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High Confidence Gas Lift Valve Optimization Survey Using Full Production Logging and MFC Caliper Data

Duncan Craig Heddleston, Indepth Production Solutions

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Abstract

A common artificial lift method uses natural gas injected at high pressure from casing into the well and mixes with the produced fluids from the reservoir. The added gas helps increase the production due to lowering the static head pressure and overcome the increase in frictional pressure loss from the large gas quantity injected.

Diagnostic surveys are necessary in order to maintain the gas lift systems, keeping the production optimal and the field operations costs low. The Gas Lift Valve Optimization Surveys (GLVOS) are run to determine if there are any ongoing issues with the completions that may reduce the lift capabilities. These high-definition GLVOS can pin point many issues occurring in the artificial lift systems.

Introduction

When oil reservoir pressures decline, artificial lift techniques are installed to help lift the liquids to surface. A low-cost common method of artificial lift, Gas Lift (GL) uses natural gas produced from its own well to aid the lifting process by injecting gas at a higher pressure traditionally down the casing into the tubing through various valves, this mixes with the produced fluids from the reservoir.

Gas lift (GL) is used when reservoirs will not produce under their own reservoir pressure to surface, this lift technique is referred to as intermittent gas lift. A column of liquid accumulates across the bottom section of the tubing. A large volume of gas is rapidly injected below this buildup of liquid, this is known as a slug effect, as the section of fluids and gas is lifted to the surface. As various valves are set, this cycle becomes repeated; however, as the reservoir pressure declines the valve locations are changed over time. As the volume of the tubing being filled changes. eventually as the reservoir depletes itself, the artificial lift choice changes as pressure declines.

The advantages of the gas lift method of artificial lift are (Pittman, 1982):

- ➢ Operating depths in excess of those attainable with rod pumps.
- ➢ High fluid production rates.
- ➢ Not affected by solids in produced fluids.
- ➢ No heavy equipment required at the wellhead.

➢ Not mechanically affected by the inclination of the wellbore.

A concern with gas lift design is the specification, spacing and pressure setting of the unloading and operating valves in order to initiate and maintain oil production with economic gas injection rate.

Increased production is due to lowering static head pressure and overcome increase in frictional pressure loss from the large gas quantity present.

This can increase the bottom-hole pressure and lowers fluid production; each well has an optimal desirable gas-lift injection rate (GLIR). The optimal gas-lift injection rate differs from that which maximizes individual well production due to the back pressure effects (the pressure drop observed across flow lines due to common tie backs further downstream) due to connected wells further downstream. (Rashid, 2012)

To maximize the benefit from artificial lift (GL) injected gas, the gas pressure near the producing interval at this depth must be greater than the flowing producing pressure at the same depth. Any difference in this can result in less pressure drawdown and a less efficient lift operation. High volumes of gas injected in the upper part of the fluid column will not have the same effect as a much smaller volume of gas injected near the producing formation depth because the fluid density is reduced only above the point of gas injection.

Diagnostic surveys are necessary in order to maintain the gas lift systems keep production optimal and the field operations costs low. The Gas Lift Valve Optimization Surveys (GLVOS) are run to determine if there are issues occurring within the tubing / completions and reducing the lift capabilities. These high-definition surveys can pin point many issues occurring in the artificial lift systems.

Gas Lift Optimization Surveys

Production engineers look to measure and identify the efficiency of their GL systems as well as understand where issues are occurring. If a GL system wasn't lifting properly, it was determined that one of the many GL (valves multi-pointing) was not assisting with the lifting & was either stuck open, leaking, failed or possibly a tubing issue (leak). The engineering staff would use a gradient survey as an intervention tool to help them trouble shoot the lifting issues.

From the 1970s through to the 2000s as pressure gauges became more reliable, the antiquated method of determining a fluid level using BHP gauges lowered into a flowing well bore to measure a pressure gradient. Numerous time-consuming station stops were run, due to antiquated technology gauges needed approximately 10 minutes to stabilize per stop. The was the traditional technique used to establish a flowing pressure gradient, which was quite time consuming on deeper wellbores.

The BHP tool string was 1 ¾" – 2″ OD in size spent a full day in the well, choking back flow, all to determine a fluid level ~ 500 – 1000 ft accuracy where the fluid level was located. Besides the inaccurate approximate fluid level, the only other data measured was the actual BHP & BHT. Figure 1 is an example of modern-day BHP gauges 2 different sizes.

When using only a BHP gauge survey, on wells with intermittent fluid slugs (slug flow) the results can look erroneous and hard to determine which valve are open and lifting, also where the real fluid level is located or where issues are occurring.

Since the time in well & length of station stop with the old-style BHP gradient gauge survey took a long time to complete. The BHP gauges are set at stations above and below the valve for a duration of time in order to allow for tool stabilization. Figure 2 shows a BHP gradient survey of a slugging well and is difficult to understand where the GLV issues occur.

