

[54] **ARTICULATED STRUCTURAL
SUPPORT LINKAGE**

[72] Inventor: James R. Lloyd, Houston, Tex.

[73] Assignee: Esso Production Research Company

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166/5, .6

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Primary Examiner—Jacob Shapiro

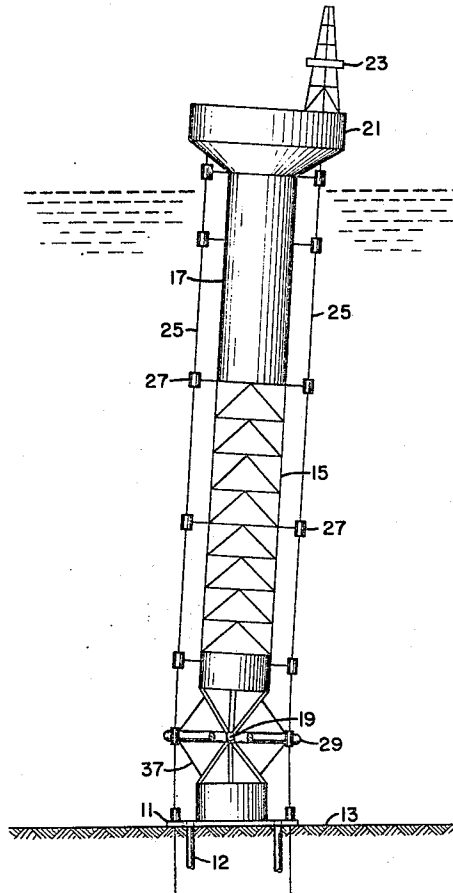
Attorney—James A. Reilly, John B. Davidson, Lewis H. Eatherton, James E. Gilchrist, Robert L. Graham and James E. Reed

[57]

ABSTRACT

Offshore apparatus is disclosed which includes a base, a tower pivotally connected to the base, at least one support member attached to the tower and adapted to slidably support a conductor pipe, and at least one conductor pipe adjacent and substantially parallel to the longitudinal axis of the tower and laterally supported by at least one support member. An articulating means connects the apparatus to a span of the conductor pipe situated in close proximity to the pivotal connection. This means provides sufficient lateral support to the pipe span to prevent buckling and at the same time controls the configuration of the pipe span as the tower sways to prevent bending stress within the pipe span from attaining a level that will cause the pipe to fail.

