SPE-228502-MS

Unconventional Leak Detection Method Without Production Loss: A Game Changing Approach Without Well Shut-In

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This paper was prepared for presentation at the SPE/ICoTA Symposium and Exhibition - Well Intervention held in Kuala Lumpur, Malaysia, 2 – 3 December 2025.

Abstract

Maintaining well integrity in aging producing wells is essential for meeting production targets and safeguarding operator revenues. Maintaining the integrity of aging wells is crucial to sustaining production levels. In one instance, an operational well experienced a significant reduction of liquid production from 546 blpd to 58 blpd. Surface inspections suggested the presence of a shallow leak. Traditionally, assessment of such issues relies on downhole logging tools deployed via slickline or other conveyance methods, which necessitate shutdowns, resulting in increased downtime, reduced production, and higher risks and associated costs.

To address these challenges, an innovative solution was implemented using a real time gas tracer system; a non-invasive diagnostic tool that operates entirely at surface and does not require intervention or interruption of well operations. This system was integrated with the well's gas lift and production lines at surface, enabling nitrogen gas to be channeled through casing-tubing communication points and measurements taken at various surface locations over time. This methodology facilitated precise determination of the leak depth while the well remained online, eliminating the need for traditional conveyance units.

After diagnostics, the gas tracer system successfully identified the tubing leak at 66 m MD RKB. To validate these results, a camera run was conducted as secondary verification. The leak was subsequently addressed using a straddle pack-off system, resulting in a substantial increase in liquid production up to 1094blpd. This well was produced at low WC of around 2%, resulting to oil production of 1074blpd.

Introduction

One of the primary causes of oil production loss in aging wells is tubing degradation through corrosion or erosion, leading to loss of integrity, ineffective gas lift performance and production decline. This was observed in Well D, where production sharply declined within a short period. Surface observations of the flow line along with well modelling suggested the presence of shallow tubing leaks as a likely cause of the production decline.

To validate their hypothesis and address the underlying issue, well integrity diagnostics followed by remediation are necessary. Typically, such assessments are performed using wireline-conveyed logging tools. However, in this instance, the production team initiated their investigation with an unconventional approach; implementing a Nitrogen based Gas Tracer system that introduces and detects nitrogen gas at the surface. This article examines the benefits and adds value of this technology in comparison to traditional leak detection methods.

Background

Well D is a dual selective completion well with Gas Lift, with the Short String (SS) shut in and the Long String (Well D) producing from A zone initially, then isolated to produce from B zone (refer Figure 1 *for Well Schematic)*.

