Feb. 24, 1970 D. SILVERMAN 3,497,869
ELECTRICAL SYSTEM FOR SIGNALING BETWEEN
A FLOATING VESSEL AND A SUBSEA WELL
Filed Sept. 9, 1968 5 Sheets-Sheet 1

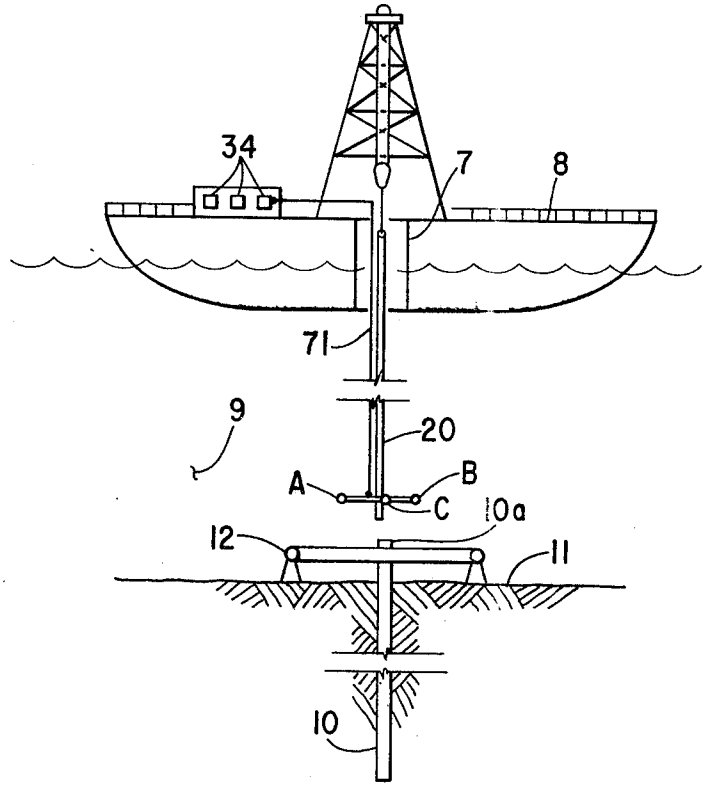


FIG. 1

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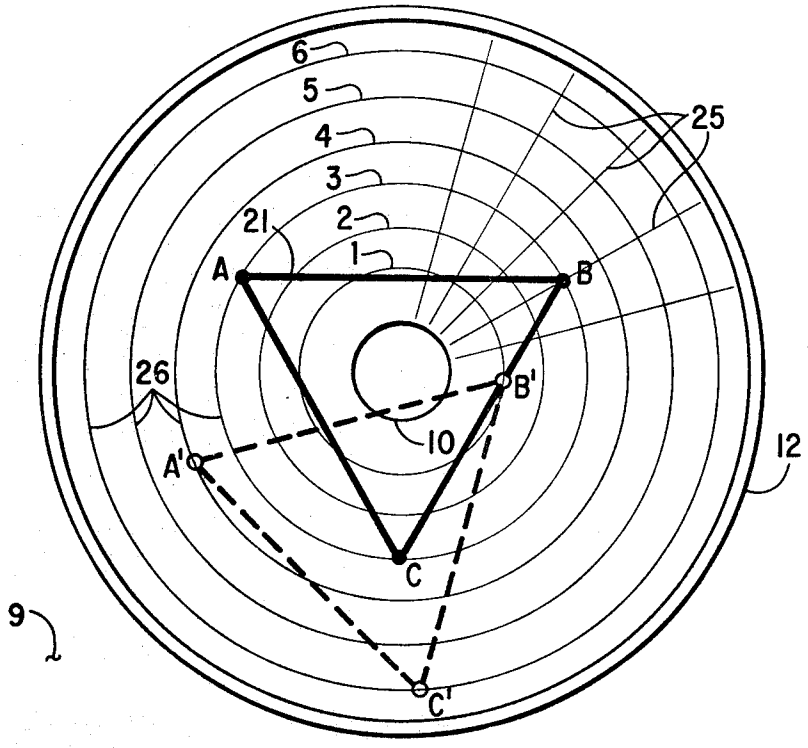


