to counteract vertical loads applied to the span. Similarly, lateral forces caused by winds or waves tending to cause the span to list, can be offset by selectively supplying air under pressure and exhausting the variable volume chambers **314** and **315**.

FIG. **12** illustrates a control system **322** for supplying and exhausting air from the variable volume chambers **311**, **314** and **315** to counteract forces applied to the span **300** and thus stabilize the span. The system includes a sensing device **323** which detects variations of orientation of the span and transmits a signal to a computer **324**. The computer operates a motor **325** which drives a compressor **326**. The compressor is connected to a compressed air tank **327** by means of a fluid line **328** including a relief valve **329**.

Compressed air is supplied to the outboard chamber **314** by means of a fluid supply line **330** and branch lines **331**. The supply line **330** is provided with a valve **332** and the branch lines **331** are provided with two-way valves **333** which are operated by the computer **324**. The two-way valves **333** are adapted to be operated to either supply air under pressure to the chamber **314** or to exhaust air in the chamber through exhaust lines **334**.

Air under pressure similarly is supplied to outboard chamber **315** by means of a fluid supply line **335** and branch lines **336**. The supply line **335** is provided with a valve **337** and the branch lines **336** are provided with two-way valves **338** which are operated by the computer **324**. The two-way valves **338** are operable either to provide air under pressure to the outboard chamber **315**, or to exhaust air therefrom through exhaust lines **339**.

To provide air under pressure to all of the variable volume chambers including the outboard chambers **314** and **315** and the inboard chambers **311**, there is provided a fluid supply line **340**, a manifold **341** and branch lines **342** which communicates with the inboard chambers **311**, a fluid line **343** which communicates with the outboard chamber **314** and a fluid line **344** which communicates with the outboard chamber **315**. The fluid supply line **340** is provided with a valve **345**, the branch lines **342** are provided with two-way valves **346**, the branch line **343** is provided with a two-way valve **347**, and the branch line **344** is provided with a two-way valve **348**, all of which are operated by the computer **324**. It will be noted that the two-way valves **346**, **347** and **348** are provided with exhaust lines **349**, **350** and **351**, respectively, so that air may be supplied to or exhausted from the chambers **311**, **314** and **315**.

In the operation of the system **322**, whenever the component span **300** is displaced vertically as a result of any loading on the bridge or the effect of tides, the sensing device **323** detects the displacement and transmits a signal to the computer **324**. The computer **324** continuously computes the corrective action for counteracting the displacement and transmits a command signal to the valves **345**, **346**, **347** and **348**, either to supply air under pressure or to exhaust the chambers, thus varying the volume of displaced water in the chambers and, correspondingly, varying the buoyant forces acting on the component span. The variation in the buoyant forces acting on the span will operate either to maintain or return the span to its predetermined level.

Whenever lateral forces caused by winds or waves are applied to the port side of the span, causing the span to list to starboard, the sensing device **323** detects the listing condition and transmits a signal to the computer **324**. The computer computes the corrective action and actuates a plurality of valves to vary the buoyant forces to provide a righting force, tending to return the span to its predetermined level orientation. In doing so, valves **332** and **345** are closed and valve **337** is opened. Simultaneously, valves **338** are operated to supply air under pressure to the outboard chamber **315** and the valves **333** are operated to vent the outboard chamber **314** to the atmosphere. This action will have the effect of increasing the displaced volume of water in outboard chamber **315**, thereby increasing the buoyant force applied to the starboard side of the span, and decreasing the displaced volume of water in outboard chamber **314**, thereby decreasing the buoyant force applied to the port side of the span, providing a righting moment, tending to maintain or return the span to its predetermined level position.

It will be appreciated that lateral forces applied to the starboard side tending to cause the span to list to port, can be counteracted in a similar manner by increasing the displaced volume of water in chamber **314** and decreasing the displaced volume of water in chamber **315**.

FIGS. **13** through **15** illustrate a modification of the embodiment shown in FIG. **11**. The modification consists of a component span **400** including a bottom wall **401**, side walls **402** and **403** and end walls (not shown). The interior of the span is provided with a plurality of longitudinal partition walls **404** and transverse partition walls **405**, defining a plurality of watertight compartments **406**. Supported on the partition walls **404** and **405** is a frame structure **407** on which there is mounted a roadway **408** and walkways **409** and **410**.