Figure 1—Bottom Hole Pressure (BHP) Gauges

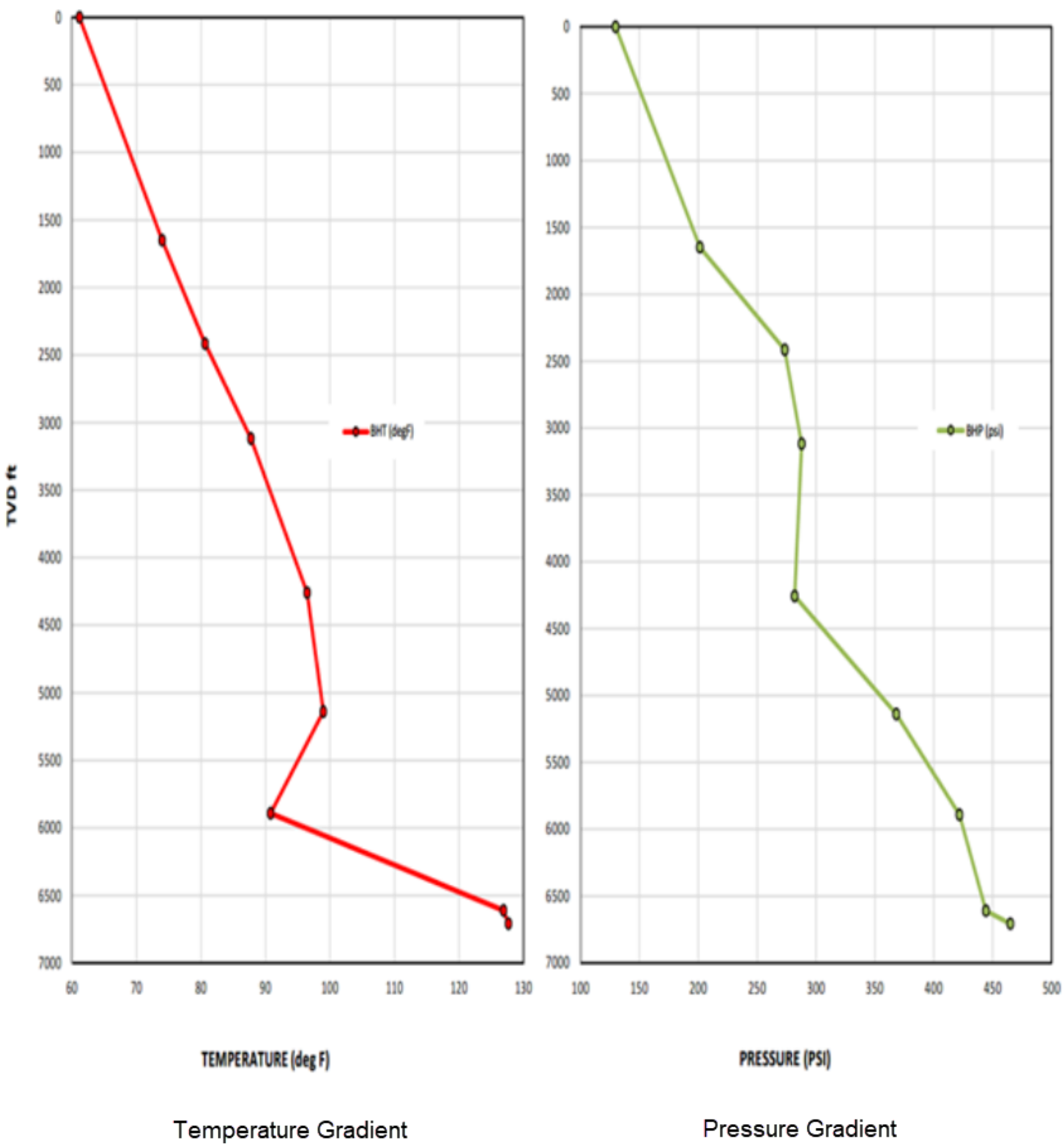


Figure 2—BHP Pressure Gradient Plots – Slugging Well Production

GLV Optimization Logging Tools

Over the years logging tool technology has changed. Tools have become more reliable and slimmer in size also the surveys have become more efficient. Today's technology now allows for slim tool size 1 3/8″ OD, with higher sample rate memory system tool string, allowing for an efficient and higher confident approach to GLVOS technique. By deploying a slim 1 3/8″ full production log platform utilizing Gamma Ray, CCL, Pressure, Temperature, Fluid Identification, Flowmeter.

As shown on figure 3 the memory production log (PLT) platform can be programed to sample at 10 samples/second at certain logging speeds will sample at ~ 40 samples / ft which scans the full joint of tubing at ~ 2,000 samples / joint of tubing.

The GR/CCL correlates depth measurement but identifies any scale buildup in the tubing, the CCL picks up tubing collars, therefore; all GL valves can be accurately depth determined. The Pressure and Temperature measurements create a smooth gradient plot versus depth that is easy to interpret, the fluid identification measurements which use density and capacitance show the fluids changing in the tubing versus depth. The flowmeter identifies the gas lift valves which are open and operating or where leaks occur, due to the change is spinner rotation as gas passes by. figure 4 is an example of the complete GLVS tool string run in memory mode.

Figure 3—Production Logging Tool Strings

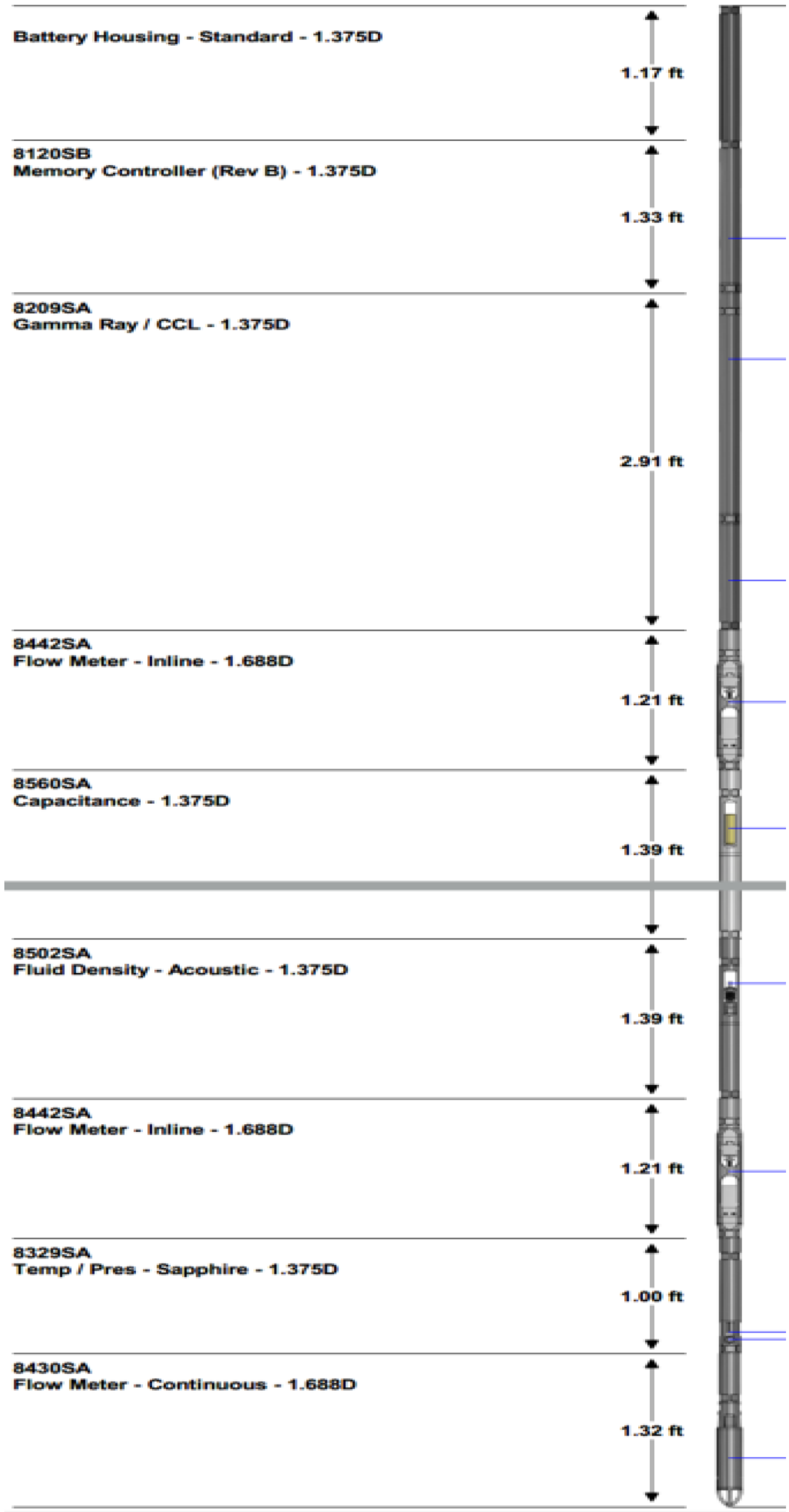


Figure 4—GLV Optimization Tool String

MFC Calipers

Operators wanting to scan their tubing, now can easily run an inspection log at the same time on the same run as a GLV survey run. Simply by adding a MFC Caliper on the same GLVOS run to inspect their tubing if any corrosion issues are occurring. A GLVOS survey is run in hole while the well is flowing / lifting. When the tools reach the end of tubing a BHP stationary survey is collected. The will is then Shut-in for 30 -60 minutes. The MFC Caliper opens and the GLVOS logging survey is logged out of the well in the shut-in conditions. The tubing is now scanned when POH of the well logging at a constant speed. figure 5 shows what the MFC Caliper tool look like as they open and are ready to log out of the well.

