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Innovative Method for Gas Lift Optimization on a Remote Satellite Offshore Platform: Reducing Environmental Footprint and Unblocking Hidden Optimization Opportunities

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Abstract

The paper addresses challenges associated with optimizing gas-lifted remote satellite platform that operates with limited facilities onboard, including constrained power supply, lifting capacity, and offshore logistics. The platforms, located in mature brownfield Offshore Borneo Island, encounter further obstacles stemming from the limited availability of instrumentation, coupled with lack of well test data. Predominantly, the platform employs dual string gas lift oil producers.

The method involves injecting nitrogen (N_2) tracer upstream, allowing it to mix and dilute. The diluted tracer fraction is measured downstream to obtain the volumetric flow rate of gas lift injection and total produced gas using dilution equation. The innovative method, equipment, and software log injection and production data, adjusting simulation parameters based on return data to evaluate gas lift system integrity.

An adaptive modular solution was deployed to address the optimization challenges of a remote satellite platform operating under limited facilities. Battery-operated modular equipment, specifically designed for adaptability to the platform's constraints, not only navigated the operational limitations effectively but also ensured that production remained uninterrupted. Confronting the scarcity of surface and subsurface instrumentation in a mature brownfield, alongside the absence of comprehensive well test data, posed significant hurdles for gas lift optimization. An innovative methodology that precisely determines injected gas lift rates and accurately measures net gas production, particularly advantageous for dual string wells, offered a tailored solution that significantly enhanced well performance and decision-making despite the prevalent data limitations. The adaptive technologies, coupled with innovative methodology, enabled immediate optimization opportunity identification that may have otherwise gone unnoticed, contributing to the efficiency and productivity of the gas lifted wells. Furthermore, the reduction in required man-hours and elimination of generator emissions minimized personnel exposure to hazardous conditions, which

collectively contributed to a notable decrease in the environmental footprint and enhanced the HSE risk profiles of the operations.

The data provided during the execution allowed the operator to calibrate the well models based on accurately measured parameters such as gas lift injection rate, net produced gas, real-time injected and produced gas composition, and injected gas lift split ratio. The actual measured parameters were used to determine the lifting depth and evaluate the annulus and tubing integrity. This case study showcases how the comprehensive data collected during the execution phase enabled to refine the well models by leveraging accurately measured parameters. These precise measurements were instrumental in determining the optimal lifting depth, conducting a thorough assessment of the annulus and tubing integrity, and making informed adjustments, thereby enhancing the overall efficiency and safety of the operations.

Introduction

Efficient management of gas lift systems is crucial for boosting production rates and reducing environmental impacts in the offshore oil and gas industry. Traditional gas lift monitoring methods, such as wireline services, face increasing challenges due to evolving well and operational conditions. The Nitrogen Tracer Surveillance System (NTSS) offers a cost-effective, carbon-free and comprehensive approach to well surveillance without the need for tools inside the well, thereby reducing health, safety, and environmental risks and avoiding production delays.

This paper introduces an innovative method to optimize gas lift on remote satellite offshore platforms, particularly those in the mature brownfield of Offshore Borneo Island. These platforms face significant constraints, including limited power supply, lifting capacity, and challenging offshore logistics, as well as limited instrumentation and well test data. The NTSS method, integrating portable equipment with tracer propagation model, was applied to seven (7) wells at Platform E in Field Y. The NTSS provided accurate insights into gas usage, facilitating comprehensive model calibration and well performance definition. It identified potential integrity issues by detecting both planned and unwanted gas injection points. Continuous compositional gas analysis of injected and produced gas streams further verified gas lift injection performance and highlighted changes in fluid composition. The production improvements identified were consistent with the reservoir management strategy. Proposed optimizations, including flow stabilization through gas lift valve settings and replacements, injection rate adjustments, and improved injection pressure management, are being implemented.

In conclusion, the NTSS method represents a significant advancement in gas lift optimization. By leveraging N_2 unique properties and integrating advanced measurement techniques, NTSS offers a comprehensive, data-driven approach to enhance gas lift efficiency and operational performance, contributing to sustainable and economically viable oil and gas production.

Statement of Theory and Definitions

For over three decades, the oil and gas industry has considered using tracers for gas lift surveillance activities. Recent technological advancements have enabled comprehensive diagnostics in this domain, leading to the development of the NTSS method through collaborations among industry leaders and research institutions.

Studies have explored the mixing and propagation characteristics of various tracer gases and tested the model's accuracy across different conditions. The primary challenge lies in correlating the measured tracer concentration over time (the "fingerprint") with specific lifting depths in the well. The NTSS method addresses this challenge by integrating gas lift measurements, annulus temperature profiling, and continuous compositional analysis, enhancing accuracy in fingerprint matching and providing additional data for optimizing operations and ensuring safety.

The NTSS method involves injecting N_2 gas into the gas lift supply of a well while monitoring compositional changes in the injected and produced gas streams downstream from the injection point. Data on composition, surface pressures, temperatures, and acoustic responses are collected and processed using proprietary software to fine-tune production parameters and assess integrity of the well. N_2 was chosen as the tracer medium over carbon dioxide (CO_2) due to its advantages, including low solubility, a low critical temperature, and environmental friendliness. Unlike CO_2, N_2 remains in the gaseous state and does not create corrosive solutions or contribute to global warming. The high density and water solubility of CO_2 pose potential risks to well integrity, while its environmental impact makes it less suitable for use in the NTSS method.

Using N_2 as a tracer aligns with the strategy of Carbon Capture and Storage (CCS) as it does not contribute to greenhouse gas emissions. Integrating N_2 as a tracer supports the goals of reducing carbon emissions and promoting sustainable energy practices.

Description and Application of Equipment and Processes

NTSS Component and Operation Overview

The rig-up process at the site involved connecting the injection and detection manifolds to designated points on the gas lift supply, the annulus wing valve, and the top-cap. The analyzed sample gas was then routed to an effluent containment system positioned at a safe distance from the operational zone, equipped with gas detectors for safety (refer to Fig. 1). Additionally, the rig-up included several other components such as a Multiphase Separator (MPS), Shkorin Gas Analyzer (SGA), Acoustic Gun, LMM Flowmeter Module, and N_2 Tank Manifold. All data is relayed and connected to the Portable Surveillance System (PSS) for data collection and interpretation. Furthermore, all equipment is powered by a DC source through a Portable Battery Module (PBM), making it suitable for remote satellite locations with no access to platform power supply.

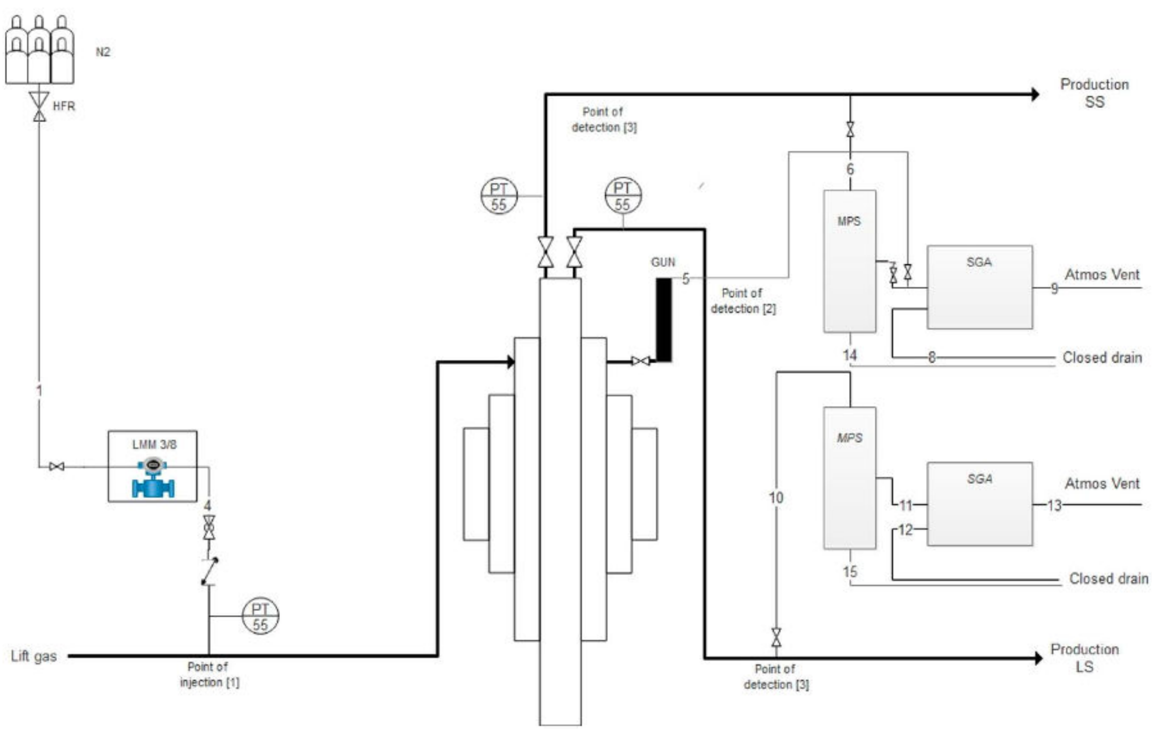

Figure 1—N_2 Tracer Equipment Rig up Diagram

The Portable Battery Module (PBM) as shown in Fig. 2, is a 24VDC battery unit designed for ATEX Zone 1 environments, specifically to power up the PSS in areas with limited power availability. The battery module comes with a charger that operates within a voltage range of 90-264VAC, ensuring flexible recharging options. These batteries are approved for Land (ADR/RID, DOT), Sea (IMDG), and Air (IATA) transport, making shipping straightforward and compliant with international standards.