Mounted on the outboard sides of side walls **402** and **403** are variable volume chambers **411** and **412** which communicate at their lower ends with the body of water. The displaced volume of water in the variable volume chambers **411** and **412** can be varied to correspondingly vary the buoyant forces acting at different points on the span to provide corrective forces tending to counteract the effects of vertical and lateral loads applied to the span.

FIG. **15** illustrates a control system **413** utilized in the modification illustrated in FIGS. **13** and **14**. The system includes a motor **414** which drives a compressor **415** to pressurize an air tank **416**. Air under pressure is supplied through a line **417** including a relief valve **418** to fluid supply line **419** and **420**. Pairs of branch lines **421** and **422** provided with valves **423** and **424** interconnect supply line **419** with the starboard chambers **412**. Similarly, pairs of branch lines **425** and **426** provided with valves **426a** and **427** interconnect the supply line **420** with port chamber **411**. In addition, there are provided equalizing lines **428** and **429**, provided with valves **430**, **431**, **432** and **433** which intercommunicate port and starboard chambers **411** and **412**. The port chambers **411** are provided with vents **435** and **436**, having valves **437** and **438**. Similarly, the starboard chambers **412** are provided with vents **439** and **440** having valves **441** and **442**.

Each of the valves in the fluid supply lines and the vent lines are electrically operated. As illustrated in FIG. **15**, the valves **430** and **433** are connected to an electrical supply circuit **443**, valves **423** and **424** are connected to supply circuit **446** and valves **440** and **441** are connected to supply circuit **447**, which are selectively energized either by a control computer **444** or a gyroscopic device **445**. Similarly, valves **431** and **432** are connected to an electrical supply circuit **443***a*, valves **426***a* and **427** are connected to a supply circuit **446**a and valves **437** and **438** are connected to supply circuit **447**a, which are selectively energized by the control computer **444** and the gyroscopic device **445**.

In the operation of the modification illustrated in FIGS. **13** through **15**, whenever the span **400** is displaced vertically from its predetermined level, a sensing device of the type as previously described with respect to the aforementioned embodiments, will transmit a signal to the control computer **444**, indicating the nature and degree of displacement. The control computer will compute the appropriate correction and selectively energize supply circuits **446** and **446***a* or **447** and **447***a*, and circuits **443** and **443***a* to supply or exhaust air from the variable volume chambers **411** and **412**. It will be appreciated that by either increasing or decreasing the displaced volume of water in the chambers **411** and **412** symmetrically, the buoyant forces acting on the span will correspondingly be varied to provide a counteracting force, tending to return the span to the predetermined position. It further will be seen that the valves **430**, **431**, **432** and **433** will be open during correction for vertical displacement to intercommunicate the port and starboard chambers, thereby preventing the formation of asymmetrical forces tending to cause the span to list either to port or starboard.

When the span is subjected to lateral forces of winds or waves as illustrated in FIG. **14**, this condition is sensed by the gyroscopic device which operates to energize the starboard supply circuit **446**, causing valves **423** and **424** to open, and air under pressure to be supplied to the starboard chambers **412** and, simultaneously, to energize supply circuit **447***a*, causing valves **437** and **438** to open, thereby exhausting air from the port chambers **411**. The effect of such action will be to increase the displaced volume of water in the starboard chambers **412** and decrease the displaced volume of water in the port chambers **411**. This, correspondingly, will increase the buoyant force acting on the starboard side of the span and decrease the buoyant force acting on the port side of the span, thereby developing a righting force tending to return the span to its predetermined level position. It will be seen that when the span is subjected to lateral forces applied to the starboard side that a similar remedial action occurs to provide a righting force to return the span to its predetermined level position. It further will be appreciated that correction for vertical displacement and list can occur simultaneously to counteract a multitude of random forces applied to the span, tending to disturb its stability.

FIGS. **16** through **19** illustrate an embodiment of the invention as applied to a vessel for stabilizing the vessel by eliminating or decreasing the effects of roll and pitch. Referring to FIGS. **16** and **17**, there is illustrated a vessel **500**, having a hull **501** including a bow section **502**, a stern section **503** and an amidship section **504**. As best seen in FIG. **16**, there is provided a roll control system **505** located amidship, and pitch control systems **506** and **507** located in the bow and stern sections. The pitch control systems **506** and **507** are similar in construction and operation, although they are operated to produce opposite effects to eliminate pitching of the vessel.