FIG. 2a

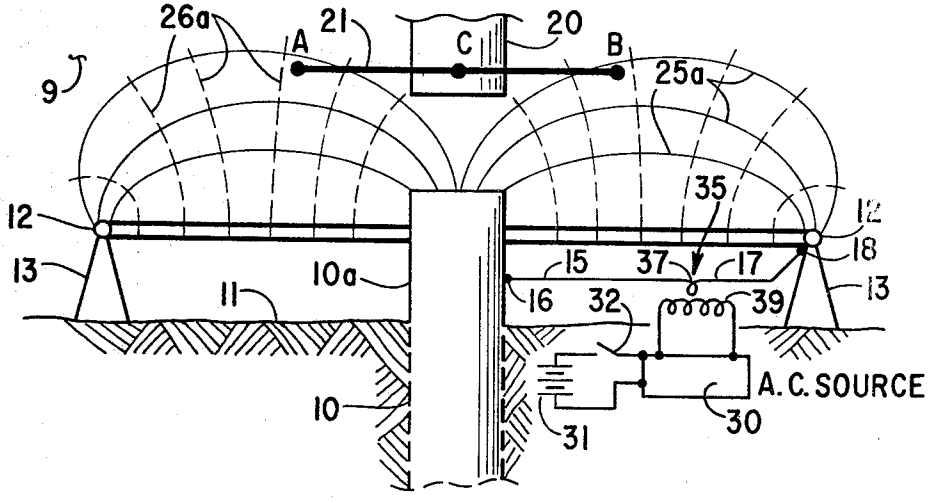


FIG. 2b

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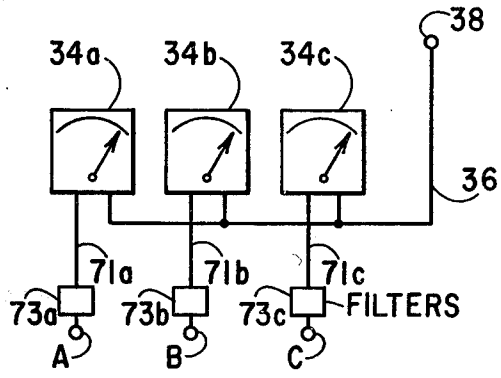


FIG. 3a

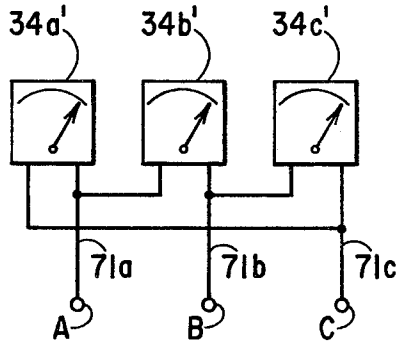
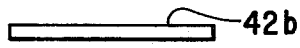