Figure 2—Portable Battery Module

The Shkorin Gas Analyzer (SGA) is a sophisticated instrument designed for real-time gas compositional analysis (refer Fig. 3). Highly portable, it can be easily transported to remote locations without the need for carrier or calibration gases, significantly simplifying logistics compared to traditional gas chromatography. This makes the SGA a versatile tool for various well testing and integrity surveillance applications, providing real-time gas flow rates and leak path identification. The SGA can be integrated with other instruments, offering a wide range of tailored services to meet specific needs. It is commonly used to analyse gas composition in annuli, detect tracer gases, measure gas flow rates in pipes, and identify leak paths.

Figure 3—Shkorin Gas Analyzer

The SGA offers several benefits, including a high sample rate (every second), no need for manual intervention, cost-effectiveness, low risk, and online analysis capability. It is also heli-portable, enhancing its mobility in remote or hard-to-access locations. In terms of deliverables, the SGA provides compositional analysis from C_1 to C_6+, along with N_2, H_2S, CO_2, and C_2H_4. It also calculates specific gravity, calorific value, and the Wobbe Index. The instrument is Ex certified, with a pressure rating of 5000 psi and flow requirements ranging from 0.1 to 15 SLPM (N_2 equivalent). The SGA communicates via Modbus RTU and Ethernet, offering flexible data transfer options.

The Multi-Phase Separator (MPS) as shown in Fig. 4 is an essential tool for separating liquids from gas in high-pressure environments. Rated at 1500 psi, this 1-gallon (4-liter) separator system efficiently removes most liquids, making it ideal for use upstream of analytical instruments. Often referred to as a "knock-out bottle," the system is designed to handle wet gas by allowing it to flow through a stem tube that enters from the top and discharges about one-third down the bottle. As the liquid settles on the walls and bottom, the gas is extracted from the top for analysis, while the collected liquid is drained from the bottom. Additionally, the MPS is useful for increasing gas flow and reducing detection times during online trace metering, enhancing its versatility in various applications.

Figure 4—Multiphase Separator

The Leak Metering Module (LMM) as shown in Fig.5, is a specialized ATEX Zone 1 module designed for measuring mass flow rates using the Coriolis principle. LMM is connected to PSS SCADA systems for both power supply and data logging, utilizing the Modbus RTU communication protocol for communication and data transfer. The LMM boasts a compact design with dimensions of 538mm in length, 406mm in depth, and 269mm in height, and weighing around 27 kilograms, it is relatively portable for field applications. Its versatile power supply supports an input range of 85-264VAC or 8-32VDC, drawing approximately 100 mA of current, providing flexibility that allows the LMM to be deployed in various setups and configurations, making it an efficient solution for leak and flow metering in Zone 1 environments.

Figure 5—Leak Metering Module

The PSS is an ATEX Zone 2 modular SCADA system, used for data acquisition (refer Fig. 6). Primary functions are communication with sensors and instruments for measurements such as flow, pressure, liquid level, gas composition etc. The PSS equipped with windows operating system and allowed multiple features in logging, reporting and communication. It is highly adaptable, allowing for the connection of various types of field equipment depending on the specific job application. The PSS supports dual power supply options, with a voltage of 24 VDC/110-230 VAC.

Figure 6—Portable Surveillance System

Annulus Acoustic Survey. The High-Pressure Acoustic Gas Gun (HPAGG) is an accessory for the Portable SCADA System designed for acoustic pressure pulse surveys in ATEX Zone 0 environments (refer Fig. 7). It measures liquid levels and operates on explosion mode in low-pressure wells and implosion mode in higher-pressure wells. The HPGG propagates a pressure pulse down the well volume, either in the annulus or production tubing, providing valuable insights into well conditions when combined with pressure manipulation. It features a large chamber for higher pulse energy, ensuring high sensitivity, low maintenance, and a digital signal for accurate measurements.

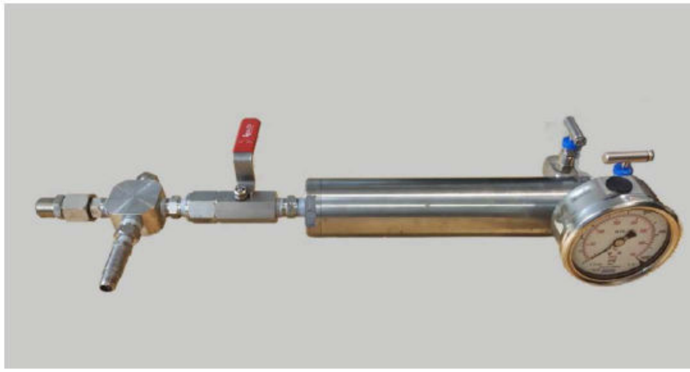

Figure 7—High-Pressure Acoustic Gas Gun

The portable acoustic logging system connected to the annulus wing valve at the surface, is used to gather the necessary data. This system emits an acoustic pulse and records the returning reflections, facilitating the measurement of the gas-liquid interface in the production annulus and determining gas volume. It also detects variations in the cross-sectional diameter within the annulus, identifying different wellbore components and potential anomalies.

A pressure pulse is generated by the acoustic gun into the A annulus to assess the liquid level and temperature gradient. This is achieved by logging the round-trip travel time of the pressure wave, which propagates at the speed of sound, originating from the acoustic gun and reflecting from side pocket mandrels, safety valves, liquid levels, or any other abrupt changes in diameter along its path. The temperature gradient is deduced from the gas composition, pressure, and temperature measured on-site, in conjunction with the travel time to each downhole reference point, commonly a side pocket mandrel.

The reference point can be interpreted as depicted in Fig. 8. The gas composition obtained will be utilized to calculate the expected acoustic velocity inside the annulus to confirm the depth indication for each of the points. A high spike, indicated by the blue vertical dashed line in Fig. 8, denotes the liquid level inside the annulus. With the depth reference and the presence of the Side Pocket Mandrel (SPM) located above the liquid level, the expected depth of the Liquid Level (LL) will be determined.

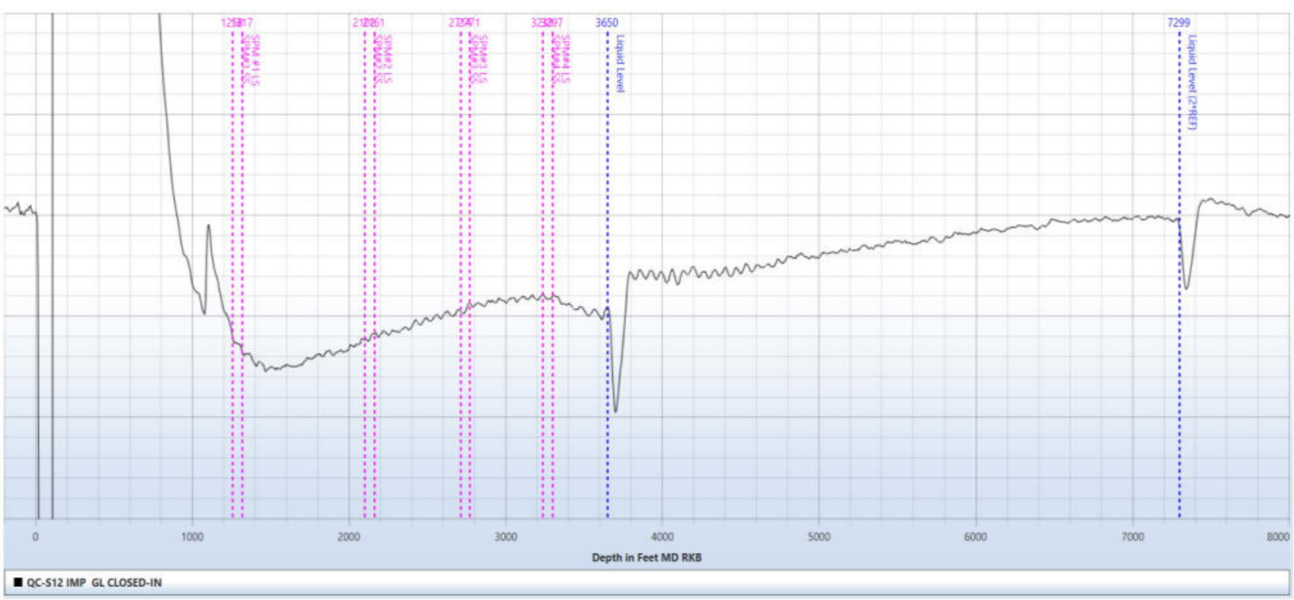

Figure 8—Acoustic log with downhole reference points

Gas lift flowrate measurement. The gas lift injection rate was determined by continuously injecting N_2 into the gas lift supply. Compositional changes downstream at the Point of Detection were monitored using an online gas analyzer. Using the mass balance dilution equation, the gas lift injection rate was calculated, considering the quantity of N_2 injected and the compositional changes observed at the detection point. The initial dilution flow rate measurement was utilized to calibrate the Ultra-Sonic Portable Gas Flow Meter, which measures the gas lift flow rate throughout the survey.