Figure 5—Caliper Logging Tool

A GLVOS consisting of slim PLT suite of tools deployed in a continuous RIH constant speed, has replaced the antiquated BHP station stops technique. This tool configuration with multiple measurements initially designed for reservoir analysis, easily measures many facets of the artificial lift system. figure 6 is an example of the GLVOS survey log plot.

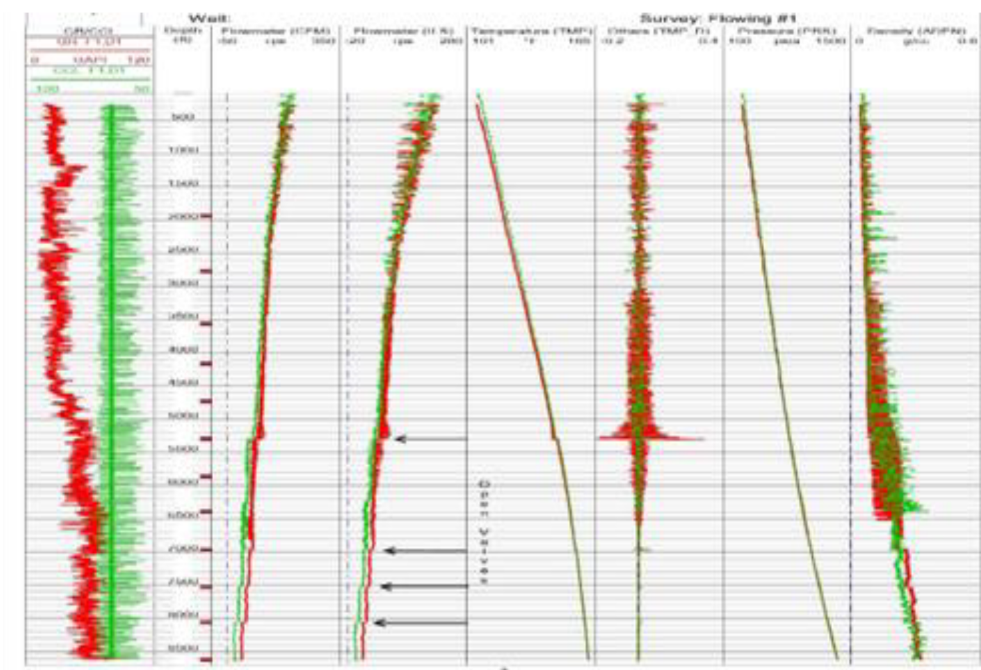


Figure 6—GLV Optimization Survey Example Plot

Case Study1

This case study example will showcase the confidence and clarity of a GLVOS deploying a PLT platform run as a gradient survey then after the shut-in survey was performed when POH a Multi-finger Caliper (MFC) is also run.

Production rates Water 9 BWPD, 306 BOPD, 1293 MCFD & Injection Gas 930 MCFD, the tubing string 2 7/8″ tubing. This well encountered lifting issues as total fluid rates had dropped off considerably.

As shown figure 7, a flowing gradient log the flowmeters are the strongest measurement the flowmeter and temperature complement each other to showcase a leak occurs ~ 3500 ft. The flowmeter measurement easily identify which valve is open and as referenced figure 8, valve 7 is open at 5217 ft.

The density measurement shows the well flows with a mixture density of gas & oil as there is no fluid level while lifting.