FIG. 3b



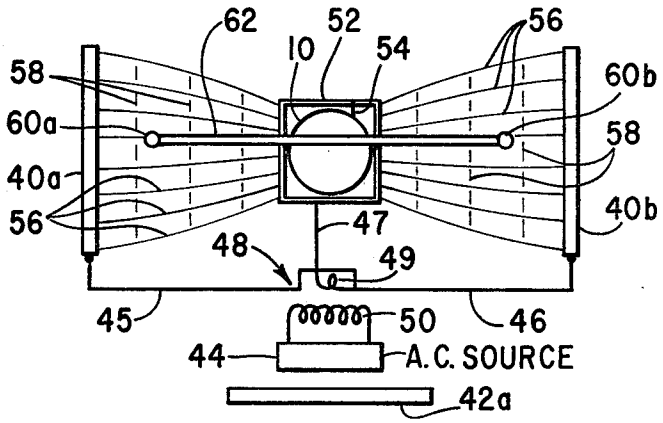


FIG. 4

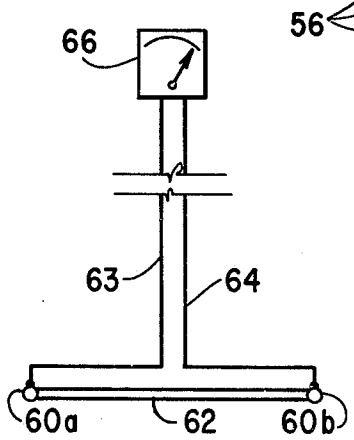


FIG. 5

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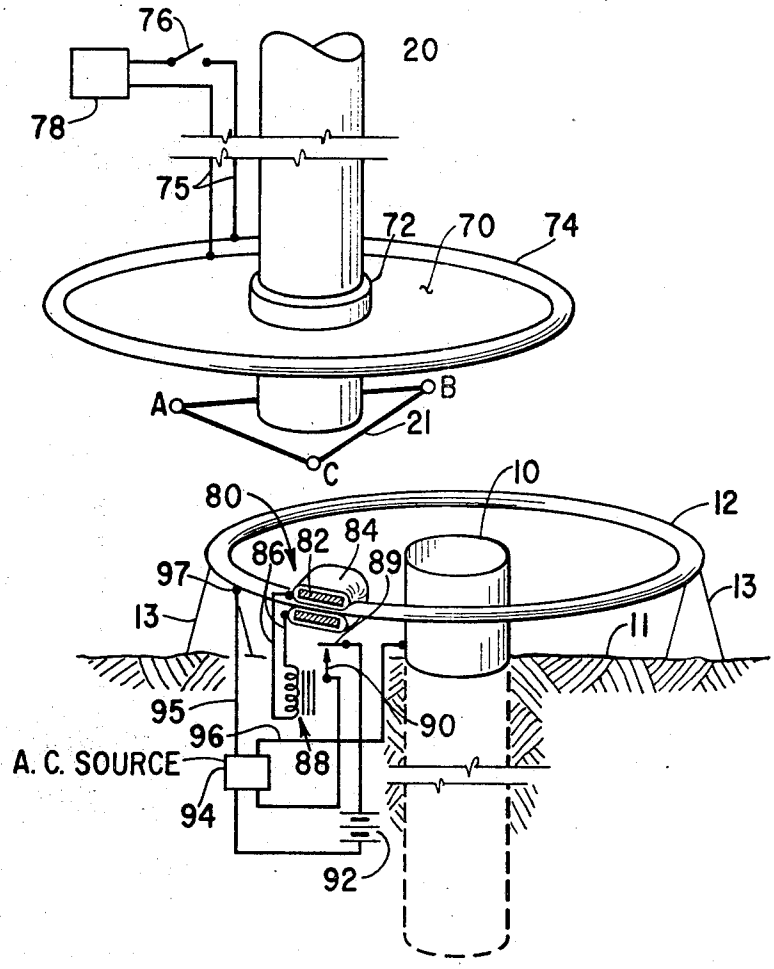


FIG. 6

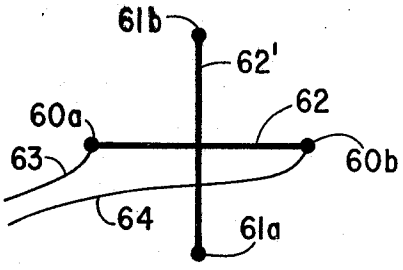


FIG. 7

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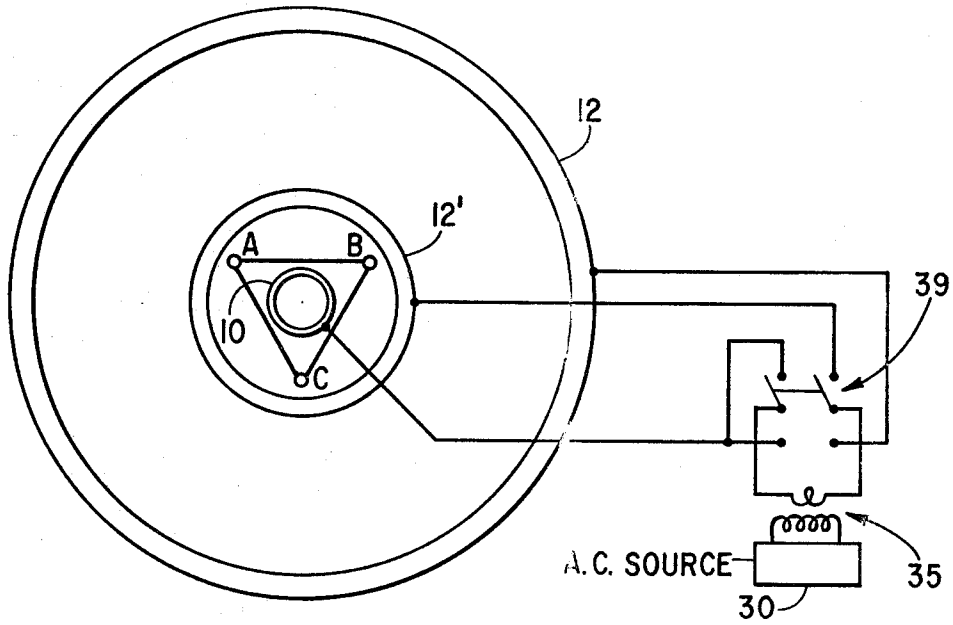