Dilution Survey for Flow Rate Determination. To measure the gas lift injection rate, N_2 was continuously injected into the gas lift system at a constant flow rate (Refer to Fig. 1, point of injection [1]), while an online gas analyzer monitored the compositional changes downstream (Refer to Fig. 1, point of detection [2]). The gas lift injection rate was then determined by applying the mass balance dilution formula, which considers the change in gas composition due to the injected N_2.

Ultra-Sonic Clamp-on Flowmeter.

Figure 9—Ultrasonic Clamp-on Flowmeter (Emerson 2021)

The Ultrasonic Clamp-on Flowmeter is an advanced device utilized to measure the flow rate of gases in pipelines without the need for penetration or modification of the pipe. Unlike traditional flowmeters, it operates based on the transit-time principle, where ultrasonic waves are transmitted through the gas flow. The primary advantage lies in the fact that the transducers, responsible for generating and receiving these waves, are clamped onto the exterior of the pipe, ensuring quick and non-invasive installation. This design eliminates the risks associated with pipe leakage and contamination, while also guaranteeing no pressure loss or obstruction in the pipeline.

N_2 pulse injection. Approximately 25 kg of N_2 from multiple N_2 cylinders was injected into each well to identify the lifting depth(s). The injected N_2 tracer mixed with the gas lift supply and traveled downhole. Subsequently, the lift gas entered the production tubing at various communication points between the annulus and the tubing, ultimately resurfacing with the produced fluids. Samples of these fluids were continuously conditioned and analyzed at Point of Detection 3 (as depicted in Fig. 1), capturing compositional changes due to the injected tracer (refer Fig. 10). Throughout the survey, surface pressure and temperature were also recorded.

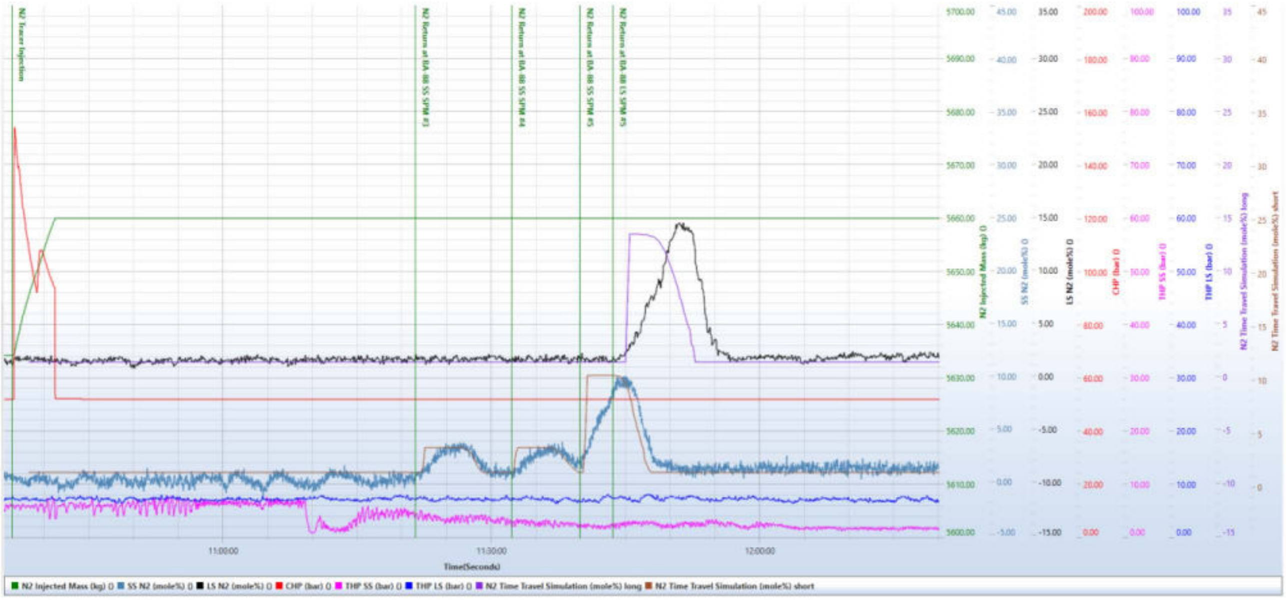

Figure 10—N_2 Pulse Injection Fingerprint

Data analysis and reporting. In the analytical flow outlined in Fig. 11, the combination of mechanical production data and pre-job simulation serves as a critical guideline before a tracer survey is conducted. Actual data from the field is input into the simulation, and then a comparison between the actual data's fingerprint and the simulated results is made to verify accuracy. This comparison is depicted in Fig. 10, which shows the N_2 Pulse Injection Fingerprint.

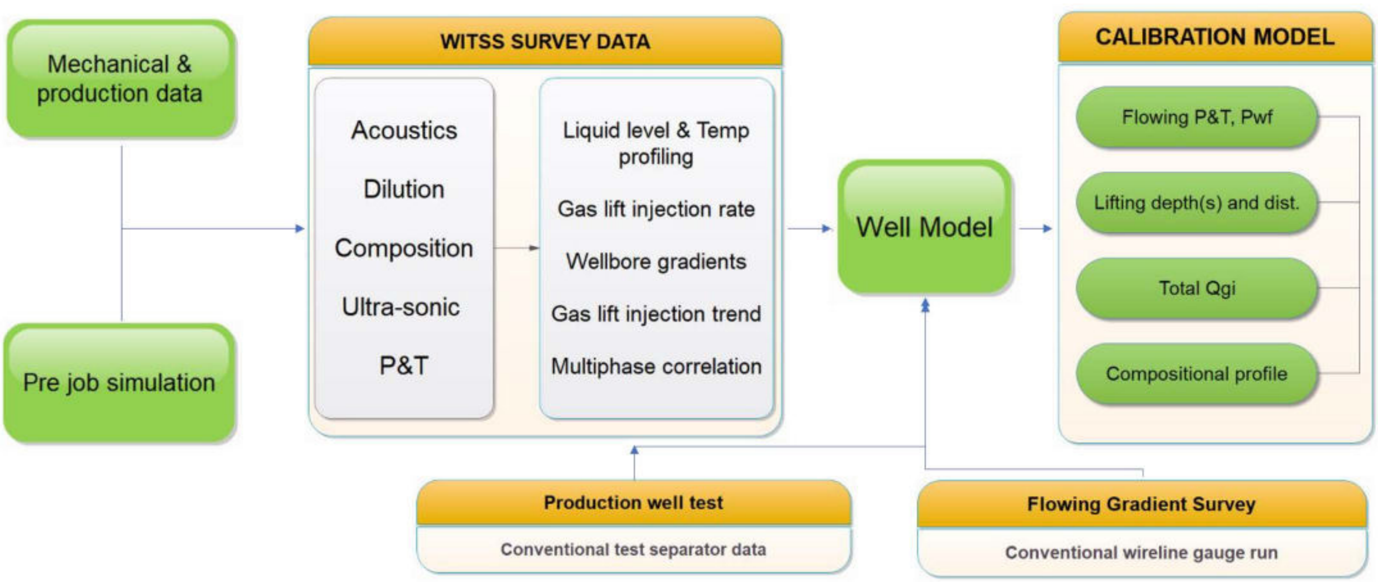

Figure 11—Survey Data Analytical Flow

Data collected during the survey is carefully processed and analyzed to determine key parameters such as the gas lift injection rate and the lifting depth(s) for each well. This information is crucial for constructing an accurate well model that serves as a reference point for calibration and further optimization of the gas lift setup. By utilizing both pre-job simulations and actual survey data, the model can be fine-tuned to ensure the most efficient gas lift configuration, thereby maximizing productivity, and minimizing operational risks.

Presentation of Data and Results

This gas lift diagnostic pilot encompasses seven (7) well candidates, comprising two (2) dual-string surveys and five (5) single-string surveys.

In Table 1, the total number of candidate wells for Platform Y-E is documented as seven (7). These wells exhibit two distinct configurations: single string and dual string. There is one (1) well with a flowing single-string configuration. Out of the six (6) dual-string wells, only two wells flow from both strings. Conversely, the remaining dual-string wells are configured such that flow originates solely from the long string, while the short string remains in a shut-in state.

