United States Patent

[11] 3,585,801

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[73] Assignee **Brown & Root, Inc.**

[54] **OFFSHORE TOWER**
12 Claims, 24 Drawing Figs.

[52] **U.S. Cl.** **61/46.5, 61/52**
[51] **Int. Cl.** **E02b 17/00, E02d 21/00**
[50] **Field of Search** 61/46.5, 46, 50, 52

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Primary Examiner—Jacob Shapiro
Attorney—Burns, Doane, Benedict, Swecker & Mathis

ABSTRACT: A tower suitable for use in offshore well operations and the like and including a plurality of generally vertical columns extending from the bed of a body of water to a position above the surface of the body of water for supporting a platform thereupon. A quaternary batter brace system is connected to the generally vertical columns in a position intermediate the ends of the columns and beneath the surface of the body of water. Piling jacket clusters are connected to the free end of each of the batter brace members and are designed to rest upon the bed of the body of water. A plurality of piles extend through the batter piling jacket clusters and pin the offshore tower to the bed of the body of water. A reinforcing lattice connects adjacent batter brace members and pile jacket clusters solely on opposite sides of the vertical columns. The region between alternate batter braces and pile jacket clusters on opposite sides of the vertical columns are free of inner connecting reinforcing structure.

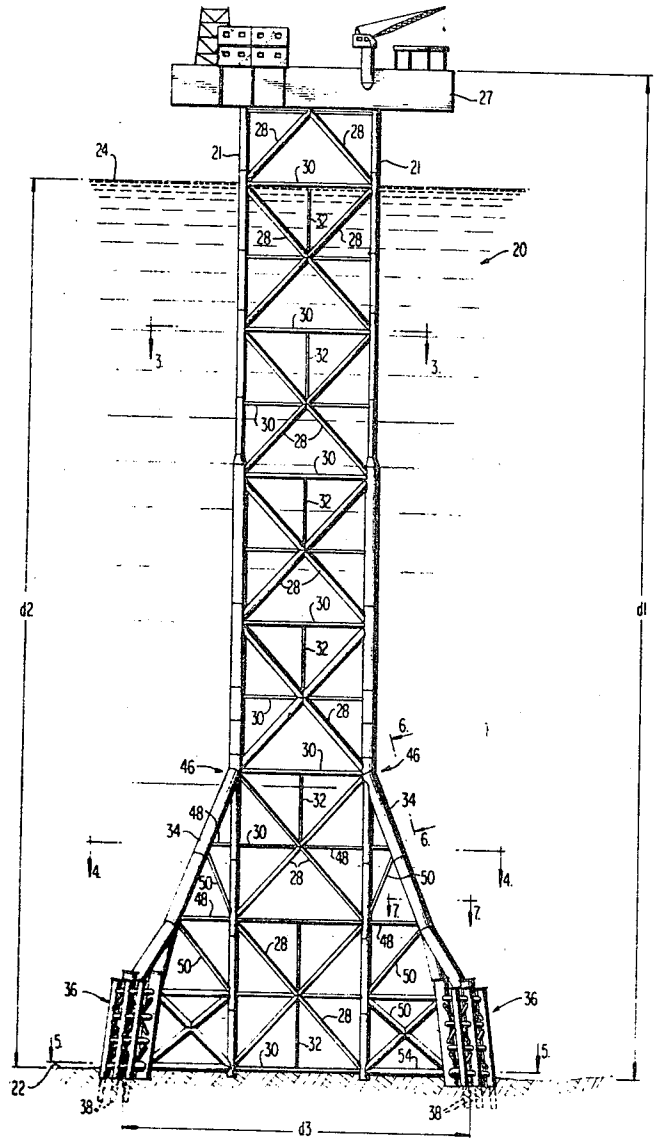
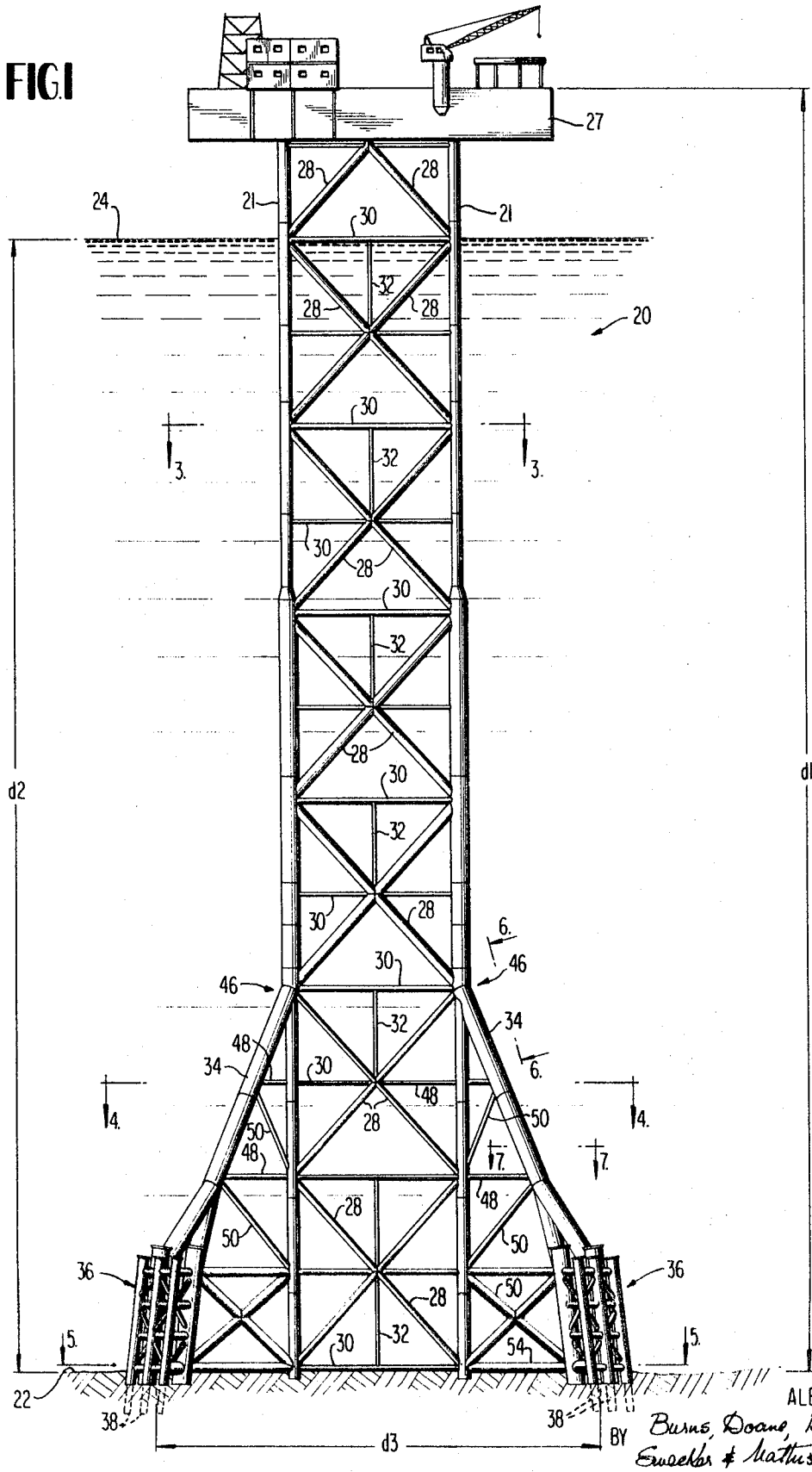


