349
Egypt. J. Chem. **Vol. 63,** No. 11 pp. 4457 - 4462 (2020)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Flashing Losses Emission Evaluation from Crude Oil Storage Tank

E.M. Mansour*, M. El Aily and S.M. Desouky

Production department, Egyptian Petroleum Research Institute, Cairo, Egypt

Abstract

Evaporation is a natural phenomenon describing when a liquid turn into gas. Evaporation from roof storage tanks is a major source of product loss in the crude oil industry. A liquid will tend to evaporate depending on its vapor pressure. A liquid's vapor pressure is dependent on the surface temperature and composition of the liquid. Evaporation losses should be minimized to help maximize company revenue, meet regulatory requirements, and reduce greenhouse gas. This flashing loss is measured by carrying out the extensive experimental test. Therefore, this paper covers how to estimate oil flashing losses emissions factor (FLEF) percentage for crude oil storage tanks by using the new developed equation to minimize human errors. This statistical technique is a linear association between possible variables to assess flashing loss percentage as a function of operating temperature, sample point height (H1), oil tank height (H2), gas/oil ratio, gas gravity and oil gravity. A good result was obtained from the proposed equation as compared with popular equations by using graphical and statistical exactness. Lastly, modeling testing is ensuring excellent agreement with laboratory work by using new different samples.

Keywords: Crude Oil Tanks, flashing losses emissions factor, popular equations, regression analysis.

1. Introduction

A major source of product loss flashing loss emission in the crude oil industry is evaporation from roof storage tanks. A liquid will tend to evaporate into a gas as a natural phenomenon depending on its vapor pressure [1]. Flashing losses emissions is defined as gases move from higher pressure to lower pressure in the liquid tank. A liquid's vapor pressure is dependent on the liquid composition where by way of the pressure on the liquid tank droplet, some of dissolved lighter compounds in the liquid tank are flashed and some of the compounds that are liquids at the initial pressure and temperature change into vapor and also emission from the tank [2]. As the dropping pressure and the amount of lighter hydrocarbons in the liquid increases, as flashing losses emissions increase. Also, both of liquid tank temperature and sampling points in storage tank are influenced on flashing losses emissions amount [3]. Flashing losses emissions occur at atmospheric storage vessels where produced liquids that came from different main areas of the pressurized vessel such as wellhead sites, tank batteries, compressors stations and gas plants as shown in figure (1) [1].

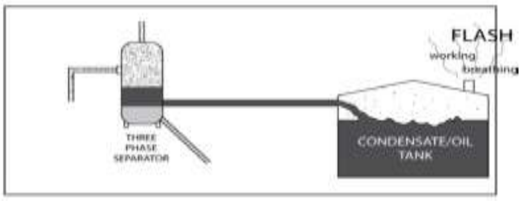


Figure (1): a typical storage vessel flashing losses emissions

Throughout the time, vapors displacement within the storage tank as a filled tank occurs as a result of changes in temperature and pressure of the storage tank. So it will be requested from each facility that has potential hydrocarbon storage tanks (e.g., condensate tank batteries, natural gas compressor stations, crude petroleum liquid storage facilities,

*Corresponding author e-mail: emanmansour84@yahoo.com (E.M. Mansour).
Receive Date: 24 February 2020, Revise Date: 18 April 2020, Accept Date: 27 April 2020
DOI: 10.21608/EJCHEM.2020.24509.2467

natural gas processing plants, etc.) to estimate flashing losses emissions factor [4]. Most petroleum companies are implementing stricter regulations to calculate the accurate quantification of evaporative losses from storage tanks because it is imperative given the impact on the company's earnings. [1]. Vasquez-Beggs Equation (VBE) developed graph to aid facility operators in determining if hydrocarbon flashing losses emissions from storage tanks (exception stock tank API gravity exceeds 60º) need to be calculated or not as shown in figure (2) [5].