4 Claims, 2 Drawing Figures



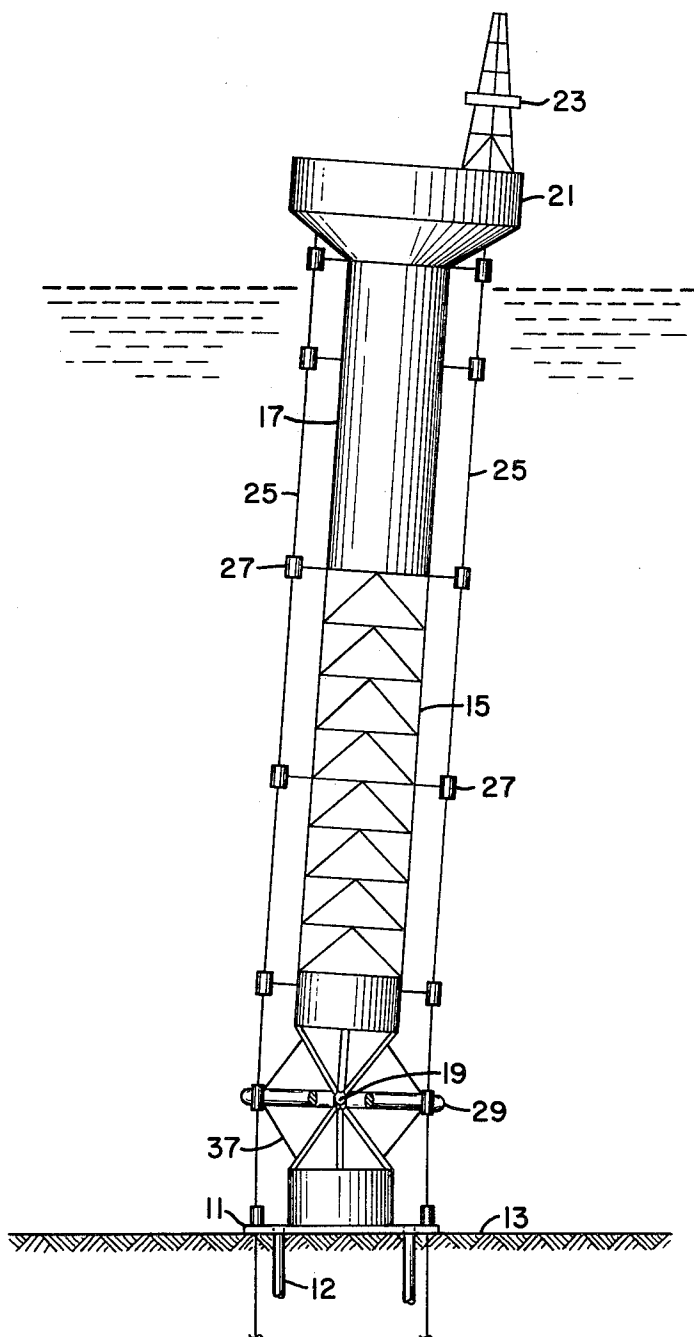


FIG. 1

INVENTOR.
JAMES R. LLOYD

BY

James E. Gilchrist

ATTORNEY

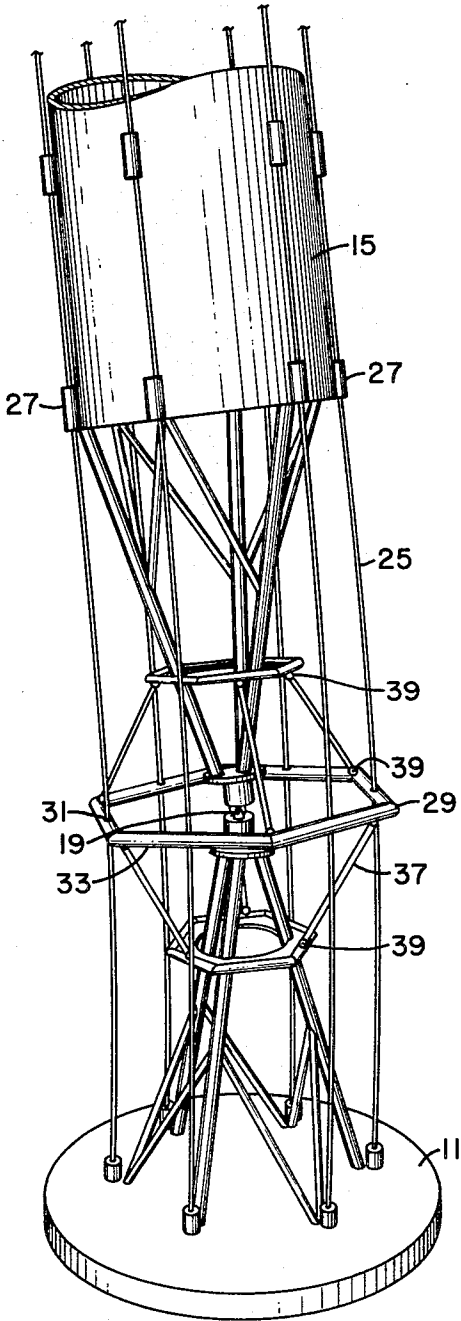


FIG. 2

INVENTOR.
JAMES R. LLOYD

BY
James E. Gibbint
ATTORNEY

ARTICULATED STRUCTURAL SUPPORT LINKAGE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention is generally directed to an improved tower for use in conjunction with the production of crude oil and natural gas offshore and is particularly concerned with a support linkage which prevents conductor pipes associated with such a tower from buckling under axial loading while reducing bending stresses by forcing them to flex with a large radius of curvature.

2. Description of the Prior Art

As efforts directed towards drilling for and production of crude oil and natural gas are extended towards deeper waters, depths will ultimately be reached which will make it impractical to use the rigid, bottom-founded platforms presently employed to support such operations. One deep water alternative to these rigid platforms is a buoyantly supported tower. These structures generally include a base fixed to the submerged bottom, an elongated tower provided with one or more buoyancy chambers near its upper end, and a pivot that connects the tower to the base and permits the tower to sway in response to wind, waves and ocean currents.

