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ELECTRICAL COMMUNICATION SYSTEM FOR OIL FIELD GATHERING SYSTEM

Filed Aug. 16, 1968

2 Sheets-Sheet 1

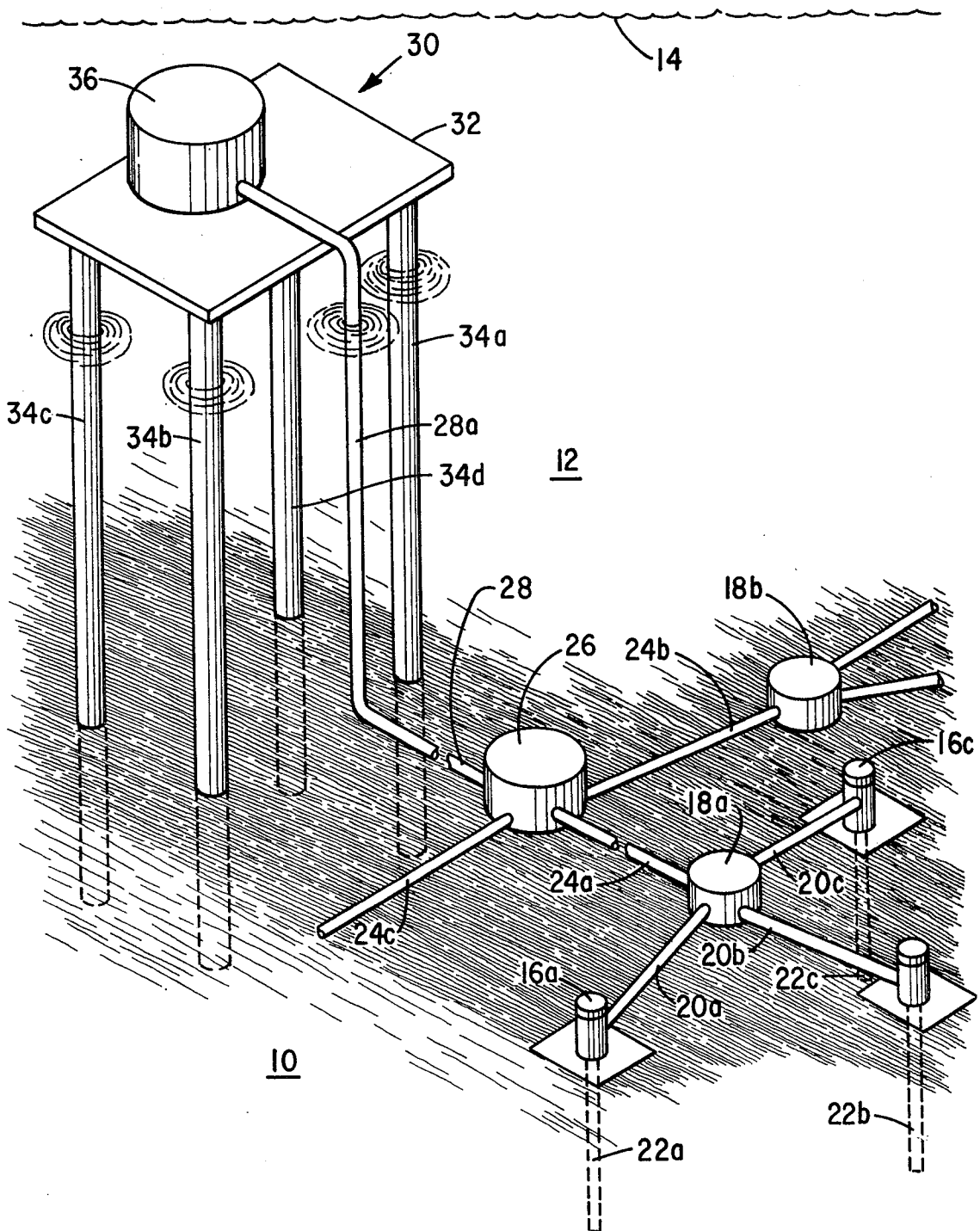


FIG. 1

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2 Sheets-Sheet 2

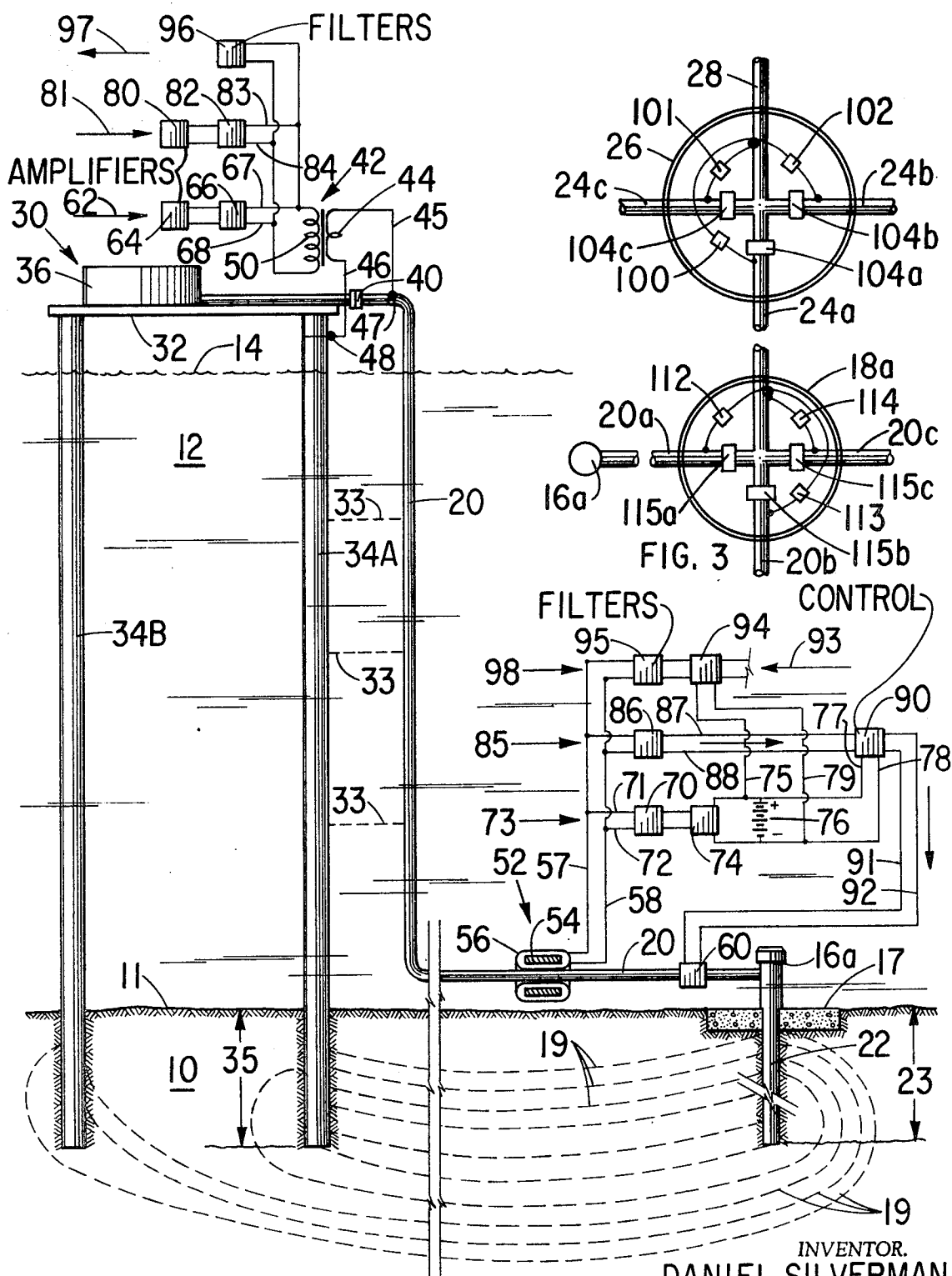


FIG. 2

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**ELECTRICAL COMMUNICATION SYSTEM FOR
OIL FIELD GATHERING SYSTEM**
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ABSTRACT OF THE DISCLOSURE

In a gathering system for oil wells drilled in water locations, the wells are connected by gathering pipelines laid on the ocean floor to a central storage area. Appropriate measuring devices, communication means, control valves, etc., are maintained at each of the wells which are accessible only with great difficulty. In accordance with this invention, these, and other devices at the wells, are communicated with, supplied with power, and controlled by appropriate signals transmitted over the connecting insulated metal pipelines. At each selected point, such as on a platform, where the pipelines are ungrounded, signal and power currents are transformed into and out of the gathering lines by step-down transformers, with low turns windings connected between the lines and ground. Toroidal transformers are used at the underwater wells where the gathering lines are grounded through casing in the wells to the earth. Separate signals to a given well are isolated from other signals and from other wells by appropriate filters.