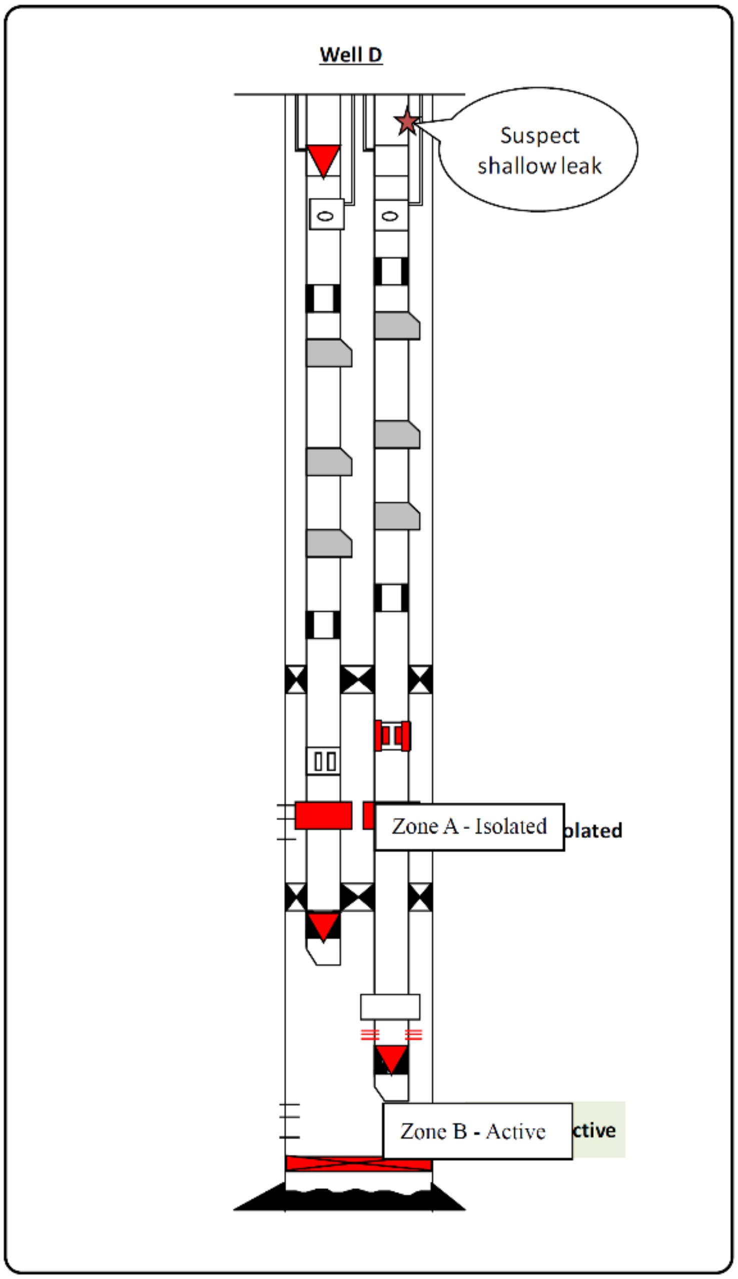


Figure 1—Well Schematic

Well D was re-entered for flow testing from the B zone. In September 2024, the Well work team has:

- Completed sand clean-out operations
- Installed tubing pack-off across SSD #1 (1,443 m MD) to isolate the A zone prone to sand production
- Performed a tubing punch at 1,842 m MD to access B

Following the completion of intervention activities, from welltest performed in early October 2024, Well D produced 546 blpd with 11% water cut and 6.68 MMscf/d gas at 100% production choke opening. However, by end of October 2024, production dropped drastically to 58 blpd, accompanied by well's gassing out and icing on the flowline, which are indications of possible shallow tubing leaks. Well modeling also showed the gas lift was not injected at the designed injection point as shown in Figure 2.

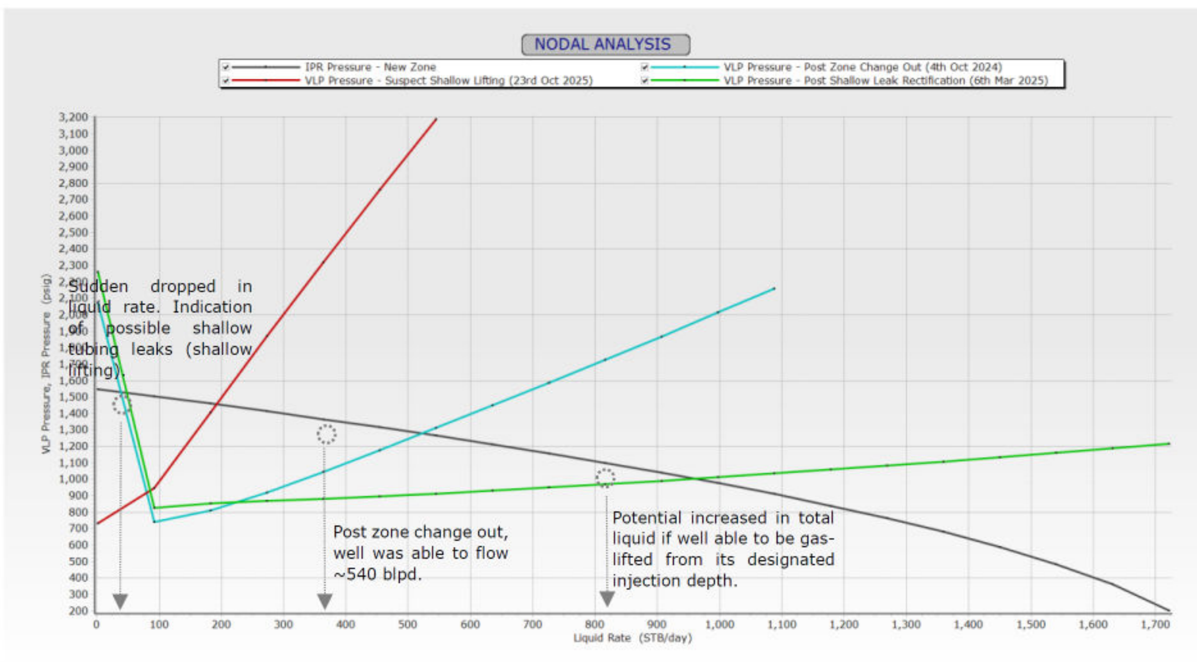


Figure 2—Well's Nodal Analysis

Technology

Conventional

Traditionally, the current available technology to detect well tubing leak(s) in the market are tools such as production logging tools[4] equipped with physical sensors which detect flow at different depths in the well. This tool is required to be conveyed using wireline units and is operated by an offshore team. This process would require mobilization of the wireline unit and operation team to the well site location. Rigging up the unit at offshore deck, which consists of the wireline mast, wellhead Blow Out Preventor and lubricator, control unit, and diesel-powered generator. As shown in Figure 3, this large equipment set up requires heavy lifting and has a large equipment footprint on the main deck[1]. This results in long duration for equipment set up, limited space and raises safety concerns especially in small sized satellite platforms.

