Oct. 29, 1968 P. A. WOLFF 3,407,610

SUBMERSIBLE VESSEL HAVING AN IRREGULAR POLYGONAL STABILIZING PATTERN

Filed May 26, 1967

FIG. 1

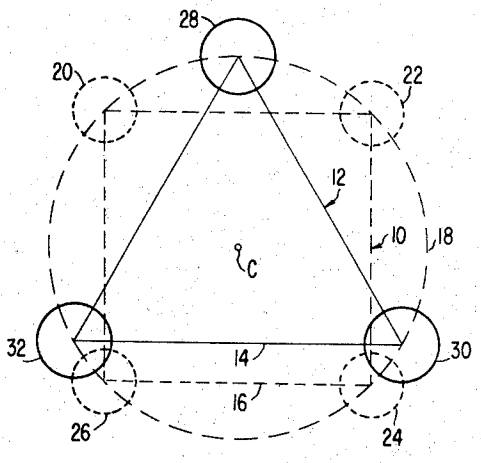


FIG. 2

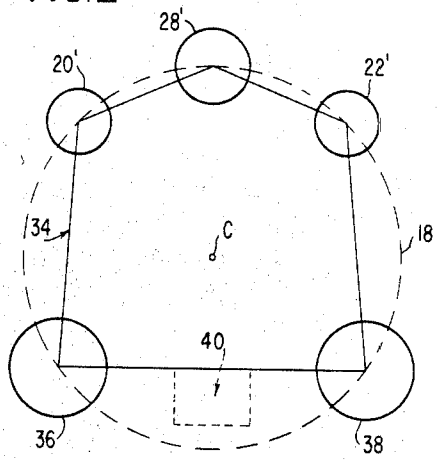
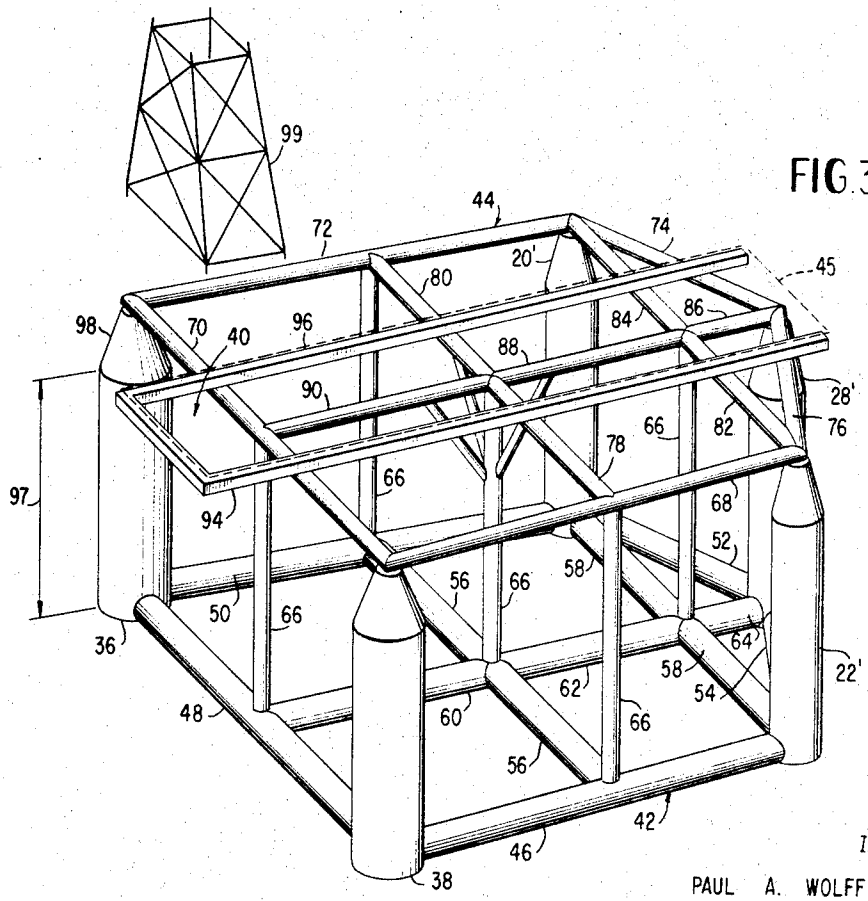