BACKGROUND OF THE INVENTION

(1) Field of the invention

This invention is concerned with communication with and remote control of individual wells or groups of wells in an oil field gathering system by transmission of signals over the gathering pipelines connecting the wells to a central storage area. More particularly, this invention is directed to the control of subsea-completed wells in offshore oil production systems.

(2) Description of the prior art

In oil field producing operations, a group of oil wells, with casing set into the earth, and in good electrical contact with the earth, are connected by pipelines of appropriate size to a central storage area. At each of the wells, appropriate control valves, metering devices, etc., are provided. On land these well-located devices are manually controlled. However, where the wells are relatively inaccessible, such as in the marsh, or in deep water covered areas, remote control devices are provided at the wells, with remote signaling systems, using electrical conductors or radio signals. In offshore areas, acoustical (sonar) signaling means are also available. All of these remote signaling systems, such as electrical cables, radio, sonar, etc., are expensive, complicated, hard to maintain and limited in their capabilities.

SUMMARY OF THE INVENTION

In this invention the pipelines, which are provided to carry oil or gas from the wells to the central storage area, are used as the communication channels. Signal currents are transduced into these pipelines by means of stepdown transformers at the storage area and at each of the wells, or groups of wells. Where the pipes are grounded by electrical connection to conductors buried in the earth, such as the oil well casings, toroidal transformers are used, with the core surrounding the pipe. Electrical signal currents introduced into the high-turns (signal) winding of the

transformer at the sending point are transformed into larger currents flowing in the pipe to a remote point, where the pipe is grounded, thence into the earth and back through the earth to the sending point. The pipes should be at least partially insulated from the earth so that the leakage current from pipe to earth is small compared to the magnitude of the signal current in the pipe at the receiving end. Appropriate metering, communicating and control devices are placed at each of the well locations.

The principal objective of this invention is to provide communication and control channels between control centers and individual subsea completed wells or groups of wells in offshore operations without the complication, expense, difficulty of maintenance and other drawbacks of the prior art systems. It is a further object of this invention to utilize existing gathering pipelines as communication channels.

These and other objects and details of this invention and advantages thereof will be clear from the following description of the several embodiments as shown in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a generalized view of an offshore oil field gathering system in which the wells are completed on the sea floor and the storage area is mounted on a platform;

FIG. 2 is a detailed view of a portion of the system of FIG. 1;

FIG. 3 is a detail of piping and signaling system at the manifolds or junction points in the gathering system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, FIG. 1 shows in schematic form a typical offshore oil field installation. The earth 10 is overlain with water 12 with the water surface at 14. A number of oil wells 16a, 16b, 16c, etc., are drilled into the earth with casings 22a, 22b, 22c, etc. The wells are completed at the subsea surface 11 (FIG. 2) with superstructures 16a, 16b, 16c, etc.

The wells in FIG. 1, are connected by gathering lines 20a, 20b, 20c, etc., to junctions or manifolds 18a, 18b, etc. A number of such manifolds 18 are connected to a junction or gathering point 26, through lines 24a, 24b, 24c, etc., and the gathering point 26 is connected by line 28 to storage means 36 mounted on producing platform 30. The platform 30 comprises, as a minimum, a working floor 32 mounted on legs or piles 34a, 34b, etc., driven into the sea floor 10.

In FIG. 2, I show a simplified system comprising well 16a supported on floor 17 with casing 22 set to a depth 23. The gathering line 20, which ordinarily is steel, goes from the well 16a to platform 20 where it is connected into the storage means 36. Line 20 is electrically insulated. The line 20 is connected to the platform through an electrically insulating joint 40. Thus the platform end of the gathering line 20 is insulated from the earth, while the well end of the gathering line is solidly grounded through casing 22.

