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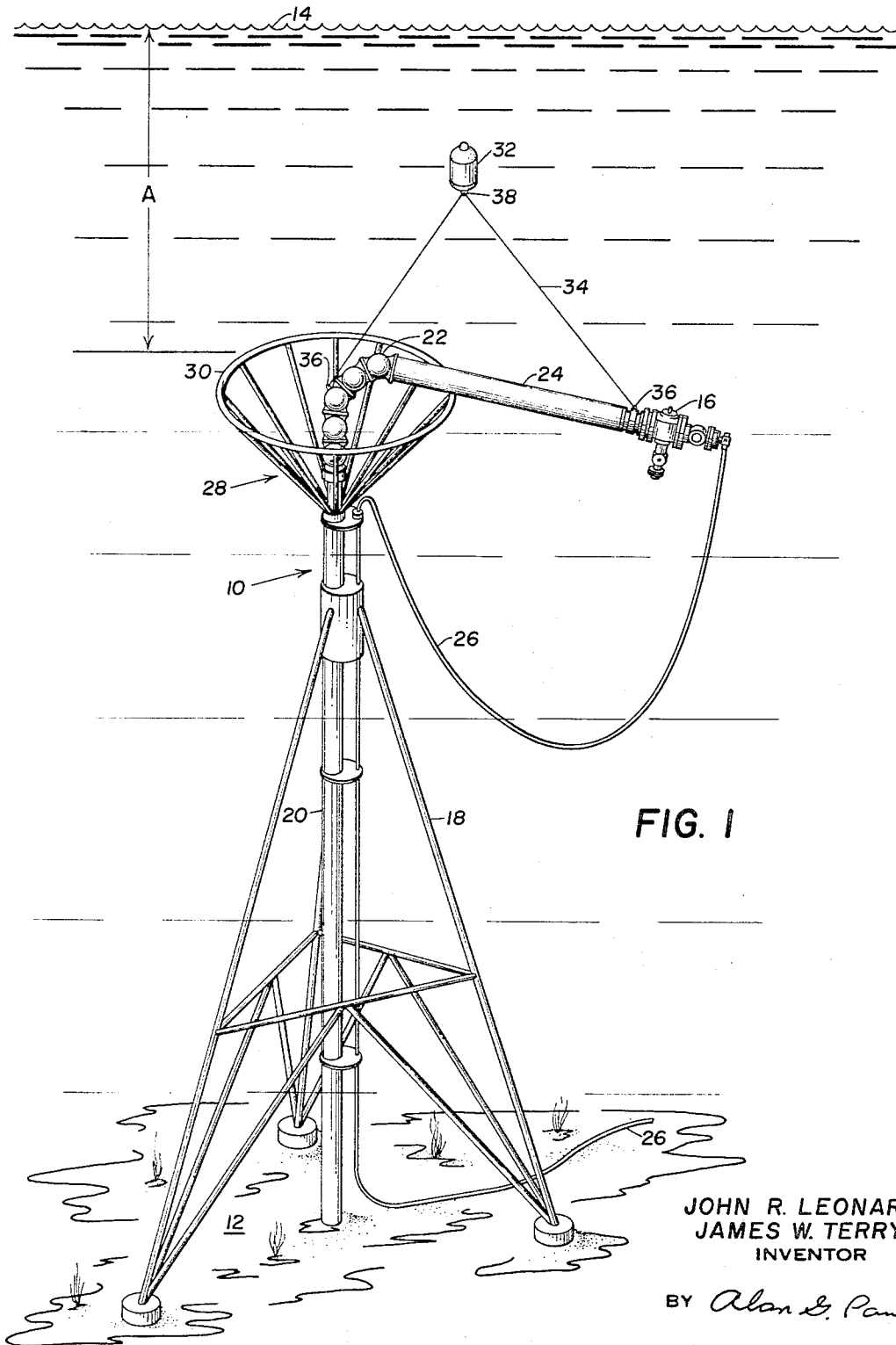
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UNDERWATER WELLHEAD