FIG. 1



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FIG2

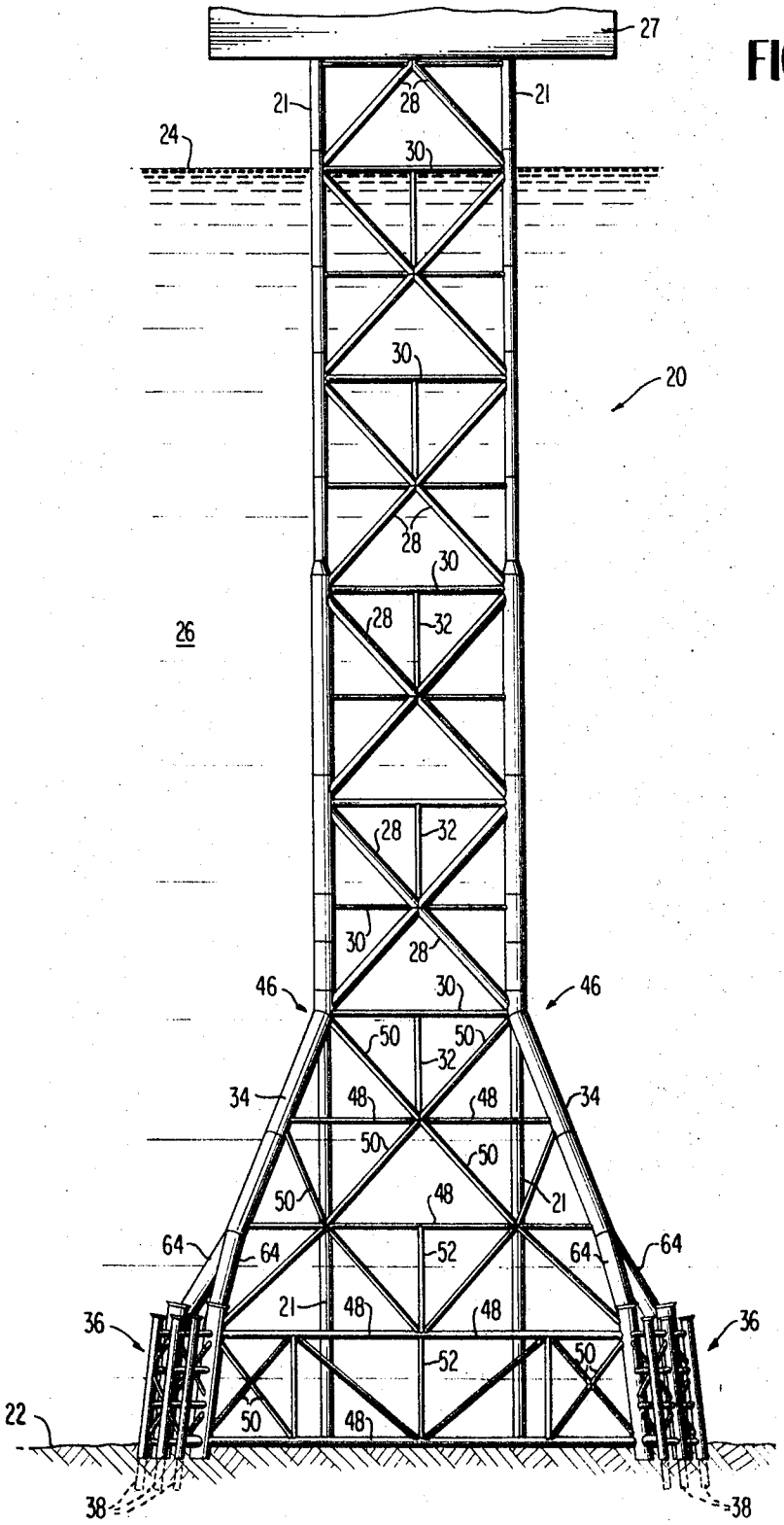

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FIG.3

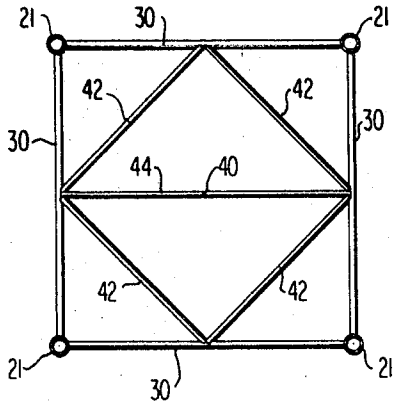
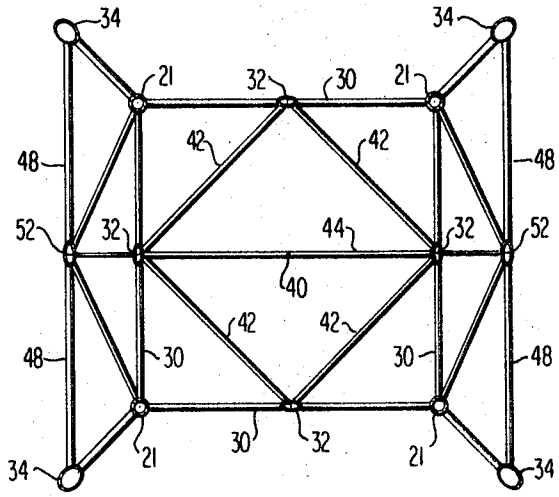


FIG.4



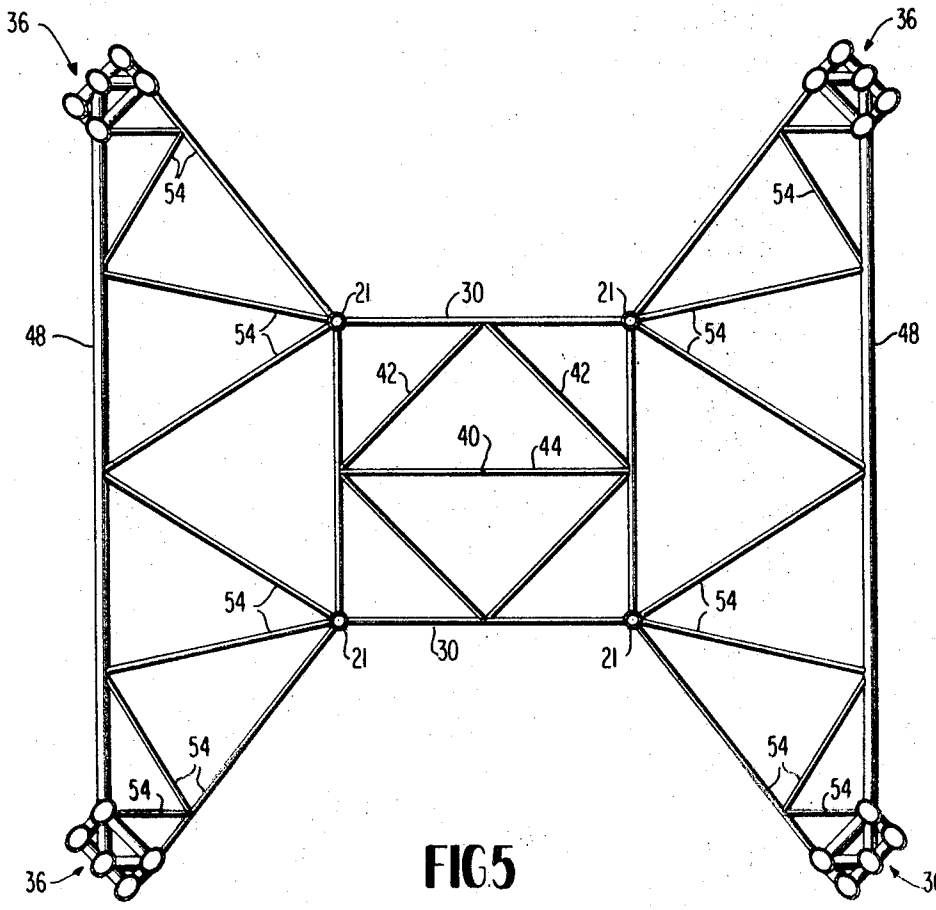
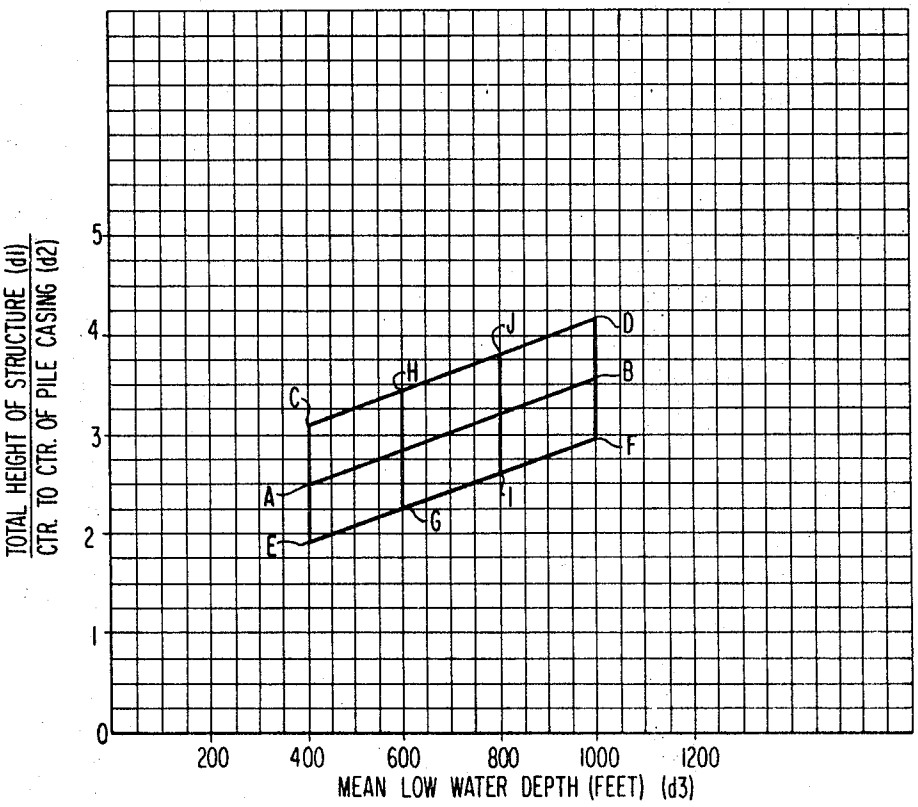