Referring to FIG. **18**, there is illustrated the pitch control system **507**. This system includes a variable volume chamber **508** disposed on the starboard side below the waterline and communicating with the water, and a variable volume chamber **509** mounted on the port side below the waterline and communicating with the water. The ends of the variable volume chambers **508** and **509** opened to the sea, are provided with space plate members **510** and **511** which readily permit flow of water into and out of the chambers, yet prevent entry of any foreign undesirable matter which might cause damage to the interior of the chambers. The starboard chamber **508** is provided with a piston member **512**, which is actuated by a hydraulic cylinder **513**. Similarly, the port chamber **509** is provided with a piston member **514** which is actuated by a hydraulic cylinder **515**. The front and rear ends of the hydraulic cylinder **513** are connected by fluid supply lines **516** and **517** to a distributor valve **518**. Similarly, fluid supply lines **519** and **520** interconnect the front and rear ends of the hydraulic cylinder **515** with the distributor valve **518**. Fluid under pressure is supplied to the distributor valve **518** through a fluid circuit **521** provided with a pump **522** driven by a motor **523**. The distributor valve **518** and the motor **523** are operated by a gyroscopic device **524**.

In the operation of the control system **507**, whenever a vertical displacement of the stern section of the hull is sensed by the gyroscopic device **524**, command signals are transmitted to the motor **523** and the distributor valve **518** to supply fluid under pressure either to the front or rear ends of the hydraulic cylinders **513** and **515** to move the piston members **512** and **514** either outwardly or inwardly to vary the volume of displaced water in the port and starboard chambers **508** and **509**. The variation in the displaced volume of water in the chambers **508** and **509** will vary the buoyant forces acting on the stern section of the hull, thus tending to return the hull section to a predetermined level position. As previously mentioned, the control system **506** functions similarly to the control section **507** producing a complementary action tending to maintain the hull of the vessel on even keel.

The roll control system **505** illustrated in FIG. **19** includes a pair of variable volume chambers **525** and **526** mounted on the starboard and port sides of the hull below the waterline and communicating with the open sea. The open ends of the chambers **525** and **526** are provided with spaced plate members **527** and **528** which similarly to the plate members **510** and **511** permit flow of water into and out of the chambers **525** and **526**, yet prevent the entry of foreign objects tending to cause damage to the interior of the chambers. The chambers **525** and **526** are provided with piston members **529** and **530** which are actuated by hydraulic cylinders **531** and **532**. The front and rear ends of the hydraulic cylinder **531** are connected to a distributor valve **533** by means of fluid lines **534** and **535**. Similarly, the front and rear ends of hydraulic cylinder **532** are connected to the distributor valve **533** by means of fluid lines **536** and **537**. Fluid under pressure is supplied to the distributor valve **533** by means of a fluid circuit **538** which includes a pump **539** driven by a motor **540**. The operation of the distributor valve **533** and the motor **540** is controlled by a gyroscopic device **541** which is adapted to sense rolling conditions, compute corrective measures and transmit command signals to the distributor valve and motor. It will be appreciated that a single gyroscopic device can be employed to sense both roll and pitch conditions and control the distributor valves and motors for each of the control systems **505**, **506** and **507**.

In the operation of the control system **505**, when the vessel tends to roll to starboard, the gyroscopic device **541** senses the condition and transmits a signal to the motor **540** and the distributor valve **533** to supply fluid under pressure to the rear end of hydraulic cylinder **531** and the front end of hydraulic cylinder **532** to extend the piston member **529** and retract the piston member **530**. The result of such piston action will be to increase the displaced volume of water in chamber **525** and decrease the displaced volume of water in the chamber **526**, as illustrated in FIG. **19**, to increase the buoyant forces acting on the starboard side of the vessel and decrease the buoyant forces acting on the port side of the vessel. Such variation in the buoyant forces will produce a righting moment tending to counteract the roll of the vessel to starboard. It will be appreciated that the control system **505** operates in a similar manner to counteract the vessel rolling to port. In addition, it will be seen that the pitch control systems **506** and **507** will operate in a complementary manner simultaneously with the operation of the roll control system **505** to maintain the vessel in a stabilized position. In operating the control systems **506** and **507** to stabilize the vessel, the control system **506** controls the buoyant forces acting on the bow section **502** of the vessel while the control system **507** controls the buoyant forces acting on the stern section **503** of the vessel. The inlets of the variable volume chambers of the pitch control system **506** are shielded by spaced plate members **542** and **543** as best illustrated in FIG. **16**.