Filed May 20, 1966

3 Sheets-Sheet 1



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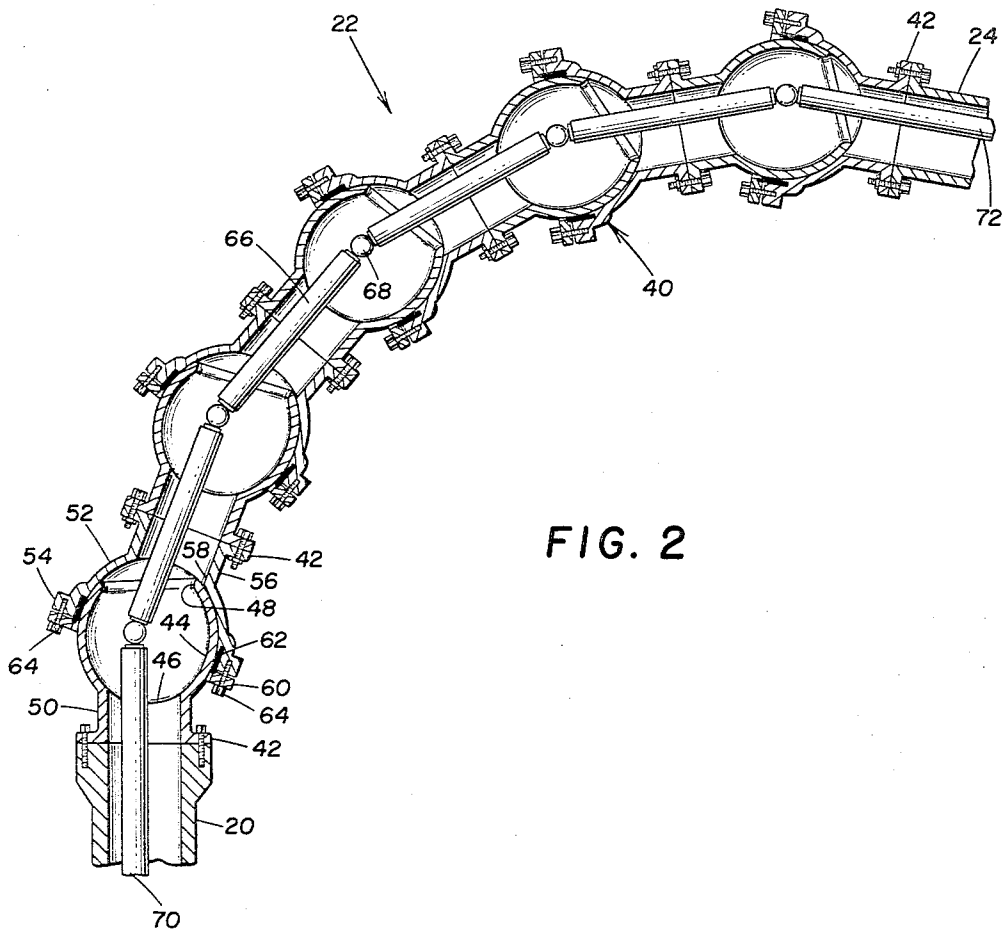
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UNDERWATER WELLHEAD

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9 Claims. (Cl 166—5)

This invention relates to a method and apparatus for completing a subaqueous well beneath the surface of a body of water so that the wellhead thereof can be raised to the surface for maintenance and repair operations, and more particularly, to a flexible conductor pipe between the subaqueous wellbore and the production wellhead.