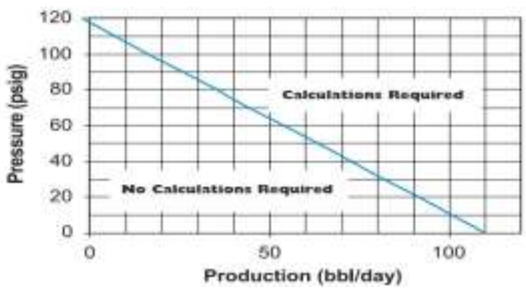


Figure (2): Vasquez-Beggs Equation (VBE) graph

Flashing losses emissions factor can be determined by experimental work or by the calculated method, But as a result of flashing losses emissions factor experimental work was been unavailability due to experimental time and money consuming, so it is necessary to use calculation method to estimate it [6]. There are many methods for calculating flashing losses emissions factor from hydrocarbon storage tanks are discussed as the following. Firstly, the most appropriate method in estimating flashing losses emissions factor is Vasquez-Beggs equation (VBE). This model only need this few input variables in calculation: temperature (ºF), molecular weight of the gas, volatile organic compounds (VOC) fraction of the emissions, volume of produced hydrocarbons (bbls/day), separator pressure (psig), API gravity less than 40º only, gas specific gravity and atmospheric pressure (psia) [7]. Although it is the simplest tool in the calculation, we shall need another more accurate method if flashing losses emissions are more than 50 TPY. environmental consultants and research equation (EC/R) is another method of calculating flashing losses emissions factor by using information as hydrocarbon liquids density, each component mass fraction in the liquid and tank throughput. This estimating method is not accurate and needs another method because flashing losses emissions assumed to be zero at a pressure below 8.8 psig and at pressures greater than 60.3 psig. There are several different [7]. The equation of state (EOS) such as Peng Robinson and Soave Redlich Kwong equation is a mathematical equation relating thermodynamic variables as specific material volume temperature and pressure with each other for estimating flashing losses emissions. Both this parameter as separator pressure, temperature and separator oil composition are required as inputs data needed for this model [8] [9]. Another method of determining flashing losses emissions is GOR determination by collecting a pressurized storage tank sample then multiplying measuring GOR by tank throughput. Process simulators manufacture such as PROSIM, HYSIS, WINSIM, HYSIM to simulate flashing losses emissions by using minimum input data from pressurized sample analysis, pressure, and temperature. All these simulators are complicated and very expensive although they not constrained by API gravity [10]. Consequently, this paper proposes specific objective is an empirical correlation for estimating flashing losses emissions factor (FLEF) which can be used in the event that pervious calculations methods derived not accurate and if experimental work is not available.

Methodology

A total of forty-four samples were collected from different hydrocarbon storage tanks with different oil tank height (H2) and sample point height (H1). This study includes experimental work and mathematical calculation.

I. Experimental work

This section stated the details of the experimental work that was carried out. Firstly, the PVT cell was cleaned by an organic solvent, dried and then evacuated to be ready for operating. A portion of the sample was charged to a high pressure visual free mercury PVT cell (VINCI Technologies, France (2013)) through a flow line by high-pressure hydraulic pump at atmospheric pressure and thermally adjusted to the tank temperature. The oil volume is then recorded (Vo1) as shown in figure (3-A). Conduct good stirring (rpm= 1000) at which the pressure was building up due to evolving of dissolved gases on the oil surface of the sample [11]. The system was kept under operating pressure &

temperature as shown in figure (3-B & 3-C) till reaching thermal equilibrium as shown in figure (3-D). The building up pressure was then released to atmospheric pressure (14.73 psia) by removing gas by gas-meter as shown in figure (3-E) and its volume was determined to calculate gas oil ratio (GOR). Also, the composition of the product was analyzed by Clarus 500 Perken Elmer gas chromatograph (GC) to calculate gas gravity by ASTM D – 6730 standard test [12]. The volume of oil was determined (Vo2) and measured density to calculate oil gravity (API) by ASTM D-4052 standard method [13]. Flashing loss emission factor (FLEF) was calculated at atmospheric pressure and tank temperature from the following equation (1);

$$(\boldsymbol{ELEF}) = [\boldsymbol{Vo1V{-}o1Vo2}] *100 \quad \ldots\ldots (1)$$