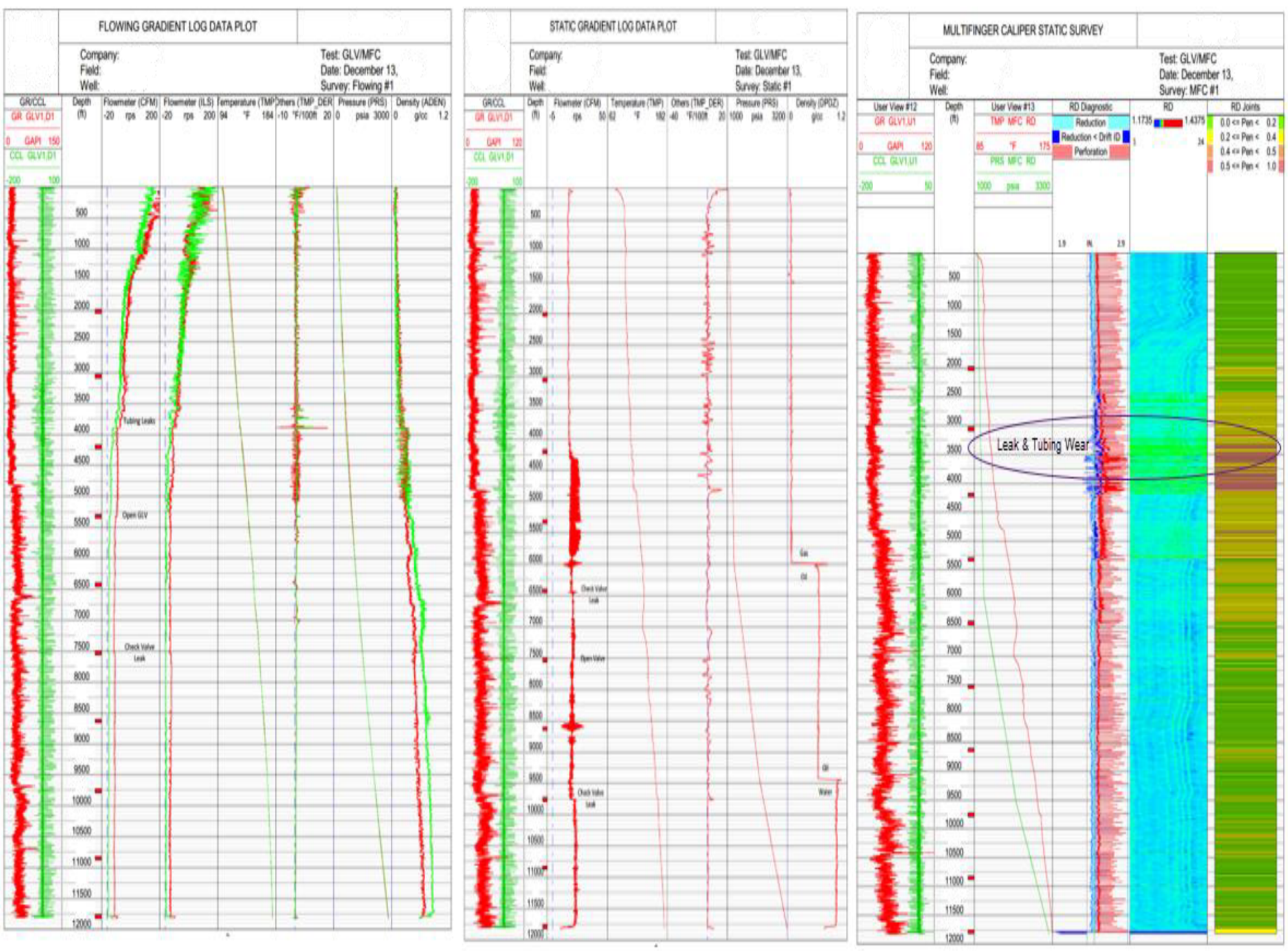


Figure 7—Case Study 1 – GLV Optimization Survey Log Plot

GAS LIFT VALVE SUMMARY TABLE											
GAS LIFT VALVE (FT)				STATUS	FLOWMETER	TEMPERATURE		PRESSURE		DENSITY
GLV	TOP		BTM.	OPEN/CLOSE	RPS	DEG F	DEG F/FT	PSI	PSI/FT	G/CC
SRF	20.0			N/A	225.4	102.0	N/A	163.7	N/A	0.08
10	2004.9	-	2009.0	CLOSED	77.9	115.6	0.007	396.4	0.118	0.15
9	3054.9	-	3059.0	CLOSED	63.7	122.3	0.007	545.8	0.150	0.16
8	4195.9	-	4200.0	CLOSED	39.0	132.1	0.009	731.5	0.168	0.31
7	5317.9	-	5322.0	OPEN	37.3	141.5	0.008	948.0	0.193	0.27
6	6422.9	-	6427.0	CLOSED	28.6	149.6	0.007	1193.9	0.223	0.33
5	7529.9	-	7534.0	CLOSED	27.1	158.5	0.008	1492.7	0.270	0.44
4	8627.9	-	8632.0	CLOSED	29.5	165.9	0.007	1816.7	0.295	0.50
3	9755.9	-	9760.0	CLOSED	29.5	172.2	0.006	2158.6	0.303	0.54
2	10846.9	-	10851.0	CLOSED	26.0	176.6	0.004	2511.4	0.323	0.63
1	11783.9	-	11788.0	CLOSED	28.3	179.3	0.003	2820.4	0.330	0.64
BTM	11807.0			N/A	38.4	179.4	0.002	2834.8	0.611	0.62

Figure 8—Case Study 1 - Gas Lift Valve Summary Table

A GLVOS also uses a surface pressure monitors shown in figure 9. The tubing pressure shows a stable lifting/flowing pressure then when the well is shut-in a pressure buildup. The gas lift gas is first shut in prior to the tubing being shut in, the casing pressure show this on figure 9 at ~ 16:30.

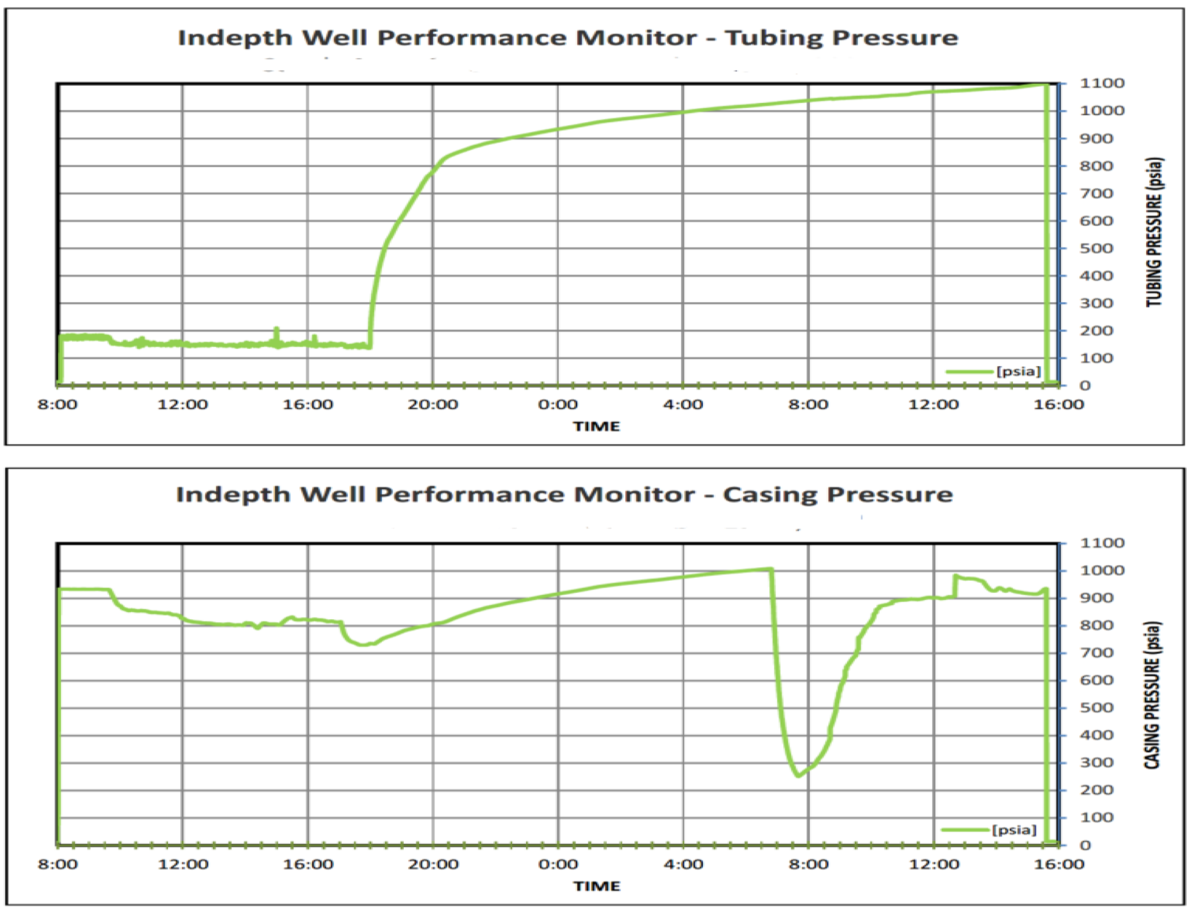


Figure 9—Case Study 1 - Well Performance Monitors – Pressure Sensors

The GLVOS also generate a flowing and shut-in pressure and temperature gradient data set as shown in figure 10. This illustration is an excellent example of what a simple bottom hole pressure (BHP) gauge survey data set would deliver. During the flowing survey there is a gradual gradient and very difficult to verify any valve which is stuck open or even where a leak would be occurring. BHP gauge surveys only rely on a pressure data set making various station stops over the depth of the wellbore. They can be erroneous in their results and do not perform at the same level of a GLVOS.

