



(43) International Publication Date
13 December 2007 (13.12.2007)

(10) International Publication Number
WO 2007/142933 A2

(51) International Patent Classification: **Not classified**

(21) International Application Number:

PCT/US2007/012681

(22) International Filing Date: 30 May 2007 (30.05.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

60/810,013 31 May 2006 (31.05.2006) US

(71) **Applicant** (for all designated States except US): **GRAFFE LIQUID MANAGEMENT SYSTEMS, INC.**
[US/US]; 619 Main Street, Grand Junction, CO 81501
(US).

(74) **Agent:** HARTZ, Edwin, L.; 2537 Falls View Circile,
Grand Junction, CO 81505 (US).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL,

IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK,
LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW,
MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL,
PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY,
TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA,
ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GO, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:

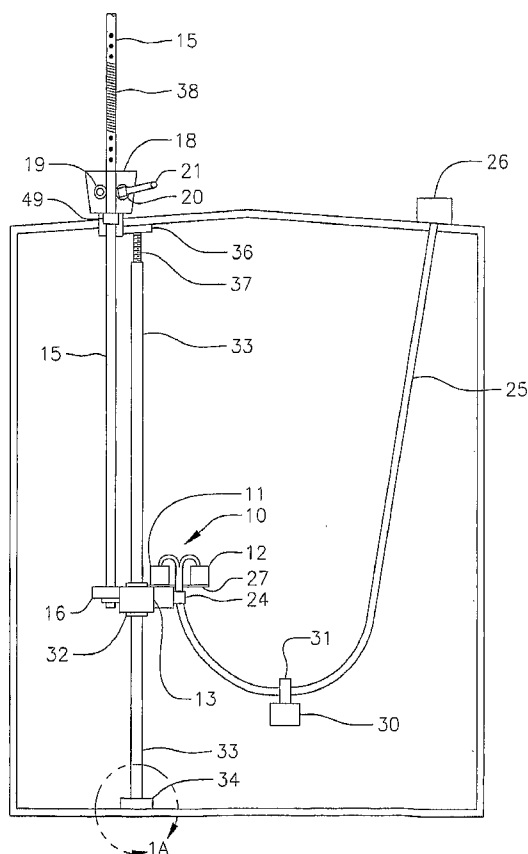
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— without international search report and to be republished upon receipt of that report

[Continued on next page]

(54) Title: LIQUID LEVEL DETECTORS AND SYSTEMS FOR USE



(57) Abstract: A system for managing stratified liquids in a storage tank includes a variable height, in-tank transducer, configured to identify liquid layers of differing and to indicate an elevation of the liquid layers, a motorized drive unit for adjusting an orifice to intercept a selected layer, wireless data transmission technology, and software to facilitate remote operation of the system.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

1 **57752/H639 - G131061**

LIQUID LEVEL DETECTORS AND SYSTEMS FOR USE

FIELD OF THE INVENTION

5

Management of liquids and more particularly the identification of liquids, the detection and use of the levels of stratified liquids and the detection and use of gradients in a liquid.

BACKGROUND OF THE INVENTION

10

[0001] There are many fields in which there is a need-to-know the gradient of a chemical, physical or electrical property of a liquid or the levels of different liquids in a container, and in some cases the level or zone of the transition from one type of liquid to another type of liquid. For example, the liquids from gas wells called natural gas liquids (NGLs) often times include valuable oil (often called condensate) as well as waste products and water. Thus, in the gas production field, it is useful to know the level of transition in a container between oil and water. In some gas well production units, the NGLs are placed in a settling tank where the liquids stratify. The clean oil, being the lightest, floats on top of the other liquids. The clean oil may be removed from the settling tank by use of a variable height inlet/outlet orifice tool as disclosed in PCT Patent Application Serial Number US2006/004479 filed February 8, 2006 and assigned to the same Assignee as this application, the disclosure of which is incorporated herein by this reference as though set forth in full.

15

20

25

[0002] In some cases, the clean oil is placed in an oil sale tank where there is further separation of the oil from water and other contaminants, typically called bottom sediment and water (BS&W). When there is primarily oil and water in a settling tank, presently available liquid level detecting units can be used to detect and record the transition between air and the top level of the oil and between the oil and the water or the bottom level of the oil. This information may be used to position the orifice of the variable height inlet/outlet orifice device referred to above for selectively

1 **57752/H639 - G131061**

removing the clean oil. Some of these detectors employ radar or sonar and are fixed in place on top of the tank or in the side wall of the tank. Others are manually inserted in the tank and then
5 removed to gauge the elevation of the level or transition, and some float in the tank.

[0003] The radar devices and sonar devices presently available are sufficiently accurate to measure the quantity of oil removed for custody transfer purposes. A radar level detector useful for this purpose is the Rosemount 3300 Radar Level Detector. A sonar level detector useful for this purpose is the Accu-gage Level Detector manufactured and sold by CTI Technologies, Inc. There
10 are other level detectors employing other technology, such as ultrasound and magnitostriiction that can provide the transition information between very different liquids, such as oil and water. These devices are most useful where there are only two liquids, e.g., oil and water.

[0004] It has been desirable for some time to provide a very accurate detection of transitions between liquids and thus liquid levels and, more particularly, the detection of zones of transition
15 from one liquid to another. It is even more desirable now to provide this accurate detection when combined with the variable height inlet/outlet orifice device of the above-referenced Patent Application. This combination results in reduced truck traffic, simplified custody transfer, and the ability to access any identified liquid or area in a container of stratified liquids independent of the other liquids. This combination also provides access for removing or adding a material from or to a
20 transition zone in a container based on a measured parameter or property of the liquid in the zone.

[0005] It has also been desirable to detect vertical gradients of a chemical, physical or electrical property of a liquid in a container.

SUMMARY OF THE INVENTION

25 [0006] Liquid levels and zones of transition may be accurately determined by the use of a sensor, using one of the known technologies, that is moved up or down on a carriage in a container or tank of a liquid or of stratified liquids. The sensor has a transducer or transmitter that sends a signal to a detector or reflector on the carriage that carries the transducer. The vertical movement

1 **57752/H639 - G131061**

of the carriage carrying the transducer and detector or reflector is monitored to provide the elevation of the sensor in the container and, thus, the liquid levels or zones of transition from a liquid having a specific chemical, physical or electrical property to a liquid having a different physical, chemical or electrical property.

[0007] In one form of the invention, the carriage for the sensor is moved up and down by an adjusting and measuring rod that passes through a gear mechanism. The adjusting and measuring rod has teeth or indentations such as disclosed in the above-referenced PCT Patent Application.

10 The gear mechanism is driven by hand or by a motor. If driven by hand, the operator notes both the distance and direction of travel of the measuring rod and thus knows the position of the sensor inside the tank. If the adjusting and measuring rod is driven by a motor, a sensor for distance traveled is included in the motor drive mechanism. A sensor for direction of travel is also included in the motor drive mechanism. Alternatively, the carriage is attached to a nut on an upright lead screw in the tank so the carriage moves up and down with the nut as the lead screw is turned. The lead screw may be turned either manually by a crank on the top of the container, or by a motor inside or outside the container. If turned manually, the direction and distance traveled are noted by the operator. If turned by a motor, sensors are provided to detect and record the distance traveled by the carriage and the direction of travel of the carriage. Further, instead of a separate carriage and drive mechanism for the moveable sensor, the sensor may be carried on the same carriage as that for the housing for the variable height inlet/outlet orifice device as disclosed in the above-referenced PCT Patent Application and as disclosed in the Provisional U.S. Patent Application Serial Number 11/413, 774 filed on April 28, 2006 and assigned to the same Assignee as this application. The disclosure of this latter application is incorporated herein by this reference as

25 though set forth in full.

[0008] The sensor, whether carried by an independent carriage or by the housing carriage for the orifice, can be any suitable type. For example, it can be an ultrasound sensor which sends

1 **57752/H639 - G131061**

sound waves from the transducer to a receiver. The time it takes for the signal sent from the transducer to reach the detector depends upon the characteristics of the liquid and particularly the density and temperature of the liquid. The sensor can also be a turbidity meter which employs light as the source and a photo detector or photoelectric cell. The amount of light dispersed by the liquid can be measured as an indication of the type of liquid present in the path of the light source. Alternatively, radar and sonar type sensors can be employed and the speed of the electromagnetic wave measured as an indication of the type of material or liquid in which the sensor is positioned. Other sensors can be employed that provide an output indicative of the type of liquid based on one or more chemical, physical, or electrical property. Additionally, the electrical conductivity, impedance (resistance) and/or capacitance of the liquid can be sensed to indicate the type of liquid and the transition. Gradients of a physical, chemical or electrical property in one liquid may also be detected. For example, temperature gradients may be sensed. Another characteristic that may be sensed is the chlorine gradient in a container of water.

[0009] The functionality of the sensor is not limited by the above examples. The sensor may be responsive to any one or more of the physical, chemical and/or electrical property of the liquid in which the sensor is used.

