

[54] **INTERFACE GAGING SYSTEM FOR UNDERWATER OIL STORAGE TANKS**[75] Inventors: **Ivan Lee Wissmiller**, Glen Ellyn, Ill.;
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Oak Brook, Ill.[22] Filed: **May 8, 1972**[21] Appl. No.: **251,053**[52] **U.S. Cl.** **318/482, 73/304 R**[51] **Int. Cl.** **G05d 9/00**[58] **Field of Search** **73/305, 313, 304 R;**
33/126.7 A; 318/482; 137/392[56] **References Cited****UNITED STATES PATENTS**2,394,220 2/1946 Wagner 33/126.7 A X
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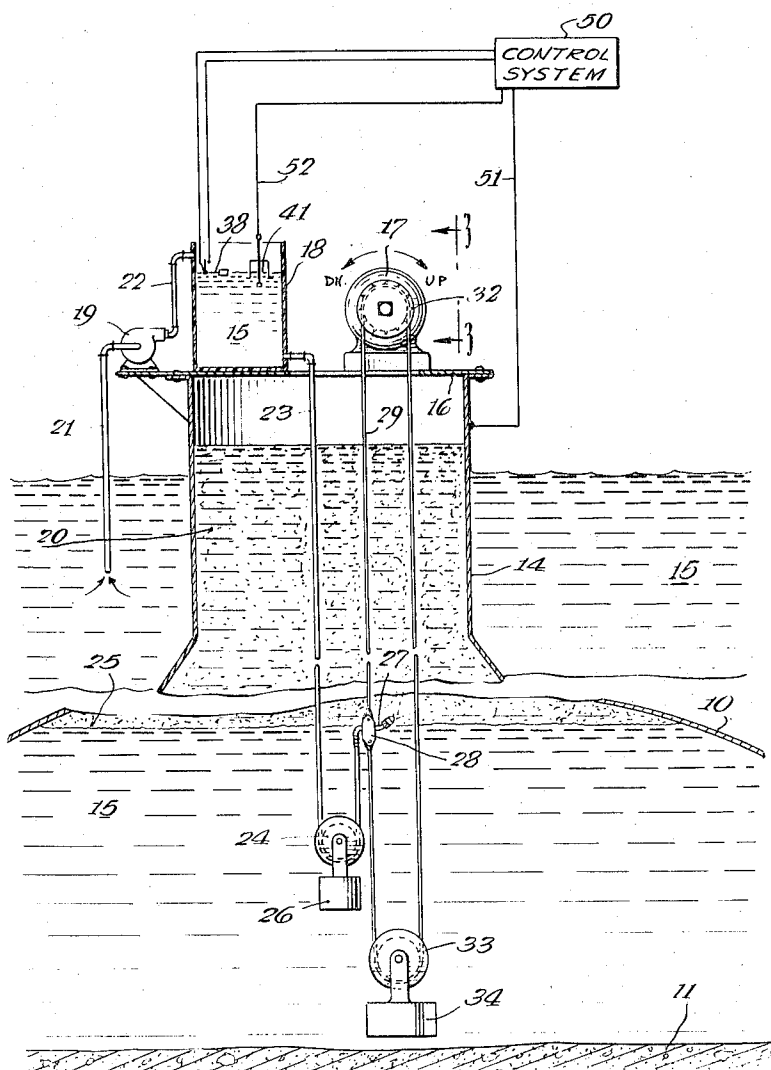
