Global Flow Measurement Workshop
22 - 24 October 2024

Technical Paper

Challenges in 2024 with Flare Measurement and Real-World Examples

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1 INTRODUCTION

With World Bank estimating 144 billion cubic meters of hydrocarbons[1] released this year, and companies concerned about regulatory reporting requirements, flare measurement is crucial to our industry. As the practice of releasing 400 million tons of CO2[2] into the atmosphere continues, the reporting, regulatory and financial impacts will require greater measurement accuracy.

The increase of governmental reporting requirements and credits be offered across countries, accurately measuring flare gas, and defining acceptable tolerances for flare readings is a continuing challenge in the industry. Measuring flared volumes is challenging as the same factors used in custody transfer measurement is applicable, such as ideal gas laws, pressure, and temperature, but the conditions which can cause measurement uncertainty are still the same.

While there is presently no custody transfer standard available for flare measurement, the industry continues to measure standard gas volume utilizing pressure and temperature. Some studies declare the compressibility factor to the standard volume is almost negligible [1], with a shortfall on studies of the effect of pressure and temperature on flare volumes.

This paper addresses Petroleum Development Oman experience and measurement challenges in upstream oil and gas fields containing more than 85 flare stacks scattered around the Sultanate of Oman wide geographical area, it also demonstrate technical flow measurement analysis on a sample of 8 flare measurements to examine the influence of high pressure (more than atmospheric pressure), atmospheric pressure and temperature on gas flare volumes to accurately measure and quantify the uncertainty in flare volume reporting.

2 EFFECTS OF PRESSURE AND TEMPERATURE ON STANDARD VOLUME

The impact of pressure and temperature can be derived from the ideal gas law, pressure varies inversely with volume also known as "Boyle's law", conversely temperature has a direct relation to volume stated by Charle's law. Considering variations in pressure and temperature to volumes can be determined by standard volumetric flow rate equation if compressibility is

[1] World Bank, "Tackling Small-Volume Gas Flares Could Cut Millions of Tonnes of Carbon Emissions," *World Bank Blogs*, July 12, 2023 https://www.worldbank.org/en/programs/gasflaringreduction/global-flaring-data#:~:text=PDF-,The%20World%20Bank's%20Global%20Gas%20Flaring%20Tracker%2C%20a%20leading%20global,of%20associated%20gas%20was%20flared.

[2] World Bank, *The World Bank's global gas flaring tracker*. World Bank. Retrieved September 11, 2024, from https://blogs.worldbank.org/en/energy/tackling-small-volume-gas-flares-could-cut-millions-tonnes-carbon-emissions#:~:text=Globally%2C%20over%2010%2C000%20flaring%20sites,million%20tonnes%20of%20CO2.

ignored [1], actual volumetric flow rate from the flowmeter is multiplied by ratio of flowing pressure and base temperature by base pressure and flowing temperature while base pressure is atmospheric pressure 101.325 kPa and base temperature is 288.15 Kelvins (Standard volumetric flowrate Equation 1).

$$Qv = qv\,(\frac{Pf \times Tb}{Pb \times Tf}) \quad \text{(Standard volumetric flowrate equation 1)}$$

Where;
qv is the volumetric flow rate at flowing conditions;
Qv is the volumetric flow rate at standard conditions;
Pf is the flowing pressure (absolute units);
Pb is the base pressure;
Tf is the flowing temperature (absolute units);
Tb is the base temperature;
Qp Pressure error flowrate;
Qt Temperature error flowrate;

2.1 Effect of pressure on flare standard volume

To estimate the pressure error flowrate (Qp), base pressure and actual pressure shall be considered from standard volumetric flowrate equation and neglect the temperature factor (Pressure Error Flowrate Equation 2), comparing pressure error with actual pressure variations from field data Figure (1) shows a declining error trend as pressure is reduced since flares are emitted to the environment the flowing pressure is nearly atmospheric (101.315 kPa) the pressure variance is minimal and combined sensitivity and error in pressure is calculated by $\frac{(Qv-Qp)}{Qv} \times 100$.

$$Qp = qv(\frac{Pf}{Pb}) \quad \text{(Pressure Error Flowrate Equation 2)}$$

Figure 1: Field data; impact of pressure variation on pressure error flowrate Qp.