FIG. 3



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United States Patent Office 3,407,610
Patented Oct. 29, 1968

3,407,610

SUBMERSIBLE VESSEL HAVING AN IRREGULAR POLYGONAL STABILIZING PATTERN

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Filed May 26, 1967, Ser. No. 641,578
7 Claims. (Cl. 61—46.5)

ABSTRACT OF THE DISCLOSURE

Submersible vessel for submarine operations, such as off-shore oil well drilling operations, in which upstanding elongated stabilizing members are specially proportioned in cross-sectional area and are located at the apices of an irregular polygon defining a stabilizing pattern for the vessel. The irregular polygonal stabilizing pattern is in the shape of an irregular pentagon and is formed by a combination of a square stabilizing pattern and a regular triangular stabilizing pattern.

This invention relates to submersible vessels for submarine operations such as off-shore oil well drilling operations, and more particularly to submersible vessels of the type disclosed in my prior United States Patent No. 3,246,476, granted Apr. 19, 1966.

A submersible vessel of the type to which the invention pertains comprises a self-contained structure which is floated to a location where the submarine operation is to be performed and at that location is partially submerged below the surface of the water to the underlying land bottom or to a depth intermediate the surface of the water and the land bottom, and maintained in the submerged position during performance of the submarine operation. When the operation has been completed, the vessel may be refloated for movement to another location.

Submersible vessels must possess adequate stability while floating, during submergence or refloating operations, and during performance of the submarine operation when the vessel is submerged. My aforesaid prior patent discloses a construction for submersible vessels which possesses the required order of stability with a minimum use of materials.

Submersible vessels constructed in accordance with the teachings of my prior patent comprise a plurality of upstanding elongated stabilizing members rigidly positioned relative to a base structure. A working platform is supported above and in spaced relationship with the base structure. The elognated stabilizing members are arranged at the apices of a substantial polygon which defines a stabilizing pattern for the vessel. A feature of the invention of my prior patent is that the cross-sectional area of the elongated stabilizing members is proportioned in accordance with the stabilizing pattern to establish moments of inertia of the water plane areas of the plurality of elongated stabilizing members about any axis of heel of the vessel upon submergence of the base structure of magnitudes to maintain the metacenter of the vessel with respect to the axis of heel above the center of gravity of the vessel at any depth of the submergence of the base structure throughout the maximum depth of water to which the vessel is submersible. Thus this feature achieves righting stability. Among other embodiments of the invention, a submersible vessel having a regular polygonal stabilizing pattern in the shape of a square and a submersible vessel having a regular polygonal stabilizing pattern in the shape of a triangle are disclosed in my aforesaid prior patent.

Moments of inertia for structures having stabilizing patterns of regular polygonal shape and having a stabilizing member of given water plane area centered at each

apex of the polygon are equal provided that such apices fall on circles of equal diameter and that the combined water plane areas of the stabilizing members of the structures in each case are equal, so that with respect to righting stability when the base structure of the vessel is without freeboard, the same stability is obtained irrespective of the number of stabilizing members, providing at least three stabilizing members are employed. Thus, with respect to the square and equilateral, triangular stabilizing patterns, if the foregoing provisions are met, vessels with the square and the triangular stabilizing patterns possess the same high order of righting stability when the base structure loses freeboard.

