

LIQUID QUANTITY MEASURING APPARATUS

The present invention relates to an apparatus for measuring the quantity of a liquid such as a fuel in a tank, and more particularly to such apparatus of the

5. type for capacitively detecting a liquid level in the tank to indicate the liquid quantity.

A capacitor type liquid quantity measuring apparatus per se is known from U.S. Patent No. 3,208,280 issued on September 28, 1965. Such an apparatus

10. utilises the principle that, if there is a dielectric substance such as air, fuel, water or the like between a pair of opposing positive and negative electrode plates, the electrode plates form a capacitor together with the substance. Thus if the electrode plates are

15. arranged vertically in a vessel such as a fuel tank, the surface area of the electrode plates in the fuel varies with the fuel level in the tank, resulting in a change of capacitance which corresponds to the fuel level. In this case, it is of course required to arrange

20. another pair of electrode plates always dipped fully in the fuel, to provide a measure of a change of dielectric constant due to any temperature change of the fuel, to compensate a relation between the capacity measured by the first pair of the electrode plates and

25. the level of the fuel in the tank. In said U.S. Patent the capacitive information from both pairs of electrode

plates is fed through an amplifier to a motor which operates a wiper of potentiometer in circuit with an indicator to convert the capacitive information into the information of fuel level and to indicate the same

5. on the indicator. However, such known system is not suitable for measuring the quantity of fuel in each of plural tanks to centrally indicate the fuel quantity, since as aforesaid, the capacity is quite sensitive to changes of temperature, and thus if the capacitive

10. information is fed in such form over a relatively long distance, the value changes to such an extent that any correction is impossible.

Said U.S. Patent is directed mainly to the fuel gauging apparatus for airplanes and there is given

15. neither disclosure nor suggestion of detecting undesired water which possibly accumulates at the bottom of the tank. This detection is a very important matter in order to remove water from fuel accommodated in an underground tank, such as in fuel dispensing stations.

20. Such a tank has a ventilation opening communicating with an inside of the tank for reasons of safety, and thus rainwater may enter the tank through that opening to form a water layer under the fuel. Furthermore if a flood occurs, a large amount of water may also enter the

25. tank through that opening. Even if such exceptional occasions are excluded, fuel such as gasoline for

77

- 3 -

- vehicles contains inevitably some quantity of water, and thus the accumulation of water cannot be avoided due to a separation thereof from the fuel during storage. Further, the temperature difference between
5. the inside of the tank and atmosphere can cause condensation of moisture in the air as water drops at the inner surface of any pipe communicating with said ventilation opening, and such water drops may flow along the surface into the fuel tank to increase water
10. level therein.

- Even if a water layer has already been formed in the fuel tank due to at least one of said or other causes, the known methods for measuring the quantity of fuel based on a level of fuel in the tank indicates the
15. remaining fuel quantity under an assumption that water is not present in the tank. It is, therefore, required to set the lower level for dispensing the fuel at a relatively high point, in order to avoid a possible supply of water-containing fuel to vehicles and the like.
20. This means that the dispensible fuel amount in the tank is decreased and that careful operation is required on suctional removal of the water, since the amount of water accumulated in the tank cannot be confirmed.

- A basic object of the present invention is to pro-
25. vide an apparatus which can be used and adapted for measuring the quantity of a liquid such as a fuel in a

tank, based on its level, and for detecting an accumulation of water in the tank, so as to make it possible to remove the undesired water from the fuel in the tank when such layer of water reaches a predetermined level.

5. A further object of the present invention is to provide an apparatus which can be used and adapted for measuring the quantity of a liquid such as a fuel in each of plural tanks and for detecting water in each tank, whereby various information on the liquids in each tank can be indicated at
10. a central location such as an office.

Another object of the present invention is to provide an apparatus which can be used and adapted for measuring the quantity of a liquid such as fuel in at least one tank, such that a warning can be given when the level of the liquid in

15. the tank reaches each of predetermined upper and lower limits, to prevent an excessive supply of fuel to the tank and to show the necessity of replenishment of fuel in the tank.

