# United States Patent

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[33] France
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Continuation-in-part of application Ser. No. 710,226, Mar. 4, 1968, now abandoned. This application Aug. 1, 1969, Ser. No. 846,866


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[54] **SEMI-SUBMERSIBLE FLOATING STRUCTURE WITH DYNAMIC POSITIONING**
**10 Claims, 7 Drawing Figs.**


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[51] Int. Cl. ..... B63b 35/00, B63b 35/44

[50] Field of Search ..... 114/0.5, 0.5D, 43.5, 61; 61/46.5



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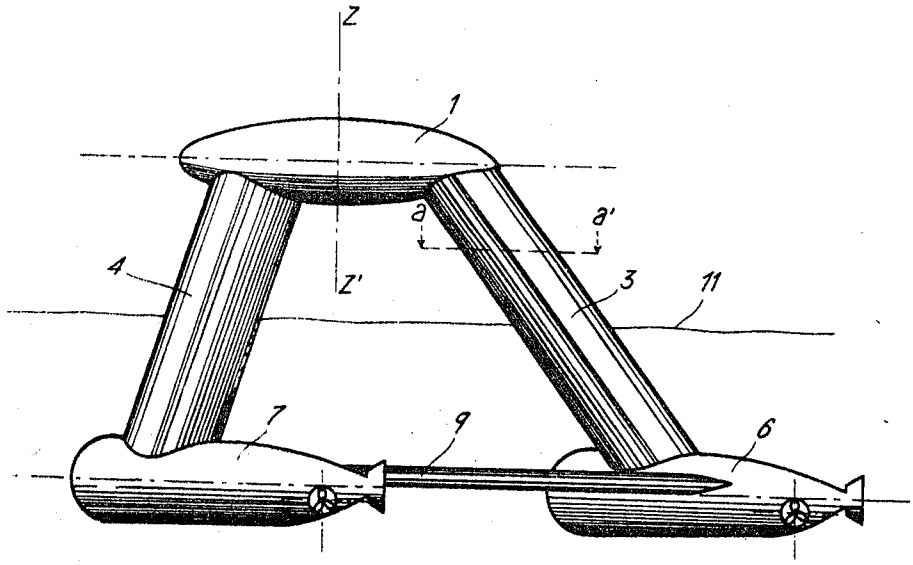
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**ABSTRACT:** This semisubmersible structure for offshore drilling operations includes profiled caissons located at the apices of a regular polygon having at least three sides, these caissons having a common direction of orientation, parallel to an axis of symmetry of the polygon and being interconnected by cross-bracing members, an aerial part supported by columns integral with said caissons. This structure is characterized in that the aerial part is a hollow structure having a flattened aerodynamic shape, substantially of revolution around a vertical axis.

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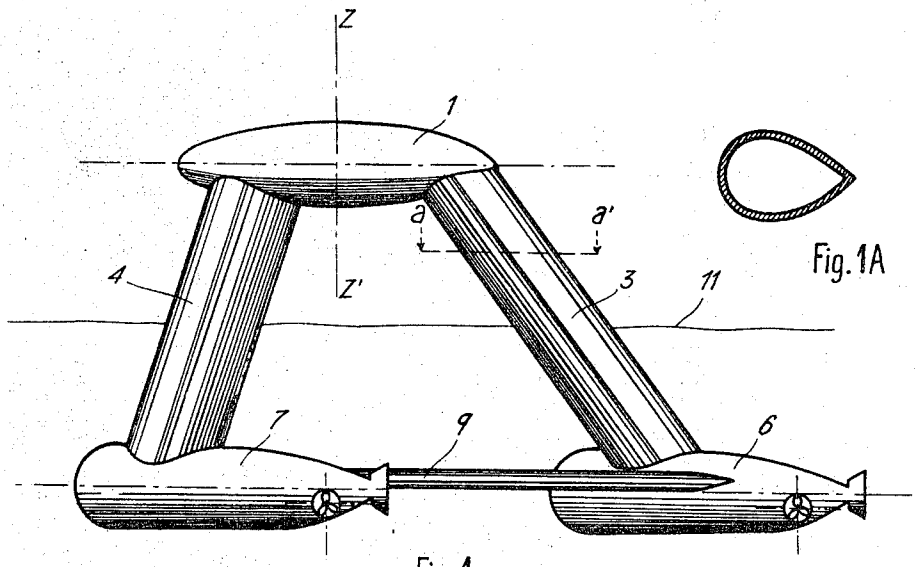