It has been found, unexpectedly, that a particular combination of two regular polygonal stabilizing patterns, one in the shape of a square and the other in the shape of a triangle, set forth in detail hereinafter, produces an overall stabilizing pattern in the shape of an irregular polygon having five apices, i.e., an irregular pentagon which when incorporated in a submersible vessel of the type disclosed in my prior patent, provides the vessel with substantially the same high order of righting stability as is possessed by a vessel with either the square or the triangular stabilizing pattern, so long as the combined water plane areas of the stabilizing members of the vessels with the square, triangular and irregular pentagonal stabilizing patterns, respectively, are equal. A vessel with the irregular pentagonal stabilizing pattern, however, has a higher order of stability against overturning when submerged to the land bottom than a vessel with either the square or the regular triangular stabilizing pattern.

The features and advantages of the present invention will become apparent from the following detailed description, which, when considered in connection with the accompanying drawings, discloses a preferred embodiment of the invention for purposes of illustration only and not for definition of the limits of the invention. For determining the scope of the invention, reference can be made to the appended claims.

In the drawings, in which similar reference characters denote similar elements throughout the several views:

FIGURE 1 diagrammatically shows the mutual relationship of a square pattern and an equilateral triangular pattern as combined to form the basis of the stabilizing pattern of the present invention;

FIGURE 2 schematically shows the irregular polygonal stabilizing pattern derived from the combination of FIGURE 1 and incorporated in submersible vessels constructed according to the present invention; and

FIGURE 3 is an isometric view of a submersible vessel embodying the principles of the invention.

Referring to the drawings in greater detail, and with particular reference to FIGURE 1, a stabilizing pattern **10** of substantially square outline, shown in broken lines, and a stabilizing pattern **12** of substantially equilateral triangular outline, shown in solid lines, are disposed in substantially concentric, coplanar relatitonship, with one side **14** of the triangle being generally parallel to one side **16** of the square to thereby position the apices of the triangular pattern at the farthest possible distances from the sides of the square pattern. The size of the square pattern **10** and the size of the triangular pattern **12** are such that the apices of each fall on circles of substantially equal diameter. This is illustrated in FIGURE 1, in which the apices of square pattern **10** and the apices of triangular pattern **12** lie on common circle **18**. Square pattern **10** and triangular pattern **12** are concentric because they have a common center C, which is also the center of circle **18**.

Vertical elongated stabilizing members **20, 22, 24,** and **26**, diagrammatically shown in horizontal cross-section, are located at the apices of the square pattern **10**. In a

stable vessel with a square stabilizing pattern **10**, according to my prior patent, the cross-sectional area of stabilizing members located at the apices of the square stabilizing pattern, which is to say, the water plane area of such members, would be proportioned in accordance with the distance between the stabilizing members measured along the sides of the square stabilizing pattern to achieve righting stability. However, since according to the present invention the two stabilizing patterns are theoretrically considered to be acting together, the cross-sectional area of stabilizing members **20**, **22**, **24** and **26** can total about one-half the area required to achieve righting stability in my prior square pattern.

The respective cross-sectional areas of the stabilizing members **20**, **22**, **24** and **26** are substantially equal to one another, so that substantially equal moments of inertia of the water plane areas of the stabilizing members are developed about all axes of the vessel. Therefore, the cross-sectional area of each of the stabilizing members **20**, **22**, **24** and **26** is substantially equal to one-fourth of the combined cross-sectional area of these stabilizing members. Since the combined cross-sectional area of stabilizing members **20**, **22**, **24**, and **26** can in the present invention be about one-half that required to establish moments of inertia of magnitudes sufficient to achieve righting stability in a vessel with my square stabilizing pattern **10**, the cross-sectional area of each of the members **20**, **22**, **24**, and **26** can be about one-eighth of the total cross-sectional area of the stabilizing members of a vessel having the square stabilizing pattern **10**.

The cross-sectional area of the stabilizing members **28**, **30**, and **32**, which are located respectively at the apices of triangular stabilizing pattern **12**, would, according to my aforesaid prior patent, be proportioned in accordance with the triangular pattern **12** to achieve righting stability. According to the present invention, however, since two stabilizing patterns are acting together, the cross-sectional area of stabilizing members **28**, **30** and **32** can be proportioned in accordance with the triangular stabilizing pattern to be about one-half the area required to achieve righting stability in accordance with my aforesaid prior patent.

