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# Real time level, temperature, Quantity and density measurements for petroleum storage tanks

Saad Daoud Al Shamma
Mosul University/Electronic Engineering College, Mosul/Iraq

***Abstract*—This work presents a cheap ,standard (out of shelf ) components real time system to measure the level, Quantity (Liter), Temperature and density of petroleum product in storage tanks based on measuring the Absolut pressure at two points with known distance . The system was designed and implemented based on one PLC , two pressure sensors and PT100 sensor per tank .the system could be used for monitoring N storage tanks simultaneously and reporting to a remote control center where a record is added to the database whenever there is a change in any parameters. The system is operational with accepted result.**

***Keywords*— PLC, DP, GUI, IIR Filter, Web Based, PT100, ADC, RS485, 4-20ma**

## I. INTRODUCTION

### *A. Level measurement*

Different methods have been used for measuring and monitoring liquid levels. Mechanical float-type depending on up / down movement of a float device placed in the vessel itself. An accurate readings could be obtained but requires frequent calibration and maintenance. An ultrasonic depending on measuring the time required for ultrasound pulses to make around from the sensor to the level although this method avoid direct contact with the fluid, but suffers from inaccuracies causes by varying temperatures and densities in the area above the fluid level and from potential confusion of echoes [1]. Microwave and radar uses low power high frequency impulses and the time difference between transmitted and received impulses to measure the level although more accurate result could be obtained as compared to ultrasound an inaccurate measurements are obtained in fluids with poor dielectric constants. Depending on the operation frequency, the antenna dimensions can limit the minimal distance to the liquid surface to be measured. Even more, all previous methods are electronic in nature so they suffer from intrinsic safety concerns. As with any electronic device, there are necessarily, heat generating Components that create, no matter how remote, the possibility of hazardous situations when used in areas where flammable materials are present. So an extra cost must be considered to make these techniques suitable for inflammable atmospheres with no risk. Optical technologies uses infrared transmitter and receiver with same principle although very good repeatability, hysteresis and response time it is used for transparent liquid and small vessels And wide bandwidth. Different laser and optical instrumentation devices have been already used in level measurement systems, such as the patent described in [2]. But in any of them the laser, so the electronic driver, is in the sensor head. To avoid electronic presence in the measuring point, optical fibers should be used in the sensor head. This idea has been used in different optical sensors but for measuring short distances or just as simple control level devices [3-4]. A remote sensor head based on optical fibers for long distance is reported in [5] but using different lenses from transmitter and receiver fibers With the complexion related to this disposition, the measuring principle is different and none optical multiplexing is discussed. Differential pressure method based on measuring the pressure difference between two points the level could be obtained when the density is known. DP transmitters are subject to errors due to changes in liquid density. Density variations are caused by temperature changes or change of product. These variations must always be compensated for if accurate measurements are to be made [6].

### *B. Density Meters*

Different methods have been used for measuring and monitoring liquid density. Pythagoras method based on measuring the mass of displaced liquid. Microwave method based on measuring the phase difference between the wave transmitted through drinking water and through the liquid for which the density have to measured Vibrating element method based on measuring the shift in resonance frequency of an element immersed in the liquid which depend on liquid density with temperature compensated method Mass measurement method based on accurate masse measurement for a known volume but none of these are continuous or on-line devices and cannot be considered densitometers. However, discrete measurements such as a pycnometer test are routinely used to prove a densitometer.[7,8].

## II. THEORY

### *A. Level measurement*

Using two pressure sensors fixed as shown in Fig. 1 with known distance between the two (D)

$$P = L * \rho * g \quad (1)$$

Where P=Pressure (Pascal) , $\rho$ = Density (Kg/m$^3$)
g = acceleration(m$^2$/s), L = level ( m)

$$P1 = L1 * \rho * g \quad (2)$$

$$P2 = L2 * \rho * g \quad (3)$$

$$\frac{P2}{P1} = \frac{L2}{L1} \quad (4)$$

$$L2 - L1 = D \quad (5)$$

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So knowing P2 and P1 from sensor reading and D ,L2 and

L1 could be found .