Heretofore, when a subaqueous well is proven and is to be placed on production, as for example in the Gulf of Mexico, usually an above-surface, bottom-supported platform is set over the well, with a riser or conductor pipe extending from the wellbore to the platform deck, and a christmas tree (production wellhead) is mounted atop the riser pipe on the deck above the surface of the body of water. A number of directional wells can then be drilled from the deck of the platform. When the field is too shallow for directional wells, separate, spaced wells are drilled and a rudimentary support structure is constructed at the riser pipe of each well to permit an above-surface wellhead. Large ships must thread their way between these structures, and utmost care must be taken, particularly during foggy weather conditions. Signal lights and other warning devices must be connected to all of the platforms and the well riser supports. However, as the more prolific producing areas become fully developed and the number of above-surface structures increases, the problems of navigation, and the resultant danger to the above-surface structures from collisions with ships, become increasingly great. While the spacing of these platforms might not appear to present a navigational hazard, at first glance, they do present one to a ship's captain who is usually confronted with navigating through large open areas with few obstacles. In the Gulf of Mexico where the density of offshore platforms is increasing at a rapid rate, there have already been several collisions.

Another problem that should be considered in conjunction with above-surface completions is that of the violent storms that ravage the Gulf Coast with almost yearly frequency. These storms take their toll of any equipment which is above the surface of the water. A large production platform, if uprooted, is a tremendous economic loss, and depending upon the individual case, ten or more wells may have to be abandoned. Even the loss of a single well can have a serious effect on the economics of a company's offshore operations.

Therefore, it would appear to be advantageous to shelter at least the production wellheads beneath the surface; however, other problems arise when a wellhead is sheltered beneath the surface of a body of water. One of the most important of these is that of servicing and maintaining the well. A diver may be used for actuating the various valves and repairing any malfunctions of the wellhead; but, even in shallow water a diver's effectiveness is less than that of a man working under atmospheric conditions and moreover he is limited at this time to working in water of several hundred feet in depth.

While robotic and TFL (through flowline) tools have been developed and are available for routine servicing or workover operations, these devices are complicated and expensive and are, at this time, only used for a few limited tasks. For production purposes, it is desirable to complete a well so that certain servicing, repair, and workover operations, not as easily accomplished by remote control equipment, can be handled under atmospheric conditions. With the newly developed capabilities of the oil com-

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panies to drill and produce oil wells in the waters of the continental shelf over two hundred fifty feet, and the expected later extension of these capabilities to the continental slope, where the depths encountered range from six hundred to two thousand feet, the need for a diver, at this time, for routine repairs, maintenance, or workover operations, must be dispensed with.

Therefore, it is an object of this invention to provide a submerged wellhead that can be brought to the surface of a body of water for repair, maintenance, and workover operations.

Another object of this invention is to provide an improved means for remotely controlling the raising of a submerged apparatus to the surface of a body of water, the apparatus having been positioned a substantial distance beneath the surface.

Other objects and advantages of this invention will be apparent from the following description taken with reference to the accompanying drawings, wherein is shown preferred embodiments of the invention:

FIGURE 1 is a pictorial representation of a christmas tree mounted on the upper end of a well conductor pipe being supported in deep water by a tripod structure and having a flexible pipe section between the tripod support structure and the wellhead;

FIGURE 2 is a cross-sectional view of the flexible section of the well conductor pipe shown in FIGURE 1;

FIGURE 3 is an elevational view, partly in cross section, showing a remotely controlled buoy of the present invention connected to a subaqueous wellhead and used as a locating marker therefor; and

FIGURE 4 is a side elevational view of a shallow water installation in which the christmas tree is mounted on the upper end of a well conductor pipe projecting only from the marine bottom. The conductor pipe has a flexible section permitting it to be bent over so that the christmas tree rests near the marine bottom and is spaced therefrom by the periphery of a buoy mounted on the upper end of the conductor pipe.

Referring now to the drawings, more in detail, by character reference, there is shown in FIGURE 1 conductor pipe 10 protruding from the subaqueous marine bottom 12 and terminating just below a designated distance *a* beneath the surface 14 of the body of water. The distance *a* indicates a sheltered depth at which apparatus will not be substantially subject to surface conditions. As to this sheltered depth at which the wave and tidal actions and surface storms would no longer be a substantial problem, this would vary with the total depth of the water. A figure used with present subsurface completions off California is one hundred feet. Of course, in the shallow waters of the Gulf Coast twenty-five to fifty feet might be more appropriate.