The respective cross-sectional areas of the stabilizing members **28**, **30** and **32** are substantially equal to one another so the cross-sectional area of each of them is substantially equal to one-third of their combined cross-sectional area. Since the combined cross-sectional area of stabilizing members **28**, **30** and **32** can be about one-half that required to establish moments of inertia of magnitudes sufficient to maintain desired stability in a vessel with triangular stabilizing pattern **12**, the cross-sectional area of each of the members **28**, **30** and **32** can be about one-sixth of the total cross-sectional area of the stabilizing members of a vessel having the triangular stabilizing pattern and having stabilizing members located at the apices of the triangular pattern and proportioned in accordance with the triangular stabilizing pattern to achieve righting stability.

In accordance with the present invention, combining the stabilizing patterns **10** and **12**, as shown in FIGURE 1, and proportioning the stabilizing members as discussed above and combining some of them as discussed hereinafter, produces a configuration for a submersible vessel in which the stabilizing members establish moments of inertia of water plane areas of magnitudes sufficient to provide the vessel with substantially the same order of righting stability when the base structure loses freeboard as is possessed by a vessel with either the square stabilizing pattern **10** or the triangular stabilizing pattern **12** and the stabilizing members proportioned in accordance with my prior patent. However, vessels embodying the present invention possess a higher order of stability against overturning when submerged to the land bottom.

Referring now to FIGURE 2, a stabilizing pattern **34**, formed by the substantially concentric coplanar disposition in FIGURE 1 of square stabilizing pattern **10** and triangular stabilizing pattern **12**, is shown to have an irregular polygonal outline having five apices. Stabilizing members **20'**, **28'**, **22'**, **36** and **38** are located at the respective apices of irregular pentagonal stabilizing pattern **34**. Stabilizing members **20'** and **22'** in this figure correspond to the members **20** and **22** in FIGURE 1. Stabilizing member **28'** corresponds to member **28** in FIGURE 1. Stabilizing member **28'** is disposed midway between stabilizing members **20'** and **22'** in terms of clockwise procession along the periphery of the stabilizing pattern **34**, as a result of the concentric, coplanar disposition in FIGURE 1 of square stabilizing pattern **10** and triangular stabilizing pattern **12**.

Stabilizing member **36** is a composite of members **26** and **32** in FIGURE 1 and stabilizing member **38** is a composite of members **24** and **30** of FIGURE 1. The cross-sectional area of stabilizing member **36** is substantially equal to the sum of the cross-sectional areas of stabilizing member **26** and stabilizing member **32** and the cross-sectional area of stabilizing member **38** is substantially equal to the sum of the cross-sectional areas of stabilizing members **24** and **30**. It will be recalled that the cross-sectional area of stabilizing member **26** is substantially equal to the cross-sectional area of either stabilizing member **20** or **22** and the same is true of stabilizing member **24**. Similarly, the cross-sectional area of either of stabilizing members **32** and **30** is substantially equal to the cross-sectional area of stabilizing member **28**. Therefore, the cross-sectional area of each of stabilizing members **36** and **38** is substantially equal to the sum of the cross-sectional area of either stabilizing member **20'** or **22'** and the cross-sectional area of stabilizing member **28'**.

The centers of stabilizing members **36**, **38**, **20'** and **28'** and **22'** all fall on circle **18**. The center of stabilizing member **36** is positioned on circle **18** at a point intermediate the centers of members **26** and **32** and the center of member **38** is located intermediate the centers of members **24** and **30**, the exact location of the center of each member **36** and **38** being arrived at by calculating the moment of inertia of each of these members as the sum of the moments of inertia of the members **26** and **32** in the case of member **36** and the sum of the moments of inertia of the members **24** and **30** in the case of member **38**.