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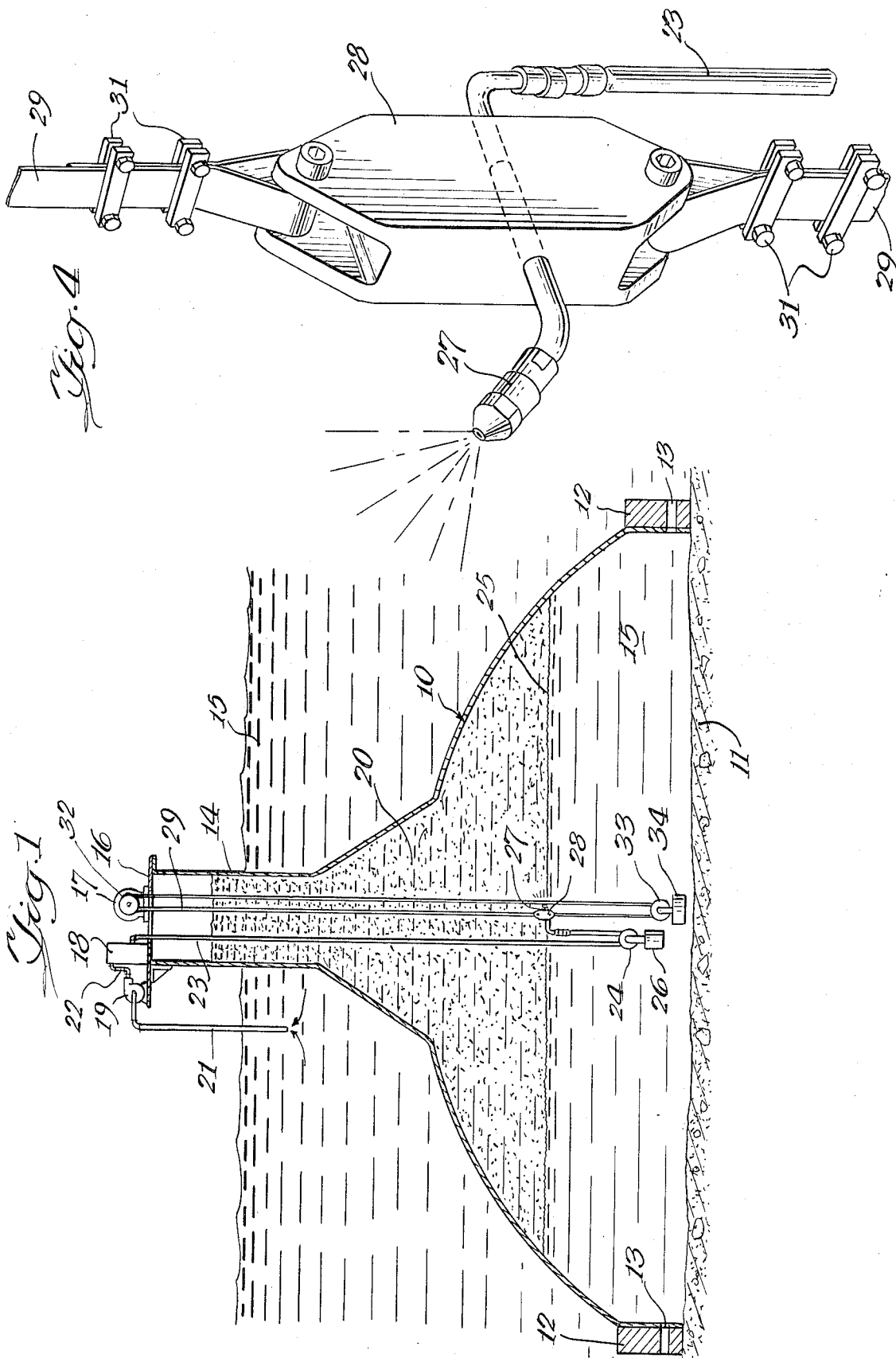
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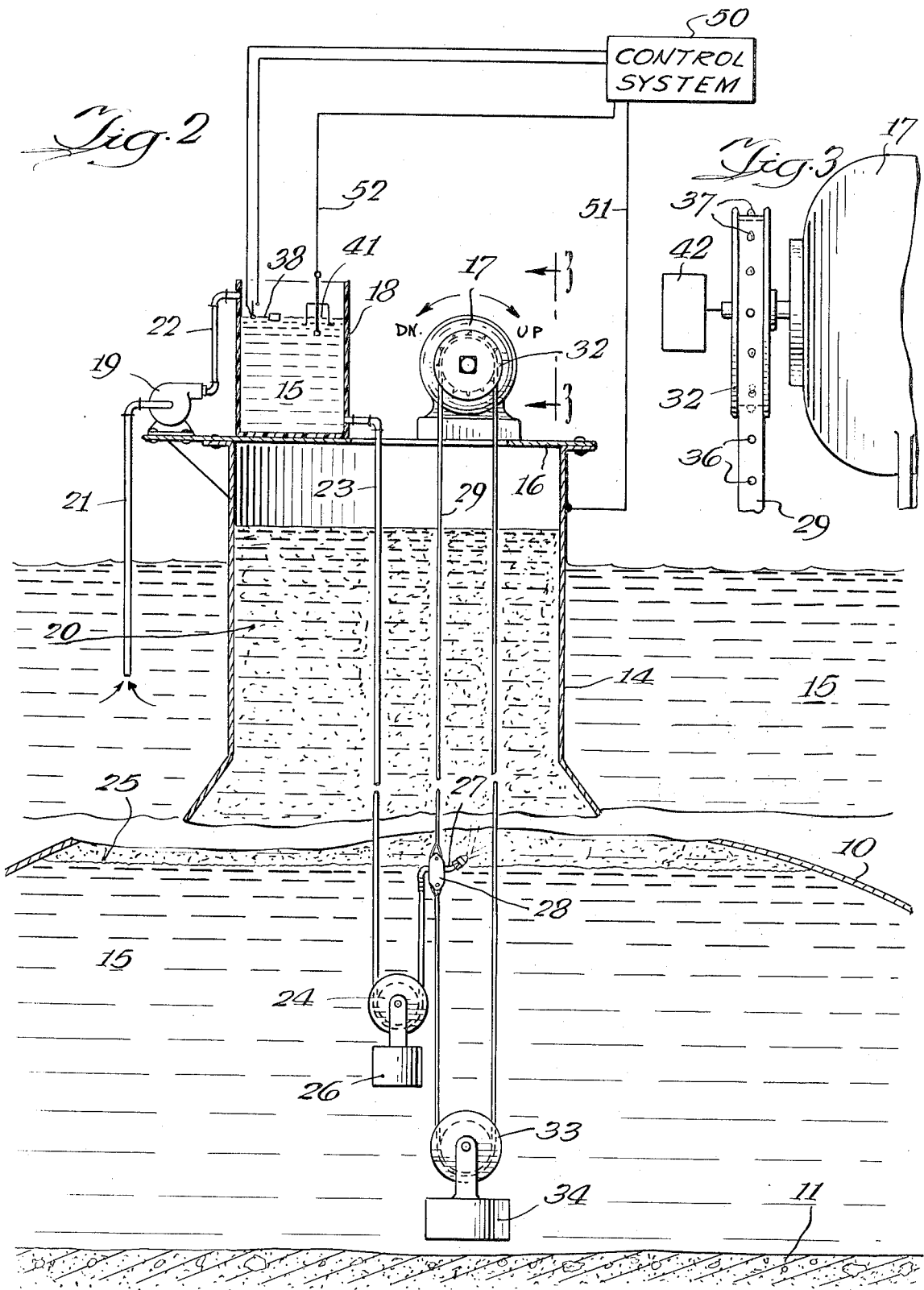
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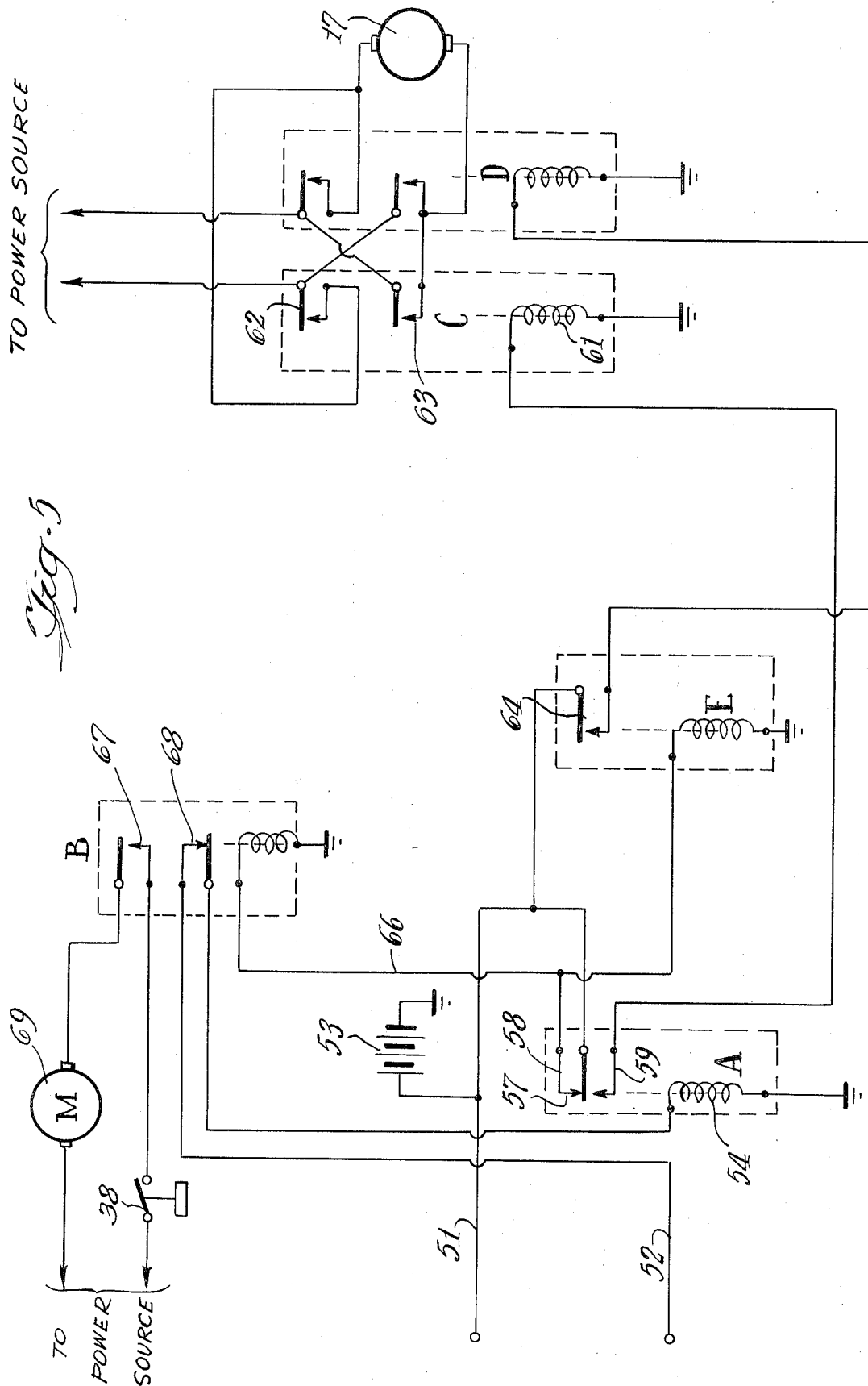
ABSTRACT