Wells drilled from such towers would normally be completed with the wellheads either on the ocean bottom or above the water surface. Prior art buoyantly supported towers normally have wellheads that are mounted on the base of the structure or on the ocean floor. In deep water, placement of underwater wellheads near the base of buoyant towers makes access difficult and will require extension of diver-operating depths as well as substantial advances in undersea well maintenance technology. Surface well completions would therefore be preferable because of the accessibility of the wells for maintenance, workovers and the like. But surface completions have the disadvantage that each well requires an independent conductor pipe that extends from the water surface to the ocean floor. These conductor pipes must bend as the tower sways and they thereby develop high stresses which may lead to their failure. Thus, surface completions, though preferable, are frequently beset with excessive bending stresses in the conductor pipes, and thus leave something to be desired for deep water operations.

SUMMARY OF THE INVENTION

The apparatus of the invention reduces conductor pipe stresses and thus will generally alleviate the problems with surface well completions outlined above. The present invention is directed to offshore apparatus comprising a base, a tower pivotally connected to the base, at least one support member attached to the tower and adapted to slidably support a conductor pipe, at least one conductor pipe adjacent and substantially parallel to the longitudinal axis of the tower and laterally supported by at least one support member, and means articulately connecting the apparatus to a span of conductor pipe situated in close proximity to the pivotal connection. The articulating means provides sufficient lateral support to the pipe span to prevent buckling and controls the configuration of the pipe span as the tower sways to prevent bending stress within the pipe span from attaining a level that will cause the pipe to fail.

The permissible level of stress within a conductor pipe as it bends through a given angle of tower sway is limited by two factors: (1) a critical radius of curvature which gives rise to an excessive bending stress, and (2) a critical unsupported length of conductor pipe which buckles under axial compressive loads. To increase the radius of curvature of the conductor pipe as it conforms to the angle of tower sway requires lengthening the unsupported span of conductor pipe; however, this in turn increases the likelihood of the conductor pipe buckling. The apparatus of the invention overcomes the problems existing in prior art towers by providing an articulately connecting the apparatus to a span of conductor pipe situated in close proximity to the pivotal connection. The articulating means provides sufficient lateral support to the pipe span to prevent buckling and controls the configuration of the pipe span as the tower sways to prevent bending stress within the pipe span from attaining a level that will cause the pipe to fail.

pipe to bend with a large radius of curvature. It will therefore be apparent that a buoyantly supported tower constructed in accordance with the invention will have significant advantages over similar structures disclosed in the prior art.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic elevation of a buoyantly supported tower having two conductor pipes that extend from the water surface to the ocean bottom and that are supported by the linkage of the invention.

FIG. 2 is an enlarged perspective view of the lower part of a buoyantly supported tower equipped with a conductor pipe support linkage constructed in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 schematically depicts a buoyantly supported tower for use in conjunction with the offshore production of crude oil and natural gas. A base 11 is shown anchored by means of pilings 12 to submerged bottom 13. An elongated tower 15 having a buoyancy chamber 17 near its upper end is connected to the base by a pivot assembly 19. A platform 21 atop the tower and above the water surface supports a drilling rig 23. Conductor pipes 25 are situated adjacent the side of the tower and substantially parallel to its longitudinal axis and are shown extending from the platform to the submerged bottom. A number of conductor pipe supports 27 are fixed to the tower structure and provide lateral support for the conductor pipes to prevent them from buckling as well as restrain them from lateral movement. These supports permit the conductors to slide freely through them so that tower sway will not impart excessive axial loads to the conductors. The conductor pipe support linkage of the invention, designated by numeral 29 and shown attached to the tower near its lower end, supports the span of conductor pipe between the lowermost fixed conductor pipe support and the ocean floor. The most severe bending stresses will occur in this span of conductor pipe because this span experiences the sharpest radius of curvature. In addition, the axial compressive load that is effective in causing buckling is at a maximum at the bottom of the tower because of the weight of the conductor pipe, internal fluids and other pipe strings suspended within the conductor pipe.