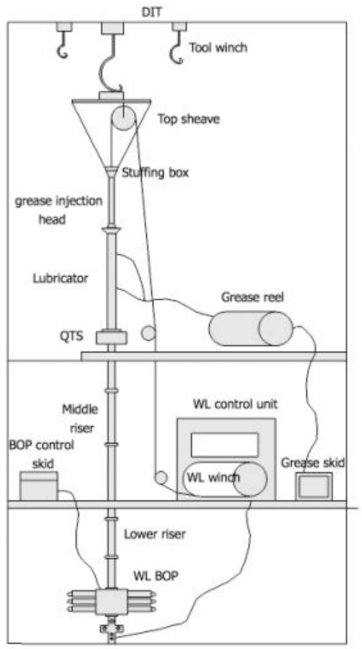
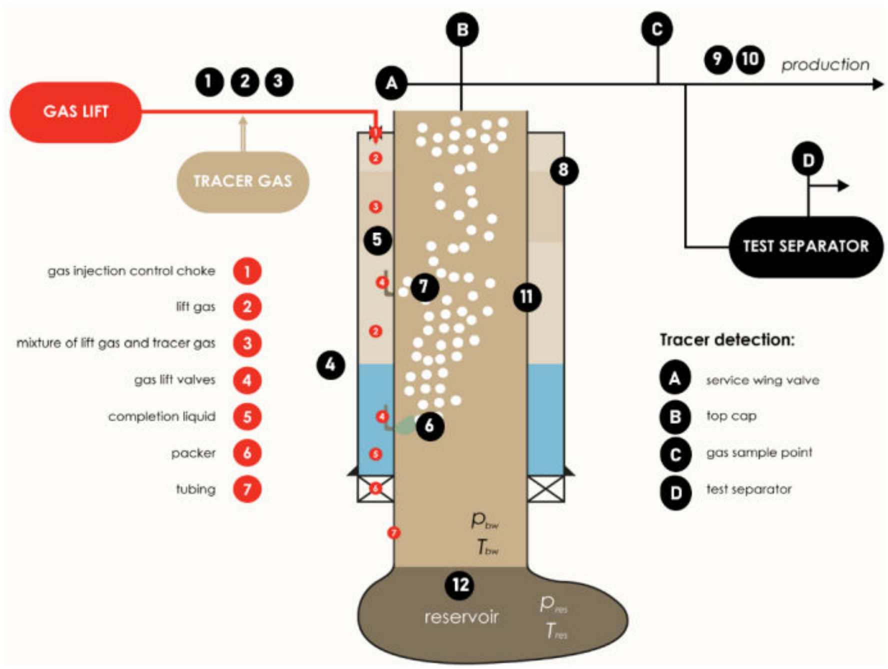


Figure 3—Slickline unit equipment and set up on Offshore rig

The wireline unit is powered by diesel and emits carbon into the atmosphere. This raises health concerns as well as environmental issues which are encouraged to be reduced. Prior to operating the equipment, it is a requirement to conduct pressure testing onto the equipment wellhead safety barrier[3] which is the blowout preventer to ensure that the unit is safe to use. Due to this, there will be a production deferment as this pressure testing requires well to shut in. The conventional way of logging which requires intervention is less desirable and an alternative to this solution has been developed.

New Technology

The innovative approach to address this matter is to conduct logging without using a wireline unit. The Production Technologist team aspired to deploy an intervention-less technology to diagnose & locate the shallow leak(s) on Well D. The N_2-Tracer Metering System (N_2-TMS) technology is primarily used for evaluating the effectiveness of a gas lift system, but for this unique case, the N_2-TMS is used as an unconventional leak detection method that does not require shutting in the flowing well. The equipment is attached only to the (i) Gas Lift Injection Line and (ii) Well Production Line that are not required to be conveyed into the well as shown in Figure 4.



The following parameters are measured and reported onsite:

● · Measurements · Method

#	Measurements	Method
01	Lift gas composition	Realtime spectroscopy
02	Lift gas rate	Tracer dilution method on lift gas
03	Lift gas velocity	Clamp-on velocity meter
04	Gas liquid contact in annulus	Acoustic logging
05	Pressure and temp. profile	Acoustic logging
06	Gas-lift depth(s)	Tracer pulse injection – Propagation model
07	Gas-lift distribution	Tracer area distribution
08	Casing integrity	Tracer mass balance
09	Total & Net gas produced	Tracer dilution method on produced gas
10	Produced gas composition	Realtime spectroscopy
11	Tubing leak depth(s)	Tracer pulse injection – Propagation model
12	Reservoir pressure	Acoustic method

Figure 4—Figure indicated the Nitrogen Gas Tracer system rig up on wellhead (i) Gas Lift Injection Line and (ii) Well's Production Line

The N_2-TMS model calculates the transport of a tracer gas in the annulus from the injection point to the gas lift valves (or potential leak points). The solution is found by dividing the annulus volume into a given number of grid boxes and solving the mass and momentum conservation equations iteratively for each box.

- Lift gas injection and gas production mass rates are measured using a tracer dilution method and mass balance equations.
- Annulus temperature gradient is derived from advanced proprietary acoustic methodology.
- Annulus and tubing head pressure, composition and surface temperature are logged throughout the survey.
- Tracer gas is measured when injected into the well, and the simulation is tuned based on survey results.