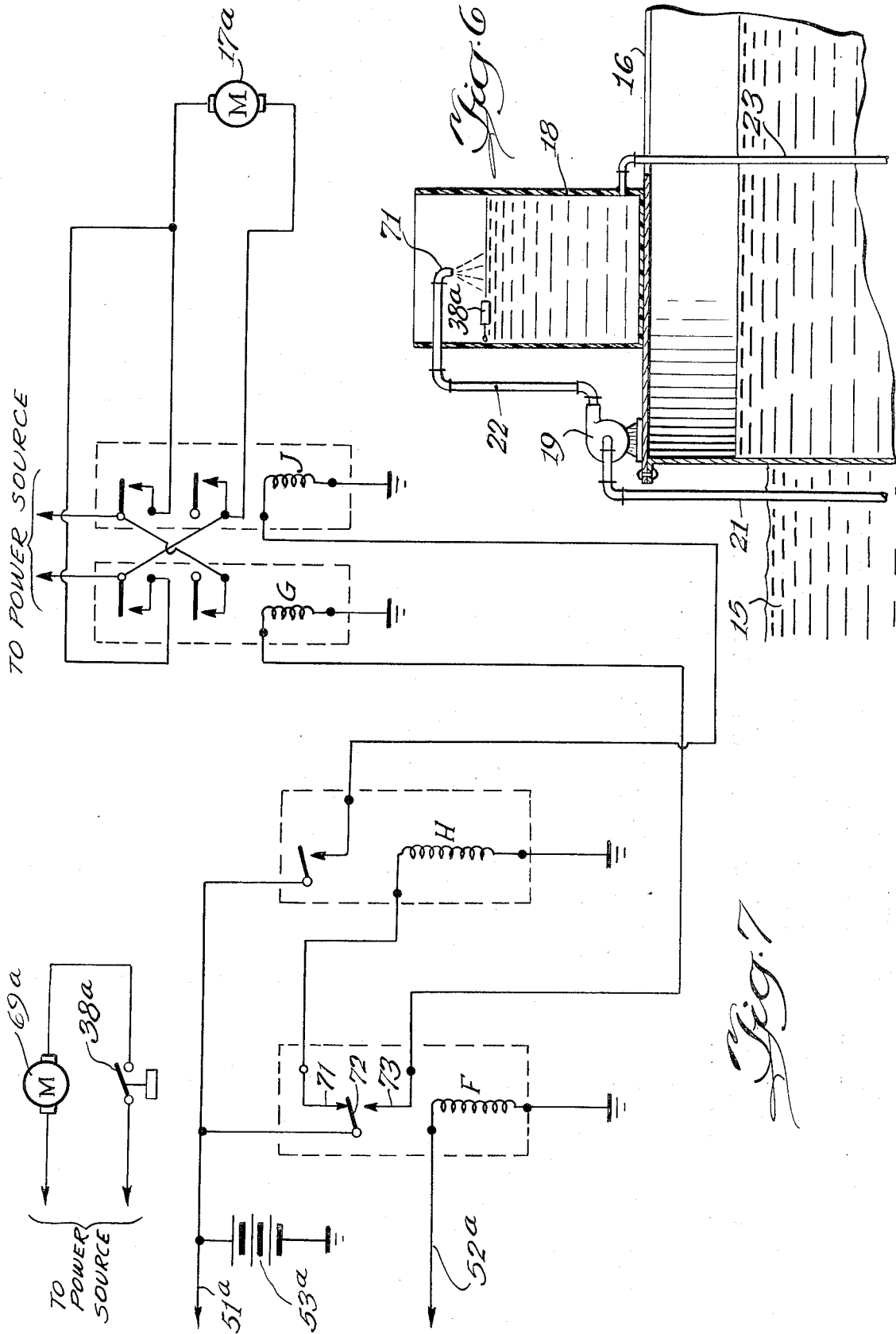
An interface gaging system for underwater oil storage tanks employs a flexible conduit through which a stream of electrically conductive seawater passes, emerging from the end of the conduit through an orifice such as a spray head or nozzle. The spray head is located in the storage tank and raised and lowered by a motor controlled by a sensing system which determines when the spray head is situated in salt water by the closing of an electrical circuit including the stream of seawater in series with the main body of seawater. When the spray head is located in the nonconductive oil, the circuit is open rather than closed, thus activating a control which drives the spray head in the appropriate direction to seek out the interface between the oil and water phases, and to stop when it is reached. The height of the spray head above the tank bottom then represents the oil level in the vessel.