The conductor pipe 10 is illustrated as capped by a production wellhead or christmas tree 16, shown schematically, and is braced by a tripod support structure 18 set on the marine bottom 12. The rigid conductor pipe section 20, below the support structure 18 is identical to conductor pipes or surface casings that are normally utilized in offshore installations. Connected to the upper end of the rigid conductor pipe section 20, above the support 18, is a flexible conductor pipe section 22 with a rigid upper conductor pipe section 24 connected to its free end. The upper rigid conductor pipe section 24 in turn terminates in the christmas tree 16 from which extends a flow or shipping line 26 for carrying the production products from a subaqueous well (not shown) to separator or storage facilities (not shown) on-shore, on the marine bottom, or on an above-surface platform. The flowline 26, originating at the christmas tree 16, has a flexible portion between the christmas tree 26 and the upper end of the support structure 18; a rigid portion, preferably of a

high strength material, such as steel pipe, paralleling the conductor pipe down to the marine bottom 12; and a flexible portion laying along the marine bottom 12. The portion of the flowline 26 paralleling the conductor pipe 10 would be supported by the conductor pipe 10 at intervals.

Fixed to the upper end of the support structure 18 is an inverted conical framework 28 terminating in a large diameter tubular rim 30 for abutting the rigid conductor pipe section 24 and supporting the christmas tree 16 regardless of the direction in which the flexible conductor pipe section 22 bends as the conductor pipe 10 is lowered beneath the surface 14 of an offshore body of water. Also connected to the conductor pipe 10 is a buoy 32 having a sonar-controlled variable buoyancy. The buoy 32 is attached to the conductor pipe 10 by a cable 34 fastened at its ends to padeyes 36 spaced along the length of the conductor pipe 10 above the upper end of the support structure 18 and slidably strung through a padeye 38 fixed to the lower end of the buoy 32.

The construction of the flexible section 22 is shown in more detail in FIGURE 2. The flexible section 22 consists of a plurality of fluidtight ball joints 40 (representatively denoted) bolted together, and to the rigid conductor pipe sections 20 and 24 by end flanges 42 to form as flexible a section 22 as necessary. Each of the ball joints 40 consists of an inner spherical shell 44 which has diametrically opposed circular openings 46 and 48 formed therethrough. The smaller circular opening 46 is extended by a tubular portion 50 integrally connected to the spherical shell 44 and having an end flange 42 fixed thereto. An outer partially spherical shell 52, less than a hemisphere in extent, and terminating in a planar rim 54, slidably mates with the inner spherical shell 44 over the larger circular opening 48. The partially spherical shell 52 has a tubular portion 56 extending therefrom coincident with a central circular opening 58 equal in size to the smaller opening 46 of the spherical shell 44, the tubular portion 56 also having an end flange 42. An annular element 60, having an inner diameter of less than the outer diameter of the spherical shell 44, is mounted thereon opposite the rim 54 of the partially spherical shell 52. A packing 62 is included in the space between the annular element 60 and the rim 54. Bolting the annular element 60 and the outer shell 52 together by means of a plurality of equally spaced bolts 64 causes a fluidtight seal between the spherical shells 44 and 52 and the packing 62, while permitting a limited universal movement therebetween. Although the allowable degree of movement of each of the joints 40 may be varied, it has been found that 20° is a good engineering compromise. If a 90° bend is desired, five joints 40 will be required.

Production tubing is set within the conductor pipe 10 and consists in part of a flexible section coincident with the flexible section 22 of the conductor pipe 10, made up of tubular elements 66 interconnected by fluidtight flexible joints 68 which may be identical in type, although smaller in size than the ball joints 40. A lower rigid section 70 of the production tubing, projecting out of the subaqueous well beneath the marine bottom 12, would be identical to that found in prior art wells. An upper rigid production tubing section 72 is fixed to the outermost flexible joint 68 and is operatively connected into the christmas tree 16.