FIG.5

FIG.12


TOTAL HEIGHT OF STRUCTURE (d1)
CTR. TO CTR. OF PILE CASING (d2)
0
1
2
3
4
5
200
400
600
800
1000
1200
MEAN LOW WATER DEPTH (FEET) (d3)
A
B
C
D
E
F
G
H
I
J

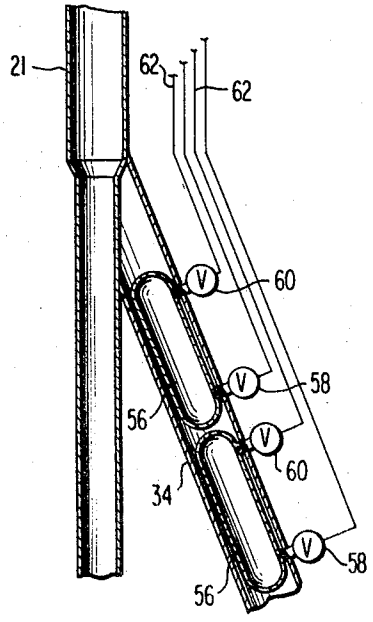

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FIG.6

FIG.7

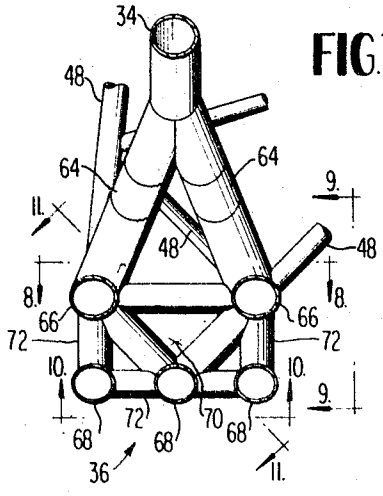


FIG.8

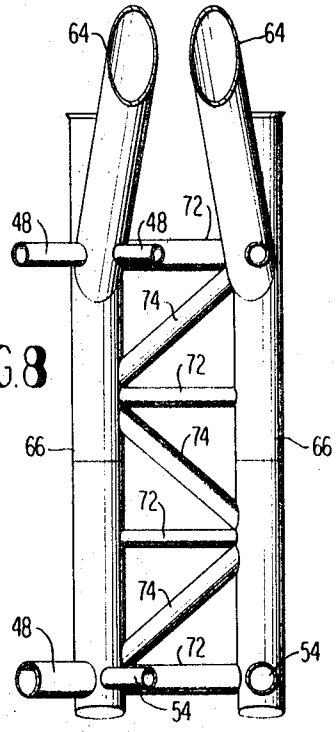


FIG.9

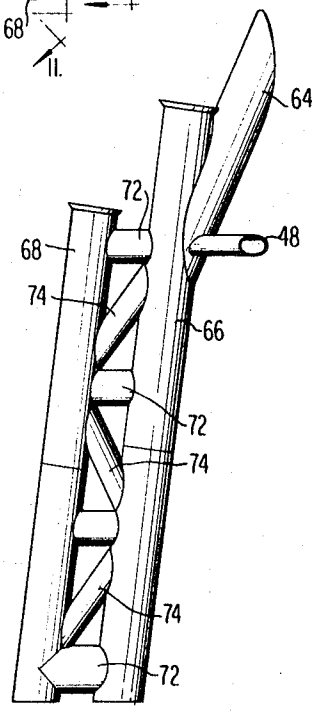


FIG.10

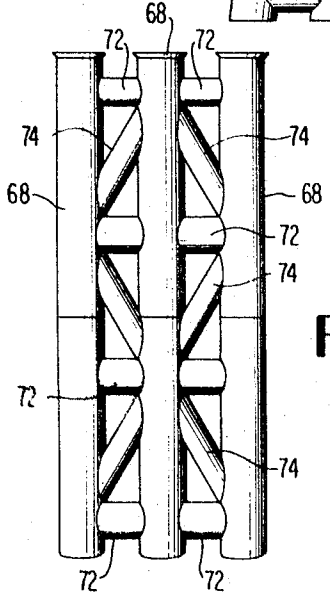


FIG.11

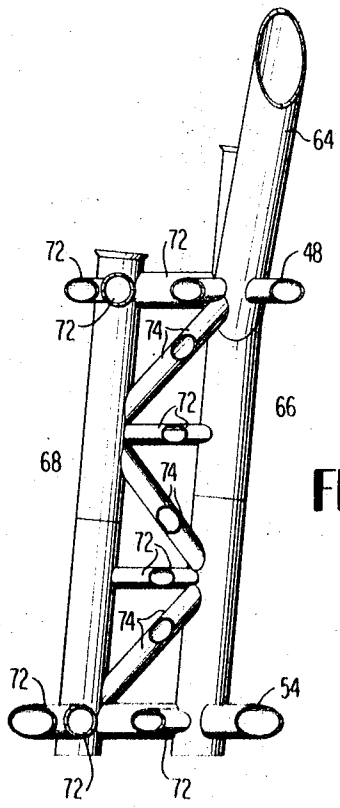


FIG13a

FIG13b

FIG13c

FIG13d

FIG13e

FIG13f

FIG13g

FIG14a
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82
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FIG14b
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82
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36

FIG14c
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21
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FIG14d
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FIG14e
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OFFSHORE TOWER

BACKGROUND OF THE INVENTION

This invention relates to an offshore tower of the type adapted to be positioned on the bed of a body of water with portions of the tower extending upwardly above the surface of the water, such as for example an offshore drilling platform, a radar tower, or the like.

Drilling for oil in oil or gas fields situated beneath the surface of a body of water, such as the ocean or sea, is frequently performed by utilizing a drilling tower supported upon the seabed and extending above the surface of the water. Many oil-yielding formations have been located along the nearshore portions of the Gulf of Mexico in water 50 to 350 feet in depth. In these locations offshore structures have been designed which consist of piling jackets with an apparent batter of approximately one to eight, pilings, and a deck. The piles are driven through the jacket legs into the bed of a body of water and the deck is mounted on top of the piles which extend through the upper portion of the jacket legs. This type of structure has subsequently been used almost exclusively in all parts of the world for offshore drilling and production platforms. The jacket concept developed for the Gulf of Mexico, however, is based on a design to withstand aerodynamic and hydrodynamic loads created by a high wind and wave environment. In this regard conventional platforms have been fabricated which are structurally as rigid as possible.

While structurally rigid towers are often acceptable and even desirable, in many instances, however, as in locations of potential seismic disturbances, a somewhat flexible tower design is more desirable to withstand the forces created by shifting earth formations. In regions of potential seismic disturbances, such as for example, the Santa Barbara Channel in California or the Cook Inlet in Alaska, it would be highly desirable to provide a tower which would be flexible and thereby minimize the seismic loading.

In water depths exceeding 200 feet conventional tower structures are often reinforced with skirt piles angled from the platform to the seabed to carry added loads. This combination of a conventional tower jacket and full length skirt piling becomes uneconomical in water depths exceeding 300 to 400 feet.

Further, known devices having a skirt piling are frequently deployed in a generally closed conical fashion from the jacket structure around the central jacket column. In these instances it is difficult to drill a plurality of wells from the tower because the conical piling structure obstructs the placement of conductors and the drill string from the drilling platform. Further, in this regard it has been difficult to connect a riser, or generally J-shaped conduit, to the slanted and vertical surfaces presented by conventional skirt reinforced column jackets.

A still further problem with conical base structures has been the difficulty in transporting and erecting the structures with conventional equipment. In this connection it will be appreciated by those skilled in the art that deep water offshore towers are enormous in size and weight, therefore movement and erection problems are very significant.

It would therefore be highly desirable to provide a tower which would be economical to construct in water depths from 400 to 1,000 feet or more. Further, it would be desirable to provide an offshore tower having a spread base structure that would permit a vertical riser to be connected to the central column portion and also would permit undestructed deployment of a conductor and drilling string at varying angles from the platform around the base of the tower structure to drill a plurality of wells. Additionally, it would be desirable to provide a tower having a spread base structure which could be transported to an offshore location by conventional barge equipment and conveniently erected at the offshore site.