- According to the present invention there is provided an apparatus for measuring the quantity of a liquid in at least
20. one tank, said apparatus comprising a first capacitive device having separate electrodes adapted to be mounted in the tank to allow passage of the liquid therebetween whereby the capacitance between the electrodes depends on the level of the liquid in the tank, a second capacitive device adapted
25. to be mounted in the tank below said first capacitive device so as to be immersed always in the liquid whereby the capacitance thereof depends on the dielectric constant of

(19)

- 5 -

the liquid, a third capacitive device arranged to provide a reference capacitance value independent of the dielectric properties of the liquid, an LC oscillator operable to produce an output frequency signal, a switching device operable to

5. connect said first, second and third capacitive devices selectively to said oscillator whereby the frequency of the output signal depends on the capacitance of the respective capacitive device, and a control box with an indicator connected to said oscillator and operable to calculate the quantity of

10. the liquid in the tank based on the frequency signals and to provide an indication of said quantity on the indicator.

Preferably said first, second and third capacitive devices have substantially the same capacitance, so as to have similar responsive characteristics.

15. The apparatus may further comprise a detector adapted to be mounted near the bottom of the tank and arranged for detecting a second liquid such as water, which detector may be formed as part of the second capacitive device. The second capacitive device may be made as a plurality of hollow

20. cylindrical members arranged in concentric manner, which constitute alternatively separate electrodes, whereby the required surface area for the separate electrodes can be obtained without unduly increasing the height thereof.

Preferably the third capacitive device comprises a

25. capacitor adapted to provide a capacitance value which is substantially constant or has little variation even if exposed to atmosphere changes. Said switching device may comprise a

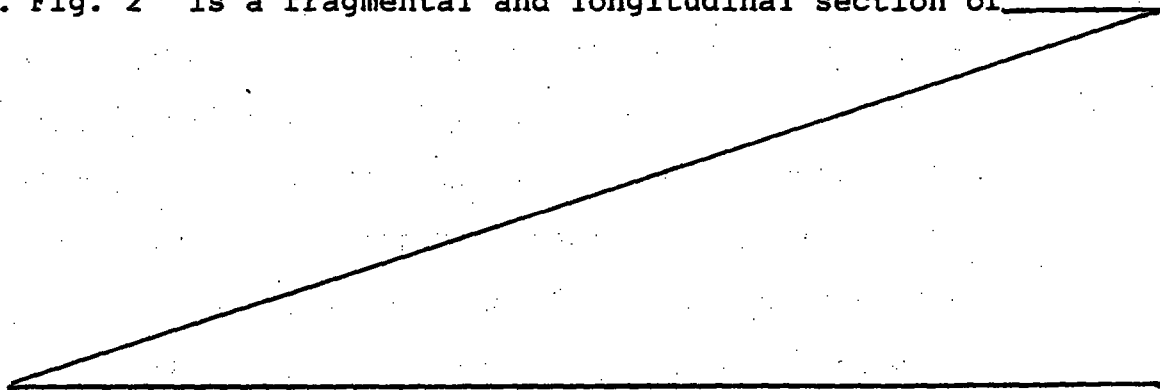
pair of relays which may constitute together with said third capacitive device and LC oscillator a level feeding device, said level feeding device being arranged near the first capacitive device to reduce the influence of ambient temperature change on capacitive information from the first, second and third capacitive devices. The level feeding device may be embedded in an insulating material body to form a unitary member, so as to facilitate replacement.

It is preferable that each of said first, second and third capacitive devices have cylindrical configurations of similar diameter and are detachably connected through a conductive support, to facilitate separation and replacement thereof.

The drawings illustrate an embodiment of an apparatus according to the present invention, wherein:-

Fig. 1 is a diagrammatic illustration of the apparatus applied for measuring a liquid such as fuel in underground tanks, a detecting part and another part thereof being shown respectively vertically and perspectively;

Fig. 2 is a fragmental and longitudinal section of



the detecting part to show its structure in detail;

Fig. 3 is a block circuit diagram showing a level feeder to be arranged in the detecting part;

5. and

Fig. 4 is a block circuit diagram showing a control circuit and circuits belonging thereto, which are employed for the apparatus.