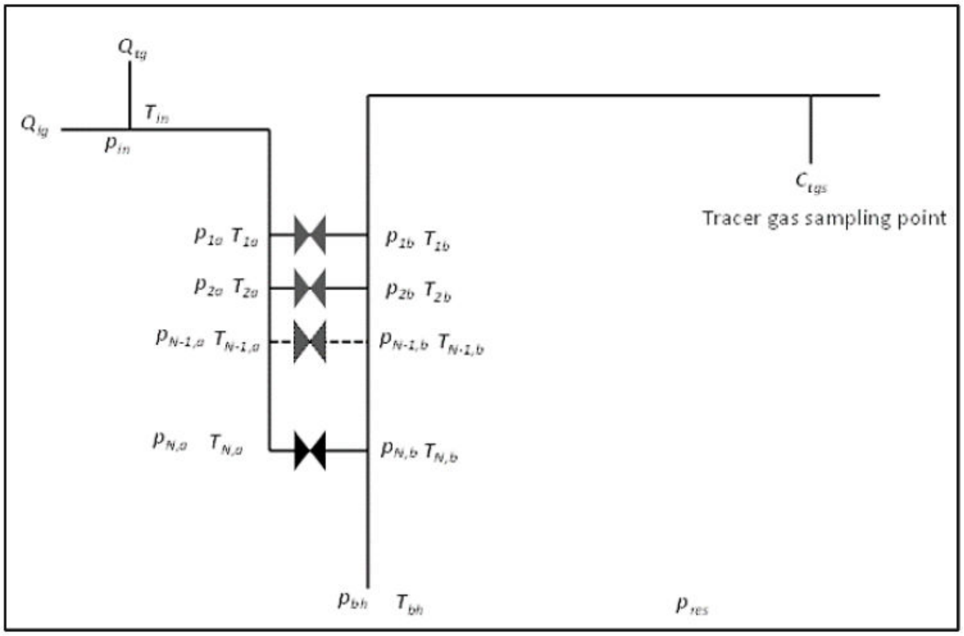


Figure 5—Figure indicated the N2-TMS Annulus and Tubing Model of Gas Tracer system

The N_2-TMS Deliverables and Benefits.

Gas-Liquid Contact in the Production Annulus

Measured using a portable acoustic logging system connected to the annulus wing valve at surface. The system records reflections from an acoustic pulse generated at surface, and the instrument measures the gas-liquid contact in the production annulus and quantifies the gas volume. It shows all changes in cross-sectional diameter in the annulus, thereby making it possible to identify wellbore components and anomalies.

Lift Gas Rate / Produced Gas Rate / Net Gas Produced Measurements

These measurements are obtained by injecting a known concentration of tracer at a 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. The increase in tracer component concentration at the sampling location, is directly proportional to the flow stream's volumetric flow rate transferring the tracer to the sampling location.

