Smart Measuring System for Oil Storage Tank: Application of IT Level Device and Process Simulator for 15 ℃ Oil Volume Calculation

Su-ri PARK, Sang-wook HAN, Byung-jick KIM
(*Dept. of Chemical Engineering, Soongsil University, Seoul 156-743, Korea*)

Abstract **– It is important to measure the oil inventory exactly for business decision. But several conventional methods are not accurate enough to satisfy oil wholesalers. To overcome this problem, IT technique and Aspen plus simulator were investigated for application. Supersonic wave device and chemical process simulator were applied to enhance the oil volume measuring system. Level error down from 1.2% to 0.15% and standard temp volume concept was introduced to reflect the temperature dependency on oil volume. The developed system from this research will drastically reduce the oil inventory error.**

Key words – level instrument; oil tank; aspen plus; supersonic waves; standard volume

Manuscript Number: 1674-8042(2011)supp1.-0049-05

doi: 10.3969/j.issn.1674-8042.2011.supp1.011

Consumption of the crude oil in South Korea is up to 2 371 000 barrel/day, which is ranked as 7th country in the world. To supply such amount of oil, South Korea has four oil refinery companies and 15 secondary oil refinery companies. There are about 1 700 whole sale and 23 000 retail gas stations around. In the case of whole sale gas station, they trade the oil of average 1 000 barrels/day. Thus the accurate measurement of oil in storage tank is very important in the sense of business. But most of gas stations use the conventional methods like measuring stick or tapeline to measure the liquid level in storage tank.

Tab.1 lists the each month's average temperature of Seoul area during 30 years from 1971 to 2000. Minimum of Jan_avg_T is -6.1 ℃ and Maximum Temperature of Aug_avg_T is 29.5 ℃. Thus the temperature difference between Min Jan_avg_T and Max Temp Aug_avg_T is 35.6 ℃. And volumetric coefficient of Gasoline is known to be 950 * 10^{-6}/℃. That means that Gas volume is sensitive to Temperature.

Tab.1 Min temp and max temp among each month's avgerage temperature for 30 years from 1971 to 2000

	Month	Min temp(℃)	Max temp(℃)
winter	1	−6.1	1.6
	2	−4.1	4.1
spring	3	1.1	10.2
	4	7.3	17.6
	5	12.6	22.8
summer	6	17.8	26.9
	7	21.8	28.8
	8	22.1	29.5
fall	9	16.7	25.6
	10	9.8	19.7
	11	2.9	11.5
winter	12	−3.4	4.2

This research is undertaken to enhance the technology to measure the amount of oil in storage tank. To solve the above mentioned problems, we tried to apply IT system for reducing level measuring error and Aspen Plus Process Simulator for compensating the temperature effect.

1 Theory

1.1 Level instruments for oil tank

General procedures for calculating the total stock of oil in oil tank are as follows: First the liquid level should be measured, then we can calculate the total stock from multiplying the bottom area by the liquid level measured. This method is quite good if the bottom area is not varying with the position in the tank. Thus accurate measurement of liquid level

* **Received:** 2011-08-23
Project supported: This work was supported by the MKE (The Ministry of Knowledge Economy), Korea, under the Convergence-ITRC (Convergence Information Technology Research Center) support program (NIPA-2011-C6150-1101-0004) supervised by the NIPA (National IT Industry Promotion Agency)
Corresponding author: Su-ri PARK (babsool@ssu.ac.kr)

is the first step to calculate the total stock of oil in storage tank. Tab.2 lists three kinds of oil level measuring devices; measuring stick type, floating type, and supersonic wave type. The first two devices are the conventional method, but last one can be classified as IT instrument.

Tab.2 Conventional and IT level instruments

Type	Conventional		IT
	Measuring stick	Floating type	Supersonic waves
Measuring ranges	1~6 m	1~6 m	0.25~12 m
Operating temperature	Severe temperature	Mild temperature	−40~80 ℃
effect of the long distance	Difficult to handle	Rotation of tapeline	No effect
The causes of the Error	Tank bottom deformation Stick deformation	set-up error, distortion, deformation Breakdown of housing	Wrong set-up
Measurment Accuracy (rel. error)	600 L (1.2%)	200~600 L (0.4~1.2%)	75L (0.15%)
Digitalization	Difficult	Difficult	Ease

Fig.1 shows the schematic diagram of level instruments.

