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APPLICATION NOTE - Well Intervention-less Tracer Surveillance System – WITSS.
Tracer dilution method for gas flow measurements.

Summary

Due to operator's commitments to reducing operational carbon footprints along with a desire to improve operational efficiency, Tracer dilution techniques, coupled with advances in online analysis technologies; are increasingly being utilized to accurately measure the volumetric rates of injected and produced fluid rates in oil and gas fields as alternatives to traditional measurements.

In particular, the gas tracer dilution method provides an alternative to conventional metering traditionally used for that purpose. Continuous tracer dilution measurement on the gas phase provides an accurate and reliable measurement of gas volumetric flow rate. The volumetric gas rate is inversely proportional to the tracer concentration injected upstream and accurate across a wide range of flow conditions. Gas lift injection rates, produced gas rates, and flare rates can all be quantified online using this technique.

This method has proven to be robust and accurate over a wide range of conditions. In practice, the tracer method is capable of measuring over a much wider range than most test separators and multiphase flow meters, making the technique well-suited for both in-situ well-testing along with verification and calibration of installed multi-phase and wet gas flow meters.

Scanwell has been deploying the N2-based dilution technique for gas lift injection rate and produced gas rate measurements for its clients worldwide. N2 tracer has unique properties resulting in homogeneous mixing and negligible partitioning into the water and oil phases. The properties of the N2 tracer medium, combined with state-of-the-art measurement instrumentation and customized procedures, result in highly accurate and repeatable measurements, with a measurement uncertainty of 5% or better.

Challenges of flow metering and verification of measurements

Gas Lift Injected Rate (GLiR)

<u>Gas Lift Injection Rate</u> is an important parameter to monitor to ensure effective production and correct allocation of available gas lift.

Gas-lifted wells can be equipped with *<u>orifice meters</u>* to quantify the volumes of injected gas lift. Inline orifice meters measure pressure drop (dP) over a given orifice diameter which is proportional to flow of a gas with known composition. Issues related to incorrectly sized, partial erosion, or clogging of the inline orifice, combined with unknown or changing gas lift composition and liquid fraction result in poor metering of the injected gas lift.

<u>Ultra-sonic clamp-on meters</u> are another alternative for quantification of injected gas lift. Ultra-sonic meters are easy to install but require the knowledge of accurate pipe diameter, wall thickness, and gas composition to convert the acoustic signal to flow rate. Unknown pipe properties, surface corrosion, liquid fraction, and unknown gas composition prevent accurate and repeatable measurements. Internal layers of deposition, external paint, and pipe geometry can cause a signal-to-noise ratio which prohibits measurement capability.

Produced Gas Rate

<u>Inline test separators and multiphase meters</u> are commonly used to quantify produced rates from wells. Lack of regular well-testing facilities and challenges related to the quality of the measurements prevent frequent quantification of produced rates. Multiphase Flow Meters, these rely heavily on accurate wellstream compositional data to ensure accuracy; often these meters are not verified and updated on a regular basis. The lack of regularly obtaining this data results in undetected optimization opportunities and allocation challenges.

Conventional practices for *<u>online applications involve portable test separators (PTS) and multiphase meter skids</u>* characterized by large operational and environmental footprints, increased cost, complicated rig up, and multiple technical challenges. Online applications may also require production deferment for shut-ins during rig up and rig down which complicates testing the rates in a steady state.

Flare Rate

Quantification of gas volumes to flare is an important part of emission control and flare optimization. In-line meters are often used to continuously monitor gas volumes released to flare, however can be inaccurate. The lack of further inline instrumentation prevents the asset operators from optimizing and quantifying the flaring process which is a key requirement under emissions regulations.

Method

The gas dilution method as described in ASTM Standard E 2029-99 comprises injecting a known concentration of tracer at a quantified constant rate into an upstream location of the flow stream. The tracer becomes mixed and diluted, and after steady-state conditions are achieved, the diluted volume fraction of the tracer is measured at a downstream location. Use of the constant-injection technique requires precise metering of the injected tracer, uniform mixing of the tracer into the transport stream, and accurate detection of the diluted tracer. When these requirements are satisfied the volume flow can be determined. The increase in the tracer component concentration at the sampling location is inversely proportional to the flow stream's volumetric rate, transferring the tracer to the sampling location. The volumetric flow rate can be derived from the dilution equation:

$$Q_{gs,d} = \frac{q_{tr,i}}{c_{tr,d}}$$

Where:

$q_{tr,i}$ – volumetric rate of injected tracer

$c_{tr,d}$ – tracer component concentration at the detection location

$Q_{gs,d}$ – volumetric flow rate at the detection location

Accuracy of the dilution measurement

The accuracy and repeatability of the measurement are primarily built on two components.