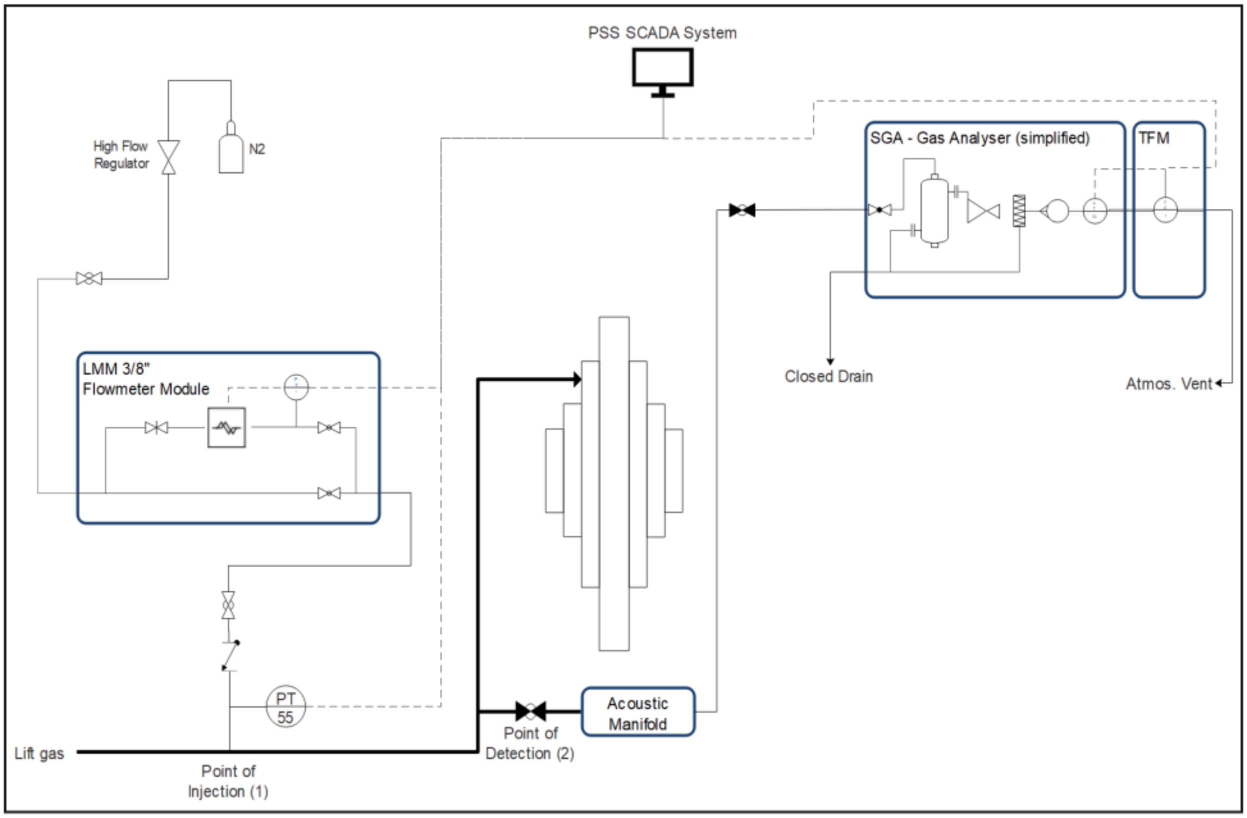


Figure 6—Figure indicated the rig up for lift gas rate measurement via N_2 Dilution Survey

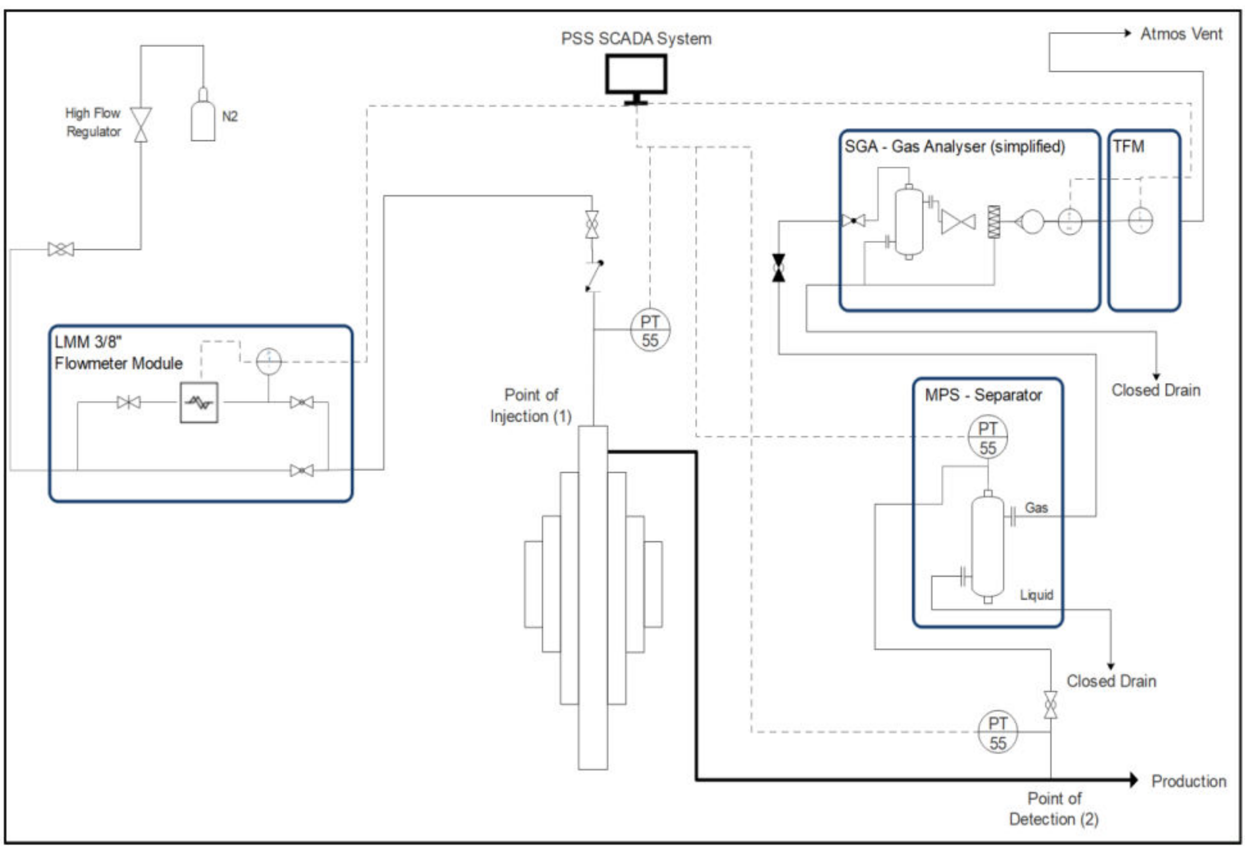


Figure 7—Figure indicated the rig up for gross produced gas rate measurement via N_2 Dilution Survey

Gas Composition

Online real-time gas analyzers perform continuous gas analysis of produced and injected gases. This includes per second measurement of the mol% of methane, ethane, propane, iso-butane, n-butane, iso-pentane, n-pentane, hexane, N_2, CO_2 and H_2S.