***B. Density measurement***

Density could calculate by three ways

$$\rho 1 = \frac{P1}{L1 * g} \quad (6)$$

$$\rho 2 = \frac{P2}{L2 * g} \quad (7)$$

$$\rho 3 = \frac{(P2 - P1)}{(L2 - L1) * g} \quad (8)$$

The final value could be calculated

$$\rho = \frac{(\rho 1 + \rho 2 + \rho 3)}{3} \quad (9)$$

***C. Quantity Measurement***

- Theoretical calculation

Knowing the theoretical tank geometry (for example cylinder) the quantity Could be calculated as follow

$$Q1 = A * (L2 + D_d) \quad (10)$$

$$Q2 = A * (L1 + D + D_d) \quad (11)$$

The final value

$$Q = \frac{(Q1 + Q2)}{2} \quad (12)$$

Where A=Tank base area=distance between the two sensors , $D_d$ = the distance from bottom to sensor P2 As shown in Fig.1

- Practical approach

A tank calibration table which give the quantity/level step have to be supplied For each tank by an authorized authority.

having this table the quantity could be found by using the measured level as an Index in the table to extract the quantity

***D. Temperature Measurement***

For each PT100 sensor a circuit as shown in Fig.5

Where R-PT100 sensor resistance as a function of temperature, $R_{in}$ =input resistance for ADC card (250 Ohms in this design) , r=cable resistance from sensor to input of ADC,I = current measured by PLC

$$R - PT100 = \frac{5}{I} - r - R_{in} \quad (13)$$

Using a lookup table where the address is the measured resistance and The content is the temperature corresponding to this resistance as given for PT-100 sensor as shown in Fig. 6, the temperature Could be measured with $1C^0$ accuracy

***E. Resolution***

Level resolution measurement correspond to level calculated when the Output from ADC change by 1 .

(for the sensor used in this design the maximum Measured pressure = 2.5 Bar and the maximum digital value for ADC = 16000 )

Level Accuracy = [2.5 *100000]/ [16000*9.81*D]

For water the accuracy D= 1000 kg/m3

Level accuracy = 1.5625 mm

Level accuracy = 2.14 mm

Which is comparable to current expensive level meters (radar, ultrasound...)

***F. Filter***

All measure parameters P2, P1 and temperature are filtered by IIR filter implemented in the PC

$$Y(n) + (1 - \alpha) * X(n) + \alpha * Y(n-1) \quad (14)$$

A good and stable measurements are obtained using α <= 0.1 with sampling frequency = 10 Hz

## III. IMPLEMENTATION

The system implementation as shown in Fig. 2

- modular PLC type with floating point instruction for filters calculation
- ADC (14 Bits (0-16000), 16 channels ADC, 0.5ms
- conversion time)
- RS485 communication module
- Pressure sensors (2.5 Bar Maximum and 4-20 ma output)
- PC GUI as shown in Fig 3 and for a single tank as shown in Fig 4.
- C# 2010 is used for software for GUI where for each tank Temp, Density, Quantity and Level are displayed
- Three modes of operation are used
  - P2-P1 mode in this mode all the parameters (L2, L1, and Density) are calculated
  -P2-D mode in this mode the density is calculated OFF line and the density Have to be entered as input to the system
  -P1-Mode the same as P2_D using P1 and Density
- SQL Database is used to store the records for each tank containing date,time,L2,L1,Temp and Density Whenever there is a change

## IV. CONCLUSION

1. Better resolution could be obtained using more than 14 Bits ADC and pressure sensors with less than 2.5 Bar (1.5 Bar ) as explained in resolution calculation
2. Better accuracy and resolution could be obtained using intelligent pressure sensors with build in processor and compensations to be connected to PC directly through standard protocol(ModBus,Can,RS485,..)
3. A web based software could be used to remotely monitoring the system from any browser
4. Control and monitoring on the petroleum products in each tank could be easily done based on database
5. A more accurate result could be obtained using multi sensors for temperature and density at different tank levels.