FIGS. **20** and **21** illustrate a modification of the embodiment illustrated in FIGS. **16** through **19**. More specifically, FIG. **20** illustrates a roll control system adapted to be positioned amidship in a vessel, and FIG. **21** illustrates a pitch control system adapted to be positioned in the bow and stern sections of a vessel.

The roll control system **600** is mounted in the amidship section **601** of a vessel and includes a starboard chamber **602** mounted in the hull of the vessel below the waterline and communicating at the lower end thereof with the open sea, and a port chamber **603** which also is positioned below the waterline and communicates at its lower end with the open sea. The lower openings in the chambers **602** and **603** are provided with spaced shield plates **604** and **605** to readily permit the flow of water into and out of the chambers **602** and **603**, yet prevent the entry of any foreign objects which would tend to cause damage to the interior of the chambers. The system **600** also includes a compressor **606** which provides a reservoir of compressed air in a tank **607** for the entire system. The tank **607** is connected to the variable volume chambers **602** and **603** by means of an air supply line **608** having a valve **609** and an air line **610** having valves **611** and **612** for controlling the air supplied to the chambers **602** and **603**. Also interconnecting the chambers **602** and **603** is a fluid supply line **613** having valves **614** and **615** adjacent the chambers **602** and **603**. The variable volume chambers also are adapted to be vented to the atmosphere through vent conduits **616** and **617** provided with valves **618** and **619**, respectively.

The various control valves for supplying and exhausting air under pressure in the variable volume chambers **602** and **603** are electrically actuated by a gyroscopic device **620** and a control unit **621**.

The roll control system **600** is operative when the vessel rolls to starboard, as illustrated in fig. **20**, to vent the air in the port chamber **602** and supply air under pressure to the starboard chamber **603**. This will have the effect of decreasing the displaced volume of water in the port chamber **602** and increasing the displaced volume of water in the starboard chamber **603** to correspondingly decrease the buoyant forces acting on the port side of the vessel and increase the buoyant forces acting on the starboard side of the vessel. The variation of buoyant forces on the starboard and port sides of the vessel will develop a righting force, tending to counteract the roll of the vessel to starboard.

The roll conditions of the vessel are detected by the gyroscopic device **620** which energizes the appropriate electrical circuits to open and close the appropriate valves to either supply or exhaust air under pressure in the variable volume chambers **602** and **603**.

The pitch control system **622**, as illustrated in FIG. **21** is intended to be positioned in the bow and stern sections of the vessel, so that a pair of systems operates in a complementary manner to counteract the effects of the pitching motion of the vessel. The system **622** includes a port chamber **623** positioned below the waterline and communicating at its lower end with the open sea, and a starboard chamber **624** also positioned below the waterline and having a lower opening communicating with the open sea. The openings in the chambers **623** and **624** are provided with shield plates **625** and **626** which readily permit the flow of water into and out of the chambers, yet prevent foreign objects from entering the chambers. The chambers **623** and **624** are supplied with air under pressure from a compressed air tank **627** through a fluid supply line **628** having a valve **629** and an air line **630** having two-way valves **631** and **632** disposed adjacent the chambers **623** and **624**. The chambers also may be vented to the atmosphere through two-way valves **631** and **632** and vent conduits **633** and **634**. The compressor **635** and two-way valves **631** and **632** are operated by a gyroscopic device **636** and a control unit **637**, either to supply air under pressure to the chambers **623** and **624**, or to exhaust air therefrom through vent conduits **633** and **634**.

In the operation of the pitch control system **622**, whenever a pitching condition is detected by a gyroscopic device **636**, the two-way valves **623** and **632** are operated either to supply or exhaust air in the chambers **633** and **624**, thereby varying the displaced volume of water in the chambers. The variation of the displaced volume of water in the chambers **623** and **624** will have the effect of varying the buoyant forces acting on the bow and stern sections of the vessel. Such variations in buoyant forces are utilized to counteract the pitching motion of the vessel, thereby stabilizing the vessel. It will be noted that the roll control system **600** and the pitch control systems **622** are operated simultaneously to counteract the roll and pitch motions of the vessel, thereby stabilizing the orientation of the vessel.