Table 1—Well candidates

Platform	Well Name	Type of well configuration	Status of string during survey	
			Long String	Short String
Y-E	E-60	Dual String	Flowing	Shut-in
	E-69	Dual String	Flowing	Shut-in
	E-70	Dual String	Flowing	Shut-in
	E-75	Dual String	Flowing	Flowing
	E-88	Dual String	Flowing	Flowing
	E-112	Single String	Flowing	
	E-115	Dual String	Flowing	Shut-in

Operational Summary

Based on the data presented in Table 2, the pilot is conducted over a total of 12 operational days, averaging 1.7 days per well. Initially, on the first day, the field team onsite conducts gas rate measurements for each produced string (long and short) using the dilution method, evaluates gas-lift rates with a clamp-on meter, analyzes gas composition, and performs an acoustic survey to detect liquid levels in the production casing Annulus-A.

Table 2—Number of days for each well

Platform Y-E	No. Days
E-75	2
E-115	1
E-69	1
E-60	2
E-88	2
E-112	2
E-70	2
Total	12
Average (days/well)	1.7

Utilizing the data gathered, the field team proceeds to simulate well modeling and estimate the optimal timing for the N_2 tracer survey. On the second day, the focus shifts to the tracer survey, monitoring gas-lift rates trending with a clamp-on meter including the measurement of gas lift injection rates from Annulus-A after the survey.

Well Y-E 88 (Dual String Survey)

This well is equipped with five Side Pocket Mandrels (SPMs) for both the short and long strings, positioned at depths of 1258, 2102, 2714, 3238, and 3589 ft MD THF for the short string, and 1317, 2161, 2771, 3297, and 3647 ft MD THF for the long string, respectively.

During assessment based on fig. 12, the liquid level was identified at 3650 ft MD THF, situated below the Side Pocket Mandrel (SPM) #5 (Orifice) LS at 3647', indicating that the first until forth SPMs remain uncovered, while the deepest SPM at the fifth mandrel is submerged. This observation was further validated through tracer pulse survey.

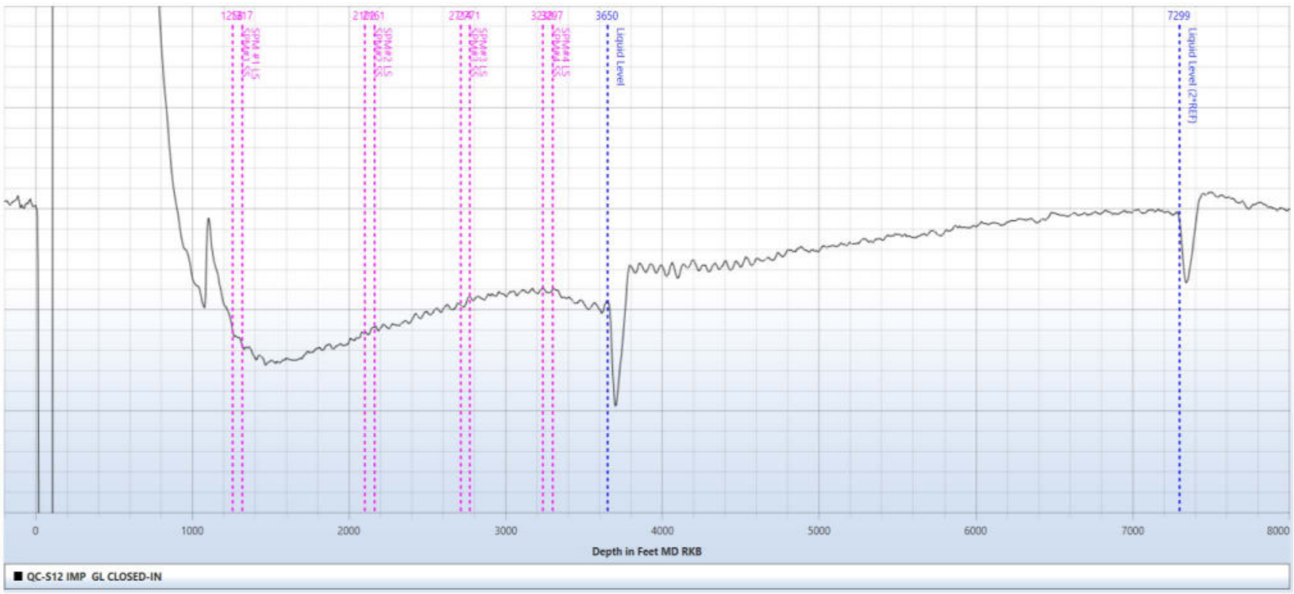

Figure 12—Acoustic survey, Well Y-E 88 Annulus A

The duration of the survey is significantly influenced by the gas-lift rate of the well. Precise gas lift metering plays a crucial role in maximizing production and effectively allocating lift gas resources. To mitigate uncertainties and enhance confidence in gas rate measurements acquired from the well test facility, the tracer dilution survey is employed to corroborate the in-line measurements of the lift gas rate. The gas lift injection rate for this well was determined using both the tracer dilution method and ultrasonic clamp-on flowmeter.

As shown in fig. 13, during this tracer dilution survey, a constant rate of 50kg/hr of N_2 gas (blue line) is injected into the gas lift flowline after FCV. Less than a minute monitoring, it is observed that the N_2 baseline increases up to 2 mol% (black line) and shows that tracer gas becomes thoroughly mixed and diluted. This diluted volume fraction of the tracer gas is measured at Annulus A gate valve. By using mass balance equation, the volumetric gas rate (pink line) can be calculated. As a result, the tracer dilution method yielded an average rate of 1374 Mscf/d.

Figure 13—Tracer dilution results, Well Y-E 88 Annulus A

Fig. 14 shows the gas lift standard volumetric flow rate (pink line) trend throughout the survey period. The ultrasonic clamp-on flowmeter registered a mean standard volume flow rate of 1376 Mscf/d. The percentage difference between the dilution tracer survey data and the mean standard volume registered by the clamp-on meter is calculated to be 0.17%. This close agreement supports the verification of the injected gas rate and is crucially utilized in the well model for nodal analysis.

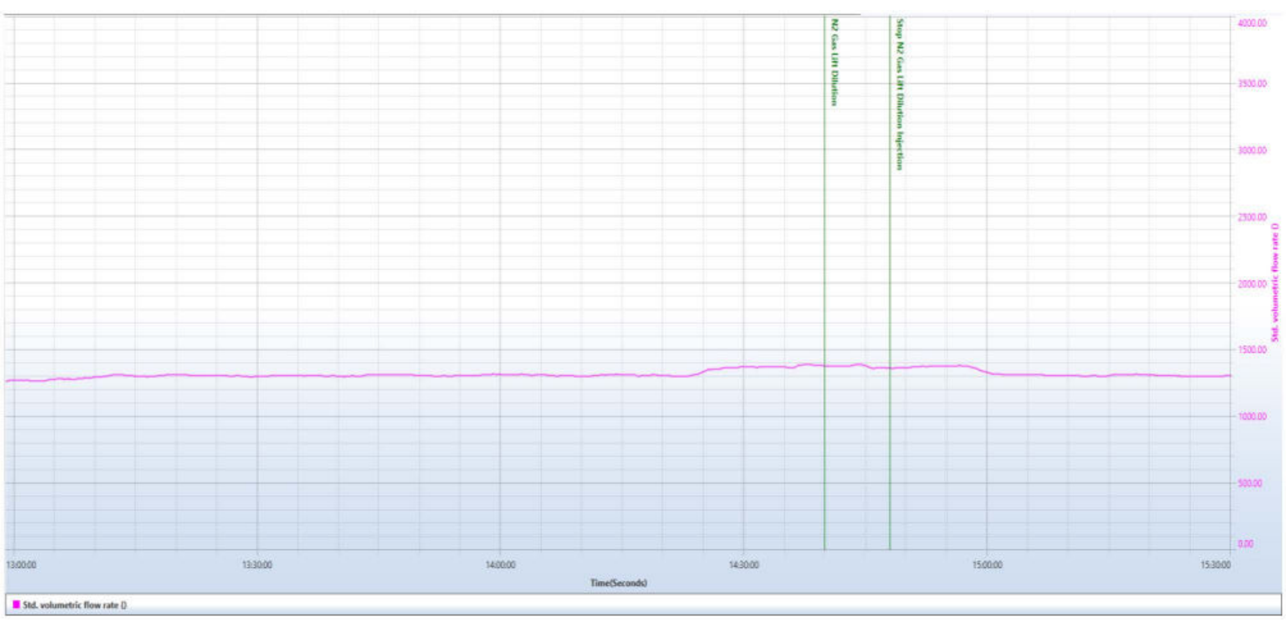

Figure 14—Ultrasonic trend, Well Y-E 88 Annulus A

To achieve high accuracy in produced gas measurement, it is essential to determine the gas-lift distribution for each string, especially in dual-string configurations. To understand the distribution of gas lift, a tracer pulse survey is employed. The tracer pulse survey employed is a non-deferment method, allowing for its execution without the need for well shut-ins, thus minimizing any impact on the production of the flowing string. On the second day, a total of 26kg of N_2 gas was injected into the casing as shown in Fig. 15 in the green line. After 90 minutes of survey, the first return was observed, followed by the second and third returns from the short string (turquoise line: SS N_2 (mol%)). Lastly, one return was observed from the long string (black line: (LS N_2 (mol%)). Analysis of the N_2 fingerprint revealed that the gas-lift distribution for the short string matches SPM#3 PPO (11%), SPM#4 PPO (11%), and SPM#5 Orifice (43%). The N_2 return from the long string matches SPM#5 Orifice (35%).