Fig. 1A

Fig. 1

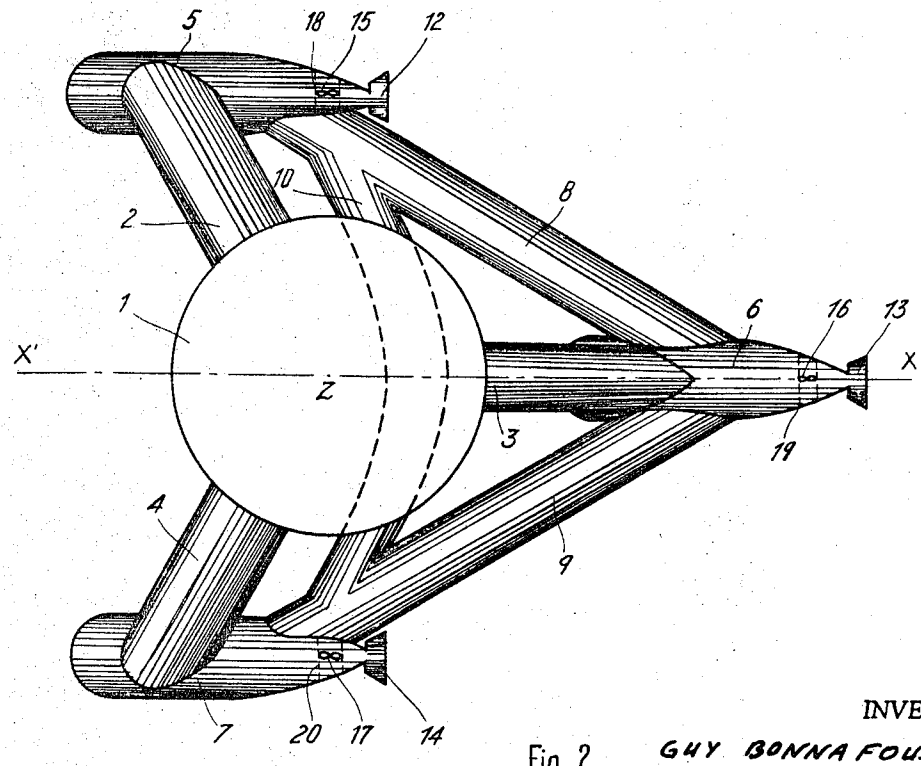



Fig. 2

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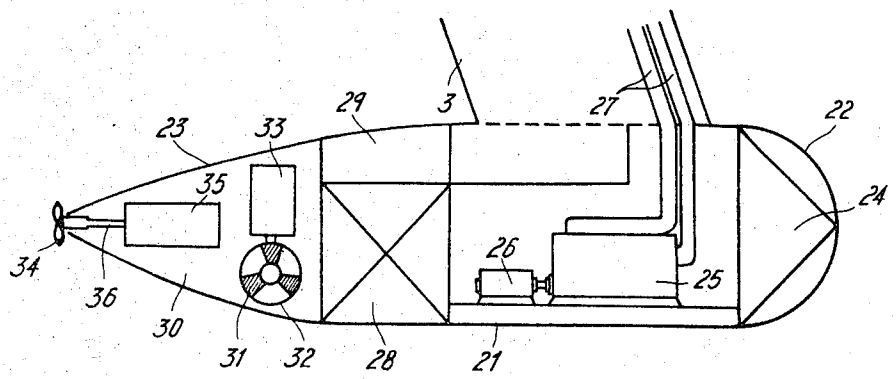