OBJECTS AND SUMMARY OF THE INVENTION

Objects

It is therefore a general object of the invention to provide an offshore tower and method of erecting the tower designed to obviate or minimize problems of the type previously described.

It is a specific object of the invention to provide an offshore tower of the type adapted to rest upon the bed of a body of water which will exhibit a particularly rigid and rugged construction to withstand excessive environmental aerodynamic and hydrodynamic forces, while simultaneously being flexible enough to minimize seismic loads.

It is another object of the invention to provide a method of establishing an offshore tower in water depths of 400 to 1,000 feet which will withstand seismic loads.

It is a further object of the invention to provide an offshore lower which will facilitate the connection operation of a riser.

It is a still further object of the invention to provide an offshore tower which will permit drilling operations to proceed unobstructedly in a plurality of locations from and about the platform resting upon the offshore tower.

It is yet a further object of the invention to provide an offshore tower which may be suitable to rest in water having depths from 400 to 1,000 feet or more, and withstand aerodynamic, hydrodynamic and seismic loads, yet which may be conveniently transported to an offshore location by conventional transporting equipment.

It is yet another object of the invention to provide a deep water offshore tower structure and method of erecting the tower in a safe and convenient manner.

BRIEF SUMMARY

One preferred embodiment of the invention intended to accomplish at least some of the foregoing objects comprises an offshore tower adapted to rest upon the bed of a body of water, with portions of the tower extending above the surface of the water to support a platform thereon. The tower includes a plurality of generally vertical columns extending from the bed of the body of water to a position above the surface of the water.

A quaternary, or four member, batter brace system is connected to the generally vertical columns at a position intermediate the lengths thereof and descends toward the bed of the body of water. A batter pile jacket cluster is connected to the free end of each of the batter brace members and is designed to rest upon the body of water. A plurality of piles may then be extended through the batter pile jacket clusters to pin the offshore tower to the bed of the body of water. A reinforcing lattice connects adjacent pairs of the batter brace members and jacket pile clusters solely on opposite sides of the vertical columns. The region, therefore, between adjacent batter braces and jacket pile clusters on alternate sides of the vertical columns is free from any interconnecting reinforcing structure; thus facilitating drilling operations and riser installation.

A significant method aspect of the invention comprises erecting an offshore tower having generally watertight columnar members extending the vertical length thereof with batter brace members connected thereto and batter pile jackets connected to the free ends of each batter brace member comprising the steps of: floating the offshore tower in a horizontal posture on a flat barge to a desired location, pulling the flat barge from beneath the offshore tower, thus leaving the tower disposed generally along the surface of the body of water, filling ballast chambers solely within the batter brace members to induce a pivoting of the offshore tower about its center of buoyancy into a generally vertical posture, providing for a generally vertical descent until the batter piling jackets rest upon the bed of the body of water and pinning the offshore tower to the body of water by securing pilings within the jacket clusters and embedding them within the bed of the body of water.

THE DRAWINGS

Other objects and advantages of the present invention will become apparent from the following detailed description of a preferred embodiment as illustrated in the accompanying drawings, in which:

FIG. 1 is a side elevational view of an offshore tower adapted to rest upon the bed of a body of water and having a portion thereof extending above the surface of the body of water for supporting a platform thereupon;

FIG. 2 is a side elevational view of the offshore tower shown in FIG. 1;

FIG. 3 is a cross-sectional view of the offshore tower disclosed in FIG. 1, taken along secton line 3–3, disclosing the orthogonal interconnecting bracing of the tower structure;

FIG. 4 is a cross-sectional view of the offshore tower disclosed in FIG. 1, taken along section line 4–4, disclosing a portion of the batter brace members and the interconnecting reinforcing lattice between adjacent batter brace members solely on opposite sides of the tower columnar structure;

FIG. 5 is a cross-sectional view of the offshore tower disclosed in FIG. 1 taken along section line 5–5, disclosing pile jacket clusters positioned at the corners of the tower structure and the interconnecting reinforcing lattice extending between adjacent pile jacket clusters solely on opposite sides of the main columnar structure;

FIG. 6 is a sectional view of a portion of the offshore tower structure disclosed in FIG. 1, which discloses the ballast tanks solely within the interior of the batter brace members;

FIG. 7 is a cross-sectional view of the offshore tower structure disclosed in FIG. 1, taken along section line 7–7, disclosing the particular arrangement and construction of the batter pile jacket clusters forming an aspect of the tower structure;

FIG. 8 is a cross-sectional view of the pile jacket cluster shown in FIG. 7, taken along section line 8–8;

FIG. 9 is a cross-sectional view of the pile jacket cluster shown in FIG. 7, taken along section line 9–9;

FIG. 10 is a side elevational view of the batter pile jacket cluster disclosed in FIG. 7, taken along section line 10–10;

FIG. 11 is a cross-sectional view of the batter pile jacket cluster as shown in FIG. 7, taken along section line 11–11;

FIG. 12 graphically illustrates optimum tower parameters for maximizing the capabilities of the tower structure to withstand seismic loads;

FIGS. 13*a*—*g* disclose in schematic form, a method of assembly and erection of an offshore tower; and

FIGS. 14*a*—*e* disclose in schematic form an alternate method of erecting an offshore tower structure.

DETAILED DESCRIPTION

Tower Structure

Referring to the drawings and particularly to FIG. 1 there will be seen disclosed a preferred embodiment of the invention. An offshore tower 20 includes a plurality of generally vertical columns 21 which extend between the bed 22 and the surface 24 of a body of water 26. The generally vertical columns 21 further extend above the body of water 26 and are designed to support a platform 27 in a generally horizontal posture. The platform may be of the multilevel type suitable to support living quarters and a plurality of drilling rigs with the attendant equipment necessary to sustain extended drilling operations in a plurality of locations around the base of the tower. In this connection, 48 or more wells may be drilled from a single tower structure.

Referring in more detail to FIGS. 1 and 2, the generally vertical columns 21 are interconnected with orthogonal support and bracing struts 28 deployed along the length of the columns 21 which form a generally diamond-shaped pattern as viewed in FIG. 1. Horizontal bracing members 30 are further employed at various levels along the length of the vertical columns and are connected with vertical braces 32 which lie generally parallel to the vertical columns 21 and serve to interconnect horizontal bracing members 30 to enhance the stability of the tower structure and support conductors (not shown) which would contain drilling strings. These conductors would be located within the central square tower structure.

It will be further noted by referring to FIGS. 1 and 2 that the cross-sectional diameter of the generally vertical columns 21 may be suitably dimensioned to accommodate an increasing load which must be supported as the height of the tower structure is increased. The central portion of the column thus may have a larger diameter than the top portion or the portion of the column 21 which is below a quaternary batter brace system.

In this connection the vertical load bearing capabilities and ability of the tower to withstand aerodynamic, hydrodynamic and seismic loads, are enhanced by batter brace members 34 which are fixedly connected to the vertical legs 21 in a position intermediate the ends thereof and below the water level as at 46. The batter brace members descend in a slanting fashion away from the vertical columns 21 to provide the offshore tower with a stabilizing spreading base structure.

Attached to the free end of each batter brace member 34 is a cluster 36 of batter pile jackets or casings. These casings serve to house a plurality of batter pilings 38 which pin the offshore tower to the bed of the body of water. The pilings 38 are coupled to the individual pile casings in a manner which will be further discussed hereinafter.

Referring now to FIG. 3, a cross-sectional view of an upper portion of the offshore tower 20 is shown taken along section line 3–3 in FIG. 1. It will be seen that the tower is provided with four generally vertical legs 21 which are symmetrically disposed about a generally vertical axis 40. The generally horizontal brace members 30, as previously discussed, orthogonally connect and serve to hold in a fixed position the four vertical legs 21. Additionally, a second orthogonal grouping of brace members 42 are provided which are disposed in a plane coincident with the plane passing through the brace members 30. The secondary grouping is rotated 90° with respect to the brace members 30. Thus the orthogonal grouping of brace members 42 serves to fixedly connect and brace the offshore tower legs 21 and horizontal brace members 30 from being displaced into a parallelogram configuration when a high hydrodynamic or aerodynamic load is received on the tower structure. To even further enhance the stability of the tower, a cross bracing member 44 is disposed between opposite corners of the secondary orthogonal bracing members 42. It will be realized that the orthogonal groupings of braces 30 and the groupings of braces 42 and the cross bracing 44 all receive virtually no vertical loading but serve the function of counteracting lateral forces on the generally vertical columns 21 nd horizontally support the conductors.

