THE CASE STUDY OF MEASURING THE ERROR IN GAS LIFT VALVE TEMPERATURE AND PRESSURE DURING DEVELOPMENT PHASE IN TUBULAR GAS LIFT SYSTEM THROUGH SLICKLINE

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ABSTRACT

The temperature allocation along the well plays a crucial role in the design performance and troubleshooting analysis of gas-lifted wells. The temperature of injection gas at each valve depth should be well-known to establish the gas flow rate spread across every valve. As gas temperature across the valve and production fluid temperature will be utilized to evaluate nitrogen pressure inside the bellow of the valve. Therefore, the temperature is the main factor in evaluating nitrogen-charged gas lift valve closing and opening pressures.

In this case study, real-time measurement of temperature pressure is done through the RTD Quartz sensor in a flowing gas lift well through a wireline. It has a completion with the 2-7/8" tubing in 5-1/2" casing with a packer, with 8 12 port IPO gas lift valves in conventional mandrels with a chemical screen below that. The new survey measured temperature and pressure across each valve in the current flowing condition are lower than the temperature used in calculating Pvc (gas closing pressure at depth) and OP (valve opening pressure at depth) of each gas lift valve. The new temperature was used to evaluate the temperature correction factor, which is then used to update Pvc and OP to justify that every gas lift valve will have new surface controls (surface opening: Pso and surface closing pressures: Psc).

Once the error in the Dome/bellows pressure originated by estimating a temperature profile lower than the actual value is evaluated, we simulated the error caused by over-estimation of the temperature profile so that we can be ready for wells with higher water cut and high liquid velocity. The accurate temperature measurement at each valve eliminated the prediction process of injection gas and valve temperatures through Shui's correlation. Also, it helped in finding favorable conditions to prevent paraffin, asphalt, hydrate, and scale creation in late times in the production tubing.
A systematic approach of updating the surface closing and opening pressure gives operational insights into what was wrong with the gas lift operating envelope. Adjustments were made to pressure production traverse curves based on new conditions using GLDP (gaslift design program). After implementing new conditions backed by the well's data, the production of the well improved and prevented a possible work-over job.

INTRODUCTION

Gaslift valves are nitrogen-filled valves installed in production string at several depths based on the well's intrinsic parameters. The nitrogen pressure filled in these valves (in the laboratory) is directly proportional to the temperature. If the temperature downhole changes then the pressure responsible for opening and closing the valve also changes. The temperature distribution along the well, during the unloading process, and in regular operation plays a vital role in the design and troubleshooting analyses of gas lift wells. To calculate the injection gas pressure at depth, its temperature along the entire length of the well must be known.

Also, nearly all gas flow equations need gas temperature; therefore, viable gas flow rate calculations through each valve gas injection temperature is required.

The temperature used in the multiphase flowing gradient calculation is also critical, and there is a need to ensure that unrealistic assumption has not been utilized for calculating production fluid temperatures.

There are a number of methods that are taken as options in evaluating valve temperature, which are currently being used in the market or provided by commercially available GLDP (gaslift design program) software. The following are some of them:

1. Taking the valve temperature equal to geothermal temperature (varies according to the valve being open or close, that's why not recommended)
2. Taking the valve temperature equal to the production temperature at the valve's depth when the unloading has been completed.
3. Taking the valve temperature equal to the gas injection temperature (few correlations estimate the gas injection pressure to be equal to the geothermal temperature adding the difference between geothermal temperature and production temperature.
4. Equal to the production temperature of the fluids rigorously determined using the equilibrium curve concept at each unloading valve.

As all the methods have been discussed, the approximations will add weight to the problem, and measuring the dynamic valve temperature in the gaslifted well, which is flowing, is required. That's why gas lift valve temperature, and pressure at every valve depth in flowing condition needs to be measured through slickline.