A submersible vessel having a stabilizing pattern **34** has substantially the same high order of floating stability when the base structure loses free-board as a submersible vessel having square stabilization pattern **10** or triangular stabilizing pattern **12**. However, vessel having the irregular pentagonal stabilizing pattern **34** possess a higher order of stability against overturning when submerged to the land bottom because of the more favorable section modulus established by stabilizing pattern **34**. It will be observed that this desideratum has been accomplished without an increase in the maximum radial dimension of the stabilizing pattern over the radial dimensions of square and triangular patterns **10** and **14**. Further, the larger area of ground contact provided by stabilizing members **36** and **38** provides greater vertical stability for a drilling or other operation conducted from location **40** than is provided either by stabilizing members **24** and **26** or by stabilizing members **30** and **32**.

A submersible vessel incorporating the irregular pentagonal tabilizing pattern **34** and including stabilizing members **20'**, **22'**, **28'**, **36** and **38** is shown in FIGURE 3. This vessel comprises a submersible base structure indicated generally at **42** and a platform supporting structure indicated generally at **44**. The latter may be supported on the stabilizing members and a deck or platform **45**, shown in dotted lines, and appropriate apparatus for conducting desired submarine operations may be carried by structure **44**. Base structure **42** includes five elonagted hollow members **46**, **48**, **50**, **52** and **54**, respectively, joined to the bases

of the stabilizing members to form an open frame structure. Base structure **42** may also include a plurality of interconnected elongated hollow members **56, 58, 60, 62** and **64** positioned within the open frame structure and connected to the elongated members **46, 48, 50, 52** and **54** to form a lattice. Elongated members **46, 48, 50, 52** and **54** and the internal members **56, 58, 60, 62** and **64** are rigidly joined together and generally lie in a common horizontal plane and may be of similar cross-sectional size and shape. Auxiliary upright supporting means **66** may be used to connect platform supporting structure **44** and base structure **42** to help support the former above the base structure. Platform supporting structure **44** includes members **68, 70, 72,** and **76,** to which the upper ends of the stabilizing members and columns **66** are connected. Additional structural members **78, 80, 82, 84 86, 88** and **90** may be located within the area defined by members **68, 70, 72, 74** and **76** in generally coplanar relationship therewith to increase the rigidity of the structure and to provide support for platform **45.**

A pair of cantilever beams **94** and **96** may be provided to extend outwardly from the vessel at location **40** to provide a support for drilling means such as derrick **99,** between stabilizing members **36** and **38.** Drilling means **99** are shown in exploded view.

Stabilizing members **36, 38, 20', 28'** and **22'** function to support the platform **45** above the base structure **42,** to stabilize the vessel when floating when the base structure loses freeboard, to provide stability to the vessel during its submergence and refloating operations, as means for controlling ballast to establish the desired bottom reaction, and also in some cases to aid in controlling submergence and refloating of the vessel, as discussed in detail in my aforesaid Patent No. 3,246,476. The lower end portions of the stabilizing members joined to the elongated members **46, 48, 50, 52,** and **54** may be considered as being parts of base structure **42.** The base structure, that is the structure including members **46, 48, 50, 52, 54, 56, 58, 60, 62, 64** and the lower end portions of the stabilizing members **20', 28', 22', 36,** and **38,** provides sufficient displacement to buoyantly support the vessel while maintaining the base structure with freeboard when the vessel is being floated to a location at which submarine operations are to be conducted. The displacement of the base structure and the displacement of the plurality of upstanding elements, the latter displacement being constituted mainly by the displacement of the stabilizing members, are sufficient to buoyantly support the vessel upon submergence of the base structure throughout a depth of water corresponding to the effective height of the stabilizing members.