At platform 32, a stepdown transformer 42 is provided. Transformer 42 has a high turns winding 50 and a low turns winding 44. The turns ratio of the winding 50 to 44 is indicated as T, which typically can be greater than about 25 and preferably greater than about 10. The winding 44 is connected by leads 45, 46 to the gathering line 20 at point 47 and the platform at point 48. The platform is a unitary welded steel structure, deeply embedded (to a depth 35), and thus is in good electrical contact with the earth 10. A desired electrical signal 62 is applied to power amplifier 64, filter 66 and through leads 67, 68 to the high turns winding 50 of the transformer 42. This will generate a larger signal current (in the ratio T) in the

secondary or low turns winding 44, which current flows through the pipe 20 to the casing 22 and back through the earth (as suggested by the flow lines 19) to the platform legs 34 and back to winding 44. The current flowing in the earth from the casing 22 to the platform legs 34 spreads out to a very large cross section, and thus the effective resistance of the earth between the casing and the platform is relatively very low.

A toroidal transformer 52 is provided near well 16a. The transformer 52 has a core 54 which surrounds pipe 20 and has a multi-turn winding 56. The pipe 20, casing 22, earth 10 and platform legs 34 act like a single turn conductor threading the core 54. The signal current in the pipe 20 thus generates a corresponding smaller signal current (in the ratio $1/T$) in the winding 56. Thus the signal current impressed on the winding 50 at the platform appears as a corresponding signal on the winding 56 at the well.

The transmitted signal can be of several types, such as a measurement of some quantity, a command to carry out a certain action, a power current, and so on. At the well location in FIG. 2, I have shown three circuits 73, 85 and 98 connected to the winding 56 of the transformer 52. One of these, 73, comprises a filter 70, rectifier 74 and electrical storage means such as battery 76. Filter 70 is connected through leads 71 and 72 to leads 57 and 58 which connect to transformer 52. A second circuit 85 comprises a filter 86, connected through leads 87, 88 to a control box 90. This control box gets power from battery 76 through leads 77, 78 and has an output through leads 91, 92 to a device 60 to be controlled. The device 60 can be of any desired type, such as a flow valve, etc.

The purpose of the filters 66, 82 and 96 at the platform and filters 70, 86 and 95 at the underwater well 16a is to control each of a plurality of signals in the pipe 20 to go to specific circuits. For example, consider the signal 62 to be a power signal of a specific frequency (that of filter 66). At the well it is desired that this signal go into circuit 73. So the filter 70 is tuned to the same frequency pass band as that of filter 66. Similarly, consider a command signal 81, which is amplified at 80, filtered by 82 and applied to the winding 50. It is desired that this signal go to circuit 85 at the well. Thus filter 86 is made to have the same frequency pass band as filter 82 which is different from that of filters 66 and 70. The use of the sets of filters 66, 70, 82, 86, etc., permits the connection of multiple circuits in parallel to each of the transformers.

While the transformers 42 and 52 appear to be different, their action is the same. That is, a current in the high turns (signal) winding induces a correspondingly larger current into the pipe 20. If the end of the pipe 20 at the platform were electrically connected to the tank 36, platform 30 and legs 34 to ground, the transformer at that point would be a toroidal transformer like that, 52, at the well where the pipe 20 is grounded to well casing 22.

Since the action of the transformers is the same, whether they are connected in series with the pipe, as is transformer 42, or in parallel with the pipe, as is transformer 52, signals can be sent from either end of the pipe to the other. For example, I have shown as circuit 98 a signal 93 going to amplifier 94 (that gets its power near leads 75, 79 from battery 76), filter 95 and to the winding 56. A corresponding signal current is set up in the pipe-earth circuit, which generates a corresponding signal in the winding 50 which through filter 96 (which is the only one that matches the pass band of filter 95) to a utilization means 97. The signal 93 can be the measurement of some quantity at the well, or an indication of the state of the device 60 (such as "the valve is open or closed"), or other information. Thus signals of various sorts can be transmitted from one point to another along the pipe 20.

In the case of transformer 52, the signal winding 56 can be said to be inductively coupled to the pipeline. In

the case of transformer 42, the signal winding 50 is inductively coupled to the low turns winding 44 which is conductively coupled to the pipeline. To cover both kinds of transformers I shall consider that the signal windings are "electrically coupled" to the pipeline, or in "electrical relation" to the pipeline. It will, of course, be clear that the transformer 52 and circuits 73, 85, 98, etc., and components 70, 86, 95, 74, 76, 94, 90, 60, etc., must all be housed in waterproof housings to avoid contact with the sea water, as is well known in the art.

I have given no details of the construction of the electrical apparatus, filters, rectifiers, control means, since they are well known in the art and form no part of the present invention. Also, while I have described the conductive element as a pipe, any metallic conductor of sufficiently low resistance can be used.