[0010] The above and other features, objects and advantages of this invention will become apparent from a consideration of the foregoing and the following description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Fig. 1 is a schematic diagram of a moveable sensor mounted to slide up and down on a support pole, and be driven by a gear mechanism and adjusting rod, in accordance with the present invention;

[0012] Fig. 1A is a schematic diagram of an attachment plate at the bottom of the support pole, in accordance with the present invention;

1 **57752/H639 - G131061**

[0013] Fig. 2 is a schematic diagram of an automated drive mechanism, in accordance with the present invention;

5 [0014] Fig. 2A is a schematic diagram of a magnetic disk for recording distance traveled by the carriage for the moveable sensor and the direction of travel, in accordance with the present invention;

[0015] Fig. 2B is a chart of the pulse output from the magnetic disk, in accordance with the present invention;

10 [0016] Fig. 2C is a chart of the output of the track for indicating one direction of travel of the carriage, in accordance with the present invention;

[0017] Fig. 2D is a chart showing the output of the track indicating travel for the carriage in a direction opposite from that shown in Fig. 2C, in accordance with the present invention;

15 [0018] Fig. 3 is a schematic diagram of a carriage for a moveable sensor driven by a nut on a lead screw turned by a hand crank, in accordance with the present invention;

[0019] Fig. 4 is a schematic diagram of a motor-driven lead screw of the type shown in Fig.3;

[0020] Fig. 5 is a schematic diagram of a moveable carriage for a sensor carried by the housing for an adjustable orifice driven by a gear mechanism and adjusting rod, in accordance with the present invention;

20 [0021] Fig. 6 is a schematic diagram of a moveable housing for an orifice carrying the sensor, with the housing for the orifice being driven by a nut on a rotatable lead screw, the nut being restrained from rotation by a support pole in accordance with the present invention;

[0022] Fig. 7 is a schematic diagram of an independent carriage for a moveable sensor in the same container with a separate moveable carriage for an inlet/outlet orifice, each carriage being
25 driven by a separate lead screw, and being restrained from rotation by a separate respective support pole in accordance with the present invention;

1 **57752/H639 - G131061**

[0023] Fig. 8 is a schematic diagram of the apparatus of Fig. 7 positioned in an oil sale tank, in accordance with the present invention;

5 [0024] Fig. 9 is a schematic diagram of the apparatus of Fig. 7 positioned in a produced water tank associated with gas wells, in accordance with the present invention;

[0025] Fig. 10 is a schematic diagram of a sensor having a transmitter and a receiver, in accordance with the present invention;

10 [0026] Fig. 11 is a schematic diagram of a sensor having a transmitter and a receiver coupled with a sonar transducer and angled reflector, in accordance with the present invention.

[0027] Fig. 12 is a fragmentary diagram of details of a moveable carriage driven by a nut on a lead screw, in accordance with the present invention, and adapted to be mounted in the tank shown in Fig. 13; and

15 [0028] Fig. 13 is a front elevation view, partially in cross-section, showing details of the top attachment and the bottom attachment in a tank for the components of Fig 12, in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

20 [0029] A moveable sensor mounted on an independent carriage or mounted on the housing for an inlet/outlet orifice is shown in the drawings. A manually operated independent carriage system for a moveable sensor in a tank or container 4 is shown in Fig. 1. A sensor 10 having a transmitter 11 and a receiver 12 is carried by a carriage 13. The carriage 13 is moved vertically up and down by an adjusting rod 15 attached to the carriage 13 by a bracket 16. The adjusting rod 15 is moved up and down and thus moves the carriage 13 up and down through a gear mechanism 18. The
25 adjusting rod 15 has crescent shaped indentations and the engaging gears 19 and 20 of the gear mechanism 18 have Woodruff-type tabs that engage the indentations in the rod 15. This gear mechanism and adjusting rod is shown in detail in the above-referenced PCT Patent Application Serial Number US2006/0044479 filed February 8, 2006. A hand crank 21 is provided to move the

1 **57752/H639 - G131061**

adjusting rod 15 up and down by operation of the gear mechanism 18 to move the sensor 10 vertically inside the container 4 through the complete range from the bottom to the top of the container.

[0030] The sensor discriminates between the liquids to provide an output indicative of the particular liquid, such as, for example, water, clean oil, dirty oil, waste oil, etc. The sensor 10 has a transmitter 11 and receiver 12. Alternatively, the receiver 12 is a reflector with the transmitter 11 including a receiver for sensing reflected energy from the transmitter.

10 [0031] A control console 26 positioned on top of the container 4 provides power and the operational signals to the sensor 10, and receives the data from the sensor 10. The console 26 is coupled to the sensor 10 through a power and data transport cable 25 sealed through the top of the container.

15 [0032] The carrier 13 has an arm 27 that extends from one side of the carrier to support the transmitter 11 and receiver 12 of the sensor 10. The cable 25 is secured to the carrier by a strap 24, and is kept relatively taut between the strap and console 26 by a weight 30 suspended from a roller 31 that easily moves along the cable 25 as the carriage is moved up and down. The carriage has an internal cylindrical sleeve 32 that makes a close sliding fit around a vertical cylindrical support pole 33 in the tank, and is free to move up and down on the pole. The carriage 13 can be constructed of oil-impregnated brass to provide electrical contact with the pole and other components, and to lubricate movement up and down the pole. Preferably, the cylindrical sleeve 32 is made of conductive PTFE, such as carbon-filled PTFE, or similar material that easily slides on the pole 33 and provides electrical contact between the pole 33 and the carrier 13. With such an insert or sleeve, the carriage does not need to provide lubrication and may be made of material other than oil-impregnated brass. It is best, however, for the material to be non-ferrous to avoid sparking upon accidental contact with the tank or any ferrous metal object. The lower end of the support pole 33 fits in a lower mounting plate 34 on the bottom of the container. The upper end of

25

1 **57752/H639 - G131061**

the support pole fits in an upper mounting plate 36 secured to the inside of the top of the container. The upper plate 36 is connected to a threaded insert 37 that cooperates with internal threads in the upper end of the pole 33 to provide for a telescoping action of the pole 33. The bottom plate 34
5 may be welded in place in new containers or, if the device is a retrofit where the container has held volatile materials, such as condensate from a gas well, then the lower plate 34 may be held in place by magnets 35 (Fig. 1A). Greater detail of the attachment of the lower plate 34 and the relationship between the lower plate 34 and the lower end of support pole 33 is shown in Fig. 1A.

10 **[0033]** The lower plate 34 has a ball 40 mounted above the top surface 41 of the lower plate 34. A brass cup 42 is attached to the lower end of the pole 33, and has a socket 43 that mates with the outer surface of the ball 40. The inner surface of socket 43 of cup 42 is lined with a conductive bearing material, such as conductive PTFE, to provide ease of movement and electrical contact between the lower plate and the pole 33 through the cup 42.

15 **[0034]** The adjusting rod 15 carries indicia 38 of elevation or position of the carrier 13 inside the container 4. As the operator turns the crank 21 to adjust the position of the carrier 13 and therefore the sensor 10 inside the tank, the operator notes the elevation mark on the rod 15 in a window 44 on the gear mechanism 18.

[0035] The apparatus shown in Fig. 2 has the same elements inside the container 4 as the
20 device shown in Fig. 1, but employs an electric motor 47 to drive the gear mechanism 18. A magnetic disk 48 is attached to one of the shafts of the gear mechanism 18, and rotates with the gear mounted on the shaft. A first sensor 49 mounted on the housing of the gear mechanism 18 reads magnetic bars 6 (Fig. 2A) on the periphery or near the periphery of the disk 48. This sensor 49 senses the distance traveled by the carrier 13 inside the tank 4 by reading the moving magnetic
25 bars on the disk 48. A second sensor 50 is mounted on the housing for the gear mechanism 18 and reads an inner track on the magnetic disk 48 to determine the direction of movement of the carrier 13 inside the tank 4. The magnetic disk is shown in Fig. 2A and has distance magnetic bars 6

1 **57752/H639 - G131061**

equally spaced on the surface of the disk near the outer periphery of the disk. These magnetic bars are sensed by the distance sensor 49. Assuming a constant speed of rotation then equally spaced
5 pulses, as shown in Fig. 2B, are produced at the output of the distance sensor 49. In any event, the number of bars counted during movement indicates the distance traveled by the carrier 13. Direction magnetic bars 7 are on an inner track on the surface of the disk 48 as shown in Fig. 2A. The direction sensor 50 provides pulses as shown in Figs. 2C and 2D to indicate the direction of movement of the carrier 13 inside the tank or container 4.

10 **[0036]** Referring to Fig. 3, the carrier 13 is moved vertically up and down inside the tank 4 by a vertical lead screw 52. A gear mechanism 53 rotates the lead screw 52 and moves the carrier 13 up and down inside the tank and thus moves the sensor 10 up and down inside the tank. The carrier 13, when used with the lead screw 52, has an inner cylindrical internally threaded piece or nut 54. The internal threads of piece 54 match the threads of the lead screw 52 to move the carrier 13 when
15 the lead screw 52 is rotated. Alternatively, the carrier 13 may be made of brass or a similar material and have an internally threaded cylinder that mates with the lead screw. In either case, the threaded part acts like a nut on the lead screw and moves vertically in the tank as the lead screw is rotated.