Fig. 3

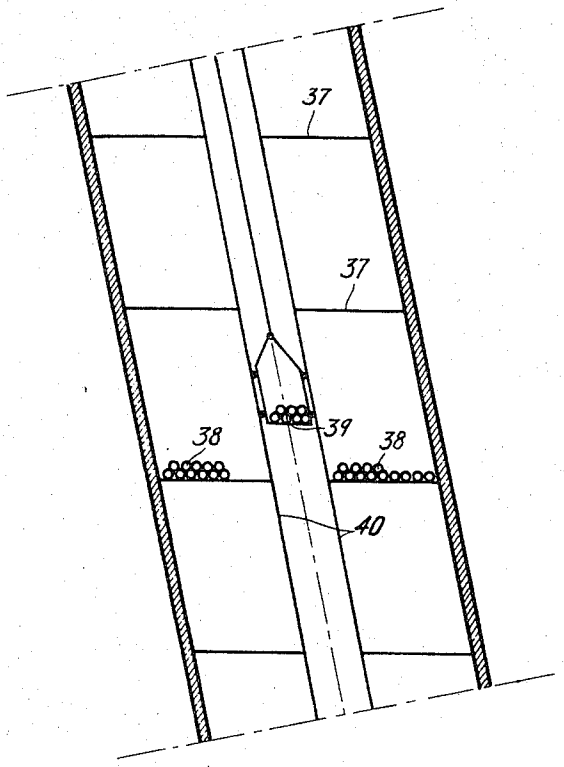



Fig. 4

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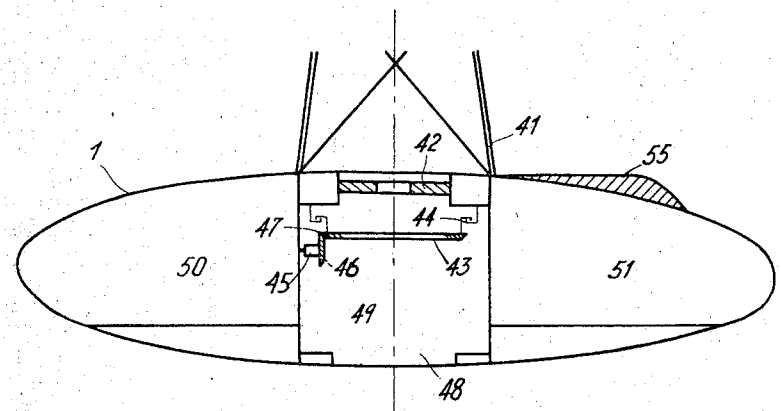



Fig.5A

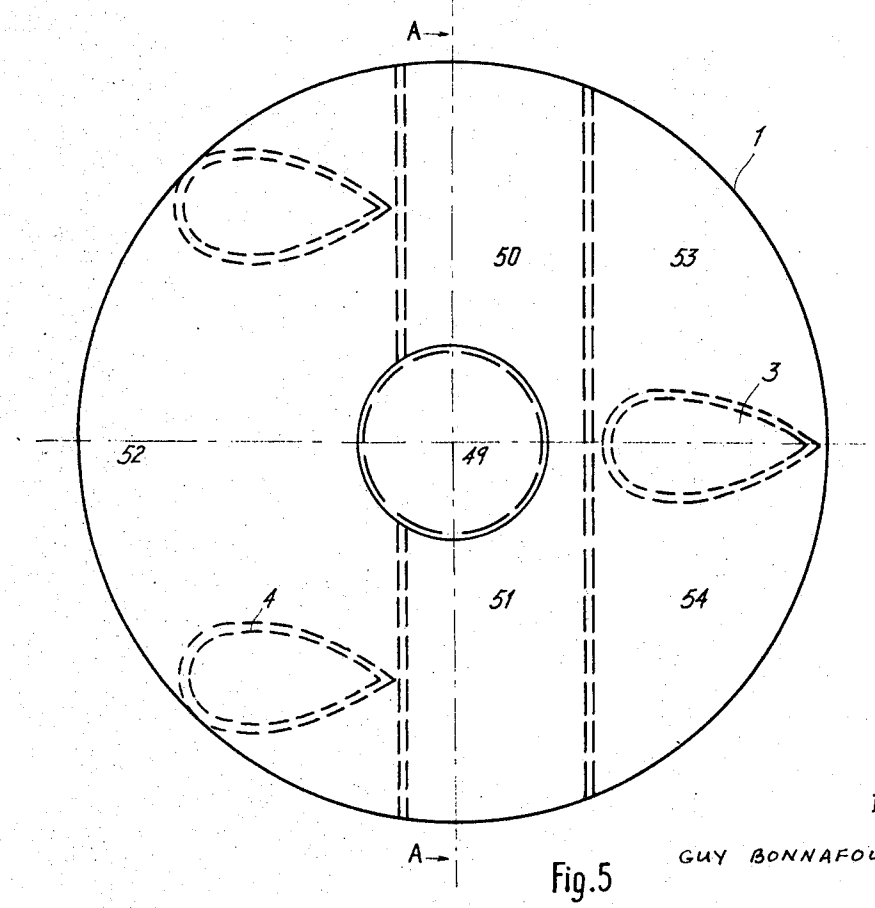



Fig.5

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# SEMI-SUBMERSIBLE FLOATING STRUCTURE WITH DYNAMIC POSITIONING

## BACKGROUND OF THE INVENTION

The present invention is a Continuation-In-Part Application of Application Ser. No. 710,226 filed Mar. 4, 1968 and now abandoned.