The first component for the accuracy of tracer dilution method depends on the accuracy of the instruments quantifying tracer injection, tracer component concentration, and background gas composition. Continuous measurement of background gas composition including the tracer component allow accurate trending of the flow rate. In addition, an injection system for quantification of tracer injection rate and controlling a constant rate of injection independent of variations in pressure in the transport gas stream (main flow).

The second component for the accuracy of the dilution method depends on the ability to account for the degree of mixing and the partitioning of the injected tracer into the liquid phase.

Tracer homogeneous mixing is achieved by allowing a sufficient distance from injection and detection points considering flow patterns, while tracer partitioning is challenging to account for. The best practice is to use a tracer component that does not partition to liquid phases typically presented in hydrocarbon streams. Inert gases with low solubility such as N2, He, and Ar reproduce the most accurate and repeatable measurements in hydrocarbon streams. Soluble tracer gas should be avoided for wet gas and multiphase flow applications.

Field application – Gas Lift:

The tracer dilution technique is a reliable and simple method to quantify gas lift injection rate. It requires two connection points on the gas lift line to perform the measurement. The choice of tracer medium is crucial for this application due to the potential high pressure of the injection line.

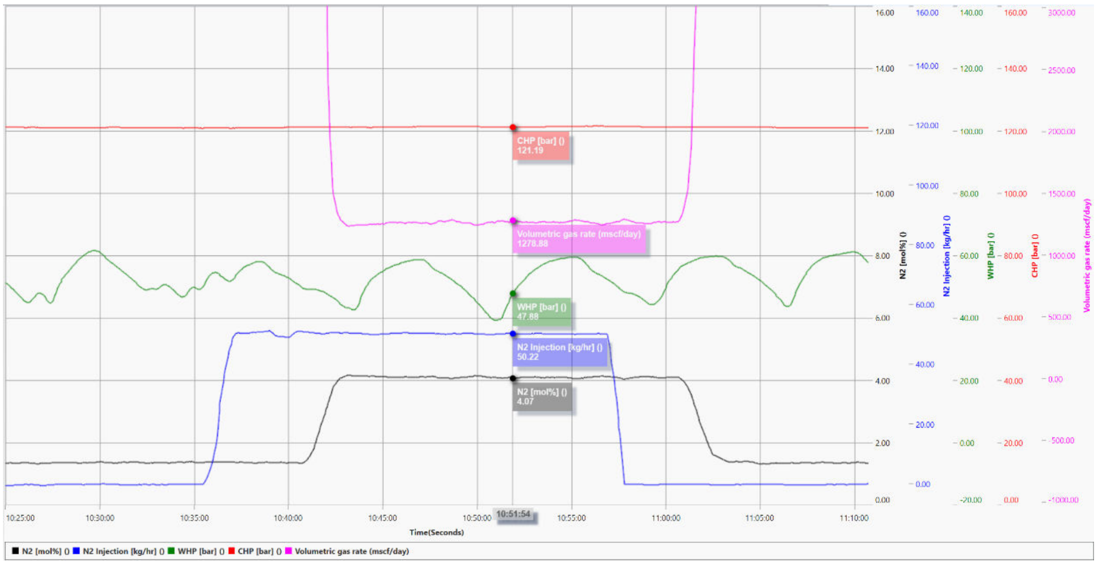
The chosen Tracer medium should be able to mix evenly with the gas phase considering the pressure and temperature of a given gas lift line. Tracer components must remain in the gas phase while entering the pressurized gas lift line to allow homogeneous mixing, hence phase behavior of the chosen tracer component must be considered. Tracers such as N2 and He are suitable for the application, while components such as CO2, Propane, Butane etc will undergo a phase change and prevent homogeneous mixing.

Additionally, the gas tracer medium must be carefully evaluated in wet gas applications, as soluble tracers will partition and result in an inaccurate measurement.

Accurately measurable inert tracer components are suitable for the application, while soluble gases and gases that undergo phase changes at in situ conditions are not.