It will be clear that the best operation of this system will be obtained where the pipe or conductor is insulated from the earth. In the case of offshore systems the pipelines that are laid on the sea floor are wrapped and treated with insulating materials for the purpose of preventing corrosion of the pipe in the sea water environment. This same insulation will prevent the leakage of the signal current from the pipe.

Consider the case in FIG. 2 where the coating on the pipe 20 is not complete, and there is some current leaking through the water from the pipe 20 to the platform legs 34, suggested by the dashed lines 33. It is obvious that current introduced into the pipe at point 47 must travel through the pipe 20 so that at least a part of it passes through the transformer 52 and into the earth through the casing 22. Dependent on the quantity of current leaking off the pipe (33), the quantity introduced into the pipe must be greater by some factor, L. To be sure of the operation of this system, the factor L is preferably greater than 2, and for greater assurance of operation should be greater than 5 or even 10.

This large current is set up in the pipe by having a transformer 42 or 52 with large step-down turns ratio T to match the low impedance of the pipe-earth path. This turns ratio T should be greater than 5, and is preferably greater than 10 or even 25 or more.

While I have shown at both ends of the gathering line 20, transformers 42, 52 with a plurality of circuits in parallel across the signal windings, it will be clear, as is well known in the art, that plural signal windings can be used on each transformer with a single circuit connected to each winding. Or, separate transformers can be used, one for each circuit. However, the system illustrated is the simplest and preferred method of operation, with each circuit isolated from the others by appropriate filters.

The system of FIG. 2 is simplified over that of FIG. 1 in the sense that a single length of gathering line 20 is connected between one station, considered for convenience as the sending station, and the receiving station. If there were no leakage current, all of the current introduced into the pipe at 47 by transformer 42 would pass through the transformer 52 to generate the signal in winding 56.

In the more general case, shown in FIG. 1, the signal current introduced into the line 28 must pass through junctions or manifolds at 26 and 18a to reach the well 16a. Each of these junctions divide the current, providing parallel circuits to ground. For the case shown, where three lines branch out from each junction 26, 18a, the current reaching 16a will, under ideal conditions, be $\frac{1}{3}$ of the current introduced into the line 28. This factor M is a function of the design of the gathering system. It acts to attenuate the transmitted signal in a manner similar to the leakage of current from the pipe to the earth, and must be compensated for by increasing the magnitude of the current introduced into the line at the sending end.

I show in FIG. 3, in schematic form, a method of avoiding the loss of current at each of the junctions 26, 18,

etc. Here, I show the flow line 28 entering the junction 26 with three branches 24a, 24b and 24c. Each of the three branches have insulating sections 104a, 104b and 104c, so that while liquid can flow into all the pipes, no current can flow from 28 to any of the pipes 24. Filters 100, 101, 102 are connected between flow line 28 and each of the lines 24, respectively. Also at the junction 18a at the outer end of pipe 24a, insulating sections 115a, 115b and 115c are inserted into flow lines 20a, 20b and 20c. Also, filters such as 112, 113, 114 are inserted between the line 24a and each of the branch lines 20a, 20b, 20c. Each of the filters, such as 100, must have a plurality of parallel circuits, as many as there are branches to the gathering line at the succeeding junction point, each one tuned to a frequency corresponding to the filters 112, 113 and 114 in junction 18a. The filter 112, for example, is tuned to the filter (corresponding, say, to 86, FIG. 2) at the well 16a. Thus, to send a signal to well 16a, a signal is generated at the platform, filtered by a filter such as 82 corresponding to the frequency of the filter, say 86 at well 16a, and with the junction filters 100 and 112, also tuned to this same frequency. Thus the signal is kept out of all of the branch lines, and goes directly and solely to well 16a without the attenuation that would result if the junction filters were not used. As in the case of the control and communication devices at the wells, the insulating joints, filters, etc., at each of the junctions must be shielded from the sea water by waterproof housings.

While I have shown certain preferred embodiments of this invention, persons skilled in the art may provide still other embodiments which are considered to be part of this invention, the scope of which is to be determined solely by the scope of the appended claims.

I claim:

1. A signaling system for transmitting electrical signals between a first and a second point on the surface of the earth, remote from each other, comprising:

- (a) surface metallic electrical conductor means at least partially insulated from the earth, extending between said two points,
- (b) at least one end of said conductor means electrically connected to buried conductor means in intimate contact with the earth,
- (c) at least two transformer means, one placed substantially at each end of and in electrical relation to said conductor means,
- (d) at least one of said transformer means comprising a toroidal transformer with its core surrounding said conductor means,
- (e) means to introduce electrical signals into one of said transformer means, and
- (f) means to detect said electrical signals at the other of said transformer means.

