PROBLEMS CRUDE OIL WEIGHT CALCULATION

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ABSTRACT

This report describes problems of crude oil weight measurement in the tanks. The results of the crude oil density and temperature measurement are presented, obtained with the different method of sampling. The uncertainty budget in measuring the crude oil weight is given.

1. INTRODUCTION

The companies involved in the activity of oil industry or in the selling of petroleum products face difficulties every day, one of which is oil weight measurement or calculation in terminal storages, tankers, railway and auto-tanks.

There are different ways to measure the weight of liquid oil products. One of the most popular methods is the volumetric-mass method.

2. WEIGHT MEASUREMENT METHODS

According the volumetric-mass method the weight of liquid is calculated by the following formula:

$$M = V \cdot \rho \qquad (1)$$

To determine the weight we need to know 3 parameters: volume (V), density (ρ) and temperature (t). The volume of liquid is measured by turbine flowmeters, using the dynamic method of measurement, or in case of the static method of measurement, level gauges placed into tanks.

To calculate a volume with high precision, it is necessary to find the level of liquid in a tank, then, having a calibration tank table, and knowing the precise level of liquid, to determine the volume of liquid in the tank for the time being.

Density and temperature are measured with a Liquid Density Transducer with a resistance thermometer or with a digital density meter or hydrometer in laboratory conditions.

The procedure of density measurement in a laboratory reveals some problems. The first of them is the representation of crude oil samples. Precise measurements of the liquid density under laboratory conditions will be useless, if the mix in a sampler does not correspond to the average sample of the oil in the tank.

3. SAMPLING

To determine the density of crude oil in the large volume tanks, it is recommended [1] to take of 5 or more samples for getting more precise results of density measurement (one sample from the surface, three from the middle and one from the bottom). It seems that this procedure is easy, but there are many outside factors that influence on each sample (temperature inside the tank, ambient temperature, evaporation the sample, oxidation at the time of, contact with air, etc.). Such procedure of sampling will give good results in case of the proportional distribution of density and temperatures along the height of the tank.

4. MEASUREMENTS RESULTS

Table 1 illustrates the results of temperature and crude oil density measurements, obtained with the standard method of sampling, as well as the results of temperature measurements made at meter intervals, along the full height of the tank with a 3000 m^3 volume capacity.
The measurements were done within two hours of oil setting after the tank had been filled in.

Table.1: The results of temperature and crude oil density measurements

Level, mm	Temperature, ^0C	Density, kg/m^3	Level, mm	Temperature, ^0C	Density, kg/m^3
surface	38.3	819.5	surface	38.3	819.5
+ 1000	38.8	819.1			
+ 1000	38.8	819.1			
+ 1000	38.8	819.1			
+ 1000	37.5	820.1	middle	38.3	819.5
+ 1000	37.0	820.5	middle	38.3	819.5
+ 1000	36.6	820.8	middle	38.3	819.5
+ 1000	36.3	821.0			
+ 1000	36.0	821.2			
+ 1000	35.6	821.5			
bottom	35.2	821.8	bottom	38.3	819.5
Average	37.2	820.3		38.3	819.5

The data included in Table1indicate that depending on the method applied for measuring the oil temperature in the tank, it is possible to obtain various mean values for temperature and density and as a result, discrepancy in weight evaluation.

5. CALCULATION

When using the laboratory method of oil density measurement, the result obtained in laboratory conditions has to be reduced to the conditions of oil volume measurements in the tank, using the formula:

$$\rho_V = \rho_M \cdot \left[1 + \alpha \cdot \left(t_\rho - t_V\right)\right] \cdot K \qquad (2)$$

where:
ρ_V is the oil density measured at temperature t_V, at the conditions of oil volume measurement, kg/m^3;
ρ_M is the oil density measured at temperature t_ρ, in the laboratory conditions, кg/м^3;
α is the coefficient of oil volume expansion, $1/^0C$;
K is the correction coefficient for temperature expansion of the glass used for density hydrometers, which is calculated for density hydrometers calibrated at 15^0C, using the formula:

$$K = 1 - 0{,}000025 \cdot \left(t_\rho - 15\right) \tag{3}$$

For hydrometer, calibrated at 20 °C:

$$K = 1 - 0{,}000025 \cdot \left(t_\rho - 20\right) \tag{4}$$

t_ρ is the oil temperature in oil density measurements, °C;

t_V is the oil temperature in measuring the volume (level) of the oil in the tank,°C;

In measuring the oil density with a digital density meter, the value of the coefficient K is considered to be equal to 1.