In Fig. 1 there is merely shown in part only one

10. underground tank RS accommodating a fuel F therein but there may be a plurality of such tanks, for instance five tanks. A detector DT belongs to each tank RS. Although an explanation of the detector DT will be given later in detail, with reference to Figs. 2 and 3, it

15. comprises a fuel dielectric constant measuring means CP arranged vertically on the bottom of the tank RS and immersed always and fully in the fuel, a fuel level detecting means MP mounted on the fuel dielectric constant measuring means CP to measure a capacity which

20. varies depending on the fuel level, and a level feeder LF incorporating a reference means and converting information on capacitances measured by said fuel dielectric constant measuring means, fuel level detecting means and reference means into frequency information at its

25. outputs. The output of the level feeder LF exclusively belonging to each tank RS is fed through each line A

to a control box CB to be installed in an office cabin (not shown). At the control box CB, there are arranged a numeral indicator 1 common to a plurality of the tanks to indicate a number identifying the specified tank, a quantity of the

5. fuel in the tank and other parameters, a plurality of first lamps 2, each of which is adapted to be lit when a quantity of liquid in the concerned tank reaches its upper limit, a plurality of second lamps 3, each being lit when a quantity of liquid in the concerned tank reaches its lower limit, a

10. plurality of third lamps 4, each being lit when a predetermined amount of water accumulates in the concerned tank, a plurality of button switches 5, each of which is operated to select a specified tank, a printer 6, another button switch 7 to operate the printer, a buzzer 8 which is operated when one

15. of said first, second and third lamps 2, 3, 4 is lit to convert the visible information into an audible information, and a ten-key keyboard 9 arranged inside a lower cover of the control box CB, which is operated for making input of various data which can be stored in a memory circuit MEC

20. described later. An alarm 10 arranged in a suitable place is connected through a line 11 to the control box CB which also has a button switch 7' to be pressed for electrically connecting the alarm to the control box CB.

The structure of detector DT will now be explained

in detail with reference to Fig. 2. The detector DT has at its lower end a sleeve 12 made of an electrical insulation material, which is mounted on the bottom of the tank RS and has at least one opening 121 to allow the

5. flow in of the fuel F in the tank and water which has entered the tank by any reason and/or separated from the fuel. On the sleeve 12, there is arranged a fuel dielectric constant measuring means CP comprising a plurality of metallic pipes 13, 13', 13", 14, 14', 14"

10. arranged in a concentric manner, wherein on one hand, each of said pipes 14, 14' and 14" constitutes a positive electrode, supported by an insulated supporting member 15 and integrally connected to a conductive member 16 and on the other hand, each of said pipes 13, 13' and 13"

15. constitutes a negative electrode supported by a conductive supporting member 17. Spaces formed between the concentrically arranged pipes constituting the fuel dielectric constant measuring means CP communicate with an inner space of said sleeve through an opening (not shown) formed

20. in the conductive supporting member 17 and are always filled with the fuel F. It is preferable that the fuel dielectric constant measuring means CP incorporates means 19 which constitutes together with the conductive supporting member 17 a water detecting means 19, since although

25. the fuel dielectric constant measuring means CP per se can detect the presence of water due to a rapid change in

its capacitive output because the capacitances of the fuel and water are quite different, if there is provided no separate water detecting means, a disassembling thereof will be required to remove water droplets on surfaces

5. of the multi-pipe structure, which are difficult to remove by merely a suctional water-removing operation. On the fuel dielectric constant measuring means CP, there is arranged a fuel level detecting means MP comprising a metallic outer pipe 20 as negative electrode
10. and a metallic inner pipe 21 as positive electrode to allow the fuel F flowing therebetween through openings (not shown) formed in the supporting member 15 and conductive member 16. The negative outer pipe 20 is conductively connected through a conductive supporting
15. member 22 to the negative electrode 13 of the fuel dielectric constant measuring means CP at the lower end thereof, and supported by a conductive supporting member 23 at the upper end thereof. The positive inner pipe 21 is supported by the supporting member 15 at its lower
20. end and by an insulated supporting member 24 at its upper end. The inner pipe 21 has in its inner space a lead 25 connected to the positive electrode of said fuel dielectric constant measuring means CP to feed the information on capacitance measured by the fuel dielectric
25. constant measuring means CP inclusive of the water detecting means 17, 19. The outer pipe 20 has an opening

- 201 near its upper end to make easy the flow in of fuel between the inner and outer pipes 20, 21. On the fuel level detecting means CP, there are sequentially arranged a level feeder LF accommodated in a metallic
5. pipe 26, a joint pipe 29 mounted through a conductive supporting member 27 on the metallic pipe 26 and a headbox 30 to vertically maintain the joint pipe 29 and make convenient the maintenance of each of the fuel dielectric constant measuring means CP inclusive
 10. of the water detecting means 17, 19, the fuel level detecting means MP and the level feeder LF. There are provided screws or the like fixing means to conductively connect the sleeve 12 with the outermost pipe or electrode 13 of the fuel dielectric constant measuring means CP,
 15. the outermost pipe 13 to the outer pipe 20 of the fuel level detecting means MP, the outer pipe 20 to the pipe 26 accommodating therein the level feeder LF, and the pipe 26 to the joint pipe 29 through respectively the supporting members 17, 15, 23 and 27, and thus the detector DT
 20. can easily be disassembled by releasing the fixing means, when one of the elements needs to be exchanged. It is preferable to arrange at the upper end of the sleeve 12 a wire net member 31 to prevent any foreign material which may be dispersed in the liquid in the tank RS,
 25. from entering the fuel dielectric constant measuring means CP and the fuel level detecting means MP. The