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# APPENDIX

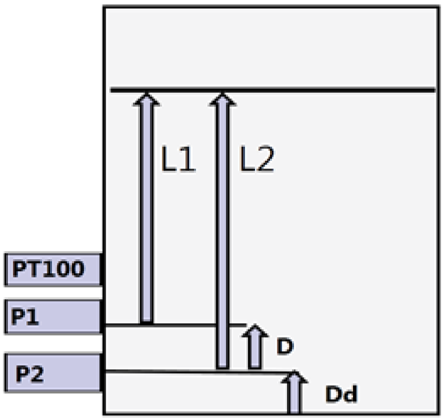



**Fig. 1. Pressure and Temperature Sensors**

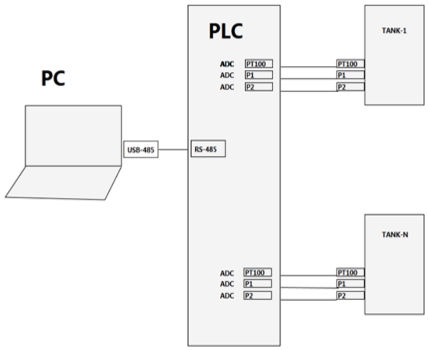



**Fig. 2. System Block Diagram**

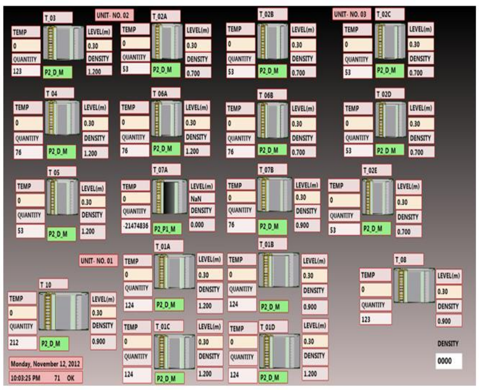


**Fig. 3. Graphic User Interface**

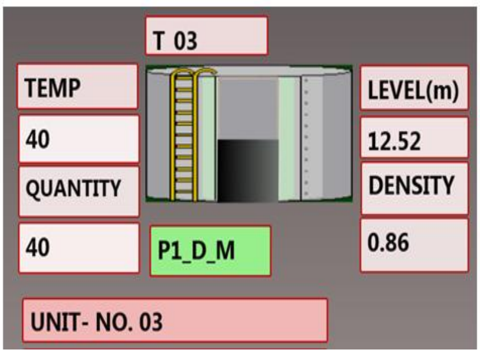



**Fig. 4. Single Tank GUI**

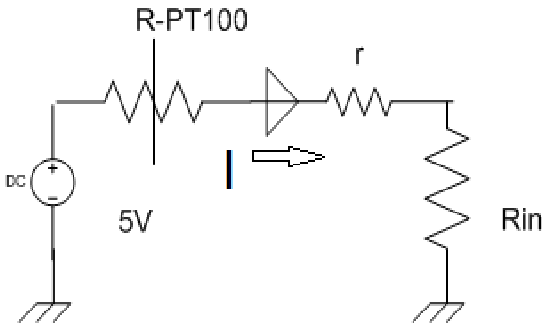
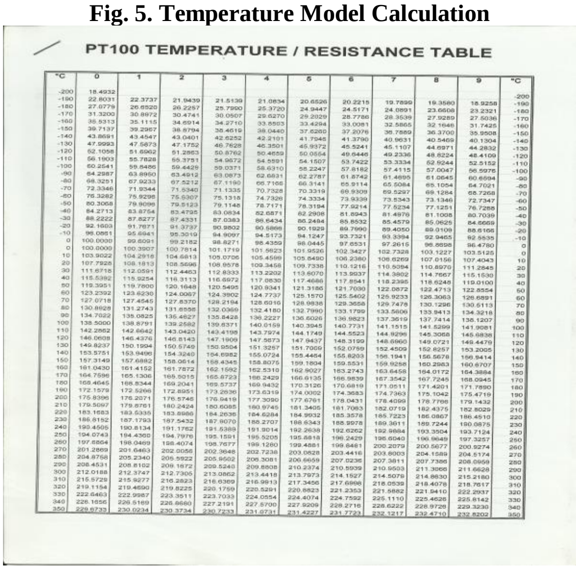



**Fig. 5. Temperature Model Calculation**



PT100 TEMPERATURE / RESISTANCE TABLE

**Fig.6 PT-100 Temperature/Resistance Table**