8 Claims, 7 Drawing Figures









INTERFACE GAGING SYSTEM FOR UNDERWATER OIL STORAGE TANKS

This invention relates to a gaging system for determining the liquid level in an oil storage tank. More particularly it relates to a gaging system of the conductivity type intended for use with underwater oil storage tanks.

Among the known methods for storage of crude oil is the use of an underwater storage tank, particularly in connection with the loading and unloading of oil tankers. Such a storage tank consists typically of a container substantially all of which is submerged below the sea level, with its bottom open to the sea and its top extending above the surface of the water. When oil is added to such a storage vessel, the oil, being lighter than the water, collects as an upper layer within the vessel and forces the sea water out through the open bottom thereof. Since the oil is not miscible with the water, there is formed an interface between the oil and water phases which rises and falls as oil is withdrawn from or added to the storage vessel. In order to determine the content of oil within the storage container at any time the elevation of the interface must be gaged.

Determining the oil level in an underwater oil storage container is complicated by the large size of such vessels. A typical container may have a capacity of five hundred thousand barrels of crude oil and may be situated in a depth of 200 feet of sea water. Adding to the complications are fouling problems arising from the emulsion and other impurities which may exist at the oil-water interface, plus the physical difficulty of installing and removing a gaging device when necessary for cleaning or replacement.

In accordance with the invention, there is provided a gaging system for use with underwater oil storage tanks which is simple in construction, easily installed and removed from the storage vessel and not susceptible to fouling in operation. Briefly described, the system includes an electrical circuit which depends on the electrical conductivity of sea water as opposed to the nonconducting nature of crude oil. The system employs a flexible conduit through which a stream of sea water constantly passes, emerging from the end of the conduit through an orifice, such as a spray head or nozzle. The spray head is raised and lowered by a motor controlled by a sensing system which determines when the spray head is situated in salt water, by the closing of an electrical circuit. When the spray head is in the oil phase, the circuit is open rather than closed, thus activating a control which drives the spray head in the appropriate direction to seek out the interface between the oil and water phase, and to stop when it is reached. The height of the spray nozzle above the tank bottom then represents the oil level in the vessel.