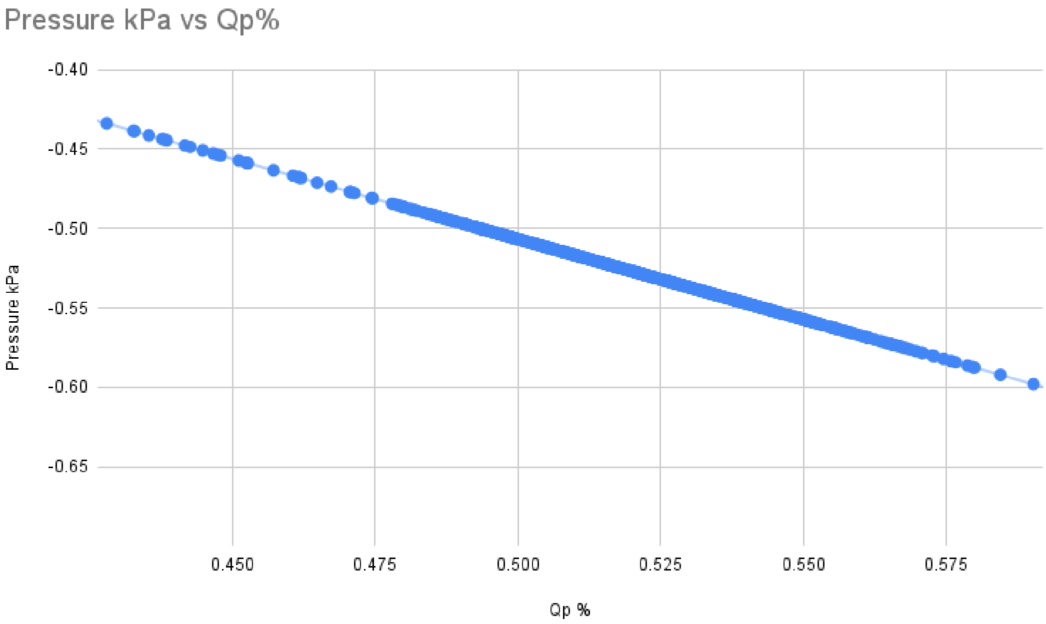

Table 1 – Combined sensitivity, error, and uncertainty on pressure measurement based on API 14.10 Natural Gas Fluids Measurement guidelines.

Variable	Combined Sensitivity and Error (S x U95)	Uncertainty
Atmospheric Pressure	-0.076	0.270 %
High Pressure	0.519	0.720%

The effect of pressure included high and atmospheric pressure, they all have shown almost similar outcomes in all sampled data summarized in Table 1, pressure tends to clearly reduce at increased flare volumes, resulting in combined sensitivity and error indicated in Table 1 and hence uncertainty calculated for pressure impact on flare volumes is less than 1%.

2.2 Effect of temperature on flare standard volume

Based on outcome Temperature is a key factor of the standard volume calculation.
Usually, temperature is exposed to high variance in flowing conditions (volumes) and understandably higher uncertainty is anticipated.

Based on data below, the uncertainty in temperature can shrink and expand depending on the pressure of the flare operated either above or at atmospheric pressure and ambient temperature during day and night.

Temperature propagation of error therefore can be derived by eliminating the pressure factor from standard volumetric flowrate equation (Temperature Error Flowrate Equation 3), and the difference between actual flowrate and pressure error is the combined sensitivity and error $\frac{(Qv-Qt)}{Qv} \times 100$..

$$Qt = qv(\frac{Tb}{Tf})$$ (Temperature Error Flowrate Equation 3)

Figure 2: Field data analysis; temperature variations impact on temperature error flowrate Qt.