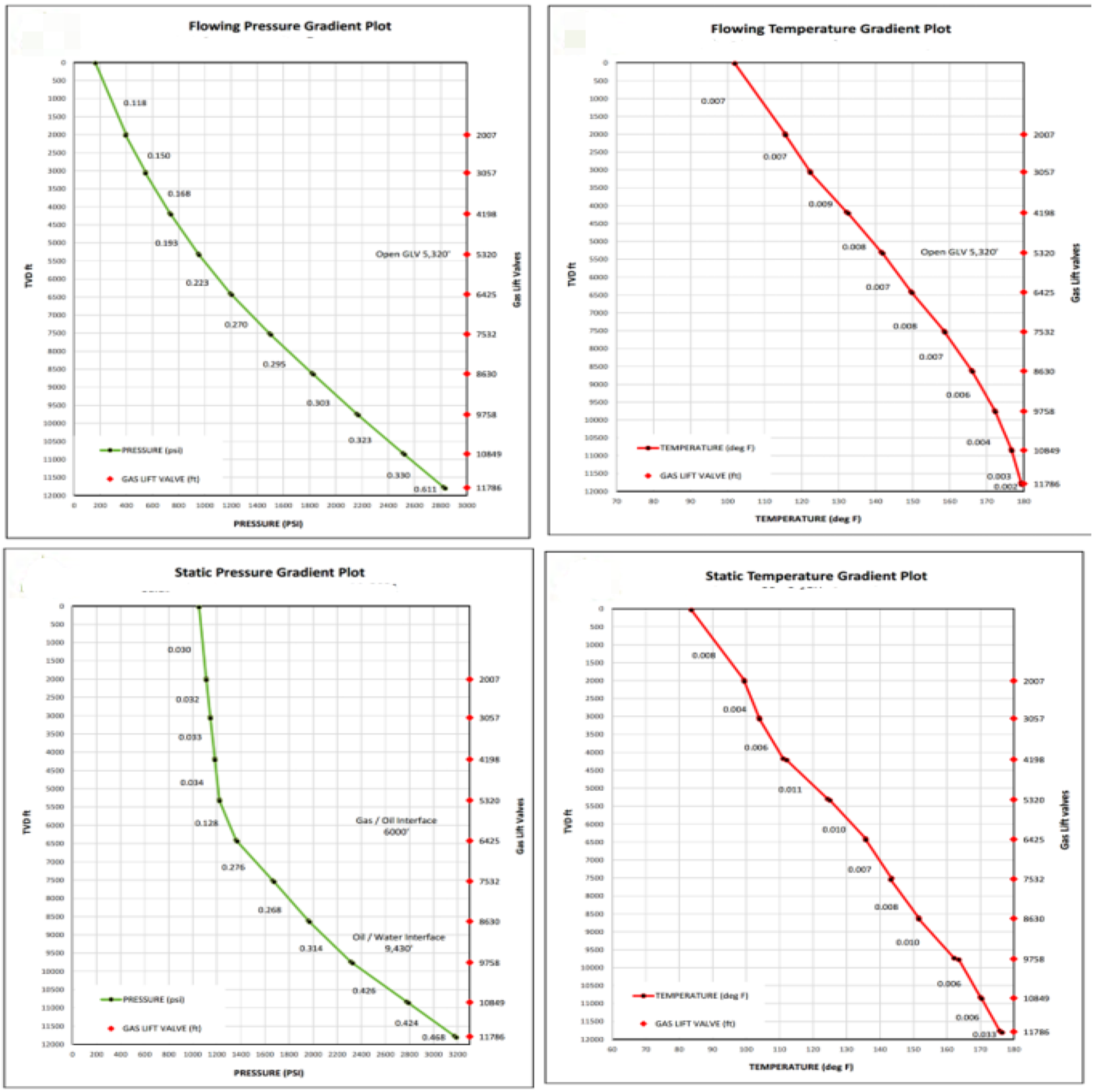


Figure 10—Case Study 1 - Flowing & Shut-in Pressure & Temperature Gradient

Case Study 2

A case study example will showcase the confidence and clarity of a GLVOS deploying a PLT platform run as a gradient survey then after the shut-in survey was performed a Multi-finger Caliper (MFC) is also run.

Production rates Water 0 BWPD, 0 BOPD, 602 MCFD & Injection Gas 605 MCFD. Tubing string 2 7/8″ tubing. This well also encountered lifting issues and no liquids were being lifted to the surface.

As shown figure 11, a flowing gradient log the flowmeters are the strongest measurement the flowmeter and on this well the temperature measurement complemented each other to showcase a leak occurs ~ 2446 ft. The flowmeter measurement easily identified that the gas lift gas injected down the annulus and would enter the hole in the tubing. The rapid change is volume shows a large cooling drop down to freezing temperature ~ 30 deg F. On both the flowing and the shut-in survey the fluid level is identified at ~ 2700 ft. figure 12 shows the table of the valves are closed due to the leak at 2446 ft.