Continuous online N2 dilution technique:

- Direct measurement of gas lift injection rate.
- Suitable for wet gas lift applications. Inert tracer medium will not be affected by the presence of a liquid phase
- Not affected by pipe geometry and pipe thickness
- Suitable for a wide range of pressures, temperatures, and flow rates
- Not affected by uncertainties related to manual sampling and offline analysis
- Does not require transit time or mass balance analysis



GLiR by N2 dilution

Field application – Produced Gas Rate

Quantification of produced gross and net rates can be a challenge, especially on aging brownfields. The use of multiphase flowmeters (MPFM) for well test measurements is increasingly becoming a standard practice along with conventional test separators. However high water-cut, high gas-volume-fraction, inaccurate meter properties, and unstable flow can all lead to errors in the measurements.

Tracer dilution has proved to be a reliable method for quantification of produced rates and verification/calibration of inline flow meters. Choosing the correct tracer medium for each phase is crucial for the application.

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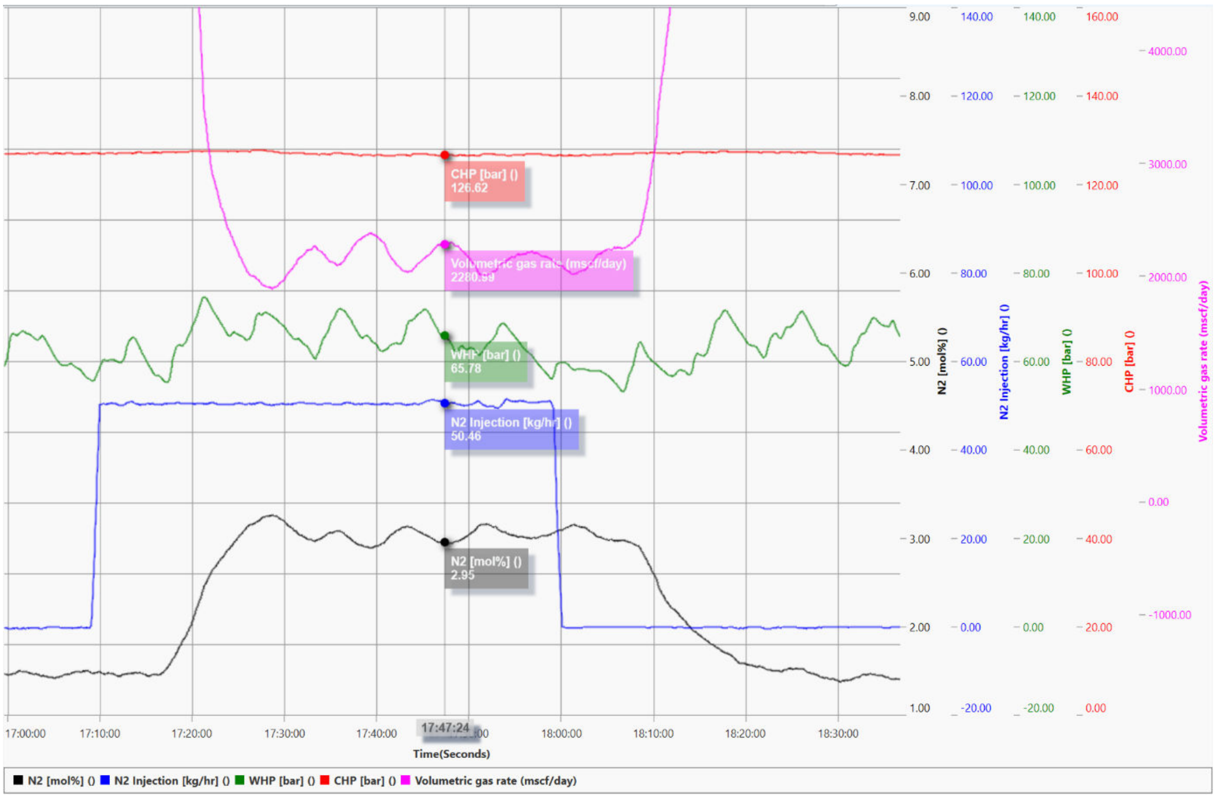
The tracer medium for the gas phase should be able to mix homogeneously with the gas fraction of the multiphase flow, considering the pressure and temperature of a given production. Tracer components must remain in the gas phase while entering the production line to allow homogeneous mixing. Here the max and min values of production pressure and temperature must be considered when evaluating the phase behavior of the chosen tracer component. Tracers such as N2, He, and Ar are suitable for the application and have a track record in the industry, while components such as CO2, Propane, Butane, etc. may undergo a phase change and prevent homogeneous mixing.

The solubility and partitioning of the tracer must be also considered, due to the continuous presence of water and oil phases in the production. Inert tracer mediums (N2, He, Ar) with low partitioning and solubility characteristics will suit the application, while soluble gas tracer (CO2, Propane, Butane, etc) partitioning into the liquid phases will not.