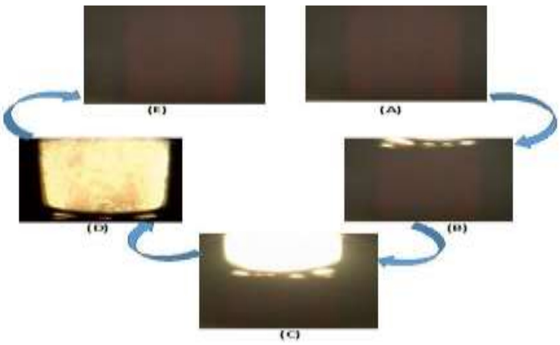


Figure (3): The following photographs illustrate dew point pressure measurements at the operating temperature for one reservoir

II. Mathematically formula model Building Up

Empirical correlation model is a linear association technique of data storage bank between different possible variables from the production field and laboratory work. It is vital to quantify which of the data base variables in our work are dependent on each other to help in better prepare our data [14]. Petroleum simulation engineering workers usually build up flashing losses emissions factor (FLEF) correlations by independent variables like oil gravity (API), separator temperature, the specific gravity of separator gas, the molecular weight of stock tank gas and atmospheric pressure. Therefore, the first step in building up this model is selecting the most important parameters that give good understanding of relationships between variables and the least ones were excluded [15]. Some exploratory forms among forty-four variables samples are carried out to correlate the best equation of flashing losses emissions factor (FLEF) in dissimilar forms of logarithmic, power and linear relationships. These numerous trials show bad accuracy because complex and unfamiliar relationships between not sufficient parameters were correlated [16]. So in this study, we use the best main basis information data anticipated to more effective on flashing losses emissions factor (FLEF) as operating temperature, sample point height (H1), oil tank height (H2), gas/oil ratio, gas gravity, and oil gravity. This data selection illustration clarifies variation in data range as results of the source difference as shown in Table (1).

Table(1): Data Description used in modeling

556.5	≤	T	≤	565.5	°R
16.6	≤	γ_{API}	≤	20.09	°API
3.2	≤	GOR	≤	5.23	SCF/STB
1.4811	≤	γ_g	≤	1.5021	(air = 1)
1.75	≤	H_1	≤	7.5	m
5.55	≤	H_2	≤	10.55	m

Multiple regression analysis is used to building up a set of independent parameters to predict a strong relationship between dependent parameters. The best regression analysis was achieved by using the next function, is given by equation (2).

[FLEF] = f (Temperature, GOR., API gravity, Gas gravity, Sampling Points) ………………………..…(2)

These preliminary studies led to using a non-linear regression model through the following parameters, as shown in equation (3) as the best regression analysis form.

$$\ln[\boldsymbol{FLEF}] = \boldsymbol{eA} + (\boldsymbol{X1})\boldsymbol{B} + (\boldsymbol{X2})\boldsymbol{C} + (\boldsymbol{X3})\boldsymbol{D} \quad ...…(3)$$

This non-linear empirical correlation was linearized, the final linear form is given by 120 equation (4):

$$\ln \ln[\boldsymbol{FLEF}] = \boldsymbol{\beta 0} + \boldsymbol{\beta 1}\ln(\boldsymbol{X1}) + \boldsymbol{\beta 2}\ln(\boldsymbol{X2}) + \boldsymbol{\beta 3}\ln(\boldsymbol{X3}) \quad ...…(4)$$

We assigned the parameters with symbols to be more easily in the calculation process,

Where:

$\boldsymbol{X1} = \boldsymbol{TR}$

$\boldsymbol{X2} = (\boldsymbol{HH12})\boldsymbol{API{-}1}$

$\boldsymbol{X3} = \mathbf{GOR}\ \boldsymbol{\gamma g}$

And:

$\boldsymbol{\beta 0}$= 29.542 $\boldsymbol{\beta 1}$= -4.934

$\boldsymbol{\beta 2}$= 2.856 $\boldsymbol{\beta 3}$= 0.703

T_R: operating temperature, H1: sample point height, H2: oil tank height, GOR: gas/oil ratio, γg: gas gravity and API: oil gravity.