The recalculation of the density by formula (2) can be done at the values of temperature difference $\left(t_\rho - t_v\right)$ of no more that ±15^{0}C. If the temperature difference exceeds the values indicated, the recalculation of the hydrometer readings is made by the formula given in ASTM D 1250 [2]:

$$\rho_t = \rho_{15} \cdot \exp \cdot (-\alpha_{15} \cdot \Delta t \cdot (1 + 0{,}8\alpha_{15}\Delta t) \tag{5}$$

$$\alpha_{15} = 613{,}97226 / \rho_{15}^2 \tag{6}$$

In measuring the density with a in-line densitometer , the oil weight is calculated by the formula:

$$M = V \cdot \rho_m \cdot \left[1 + \alpha(t_\rho - t_v) + \gamma(P_v - P_\rho\right] \tag{7}$$

where:

V is the oil volume measured with a flow-meter, m^3;

ρ_m is the oil density measured with a densitometer, kg/m^3;

t_ρ is the oil temperature in measuring the density,^{0}C;

t_v is the oil temperature in measuring the volume,^{0}C;

α is the coefficient of oil volume expansion at the temperature of t_ρ, 1/^{0}C;

γ is the coefficient of oil compression at the temperature of t_ρ, 1/MPa;

P_v is the oil excess pressure in measuring the oil volume, MPa;

P_ρ is the oil excess pressure in measuring the oil density, MPa;

Discrepancy between the laboratory results in measuring the crude oil density and its monitoring, as our investigation show can reach 8 кg/m^3 .

In this case, the companies involved in transportation and selling of the oil are forced to carry out more profound investigations in order to determine the cause of discrepancy.

Moreover, the uncertainty in the oil mass measurements depends not only on the corrections of measuring the parameters of equation (1), but also on the applied method of approximations in reducing the results to standard conditions.

6. PHASE COMPOSITION INFLUENCE

The second problem of this process is that the flow of liquid is not uniform in its phase composition. There are oil gas, water and salts in the flow of the crude oil. The amount of gas may change during the process and the availability of gas bubbles influences the precision of volume measurements. To decrease the error of volume measurement one needs to know the amount of free gas in the crude oil. With this in view, new instruments and methods have been developed. They provide the correction of measurement results in the real-time operation.

The operation of one of the newly developed instruments is based on applying the radioisotop method for measuring the density of liquid under control.

The volumetric part of a free gas (φ) in oil is determined from the following equation:

$$\phi = 1 - \left(\frac{\rho_m}{\rho_o} \right) \quad (8)$$

where:
ρ_m , ρ_o are the density values of the gas – oil mixture and oil respectively.

The density of oil-gas mixture is measured during the full time of measurement, both at the moments, when the oil containing bubbles of free gas flows through the pipe line and at the moments when no bubbles are present.

The density of oil is measured only at the moments when there is no bubbles. All operations with the output signal of a primary measurement transducer, when φ is determined, are automatically accomplished with an information processing device.

The output signal of the device is the measured value of the volumetric part of free gas in oil, which provides to take account of oil weight in a more precise manner.

The next problem in calculating the weight of crude oil is the measurement of content of water and salts content of the moisture in the oil mixture: the dynamic method with application moisture flow meters and the laboratory one, that is the distillation method based on ASTM D 95 [2] or centrifuging according to ASTM D 4007 [3]. If we compare monitoring and laboratory results obtained with these methods, we can see their difference. The causes of this difference are the same, as in case density measuring, which is due to a sampling error.

7. UNCERTAINTY BUDGET

The uncertainty budget in measuring the crude oil weight is given in [4]: :

$$\delta M = \pm 1{,}1 \sqrt{\delta V^2 + G^2 (\delta\rho^2 + \beta^2 10^4 \cdot \Delta T_\rho^2) + \beta^2 10^{-4} \Delta T_v^2 + (\delta W_1 + \delta W_2 + \delta W_3 + \delta W_4)^2} \quad (9)$$

where:
δV is the relative uncertainty due to the crude oil volume measurement;
G is the temperature coefficient, calculated by the formula:

$$G = \frac{1 + 2\beta \cdot T_v}{1 + 2\beta \cdot T_\rho} \quad (10)$$

$\delta\rho$ is the relative uncertainty due to the oil density measurement;
β is the coefficient of oil volume expansion;

$\Delta T_{\rho}, \Delta T_{v}$ are the absolute uncertainty values of the oil temperature measurements when measuring the volume and density;

T_v, T_{ρ} are the temperature of the oil in measuring the volume and density;

$\left(\delta W_1 + \delta W_2 + \delta W_3 + \delta W_4\right)$ are the relative uncertainty of the measurement results for salts, mechanical impurities, water and free gas content.

ACKNOWLEDGEMENTS

Application of equation (9) for calculation of the crude oil weight provides owners of the company involved in oil transportation and selling with the possibility to make choice of an optimum relations between the cost and quality of methods and instruments measuring the crude oil weight in order to obtain reliable results.

REFERENCES

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