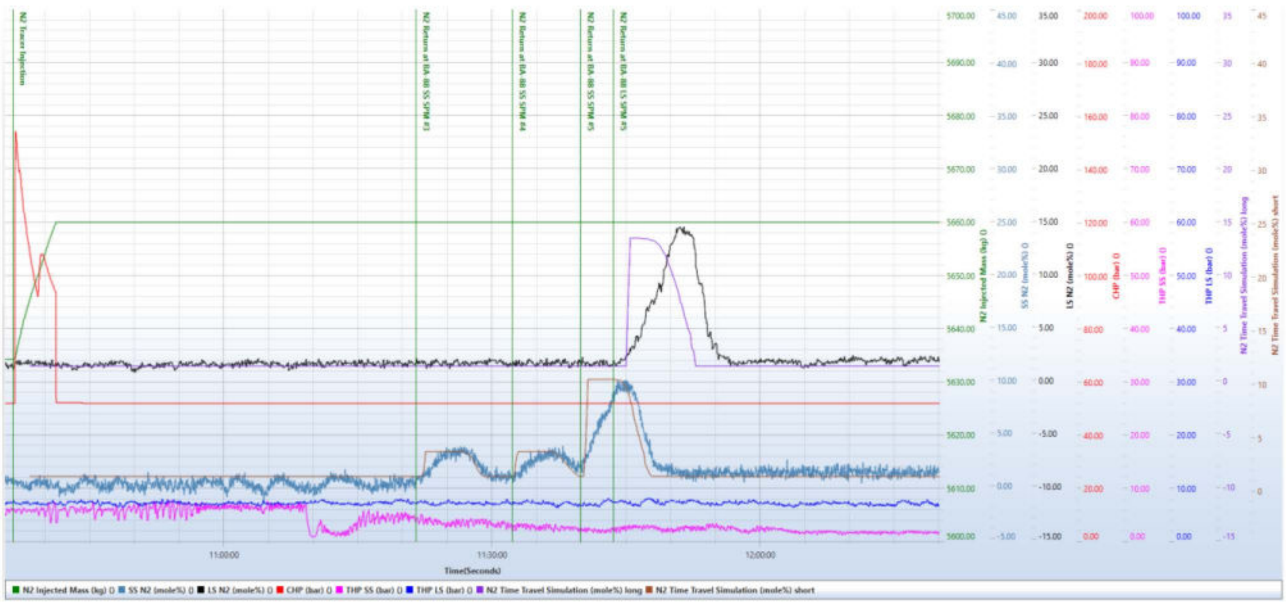

Figure 15—N_2 Fingerprints vs Simulated Results

The dilution method is also employed to ascertain the produced gas rate for each string. By discerning the gas lift distribution from both strings, the net produced gas from each string can be determined, thereby enhancing the confidence in actual formation gas volumes. Referring to Fig. 16, N_2 is injected into the top cap of long string for 5 minutes and the return is collected at production line after choke valve. The total produced gas (pink line) for the long string is measured at an average of 585 Mscf/d. Subtracting the gas lift rate of 35%, we obtain a net formation gas of 104 Mscf/d.

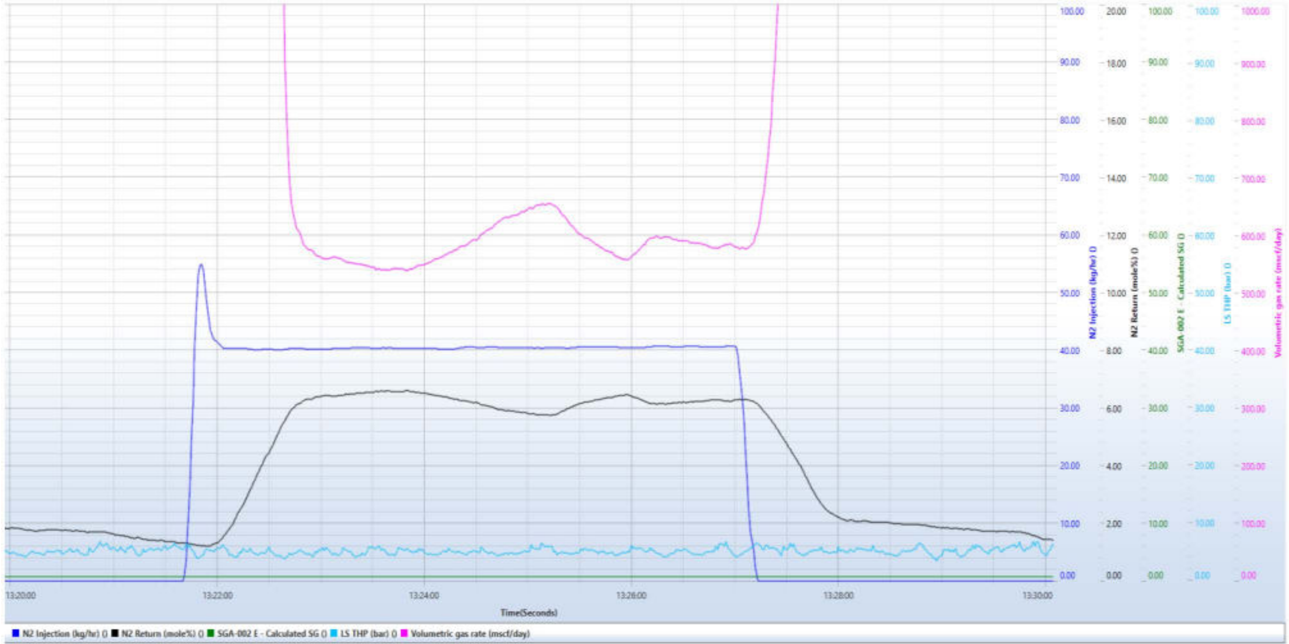

Figure 16—Tracer dilution results, Well Y-E 88 Long String

Similarly, for the short string on Fig. 17, N_2 gas is injected into the top cap of short string for 7 minutes and the return is collected at production line after choke valve and the total produced gas (pink line) is measured at an average of 949 Mscf/d. Subtracting the gas lift rate of 65%, a net formation gas of 56 Mscf/d is calculated.

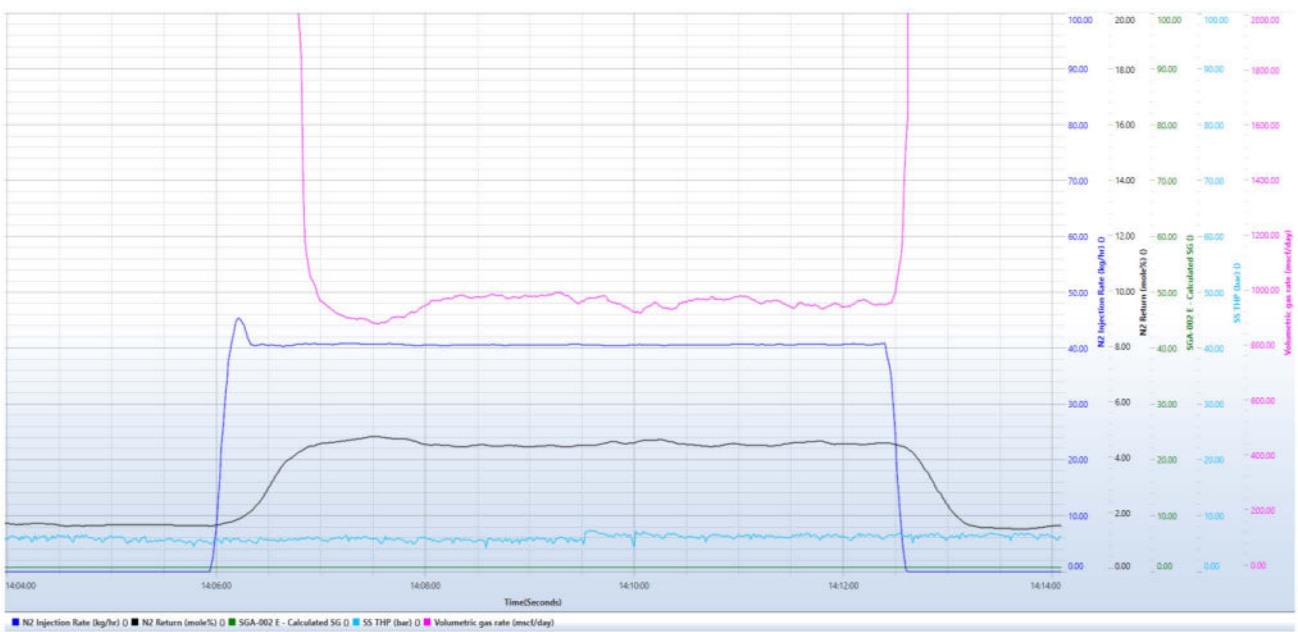

Figure 17—Tracer dilution results, Well Y-E 88 Short String

Well Y-E 69 (Single String Survey)

This is another example of a pilot survey, completed within a single day. This well is operated with flow the long string while the short string is shut in. The well is equipped with five Side Pocket Mandrels (SPMs) for both the short and long strings. The long string has a tubing patch installed at SPM #1 from 1276’ to 1330’ with a spacer pipe. The initial liquid level was detected at 1320ft MD THF, which is below the SPM#1 (Dummy) of the Long String, indicating that the remaining SPMs are submerged (as shown in Fig. 18).