Results and Discussion

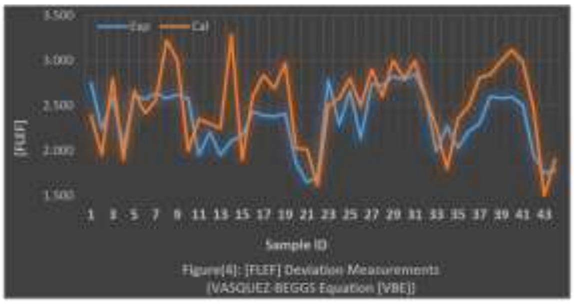
We will use forty-four samples to inspect the performance of new empirical correlation as compared to other popular methods as the equation of state for Peng Robinson, Soave Redlich Kwong, and Vasquez-Beggs equation. Finally, testing the proposed method with different new samples in the same data acquisition. This section includes model performance and model testing.

I. Model Performance

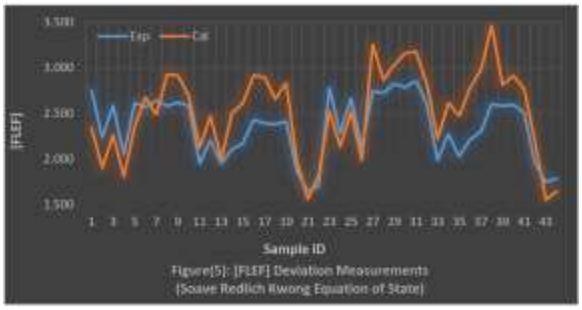
A comprehensive study by graphical and statistical errors was performed to compare these different methods.

I.1. Graphical Error Analysis

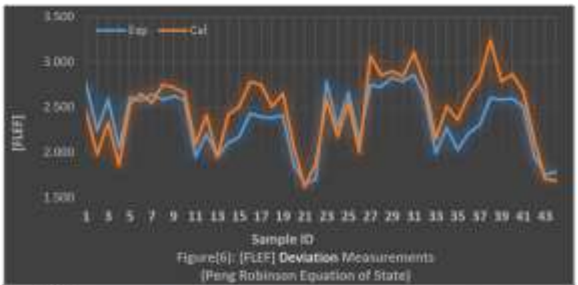
In this part, we use graphic error analysis to study methods accuracy, where the calculated data of flashing losses emissions factor (FLEF) from popular methods were plotted with the measured one. As plotted data points of experimental work and calculated one are close to each other, as the better correlation is used [14]. Figures (4 - 7) clarify the behavior of the predicted flashing losses emissions factor (FLEF) by Vasquez-Beggs equation, Soave Redlich Kwong equation of state, Peng Robinson equation of state and new empirical model respectively compare with the laboratory work for all data points. None of the popularly considered equations is accurately estimated flashing losses emissions factor (FLEF) as shown in figures (4 - 6). This ensures that all these methods need to be developed by high accuracy degree with the presented data. Figure (7) is the most accurate one for the selected fluid properties data range.



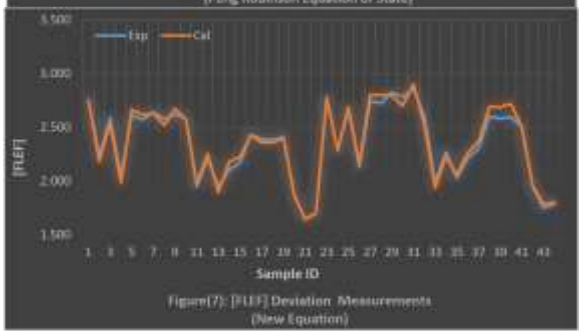
Figure(4): [FLEF] Deviation Measurements (VASQUEZ-BEGGS Equation [VBE])



Figure(5): [FLEF] Deviation Measurements (Soave Redlich Kwong Equation of State)



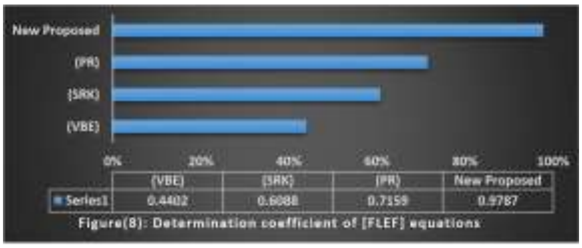
Figure(6): [FLEF] Deviation Measurements (Peng Robinson Equation of State)