The present invention relates to a semisubmersible floating structure or rig with dynamic positioning, which is particularly adapted for offshore drilling operations.

The use of floating structures for offshore operations, such as oil well drilling operations, presents with respect to the use of structures supported by columns on the water-bottom, the advantage of not being limited to shallow water, of suppressing long and difficult operations of self-elevation of the structure along its columns, and of eliminating the risks of an impossibility of implantation or of serious accidents during the drilling operation, as a result of an insufficient mechanical resistance of the water-floor.

However, the action of external elements (swell, winds and currents) on floating structures is susceptible to cause displacements thereof which are hardly compatible with the development of operations such as drilling operations.

In particular, the periodical movements caused by the swell, taking into account the magnitude of the forces which are applied, can be reduced only by specially designing the structure so as in particular to reduce the resistance to the swell of the part of the structure which traverses the water surface.

There is furthermore an attempt to give the structure such a design that it exhibits the same response to the action of the swell whatever the direction of propagation of the latter may be (isotropy with respect to the swell), in order that the possible variations of this direction do not cause any servitude regarding the heading which is given to the structure during the positioning thereof.

One of the problems which remain is then that of the action of the currents on the structure.

In order to reduce this action, it is desirable that this structure exhibits a direction of less resistance to the current.

This provision has however a signification only if it is possible at every instant to align this preferred direction of the structure with the direction of the current.

With the conventional anchoring means using anchors or mooring blocks which have a fixed position on the water bottom and are connected with the structure through moorings, cables or chains, the modifications in the heading of the structure are time-consuming and difficult and it is practically impossible during a change in the heading of the structure to keep at every instant the position of anchoring itself. It is therefore necessary, in the case of drilling operations performed from the structure, to then interrupt these operations.

Moreover the use of these anchoring means is limited to shallow water and the position thereof at the locations selected for anchoring the structure is time-consuming, expensive and difficult.

Furthermore, whatever the selected anchoring means are, if the heading with which the structure is anchored is liable to be modified while operations such as drilling operations are performed, the structure must be so designed that its rotation about itself will not substantially affect the development of these operations.

Another problem arises during the operation of the structures which have been built up to now and this problem probably constitutes the most serious one arising during the use of these structures: it is the problem of the action of the wind on the presently available platforms, this action not only resulting in very important permanent stresses in the structure, but also in dynamic actions caused by wind squalls.

## SUMMARY OF THE INVENTION

Accordingly, one of the objects of the present invention is to provide a semisubmersible floating structure having a minimal response to the action of the swell, irrespective of the direction of propagation thereof, and positioning means which can be used irrespective of the water depth and capable of absolutely maintaining the position of the structure irrespective of the heading thereof and of the possible variations in this heading.



Another important object of the invention is to provide a structure which is as little responsive as possible to the permanent as well as instantaneous actions of the wind.

An essential object of the invention is to provide a structure which simultaneously exhibits a great lightness of construction, a maximal stability and a minimal resistance to the wind, for a given useful load.

The objects are achieved, according to the invention, with a semisubmersible structure including profiled caissons located at the apices of a substantially regular polygon having at least three sides, these caissons having a common direction parallel to an axis of symmetry of the polygon and being interconnected by cross-bracing members, said structure also including an aerial part supported by columns integral with said caissons, wherein said aerial part is a hollow structure having a flattened aerodynamic shape which is substantially of revolution about a vertical axis.

This structure will advantageously include three caissons located at the respective apices of an equilateral triangle and the aerial part will then be located at the top of a tetrahedron having said equilateral triangle as a basis.

According to a preferred embodiment of the invention, the caissons may be provided with means for propulsion in a direction parallel to the axis of symmetry of the basis polygon and with means for propulsion in a transverse direction, at right angles to the first mentioned direction, these last means being advantageously distinct from the first ones and housed in tunnels traversing the caissons.

When the structure according to the invention will be used for offshore drilling, its aerial part will preferably include a central circular element rotatable with respect to the remainder of the structure around the vertical axis of this aerial part which will then be provided with means for rotating this central element around said vertical axis.