Pressure-Temperature Gradients in Production Annulus

Pressure and temperature gradients in the production annulus are critical for accurate determination of lifting depths using the tracer method. The pressure and temperature gradients are calculated from the acoustic velocity profile in the wellbore, the gas composition, and the surface pressure. The measured P/T gradient is then tuned based on comparison to the simulated P/T gradients using Hasan-Kabir correlation.

Measured Lift Gas Propagation / Determination of Lifting Depth(s)

The tracer gas is injected with the lift gas using a tracer injection module. The tracer injection module is equipped with a Coriolis flowmeter and quantifies mass, pressure and the temperature of the injected tracer. The tracer travels down the production annulus with the lift gas and returns to surface with the produced fluids. A tracer detection system is connected to the flow line at surface and records the tracer returns in real-time. The lifting depth is determined based on the round-trip travel time of the tracer gas. The area underneath the return peak of the tracer is used to determine the amount of tracer returning from one or more lifting depths. Any loss of tracer is detected by calculating the mass balance of the system.

The equipment package consists of five lightweight portable equipment which are laid out on the wellhead deck, saving space and minimizing lifts. All the equipment is powered by electricity available on the platform hence reducing carbon emissions. The N2-TMS system is required to be operated by only two personnel which reduces costs and risk of accidents at site. Primarily, the N2-TMS equipment provides a smaller footprint, lower direct and indirect carbon footprint and a simpler operation as compared to a conventional logging method. Figure 8 shows Lightweight equipment set up.

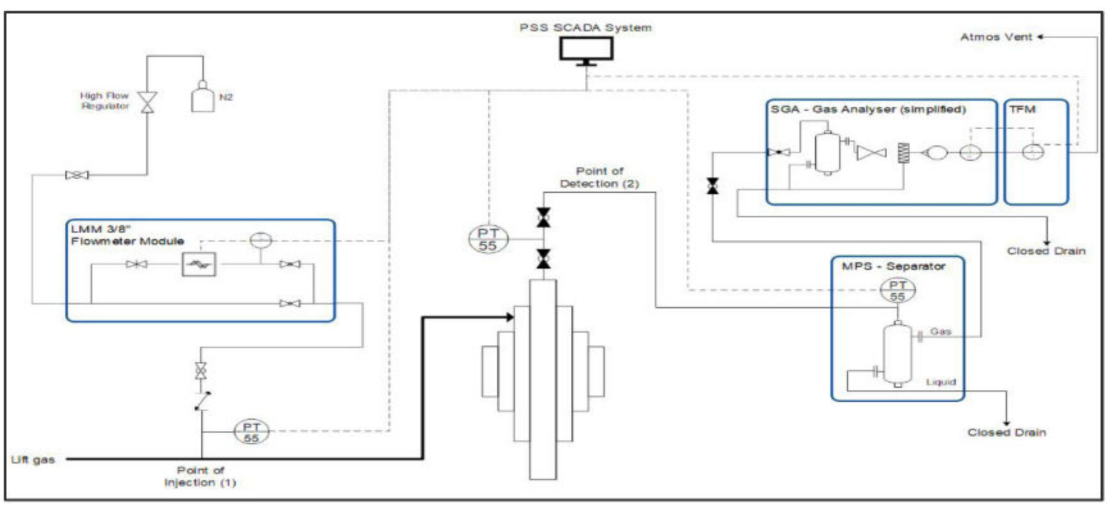


Figure 8—Figure indicated the nitrogen Gas Tracer system rig up on wellhead and equipment (i) Leak Metering M, (ii) Gas Analyser and (iii) Multi phase separator

Methodology

Initial Setup & Baseline Data

Prior to conducting the gas survey, historical well performance data are reviewed as shown in Table 1. Data such as the liquid production (blpd) and gas lift injection rate (Mmscfd) are used for pre-modelling of the expected survey to ascertain suitability of (i) quantities of tracer required and (ii) expected survey times. Primarily, the gas lift injection rate will be used as a reference upon commencement of the survey. This ensures that the selected well is suitable for a gas tracer survey as a leak detection method. Baseline well parameters that are collected include the tubing and annulus pressures, temperatures, and flow conditions.

Table 1—Well D Well Production Data

Welltest Date	Prod. Choke (%)	THP (psig)	PCP (psig)	Temp (degC)	Oil (bopd)	Water (bwpd)	Liquid (blpd)	Gas (MMscfd)	WC (%)	GOR (scf/stb)	GLR (scf/stb)
4-Oct-24	100	614	1,171	7	486	60	546	6.68	11	13,757	12,243
21-Oct-24	50	606	1,293	-4.2	99	5	104	4.95	5	49,839	47,596
23-Oct-24	100	476	1,407	1.8	52	6	58	2.88	11	55,290	49,485

Gas Lift & Production Measurements via Tracer Dilution

At the well site location, a precise measurement of the gas lift injection rate and gross gas production rate of the well are taken via the N_2-TMS system via continuous tracer dilution technique as these are critical inputs to the transport model.