[0037] Lead screw 52 has a bottom mount similar to the mount 1A shown for the support pole
20 33 of Fig. 1. A cup 56 is attached to the bottom of the lead screw 52 and sits on a ball 57 on a support plate 58. Support plate 58 is either welded to the bottom of the tank 4 or is magnetically attached or in some other way attached to the bottom of the tank 4. The gear mechanism 53 is operated by a handle 55 to rotate the lead screw 52 and move the carrier vertically up or down inside the container 4. The carrier 13 includes a guide section 56 which makes a close sliding fit
25 partly around vertical support pole 33 to restrain the nut from rotating and to provide precision alignment of the nut 54 on lead screw 52 to insure smooth, low friction operation. As shown in

1 **57752/H639 - G131061**

Fig. 4, the movement of the carrier 33 by rotation of the lead screw 52 is automated by use of a motor 59 driving the gear mechanism 53.

5 **[0038]** Referring to Fig. 5, the moveable sensor 10 is attached to a housing 61 for a variable height inlet/outlet orifice 62. The housing 61 has an extension 65 that supports the transmitter 11 and receiver 12 of the sensor 10. The housing 61 slides up and down a support pole 64 that contains either guide rails or ribs on the exterior or a slot to cooperate with either slots in the housing 61 or a protrusion on the housing 61 to restrain the housing from rotating relative to the
10 pole. The housing 61 is adjusted inside the tank 4 by an adjusting rod 67 and gear mechanism 18, the lower end of rod 67 being connected by a bracket 68 to the housing. As shown in Fig. 5, the orifice 62 is coupled to a conduit such as a flexible hose 69. The inner end 70 of the flexible hose is connected through a 90° elbow 71 to the orifice 62. The outer end 72 of the hose is connected to an outlet 73 through a standpipe 74 from the tank 4.

15 **[0039]** Referring to Fig. 6, the housing 61 is moved vertically inside the tank 4 by rotation of a lead screw 77. The gear mechanism 18 of Fig. 5 may be manually operated or automatically controlled. Similarly, the lead screw 77 and its gear mechanism 78 may be manually operated by use of a crank, not shown, or automatically controlled through a motor 79. As with the embodiment shown in Fig. 3, the carrier 13 of Fig. 6 includes a guide section 56 which makes a
20 close sliding fit partly around vertical support 33.

[0040] The moveable level detector or sensor has particular application with NGLs from gas wells as representatively shown in Figs. 7, 8 and 9. In Fig. 7, the sensor 10 is independently moved vertically inside the tank 4 by its own carrier 80 on a separate lead screw 82. The variable height orifice 83 carried by housing 84 is independently moved and positioned vertically by its separate
25 lead screw 85. The carrier 80 and housing 84 each have a guide section 56 that makes a close sliding fit partly around a separate respective support pole 33. The tank 4 has an outlet 86 near the bottom for removal of the bottom liquid independently of the liquids that may be floating on top of

1 **57752/H639 - G131061**

the bottom liquid. The upper liquids are removed through orifice 83 and its conduit 88 and outlet 87, independently of the other liquids in the tank.

5 **[0041]** An oil sale tank 4 associated with gas wells is diagrammatically shown in Fig. 8, and it includes the same apparatus shown in Fig. 7. An oil sales tank typically has a layer of BS&W 90 in the bottom of the tank, a layer of water 91 above the BS&W 90 and a layer of oil 92 floating on the water layer 91. The transition between the air 93 at the top of the tank and the oil 92 is sensed by a moveable sensor 10. This transition may also be sensed by a fixed liquid level detector such as a
10 Rosemount Model 3300 Radar Detector or an Accu-gage Sonar Detector. The sensor 10, driven by a lead screw 82, is moved up or down through the layers in the tank 4, and the transition between air and oil and the transition between oil and water are detected and noted. The outlet orifice 83 is then positioned near the bottom of the layer of oil 92 for removal of the oil.

15 **[0042]** A produced-water tank 4 associated with gas wells is representatively shown in Fig. 9. Some of these tanks have stratified liquids, including clean oil or condensate 95, dirty oil 96, waste oil 97, water 98, and the BS&W 99. Locating the position of the transition between the air 94 at the top of the tank and the clean oil 95, the transition between the clean oil 95 and the dirty oil 96, the transition between the dirty oil 96 and waste oil 97 and the transition from waste oil 97 to water 98 is done using a moveable sensor 10, as shown in Fig. 9. Once the levels of the transitions are
20 detected and recorded, it is then easy to remove liquid from or add liquid to any selected liquid layer of the various stratified liquids. An orifice 100 is positioned in the selected liquid such as the dirty oil 96 as shown in Fig. 9 to remove or add to the liquid. Material, such as an demulsifier or emulsion breaker, may be added to the dirty oil 96, or the dirty oil may be removed from the tank.

25 **[0043]** The sensor 10 may be any of many different types of sensors, and the theory of operation of some of the possible sensors is explained below with reference to Fig. 10. A representative sensor 10 having a transmitter 11 and a receiver 12 is diagrammatically shown in Fig. 10. The sensor 10 may have a light source 11, such as an infrared light-emitting diode or some

1 **57752/H639 - G131061**

other light source in other frequency ranges, with a photoelectric cell or photo-detector 12 as the receiver. Such a sensor responds to turbidity. Turbidity is an expression of the optical property
5 that causes light to be scattered and absorbed rather than transmitted in straight lines through a sample, or in this case through the liquid. The detector 12 may be in a straight line relative to the light transmitted from the diode 11. Such positioning is most useful when there are only small particles suspended in the liquid between the light source and detector. For larger particles, it is best to have the receiver or photoelectric cell positioned at a right angle to the light path from the
10 light source to be responsive to the scattered light. While turbidity is the measure of relative liquid clarity and not color, it is sometimes advantageous to consider color of the particles or liquid. The reduction in the intensity of the light received at the detector is primarily caused by the suspended solids in the liquid scattering the light. However, absorption, i.e. color, from dissolved substances can also reduce the intensity and may be taken into consideration by manually or automatically
15 compensating for its effect.

[0044] A separate photometer may be used in combination with a turbidity meter to combine the effects of scattering and absorption where the liquids are NGLs from a gas well that are contained in a settling or storage tank. The turbidity meter, alone or in combination, may be moved from the top of the storage tank to the bottom of the interior of the storage tank or vice versa.
20 When the instrument carriage and turbidity meter are energized and moved in a storage tank, the output may be analyzed to calibrate the turbidity meter to indicate the chemical, physical or electrical gradient of a liquid or the levels or zones of various liquids. When the turbidity meter passes through NGLs, such as clean oil, dirty oil, waste oil and/or water it is calibrated for these liquids. In some liquids, it is possible that the cover or lens for the light source and the cover or
25 lens for the detector may become coated with undesirable materials to the point where the turbidity meter is rendered ineffective. An ultrasound source may be combined with a turbidity meter and

1 **57752/H639 - G131061**

positioned to clean the covers or lenses at selected intervals, or the covers or lenses may pass by a brush (not shown) attached to the support poles for removal of contaminants.

5 **[0045]** The instrument used to detect the transition between different liquids and/or the zone of transition between different liquids may operate on many different principles. For example, instead of the passage of light between a light source and a detector, the passage of electromagnetic waves between a source and detector may be employed. The electromagnetic waves may be high frequency waves supplied by a radar unit or low frequency waves supplied by a sonar unit. The time of travel is sensed when employing electromagnetic waves. Further, the energy passed between the source 11 and the detector 12 may be vibratory mechanical energy in the form of sound waves. The sound waves may be provided by an ultrasonic source that uses one of the two general types of transducers. These types of transducers are magnetostrictive or piezoelectric. A magnetostrictive transducer converts electrical energy to magnetic energy, and then the magnetic energy to mechanical energy to provide the sound waves or the vibratory mechanical energy. A piezoelectric transducer converts electrical energy directly to mechanical energy and can operate in the megahertz range while a magnetostrictive transducer typically operates below the 20 kilohertz range. The instruments utilizing sound waves and electromagnetic waves measure the speed of travel or the time it takes for the energy to travel from the source or transmitter to the receiver or detector. These instruments are also calibrated to the type of liquids in which the instrument is used.

15 **[0046]** A sensor 10 for detecting liquid transitions and levels is combined with a sonar transmitter/receiver 75 and an angled reflector 76 as shown in Fig. 11. The sonar unit, 75 and 76, detects and records the position of the carrier 13 and orifice 62 relative to the bottom of the tank and the top of the tank (not shown in Fig. 11). The reflector 76 causes energy to be directed up toward the top of the tank and down toward the bottom of the tank so that energy is reflected back

1 **57752/H639 - G131061**

to the sonar transmitter/receiver. The time interval is measured to give the exact location (elevation) of the orifice and sensor in the tank.

5 **[0047]** Greater detail of a moveable instrument carriage device is shown in Figs. 12 and 13. As shown in Fig. 13, a coupling 101 welded through the top of a tank 102 has internal threads 103 vertical, or nearly vertical, and parallel to the side 104 of the tank 4.

10 **[0048]** A lead screw 110 and support pole 111 are each substantially vertical in the tank to carry the sensor 10 shown in Fig. 12. The sensor has a transmitter 11 and a receiver 12 horizontally spaced from each other, and mounted on a horizontal table 112 attached to and extending from a first bracket 113 welded or otherwise attached to a sliding tube 114 on the support pole 111 so the sensor can be moved up and down. The sliding tube 114 has a nonferrous bushing 115 at the top and another nonferrous bushing 116 at the bottom.