An additional point of significance is the duration of measurement. Slugging wells are characterized by variations in gas and liquid rates. The duration of the tracer dilution survey must be sufficient to trend the gas rate over multiple slug cycles for a representative gross rate measurement.



Gross gas produced 1 by N2 Dilution

Continuous online N2 dilution technique:

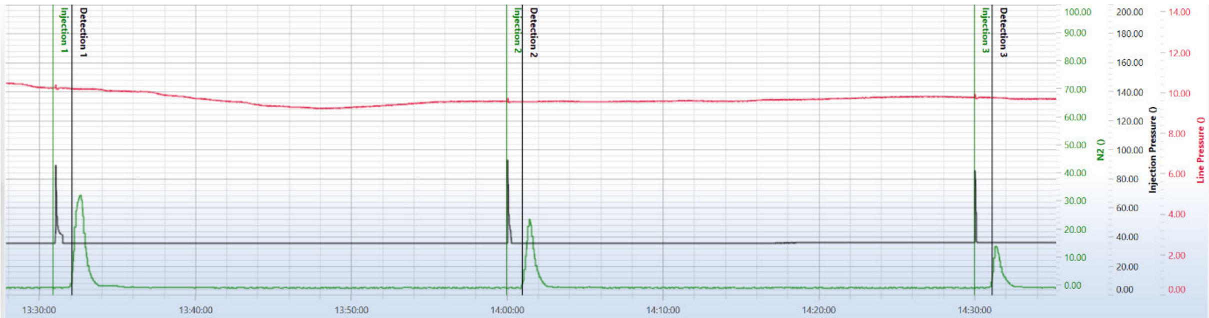
- Direct measurement of produced gas rate in multiphase flow and wet gas production
- Inert tracer medium will not be affected by the presence of a liquid phase
- Not affected by pipe geometry and pipe thickness
- Suitable for a wide range of pressures, temperatures, and flow rates
- Online continuous measurement of the gas rate for the required duration
- Trending of gas rate allows visualization of flow regimes
- Not affected by uncertainties related to manual sampling and offline analysis
- Does not require transit time or mass balance analysis

Alternative tracer methods for volumetric rate quantification

Transit time method

In addition to the tracer dilution method, which is described in detail above; A Tracer transit time method can also be applied to evaluate the flow rate of the transport stream. The tracer transit time technique involves a pulse of a tracer fluid being injected into the main line and the time taken for the tracer to pass between two points of known separation length measured. Thus, a velocity is determined from the travel distance and transit time.

If the cross-sectional area of the pipe throughout the tracer travel path is known, the volumetric flow rate of the transport flow can be calculated.



Transit travel time – N2 pulse injection method

This method is highly affected by flow regimes and flow profiles which can lead to erroneous results. In multiphase applications, where the flow is often unstable, transit time will represent only one velocity during the time of measurement and will not provide information to evaluate the flow profile of the measured phase. For example, intermittent flow regimes such as slug flow are generally unsuitable for this method since the velocity profile will not be uniform.

In vertical pipe applications, such as gas-lifted wells, where the tracer is injected into the gas lift supply and measured at the surface on the production. The temperature and pressure gradients, together with gas composition, must be known to minimize errors related to the determination of the gas velocity.

Another challenge in the Transit Time method is the expansion of the tracer medium during injection. The pulse injection is introduced to the transport flow at a higher pressure and typically expands during initial mixing. This will also affect the velocity calculation from transit time if not accounted for.

Lastly, an additional source of error comes from the uncertainty associated with the internal cross-sectional area of the pipe between the injection and the detection of the tracer. It is unlikely that this will be constant across the path and as such any deviation from the nominal pipe diameter will result in errors in the calculation of volumetric rate. Other process conditions, such as deposition and erosion, can also influence the pipe geometry over time. If this is not accounted for in the calculation, errors will occur.