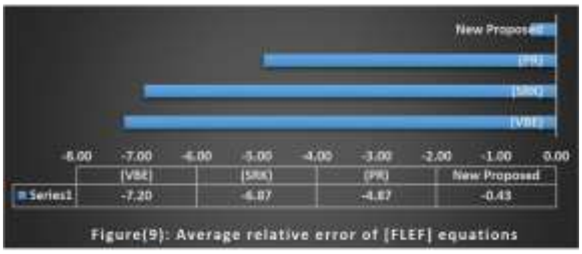
Figure(7): [FLEF] Deviation Measurements (New Equation)

I.2. Statistical Error analysis

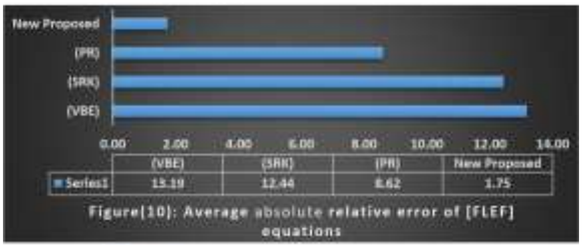
To be more accurate, we apply statistical error analysis which as the coefficient of determination (r2), average absolute relative error (AARE %), average percent relative error (ARE %) and standard deviation (SD)[15] . Figures (8 - 11) describes all statistical error analysis results of flashing losses emissions factor (FLEF) for all samples. All these figures prove that Peng Robinson equation of state has a high coefficient of determination (r2 %) of 71.59 and also the low value of both average absolute relative error (AARE %), standard division (SD) of 8.62%, 10.27%, respectively. Therefore Peng Robinson equation of state is a more suitable method for estimating flashing losses emissions factor (FLEF) as compared with Vasquez-Beggs equation and Soave Redlich Kwong equation of state. But new empirical model is the most appropriate technique as compared with all popular equations with highest coefficient of determination (r2 %) of 97.87 and the lowest value of average absolute relative error (AARE %) of 1.57, average percent relative error (ARE %) of -0.43 and standard deviation (SD) of 2.14.



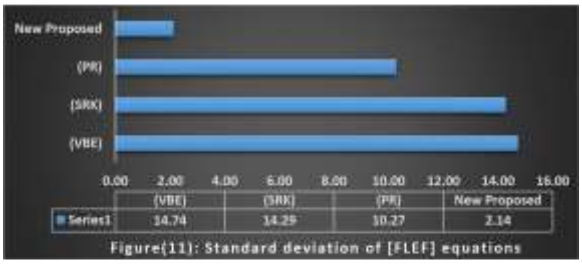
Figure(8): Determination coefficient of [FLEF] equations



Figure(9): Average relative error of [FLEF] equations



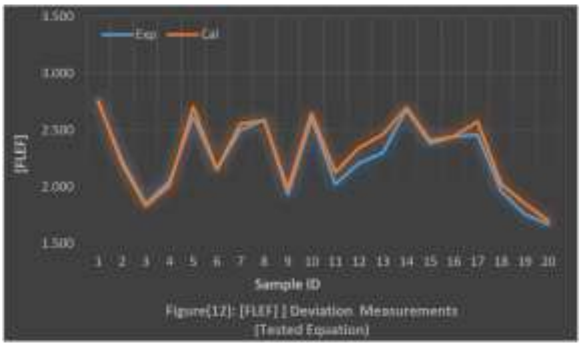
Figure(10): Average absolute relative error of [FLEF] equations



Figure(11): Standard deviation of [FLEF] equations

II. Model Testing

In order to ensure that the newly empirical model was considered the best one, we decided to make validation using twenty samples not used in building up the modeling. All these data have different conditions and properties in the same data range of building up this model [17&18]. The observed value will be discussed through graphical and statistical error analysis. Figure (12) shows the errors by using newly correlation with new data points are considered very near to the errors caused by the samples used in building up. Also, the statistical analyses illustration highest (r2 %) of 96.98, lowest (AARE %) of 2.57, (ARE %) of -2.08 and (SD) of 3.38, which reaches a minimum error as compared with the original building up data [19&20].