15 **[0049]** The internal diameter of the bushings 115 and 116 are smaller than the internal diameter of the sliding tube 114. The bushings 115 and 116 are preferably made of a carbon-filled PTFE material or an oil-impregnated brass to provide electrical contact between the sliding tube 114 and the support pole 111. The bushings 115 and 116 also provide a bearing surface between the bushings 115 and 116 and the support pole 111.

20 **[0050]** A second bracket 120 is welded or otherwise attached to the sliding tube 114. The second bracket 120 carries a lead screw nut 121 mounted on the lead screw 110. The second bracket 120 has four threaded holes 122, two of which are shown in Fig. 12. The other two are behind the two shown in Fig. 12. Bolts 123, extending through respective bores (not shown) in the nut, are each threaded into a respective hole 122 to secure the nut to the second bracket.

25 **[0051]** Referring to Figs. 12 and 13, the bottom end 125 of the lead screw 110 is stabilized by an upwardly opening alignment sleeve cup 126 secured to the top of a horizontal table 129 extending from a two-piece mounting bracket 127 attached to the support pole 111 by bolts 128 or some similar attachment means. The non-threaded lower end of the lead screw makes a close

1 **57752/H639 - G131061**

sliding and rotatable fit in the alignment sleeve cup. The sleeve cup 126 and table 129 do not support a vertical load from the lead screw 110 because the lead screw 110 is supported from the top of the tank by thrust bearings (not shown) in an adaptor 130 threaded into the upper end of coupling 101. Preferably, all the weight of the lead screw and the apparatus supported by it is carried by the thrust bearings so the lower end of the lead screw is spaced above the bottom of the inside of the sleeve cup to allow for thermal expansion and contraction of the lead screw. A vertical bore 131 through the table and the bottom of the cup allows incidental sediment to be expelled from the cup.

[0052] The bottom end of support pole 111 is secured in a vertical sleeve 132 welded at its lower end to a horizontal mounting plate 133 welded or otherwise attached to the bottom of the tank 102. The lower end of the support pole 111 is fixed in place by horizontal bolts 134 which are threaded thru sleeve 132 to fit in indentations (not shown) in the bottom of the support pole 111. The bolts in the indentations prevent rotation of the support pole 111 and also hold it in place in the tank.

[0053] The upper end of support pole 111 is free to move vertically to accommodate thermal expansion and contraction of the pole in a sleeve 136 attached to the underside of a horizontal mounting plate 137 by a bolt 138 and nut 139 as shown in Fig. 13. Mounting plate 137 has a cylindrical, vertical extension 140 threaded into the lower end of coupling 101 to hold the mounting plate 137 in place as well as the support pole 111. Lead screw 110 extends through the top of adapter 130 and is configured to mate with a crank or a motor for drive of the lead screw.

[0054] Although the apparatus or devices for determining the vertical elevation in a container of the transition zone or the transition line between liquids having different chemical, physical and/or electrical properties have been described in connection with NGLs they are not so limited.

[0055] Vertically moveable sensors inside a container are also useful where there is a single liquid in the container having a chemical, physical or electrical property that varies from the top to

1 **57752/H639 - G131061**

the bottom of the liquid. The variation may be continuous so that the detected difference varies as a gradient. For example, aircraft fuel in a storage tank varies in quality from top to bottom. The
5 gradient becomes more pronounced with age. The quality variation may be detected by use of a movable sensor in the fuel.

[0056] A moveable sensor is also useful in detecting and, if desired, recording the pH variation or some other chemical, physical or electrical property in a liquid, such as water.

[0057] Vertical temperature variation in a liquid or liquids may also be detected by a vertically
10 moveable thermometer, which may be carried by the same carriage on which another sensor is carried. Other sensors, such as a sonar based sensor, may be used in place of a thermometer to sense temperature, variations or gradients.

[0058] The external drives for the adjusting rod 67 for the lead screw 77, such as shown in Figs. 5 and 6, respectively, can be modified so they are located within the container or tank, and
15 therefore better protected from the elements. For example, referring to Figs. 2 and 5, the gear mechanism and motor 47 can be attached to the underside of the top of the tank or container, and electrical power supplied to the motor through a cable (not shown) sealed through the container top. In this case, a suitable sliding seal is provided for that part of the adjusting rod 67 which extends above the container top. In yet another alternate embodiment of the arrangement shown in
20 Figs. 2 and 5, and modified to mount the gear mechanism and electric motor to the underside of the container top, the adjusting rod 67 can be contained entirely within the tank, and be immovable. The gear mechanism and electric motor are modified to move up and down on the adjusting rod, and carry the associated equipment with it. In this case, the electric motor is provided power through a cable long enough to accommodate the required vertical movement of the gear
25 mechanism and electric motor. The position of the gear housing and motor, along with the apparatus carried by it, is determined with the sensor system described with respect to Figs. 2, 2A, 2B, 2C and 2D.

1 **57752/H639 - G131061**

5 **[0059]** With respect to the motor-driven lead screw 52 such as that shown in Figs. 4, 6, 7, 8, 9, 12, and 13, the motor and gear mechanism can be mounted to the underside of the container top to protect that equipment from the weather. In that embodiment, the electric motor is provided power through a cable (not shown) sealed through the top of the container. Moreover, the apparatus shown in the figures just referred to can be modified so that the lead screw does not rotate. Instead, the housing for the nut on the lead screw can be modified to carry a motor which rotates the nut, causing the nut and associated equipment to move up and down the lead screw, which need not
10 rotate.

15 **[0060]** The control console 26 shown in Fig. 8 can also be mounted to the underside of the container top so that it is protected from the weather. Power to the control console with that arrangement is supplied through a cable sealed through the top (or side) of the container.

20 **[0061]** Although the description above contains specificity, this should not be construed as limiting the scope of the invention. Although preferred embodiments have been described, the invention is not limited to the specific embodiments, but rather the scope of the invention is to be determined as claimed.

25

25

CLAIMS

1. Apparatus for managing stratified liquids in a container comprising a liquid discrimination sensor inside the container for identifying different liquid layers and the elevation of each in the container and means for moving the sensor through the liquids in the container.
2. Apparatus for managing stratified liquids in accordance with Claim 1, further comprising a variable height inlet/outlet orifice, and means for positioning the orifice at a selected container in response to the output of the sensor.
3. Apparatus for managing stratified liquids in accordance with Claim 1, further comprising a carrier housing for the orifice and wherein the housing carries the sensor.
4. Apparatus for managing stratified liquids in accordance with Claim 5, wherein the moving means comprises a variable height inlet/outlet orifice housing adjustable from the exterior of the container.
5. Apparatus according to Claim 1, wherein the sensor output is based on time of flight in the liquid.
6. Apparatus for managing stratified liquids in a container comprising means inside the container for identifying zones or lines of transition between liquids and registering the elevation of each zone or line and means for moving the identifying means vertically inside the container
7. A method for managing stratified liquids in a container comprising the steps of determining the level of the transition from one liquid to another,

- monitoring the level of each transition, and positioning an orifice at a selected level inside the container based on the level of each transition.
8. Apparatus for managing stratified liquids in a container comprising a liquid discrimination sensor inside the container for generating a signal indicative of a transition between stratified liquids, a variable height inlet/outlet orifice inside the container, means for controlling the position of the orifice, a computer with a display, the computer having application software for displaying an image based on the signal from the sensor.
 9. Apparatus in accordance with Claim 8, further comprising interface controls which allow the user of the computer to designate a stratified liquid layer for addition to or removal and a send control operatively connected to move the orifice to a selected position inside the tank.
 10. Apparatus according to Claim 9 wherein the application software logs the identity of the user of the computer.
 11. Apparatus according to Claim 9 wherein the application software identifies and records the tank accessed by the user of the computer.
 12. Apparatus according to Claim 11 wherein the application software records the time and date that the user of the computer accesses a container.
 13. Apparatus according to Claim 12 wherein the application software further records the quantity of liquid removed from the container that is accessed.
 14. Apparatus in accordance with Claim 13 further comprising means for sensing the temperature of the liquid removed from the container.

15. Apparatus in accordance with Claim 9 further comprising means for recording the specific gravity of the liquid removed from the container.
16. A method for managing stratified liquids in a container comprising the steps of determining the level of the transition from one liquid to another, monitoring the level of each transition, positioning an orifice at a selected level inside the container based on the level of each transition, recording the identity of the operator performing the steps of monitoring the level and positioning the orifice, identifying and recording the container accessed, the time and date of access, the quantity of liquid removed and recording the temperature of the liquid removed.