Tracer transit time method features:

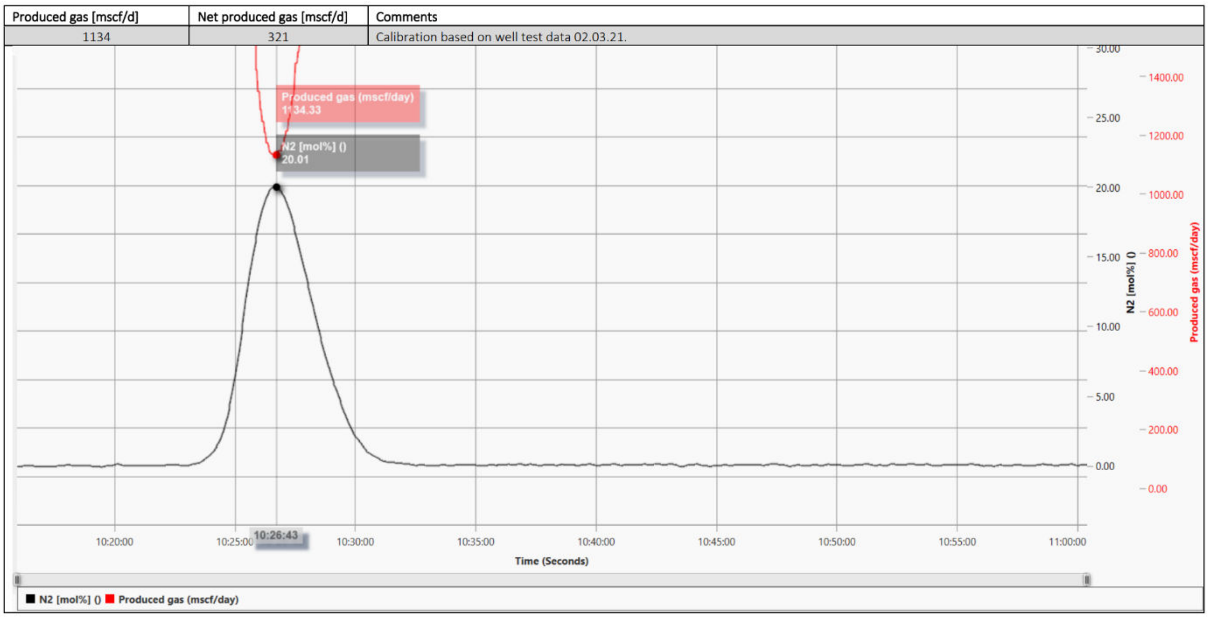
- Highly affected by pipe geometry including deposition. Requires nominal diameter of the pipes.
- Requires accurate pressure, temperature, and background compositional data
- Highly affected by the ability to determine the transit time accurately
- Not suitable for intermittent/slug flow
- Not suitable for multiphase flow with unknown liquid fraction

Mass-balance method

An additional method for calculating flow rate from a pulse injection is utilizing mass balance calculations. When the injected pulse is measured and the total injected mass is quantified, the produced flow rate during the tracer detection can be calculated by the following formula:

$$\frac{M_{tr,i}}{M_{prod.g}} = \frac{\sum A_{tracer}}{\sum A_{total}}$$

The produced gas rate is derived from analyzing the signal area generated under the concentration trend due to the tracer return. Assuming that all the injected tracer is detected when produced, the sum of the area under each return is proportional to the volumetric rate of total gas produced during the detected return.



Produced gas from mass balance by N2 pulse injection

Mass-balance time method features:

- Calculates average flow rate during the peak detection only
- Highly affected by start and end points chosen for area determination
- Requires accurate pressure, temperature, and background compositional data to convert mass to volume
- Assumes no partitioning into the liquid phase
- Not suitable for intermittent/slug flow

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References:

- SPE 114127. Reliability of Multiphase Flowmeters and Test Separators at High Water Cut
- ASTM E2029. Standard Test Method for Volumetric and Mass Flow Rate Measurement in a Duct Using Tracer Gas Dilution
- SPE 80501. MultiPhase flow measurement using tracer technology at Dulang oil field, Malaysia
- SPE 49162. Wellsite Wet Gas Measurement System in Saudi Arabia Ahmed B. A1-Taweel,SPE, Steve G. Barlow, Shahid Hussain, Saudi Aramco.
- Flare Gas Flow Rate Measurement by a Steady State Tracer Dilution Method. J.S.Tang JT Petroleum Consulting
- Uncertainty In Air Flow Calculations Using Tracer Gas Measurements. M.H.Sherman. Indoor Environment Program Applied Science Division Lawrence Berkeley Laboratory University of California Berkeley, California, 94720
- Uncertainty estimates of tracer gas dilution flow measurements in large scale exhaust ducts Rodney A. Bryant. National Institute of Standards and Technology, 100 Bureau Drive, MS 8662, Gaithersburg, MD 20899, United States.
- WP5 – Tracer Report: Literature Review. NEL 2018/302. Department for Business, Energy & Industrial Strategy.