## BRIEF DESCRIPTION OF THE DRAWINGS

The advantages of the structure according to the invention will be better understood from the following description taken with reference to the drawings wherein:

FIG. 1 is a side view in elevation of an embodiment of this structure,

FIG. 1A corresponds to the section *aa* of FIG. 1 and illustrates the profile of a caisson,

FIG. 2 shows the same structure as seen from above,

FIG. 3 illustrates an internal arrangement of a caisson,

FIG. 4 is a perspective longitudinal section showing an internal arrangement of a column used for stocking the tubular elements of a drill string,

FIGS. 5 and 5A show in a view from above and an axial section taken along AA respectively a possible arrangement of the aerial part of such a structure adapted for offshore drilling operations.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

The structure according to the invention, shown by FIGS. 1 and 2, includes an aerial part 1 supported by columns 2,3,4, which are integral with caissons 5,6,7 interconnected by cross-bracing members 8,9,10. In this embodiment, the caissons are three in number, which seems to be the minimum necessary to provide for a good isotropy of the structure with respect to the swell, but it should be understood that the number of the caissons is not limited to three, although an increase in this number increases the cost of the structure and the complexity thereof.

The assembly of the columns and of the cross-bracing members substantially constitutes a tetrahedron, which provides the structure with a perfect rigidity and has a minimum of cross-bracing members.

The three caissons are in this embodiment substantially located at the respective apices of an equilateral triangle.

The assembly constituted by the columns and the caissons is adapted to support the structure in the semiimmersed position shown by FIG. **1**, wherein **11** designates the water level.

The three caissons are substantially profiled like underwater streamlined hulls parallely to one and the same directly of elongation x'x which constitutes the direction of less resistance to current and which is at right angles to one of the bases of the equilateral triangle, each caisson including a cylindrical part **21** connected with a round cap **22** at the bow of the caisson and at the stern thereof with a tapered part **23** which is slowly decreasing section, so as to permit the detachment and the turbulence of the water streams at the stern of the caisson.

In the illustrated embodiment the caisson has a length equal to about four times its greatest width.

More generally, the ratio of the length of the caisson to its greatest width will be for example equal to about 3.5 so as to provide for sufficient profiling, but less than 5 so as not to decrease the isotropy of the structure with respect to the swell.

The hydrodynamic shape of the caisson may optionally be slightly retouched so as to take into account the problems of equilibrating the structure with respect to the swell.

The axis x'x will be substantially oriented along the direction of the current during the periods when the structure is kept in its working position.

Owing to the particular configuration of the caissons in the structure according to the invention, this structure tends moreover to align itself with the direction of the current, even when the latter has not a high strength.

The structure will be kept in position by means of an assembly of propulsion units belonging to a dynamic anchoring or positioning system and adapted to the caissons **5,6,7**.

In the advantageous embodiment which has been considered by way of example, these propulsion units are six in number (two for each caisson) and include three longitudinal propulsion units **12,13,14** which normally provide for the displacement of the structure along the axis x'x in either direction.

These propulsion units may for example be screw-propellers with adjustable pitch and substantially constant speed of rotation, allowing to vary the magnitude of the thrust (and even to rapidly reverse the direction of this thrust) by only varying the propeller pitch, without reversing the direction of rotation of this propeller.

The structure also includes three transverse propulsion units **15,16,17** which permit to exert on the structure transverse thrusts (at right angles to the axis x'x) and/or rotational forces (for rotation of the structure about itself, so as to, for instance, maintain the axis x'x in the direction of the current)

These propulsion units **15,16,17** may advantageously be screw-propellers with adjustable pitch and substantially constant speed of rotation, housed in tunnels **18, 19** and **20**, respectively, which traverse the caissons from side to side and are comparable to the bow propulsion units which some types of ships, particularly tugboats, are provided with.

Obviously a structure according to the invention may be provided with other types of propulsion units than the screw-propellers with adjustable pitch which have been mentioned, it is possible for example to use hydroreactors, i.e. propulsion means using fluid jets.

Owing to its self-contained propulsion means, the structure according to the invention will not need to be tugged to the location selected for the the anchoring thereof and this constitutes an important advantage with respect to the marine platforms which have been heretofore proposed.

The transverse propulsion units **15** and **17** will advantageously be so located that their directions of thrust are aligned and substantially converge with axis z'z.

In this way, these two propulsion units will practically not exert any rotational force on the structure (their moments of rotation being equal to zero), and only apply on this structure a transverse force perpendicular to the axis x'x.

Rotational movement of the structure on itself, around the axis z'z may be effected by the sole propulsion unit **16** with a relatively small thrust, since, on the one hand, this propulsion unit is located at a point remote from the axis z'z and, on the other hand, the structure has a tendency to orient itself along the direction of the current and no antagonistic torque, due to the action of the wind, is applied to the aeriai part of the structure.