Acoustic Survey by Sonogram Technique

Liquid levels in the well tubing and annulus were measured using acoustic survey equipment, which emits echoes into the gas-filled space and records reflections at density interfaces. This reveals fluid distribution and well performance. It's essential to confirm that any packer fluid in the annulus is below the target depth for nitrogen injection into the annulus. Additionally, temperature variations along the wellbore are monitored to identify well behavior and potential issues

Tracer Pulse Surveys

The nitrogen gas is injected in controlled amounts of tracer pulses (10 kg, 5 kg, 3 kg) into the A Annulus. The various mass sizes provide a variation in collected data, which allows the data points to have a higher resolution. Monitored tracer returns in the production tubing using gas composition analysis. Observed consistent and rapid tracer returns pinpointing the leak entry depth.

Composition

Wellbore Gradients: Analysis of compositional gradients along the wellbore provides valuable information on fluid characteristics and reservoir properties. The modelled flowing gradient survey based on the TMS results provide a dP vs Depth chart between A-Annulus and Tubing under production conditions allowing confirmation of communication potential.

Data Correlation & Depth Confirmation

The N2-TMS tracer Cross-referenced tracer pulse arrival times at the production line, gas injection and production flow rates, and acoustic data with well completion schematic as shown in Figure 9. The transport model identified a major shallow leak at 66 m MD RKB, accounting for 100% of GLIR (1.89 MMscf/d).