FIGS. **22** through **24** illustrate the application of the invention in stabilizing a floating section **700** of an aircraft take-off and landing deck. As illustrated in FIGS. **22** and **23**, the floating section **700** includes a plurality of component spans **701**, each of which are anchored to the bottom of a body of water **702** by means of anchor cables **703**. Each span **701** includes a plurality of stabilizing systems **704** which are operative to prevent the span from listing either to starboard or port as a result of lateral forces applied to the span by winds or waves. The system **704** consists of a chamber **705** disposed below the waterline of the body of water and communicating with the open sea. Mounted in the chamber **705** is a piston member **706** having a pair of piston rods **707** and **708**, guided in bearing members **709** and **710** and interconnected at their rearward ends by a member **711**. The piston member **706** is normally biased outwardly by a pair of springs **712** and **713** and is adapted to be moved inwardly by a hydraulic cylinder **714** operatively connected to the cross piece member **711**.

Pivotally mounted on the lower submerged side of the span **701** is a detecting vane **715** which extends above the waterline. The vane **715** has a plane surface which is engaged by wind and waves, so that it may detect the degree of such forces applied to the side of the span. The vane **715** is provided with an actuating rod **716** slidably connected at one end to the vane as at **717** and rigidly connected to a piston member **718** at the opposite end thereof, slidably mounted in a cylinder **719** in the side of the span **701**. The closed end of the cylinder **719** is provided with a working fluid and communicates with the front end of the hydraulic cylinder **714** through a closed fluid line **720**.

It thus will be seen that when the lateral forces of winds or waves are applied to the detecting vane **715**, ti will be caused to pivot towards the span **701**, moving the piston member **718** inwardly to force working fluid from the chamber **719** to the hydraulic cylinder **714**. The admission of working fluid into the cylinder **714** will cause the piston rods **707** and **708** and the piston member **706** to move inwardly, thereby decreasing the displaced volume of water in chamber **705**. The decrease in the displaced volume of water in chamber **705**, will have the effect of decreasing the buoyant force acting on the span at the point of the chamber **705**, thus counteracting the lateral force applied to the span, tending to lift the span upwardly. The cooperation of the various systems **704** located on the starboard and port sides of each span **701** will have the effect of stabilizing the landing deck **700**.

I claim:

1. A floating structure adapted to maintain a predetermined orientation comprising a body only partially immersed in a fluid, said body having a plurality of constantly totally immersed, vertically disposed chambers communicating at the lower ends thereof with said fluid, means for supplying air under pressure to and venting said chambers, means for controlling the supply of air under pressure to and the venting of said chambers, means for sensing variations of said floating structure relative to said predetermined orientation, and said control means being operable responsive to said sensing means to selectively supply air under pressure to and vent said chambers to provide variable pressures in said chambers to vary the volumes of displaced fluid in said chambers and correspondingly vary the buoyant forces acting on said floating structure, while maintaining constant the resultant buoyant force applied to said floating structure, acting through the center of gravity thereof, to return said structure to said predetermined orientation.

2. A floating structure according to claim **1** wherein said sensing means includes means for sensing vertical loads applied to said floating body.

3. A floating structure according to claim **2** wherein said means for sensing vertical loads applied to said floating body comprises weighing means.

4. A floating structure according to claim **1** wherein said sensing means includes means for sensing lateral loads applied to said floating body.

5. A floating structure according to claim **2** including a second plurality of constantly totally immersed, vertically disposed chambers, disposed on opposite sides of said body, having the lower ends thereof communicating with said fluid, means for supplying air under pressure to and venting said chambers second means for sensing variations of said body relative to said predetermined orientation to lateral forces applied to said body, and said control means being operable responsive to said second sensing means to selectively supply air under pressure to and vent said second plurality of chambers to provide variable pressures in said chambers and thereby vary the volumes of displaced fluid therein and correspondingly vary the buoyant forces acting on said body to counteract the upsetting effects of said lateral forces, and return said body to said predetermined orientation.

6. A floating structure according to claim **1** wherein said sensing means includes means for sensing both vertical and lateral loads applied to said floating body.

7. A floating structure adapted to maintain a predetermined orientation comprising a floating body only partially immersed in a body of water, having longitudinal and transverse center lines and a plurality of vertically disposed chambers communicating at the lower ends thereof with said body of water, disposed on each side of at least one of said center lines, said chambers being disposed constantly below the water line, means for supplying air under pressure to and venting said chambers, means for sensing variations of said floating body relative to said predetermined orientation, and control means responsive to said sensing means for selectively supplying air under pressure to and venting said chambers to provide variable pressures in said chambers, for varying the displaced volumes of water in said chambers and correspondingly varying the buoyant forces acting on said fluid body, while maintaining constant the resultant force applied to said floating structure, acting through the center of gravity thereof, to provide counteracting forces operable to return said floating body to said predetermined orientation.