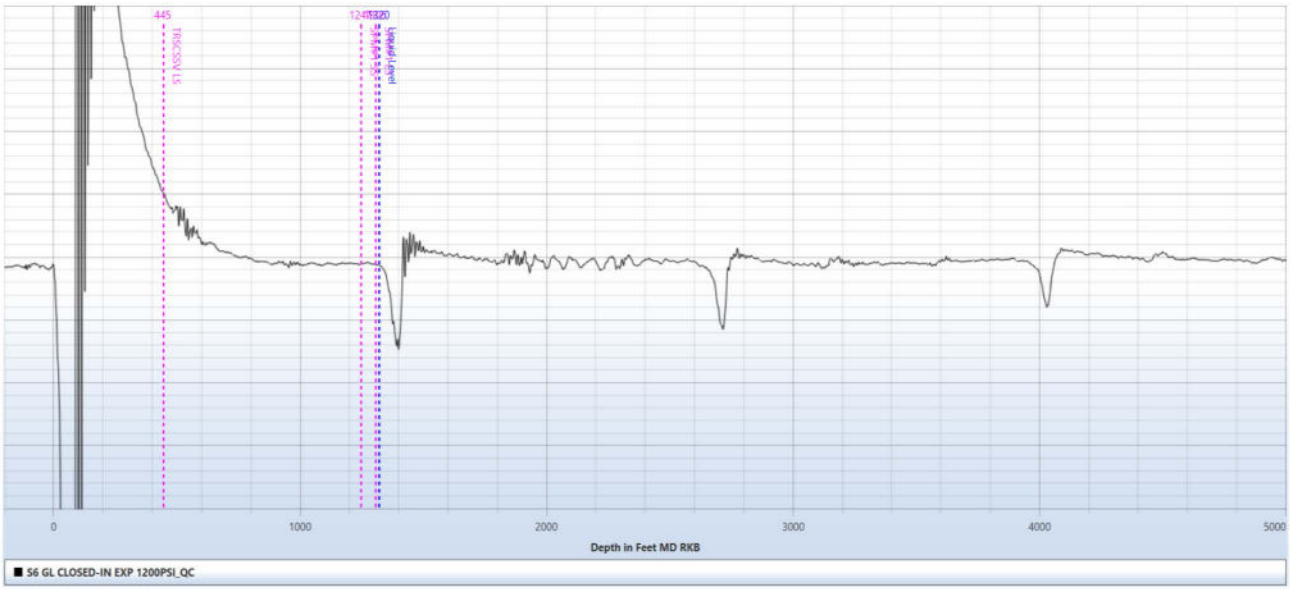

Figure 18—Acoustic survey, Well Y-E 69 Annulus A

The tracer dilution method yielded a rate of 2404 Mscf/d, as depicted in Fig. 19, while the ultrasonic clamp-on flowmeter registered mean standard volume flow rate of 2223 Mscf/d. Due to the low liquid level and high gas-lift rate, the survey for this well can be completed within a day.

Figure 19—Tracer dilution results, Well Y-E 69 Annulus A

The dilution method is also employed to ascertain the produced gas rate for long string. An average reading was calculated from stable N_2 concentration region during the dilution exercise. A net formation gas of 168 Mscf/d is calculated based on the total produced gas of 2572 Mscf/d as shown in Fig. 20.

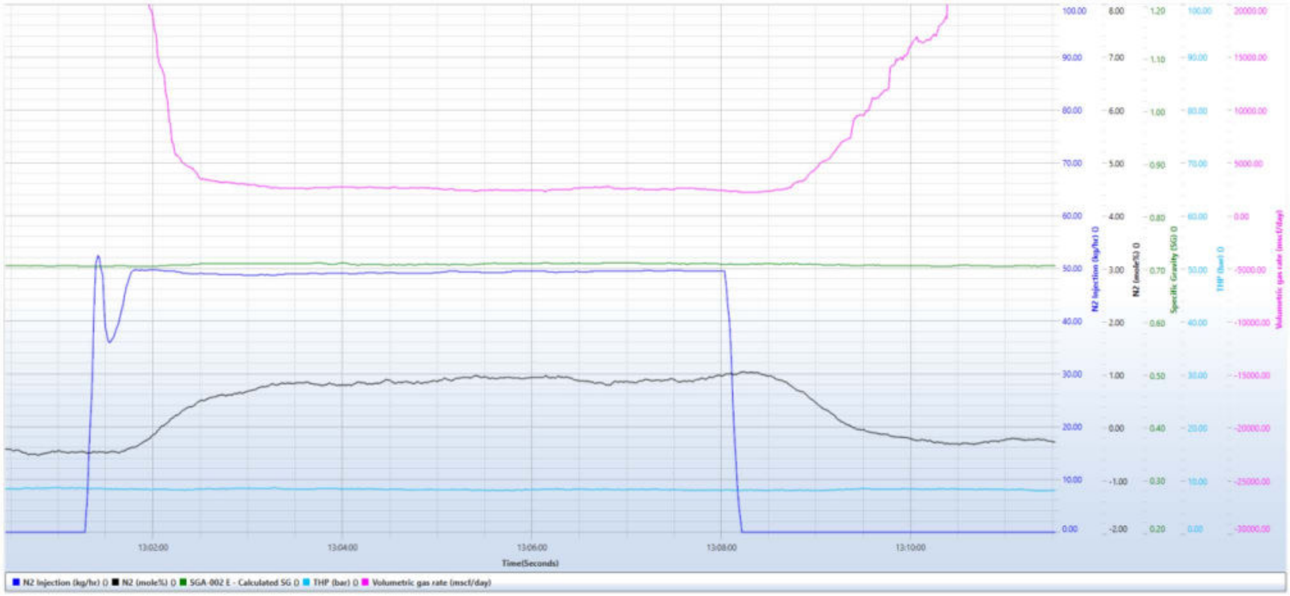

Figure 20—Tracer dilution results, Well Y-E 69 Long String

Without sophisticated monitoring techniques, detecting an integrity breach in this well would have been unfeasible. However, the tracer pulse method successfully identified an unintended injection point at 1306' SPM #1 (Dummy valve) as shown in fig. 21, significantly reducing the well's production optimization. There is a potential leak around SPM#1, indicated by a very low Casing Head Pressure (CHP) and a high gas lift injection rate. This issue may be due to an improperly installed dummy valve in SPM#1. To address this, the valve installed in SPM#1 should be inspected to verify the correct installation of the dummy valve. If the dummy valve is properly installed, the next step is to check for a tubing leak near SPM#1.

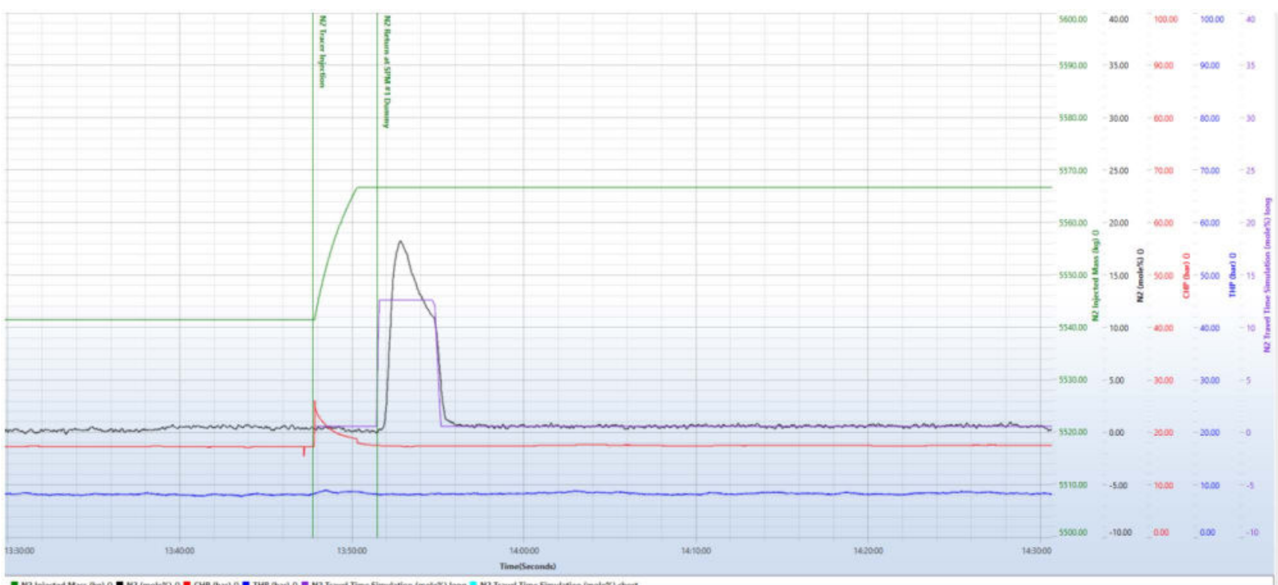

Figure 21—N_2 Fingerprints vs Simulated Results

This graph illustrates the gas lift rate by comparing three different methods. The blue bar represents the gas lift rate obtained from the client's well test facility. The orange bar shows the gas lift rate obtained from the dilution survey, and the green bar represents the rate from the ultrasonic clamp-on measurement. It is evident that there is a significant discrepancy between the well test data and the dilution survey method, whereas the dilution survey method aligns closely with the ultrasonic measurement trend data throughout the day. The combination of the dilution method and ultrasonic clamp-on measurement can enhance the accuracy of the data. This increased accuracy is crucial, as the data plays a vital role and is highly sensitive during the simulation process.