- reason why the fuel dielectric constant measuring means CP is constructed in the manner of a concentrically arranged multi-pipe lies in that the total surface area of the cylindrical electrodes 13, 13', 13" or 14, 14', 14" is large enough to make the capacity measured by such electrodes similar to that measured by the fuel level detecting means MP without requiring a correspondingly increased height or length, so that any capacitive change depending on the kind and temperature of the fuel can accurately be measured. The level feeder LF is conductively connected to the negative pipe 26 through a line 32, converts capacitive information from the fuel dielectric constant measuring means CP inclusive of the water detecting means 17, 19 and the fuel level detecting means MP through respectively lines 25 and 33 into corresponding frequency signals, incorporates a reference means, converts also a capacitive information measured by the reference means into a corresponding frequency signal, and feeds as outputs those frequency signals to the control box CB (Fig. 1) through a line 34. As is explained later with reference to Fig. 3, the level feeder LF has various elements which are supported by a rod 37 which is in turn supported by insulated supporting members 35, 36, arranged in the pipe 26 and embedded in a body 38 of an insulating synthetic resin for instance epoxy resin. The joint pipe

29 serves to connect the headbox 30 to be installed at the ground surface level to the pipe 26 of the level feeder LF to be installed near the fuel level detecting means MP which should be arranged in the underground

5. tank RS, the installation depth of which may be different in various conditions in each case. Therefore, the length of joint pipe 29 is initially set as having a relatively long size and, if necessary the joint pipe 29 is cut by taking the depth where the tank is embedded under the

10. ground, when the detector DT (see Fig. 1) is installed at the tank in question.

As seen from Fig. 3, the level feeder comprises two relays (contacting relays) RE_1 , RE_2 , an LC oscillation circuit OSC, and a reference means (reference capacitor)

15. RC. The reference capacitor constituting the reference means RC is a high class capacitor which shows almost no capacitive variation due to ambient temperature change and ageing and is selected to have a capacity similar to those measured by the fuel dielectric constant measuring

20. means CP and the fuel level detecting means MP (Fig. 2). The LC oscillation circuit OSC comprises a plurality of coils and capacitors and serves to oscillate in response to the capacitive information to be fed from the fuel level detecting means MP, the fuel dielectric constant

25. measuring means CP and reference means so as to convert the same into corresponding frequency signals. In output

lines of the level feeder LF, lines a and b are relay lines, f is a feeding line of the frequency signals, and g is a grounding line.

- Fig. 4 is a block circuit diagram to show functions
5. of the control box CB illustrated in Fig. 1, in the case where there is a plurality of tanks (five tanks). In the Figure, means designated by reference symbol TDSC is a tank designation switching circuit, each of lines A_1 to A_5 is a signal line connected to the feeding
 10. line f (see Fig. 3) of the level feeder LF belonging to a specified one of the tanks, said switching circuit being subsequently switched by a signal from a control circuit of central processing unit CPU. A signal from the switching circuit TDSC is fed to a memory circuit
 15. MEC through a receiving circuit REC. The memory circuit MEC has memories of equations for calculating a fuel level based on the frequency signal from the level feeder LF and a quantity of liquid in the tank based on the calculated fuel level, upper and lower limit quantities
 20. for each tank and other matters as well as an area for retaining in memory the quantity of the liquid in each tank. An operation or arithmetic circuit OPC serves to calculate the liquid quantity based on a signal from the receiving circuit REC and the equations stored by the
 25. memory circuit MEC and also to judge whether or not the calculated quantity reaches the upper or lower limit

quantity on the specified tank. An output signal of the operation circuit OPC is then fed to an indication printer circuit (IDC+PTC) electrically connected to the buzzer 8, the lamps 2, 3, 4, indicator 1 and printer 6 5. (Fig. 1). The tank selection button 5, the printer operating button 7, a timer TM, the ten-key keyboard 9, the alarm button 7', an alarm circuit AR and each of said circuits are electrically connected to the control circuit CPU. The alarm circuit AR is connected to the 10. alarm 10 which may be arranged at a place remote from the control box CB (Fig. 1).