2. Apparatus as in claim 1 in which said buried conductor means comprises an oil well casing placed in a drilled hole in the earth.

3. Apparatus as in claim 2 in which said conductor means comprises metallic conduit means connected to said well casing.

4. Apparatus as in claim 3 in which said conduit is at least partially insulated from the earth.

5. Apparatus as in claim 1 in which at least part of said conductor means and one of said transformer means are on the surface of a portion of the earth covered by water.

6. Apparatus as in claim 1 in which said transformer means each has a turns ratio such that the application of a signal current of magnitude i will cause a current to be set up in said conductor means of magnitude Ti , where T is a factor greater than 1.

7. Apparatus as in claim 6 in which said factor T is greater than 10.

8. Apparatus as in claim 7 in which factor T is greater than 25.

9. Apparatus as in claim 1 in which at least part of the signal current introduced into the signal sending end of said conductor means leaks off to the earth before the current reaches the receiving end, and the ratio L of current in said conductor means at the sending end to the total leakage current is greater than 1.

10. Apparatus as in claim 9 in which the ratio L is greater than 5.

11. Apparatus as in claim 9 in which the ratio L is greater than 10.

12. Apparatus as in claim 1 in which both ends of said conductor means are connected to buried conductor means and both transformer means comprise toroidal transformer means.

13. Apparatus as in claim 1 in which one end of said surface conductor means is insulated from the earth and the transformer means at that end comprises step-down transformer means with the signal applied to the high turns winding and the corresponding low turns winding connected between the surface conductor means and a buried conductor means in contact with the earth.

14. Apparatus as in claim 1 in which the turns ratio of both of said transformer means is the same.

15. Apparatus as in claim 1 including at the receiving end filter means connected between the high turns winding of the transformer means and the signal detecting means.

16. Apparatus as in claim 1 in which said signal comprises a constant frequency current and said signal detecting means includes rectifier and storage battery means.

17. Apparatus as in claim 1 in which more than two transformer means are placed at separated points in electrical relation to said surface conducting means.

18. Apparatus as in claim 1 in which a plurality of pipes, each connected at one end to different well casings, are connected at their other ends through insulating joints through manifold means, to a single flow line and to a sending transformer, said flow line being connected across said insulating joints at said manifold, through different electrical filters to each of said plurality of pipes.

19. A signaling system for transmitting electrical signals between two points on the surface of the earth remote from each other, comprising,

- (a) at least one well casing sunk into the earth and in good electrical contact with the earth, said casing being at a first point,
- (b) a second point remote from said first point,
- (c) metallic conductor means extending between said first and second points and in electrical contact at one end with said at least one well casing,
- (d) at least one toroidal transformer means surrounding said conductor means at said first point, said toroidal transformer having a first signal winding,
- (e) transformer means at said second point in current transformation relation to said conductor means, said transformer means having a second signal winding,
- (f) means to apply electrical signals to the terminals of one of said winding, and
- (g) means to detect electrical signals at the terminals of the other of said windings.

20. In an offshore oil producing system including at least one subsea well with well casing, gathering line pipe conduit means from said at least one well to an oil storage means, a signaling system for communication between a first point on said gather line means and said well comprising,

- (a) said gathering line means connected electrically to said casing,
- (b) toroidal transformer means near the position of said well, the core of said transformer means encircling said line means,
- (c) transformer means in electrical association with said gathering line at a point remote from said well,
- (d) means for applying electrical signals to one of said transformer means, and

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(e) means for detecting said electrical signal at the other of said transformer means.

21. Apparatus as in claim 20 including filter means connected in series with the signal windings of each of said two transformer means, said filters tuned to substantially the same frequency pass band.

22. Apparatus as in claim 20 including a plurality of signal circuits connected through separate filters, f_1 , f_2 , etc., in parallel across the signal winding of one of said transformer means, a second plurality of signal circuits connected through separate filters f_{11} , f_{12} , etc., in parallel across the signal winding of the second of said transformer means, said two pluralities of filters related such that (f_1 and f_{11}) have the same frequency pass band, and

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(f_2 and f_{12}) have the same frequency pass band different from that of f_1 .

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U.S. Cl. X.R.

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