Compositional Profiling

Compositional data was obtained throughout the survey, and the initial compositional profile data has been tabulated as shown in Table 3. It was observed that the injection gas-maintained consistency across all wells, as it originated from the same gas supply. This compositional data improves the quality of the analysis, as it is used in various parts: liquid level detection, measuring gas lift rate by dilution, simulating tracer return, and calibrating the ultrasonic clamp-on flowmeter gas lift trend using specific gravity.

Table 3—Gas Compositional Analysis

Measurement Principle	**Well status**	**Comments**	
Tunable Filter Spectroscopy	**Flowing**	**Continuous compositional analysis. Averaged values.**	
Produced gas	***MOL FRAC.***	***Lift gas***	***MOL FRAC.***
Nitrogen N_2	0.003	Nitrogen N_2	0.000
Carbon dioxide CO_2	0.025	Carbon dioxide CO_2	0.025
Methane CH_4	0.840	Methane CH_4	0.842
Ethane C2H6	0.060	Ethane C2H6	0.061
Propane C_3H_8	0.040	Propane C_3H_8	0.040
iso - Butane i-C_4H_{10}	0.016	iso - Butane i-C_4H_{10}	0.016
n-Butane n-C_4H_{10}	0.008	n-Butane n-C_4H_{10}	0.008
iso-Pentane i-C_5H_{12}	0.008	iso-Pentane i-C_5H_{12}	0.008
n-Pentane n-C_5H_{12}	Below detection limit	n-Pentane n-C_5H_{12}	Below detection limit
Hexane C_6+	Below detection limit	Hexane C_6+	Below detection limit
Hydrogen Sulfide	N/A	Hydrogen Sulfide	N/A

Produced Gas Rates Measurements

By understanding the compositional profile and the produced gas rate (from the dilution method and gas lift distribution from tracer return), this information can be used to calibrate well test data. With the known Gas-Oil Ratio, the oil production rate can be back-calculated, ensuring more accurate and reliable production data. This comprehensive approach allows for enhanced optimization of the gas lift process, improved reservoir management, and better prediction of future production performance. Furthermore, the integration of compositional data into the analysis provides a robust framework for making informed decisions operational adjustments, ultimately leading to increased efficiency and productivity in the field.

Ultrasonic Clamp-on Flowmeter Correction

One of the challenges in understanding gas-lifted wells is ensuring the accuracy of the gas lift rate. In this paper, we present a systematic framework that identifies the rates and reduces uncertainty while improving the confidence level of the data. By leveraging specific gravity data from the compositional analysis, the ultrasonic clamp-on flowmeter gas-lift rate can be calibrated and compared with the gas-lift rate measurements obtained from the dilution method. This allows for the calibration of the gas-lift rate, which can then be trended throughout the survey timeframe. The accuracy of the ultrasonic clamp-on flowmeter system is highly dependent on several factors, including gas data such as specific gravity, pressure, and temperature, as well as pipeline data such as wall thickness and type of pipe. Integration of comprehensive gas and pipeline data into the analysis ensures more precise and reliable gas-lift rate measurements, enhancing the efficiency and effectiveness of gas-lift operations.

Gas Lift Data Accuracy and Allocation

Fig. 22 illustrates the gas lift rate by comparing three different methods. The blue bar represents the gas lift rate obtained from the client's well test facility. The orange bar shows the gas lift rate obtained from the dilution survey, and the green bar represents the rate from the ultrasonic clamp-on measurement. It is evident that there is a significant discrepancy between the well test data and the dilution survey method, whereas the dilution survey method aligns closely with the ultrasonic measurement trend data throughout the day. The combination of the dilution method and ultrasonic clamp-on measurement can enhance the accuracy of the data. This increased accuracy is crucial, as the data plays a vital role and is highly sensitive during the simulation process.

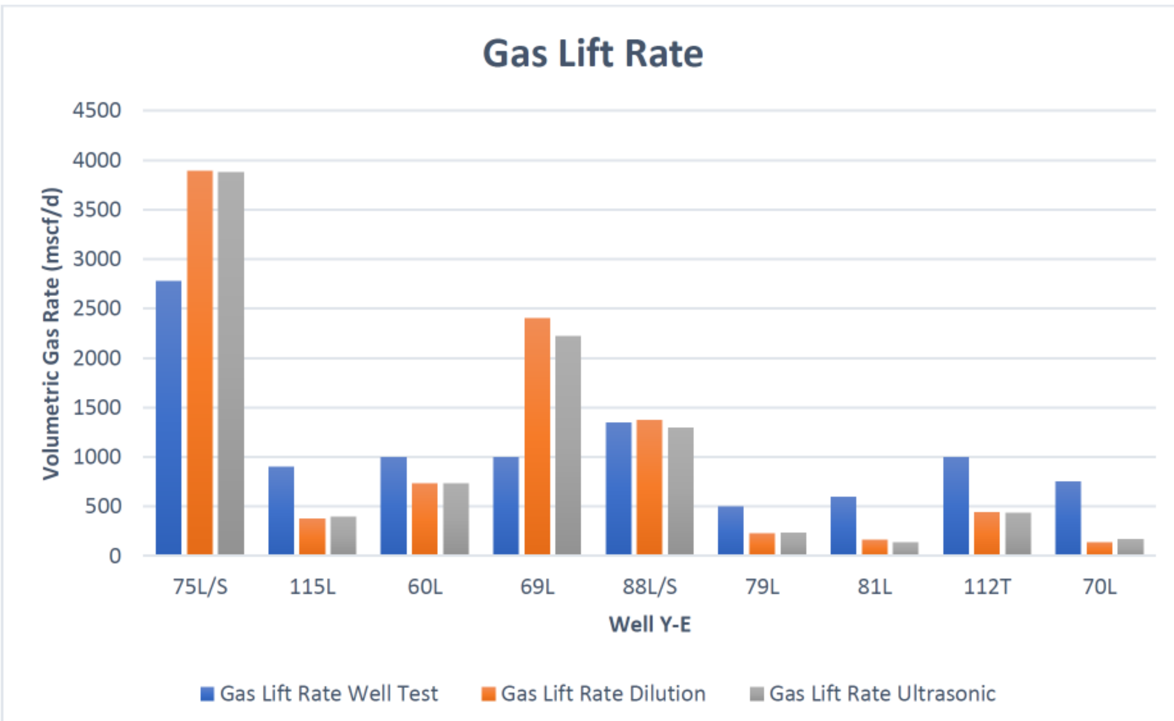

Figure 22—N_2 Fingerprints vs Simulated Results

Power Supply Limitation

To address the challenge of power supply limitations at unmanned remote platforms, a Portable Battery Module (PBM) is deployed to ensure continuous equipment operation throughout daily onsite activities until all required data is successfully collected. As depicted in Fig. 23, batteries are utilized to power all equipment in the field continuously without any interruption, particularly during offshore operations, which typically occur between 10 am to 5 pm for single-string and dual-string surveys.