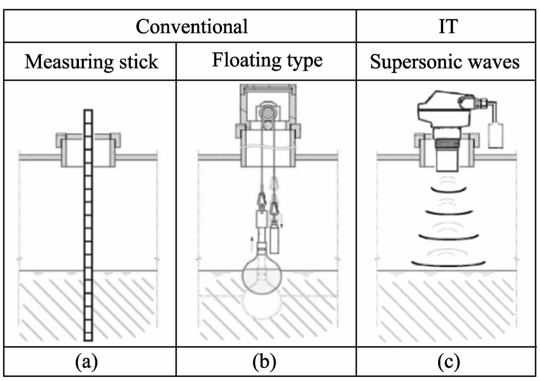

Fig.1 Schematic diagram of level instruments

Level stick is the most using instrument for oil storage tank. Fig.1(a) shows the level stick. The procedures are as follows: First we open the manhole cover and take the long stick out of the tank and clean up the surface of the stick with wash cloth, then reinsert the stick in the tank. Again take the stick out of the tank. Identify the trace border of oil and read the scale of the stick. Floating type instrument is also widely used. One side of scaled-tapeline is connected with a cylinder shaped weight and the other side is connected with a balloon float. Scaled- tapeline get through the housing which functions as a pulley. We can identify the lever by reading the scale. Level stick and floating type instrument were classified as the conventional method. Supersonic wave typed instrument can be classified as IT technique. Fig.1(c) shows the supersonic wave type level instrument. The return time of the supersonic pulse was measured to calculate the distance to the surface.

1.2 Temperature dependency of oil volume

Among all petroleum products, auto-gasoline, kerosene, and petro diesel are most sales ones. Tab.3 lists main properties of mainly trading oils. And Tab.4 lists linear and volumetric coefficients of 4 different oil tank materials. β value of tank materials is relatively smaller than that of gasoline. Thus we can ignore the tank expansion.

Tab.3 Main properties of gasoline, kerosene, and diesel

Main property	Gasoline	Kerosene	Diesel
Carbon number	C4~C12	C6~C16	C8~C21
Specific gravity	0.751~0.77	0.78~0.81	0.78~0.85
Fractional distillation	30~200 ℃	150~275 ℃	200~350 ℃

Tab.4 Linear and volumetric coefficients of 4 different oil tank materials

	Linear coefficient, α, at 20 ℃ (10^{-6}/℃)	Volumetric coefficient, β, at 20 ℃ (10^{-6}/℃)
Gasoline	317	950
PVC	52	156
Stainless steel	17.3	51.9
concrete	12	36
Iron	11.1	33.3

1.3 General volumetric thermal expansion coefficient

In the general case of a gas, liquid, or solid, the volumetric coefficient of thermal expansion is given by Eq.(1)

$$\alpha_v = \frac{1}{v}\left(\frac{\partial V}{\partial T}\right)_p \qquad (1)$$

The subscript p indicates that the pressure is held constant during the expansion, and the subscript "V" stresses that it is the volumetric (not linear) expansion that enters this general definition. In the case of a gas, the fact that the pressure is held constant is important, because the volume of a gas will vary appreciably with pressure as well as temperature.

1.4 Linear expansion

The linear thermal expansion coefficient relates the change in a material's linear dimensions to a change in temperature. It is the fractional change in length per degree of temperature change. Ignoring pressure, we can write the relation by Eq. (2)

$$\alpha_L = \frac{1}{L}\frac{\mathrm{d}L}{\mathrm{d}T}. \tag{2}$$

where L is the linear dimension (e. g. length) and $\mathrm{d}L/\mathrm{d}T$ is the rate of change of that linear dimension per unit change in temperature.

The change in the linear dimension can be estimated as

$$\frac{\nabla L}{L} = \alpha_L \nabla T \tag{3}$$

This equation works well as long as the linear expansion coefficient does not change much over the change in temperature ΔT. If it does, the equation must be integrated.

2 Computer simulation

To get the volumetric thermal expansion coefficient, we made computer simulations by use of Aspen Plus, general chemical process simulator. Tab. 5 shows the sample of Aspen simulation in Gasoline Case.

Tab. 5 Sample of Aspen simulation in gasoline case

Input	Property method	NRTL
	Feed	Temperature 15 ℃ Pressure 1 atm Total flow 10 cum/hr C6～C12 mole fraction
	Block	Cooler · Heater −10 ℃～40 ℃
Output	10.05 cum/hr	

Fig. 2 shows the Aspen Plus Process Flowsheet for Specific Gravity for Gasoline, Kerosene, and Diesel. G15-IN and G50-out indicate the gasoline input at 15 ℃, the gasoline output at 50 ℃ respectively. And Heater-G is Block Name of the heater for Gasoline.