Referring again to FIGS. 1 and 2, and in conjunction with FIG. 4, it will be seen that a cross-sectional view taken along section line 4–4 of FIG. 1 discloses a central orthogonal bracing network as previously discussed in connection with FIG. 3. In addition it will be seen that lateral batter brace members 34 extend from each of the legs 21 at a position intermediate the ends thereof as generally depicted at points 46. The batter brace members 34 are fixedly interconnected solely on opposite sides of the tower by a lattice network of generally horizontally disposed brace members 48, which are interconnected with slanting strut members 50 to provide an interconnecting lattice work which serves both a lateral bracing and vertical support function. A vertical tie member 52 is disposed between adjacent horizontal braces 48 and in the uppermost instance between brace members 48 and brace members 30 for the purpose of further interconnecting the various struts and braces to solidify the resulting bracing and supporting network.

Referring now to FIG. 5, there is shown a sectional view of the offshore tower 20 taken just above the mudline of the bed 22 of the body of water 26 at section line 5–5 of FIG. 1. It will be seen again that the central columnar structure is composed of vertical columns 21 with interconnecting orthogonal brac-

ing members 30 and 42 as previously depicted and discussed at the elevations taken through sections 3–3 and 4–4 of FIG. 1. Thus, it will be appreciated that the central columnar structure is uniform throughout and provides the necessary supporting capabilities to accommodate a large portion of the vertical loads provided by the platform and drilling equipment while maximizing the symmetry and repetitive components which may be utilized in the central core structure. Mass production techniques may therefore be utilized for the structural components and the structure may be fabricated in subassemblies.

It will be further seen, by referring to FIG. 5, that a cluster 36 of batter pile casings are disposed symmetrically about the tower axis 40 and directly connect with the batter brace members 34 in a manner which will be more fully discussed hereinafter. The batter pile casing clusters 36 are connected by bracing members 48 and struts 50 to the lattice network of bracing members and struts which connect adjacent batter brace members 34. It will be further noted that the adjacent horizontally disposed brace members 30 and 48 which are juxtaposed to the mud line are interconnected to each other a plurality of brace members 54.

Turning now to FIG. 6 there is disclosed a segmental portion of one of the generally vertical columns 21 and a connecting batter brace member 34. Vertical columns 21 are weldably joined at their various junctions locations along the lengths thereof in a watertight manner such that the vertical columns may be devoid of water even in the erected position for reasons which will be more fully discussed hereinafter. The batter brace members 34 which depend from the vertical columns 21 are further welded in place in a watertight manner but are internally provided with ballast chambers 56.

Each of the ballast chambers 56 is provided with a valve 58 which may be actuated by conventional means to establish fluid communication with the body of water 26 or provide an effective high pressure seal. An additional valve 60 is provided in each of the ballast chambers 56 and connects via a high pressure line 62 to the surface whereby air may be selectively introduced into the ballast chambers to blow fluid therefrom when it is desired to raise the offshore tower structure 20. These ballast chambers are provided solely in the batter brace members 34 and are symmetrically disposed about the vertical axis 40.

Thus, it will be realized that in launching operations the ballast chambers may be selectively opened to admit fluid thereinto for the purpose of rotating the slightly positively buoyant central columnar structure, which includes the watertight vertical columns 21, to a generally vertical posture. By the establishment of the center of gravity of the overall structure below the center of buoyancy of the structure, a vertical descent of the offshore tower 20 is insured.

Turning now to FIGS. 7—11, there will be seen a batter pile jacket or casing cluster 36 in various views. Referring now in detail to FIG. 7, the lower portion of a batter brace member 34 is shown having a bifurcated end portion 64 which unites directly with two batter pile casings 66. The casings 66 combine with three similar batter pile casings 68 having generally parallel axes to form a cluster 36 of batter pile casings. The cluster 36 has an axis 70 which is parallel with the axes of the individual piling jackets and is disposed equidistantly from the axes of piling jackets 66 and the most remote piling jackets 68.

Referring now specifically to FIGS. 8—11, there will be seen various views of the batter pile casing cluster 36, as taken along section lines 8–8 to 11–11 of FIG. 7. The piling jackets 66 and 68 are interconnected by a plurality of generally horizontal brace members 72 and sloping struts 74.

The pile jackets 66 and 68 are designed to receive pilings 38 which may be driven from the platform through the jackets and into the bed 22 of the body of water 26. The pilings extend from the platform 27 and are guided against lateral buckling by conventional guide collars 25 (note FIGS. 13 and 14). The pilings may be set by conventional techniques such as driving or jacking. The dimensions of the pilings 38 and jackets 66 and 68 are such that a concentric space is formed between the exterior of the piling and the interior of the jacket or casing. This space may be suitably filled with grouting or the like to fixedly couple the jackets to the pilings and thus secure the tower structure to the bed of the body of water. While in many instances grouting alone is sufficient to fixedly connect the piling and the outer jacket, in some instances it may be desirable to weld annular rings (not shown) around the outer periphery of the piling and the inner periphery of the jacket. The rings are provided with sloping finger members to bind with the grouting and insure a secure interlock between the jacket and the piling. For a more detailed description of this grouting technique and structure reference may be had to a Hauber et al. U.S. Pat. No. 3,315,473, assigned to the assignee of this application. The disclosure of this patent is hereby incorporated by reference as though set forth at length.

After the pilings have been grouted in place, the portion of the pilings extending above the top of the piling jackets 66 and 68 may be severed by conventional techniques, such as underwater torch cutting or explosive severing, and thus the pilings need not extend to the surface as is the case with many conventional offshore structures secured by pilings.

Seismic Structural Parameters

The development of the specific structure described above took into consideration a multiplicity of design considerations, such as, for example, aerodynamic loads, hydrodynamic loads, seismic loads, loads resulting from drilling operations and production and storage, and dead loads of the total structure.

Of these various loads it was determined that in the design of a reliable offshore tower structure, the seismic loading was of paramount significance. This determination was reached from an analytical study of an elastic lump mass system which took into consideration the dead weight of the structure, the weight of water displaced by the column members, the water contained within the column members, the drilling and production loads, and the overall structure dimensional ratios. An earthquake spectra was developed from the 1940 El Centro earthquake and ground accelerations of 33 percent and 50 percent were used for studying the elastic and plastic designs, respectively.

From the above generally outlined considerations it has been determined that an offshore tower of the general configurations disclosed in FIGS. 1—11 should, for seismic considerations, optimumly exhibit for a particular given means low water depth ($d3$), a desirable dimensionless ratio of the total tower height ($d1$) taken from the mud line 22 to the top of the platform 27 divided by the lateral distance ($d2$) the mud line between the axes 70 of adjacent batter pile jacket casing clusters 36.

In this connection FIG. 12 is a plotting of these desired optimum ratios for various means low water depths. The ordinate or Y-axis comprises the dimensionless ratio of the total height of the offshore tower structure ($d1$) to the lateral distance ($d2$) from corner to corner of adjacent pile clusters 36 taken from the central axes 70 thereof and along the mud line or bed of the body of water 22. The abscissa or X-axis comprises the means low water depths ($d3$) in feet of the body of water 26.

Referring now specifically to the graph, point A has an ordinate value of 2.5 and an abscissa value of 400. Point B has an ordinate value of 3.6 and abscissa value of 1000. The nature of the locus of points forming line A–B comprises the optimum ratios of ($d1$) to ($d2$) at particular mean low water depths ($d3$). The equation of line A–B may be expressed by the following formula:

$(d1)/(d2)=0.00183(d3)+a1.77$. The nature of line A–B was quite unexpected inasmuch as it will be recognized that the optimum ratios of the total tower height ($d1$) to the distance between the corners of adjacent pile casing groups ($d2$) did

not remain constant as would be expected but increased linearly as water depths ($d3$) increased.

While line A–B comprises the optimum ratio values at various mean low water depths it has been determined that a range of variants would be permissible which will still provide a tower that will successfully withstand seismic loading. In this connection it has been determined that an upper bound is line C–D and a lower bound in line E–F. Point C has an ordinate value of 3.11 and an abscissa value of 400, while point D has an ordinate value of 4.21 and an abscissa value of 1000. The equation of line C–D may be expressed by the following formula:

$$(d1)/(d2)=0.00183(d3)+a2.38.$$

Point E has an ordinate value of 1.86 and an abscissa value of 400 while point F has an ordinate value of 2.96 and an abscissa value of 1,000. The equation of line E–F may be expressed by the following formula:

$$(d1)/(d2)\ 0.00183(d)+1.13.$$

Thus, it will be realized that lines C–D and E–F are parallel to the optimum line A–B. It has been determined that values outside these limits increase to a greater extent the susceptibility of the offshore tower to seismic destruction. Therefore, an offshore tower having external parameters which fall within the parallelogram ECDF as disclosed in FIG. **12** will exhibit stability if subjected to seismic loads where other design parameters such as, for example, dead weight are held constant.