The operation of the apparatus will now be explained.

When the switching circuit TDSC is electrically connected to the line A_1 of the signal line from the 15. level feeder LF of the first or No. 1 tank by a signal from the control circuit CPU, a signal from the control circuit CPU is fed to the relays RE_1 and RE_2 to cause switching thereof from the state as illustrated in Fig. 3 and complete a circuit connecting the reference means 20. (reference capacitor) RC to the LC oscillator OSC, so that a frequency signal corresponding to the capacity measured by the reference capacitor RC is fed to the memory circuit MEC through the receiving circuit REC. The signal to the relay RE_2 is then removed to complete a circuit 25. connecting the signal line 25 from the fuel dielectric constant measuring means CP to the LC oscillator OSC, so

- that a frequency signal in response to the capacity measured by the fuel dielectric constant measuring means CP is fed to the memory circuit MEC through the receiving circuit REC. Finally the signal to the relay RE₁ is
5. removed to complete a circuit connecting the signal line 33 from the fuel level detecting means MP to the LC oscillator OSC, so that a frequency signal in response to the capacity measured by the fuel level detecting means MP is fed to the memory circuit MEC through the
 10. receiving circuit REC. This frequency signal information stored by the memory circuit is converted by the operation circuit OPC into liquid quantity information signals based on the liquid quantity calculating equation stored by the memory circuit MEC and the resulting liquid
 15. quantity information is compared with the upper and lower limit quantity information also stored by the memory circuit MEC, whereby if the calculated quantity is higher than the upper limit, the lamp 2 is lighted and an audible sound is issued by the buzzer 8 and if the calculated
 20. quantity is lower than the lower limit, the lamp 3 is lighted and an audible sound is issued by the buzzer 8.

The time period required to measure the liquid quantity for each tank is about one second. Upon completion of the measurement, a signal is automatically issued from

25. the control circuit CPU to switch the switching circuit TDSC to connect the same to the signal line A₂ of the second

tank and to commence a measurement on this tank in a manner similar to the first tank. This measuring operation is repeated to the last tank of No. 5 tank and then to the first tank. In other words, measurement 5. for the tanks is continuously carried out in a linking manner.

Therefore, if one of the tank designation buttons 5 is then pushed down, a liquid quantity in the designated tank is indicated on the indicator 1 together with 10. its tank number and if the button is reset, the indicator 1 indicates the time based on signals from the timer TM. In other words, the indicator 1 serves as a digital clock, when it is not employed for indicating the liquid quantity in one of the tanks.

15. If the printing button 7 is pressed down when the tank designation button 5 has been pressed down, the liquid quantity in the designated tank and the time are printed out by the printer 6.

Further, if an alarm button 7' is pressed down at 20. a time when the liquid dispensing service operation is finished such as at the time for closing the fuel dispensing station, the liquid quantity in each tank at that time is stored in memory by the memory circuit MEC and thus if there is a quantity change in any tank over 25. a predetermined amount due to flow in of water, robbery or the like, an alarm signal is issued from the alarm

circuit AR to operate the alarm 10 which may be installed at a suitable place such as at a guard company to enable a suitable counter measure to be taken. The alarm signal may also operate the printer 6 through the 5. control circuit CPU and printer circuit PTC to print out the changed quantity of the liquid and the time.

Further, if water is accumulated in the tank RS to reach the level of the part 19 of the water detecting means 17, 19, the frequency information signal shows an 10. abnormal value when the fuel dielectric constant measuring means CP is connected to the LC oscillator OSC, since the dielectric constant of water is very high as about 81.6 in comparison with values of about 2.1 and 1.0 for oils and air respectively, to cause a rapid increase in the 15. capacity. The detection of such abnormal information will visually and audibly be informed by lighting up of the lamp 4 and sounding of the buzzer 8. The removal of water may be carried out by a conventional manner but according to this embodiment of the invention, the 20. water content in the tank can be estimated by the presence of the water detecting means 17, 19 to make easy the removal operation.