FIG. 9

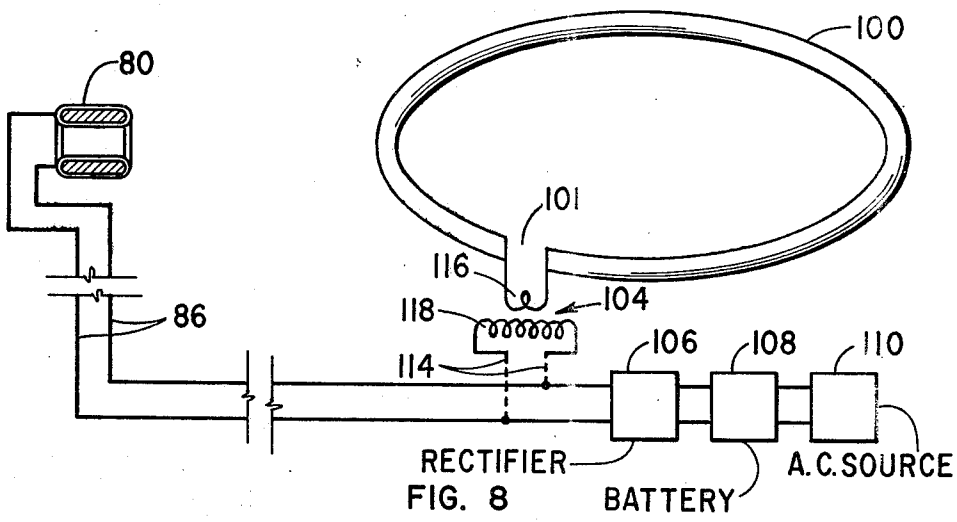


FIG. 8

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Patented Feb. 24, 1970

3,497,869

ELECTRICAL SYSTEM FOR SIGNALING BETWEEN A FLOATING VESSEL AND A SUBSEA WELL

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Int. Cl. H04b *13/02;* G01v *1/00*
U.S. Cl. 340—4 15 Claims

ABSTRACT OF THE DISCLOSURE

In offshore drilling and producing operations, it is frequently necessary to lower pipes, such as riser pipes, from a floating drilling vessel to a subsea well and to signal between the vessel and the subsea well. Electrodes mounted on the sea floor and symmetrically placed with respect to the well, supplied with A.C. current, set up a potential field. A plurality of electrodes supported by the riser pipe are immersed in this potential field and send signals to the vessel indicating their individual potentials. The pattern of potentials on the plurality of electrodes indicates the position of the pipe with respect to the well. Modifications are described.

BACKGROUND OF THE INVENTION

Field of the invention

This invention is concerned with the drilling and production of oil and gas wells in offshore areas. More particularly, it concerns means for indicating the relative position of a subsea well and the drilling or producing apparatus, supported by and lowered from a floating vessel. It includes also the signaling from the vessel to the subsea installation as well as the signaling from the installation to the vessel.

Description of the prior art

In the drilling for and production of oil and gas in offshore locations, particularly in deep water, it is necessary to have some means of re-entry of drilling or producing means into the subsea well once they have been removed. In relatively shallow water, this can be done by the use of divers at the subsea well location observing the apparatus and signaling the operators on the floating vessel from which the drilling means, such as riser pipe, drill pipe, etc., depends. In deep or murky water this is not possible. There are also sonic means using a plurality of stationary pulsed sonic sourses symmetrically placed on the sea floor, cooperating with a receiver mounted on the lower end of the riser pipe. By noting the travel time of the sonic pulses from each of the separate sources to the single receiver it can be determined in which direction to move the riser pipe until it is centered over the well.

These and other less common methods, including magnetic means, are either difficult to operate or are expensive to install, and require extensive maintenance. The method of this invention is simple and inexpensive to install and maintain, and provides many advantages over the prior art.