8. A floating structure comprising a first body section adapted to maintain a predetermined orientation, means for limiting the upper displacement of said first body section, a second body section supporting said first body section said first body section being displaceable relative to said second body section, said second body section having a portion thereof partly immersible in a fluid to produce a buoyant force acting on said structure, means for varying the displacement between said body sections, means responsive to variations of said first body section relative to said predetermined orientation for actuating said means for varying the displacement between said bodies thereby varying the immersed volume of said second body section whereby the buoyant forces acting on said structure are varied to produce counteracting forces tending to return said first body section to said predetermined orientation and said actuating means including means for sensing variations of said first body section relative to said predetermined orientation.

9. A floating structure according to claim 8, wherein said means for varying the displacement between said bodies comprises at least one variable volume chamber disposed between said body sections and said actuating means comprises a system of fluid under pressure connected to said chamber for varying the volume thereof whereby a variation of volume of said chamber will cause displacement between said body sections thus producing corresponding variations in the buoyant forces acting on said structure.

10. A floating structure according to claim 8, wherein said sensing means includes a weighing means for sensing vertical loads applied to said first body section.

11. A floating structure adapted to maintain a predetermined orientation comprising a floating body at least partially immersed in a fluid, means mounted in said body at selected loci varying the buoyant forces acting on said selected loci, means responsive to variations of said floating body relative to said predetermined orientation for actuating said means for varying said buoyant forces whereby said buoyant forces are varied at selected loci to produce counteracting forces tending to return said floating body to said predetermined orientation and said actuating means including means for sensing variations of said floating body relative to said predetermined orientation, said sensing means including a weighing means for sensing vertical loads applied to said floating body.

12. A floating structure according to claim 11 wherein said means mounted at selected loci for varying the buoyant forces acting on said floating body comprise a plurality of immersed chambers communicating with said fluid, each of said chambers having a piston for varying the displaced volume of fluid therein, said piston being operatively connected to said actuating means, and wherein said actuating means comprises a fluid system including a source of fluid under pressure, fluid operated actuators for extending and retracting said pistons to vary the displaced volume of said fluid selectively, and control means responsive to said sensing means for selectively supplying fluid under pressure to said fluid operated actuators.

13. A floating structure according to claim 11 wherein said means mounted at selected loci for varying the buoyant forces acting on said floating body comprise a plurality of immersed chambers communicating with said fluid, each of said chambers having a piston for varying the displaced volume of fluid therein, said piston being operatively connected to said actuating means, and wherein said sensing means comprises a weighing means for sensing vertical loads applied to said floating body.

14. A floating structure adapted to maintain a predetermined orientation comprising a floating body at least partially immersed in a fluid, means mounted in said body at selected loci for varying the buoyant forces acting on said selected loci, means responsive to variations of said floating body relative to said predetermined orientation for actuating said means for varying said buoyant forces whereby said buoyant forces are varied at selected loci to produce counteracting forces tending to return said floating body to said predetermined orientation and said actuating means including means for sensing variations of said floating body relative to said predetermined orientation, said means mounted at selected loci for varying the buoyant forces acting on said floating body comprising a plurality of immersed chambers communicating at the lower ends thereof with said fluid, said actuating means comprising a pneumatic system including a source of gas under pressure, circuit means interconnecting said source of gas under pressure with said chambers, means for venting said chambers and control means responsive to said sensing means for selectively supplying fluid under pressure to and venting said chambers, and said sensing means comprising a weighing means for sensing vertical loads applied to said floating body.

15. A floating structure adapted to maintain a predetermined orientation comprising a floating body having longitudinal and transverse center lines, said floating body being at least partially immersed in a fluid, at least one means for varying the buoyant forces acting on said floating body mounted in said floating body on each side of at least one of said center lines, means responsive to variations of said floating body relative to said predetermined orientation for actuating said means for varying the buoyant forces whereby said buoyant forces are varied to produce counteracting forces tending to return said floating body to said predetermined orientation and said actuating means including means for sensing variations of said floating body relative to said predetermined orientation, said sensing means including a weighing means for sensing vertical loads applied to said floating body.