While specific outer limits have been designated in FIG. **12**, it should be emphasized that as the outer parallelogram is incrementally diminished toward line A–B, which represents the optimum values, the capability of the tower structure to withstand seismic disturbances is enhanced.

Moreover, and further graphically depicted in FIG. **12**, at each particular mean low water depth there will exist a particular tower configuration ratio which will maximize the capability of the tower to withstand a seismic disturbance and a range of permissible ratios. In this connection parallelograms ECHG, GHJI and IJDF have been drawn at mean low water depths of 400 to 600, 600 to 800 and 800 to 1000 feet, respectively. At each mean low water depth, it will be appreciated that there is a particularly advantageous range of tower dimensions which extends along the ordinate between the lines E–F and C–D, with the optimum ratio lying on line A–B. For example, at 600 feet the optimum ratio of ($d1$) to ($d2$) is 2.87 and a permissible range is 2.23 to 3.48.

A sequential methodology of establishing an offshore tower to resist seismic disturbances includes the steps of first selecting a potentially productive site. The first step may be accomplished by conventional techniques well known in the petroleum exploration industry. The depth of the body of water at the selected site is then determined. Again this step may be performed by conventional techniques. If the mean low water depth lies between 400 and 1,000 feet, a tower is constructed as generally depicted in FIGS. **1—11** having the ratio of ($d1$)/($d2$) optimumly determined for seismic considerations by the equation:

$$(d1)/(d2)=0.00183(d3)+1.77$$

where ($d3$) is the mean low water depth of the water at the selected offshore drilling site. The offshore tower is then transported and erected at the selected offshore drilling site by a preferred method and apparatus which will be more fully discussed hereinafter.

While an offshore tower may be constructed having the optimum ratio it has been found, as previously mentioned, that a range of ratios are permissible whereby an offshore tower constructed within the ratios will withstand seismic loads. In this connection, at any given mean low water depth ($d3$) between 400 and 1,000 feet an upper ratio may be determined by the equation:

$$(d1)/(d2)=0.00183(d)+2.38.$$

and a lower ratio may be determined by the equation:

$$(d1)/(d2)=0.00183(d)+1.13.$$

As previously mentioned, ratios outside these limits increase the susceptibility of the offshore tower to seismic destruction.

While the above discussed dimensional parameters optimize the ability of the tower to withstand seismic loads. Wherein all other parameters are held constant, it has been found that minimizing the mass (composed of the dead load, live load, the displaced water and the enclosed water) of the structure also enhances the capability of the tower to withstand a seismic disturbances. The generally vertical columns **21** are therefore constructed to be watertight where seismic loads may be anticipated in order to minimize the mass of the enclosed water. Similarly the tower may be dimensioned such that in the fully erected posture the displaced water will be minimized.

METHOD OF TRANSPORTATION AND ERECTION

As previously mentioned, the subject tower has further been designed for economic fabrication and transportation to an offshore site. In this connection, reference may now be had to FIGS. **13**(*a—g*) where a method of transporting a tower and constructing the same in at an offshore site is generally sequentially depicted.

Referring now particularly to FIGS. **13***a* and **13***b*, there will be seen a conventional flat barge **76** adapted to carry a main columnar portion **23** and a portion **35** of a spread base structure of a tower **20** above the surface **24** of a body of water **26**. The remaining portion **78** of the spread base structure may be transported to the erection site on a secondary barge **80**, as best seen in FIG. **13***c*. The bottom portion **78** of the offshore tower **20** may be slid from the barge **80** by skidding the structure along the deck thereof by using available jacking techniques or by pulling the section **78** from the deck of the barge **80** by a tug boat (not shown) until the lower portion **78** of the offshore tower **20** is disposed within the body of water, as best seen in FIG. **13***d*. The batter brace members **34** are depicted as being disposed toward the bed of the body of water **26**. The ballast chamber contained solely within the batter brace members **34** may, if necessary, be slightly flooded to obtain this posture.

The major portion **23** of the offshore tower **20**, as indicated in FIG. **13***e*, may then be brought into intimate abutting contact with corresponding members of the bottom portion **78** of the offshore tower **20** and welded thereto. The unitized tower then may be slid into the body of water **26** by jacking the tower off of the barge **76** or pulling the tower from the barge by a tug boat (not shown).

The previously discussed ballast chambers located within the batter brace members **34** may then be selectively opened to take water and thus rotate the offshore tower to a generally vertical posture as best seen in FIG. **13***f*. As previously mentioned, the columnar legs **21** have been fabricated to be watertight so as to provide the center of buoyancy of the offshore tower in a location above the center of gravity of the tower. Thus, a vertical descent of the tower **20** is insured.

As best seen in FIG. **13***g* the tower will come to rest upon the bed **22** of the body of water **26** in a vertical posture. A platform **27** may then be constructed on top of the tower **20** and piles **36** are driven through the piling jackets and into the bed **22** of the body of water **26**. The pilings **38** may be grouted to the jackets or casings to unite the pilings with the casings, thus pinning the tower **20** to the bed **22** of the body of water **26**. The upper portions of the piles **38** may then be severed at the tops of the piling casings to enable the piling strings above the casings to be reused in subsequent operations. With the platform **27** securely supported the drilling operations may proceed.

In this connection it will be appreciated that on at least two opposite sides of the central columnar structure the spread

base support is devoid of an interconnecting network of supporting structures, as best seen in FIGS. 5 and 13. Thus a plurality of wells may be drilled near the sides of the central columnar structure without encountering a large amount of supporting structural work of the tower. Further, it will be appreciated that a riser pipe may be vertically connected to any of the columnar legs 21 in a conventional manner without accommodating for various angles which usually accompany a spread base tower structure.

Referring now to FIGS. 14(*a—e*) there will be shown an alternate method of economically transporting and erecting an offshore tower 20. More specifically, a conventional flat barge 82 is shown in FIGS. 14(*a* and *b*) supporting the entire tower structure upon the surface of a body of water 26, thus eliminating location assembly of sections. In this transport posture it will be seen that the lower batter pile clusters 36 extend within the body of water which, of course, creates somewhat a drag that may slow movement of the barge 82 through the water. It should be appreciated, however, that in this posture the majority of the interconnecting reinforcing members are limited to the lateral sides of the central columnar structure 23 and therefore the reinforcing network is substantially above the surface 24 of the body of water. Thus, particular where long voyages to an offshore site are not anticipated, this manner of transportation is both feasible and desirable.

In FIG. 14*c*, there is shown the tower structure disposed in a generally horizontal posture with the body of water 26, after it has been jacked from or pulled from the barge 82 in a manner similar to that described above. The tower is designed to rest in a general horizontal posture in the water, because, as previously discussed, the outer columns 21 are watertight. The ballast chambers in the batter brace members 34 may be opened to take water, which will thus rotate the tower in a generally vertical posture, as best seen in FIG. 14*d*. As previously discussed, the center of buoyancy of the tower is designed to remain above the center of gravity and thus a vertical descent of the tower structure will be realized.

In FIG. 14*c* there is shown the tower resting upon the bed of the body of water. In this position, a platform 27 may be constructed on top of the tower 20 and pilings 38 may be inserted through the piling guide brackets 25 and into the piling jackets and driven into bed 22 of the body of water. These pilings may be grouted to the interior of the jackets or casings, thus uniting the piles to the tower structure and pinning the structure to the ocean floor. The upper portions of the pilings may then be cut off at the top of the pile casings, thus enabling the piling strips to be reused in subsequent operations. With the platform structure 27 thus firmly supported drilling operation may begin.

With both techniques of erection disclosed in FIGS. 13 and 14 it will be appreciated that subsequent to drilling operations tower 20 may remain as a production station or in those instances where drilling efforts were unproductive the tower 20 may be raised by severing the pilings 38 at the mud line 22 and blowing the ballast chambers within the batter brace members 34. The offshore tower will thus rise for transportation to another offshore site and reset in a new location once the casings are replaced.

MAJOR ADVANTAGES OF THE INVENTION

It will be appreciated that the above disclosed offshore tower is rigid enough to withstand aerodynamic and hydrodynamic loads, yet will also withstand seismic disturbances in order to prevent a catastrophic destruction of the tower.

A further advantage is a method of constructing an offshore tower in a body of water having a mean low water depth of 400 to 1,000 feet which will withstand seismic loads.

Another significant advantage is realized in that the tower design provides an economical means of supporting a drilling platform in depths of water ranging from 400 to 1,000 or more feet.

Further, a plurality of wells may be drilled from a single tower position without encountering a large amount of structural lattice work designed to support a spread base tower structure.