This arrangement of the propulsion units **15,16,17**, which permits to definitely dissociate the functions of transversally moving the structure and of rotating it around the axis z'z has the advantage of avoiding that during normal operation, the thrust to be exerted by transverse propulsion unit is determined by superposing a translation component, which may be of high amplitude, and a rotational component, which is generally of much smaller amplitude and contributes in keeping the structure in the direction of the current, such a composition of forces which are most of time of very different magnitudes, being detrimental to the precision of the positioning.

The transverse thrust exerted by the propulsion unit **16** being very small during normal operation will not result in any appreciable transverse displacement of the structure, but it is obviously possible to balance this transverse thrust by the action of at least one of the propulsion units **15** and **17**.

A dynamic anchoring or positioning system for the structure may for example be constituted by means for controlling the magnitude of the thrusts exerted by the propulsion units **15** and **17** as a function of signals provided by any suitable measuring means which detects the displacements of the structure in a direction perpendicular to the axis x' n d with means for controlling the thrusts exerted by the propulsion units **12, 13** and **14** as a function of signals provided by any suitable measuring means which detects the displacements of the structure along the axis x'x, the magnitudes of the thrusts exerted by the propulsion units **12** and **14** being preferably always equal to each other, so that their rotational moments equilibrate each other.

The thrust of the propulsion unit **16** may be controlled in an entirely independent way either manually or automatically, as a function of the indications of an instrument which measures the direction of the current.

This way of realizing the dynamic positioning of the structure is however not at all limitative.

It should furthermore be noted that the arrangement of the propulsion units in the illustrated embodiment (FIG. **2**) allows to continue the dynamic positioning of the structure even in case of simultaneous failure of two propulsion units whatever they are, and even if three propulsion units out of six ones are simultaneously failing (under the condition however, in this last case, that the directions of thrusts of these three propulsion units are not parallel).

The propulsion units which then remain in operation are capable of moving the structure as well along the axis x'x as along a direction at right angles thereto, and/or rotating the structure around itself, which permits to provide for dynamically positioning the structure.

According to an important feature of the invention, the aerial part **1** of the structure has substantially an aerodynamic shape of revolution around a vertical axis z'z which constitutes the axis of the structure and coincides in this embodiment with the axis of the equilateral triangle at the apices of which the caissons are located.

This shape of the aerial part of the structure is advantageously close to that of an ellipsoid of revolution the small axis of which coincides with the axis z'z (ellipsoid flattened along a horizontal plane). Tests which have been performed in a wind tunnel have shown that this shape exhibits a very small resistance (or drag) to the wind.

The aerial part **1** will be hollow and will in particular provide housing for the crew necessary for the operation of the structure and the execution of underwater operations, such as offshore drilling operations.

The superstructures above the aerial part 1 will be reduced to a minimum and, for example, in the case of drilling, to the sole derrick located along the vertical axis z'z of the structure.

Under these conditions, the resistance to the wind of the structure according to the invention will be much smaller than that of the floating platforms which have been heretofore proposed.

In order to reduce as much as possible the volume and the weight of the aerial part 1 of the structure, there will be located inside the caissons 5,6,7 all that part of the equipment which does not absolutely need to be located above the water surface and which, in the case of offshore drilling, as hereinafter indicated with reference to FIGS. 4, 5 and 5A, includes most of the heaviest elements of this equipment.

In this way a reduction in the displacements of the structure will be obtained and this all the more as placing the most important loads of this structure in the immersed volumes permits a lighter construction of the assembly of columns and cross-bracing members, increasing at the same time the stability of the whole structure and its moments of inertia, which allows to obtain periods of natural oscillation higher than the highest periods of swell which are usually encountered, thereby protecting the structure against phenomena of resonance to swell.

The small height of the center of gravity of the system above the caissons permits to reduce the section of the columns, thereby keeping a sufficient stability of the structure, the more as the torques due to wind tending to include the structure are very small.

The columns and cross-bracing members will advantageously be profiled (FIG. 1A) in the direction of alongation of the caissons, so as to further reduce the resistance to current.

In the case where the structure according to the invention is used for drilling operations, comprising the lowering and raising of a guide tubing along the axis z'z, an incurved or V-shape will advantageously be given to the cross-bracing member 10 such as, for example, the one illustrated by FIG. 2, so as to clear the axis of the structure, allowing for passage of the drill guide tubing.

FIG. 3 shows a purely illustrative embodiment of the internal arrangement of each of the three caissons, these caissons being identical.