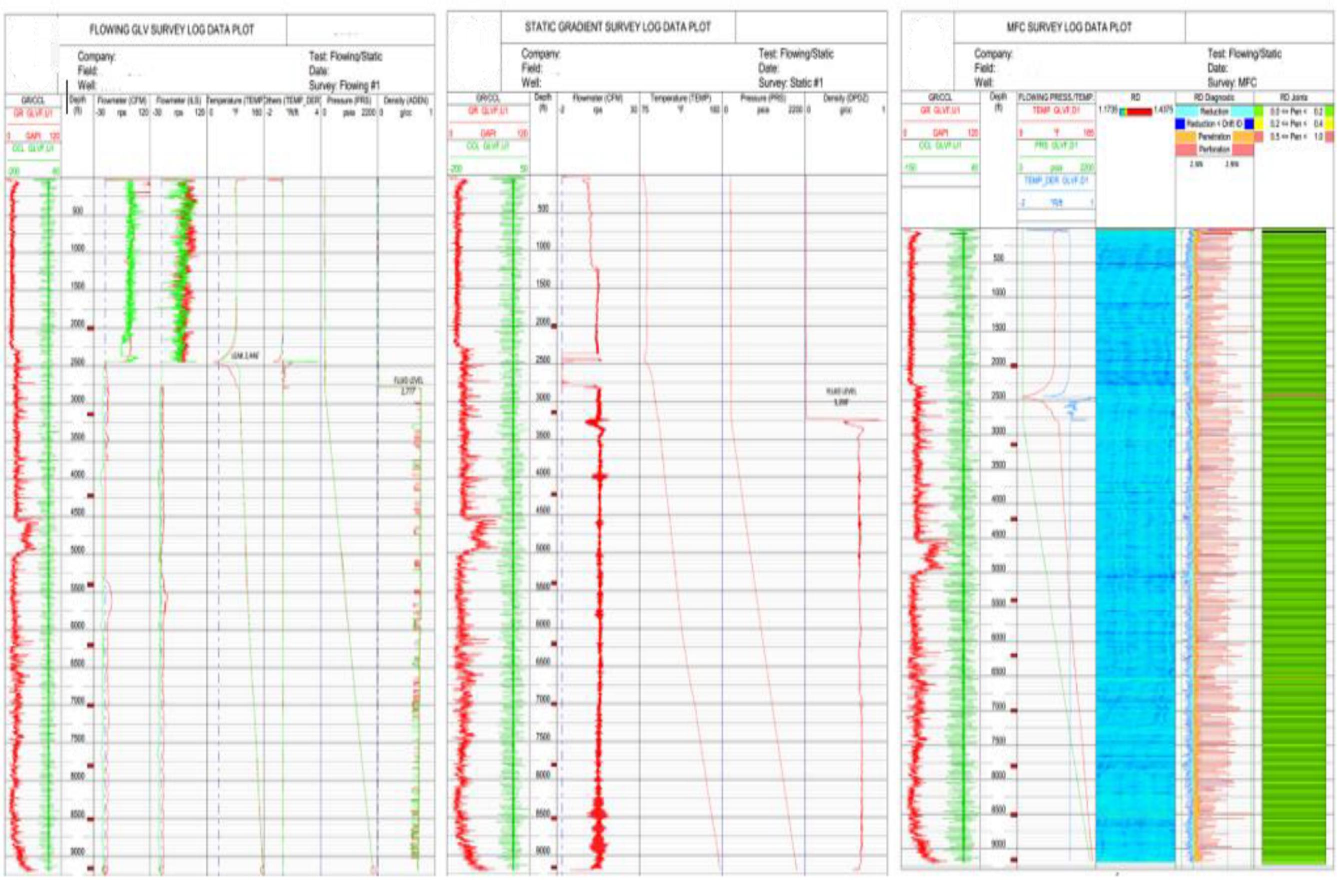


Figure 11—Case Study 2 – GLV Optimization Survey Log Plot

GAS LIFT VALVE SUMMARY TABLE										
GAS LIFT VALVE (FT)				STATUS	FLOWMETER	TEMPERATURE		PRESSURE		DENSITY
GLV	TOP		BTM.	OPEN/CLOSE	RPS	DEG F	DEG F/FT	PSI	PSI/FT	G/CC
SRF	35.0			N/A	62.8	80.5	N/A	144.4	N/A	0.01
9	1994.7	-	1998.8	CLOSED	62.5	79.5	0.000	158.1	0.007	0.01
8	3139.0	-	3143.1	CLOSED	-6.4	94.6	0.014	250.8	0.083	0.76
7	4219.0	-	4223.1	CLOSED	-7.6	103.0	0.008	561.9	0.287	0.75
6	5396.7	-	5400.8	CLOSED	-6.6	113.1	0.009	900.6	0.288	0.76
5	6197.4	-	6201.5	CLOSED	-5.2	120.6	0.009	1131.5	0.288	0.73
4	6997.9	-	7002.0	CLOSED	-6.2	131.4	0.014	1364.9	0.292	0.75
3	7800.9	-	7805.0	CLOSED	-5.3	141.4	0.012	1604.4	0.298	0.72
2	8508.0	-	8512.1	CLOSED	-6.2	149.3	0.011	1819.5	0.304	0.71
1	9160.0	-	9164.1	CLOSED	-4.9	157.1	0.012	2012.3	0.295	0.71
BTM	9206.0			N/A	-5.2	157.4	0.008	2027.7	0.309	0.70

Figure 12—Case Study 2 – GLV Optimization Survey Table

A GLVOS also uses a surface pressure monitors shown in figure 13. The tubing pressure shows an unstable lifting/flowing pressure then when the well is shut-in the tubing & casing pressure are equal. The gas lift gas is first shut in prior to the tubing being shut in, the casing pressure show this on figure 13 at ~ 19:00