16. A floating structure adapted to maintain a predetermined orientation comprising a floating body having longitudinal and transverse center lines, said floating body being at least partially immersed in a fluid, at least one means for varying the buoyant forces acting on said floating body mounted in said floating

body on each side of at least one of said center lines, means responsive to variations of said floating body relative to said predetermined orientation for actuating said means for varying the buoyant forces whereby said buoyant forces are varied to produce counteracting forces tending to return said floating body to said predetermined orientation and said actuating means including means for sensing variations of said floating body relative to said predetermined orientation, said actuating means being operable selectively to actuate both of said varying means simultaneously to counteract any vertical displacement of said floating body thus returning said floating body to said predetermined orientation, to actuate said varying means selectively to produce righting forces about said center line to counteract external forces applied to said floating body tending to produce upsetting moments about said center line thus returning said floating body to said predetermined orientation, and to actuate said varying means to produce opposed forces acting vertically and about said center line to counteract a combination of forces tending to displace said floating body vertically and simultaneously producing an upsetting moment about said center line thus returning said floating body to said predetermined orientation, and said sensing means including a weighing means for sensing vertical loads applied to said floating body.

17. A floating structure adapted to maintain a predetermined orientation comprising a floating body having longitudinal and transverse center lines and at least a portion thereof immersed in a fluid, at least one set of first reaction means mounted in said floating body, disposed symmetrically relative to at least one of said center lines for varying the buoyant forces acting on said floating body, at least one set of second reaction means mounted in said floating body, symmetrically relative to one of said center lines, for varying the buoyant forces acting on said floating body, means responsive to variations of said floating body relative to said predetermined orientation for actuating said first and second reaction means for varying the buoyant forces whereby said buoyant forces are varied to produce reaction forces tending to return said floating body to said predetermined orientation and said actuating means including means for sensing variations of said floating body relative to said predetermined orientation, and said sensing means including a weighing means for sensing vertical loads applied to said floating body.

18. A floating structure adapted to maintain a predetermined orientation comprising a floating body at least partially immersed in a body of fluid, a platform supported on said floating body, said floating body having a first plurality of spaced chambers, means for detecting loads applied to said platform, means for varying fluid in said first plurality of chambers in response to loading of said platform to vary the buoyant forces acting on said floating body in counteracting the effects of said loading and returning said structure to said predetermined orientation, said floating body having a second plurality of spaced chambers communicating with said body of fluid, means for displacing fluid in said second plurality of chambers, and means responsive to exterior forces applied to said structure tending to displace said structure from said predetermined orientation for actuating said displacing means to vary the buoyant forces produced by said second plurality of chambers to counteract the upsetting effects of said exterior forces and returning said structure to said predetermined orientation.

19. A floating structure adapted to maintain a predetermined orientation according to claim **18** wherein said detecting means comprises weighing means.

20. A floating structure adapted to maintain a predetermined orientation according to claim **18** wherein said displacing means comprise pistons.

21. A floating structure adapted to maintain a predetermined orientation according to claim **18** wherein said actuating means comprise vanes operatively connected to said displacing means.

22. A floating structure adapted to maintain a predetermined orientation according to claim **18** wherein said displacing means comprise pistons and said actuating means comprise vanes operatively connected to said pistons.

23. A floating structure adapted to maintain a predetermined orientation according to claim **22** wherein said vanes are pivotally connected to said floating body and are engageable by wind and waves acting on said structure.

24. A floating structure adapted to maintain a predetermined orientation according to claim **18** including means for limiting the upward movement of said floating body.

25. A floating structure adapted to maintain a predetermined orientation according to claim **18** wherein said detecting means comprises weighing means, said displacing means comprise pistons, said actuating means comprise vanes pivotally to said floating body and operatively connected to said pistons, and including means for limiting the upward movements of said floating body.

26. A floating structure adapted to maintain a predetermined orientation according to claim **18** wherein said chambers operable to vary the buoyant forces acting on said floating body are disposed on opposite sides of at least one center line of said floating body to produce selectively vertical and righting forces counteracting upsetting forces applied to said structure.

27. A floating structure adapted to maintain a predetermined orientation according to claim **26** wherein said chambers are disposed equidistantly relative to said center line.

28. A floating structure adapted to maintain a predetermined orientation according to claim **26** wherein said vanes are disposed on opposite sides of said floating structure and are operatively interconnected to simultaneously actuate at least two displacing means producing cooperative righting forces.

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