SUMMARY OF THE INVENTION

In this invention, an electrode system of specified geometry is mounted on the sea floor in precise geometric relation to the subsea well. The electrodes are powered by a source of monofrequency A.C. current. This sets up a potential field in the sea water between the electrodes which is symmetrical with respect to the well. A symmetrical pattern of electrodes is mounted on the riser pipe or other drilling producing apparatus being lowered from the floating vessel for entry into the well. Each of the electrodes is connected by electrical conductor up the riser pipe to the vessel, where they are connected to voltmeter means to indicate some function of their individual potentials. The potential on each electrode is a function of the part of the potential field in which it is placed. Thus by observing the potentials on each of the plurality of electrodes, the riser pipe can be moved in the proper direction until the electrodes on the riser pipe (and thus the pipe itself) are symmetrically placed with respect to the electrodes on the sea floor, and thus with respect to the subsea well.

In addition, in a preferred embodiment, means are provided on the riser pipe, powered by a source of single frequency A.C. on the vessel, for signaling to the electrode system on the sea floor. By this means, signals, power or commands can be sent from the vessel to the well apparatus on the sea floor, and signals can be sent from the well apparatus to the vessel.

It is, therefore, a principal object of this invention to provide a means for signaling from a first electrical A.C. system on the sea floor to a second electrical means supported on an elongated structure hanging from a floating vessel. The signals can be for determining relative position of the two systems, or they can be for transmittal of data. Another object is to provide means for transmitting power and signals from the floating vessel to the electrical system on the sea floor.

These and other objects and details of this invention will be made clear from the following description of the invention taken in conjunction with the attached drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a schematic view of a floating vessel, the dependent structural means and the subsea well;

FIGURE 2*a* is a vertical view of indications of electrical potential about the well ahead and position of detecting electrodes;

FIGURE 2*b* illustrates one embodiment of the invention using circular symmetry of the sea floor electrode system, and a triangular pattern of detectors;

FIGURES 3*a* and 3*b* indicate alternate means of indicating the potentials on the electrodes;

FIGURES 4, 5 and 7 indicate another embodiment using rectangular symmetry;

FIGURE 6 indicates a system for signaling from the vessel to the well;

FIGURE 8 indicates an alternate detail of the system of FIGURE 6, and

FIGURE 9 indicates an alternate detail of the system of FIGURE 2*b*.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the figures, and in particular, to FIGURE 1, I show in simplified form a drilling vessel **8** floating on the surface of a body of water or sea **9**. This vessel has a central opening **7** or "moon pool" through which drilling apparatus, such as the riser pipe **20**, is lowered from the ship to the sea floor. All such drilling apparatus is well known in the art and form no part of this invention.

The novely of this invention lies in the means by which the position of the lower end of the riser pipe **20** with respect to the casing **10** in the earth under the sea can be determined. These means involve electrode **12** on the sea floor, and electrodes A, B, C, attached to the riser pipe. The electrodes A, B, C are connected by conductors **71** to indicating meters **34** on the ship. All of these features will be described more fully in connection with the other drawings.

In FIGURES 2*a* and 2*b* I show an oil well casing **10** placed in a drill hole in the earth below the water **9**, with its top **10***a* projecting into the sea water above the sea floor **11**. Encircling this casing symmetrically is a circular uninsulated conductor or ring electrode **12** set on insulators **13** so that its plane is close to the level of the top of the casing **10***a*.

A source of A.C. voltage **30** is provided with its output leads connected to a stepdown transformer **35**, the low turns winding **37** of which is connected by leads **15**, **17** to points **16** and **18**, respectively, on the casing and on the ring electrode. The source **30** is supplied with power from a self-contained power source such as battery **31** connected through switch **32**.

Numeral **20** represents a casing, riser pipe, drill pipe, or other elongated structural element that must be positioned in or close to the casing. For convenience this will be designated as a riser pipe or, simply, pipe. This is generally lowered from the drill ship **8** or other structure floating on the surface of the sea **9** until it is just above the sea floor. This invention serves to provide an indication to the operators on the ship, for example, of the position of the pipe **20** in relation to the casing top portion **10***a*.

On the lower end of the pipe **20** is a structure or plate of insulating material **21**, triangular in shape, with three electrodes A, B, C, mounted on the corners of the plate, which is itself fastened to the pipe by conventional means. The radius of the electrode circle is less than the radius of the ring, preferably in the order of ½ the radius of the ring. The radius of the ring is chosen to be comparable to the maximum displacement of the pipe from the casing for which a useable indication of position can be obtained. This could be of the order of 25–50 or 100 feet or more, depending on the power available from source **30**.