The stabilizing members comprise vertically disposed elongated hollow cylindrical members having their lower ends closed by end plates (not shown). Each elongated stabilizing member presents continuous external surfaces and is of appreciable cross-sectional area throughout its effective height. In the embodiment illustrated, the major portion **97** of the height of the stabilizing members extending upwardly from the base structure is of substantially constant diameter to provide a cross-section defining a substantially uniform area throughout its height, which comprises the effective height of the stabilizing members and determines the maximum depth of water in which the vessel is submersible. The remaining portion **98** of the stabilizing members provides wave clearance beneath the platform **44** when the vessel is submerged in the maximum depth of water and is of reduced cross-sectional area to minimize wave action influence upon the vessel.

The elongated hollow members forming the base structure and the stabilizing members **36, 38, 20', 28'** and **22'** are preferably of non-rectangular cross-section, such as elliptical or circular cross-section, because the vessel is subject to hydrostatic pressures. Such members are shown in the form of hollow cylindrical elements which may be fabricated from formed and welded steel plates. The elongated hollow members of the base structure are provided with spaced bulkheads (not shown) to segregate the members into a plurality of water-tight ballast compartments which are provided with suitable pumps, valves and conduits for controlling ballast in the compartments, as set forth in my aforesaid prior patent. The stabilizing members are also preferably formed to provide water-tight ballast compartments provided with suitable pumps and conduits for controlling ballast therein. The base structure displaces a volume of water in accordance with the total mass of the vessel including the weight of apparatus and supplies required for the submarine operation to buoyantly support the vessel with the base structure having freeboard, when compartments of the base structure and the stabilizing members are properly deballasted.

When it is desired to submerge the vessel, sufficient ballast is selectively added to the compartments of the base structure to submerge the base structure below the surface of the water. When the base structure loses freeboard, vertical stability of the vessel and righting stability of the vessel about any axis of heel are obtained by the stabilizing members **36, 38, 20', 28',** and **22'.** Since the effective height of the stabilizing members corresponds to the maximum depth of water in which the vessel is submersible, all phases of stability will be maintained throughout the submergence of the base structure. As the buoyance presented by the stabilizing members increases upon continued submergence of the base structure below the surface of the water (vertical stability), it is necessary to controllably add ballast continuously to the compartments throughout submergence of the vessel. Upon submergence of the base structure to the land bottom, ballast is regulated to establish the desired bottom reaction and it may be convenient to controllably add ballast to the stabilizing members for this purpose. When it is desired to refloat the vessel, any ballast added to the stabilizing members is removed and then ballast is selectively removed from the compartments of the base structure to render the vessel buoyant. Thereafter, the vessel may be refloated in accordance with the rate of ballast removal from the compartments of the base structure.

Although the present invention has been described in connection with a preferred embodiment, resort can be made to modifications of the embodiment illustrated without departing from the spirit of the invention, as those skilled in the art will understand. Such modifications are considered to be within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A submersible vessel, comprising

a submersible base structure,

a platform, and

supporting means for supporting the platform above and in spaced relationship with the base structure,

the supporting means including a plurality of upstanding elements associated with and extending upwardly from the base structure,

the plurality of upstanding elements including five elongated stabilizing members, each extending upwardly an effective height above the base structure, the effective height being equal to the maximum depth to which the vessel is submersible,

each elongated stabilizing member being located at an apex of an irregular pentagon defining a stabilizing pattern having an outline formed by substantially concentric coplanar dispositon of a stabilizing pattern of substantially square outline and a stabilizing pattern of substantially equilateral triangular outline, with one side of the triangular stabilizing pattern generally parallel to one side of the square stabilizing pattern, and with all the apices of the triangular

stabilizing pattern and all the apices of the square stabilizing pattern located on a common circle,

the cross-sectional area of the five stabilizing members throughout the effective heights thereof being proportioned in accordance with the stabilizing pattern to establish moments of inertia of the water plane areas of the five stabilizing members about any axis of heel of the vessel upon submergence of the base structure of such magnitudes as to maintain the metacenter of the vessel with respect to the axis of heel above the center of gravity at any depth of submergence of the base structure throughout the maximum depth to which the vessel is submersible.