As described hereinbefore, the liquid quantity measuring apparatus attains an accurate measurement by 25. compensating with the liquid dielectric constant measuring means a variation of the dielectric constant of the

liquid to be measured, and with the reference means a variation of the response of the LC oscillator. Further, it is possible to install the indication part at a position apart from that for the detection part,

5. in order to centrally conduct the data on plural tanks, since the measured capacitance which is of an analogue nature is converted near the detection part into the frequency information which is of a digital nature and does not cause any change in the data
10. information due to outer disturbances.



34

- 20 -

CLAIMS

1. An apparatus for measuring the quantity of a liquid in at least one tank, said apparatus comprising a first capacitive device having separate electrodes adapted to be mounted in
5. the tank to allow passage of the liquid therebetween whereby the capacitance between the electrodes depends on the level of the liquid in the tank, a second capacitive device adapted to be mounted in the tank below said first capacitive device so as to be immersed always in the liquid whereby the
10. capacitance thereof depends on the dielectric constant of the liquid, a third capacitive device arranged to provide a reference capacitance value independent of the dielectric properties of the liquid, an LC oscillator operable to produce an output frequency signal, a switching device operable to
15. connect said first, second and third capacitive devices selectively to said oscillator whereby the frequency of the output signal depends on the capacitance of the respective capacitive device, and a control box with an indicator connected to said oscillator and operable to calculate the quantity of
20. the liquid in the tank based on the frequency signals and to provide an indication of said quantity on the indicator.
2. An apparatus as claimed in claim 1, wherein said first, second and third capacitive devices have substantially the same capacitance.
25. 3. An apparatus as claimed in claim 1 or 2, further comprising a detector adapted to be mounted near the bottom of the tank and arranged for detecting the presence of a second liquid,



namely water.

4. An apparatus as claimed in any one of claims 1 to 3, wherein said second capacitive device comprises a plurality of hollow cylindrical members arranged in concentric manner.
5. 5. An apparatus as claimed in any one of claims 1 to 4, wherein said third capacitive device comprises a capacitor of substantially fixed capacitance.
6. An apparatus as claimed in any one of claims 1 to 5, wherein said switching device comprises a pair of relays
10. which constitute together with said third capacitive device and LC oscillator a level feeding device arranged near said first capacitive device.
7. An apparatus as claimed in any one of claims 1 to 6, wherein each of said first capacitive device, said second
15. capacitive device and a housing accommodating said third capacitive device have cylindrical outer configurations with similar diameters and are detachably connected through conductive supports.
8. An apparatus as claimed in any one of claims 1 to 7,
20. wherein said control box accommodates a receiving circuit to monitor the frequency fed from said LC oscillator, a control circuit connected to the receiving circuit to control calculation of a level of liquid in the tank and a quantity thereof based on the frequency monitored by said receiving
25. circuit, and an indicator printer circuit to display and print out a result processed by said control circuit.
9. An apparatus as claimed in claim 3, wherein said water



detector is formed as a part of said second capacitive device.

10. An apparatus as claimed in claim 6, wherein all of the elements constituting said level feeding device are mounted on a common support arranged in a cylindrical housing and

5. embedded in an insulating material body.

11. An apparatus as claimed in claim 8, wherein said control circuit is also connected respectively to a memory circuit, a keyboard for use in the input of information to be stored in the memory circuit, an operation circuit for calculating

10. liquid quantity based on information from the receiving circuit and data stored in the memory circuit, a tank designation switching circuit for specifying a selected said tank and a timer.

12. An apparatus as claimed in claim 11, wherein said memory
15. circuit retains in memory upper and lower limit quantities of liquid on each tank, whereby an alarm signal is issued from the operation circuit, when a quantity of liquid in the tank specified by the tank designation switching circuit reaches the upper or lower limit.

20. 13. An apparatus as claimed in claim 11, wherein time information from said timer is fed to a printer part or indication part of said indicator printer circuit, on actuation of said tank designation switching circuit.

14. An apparatus as claimed in claim 11, wherein said control
25. circuit is further connected to an alarm circuit which is in turn connected to a remote alarm device to issue an alarm indication, and wherein said memory circuit retains in memory

37



- 23 -

information for actuating a printer through said control circuit and indicator printer circuit, when a quantity of the liquid in any tank varies more than a predetermined amount, whereby the liquid quantity change can be detected

5. and printed out together with the time thereof and a signal informing such change is issued by said remote alarm device through said alarm circuit.

15. Apparatus according to claim 1, substantially as hereinbefore described with reference to and as illustrated in the
10. accompanying drawings.