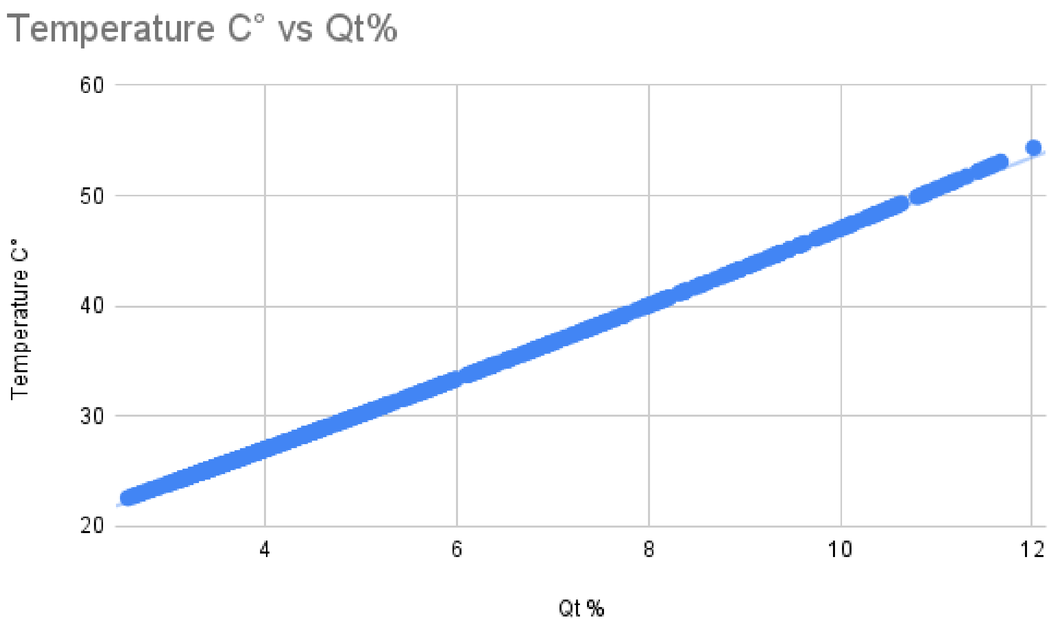

Table 2 - Temperature combined sensitivity, error, and uncertainty according to API 14.10 Natural Gas Fluids Measurement.

Variable	Combined Sensitivity and Error (S x U95)	Uncertainty
Temperature	5.505	2.295%

Unlike pressure, as temperature rises, as illustrated in Figure 2 field data analysis effect of temperature variations to temperature error flowrate Qt, changes in flared volumes occur, leading to combined sensitivity and error in temperature measurement. This change can be almost nine times higher than pressure error, therefore the uncertainty is higher. Table 2 Temperature combined sensitivity, error, and uncertainty calculated according to API 14.10 Natural Gas Fluids Measurement shows the total uncertainty of temperature that affects the standard flared volume.

3 Conclusion

This study aimed to examine the impact of pressure and temperature in flared volume based on a sample of 8 flare meters data in PDO an upstream oil and gas company, since no mandate exist in international standards.

The analysis demonstrated from real field data in this paper shows the importance of installing pressure and temperature devices, alternatively, adopting the common practice of using fixed pressure and temperature values in the DCS/SCADA System can also be beneficial.

As this paper has shown, the uncertainty associated with pressure is very minor while temperature uncertainty is more significant, these findings are crucial for optimizing flare system design and improving environmental compliance.

In conclusion the analysis conducted on high and atmospheric pressure flare revealed similar uncertainty figures, with combined uncertainty of pressure and temperature impact on standard flared volume being approximately 3%. When designing flare measurement systems to comply with environmental regulations and measurement requirements, this level of uncertainty (~3%) may be adequate depending on the limit set by local or national environmental regulatory agencies.

4 REFERENCES

[1] API 14.10. Natural Gas Fluids Measurement – Measurement of Flow to Flares, Second Edition.

[2] World Bank, "Tackling Small-Volume Gas Flares Could Cut Millions of Tonnes of Carbon Emissions," *World Bank Blogs*, July 12, 2023 https://www.worldbank.org/en/programs/gasflaringreduction/global-flaring-data#:~:text=PDF-,The%20World%20Bank's%20Global%20Gas%20Flaring%20Tracker%2C%20a%20leading%20global,of%20associated%20gas%20was%20flared.

[3] World Bank, *The World Bank's global gas flaring tracker*. World Bank. Retrieved September 11, 2024, from https://blogs.worldbank.org/en/energy/tackling-small-volume-gas-flares-could-cut-millions-tonnes-carbon-emissions#:~:text=Globally%2C%20over%2010%2C000%20flaring%20sites,million%20tonnes%20of%20CO2.