The sea water environment in which the casing, ring and plate are placed is electrically conducting. Thus, with an A.C. voltage impressed between the casing and ring, current will flow. This is indicated by the radial lines **25** in FIGURE 2*a* and the curved lines **25***a* in FIGURE 2*b*. The resistance of the path from **10** to **12** will be low, and, therefore, the power source feeding it should be of low impedance. This can be done by using a stepdown transformer **35** with high turns winding **39** connected to the power source **30**, and the low turns winding **37** connected between casing and ring.

There will be equipotential surfaces indicated by the dashed lines **26***a* in FIGURE 2*b* and the circles **26** in FIGURE 2*a*. An electrode placed in the potential field **25** will take up the potential of the equipotential surface **26** passing through its position. Thus, the potentials of the electrodes A, B, C should indicate the precise position of the electrodes in relation to ring **12** and casing **10**.

For example, in FIGURE 2*a* I show in the dashed position, electrode A′ on equipotential surface **4**, B′ on surface **1** and C′ on surface **6**. When the pipe **20** is centered over the casing **10**, the electrodes will all be positioned on the same equipotential surface **26** having a designated potential **3**. By observing the potential of each electrode, the pipe **20** is moved in the proper direction to bring the electrode with the highest potential in toward the pipe **20**. This will bring its potential down, and raise the potential of the other two. This process is continued until all three potentials are equal. The pipe **20** will then be centered over the casing.

The three electrodes A, B, C are shown in FIGURE 3*a* connected by leads **71***a*, **71***b*, **71***c*, respectively, to three voltmeters **34***a*, **34***b* and **34***c* mounted on the vessel. The second lead **36** to each of the voltmeters goes to a distant electrode **38** in the water. Comparison of the readings of the three voltmeters will give an indication of the position of the pipe **20** with respect to the casing **10**. To improve the signal to noise ratio, sharp bandpass filters **73***a*, **73***b*, **73***c* can be used.

It will be clear also, as shown in FIGURE 3*b*, that the three indicating voltmeters can be connected so as to measure the difference in potential between adjacent electrodes, rather than the potential of each electrode. This is done by connecting each voltmeter, such as **34***a*′ between leads **71***a* and **71***c*, connected to electrodes A and C, respectively, and so on. In the symmetrical position of pipe **20** over casing **10**, all three voltmeters should read zero. Of course, there are many other ways in which the three potentials indicated by meters **34** can be indicated and displayed, as is well known in the art. It is possible also to devise a servo system to utilize these potentials and to automtaically position the pipe **20** to its proper position.

There are other configurations of electrodes than the circle **12** and casing **10**. In FIGURE 4, I show a pair of parallel linear electrodes **40***a*, **40***b* placed on insulators (not shown) like electrodes **12** on insulators **13**, and spaced equally on opposite sides of the casing **10**. The inner electrode can be the casing **10**, or preferably a little larger square conductor **52**, with sides parallel to elongated electrodes **40***a*, **40***b*. A.C. power is again supplied by a stepdown transformer **48** with low turns winding **49** connected by lead **47** to the square **52** (and by **54** to the casing) and by leads **45** and **46** to electrodes **40***a* and **40***b*, respectively. As shown in FIGURE 5, two electrodes **60***a* **60***b* are mounted on the ends of an insulator **62**. The positions of the electrodes **60***a*, **60***b* are indicated in the potential field of FIGURE 4. The two electrodes **60***a*, **60***b* can be connected by leads **63**, **64** to voltmeter **66** (as in FIGURE 3*b*) or two voltmeters can be separately connected to leads **63**, **64**, respectively, and to a distant electrode as in FIGURE 3*a*.

As in the case of FIGURES 2*a*, 2*b*, current will flow from the square **52** to the electrodes **40***a*, **40***b* as indicated in general form by the current lines **56**. There will also be equipotential surfaces, the traces of which are indicated by dashed lines **58**. The electrodes **60***a*, **60***b* will indicate their position by their potential, and thus they can be moved parallel to the line joining them until they are symmetrically placed with respect to the casing **54**.

Since the traces **58** of the equipotential planes are essentially straight lines parallel to the electrodes **40**, the potential on the electrodes **60** do not indicate the position of the arm **62** perpendicular to its direction. To get this indication of position we need a second pair of electrodes **42***a*, **42***b* and a second pair of electrode **61***a*, **61***b*, FIGURE 7, mounted on an insulator **62**′ at right angles to **62**. In the interest of clarity and simplicity this has not been shown on FIGURE 4, but would be similar to the circuit elements shown for the electrodes **40***a*, **40***b*. Preferably, the frequency of the power source for the electrodes **42** would be different from the frequency of the power source for electrodes **40**, so that each of the electrode pairs **60***a*, **60***b* and **61***a*, **61***b* could indicate their position without interference from the other.