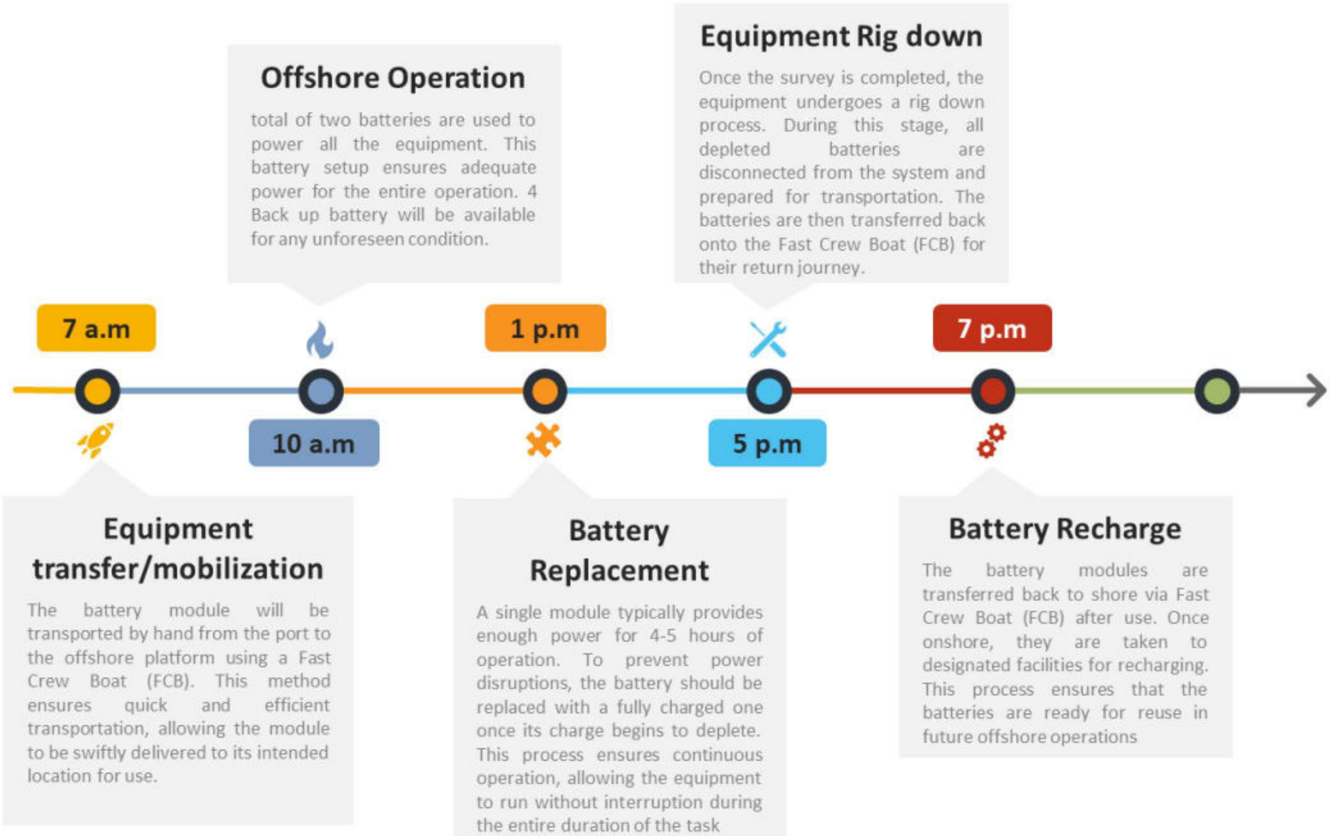

Figure 23—Battery operated timeframe for Field Y-E

In terms of cost savings, the PBM also provides a solution that eliminates the need to mobilize a power generator set offshore. Additionally, the use of a power generator set would require the presence of a chargeman onboard to facilitate its operation. Thus, the implementation of the PBM significantly reduces operational costs.

Gas Lift Optimization Opportunity

The gas-lift optimization study, based on NTSS data as per shown in Fig. 24, reveals significant potential for improving production efficiency and gas usage across the surveyed wells. The analysis identified a total potential production gain of approximately 200 barrels of oil per day (bopd) by optimizing gas injection rates and addressing operational inefficiencies. Gas savings can be substantial, particularly in wells with over-injection, potentially reducing gas lift rates by up to 2400 mscfd. For instance, gas savings from well Y-E 75 long string can be diverted to other wells that require more gas, thereby optimizing the overall gas distribution.

The survey indicated that 11% of the strings are operating at optimal gas injection rates, while 44% are over-injected and 44% are under-injected. Multi-point injection was identified in 44% of the strings, highlighting areas for improvement in injection strategy. A potential tubing leak was detected in one well, necessitating further investigation and corrective action.

Overall, the NTSS has proven to be a valuable tool, offering detailed insights into gas lift performance, pinpointing inefficiencies, and providing actionable recommendations. The benefits of running such a survey include enhanced data accuracy for calibrating well models, better-informed decisions for adjusting gas lift rates, and ultimately, improved oil production and gas lift efficiency. The comprehensive data gathered enables targeted interventions, ensuring optimal resource utilization and maximizing production gains.

Well Name	String	No. of Returns	GL Rate (mscfd)	GL Injection from Orifice	GL Injection from Unloader Valves	Multi-Point Injection	Lifting Points SPM #	Tubing Leak	Measured Total Produced Gas (mscfd)	Measured Net Produced Gas (mscfd)	Injection Rate Status	Production Potential Gain (%)	Description to Enact Production Change
Y-E 75	LS	1	3462 (89%)	Yes	No	No	2	No	3680	218	Over injection	25	Reduce gas lift injection rate from 3400 to 1000 mscf/d and inject in Mandrel #3 to achieve an oil gain of 30 bopd.
	SS	1	428 (11%)	Yes	No	No	2	No	515	87	Low injection	14	Increase gas lift injection rate to 900 mscf/d and inject in Mandrel #3 for a 20 bopd increase.
Y-E 115	LS	3	576	Yes	Yes	Yes	2,3,4	No	821	245	Low injection	93	Increase gas lift injection rate to 800 mscf/d and reduce tubing head pressure to about 120 psi to achieve a 40 bopd gain.
Y-E 69	LS	1	2404	No	No	No	1	Yes	2572	168	Over injection	-	Check and correct dummy valve installation or address potential tubing leak near SPM #1. Recommended to rerun the tracer survey after rectifying the leak to evaluate the production gain.
Y-E 60	LS	2	734	Yes	Yes	Yes	4,5	No	897	163	Low injection	29	Increase gas lift injection rate to 1200 mscf/d for a potential gain of 40 bopd and adjust PTRO settings of PPO valve in Mandrel #4 to ensure that the gas lift injection is only in the orifice.
Y-E 88	LS	1	481 (35%)	Yes	No	No	5	No	585	104	Optimized	-	LS is optimized and can produce according to current operating conditions.
	SS	3	893 (65%)	Yes	Yes	Yes	3,4,5	No	949	56	Over injection	-	Reducing the THP to around 120 psi would close the unloader valves, potentially saving gas lift injection. The value gained would be more from gas savings than from oil production.
Y-E 112	LS	2	440	No	Yes	Yes	1,2	No	1106	666	Over injection	-	Based on well test, the GOR is high, indicating the well might flow without gas lift. Evaluate well flow without gas lift to confirm potential discontinuation of gas lift and reallocation of gas to other wells. The value gained would be more from gas savings than from oil production.
Y-E 70	LS	1	140	No	No	No	2	No	540	400	Low injection	-	Gas lift injection rate was not stable during the survey. There is a potential that fluid level in the tubing is around the SPM #2 when well was shut in. Recommended to perform new well test to understand potential and investigate deepening the gas lift injection point by acquiring static fluid level acoutics shot in the tubing.

Figure 24—Gas-Lift Optimization

Conclusions

In conclusion, the integration of advanced tracer surveillance techniques marks a pivotal advancement in gas-lifted well operations, offering a comprehensive solution to enhance various aspects of the oil and gas industry. Through meticulous analysis of data gathered from pilot surveys and field operations, several key insights emerge. The successful management of multiple gas-lifted wells without wireline intervention underscores the operational efficiency achieved with tracer surveillance. This approach not only reduces operational days but also provides valuable insights beyond conventional wireline methods, showcasing its effectiveness in managing complex well systems. The identification of gas-lift system issues presents an opportunity to optimize production and increase overall output. By analyzing well behavior through nodal analysis and gas injection optimization, operators can maximize production uplift while minimizing operational disruptions. Furthermore, the absence of production loss during surveys, enabled by the continuous flow of wells without shutdowns, ensures operational stability and maintains consistent production levels.

In terms of competency and safety, the adoption of tracer surveillance reduces operational risks and enhances team competence by eliminating the need for CO_2 cylinders and Ex-rated generators, fostering a safer work environment. Moreover, the environmental benefits of using battery-operated equipment and avoiding CO_2 emissions demonstrate a commitment to sustainability and environmental stewardship in oil and gas operations.

From a financial perspective, the significant NPV gains achieved through efficient OPEX utilization highlight the cost-effectiveness of tracer surveillance, making it a compelling investment for operators seeking to maximize profitability. In essence, the transformative impact of advanced tracer surveillance techniques extends beyond operational efficiency to encompass production enhancement, environmental responsibility, competency development, safety improvement, and data accuracy, ultimately optimizing overall operational efficiency and effectiveness in gas-lifted well operations.

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Nomenclature

NTSS	Nitrogen Tracer Surveillance System
N_2	Nitrogen
LS	Long String
SS	Short String
CHP	Casing Head Pressure
THP	Tubing Head Pressure
NVD	Non vessel day
WOW	Wait on weather
PBM	Portable battery module
MD	Measured Depth
THF	Tubing Head Flange
PPO	Production Pressure Operated
FCV	Flow Control Valve
CO_2	Carbon Dioxide
NPV	Net Profit Value
OPEX	Operational Expenditure

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