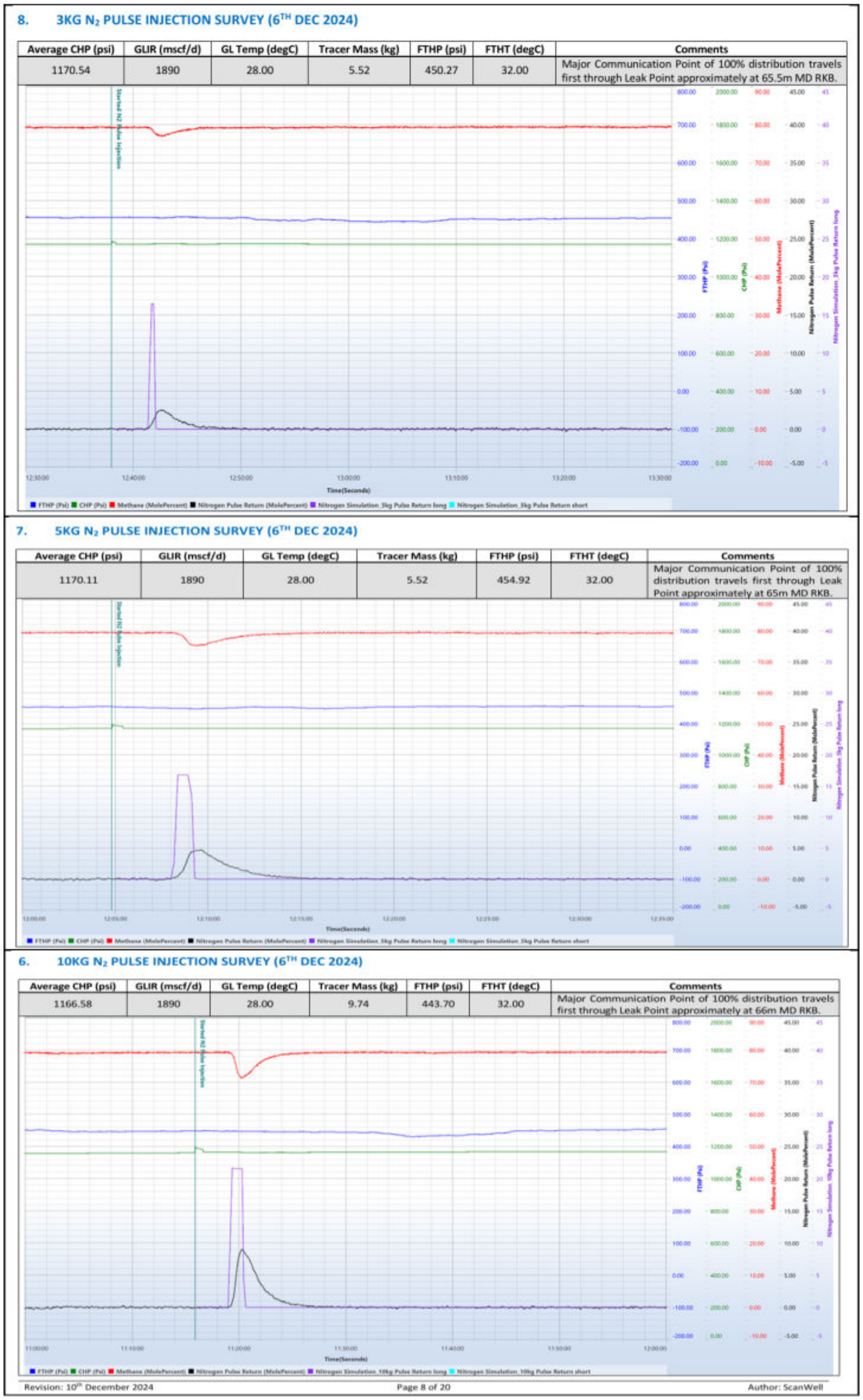


Figure 9—Figure indicated the nitrogen Gas Tracer system result Volume Mmscf vs time(s) (i) 3kg Pulse Injection (ii) 5kg Pulse Injection (iii) 10kg Pulse Injection

Results

The Gas Tracer team completed the leak investigation over two (2) survey days via the N_2-TMS tracer without any production deferment. The result indicated 100% injected Nitrogen return from a shallow leak point at depth of 66 m MD RKB. As the N_2-TMS tracer technology is newly introduced and being applied for the first time in the Seligi field to diagnose tubing leak(s), an independent validation was necessary to validate the result from the N_2-TMS tracer technology. The team agreed to conduct a camera run in February 2025. Camera findings indicated that the depth of the leak is accurately at 66 m MD RKB as shown in Figure 10.

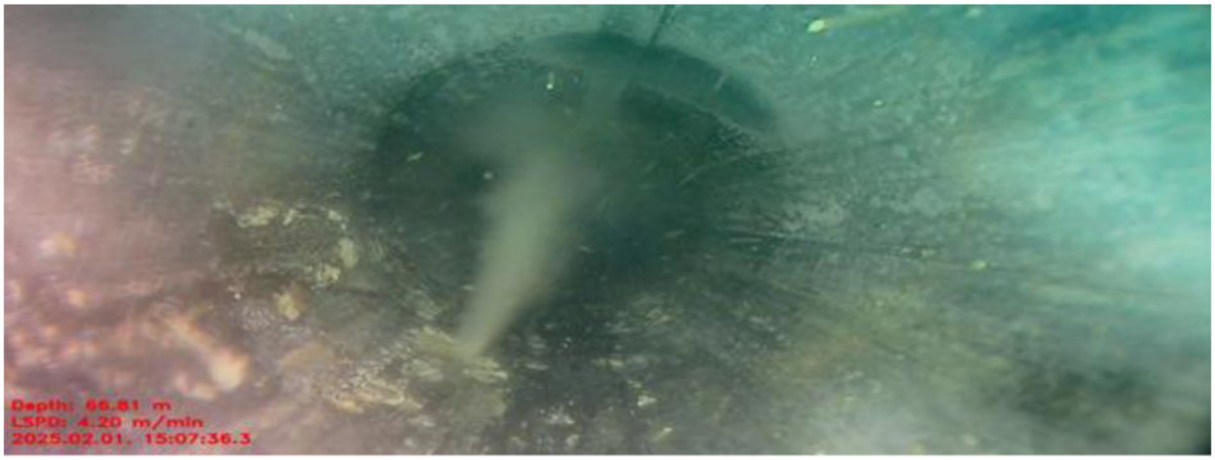


Figure 10—Figure indicates camera run snapshot identifying leak at depth 66 m MD RKB

The leak depth from the N_2-TMS tracer was identified at 66 m MD RKB and was later verified by a camera run, 66m MD RKB. The leak was rectified with installation of tubing pack-off across the leak point and the well was tested post shallow leak rectification. Welltest conducted post leak rectification resulted to liquid production of 1094blpd, 2% water cut, which equivalent of oil production of 1074blpd.

Conclusion

The sudden drop of liquid production of Well D from 546blpd down to 58blpd was required to be identified and addressed. Based on the final camera run, the suspected leak on Well D was accurately identified at 66m MD RKB using this new technology, N_2-TMS tracer. This is a far improvement to the available conventional technology, *wireline conveyed logging tool*. This new technology, N_2-TMS has a smaller footprint, less carbon emission, lightweight and is faster to obtain the result. The well's diagnosis was then rectified with the installation of tubing pack-off to rectify the shallow leak and resulted in improved of liquid production up to 1094blpd, equivalent to 1074bopd. This intervention-less technology has helped to perform well diagnostic with quicker and reliable results, thus reducing well downtime against wireline well intervention and eliminating the risks associated with wireline well intervention.

Nomenclatures

Blpd = Barrels Per Day
dP = Delta Pressure
GLIR = Gas Lift Injection Rate
m MDRKB = Meters Measured Depth Rotary Kelly Bushing
Mmscf = Million Standard Cubic Feet
MMscf/d = Million Standard Cubic Feet Per Day
N_2-TMS = Nitrogen -Tracer Metering System
TMS = Tracer Metering System

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