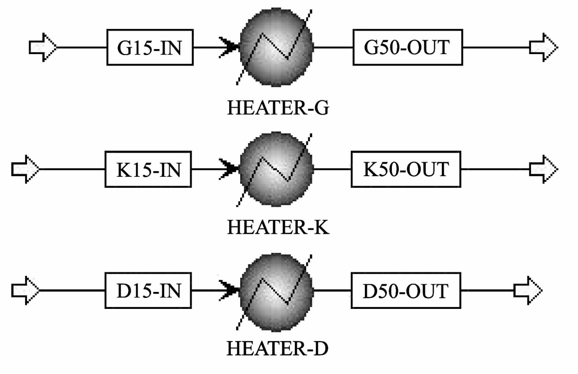

Fig. 2 Aspen process flowsheet for SG calculation

We made Aspen simulations to get the SG (Specific Gravity) of Gasoline for the temperature ranges from 15 ℃ to 50 ℃. In a similar way, we made Aspen simulations for the case of kerosene and diesel. Tab. 6 shows the SG of gasoline, kerosene, and diesel. Relative volume is a reciprocal of SG. Fig. 3 indicates the Relative Volume of G, K, and D for the same temperature range.

Tab. 6 SG of gasoline, kerosene, and diesel in the temp ranges from 15 ℃ to 50 ℃

Temp	Gasoline	Kerosene	Diesel
15 ℃	1	1	1
20 ℃	0.994 7	0.995 2	0.995 8
25 ℃	0.989 4	0.990 5	0.991 7
30 ℃	0.984 1	0.985 7	0.987 5
40 ℃	0.973 3	0.976 1	0.979 1
50 ℃	0.962 5	0.966 3	0.970 6

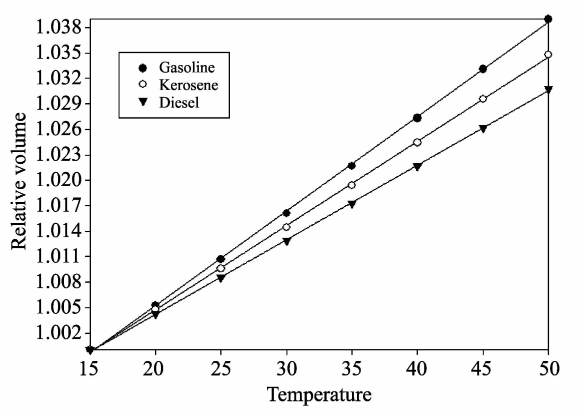

Fig. 3 Relative volume of gasoline, kerosene, and disesel for the temperature ranges from 15 ℃ to 50 ℃

In Fig. 4 solid line is drawn by connecting maximum values of each month average temp and dotted line is drawn by connecting minimum values of each month average temp for 30 years from 1971 to 2000.

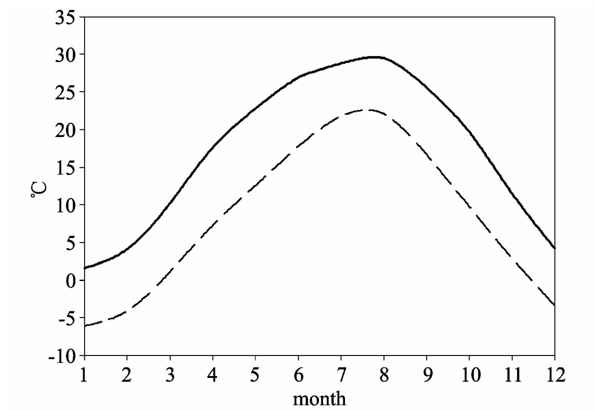

Fig. 4 Maximum and minimum values of the monthly average temperature for 30 years

We used the solid line temperatures to calculate the volume error due to thermal expansion for the case of Gasoline, Kerosene, and Diesel. The simulation results are shown in Fig. 5. In August, the volume errors of G, K, and D are 1.556, 1.396, and 1.241% respectively.

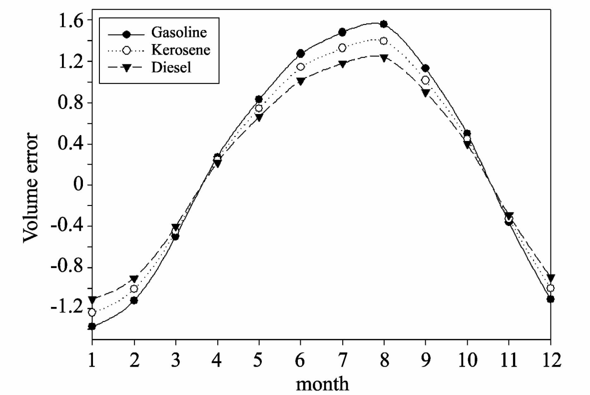

Fig. 5 Volume errors due to thermal expansion for the case of gasoline, kerosene, and diesel for 12 months

3 Smart measuring system

Fig. 6 shows that Smart measuring system for oil storage tank. The liquid level is measured by supersonic waves and oil temperature and pressure are measured by Digital Device. From these raw data, Aspen simulator calculates the 15 ℃ oil volume of the stock.