FIG. 1

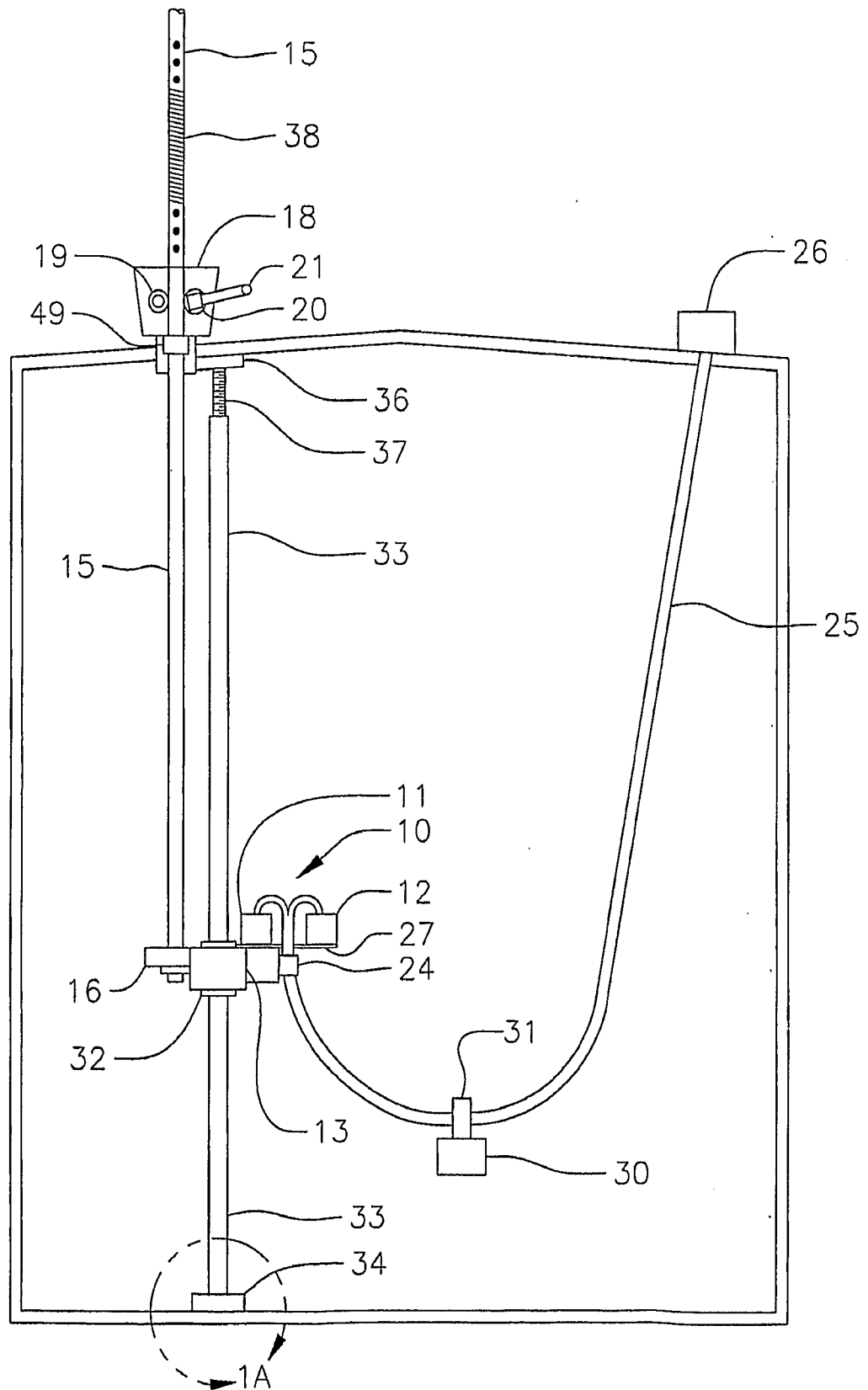


FIG. 1A

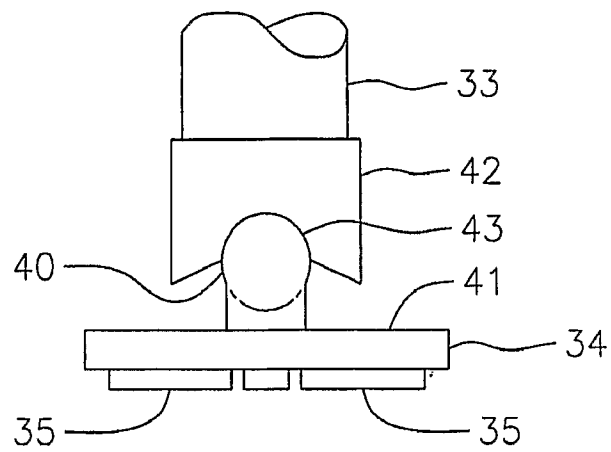


FIG. 2

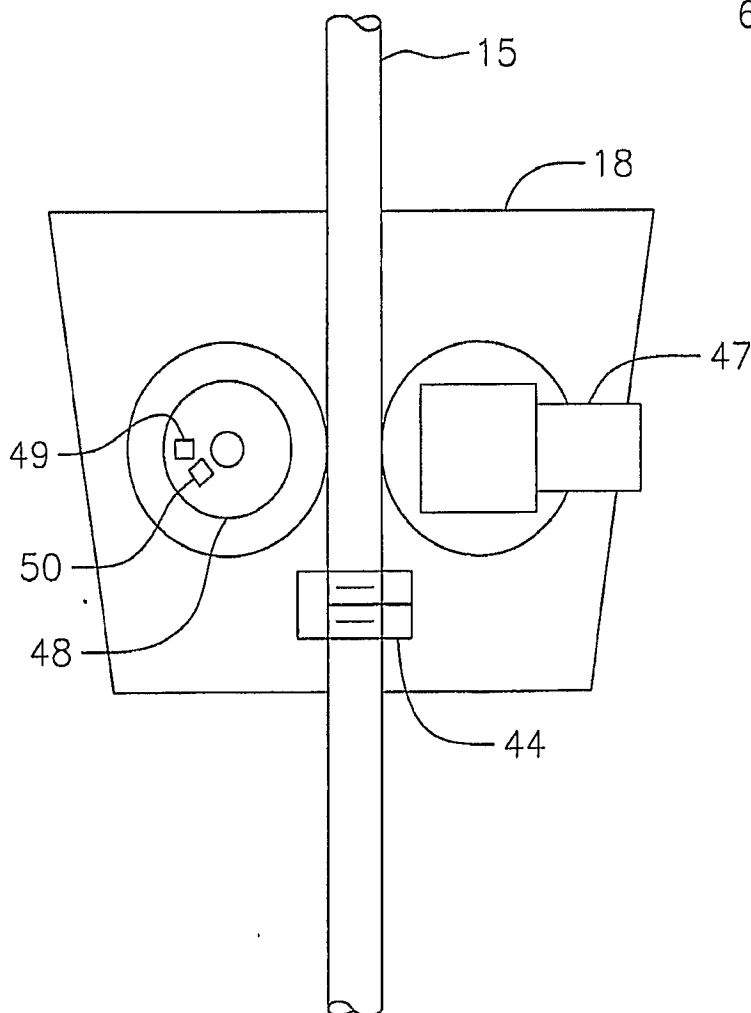


FIG. 2A

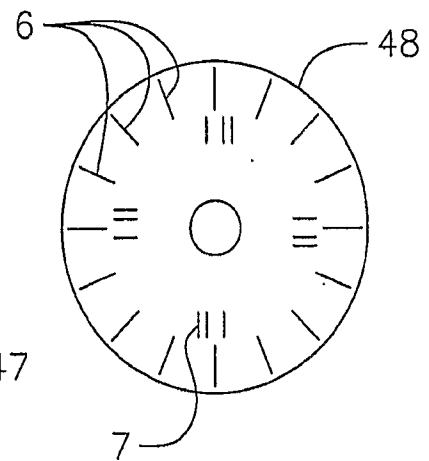