The A.C. power source **30** (FIGURE 2*b*) used to energize the potential field between the casing and ring has a power source such as battery **31**, and a siwtch such as **32**. This could be a time switch—or could be a proximity switch, which would turn on the source whenever the pipe **20** was removed from the casing, or in many other ways.

I prefer to control the source **30** by signal from the vessel by means of a cable down to a multi-turn coil **74**, FIGURE 6, mounted on a non-conducting plate **70** attached to the pipe **20**. This can be positioned immediately above the electrodes A, B, C, for example. There is a toroidal transformer **80** surrounding the ring electrode **12**. This comprises a cylindrical core **82** and a toroidal winding **84**. The leads from this winding go to relay **88**. Thus, when an A.C. signal is applied from source **78** through switch **76** and leads **75** to the coil **74**, an electromagnetic field is set up which encircles the coil **74**. Flux that encloses both the coil **74** and the ring **12** will induce

current in the ring **12**. This will generate current in the winding **84** which will operate the relay **88** to apply power from battery **92** to the power source **94**, and thus to apply potential between the casing and ring. So long as the current in **74** is maintained, the relay will hold. Or, if desired, a time-controlled hold can be applied to the relay, to hold it closed for a desired period after the relay is closed by current from transformer **80**.

If desired, as shown in FIGURE 8, the current output from the transformer **80** can be connected to a rectifier **106**, and battery **108**. The battery can supply power to the A.C. source **110**. So long as current is supplied to coil **74**, the battery **108** will be charging and ready for use. Preferably, the frequency of the current source **78** is much different, and preferably higher, than the signal current applied to the ring **12**.

In FIGURE 8, I have shown by dashed lines **114** an alternate connection for the rectifier **106**. I show the ring electrode **100** (corresponding to the ring **12**). This has a break or opening **101** with the ends connected to the low turns winding **116** of a step-up transformer **104**. The high turns winding **118** is connected by leads **114** to the rectifier **106**, etc. Thus, a series step-up transformer can be used with a single turn coil **100**, or a multi-turn coil can be used with or without transformer. If a closed coil or ring is used, then the toroidal transformer **80** can be used.

The transmission of signal from the ring **12** to the electrodes A, B, C can be carried on over a large area. Thus, the ring **12**, since it is stationary on the sea floor, can be quite large, possibly 50 to 100 feet in diameter. In this case, the spacing of electrodes A, B, C should also be large, although a smaller spacing will still work, but the less resolution. While the preferred diameter of the electrode circle ABC is equal to the radius of the ring **12**, this invention will work for smaller electrode spracings. It is possible also to have a second smaller ring, like **12'**, FIGURE 9, and concentric with **12**, surrounding the casing **10**. The power source and transformer **30, 35** can be connected alternately to the smaller and the larger ring by means **39**, for example. Or each of the two rings can be excited simultaneously with currents of two different frequencies. The same electrodes A, B, C can be used to detect both signals, which can be separated by appropriate filters. Thus, a large ring can be used for rough positioning and a small ring for precise positioning.

In the transmission of signal from the ship through coil **74**, as shown in FIGURE 6 to the ring **12**, it is not practical to carry a very large coil **74** on the riser pipe. Perhaps a practical limit of size would be 10–15 feet, where the ring **12** may be 50–100 feet. In this case, the coil **74** is swept transversely over a large area such that at one time a portion of the coil **74** and ring **12** are close enough so that flux will link both of them. A momentary coupling of flux is all that is needed to switch on the power source **94**, FIGURE 6.

Later, when the riser pipe is in final position over the casing, the coil **74** will be concentric with the smaller ring **12'** and can be used to transmit power to charge batteries or carry on other operations by suitable coded signals, etc., as is well known in the art.

Of course, any of the embodiments described can be used in various configurations and combinations. Together, they permit signaling from the sea floor to indicate the position of an elongated member, supported from the sea surface, with respect to the casing. Also, by choice of different frequencies of signaling (different frequency source **30**) different messages can be transmitted. The various embodiments also provide means to signal and transmit power from the surface to the sea floor installation. Since separate monofrequency signals are sent (in both directions) suitable sharp pass and reject band filters can be used, as is well known in the art, to separate simultaneous signals of different frequencies, and to improve the signal to noise ratio.