It can be seen in (FIGURE 1) that the conductor pipe 10 and the included production tubing are arranged to be bent over into a position in which the christmas tree 16 rests on the rim 30 a safe distance beneath the surface 14. In such a position, the subsea installation would not be a navigational hazard and would be protected from surface conditions, such as wind, waves, and violent storms. The weight of the christmas tree 16 and the upper rigid conductor pipe section 20 is alone enough to cause the conductor pipe 10 to bend into the sheltered position. In reasonably calm water the conductor pipe 10

will hold this position until raised. Any movement of the upper end of the conductor pipe 10 caused by shifting currents and tides will not affect the depth at which the christmas tree 16 rests due to the circular configuration of the rim 30.

To raise the christmas tree 16 back to the surface 14 for repair or workover operations, the buoy 32 is activated by a sonar signal, causing it to fill with gas and thereby expelling the water therefrom (as will be explained). The buoyancy of the buoy 32 carries it toward the surface 14 trailing the conductor pipe 10 along by means of the cable 34. The buoy 32 may be designed to bring the christmas tree 16 completely out of the water or it may only rise enough so that the buoy 32 itself shows on the surface. In the latter case a barge or derrick nearby would be used to haul in the cable 34 until the christmas tree 16 has reached the desired position above the surface 14 of the water.

In FIGURE 3 the buoy 32 is shown floating on the surface 14 of a body of water and connected to a permanently submerged christmas tree 16 of a subaqueous well by a cable 34'. Although in this view it is shown merely as a marker (which would be another use for such a buoy), it would be of the same construction as that illustrated in FIGURE 1, although smaller. At 32' the same buoy, resting on the bottom, is shown in expanded cross-section (at the right). The cable 34' is stored on the ocean's bottom until it is needed and the chance of this cable being broken, or the buoy damaged during severe storms, as is possible if a continuously floating buoy is utilized, is reasonably overcome. The buoy 32' consists of a hollow shell 74 having a ballast section 76 therein. The ballast section 76 is designed to hold the buoy 32' firmly to the marine bottom 12, as well as to insure proper alignment of a sonar antenna 78. A check valve 80, biased closed, is fitted in the shell 74 of the buoy 32' to permit the expelling of the water therefrom due to internal pressure. The water is expelled by means of high pressure gas, in this case nitrogen, carried in a capsule 82 within a dome 84 on the shell 74 of the buoy 32'. An actuator 86 is operatively connected to the sonar antenna 78, and by conventional means, will release the nitrogen gas from the capsule 82 on command. Such a release means could be an explosively driven pin that would puncture the nitrogen capsule to permit the gas to escape therefrom or a battery-operated solenoid that would unscrew a cap from the capsule. Such actuators are well known, and it is not believed necessary to discuss the details of such a device. A plug 88 is threaded into one end of the shell 74. By moving this plug 88, gas pressure can be released and the buoy 32' reflooded.

Now referring to FIGURE 4, the invention is shown as it would be utilized in fairly shallow water of approximately one hundred feet or less. The depth at which a supplementary support structure is not necessary is determined by a number of factors including the length of conductor pipe that a buoy could lift to the surface. The lower rigid conductor pipe section 20 extends only a short distance up from the marine bottom 12, supported in a landing base 90, above which it is continued as a flexible section 22. The flexible section 22 of the conductor pipe 10 as in FIGURE 1 terminates in an upper rigid conductor pipe section 24 which is capped by a christmas tree 16. The flexible section 22 would be of the same length as that shown in FIGURE 1, the length being determined only by the amount of bending required.

A second embodiment of the buoy is shown which incorporates the feature of spacing the christmas tree 16 from the marine bottom 12. The buoy, generally designated 92, mounted directly on the conductor pipe section 24, has a large diameter ring-shaped element forming a hollow toroidal shell 94 supported on the conductor pipe section 24 by a rigidly fixed inner sleeve or hub 96 and a plurality of interconnecting radial spokes 98. The toroidal shell 94 serves the double functions of a variably buoyant

compartment and a spacer to keep the christmas tree 16 away from the marine bottom 12 regardless of what direction the conductor pipe 10 has been bent. The design of the spacer-buoy 92 can be varied, within the concept of the invention, by enlarging the dimensions of the hub 96 and constricting the toroidal diameter of the shell 94, the hub having the hollow compartment and functioning as the buoy while the other shell is only a spacer ring. However, as envisioned, as the preferred embodiment, the toroidal shell 94 would be the hollow compartment and would be large enough to act as a floating base to support the christmas tree 16 straight up out of the water when it is actuated.