Figure(12): [FLEF] Deviation Measurements (Tested Equation)

Conclusions

- The objective of this paper was to predicate the value of flashing losses emissions factor (FLEF) by the quick empirical formula for the petroleum industry.
- The flashing losses emissions factor (FLEF) is critical for production allocation measurements for oil producing companies.
- Molding Build up by non-linear regression analysis including a selection of simply measurement inputs data as operating temperature, sample point height (H1), oil tank height (H2), gas/oil ratio, gas gravity and oil gravity.
- Evaluation performance of the literature review equations and new modeling to identify flashing losses emissions factor (FLEF) was done using statistical and graphical error analyses.
- The obtained analysis shows that the new molding is the best of its kind nowadays in the petroleum industry with (r2 %) of 97.87, (AARE %) of 1.57, (ARE %) of -0.43 and (SD) of 2.14.
- Validating and testing the new model with excellent accuracy based on newly selected data not used before.
- The new equation represents a quick robust model to estimate flashing losses emissions factor (FLEF).

Reference:

1. Connors, K., Evaporation loss measurement from storage tanks. 1984, The Standard Oil Co.(Ohio), Cleveland, OH.
2. Sulaiman, S.A., et al., Automated Calculations for Improvement of Tank Inventory at Fuel

Terminals. Journal of Applied Sciences, 2011. 11(10): p. 1770-1776.

3. Wortman, C.B. and R.C. Silver, The myths of coping with loss. Journal of consulting and clinical psychology, 1989. 57(3): p. 349.
4. Nesvacil, D., et al., Upstream Oil and Gas Storage Tank Project Flash Emissions Models Evaluation. 2009.
5. Hendler, A., et al., VOC emissions from oil and condensate storage tanks. Houston Advanced Research Center, 2009.
6. Hasselmann, D.E., System and method for automatically monitoring liquid volume changes in storage tanks. 1987, Google Patents.
7. Wiggins, J.H., Evaporation loss of petroleum in the Mid-Continent field. 1922, Bureau of Mines, Washington, DC (USA).
8. Soave, G., Equilibrium constants from a modified Redlich-Kwong equation of state. Chemical engineering science, 1972. 27(6): p. 1197-1203.
9. Peng, D.-Y. and D.B. Robinson, A new two-constant equation of state. Industrial & Engineering Chemistry Fundamentals, 1976. 15(1): p. 59-64.
10. Warneke, C., et al., Volatile organic compound emissions from the oil and natural gas industry in the Uintah Basin, Utah: oil and gas well pad emissions compared to ambient air composition. Atmos. Chem. Phys, 2014. 14(20): p. 10,977-10,988.
11. Mansour, E., et al., Predicting PVT properties of Egyptian crude oils by a modified Soave–Redlich– Kowng equation of state. Egyptian Journal of Petroleum, 2013. 22(1): p. 137-148.
12. Andersson, R., M. Boutonnet, and S. Järås, On-line gas chromatographic analysis of higher alcohol synthesis products from syngas. Journal of Chromatography A, 2012. 1247: p. 134-145.
13. International, A., Standard test method for density, relative density, and API gravity of liquids by digital density meter. 2011: ASTM International.
14. Mansour, E., et al., The effect of asphaltene content on predicting heavy dead oils viscosity: Experimental and modeling study. Fuel, 2018. 212: p. 405-411.
15. El Aily, M., et al., Modeling viscosity of moderate and light dead oils in the presence of complex aromatic structure. Journal of Petroleum Science and Engineering, 2019. 173: p. 426-433.
16. El Aily, M., et al., Experimental studies on constant mass–volume depletion of gas-condensate systems. Egyptian Journal of Petroleum, 2013. 22(1): p. 129-136.
17. Mansour, E., et al., Modification proposed for SRK equation of state. Oil and Gas Journal, 2012. 110(6): p. 78-91.
18. Mansour, E., et al., A new estimating method of minimum miscibility pressure as a key parameter in designing CO2 gas injection process. Egyptian Journal of Petroleum, 2018. 27(4): p. 801-810.
19. Mansour, E., et al., A laboratory investigation of carbon dioxide-enhanced oil recovery by focusing on CO2-oil physical properties. Egyptian Journal of Petroleum, 2019. 28(1): p. 21-26.
20. Mansour, E., et al., Experimental Approach of Minimum Miscibility Pressure for CO2 Miscible Flooding: Application to Egyptian Oil Fields. Egyptian Journal of Petroleum, 2016. 2(5): p. 105-112.