The maximum permissible unsupported length of conductor pipe is controlled by the tendency of the conductor pipe to buckle. Assuming the lowermost span is clamped at the bottom where it emerges from the ocean floor, and is pinned, i.e., subject to no moments, at the first fixed support, the conductor pipe will be in stable equilibrium provided the axial load is lower than P_{cr} as defined by the following relation:

$$P_{cr} = cEI/L^2$$

where:

P_{cr} = the maximum permissible axial compressive load for a condition of stable equilibrium

E = modulus of elasticity of pipe material

I = moment of inertia of the effective conductor pipe cross section

L = unsupported length of the conductor pipe

$c = 20.2$, a constant consistent with the assumed end conditions

Inspection of the above relation will readily indicate that decreasing the unsupported length by a factor of 2 will increase the axial load that can be withstood without buckling by a factor of 4. This could be accomplished by slidably supporting the lowermost span at its midpoint with a support member that is fixed to the tower, such as those depicted by numeral 27 in FIG. 1. However, shortening the unsupported span in this fashion is not desirable since the fixed support would force the pipe to bend more sharply for any given angle of tower sway, thereby reducing the radius of curvature of the pipe and substantially increasing the bending stress in the pipe.

Bending stress within the conductor pipe resulting from deflection caused by tower sway is governed by the following approximate relation:

$$\sigma = (D/2)(\phi/L)E$$

where:

- σ = bending stress in the pipe
- E = modulus of elasticity of pipe material
- L = length of unsupported section
- ϕ = bending angle = L/R (radians)
- R = radius of curvature
- D = pipe diameter

It will be noted from the above that cutting the length of the unsupported section in half will have the effect of doubling the bending stress in the conductor pipe for a given angle of tower sway. Thus, while improving the resistance of the conductor pipe to buckling, the additional fixed lateral support would substantially increase the bending stress within the pipe.

The conductor pipe support linkage depicted by numeral 29 in FIG. 1 reduces the buckling tendency of the conductor pipes without substantially increasing the level of bending stress. The linkage accomplishes this by slidably supporting the conductor pipes and, at the same time, forcing them to bend with a large radius of curvature. The supports shown are each connected to the tower structure by a pair of articulated rigid members. One member is connected to the tower and the other to the tower base so that as the tower sways towards the conductor pipe, the hinged support linkage thus formed pushes the conductor away from the tower. As the tower flexes in the opposite direction, the hinged support linkage draws the conductor towards the tower. The articulated members that form the hingelike conductor pipe support linkage are sized and positioned to maintain the unsupported span of each conductor pipe in a configuration that closely approaches a circular arc, regardless of the angle of tower sway. Preferably the linkage is attached at a point about midway between the ocean floor and the lowermost fixed conductor pipe support and is configured to force the unsupported pipe span between these two points to bend in a configuration approaching that of an arc having a constant radius of curvature over any segment between the ends of the span. This radius of curvature should be smaller than that of any other segment along the conductor pipe. It will be apparent that when the tower sways, the hinged support linkage, if employed to slidably support the lowermost unsupported span near its center, will reduce the unsupported length of the span by a factor of 2 without substantially reducing the radius of curvature of the conductors during tower sway. Thus, for any given angle of sway, the axial load that can be tolerated without the conductor pipes buckling can be increased by a factor of approximately 4 without substantially increasing the bending stress. Conversely, for a given angle of tower sway and for a given axial compressive load in the conductor pipe, the bending stress can be cut in half by using this support linkage.

It will be obvious that any number of these linkages could be employed, each further subdividing the unsupported span into shorter and shorter lengths without increasing the bending stress. It will also be obvious that the incremental benefit to be derived from each additional linkage diminishes as the number of linkages increases.

FIG. 2 is an enlarged perspective view of a conductor pipe support linkage constructed in accordance with the invention. Identical numerals have been used in FIG. 2 to designate elements of structure corresponding to those shown in FIG. 1. Thus, a base section 11 is shown connected to the lower portion of a buoyantly supported tower 15 by means of a pivot assembly 19. A number of conductor pipes 25 extend upwardly from the base and are situated adjacent and substantially parallel to the longitudinal axis of the buoyantly supported tower. The last two fixed conductor pipe supports 27 are shown on the lower portion of the tower. These devices serve to slidably support the conductor pipe to prevent it from buckling and to restrain it from moving laterally. The conductor pipe will therefore conform to the configuration of the tower as it sways.