Another advantage lies in the fact that a riser may be connected vertically along the central columnar structure without encountering varying angles of outer structural framework.

Further, the tower may be conveniently transported to a suitable offshore site on conventional barge structures and erected in a vertical posture on the bed of the body of water in a convenient and safe manner.

It will also be appreciated that the tower may be raised by blowing the ballast chambers in the batter brace members so that when the casings are replaced the tower structure may be reused at another offshore site.

While the invention has been described with reference to preferred embodiments, it will appreciated by those skilled in the art that additions, deletions, modifications and substitutions, or other changes not specifically described, may be made which will fall within the purview of the appended claims.

What is claimed is:

1. An offshore tower adapted to rest upon the bed of a body of water with an upper portion thereof extending above the surface of the body of water for supporting a platform thereupon, said tower comprising:

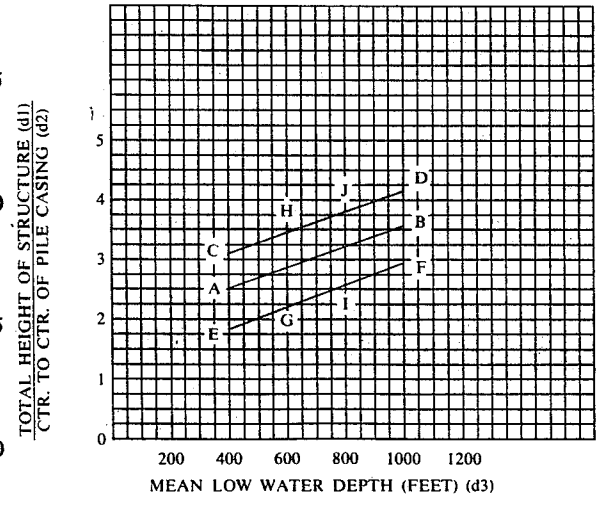
a plurality of generally vertical columns extending between the bed of the body of water and the platform, said columns being generally symmetrically disposed about a vertical axis;

means interconnecting adjacent vertical columns for enhancing the stability thereof;

batter brace members symmetrically disposed about the axis of said vertical columns each being fixedly attached at one end thereof to one of the vertical columns at a position intermediate the length of the attached vertical column for stabilizing said vertical columns and enhancing the load carrying capacity thereof; and

batter pile jacket means, one jacket means being fixedly attached to the other end of each of the batter brace members, said batter pile jacket means being adapted to rest upon the bed of the body of water for supporting and stabilizing said batter brace members; wherein

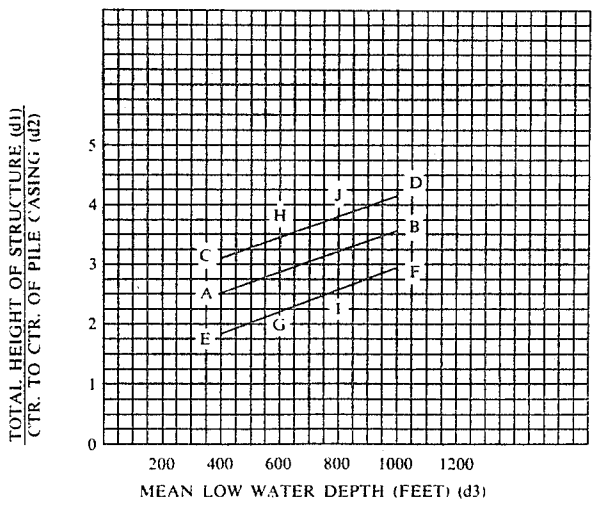
the relationship of the ratio of the total height of said offshore tower to the lateral distance between adjacent batter pile jacket means at the bed of the body of water over the depth of the body of water in feet is defined by the points falling within the parallelogram ECDF in the following graph:



2. An offshore tower adapted to rest upon the bed of a body of water with an upper portion thereof extending above the

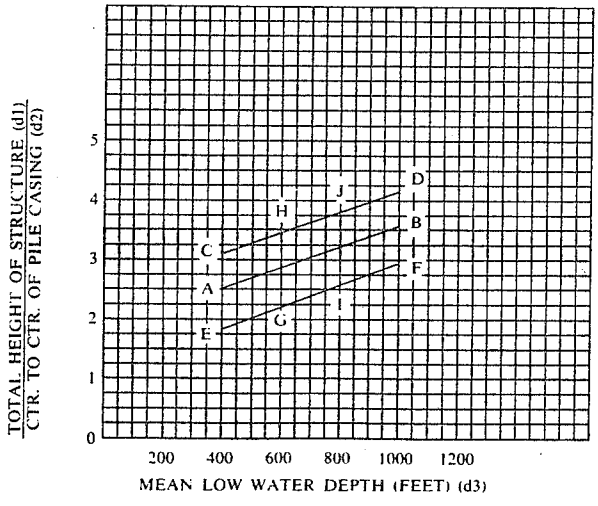
surface of the body of water for supporting a platform thereupon as defined in claim 1 wherein:

the relationship of the ratio of the total height of said offshore tower to the lateral distance between the axes of adjacent batter pile jacket means at the bed of the body of water over the depth of the body of water in feet is defined by the points falling along the line AB in the following graph:



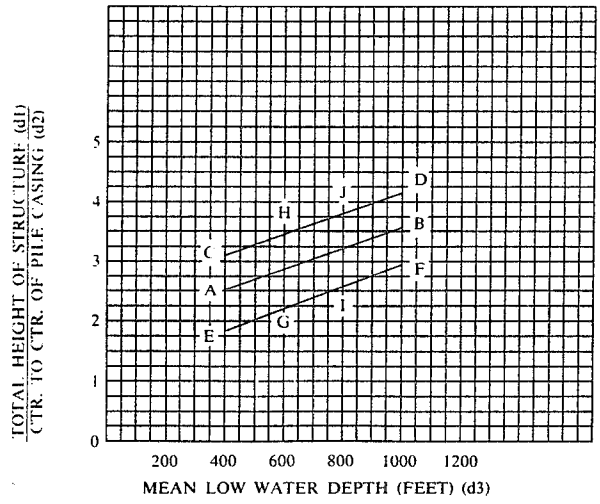
3. An offshore tower adapted to rest upon the bed of a body of water with an upper portion thereof extending above the surface of the body of water for supporting a platform thereupon as defined in claim 1 wherein:

the relationship of the ratio of the total height of said offshore tower to the lateral distance between adjacent batter pile jacket means at the bed of of water over the depth of the body of water in feet is defined by the points falling within the parallelogram ECHG in the following graph:



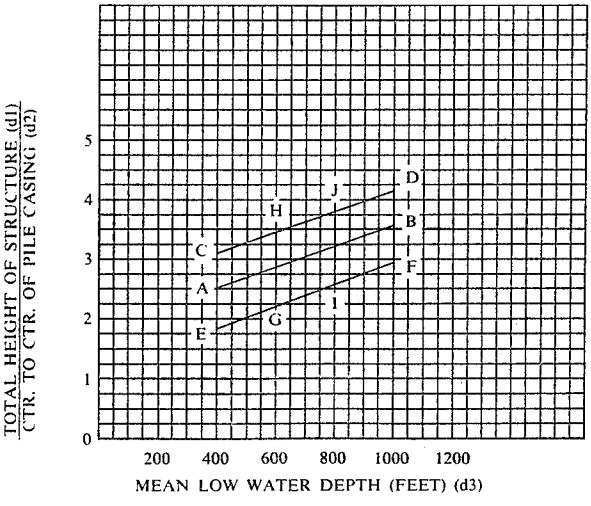
4. An offshore tower adapted to rest upon the bed of a body of water with an upper portion thereof extending above the surface of the body of water for supporting a platform thereupon as defined in claim 1 wherein:

the relationship of the ratio of the total height of said offshore tower to the lateral distance between adjacent batter pile jacket means at the bed of the body of water over the depth of water in feet is defined by the points falling within the parallelogram GHJI in the following graph:



5. An offshore tower adapted to rest upon the bed of a body of water an upper portion thereof extending above the surface of the body of water for supporting a platform thereupon as defined in claim 1 wherein:

the relationship of the ratio of the height of said offshore tower to the lateral distance between adjacent batter pile jacket means at the bed of the body of water over the depth of the body of water in feet is defined by the points falling within the parallelogram IJDF in the following graph:



6. An offshore tower adapted to rest upon the bed of a body of water with an upper portion thereof extending above the surface of the body of water for supporting a platform thereupon, said tower comprising:

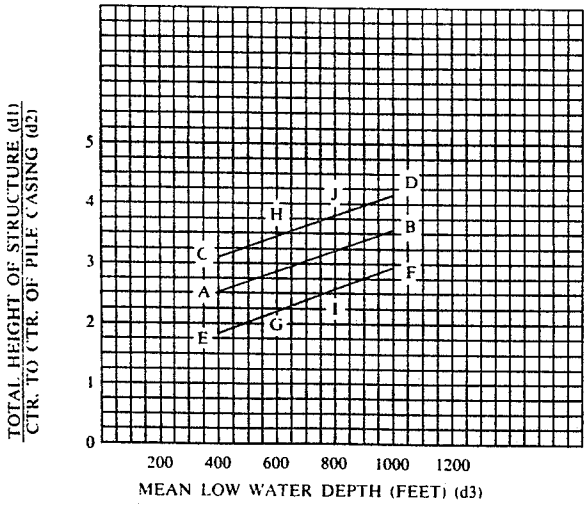
a plurality of generally vertical columns extending between the bed of the body and the platform, said columns being generally symmetrically disposed about a vertical axis;

means interconnecting adjacent vertical columns for enhancing the stability thereof;

a plurality of batter means symmetrically disposed about the axis of said vertical columns each being fixedly attached at one end thereof to one of said vertical columns at a position intermediate the length of said vertical column and extending to the bed of the body of water for stabilizing said vertical column and enhancing the load carrying capacity thereof; wherein

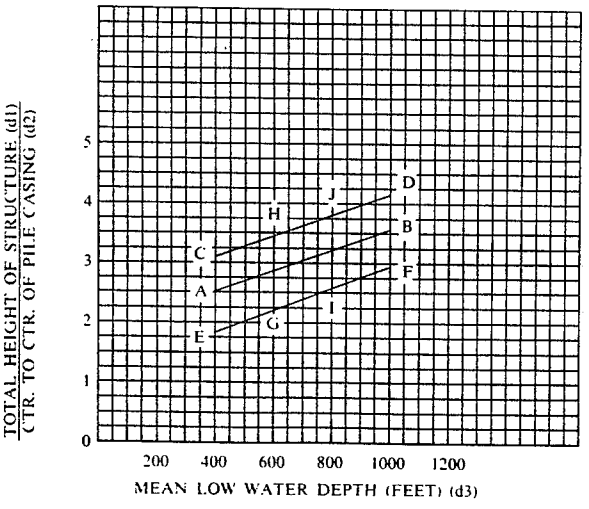
the relationship of the ratio of the total height of said offshore tower to the lateral distance between adjacent

batter means taken at the bed of the body of water over the depth of the body of water in feet is defined by the points falling within the parallelogram ECDF in the following graph:



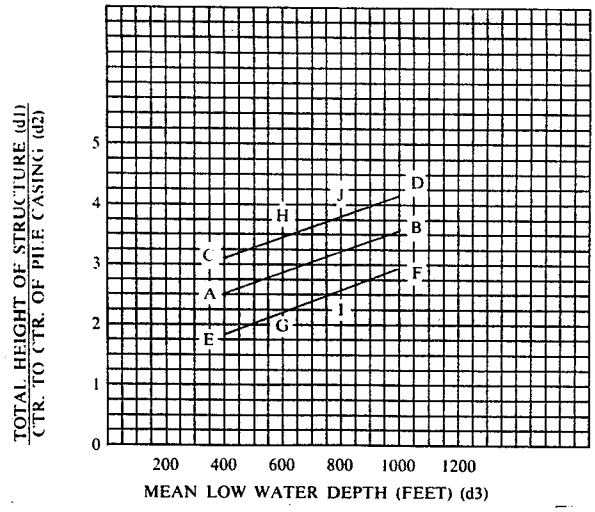
7. An offshore tower adapted to rest upon the bed of a body of water with an upper portion thereof extending above the body of water for supporting a platform thereupon as defined in claim 6 wherein:

the relationship of the ratio of the total height of said offshore tower to the lateral distance between adjacent batter means at the bed of the body of water over the depth of the body of water in feed in defined by the points falling along line AB in the following graph:



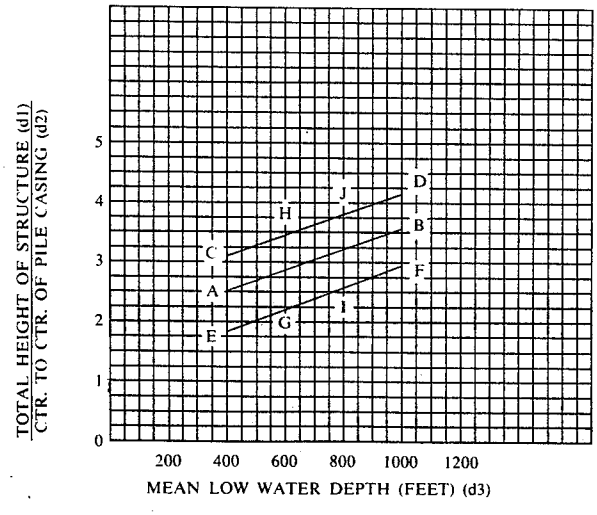
8. An offshore tower adapted to rest upon the bed of a body of water with an upper portion thereof extending above the body of water for supporting a platform thereupon as defined in claim 6 wherein:

the relationship of the ratio of the total height of said offshore tower to the lateral distance between adjacent batter means at the bed of the body of water over the depth of the body of water in feet is defined by the points falling within the parallelogram ECHG in the following graph:



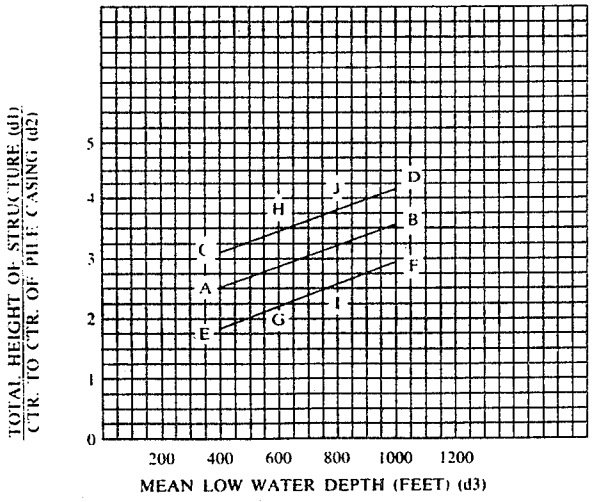
9. An offshore tower adapted to rest upon the bed of a body of water with an upper portion thereof extending above the body of water for supporting a platform thereupon as defined in claim 6 wherein:

the relationship of the ratio of the total height of said offshore tower to the lateral distance between adjacent batter means at the bed of the body of water over the depth of the body of water in feet is defined by the points falling within the parallelogram GHJI in the following graph:



10. An offshore tower adapted to rest upon the bed of a body of water wit portion thereof extending above the body of water for supporting a platform thereupon as defined in claim 6 wherein:

the relationship of the ratio of the total height of said offshore tower to the lateral distance between adjacent batter means at the bed of the body of water over the depth of the body of water in feet is defined by the points falling within the parallelogram IJDF in the following graph:



11. A method of establishing an offshore tower having a plurality of generally vertical column members extending the length thereof and batter brace members depending from a lateral portion of said vertical column members and batter piling jacket means connected to the free end of each of said batter brace members, said piling jacket means adapt upon the bed of a body of water comprising the steps of:

selecting an offshore tower erection site in a body of water having a depth between 400 and 1,000 feet;

determining the depth of the body of water at the selected erection site;

constructing an offshore tower having a ratio of the total height of the offshore tower ($d1$) to the lateral distance at the base between adjacent batter piling jacket means ($d2$) lying between the values determined by the equations:

$$(d1)/(d2)=0.00183(d3)+2.38 \text{ and}$$

$$(d1)/(d2)=0.00183(d3)+1.13,$$

where ($d3$) is the previously determined means low water depth of the body of water at the selected erection site;

transporting the constructed offshore tower to the selected erection site; and

erecting the constructed offshore tower at the erection site.

12. A method of establishing an offshore tower having a plurality of generally vertical column members extending the length thereof and batter brace members depending from a lateral portion of said vertical column members and batter piling jacket means connected to the free end of each of said batter brace members, said piling jacket means adapted to rest upon the bed of a body of water comprising the steps of:

selecting an offshore tower erection site in a body of water having a depth between 400 and 1,000 feet;

determining the depth of the body of water at the selected erection site;

constructing an offshore tower having a ratio of the total height of the offshore tower ($d1$) to the lateral distance at the base between adjacent batter piling jacket means ($d2$) determined by the equation:

$$(d1)/(d2)=0.00183(d3)+1.77,$$

where ($d3$) is the previously determined mean low water depth of the body of water at the selected erection site;

Transporting the constructed offshore tower to the selected erection site; and

erecting the constructed offshore tower at the erection site.