It is of interest to identify the performance of the smart measuring system. Comparisons were made between the conventional method and IT applied method from the following case study of a certain oil wholesaler.

Case Study (Estimation of Inventory Error):

One day in August, an oil wholesaler(shown in Fig. 7) located in Seoul has 14 oil tanks, each tank hold-up = 60 000 L. 5 tanks contain Gasoline, another 5 tanks contain Kerosene, the rest 4 tanks contain Diesel. All tank contain 60% of full capacity. After business hour, they want to check the oil inventory.

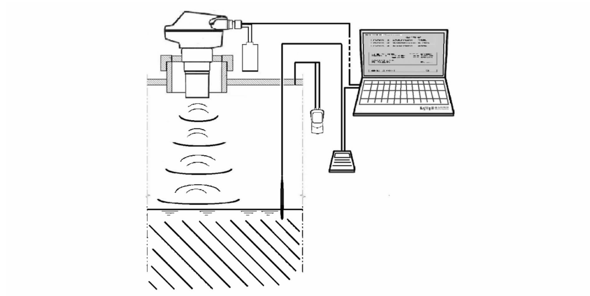

Fig. 6 Schematic diagram of smart measuring system

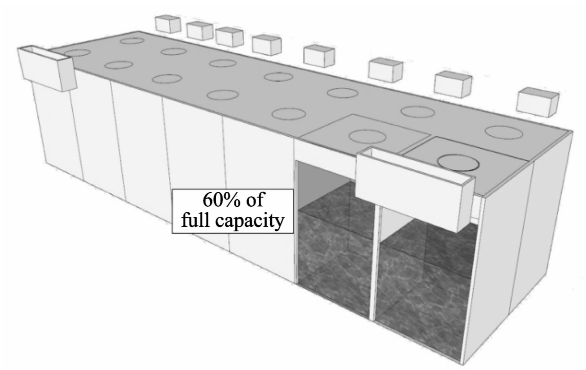

Fig. 7 The schematic diagram of 14 oil tanks of a certain wholesaler located in Seoul

Tab. 7 lists the comparisons between the conventional method and smart system. At the bottom line of the table, the wholesaler's inventory errors turned out to be as much as 26 million won by conventional method.

Tab. 7 Conventional method vs. smart system when 30 ℃ and usual level errors

	Conventional	Smart system	
Level error	+5 cm	+0.75 cm	0
liqid vol/ tank, 1000 L	30.50	30.075	30
Sum of G, K and D, 1000 L	SumG = 152.5 SumK = 152.5 SumD = 122.0	SumG = 150.4 SumK = 150.4 SumD = 120.3	SumG = 150 SumK = 150 SumD = 120
at 15 ℃	N/A	SumG = 148.0 SumK = 148.2 SumD = 118.8	G = 147.615 K = 147.855 D = 118.500
Vol errors, 1000 L	+ ΔG: 4.885 + ΔK: 4.645 + ΔD: 3.500	+ ΔG:0.369 + ΔK:0.369 + ΔD:0.296	+ ΔG = 0 + ΔK = 0 + ΔD = 0
Cost errors 1L = W2000	Sum ΔG = 9 770 Sum ΔK = 9 290 Sum ΔD = 7 000	Sum ΔG = 738 Sum ΔK = 738 Sum ΔD = 592	Sum ΔG = 0 Sum ΔK = 0 Sum ΔD = 0
Inventory error	26 060 000	2 068 000	0

G: Gasoline ;K: Kerosene; D: Diesel

4 Conclusions

The following conclusions were drawn from computer simulations and onsite experiments.

1) By replacing conventional level measurement with IT level measurement, the absolute distance error was reduced from 5 cm to 0.75 cm, which corresponds from 600 L to 75 L in oil volume.

2) From Aspen simulation, we get the volumetric thermal expansion coefficient of Gasoline, Kerosene, and Diesel for the temperature ranges from 15 ℃ to 50 ℃.

3) The case study showed that the wholesaler's inventory errors could be as much as 26 million won (about $24 000) by conventional method.

4) We developed the smart measuring system, in which level, temp, and pressure are measured by digital device and 15 ℃ oil volume of the stock is calculated by Aspen Plus.

References

[1] Joe J-H, Noh S-G, Ko S-T, et al. Chemical processes simulation of using Aspen Plus. Multi-information company, 2001.

[2] Park J-H. The Petrochemical Industry. DonghwaeTechnology, 2010.

[3] Choi G -B. Level gauge, Make public patent 10-2008-0111870, The Korea Intellectual Property Office, 2008.

[4] Korea National Oil Corporation.

[5] Korea Oil Association.

[6] Donald R. Gillum. Industrial pressure, level, and density measurement , 2008.

[7] TPC Training systems. Level measurement: instruments and techniques for measuring levels of fluids and solids, 1979.