FIG. 2B

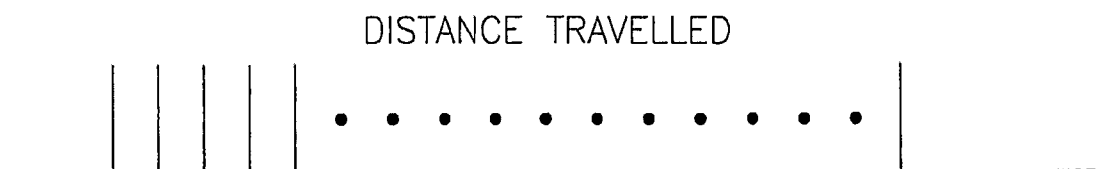


FIG. 2C

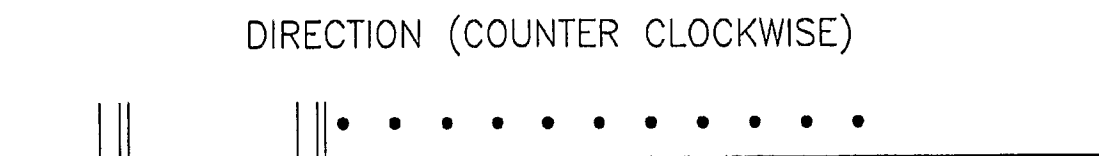


FIG. 2D

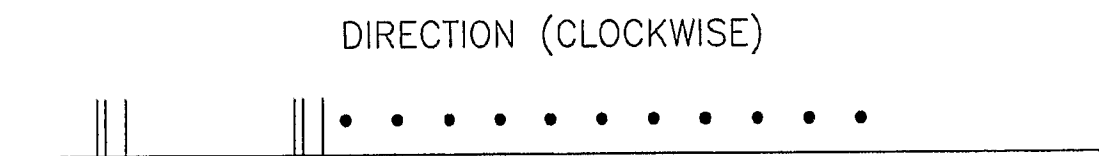


FIG. 4

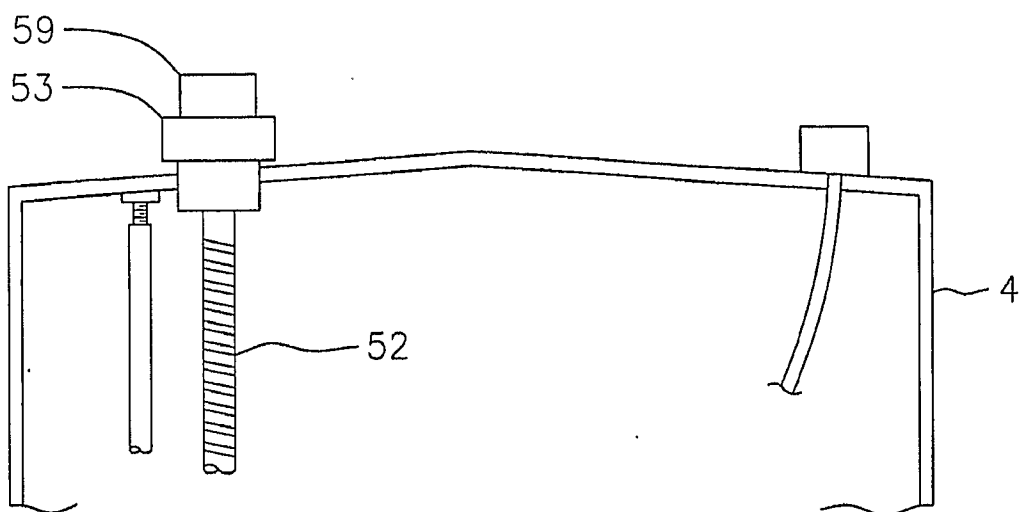