2. A submersible vessel as defined in claim 1, wherein the cross-sectional area of the five stabilizing members is substantially equal to about one half the sum of

the cross-sectional area of the stabilizing members of a first hypothetical vessel having stabilizing members located at the apices of the square stabilizing pattern and proportioned in accordance with the square stabilizing pattern to establish moments of inertia of the water plane areas of the stabilizing members of the first hypothetical vessel about any axis of heel of the first hypothetical vessel of such magnitudes as to maintain the metacenter of the first hypothetical vessel with respect to the axis of heel above the center of gravity at any depth of submergence throughout the maximum depth to which the first hypothetical vessel is submersible, and

the cross-sectional area of the stabilizing members of a second hypothetical vessel having stabilizing members located at the apices of the triangular stabilizing pattern and proportioned in accordance with the triangular stabilizing pattern to establish moments of inertia of the water plane areas of the stabilizing members of the second hypothetical vessel about any axis of heel of the second hypothetical vessel of such magnitudes as to maintain the metacenter of the second hypothetical vessel with respect to the axis of heel above the center of gravity at any depth of submergence throughout the maximum depth to which the second hypothetical vessel is submersible.

3. A submersible vessel as defined in claim 2, wherein

the cross-sectional area of each of two of the five stabilizing members, throughout the effective height thereof, is about one-eighth of the total cross-sectional area of the stabilizing members of the first hypothetical vessel, and

the cross-sectional area of a third stabilizing member throughout the effective height thereof is about one-sixth of the total cross-sectional area of the stabilizing members of the second hypothetical vessel,

4. A submersible vessel as defined in claim 3,

the cross-sectional area of each of fourth and fifth stabilizing members being equal to about one-half the sum of the cross-sectional area of a stabilizing member of the first hypothetical vessel and the cross-sectional area of a stabilizing member of the second hypothetical vessel,

the center of the cross-sectional area of each of the fourth and fifth stabilizing members being positioned to establish a moment of inertia of the water plane area of each of the fourth and fifth stabilizing members of a magnitude equal to about one-half the sum of the moment of inertia of the water plane area of said stabiiizing member of the first hypothetical vessel and the moment of inertia of the water plane area of said stabilizing member of the second hypothetical vessel.

5. A submersible vessel as defined in claim 1, wherein the five stabilizing members consist of

first and second stabilizing members, each having substantially the same cross-sectional area throughout its effective height as the other,

a third stabilizing member having a cross-sectional area throughout its effective height which is greater than the cross-sectional area of each of the first and second stabilizing members,

the tliird stabilizing member being disposed between said first and second stabilizing members, along the periphery of the irregular pentagonal stabilizing pattern, and

fourth and fifth stabilizing members, each having a cross-sectional area throughout its effective height which is substantially equal to the sum of the cross-sectional area of one of said first and second stabilizing members, and the cross-sectional area of the third stabilizing member,

said fourth and fifth stabilizing members being disposed between said first and second stabilizing members along the periphery of the irregular pentagonal stabilizing pattern.

6. A submersible vessel as defined in claim 5,

the third stabilizing member being substantially equidistant from said first and second stabilizing members along the periphery of the irregular pentagonal stabilizing pattern,

said fourth stabilizing member being spaced from said first stabilizing member a distance substantially equal to the distance the fifth stabilizing member is spaced from said second stabilizing member, along the periphery of the irregular pentagonal stabilizing pattern, and

the centers of the cross-sectional areas of said fourth and fifth stabilizing members being spaced from each other a distance along the periphery of the irregular pentagonal stabilizing pattern which is greater than a side of the square stabilizing pattern and less than a side of the triangular stabilizing pattern.

7. A submersible vessel as defined in claim 5, and further comprising,

drilling means supported by the platform at a location between the fourth and fifth stabilizing members.

References Cited

UNITED STATES PATENTS

3,241,324	3/1966	Storm et al.	61—46.5
3,246,476	4/1966	Wolff	61—46.5

JACOB SHAPIRO, *Primary Examiner.*