In the bow part of the caissons, constituted by the rounded cap 22, are located ballasting and/or stocking containers 24.

The cylindrical middle part 21 of the caisson is reserved for the installation of a machinery compartment, including for example a diesel engine 25-alternator 26 group supplied with air from the aerial part 1 through the interior of the column surmounting the caisson and the exhaust gases of which are driven to the aerial part 1 through collectors such as 27.

The free remaining space in the cylindrical part 21 may also be occupied by stock containers.

Another stock container, 28 traversed by a tunnel 29 separates the machinery compartment from the stern compartment 30 in which are located the propulsing means, including, on the one hand, a first screw-propeller 31 with adjustable pitch housed in a transverse tunnel 32 and driven by an asynchronous electrical motor 33, and, on the other hand, a second screw propeller with adjustable pitch 34 located outside the caisson and the axis of which coincides with the longitudinal axis of this caisson.

The screw-propeller 34 is driven by an asynchronous electric motor 35 through a shaft line 36.

Each of the columns 2, 3 and 4 is traversed over its whole height by connecting means between the corresponding caisson and the aerial part of the structure.

These means include in particular the exhaust manifolds of the diesel engine housed in the caisson, the ventilation pipes, the lines for remotely controlling the separate devices housed in the caisson from the aerial part of the structure. These connecting means also include electric cables constituted, on the one hand, by the cables connecting the alternator in the caisson with a main switchboard located in the aerial part 1 and, on the other hand, by cables providing the distribution of the electric energy from this switchboard to the respective driving devices.

The column illustrated by FIG. 4 is arranged for the stocking and handling of the rigid tubular elements of a drill string.

This column includes at different levels horizontal stocking areas 37 on which are placed the tubular elements 38. A lifting platform 39 is displaceable along the middle line of the column on a guiding roller track 40

The tubular elements are placed on this platform from their stacking areas.

In the considered embodiment the column traverses from side to side the aerial part 1 and opens out at the upper part thereof, which allows to lift the tubular elements up to the derrick 41 FIGS. 5 and 5A).

In a modification of this embodiment, the tubular elements will be stacked parallely to the respective directions of extension of the columns and the hanging of these elements on the handling means of the derrick will be made easier by locating the top of this derrick substantially in the extension of the column used for stacking the tubular elements.

On FIGS. 5 and 5A have been shown the main elements in an embodiment of the internal arrangement of the aerial part 1 of the structure (the derrick has not been fully illustrated in FIG. 5A) which is equipped for offshore drilling operations.

The drilling equipment includes an assembly located at the base of the derrick, at the upper level of the aerial part 1, this assembly essentially including a rotation table 42 and an annular plate 43 having the same vertical axis z'z as the table 42 and freely rotatable about this axis being supported by a circular roller track 44 integral with the fixed peripheric part of the rotation table.

This place 43 is used for hanging the guide pipe or riser, which is of conventional use in offshore drilling, and all the guide cables providing for connection of the floating structure with the submerged wellhead.

A control system will permit to suppress any rotation of the plate 43 with respect to the sea floor, irrespective of the variations in the heading of the structure.

This control system may in particular include an electric motor 45 capable of rotating the plate 43 with respect to the structure through gear means 46 cooperating with a toothed wheel 47 which surrounds the plate 43 and is integral therewith.

The relative rotation of the plate 43 may be controlled by signals generated by a gyrocompass.

The aerial part 1 of the structure will include at its lower level an opening 48 centered on axis z'z and having a diameter sufficient for allowing the free passage of the different elements of the drill string, of the well head and of their equipments.

The cylindrical space 49 which remains free between the annular plate 43 and the aperture 48 will be advantageously used for the coupling and working up of the heaviest elements of the well head equipment, particularly of the base plate of this well head and of the blowout preventers which can be stacked on areas 50,51 which are specially arranged for this purpose.

All the navigational and pilot spaces of the structure will be placed together in the area 52 of the aerial part 1, located at the head thereof with respect to the normal direction of displacement of the structure. In this area will be in particular located the pilot quarter housing on the one hand the conventional navigational instruments, on the other hand the equipments peculiar to dynamic positioning, as well as the centralizing control station for the machines, including the whole of the devices for remotely controlling the diesel-alternators sets housed in the caissons and also the main switchboard for the electricity supply, including in particular means for coupling the alternators and means for disconnecting and protecting all the networks supplying electricity to the various points of

utilization in the structure. Owing to this centralizing control station for supplying the energy, it is possible to provide for safe and uninterrupted operation of the whole installation in case of failure of one or other of alternator sets, allowing in particular to supply with electric energy the propulsion set of any caisson through the diesel-alternator sets of the other caissons.