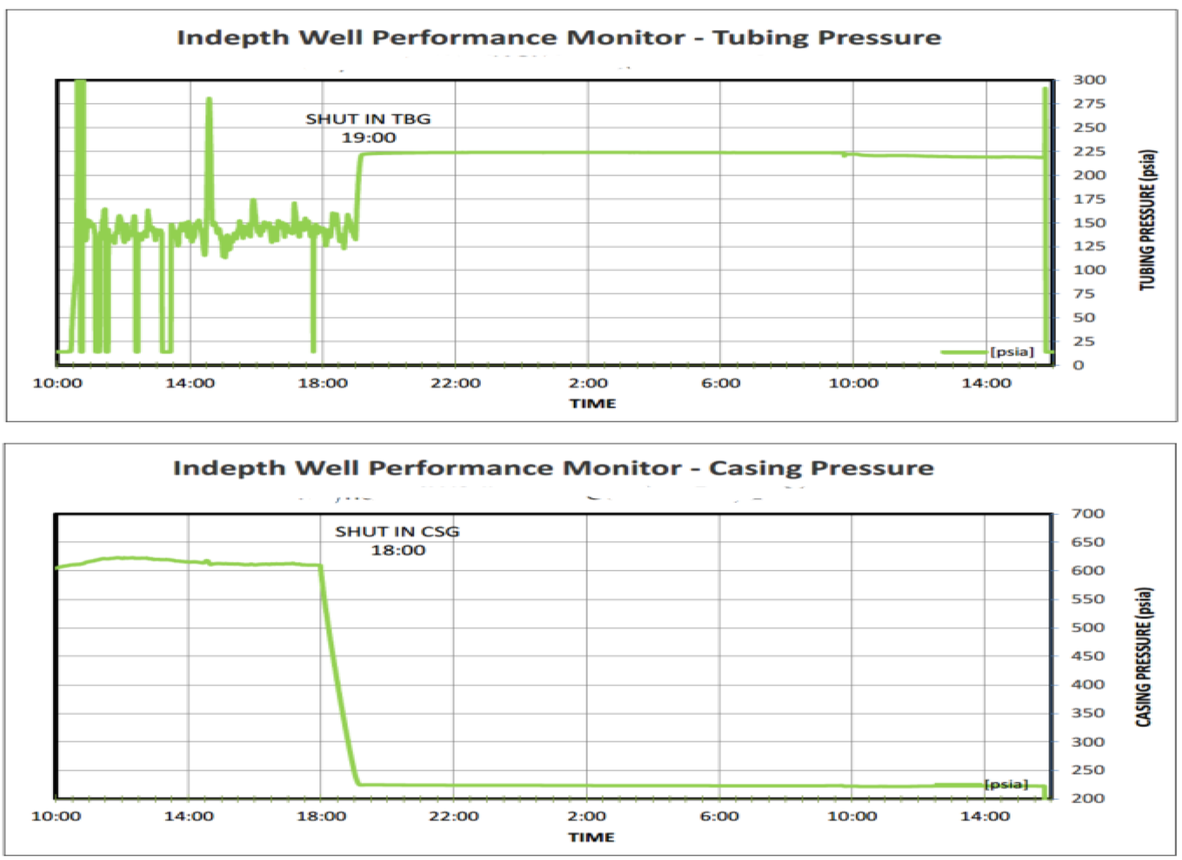


Figure 13—Case Study 2 - Well Performance Monitors – Pressure Sensors

The GLVOS also generate a flowing and shut-in pressure and temperature gradient data set as shown in figure 14. This illustration is an excellent example of what a simple bottom hole pressure (BHP) gauge survey data set would deliver. During the flowing survey there shows a gas gradient and can be difficult to verify any valve which is stuck open or even where a leak would be occurring. The apparent fluid level is below 2700 ft the gradient changes to a water gradient. BHP gauges surveys only rely on a pressure data set making various station stops over the depth of the wellbore. They can be erroneous in their results and do not perform at the same level of a GLVOS.

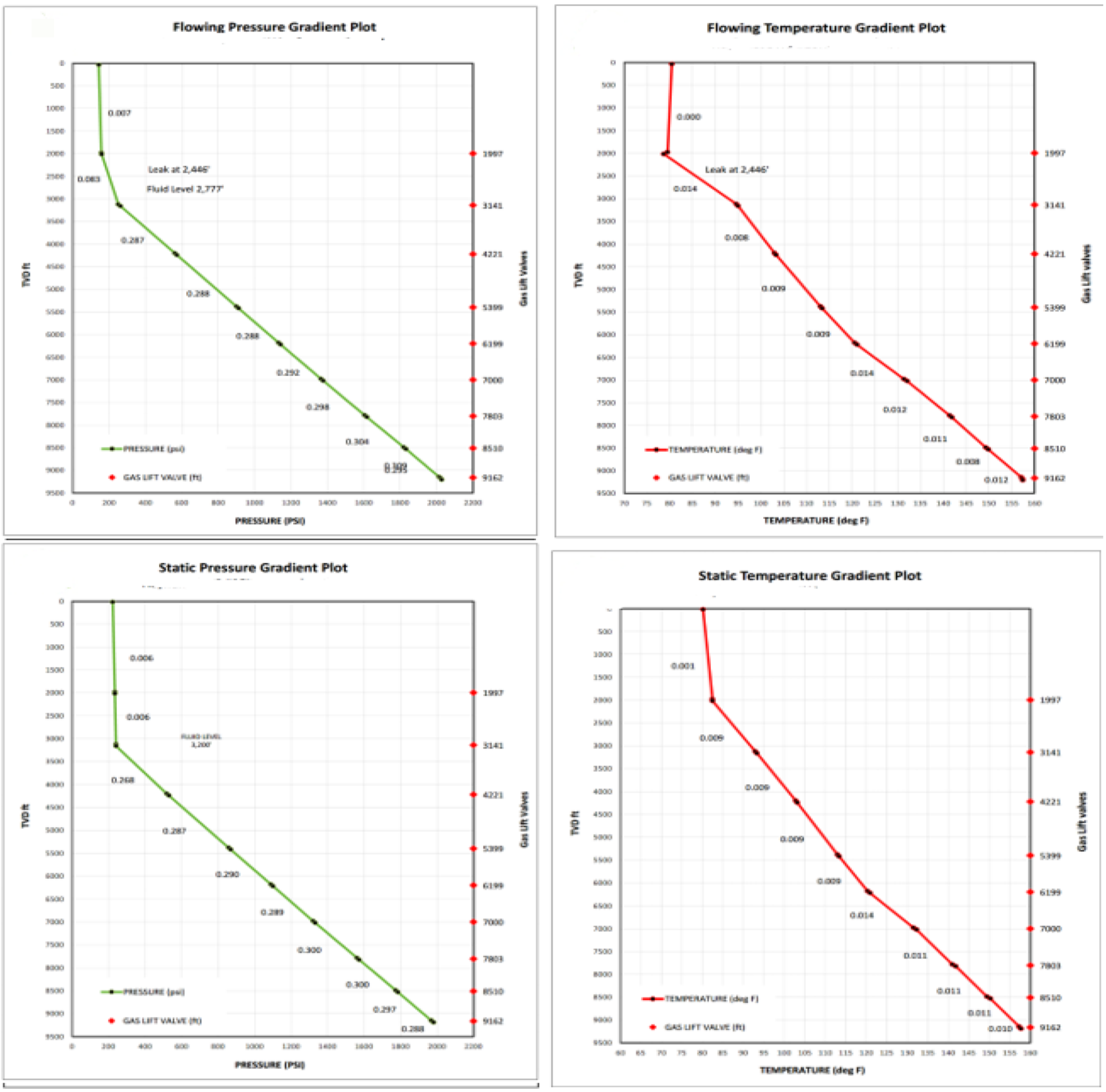


Figure 14—Case Study 2 - Flowing & Shut-in Pressure & Temperature Gradient

The Multi-finger Caliper (MFC) tools run in tubing measures with 24 fingers the internal of the tubing walls. The surveys will calculate a min & max penetration, the software grades each joint for wear. In this case study the MFC was able to measure and determine there was a small pin hole leak below the collar. figure 15 and figure 16 illustrates the tubing wear analysis, and the small pin hole leak is averaged to have ~ 55% penetration.