I claim:

1. A system for guiding in two dimensions a first end of a movable first cylindrical structure into end-to-end axial alignment with the first end of a fixed second cylindrical structure,. both structures being immersed in a body of sea water, comprising,

(a) a first electrode assembly comprising at least two separate electrodes, said electrode assembly having symmetry with respect to the axis of said second structure,

(b) at least one alternating current means of a first frequency connected between said at least two electrodes, whereby a first current flow is set up in said sea water between said at least two electrodes, said first current flow defining a first series of equipotential surfaces,

(c) a second electrode assembly of at least three electrodes in an array symmetrical about the axis of said first structure, said second electrode assembly positioned near the first end of said first structure in a plane substantially perpendicular to the axis of said first structure, each of said at least three electrodes in said second electrode assembly adapted to take on the potential of the equipotential surface passing through its position, and

(d) means for indicating a quantity related to the potential of each of said electrodes in said second electrode assembly,

whereby when said second electrode assembly is immersed in the current field of said first electrode assembly, and when said first structure is in axial alignment with said second structure, said indications of said quantities related to the potential of each of said at least three electrodes will be equal.

2. The apparatus of claim **1** including means for moving said first structure until a predetermined pattern of potential is detected on said plurality of electrodes of said second electrode assembly.

3. Apparatus as in claim **1** in which said second electrode assembly comprises three electrodes spaced at the verticles of an equilateral triangle.

4. Apparatus as in claim **1** in which said first electrode assembly comprises first linear electrodes parallel to each other and equally spaced on opposite sides of said second cylindrical structure, and including a second pair of similar linear electrodes similarly placed with respect to said second structure and oriented perpendicular to said first linear electrodes.

5. Apparatus as in claim **4** in which said detecting electrodes comprise at least four electrodes in two pairs, the lines joining the two electrodes of each pair being substantially perpendicular to the directions of the linear electrodes of each pair.

6. Apparatus as is claim **4** in which the alternating current supplied to said first pair of linear electrodes is of said first constant frequency and the current supplied to the second pair of linear electrodes is of a second contrast frequency different from said first frequency.

7. A system for guiding in two dimensions a first structure to be lowered from a vessel floating on a body of sea water for engagement with a second structure on the sea floor, comprising,

(a) a first electrically conducting circular ring of radius r, supported on the sea floor surrounding said second structure and concentric with respect to the axis of said second structure,

(b) a second electrically conducting circular ring of radius R (where R is greater than r) substantially concentric with said first ring, supported on said sea floor,

(c) alternating current means of constant frequency conected between said first and second rings, whereby a current flow is set up in said sea water between said rings, and current flow defining equipotential surfaces,

(d) three equally spaced detecting electrodes mounted on said first structure in a substantially horizontal plane, symmetrically placed with respect to the vertical axis of said first structure and immersed in said sea water, each of said electrodes taking the potential of the equipotential surface passing through its position, and

(e) means for indcating a quantity related to the potential of each of said detecting electrodes,

whereby when the axis of said first structure is aligned with the axis of said second structure, said quantities related to the potential of each of said detecting electrodes will be equal.

8. Apparatus as in claim **7** in which said first ring is a vertical metallic casing in the sediments below the sea floor.

9. Apparatus as in claim **7** in which said means for indicating includes a plurality of potential indcators each connected respectively to one electrode of said second electrode assembly and to a common distant electrode immersed in said sea water.

10. Apparatus as in claim **7** in which said means for indicating includes a plurality of potential indcators each connected respectvely between adjacent pairs of said electrodes.

11. Apparatus as in claim **7** including coil means mounted concentric with said plurality of electrodes on said first structure, alternating current means connected to and circulating a third current in said coil means, and means to utilize the fourth current induced in said second ring electrode by said third current.

12. Apparatus as in claim **11** in which said second circular ring comprises a single turn closed ring of conducting material and including toroidal transformer means inductively coupled to said ring.

13. Apparatus as in claim **11** in which said second circular ring comprises a single turn ring of conducting material, said ring cut and the two ends connected to a step-up transformer.

14. Apparatus as in claim **11** in which said means to utilize said fourth current includes energy storage means.

15. Apparatus as in claim **11** including two second circular rings, both concentric with said first ring, one of diameter substantially equal to said coil means, and the other of much larger diameter.

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RICHARD A. FARLEY, Primary Examiner