Although no dome 84, carrying the sonar antenna 78, the nitrogen capsule 82, and the actuator 86, is illustrated in this view, one would be necessary if the buoy is to be remotely actuated. The dome 84 could be mounted on the toroidal shell 94 or on the conductor pipe 10.

Although the present invention has been described in connection with details of the specific embodiment thereof, it is to be understood that such details are not intended to limit the scope of the invention. The terms and expressions employed are used in a descriptive and not a limiting sense and there is no intention of excluding such equivalents in the invention described as fall within the scope of the claims. Now having described the apparatus herein disclosed, reference should be had to the claims which follow.

What is claimed is:

1. Apparatus for producing oil and/or gas from a subaqueous well, consisting of: a conductor pipe set in the wellbore and protruding therefrom, said conductor pipe being long enough for the upper end to project above the surface of the body of water at the well site when said conductor pipe is vertically positioned; a christmas tree fixed on said upper end of said conductor pipe and operatively connected therewith; means for sheltering said christmas tree beneath said surface of said body of water including a flexible section in said conductor pipe; production tubing within said conductor pipe for operatively connecting a producing zone in said subaqueous well with said christmas tree for producing the fluid therethrough; and a flexible section in said production tubing substantially coincident with said flexible section in said conductor pipe whereby said conductor pipe and said included production tubing can be bent to shelter said christmas tree beneath said surface of said body of water, and can be vertically straightened to project said christmas tree above said surface of said body of water.

2. The oil and/or gas production apparatus as recited in claim 1 wherein said flexible conductor pipe consists of a plurality of spherical ball joints having a continuous passage extending therethrough, each of said ball joints having a limited degree of universal movement.

3. The oil and/or gas production apparatus as recited in claim 1 wherein there is means for coaxing with said conductor pipe between said flexible section

and said christmas tree to limit the bending of said flexible section.

4. The oil and/or gas production apparatus as recited in claim 3 within said limiting means consists of an inverted conical framework having an upper tubular rim, said conical framework being fixed, at least at its apex, on said conductor pipe beneath said flexible section, whereby said conductor pipe, between said flexible section and said christmas tree, abuts said tubular rim of said conical framework as the conductor pipe is bent down to be sheltered.

5. The oil and/or gas production apparatus as recited in claim 3 wherein said limiting means consists of a large diameter ring-shaped element mounted on said conductor pipe between said flexible pipe section and said christmas tree, whereby the periphery of said ring-shaped element abuts a horizontal surface beneath said flexible section of said conductor pipe as said conductor pipe is bent down to be sheltered.

6. The oil and/or gas production apparatus of claim 1 wherein there is remotely controlled means for straightening said conductor pipe to position said christmas tree at least above its sheltered position.

7. The oil and/or gas production apparatus of claim 6 wherein said remotely controlled means for straightening said conductor pipe consists of: a variably buoyant buoy; means for attaching said buoy to said conductor pipe; and means for remotely increasing the buoyancy of said buoy whereby a command signal at the surface will cause said upper end of said conductor pipe to rise toward said surface with said christmas tree.

8. The oil and/or gas production apparatus of claim 7 wherein said means for attaching said buoy to said conductor pipe consists of: a cable connected between axially spaced points on said conductor pipe; and means for slidably attaching said buoy to said cable between said spaced points.

9. The oil and/or gas production apparatus of claim 7 wherein there is means associated with said buoy for limiting the bending of said conductor pipe and spacing said christmas tree a distance above a horizontal surface below said limiting means consisting of a toroidally shaped hollow compartment coaxially encircling said conductor pipe; and said means for attaching said buoy to said conductor pipe consists of a sleeve fixed on said conductor pipe, having radial spokes interconnecting said sleeve and said buoy.

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