The conductor pipe support linkage of the invention is again generally depicted by numeral 29. The linkage shown is designed to support six conductor pipes; however, a larger (or

smaller) number of conductor pipes could be handled in a similar fashion. The individual slidable supports are comprised of sleeves 31, which pass through a polygonal frame 33 and may have a series of corner braces (not shown). Other configurations of slidable supports and of the structural framework could, of course, also be employed. The support structure is shown connected to the tower by six struts or similar rigid members 37. These rigid members are connected to the frame and to the tower structure by articulatable joints 39, e.g., ball or universal joints. The articulated rigid members are spaced around the hexagonal frame at 60° intervals and are connected alternatively to the tower section and the base section. Thus, three articulated rigid members connect the frame to the tower and three articulated rigid members connect the frame to the base. The articulated rigid members are shown in FIG. 2 to be spaced evenly about the tower axis. It will be apparent, however, that other configurations of these articulated rigid members could be used, provided they support the frame in such a way as to provide lateral support for the conductor pipes and to force the pipes to bend in substantially circular arcs as the tower sways.

What is claimed is:

1. Offshore apparatus comprising a tower structure including a base affixed to a marine bottom and a tower pivotally connected to said base; a conductor pipe anchored at least adjacent said bottom, situated adjacent and substantially parallel to said tower, and supported laterally and slidably by at least one conductor pipe support attached to said tower near the lower end thereof; and a means articulately connecting said tower structure to a point proximate the midpoint of a span of conductor pipe defined between said anchored point and said lower conductor pipe support, said means providing sufficient lateral support to said pipe span to prevent buckling and controlling the configuration of said pipe span as the tower sways to prevent bending stress within said pipe span from attaining a level that will cause the pipe to fail.
2. Apparatus as defined by claim 1 in which said articulatable means forces said pipe span to bend in a configuration approaching that of an arc having a constant radius of curvature over any segment between the ends of said span, said radius of curvature being smaller than that of any other segment along said conductor pipe.
3. Offshore apparatus comprising a tower structure including a base affixed to a marine bottom and a tower pivotally connected to said base; at least one conductor pipe support attached to the tower and adapted to slidably support a conductor pipe, at least one conductor pipe adjacent and substantially parallel to the longitudinal axis of the tower and laterally supported by at least one said conductor pipe support, and a means articulately connecting said tower structure to a span of conductor pipe situated in close proximity to said pivotal connection, said means providing sufficient lateral support to said pipe span to prevent buckling and controlling the configuration of said pipe span as the tower sways to prevent bending stress within the pipe span from attaining a level that will cause the pipe to fail, said means including,
 - a. a support frame situated in proximity to said pivotal connection and having at least one conductor pipe support member attached thereto;
 - b. a first plurality of rigid members spaced about said frame, each said member having one end articulately connected to said frame and the opposite end articulately connected to said base; and
 - c. a second plurality of rigid members spaced about said frame, each said member having one end articulately connected to said frame and the opposite end articulately connected to said tower.
4. In an offshore structure of the type which includes a base anchored to a submerged bottom, a first vertical member pivotally connected to the base, a second vertical member affixed to and extending upwardly from said bottom that is both adjacent and substantially parallel to said first vertical member and is laterally supported by at least one support

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member attached to said first vertical member, the improvement comprising an articulatable means adapted to connect a span of said second vertical member proximate said pivotal connection to said structure, said means providing sufficient lateral support to prevent said span from buckling and forcing said span to bend with a radius of curvature such that bending stress within the span will not attain a level that will cause said second vertical member to fail when said first member pivots, and said means including,

a. a frame having at least one support sleeve attached

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- thereto;
- b. a first plurality of rigid members spaced about said frame, each said rigid member having one end articulately connected to said frame and the other articulately connected to said base; and
- c. a second plurality of rigid members spaced about said frame, each said member having one end connected to said frame and the other articulately connected to said first vertical member.

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