FIG. 3

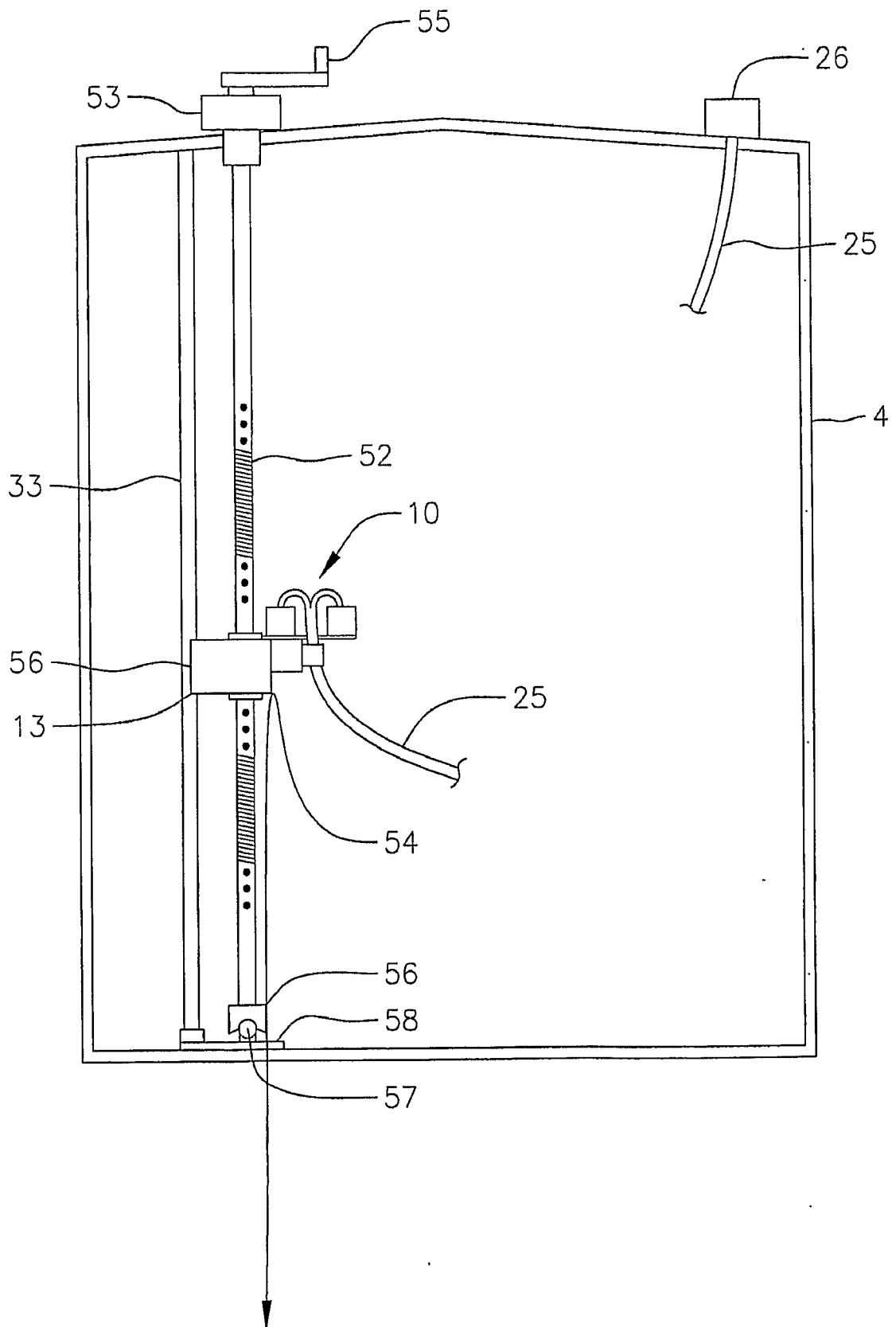


FIG. 5

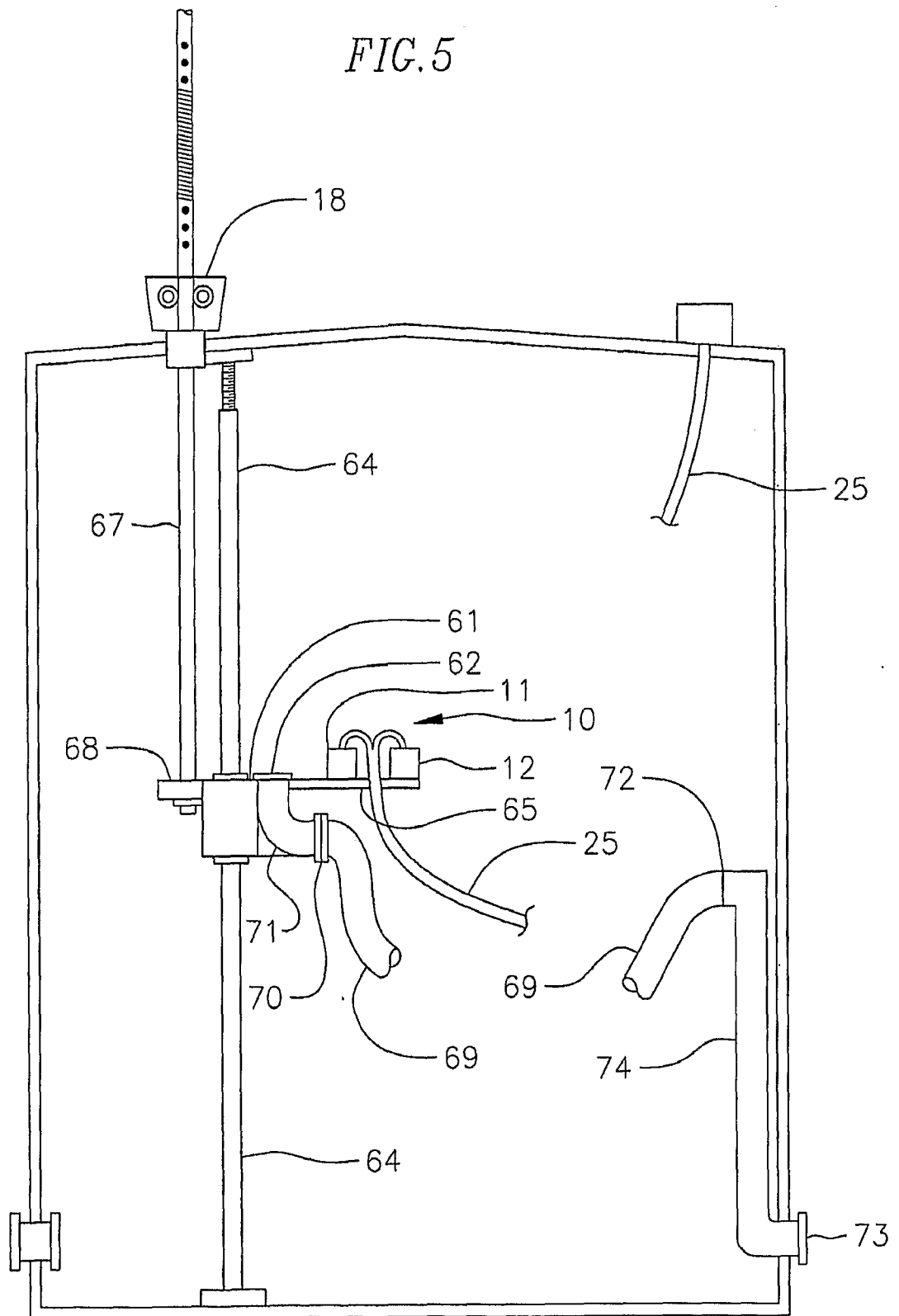


FIG. 6

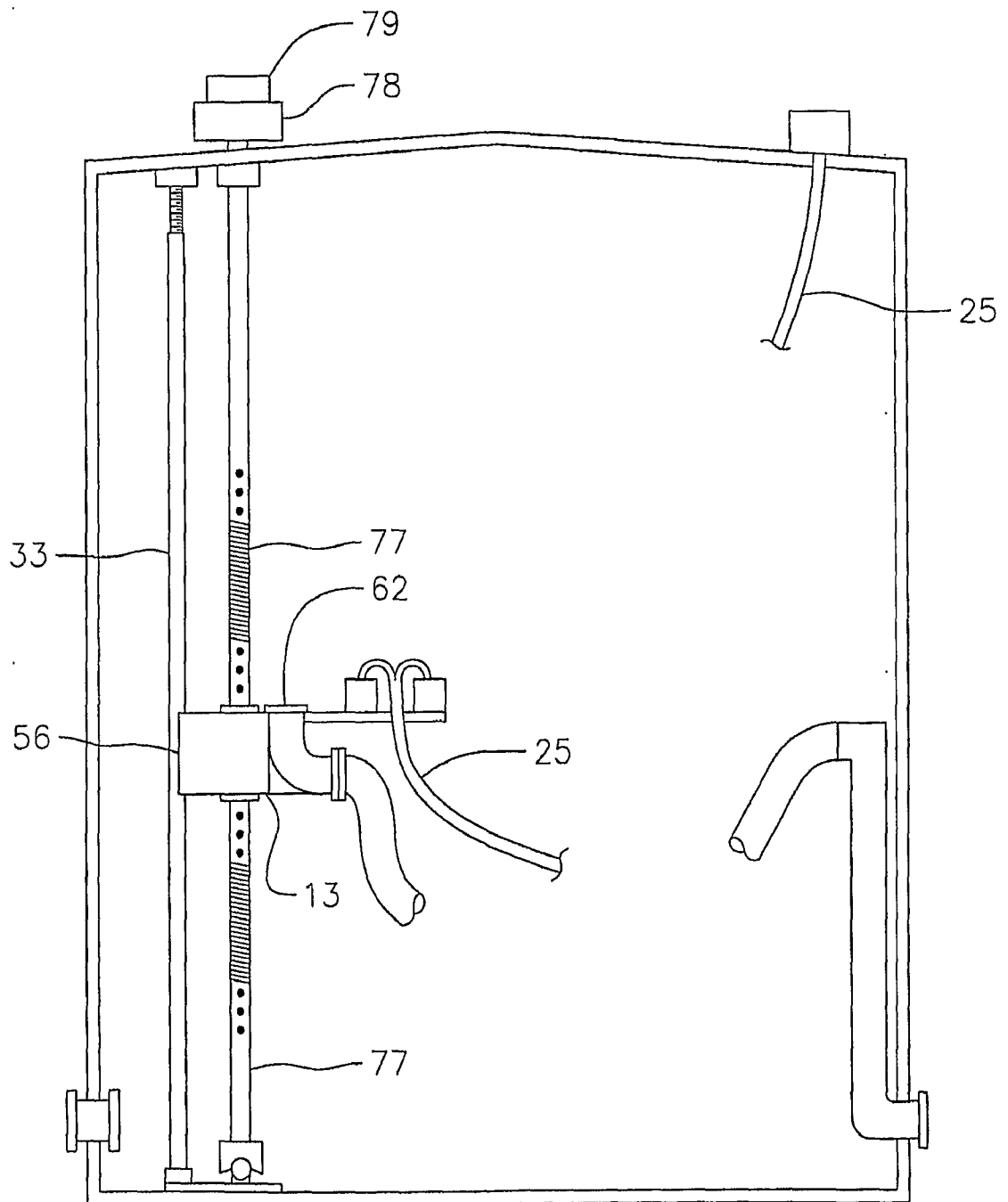


FIG. 7

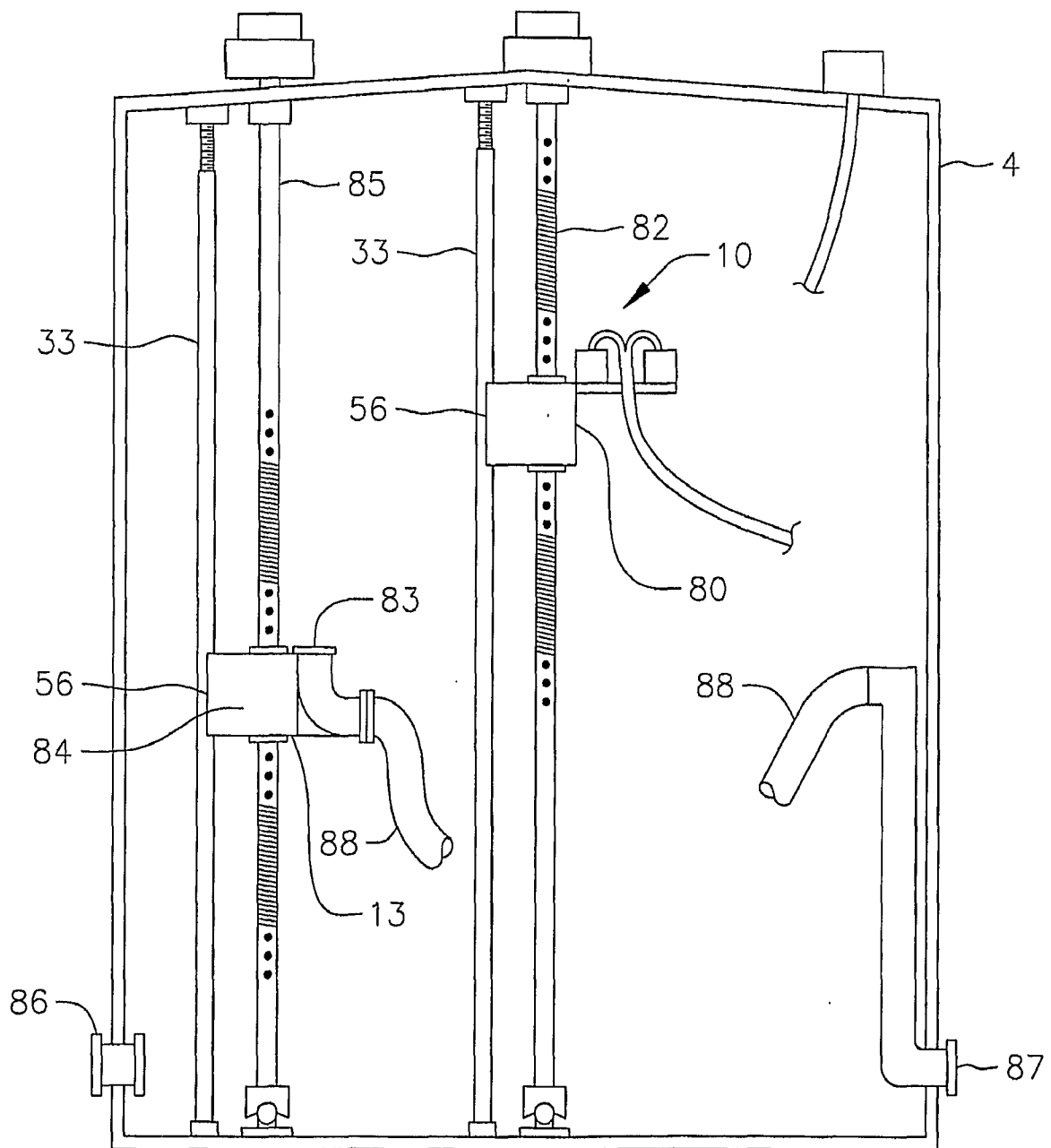


FIG. 8