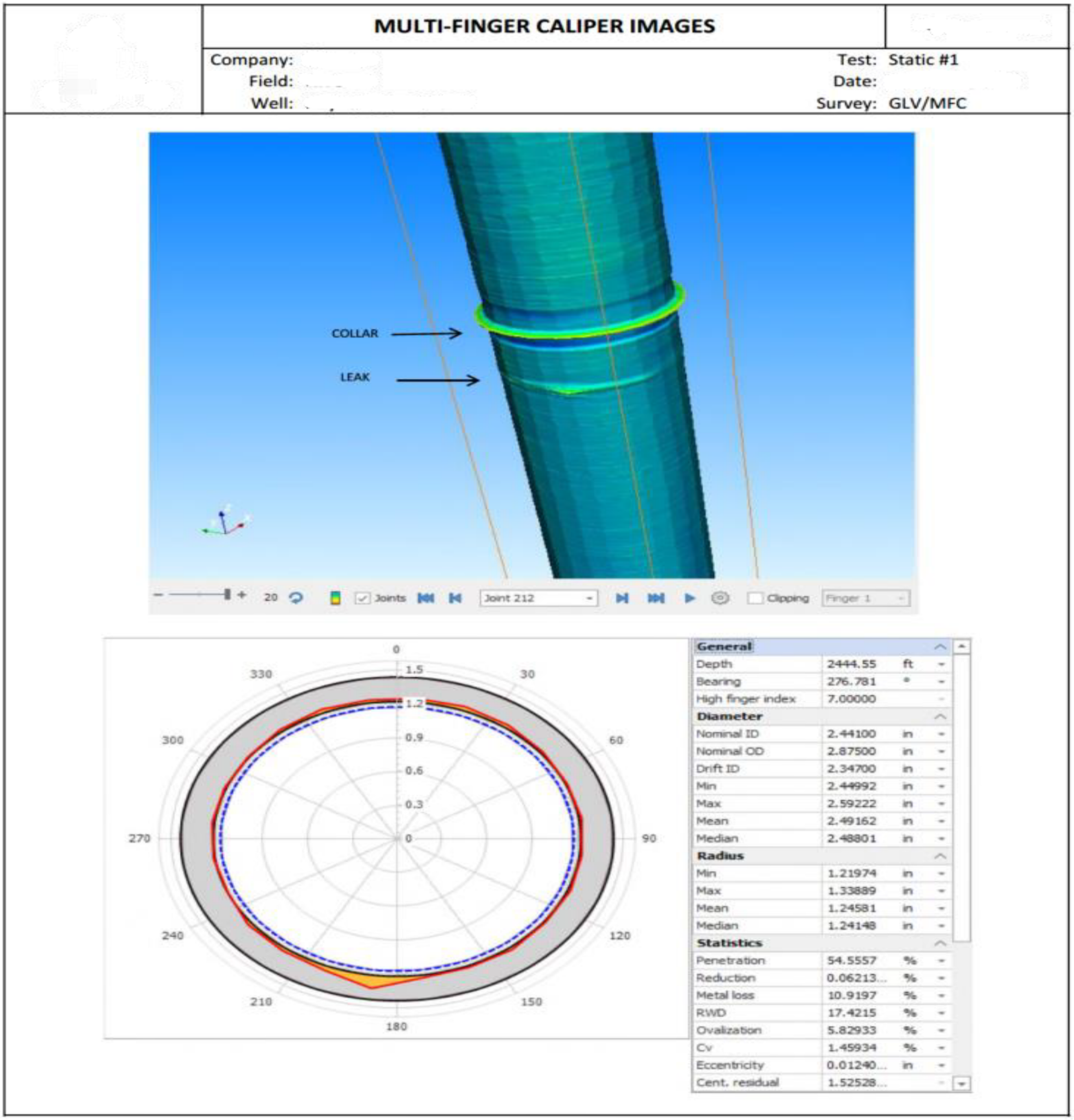
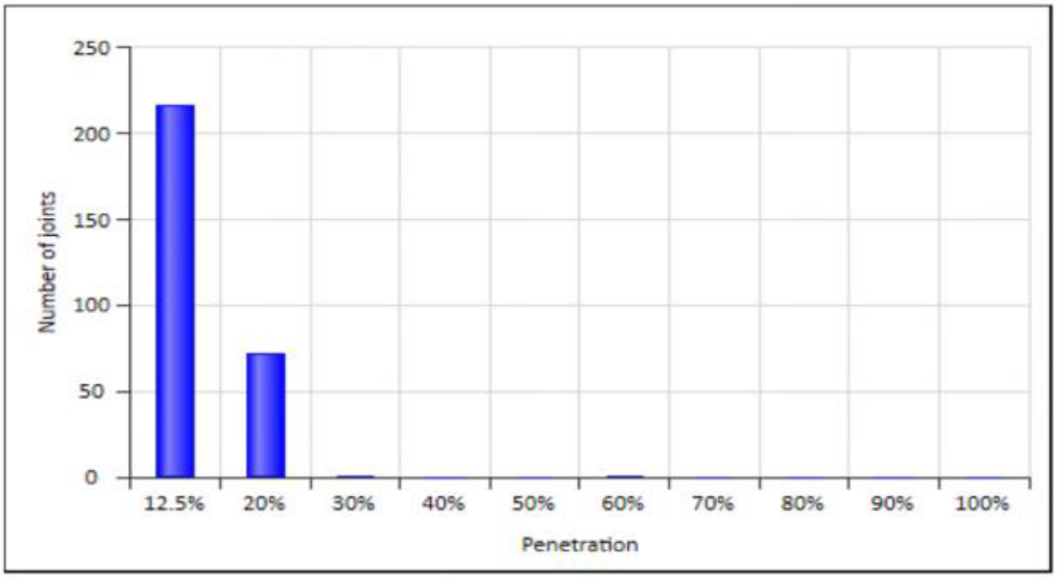


Figure 15—Case Study 2 – MFC Caliper Log Analysis GLV Optimization Survey



Penetration range	Number of joints
0% - 12.5%	216
12.5% - 20%	72
20% - 30%	1
30% - 40%	0
40% - 50%	0
50% - 60%	1
60% - 70%	0
70% - 80%	0
80% - 90%	0
90% - 100%	0
Total	**290**

Max. penetration	Depth
%	ft
54.56%	2410.55

Figure 16—Case Study 2 – MFC Caliper Log Analysis Joint Wear Analysis

Conclusion

The advantage when deploying this PLT - GLVOS platform, the amount of data acquired helps determine a very clear/accurate result that can assist the production engineering team to help design an efficient artificial lift system to ultimately gain more production. This style of PLT - GLVOS platform samples ~ 2,000 to 2500 samples per joint of tubing (depending on logging speeds) and can easily identify all the leaks and GL issues. The easy of adding in a MFC to the platform and making a simple log while performing the GLVOS at the same time gathers additional data to help with the diagnosis. This PLT – GLVOS & MFC delivers a high confidence gas lift valve optimization survey result you can trust.

Nomenclature

GLVOS – Gas Lift Valve Optimization Survey
PLT – Production Log Technology
GL – Gas Lift
GLIR – Gas Lift Injection Rate
BHP – Bottom Hole Pressure
BHT – Bottom Hole Temperature
OD – Outside Diameter

FT	– Foot
MFC	– Multi-finger Caliper
POH	– Pull out of hole
RIH	– Run in Hole
CCL	– Casing Collar Locator
TD	– Total Depth
Max.	– Maximum
Deg F	– Temperature in Fahrenheit
PSI	– Pressure in pounds per square inch
PRES	– Pressure
Temp	– Temperature
MMCFD	– Million cubic foot per day gas rate
MCFD	– Thousand cubic foot per day gas rate
Bwpd	– Barrel of water per day rate
Bopd	– Barrel of oil per day rate

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Biography

Duncan Heddleston holds a Petroleum Engineering Degree from the University of Alberta & earned an MBA Degree from Phoenix University as well as MBA Marketing from Caltech. In 2006 Mr. Heddleston created & founded Indepth Production Solutions, previous positions as the Global Manager for Baker Hughes Wireline head of the Specialty Cased Hole Logging product lines focused on production logging, over saw worldwide projects and was involved in building new technologies and data analysis packages for the industry. Mr. Heddleston has presented over 10 technical publications throughout the industry and is regarded as an industry subject matter expert in specialty cased hole & production logging services.