The invention will be better understood from the following description thereof, taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a side elevation of a typical underwater storage container in partial section, showing one embodiment of the gaging system of the invention installed therein;

FIG. 2 is an enlarged view of portions of the container shown in FIG. 1, showing further details of the gaging system;

FIG. 3 is a partial view along the line 3—3 of FIG. 2 showing the motor means for raising and lowering the spray head for determining the interface level;

FIG. 4 is an isometric view showing the constructional details of a typical spray head assembly;

FIG. 5 is a schematic diagram of the control system which is used with the embodiment of FIG. 1 to control the upward and downward movement of the spray head assembly;

FIG. 6 shows an alternative embodiment of the means for supplying the stream of salt water which passes through the spray assembly; and

FIG. 7 is a schematic diagram of the control system used with the embodiment of FIG. 6.

As shown in FIG. 1, a typical underwater storage vessel consists of a generally bell-shaped container 10 open at its bottom and resting on the floor 11 of the sea. Container 10, typically made of electrically conductive material such as steel plate, is anchored by means of weights 12 provided with conduits 13 through which the sea water 15 may enter and leave the interior of the vessel. Oil 20 held in container meets the water 15 at interface 25, which rises and falls as oil is removed from or added to container 10. The upper portion of container 10 narrows into a neck-like portion 14 which extends above the surface of the water. The top of container 10 is provided with a horizontal platform 16 which supports the components of one embodiment of the level gaging system of the invention shown in greater detail in FIG. 2.

As shown in FIG. 2, mounted on platform 16 is tank 18, which is made of an electrically nonconductive material, such as glass-fiber reinforced plastic. Tank 18 is provided with a filling system comprising conduit 22, and pump 19, driven by a suitable motor (not shown in FIG. 2; shown as item 69 in FIG. 5), which draws its supply of water through pipe 21, the open end of which is submerged below the surface of the sea. Pump 19 is controlled in a manner hereinafter to be described so that tank 18 always contains an adequate reserve of sea water. Attached to the wall of tank 18 at a point near its bottom is flexible hose 23 made of an electrically nonconductive material such as rubber. Hose 23 is weighted by means of pulley 24 and weight 26. The free end of hose 23 is provided with spray head 27, which, as shown in FIG. 4, is mounted in an electrically nonconductive holder 28, which in turn is connected at its top and bottom ends to metal tape 29 by clamps 31.

Also mounted on platform 16 is drive motor 17, having sheave 32 attached to its shaft (FIG. 3). Together with spray head holder 28, tape 29 forms a closed loop, the top end of which passes around sheave 32, while the lower end passes through lower sheave 33 which in turn is weighted by weight 34 to maintain its position near sea floor 11. The upper part of tape 29, which runs over upper sheave 32, is provided with perforations 36 which engage corresponding pins 37 on the surface of upper sheave 32, as shown in FIG. 3, thereby assuring positive, non-slip engagement of the tape and sheave. In response to control signals from control system 50, drive motor 17 can be caused to rotate in a clockwise or counterclockwise direction, thereby raising or lowering spray head 27. Cooperating with control system 50, are float switch 38 which is actuated by the level of sea water in tank 18 and hose electrode 41 which floats on the surface of the water in tank 18 and makes electrical contact therewith.

The vertical position of spray head assembly 27, and thus the level of the oil-water interface in container 10 is shown by indicator 42, which is connected to the

shaft of drive motor 17 and is suitably calibrated for this purpose. Since tape 29 has a constant length and the engagement of pins 37 with perforations 36 in the tape prevents relative slippage therebetween, indicator 42 can be a simple rotary counter for the shaft of motor 17, calibrated to read the linear position of the tape. Other suitable level indicators will be apparent to those skilled in the art.

Control system 50 is connected as shown by electrical cables 51 and 52 to the metallic structure of container 10 and to hose electrode 41. As shown in FIGS. 2 and 5, there is thus formed an electrical circuit including conductor 52, electrode 41, the conductive sea water in tank 18 and inside hose 23, the conductive sea water below the oil-water interface in the underwater storage container 10 (when spray head 27 is situated below the interface), the metal structure of the underwater container 10, and cable 51. In the event that container 10 is made of a nonconductive material, or is electrically insulated from the liquid therein, e.g., by a nonconductive paint or other surface coating, an electrically conducting electrode can be positioned in the sea water outside of container 10. All electrical connections indicated as being made to the structure of container 10 (e.g., conductor 51) would be made instead to this electrode. It will be seen that when spray head 27 at the lower end of hose 23 is positioned in sea water, the circuit is closed; when spray head 27 is in the oil phase the circuit is broken by reason of the nonconductive nature of the oil.