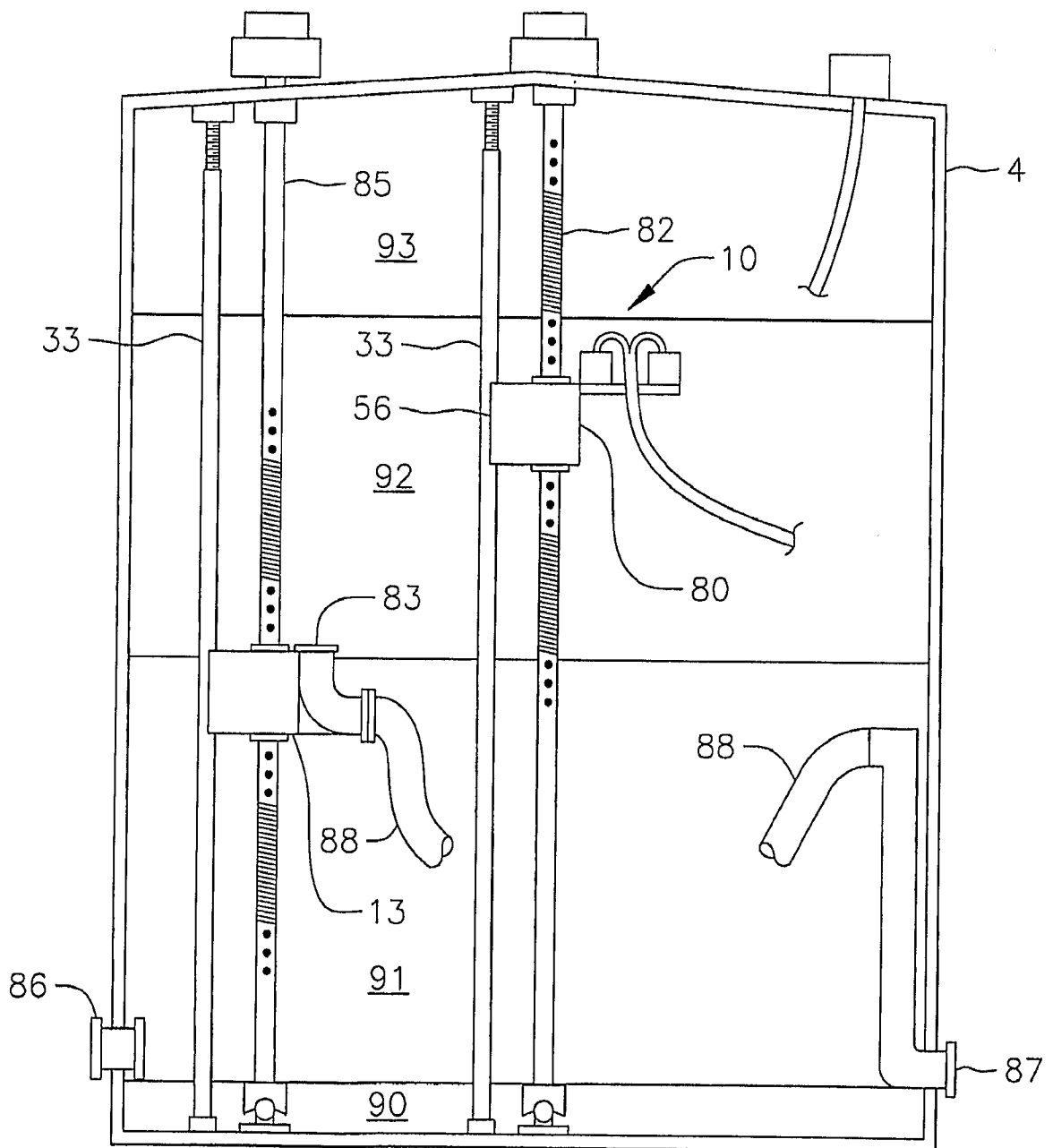


FIG. 9

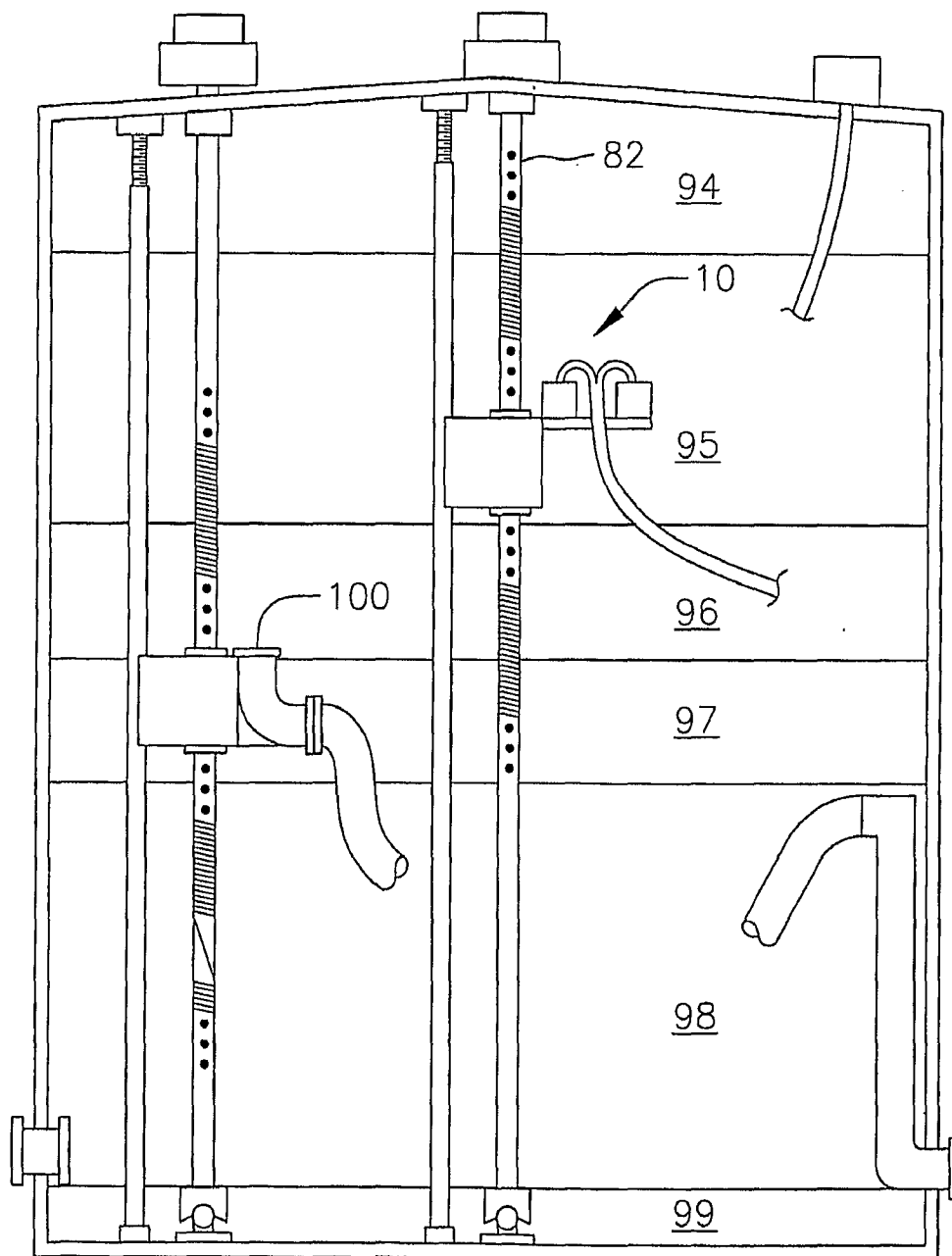


FIG. 10

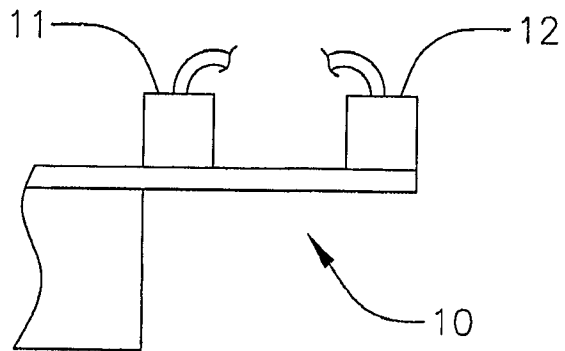


FIG. 11

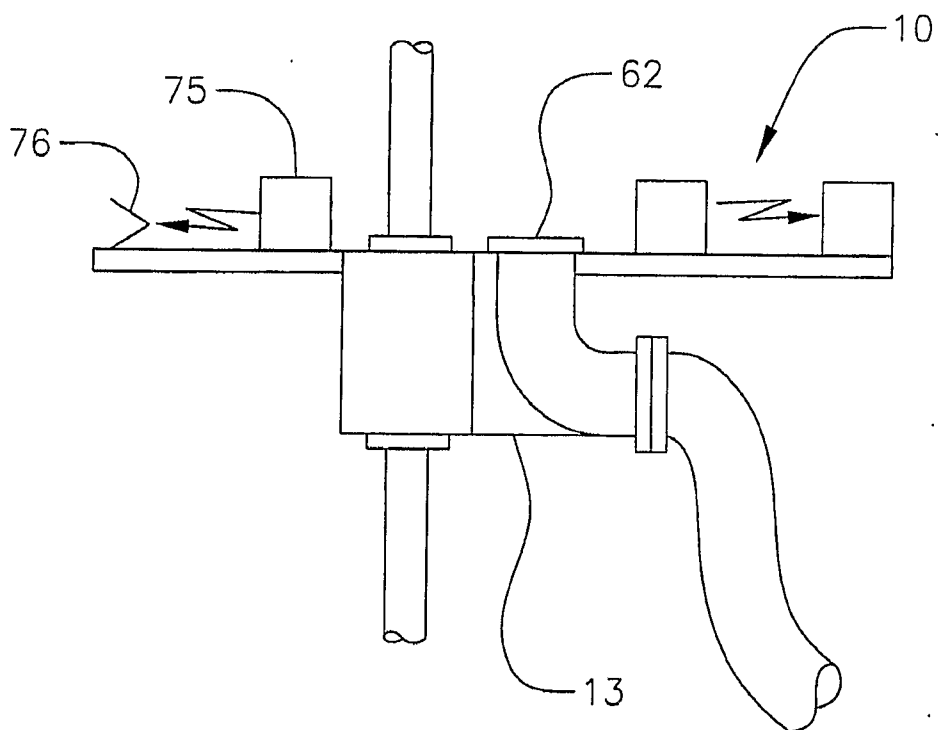


FIG. 12