The areas which remain vacant inside the aerial part **1**, such as the areas **53** and **54** will be used for accommodation of the whole complement serving afloat.

On the aerial part **1** will be provided a flattened area **55** arranged as a heliport.

I claim:

**1**. Semisubmersible mobile marine structure including three submersible caissons located at the respective apices of a substantially equilateral triangle, said caissons being interconnected by cross-bracing members, an aerial part supported by columns integral with said caissons, the assembly of said cross-bracing members and of said columns constituting a substantially regular tetrahedron, each of said caissons having a streamlined shape and being elongated in a common horizontal direction parallel to an axis of symmetry of said equilateral triangle, each of said caissons having a length in said horizontal direction at most equal to 5 times its greatest vertical width, longitudinal and transverse propulsion means adapted to said submersible caissons for dynamically positioning said structure.

**2**. Semisubmersible mobile marine structure including three submersible caissons located at the respective apices of a substantially equilateral triangle, said caissons being interconnected by cross-bracing members, an aerial part supported by columns integral with said caissons, the assembly of said cross-bracing members and of said columns constituting a substantially regular tetrahedron, each of said caissons having a streamlined shape and being elongated in a common horizontal direction parallel to an axis of symmetry of said equilateral triangle, each of said caissons having a length in said horizontal direction at most equal to 5 times its greatest width, propulsion means adapted to said submersible caissons, said propulsion means forming a system for dynamically positioning said structure and said aerial part being a substantially closed hollow structure having an aerodynamic flattened shape, substantially of revolution around a vertical axis.

**3**. Semisubmersible mobile marine structure according to claim **1**, wherein said aerial part includes a circular working platform rotatable with respect to the remainder of the structure around a vertical axis and which further includes means for rotating said working platform about said axis, and means for maintaining a fixed orientation of said rotatable working platform with respect to the water bottom, irrespective of the variations in the heading of the structure.

**4**. Semisubmersible mobile marine structure according to claim **1**, wherein the center of said aerial part and the center of said equilateral triangle are located substantially on one and the same vertical axis.

**5**. Semisubmersible mobile marine structure according to claim **4**, wherein a derrick is provided on said aerial part, said derrick being substantially located on said vertical axis.

**6**. Semisubmersible mobile structure according to claim **4**, wherein each of said three caissons is provided with means for propulsion in the direction of its axis and with separate transverse propulsion means housed in a tunnel traversing said caisson at right angles to the axis thereof, the tunnels of two of said caissons being aligned along a common axis located in one and the same plane as said vertical axis.

**7**. Semisubmersible mobile marine structure including three profiled submersible caissons located at the respective apices of a triangle having an axis of symmetry, said caissons being interconnected by cross-bracing members, and an aerial part supported by columns integral with said caissons, the assembly of said cross-bracing members and of said columns constituting a tetrahedron, said caissons having a streamline shape and being elongated in a common horizontal direction parallel to said axis of symmetry and having in said horizontal direction a length limited to at most 5 times the greatest width of said caissons and a system of longitudinal and transverse propulsion means adapted to said submersible caissons for dynamically positioning said structure.

**8**. Semisubmersible structure according to claim **1**, adapted for offshore drilling operation, wherein the caissons of said structure include a power station, reserves of fuel, ballast tanks for submersion and an equipment for the circulation of drilling mud connected with said aerial part of the structure through the interior of the columns and wherein said aerial part includes a centralizing station for remotely controlling said propulsion means of the caissons.

**9**. Semisubmersible structure according to claim **1**, wherein at least one of the said columns is used for stacking parallely to said column the elements of a drill string and wherein said aerial part is provided with a derrick, the top of which is substantially located in the extension of said column used for stacking the elements of the drill string.

**10**. Semisubmersible mobile marine structure including three profiled submersible caissons located at the respective apices of a triangle having an axis of symmetry, said caissons being interconnected by cross-bracing members, an aerial part supported by columns integral with said caissons, the assembly of said cross-bracing members and of said columns constituting a tetrahedron, said aerial part being substantially a closed hollow structure having an aerodynamic flattened shape, substantially of revolution around a vertical axis, said caissons being elongated in a common horizontal direction parallel to said axis of symmetry and having a length limited to at most 5 times the greatest width of said caissons and a system of propulsion means adapted to said submersible caissons for dynamically positioning said structure.