A suitable control system for controlling the movement of spray head 27 in such a manner as to locate the oil-water interface is shown in FIG. 5. As there depicted, the control system includes a battery 53, or other source of electromotive force, one side of which is connected through conductor 51 to the metal structure of container 10 while the other side is connected (via the ground connection) through coil 54 of main control relay A, normally closed switch 68 of holding relay B and conductor 52 to hose electrode 41. As long as spray head 27 discharges into the electrically conducting sea water there is a conducting electrical path between conductors 51 and 52. As a consequence, a circuit is completed across battery 53 and main control relay A is thereby activated, causing normally open contacts 58, 59 to close and normally closed contacts 57, 58 to open. The closing of contacts 58, 59 completes the circuit from battery 53 to the coil 61 of "up" control relay C, causing the closing of normally open switches 62 and 63, supplying power to drive motor 17 and causing upward movement of spray head 27, which continues so long as the circuit between conductors 51 and 52 is closed. As soon as spray head 27 moves into the nonconducting oil phase in container 10, however, the circuit between conductors 51 and 52 opens, causing contacts 58, 59 to open and contacts 57, 58 to close, thus deactivating "up" control relay C and causing drive motor 17 to stop.

In order to avoid continuous hunting of the spray head about the oil-water interface, the control system provides a delay which occurs after the upward movement of spray head 27 stops, i.e., when the spray head enters the oil phase. The closing of contacts 57, 58 actuates time delay relay E, which after an appropriate time delay (e.g., 5 minutes) closes normally open switch 64, applying voltage to "down" control relay D, supplying power to drive motor 17 and causing spray

head 17 to descend, provided that spray head 27 is still located in the oil phase. The spray head will continue to descend until it enters the electrically conductive water phase, thereby completing the circuit between lines 51 and 52, as previously described, thus causing drive motor 17 to reverse its direction. In this way the level gaging system periodically seeks out the oil/water interface and indicates its position. The specific time delay involved in the operation of relay E is a matter of choice depending on how rapidly fluctuations occur in the oil level within the storage system.

The remaining portion of the control system shown in FIG. 5 is directed to maintaining an adequate reservoir of sea water in tank 18. Because of the possibility that a false indication of a completed circuit between conductors 51 and 52 might occur during periods when the tank is being filled (i.e., from hose electrode 18 through the stream of water in pipe 22, pump 19, and pipe 21 to the main body of the sea and thence to container 10), the control system is designed so that tank 18 is filled only during the periods while time delay relay E is in a period of delay. Relay B is of the holding type, such that once energized it remains in the energized condition for a predetermined time somewhat less than the delay period of relay E (e.g., 4 minutes holding time for a 5 minute delay period). As soon as time delay relay E is activated by the closing of contacts 57, 58, holding relay B is also activated (through conductor 66) closing normally open switch 67 and opening normally closed switch 68. If at that time the water level in tank 18 is low enough to cause float switch 38 to close, power is applied to pump motor 69, causing pump 19 to start filling tank 18 with sea water. The filling will continue until float switch 38 opens, removing power from the pump, or the holding period of relay B expires, whichever is the first to occur. It will be seen therefore that pump motor 69 can be energized only during the periods in which the drive motor 17 is disabled by time delay relay E, thus avoiding false indications of a change in oil level.

An alternative embodiment of the invention in somewhat simpler form is shown in FIG. 6. In this case, the system used for supplying sea water to tank 18 uses a spray nozzle 71 positioned above the tank, which breaks up the entering stream of water into discrete particles, thereby destroying its conductivity. Accordingly, no circuit can be completed from hose electrode 18 through pump 19 and connecting pipes 21 and 22 to the main body of the sea. There is therefore no necessity for a tank-filling system which prevents operation except during the delay period of relay E. (FIG. 5) Accordingly, as shown in FIG. 7 the control circuit for pump motor 69a comprises only float switch 38a which opens and closes as necessary to maintain a supply of sea water within tank 18. The associated level control system (FIG. 7) can also be somewhat simplified compared to that of the embodiment shown in FIG. 5. As indicated in FIG. 7, when a circuit is completed between lines 51a and 52a as spray head 27 enters the water phase within container 10, main control relay F is energized by battery 53a, opening normally closed contacts 71, 72 and closing normally open contacts 72, 73. The closing of contacts 72, 73 energizes "up" relay G, which applies power of a polarity which drives drive motor 17a in such a direction as to raise spray head 27. The upward movement of the spray head will continue until such time as the spray head enters the oil phase,

thereby breaking the circuit between lines 51a and 52a, causing main control relay F to be deenergized, closing contacts 71, 72, and thereby actuating time delay relay H, which after the delay period energizes "down" relay J, causing drive motor 17a to reverse and lower the spray head 27.

Although the invention has been described with particular reference to an underwater oil storage container, it will be apparent that its use is not restricted thereto. The apparatus and method of the invention can be used in general to gage the level of the interface between any two immiscible liquids of different densities stored in a container, only one of said liquids being electrically conductive, regardless of the specific identities of the liquids.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

We claim:

1. Level gaging apparatus for gaging the interface level between two immiscible liquids of different densities in a storage container, one of said liquids being electrically conductive and one being nonconductive, said apparatus comprising:

flexible electrically nonconductive conduit means provided at one end with an orifice located within said container, the vertical position of said orifice being controllable;

means for establishing a stream of said electrically conductive liquid within said conduit means, said stream discharging through said orifice into the main body of one of said liquids in said container, depending on the vertical position of said orifice; electrical circuit means including in series, the main body of said electrically conductive liquid and said stream of conductive liquid, said circuit being closed when said stream discharges into the main body of said conductive liquid and open when it discharges into said nonconductive liquid;

positioning means for varying the vertical position of said orifice within said container;

control means responsive to the opening and closing of said circuit means for activating said positioning means to move said orifice in a direction toward the interface between said liquids and stopping said movement when said interface is reached; and indicating means for indicating the level of said orifice.

2. The apparatus of claim 1 wherein said storage container is a part of the series electrical circuit.

3. The apparatus of claim 1 in which the means for establishing a stream of said conductive liquid includes an electrically insulated tank supported above the top of said container, to which tank is connected said flexible conduit, said stream of liquid being produced by the force of gravity.

4. The apparatus of claim 1 in which said positioning means includes an endless belt and a rotatable sheave which supports said belt in a vertical position, the orifice of said flexible conduit being attached to said belt, adjustment of the vertical position of said orifice being effected by rotating said sheave.

5. The apparatus of claim 1 in which said control

means includes:

relay means which is actuated on the closing of said circuit means to cause said positioning means to move said orifice in a first direction toward said interface and to stop said movement when said interface is reached; and

time delay relay means which is actuated on the opening of said circuit to move said orifice in a second direction opposite to said first direction, after the expiration of a time delay.

6. The apparatus of claim 1 which includes:

an electrically insulated tank supported above the top of said container, to which tank is connected said flexible conduit, said stream of liquid being produced by the force of gravity;

relay means which is actuated on the closing of said circuit means to cause said positioning means to move said orifice in a first direction toward said interface and to stop said movement when said interface is reached;

time delay relay means which is actuated on the opening of said circuit to move said orifice in a second direction opposite to said first direction, after the expiration of a time delay, and

means for filling said insulating tank with said conductive liquid, comprising:

pump means for pumping said liquid into said tank; and

control means for controlling the operation of said pump means and which limits the operation of said pump means to delay periods of said time delay relay means.

7. A method of gaging the interface level between two vertically adjoining bodies of immiscible liquids of different densities, one of said liquids being electrically conductive and one being nonconductive, which method comprises:

establishing a stream of said conductive liquid through a flexible electrically nonconductive conduit, said stream being electrically conductive and discharging through an open end of said conduit; positioning said open end of said conduit in one of said bodies of liquid, whereby said stream discharges directly into said one of said bodies and sensing when said stream discharges into said conductive liquid and makes electrical contact therewith;

establishing an electrical circuit including an electromotive force in series with said stream of conductive liquid and the main body of said conductive liquid, said circuit being closed when said stream discharges into said main body and is otherwise open;

moving said open end of said conduit vertically in a direction which will cause it to pass through the interface between said conducting and said nonconducting liquids; and

gaging the location of said interface by the change sensed in said circuit between open and closed conditions.

8. The method of claim 7 wherein said conductive liquid is sea water and said nonconducting liquid is oil.

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