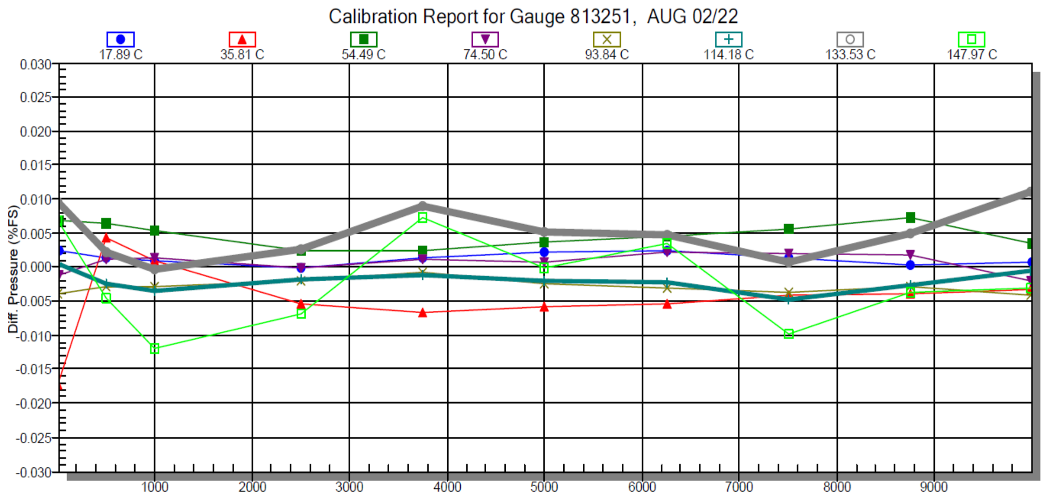
METHODOLOGY

As there is already a gas lift design in our well, we will be examining the current well parameters such as well type, deviation and completion type. This well is producing through a 2-7/8" tubing in 5-1/2" casing with a packer. The well is producing through a tubular gaslift with 8 12 port IPO gas lift valves with a chemical screen below it. As we are measuring the presssure and temperature at each valve of the flowing well therefore, the gauge type and claiberation is very important.

Gauge Conformance and calibration

Some P/T (Pressure/Temperature) gauges have higher relaxation time which means that the time they encounter the P/T reading in the well is not equal to the time at which they register it going against or with the flow. Due to this reason, sometimes the wireline operator stops the gauge at and below each valve to allow gauges to adjust themselves for the next dynamic reading. The gauge we used in our casestudy is RTD(Resistance Temperature Detector), and didn't need any stop time to compensate for the delay in recording the readings.

However, the gauge must be calibrated for several temperature and pressure test charge readings in the shop. The calibration data set for our RTD gauge which was used in our case study can be shown in Figure # 1.



GAUGE NUMBER: 813251

2-D POLYNOMIAL LMS CURVEFIT

Source of f:	Pres	Temp	Pressure Equation:
Fit Order:	3	4	Pressure (PSI) = A + xp(B + xp(C + xp(D)))
Prescale:	xp = m * (fp - fp0)	xt = m * (ft - ft0)	
m:	0.01	0.01	Temperature Compensation:
	fp0 = 708764	ft0 = 155801	A = A0 + xt(A1 + xt(A2 + xt(A3 + xt(A4))))
			B = B0 + xt(B1 + xt(B2 + xt(B3 + xt(B4))))
			C = C0 + xt(C1 + xt(C2 + xt(C3 + xt(C4))))
			D = D0 + xt(D1 + xt(D2 + xt(D3 + xt(D4))))

Pressure (psi) STANDARD FIT COEFFICIENTS:

0	1	2	3	4
A 13.39544244	-0.00520829495	-0.0004411343605	-2.580699692E-06	-4.457336743E-09
B 4.097646469	-0.0032893618	7.9165719E-07	4.275736609E-09	1.466911013E-11
C -1.034248081E-05	-1.20197934E-08	-7.204735117E-10	-4.67912097E-12	-1.006992181E-14
D 8.692989253E-11	-4.498913252E-12	3.521966802E-14	5.046490761E-16	1.638015081E-18

Temperature (C) STANDARD FIT COEFFICIENTS

A 17.9816338

B -0.3286481953

C 3.96320553E-05

D -1.917164244E-07

Figure 1: Pressure Gauge Certificate of Calibration

Pressure psi	Temperature Deg. C	Count (Pres)	Count (Temp)	DIFF (press) psi
13.17	17.89	708764.33	155801.00	0.24
506.89	17.88	720817.00	155825.88	0.14
1001.05	17.87	732890.00	155832.63	0.09
2501.14	17.87	769595.33	155856.50	-0.02
3751.03	17.91	800236.17	155861.88	0.14
5003.61	17.92	830979.50	155856.13	0.22
6254.71	17.94	861703.50	155830.38	0.23
7504.68	17.90	892441.17	155811.88	0.14
8753.75	17.94	923163.83	155777.00	0.03
9996.99	17.94	953751.67	155731.00	0.08
13.16	35.81	708733.17	150405.88	-1.72
506.87	35.82	720330.33	150402.00	0.43
1001.03	35.83	731890.17	150420.88	0.10
2501.12	35.84	767040.33	150450.88	-0.53
3751.01	35.87	796370.83	150438.13	-0.66
5003.60	35.86	825830.50	150453.50	-0.58
6254.69	35.90	855268.00	150439.75	-0.54
7504.67	35.83	884714.50	150426.38	-0.42
8753.73	35.92	914120.00	150382.38	-0.38
9996.98	35.86	943443.33	150359.50	-0.33
13.17	54.49	708818.17	144871.38	0.68
506.88	54.52	719884.17	144885.63	0.65
1001.04	54.51	730967.33	144895.88	0.54
2501.13	54.46	764668.50	144935.25	0.25
3751.02	54.53	792785.00	144918.25	0.25
5003.60	54.50	821028.50	144936.88	0.36
6254.70	54.56	849244.00	144915.88	0.46
7504.68	54.49	877495.67	144920.50	0.55
8753.74	54.62	905681.17	144867.38	0.74
9996.99	54.51	933841.50	144877.50	0.36
13.17	74.50	708818.17	139157.63	-0.13
506.87	74.54	719425.17	139164.25	0.12
1001.04	74.54	730046.50	139177.88	0.15
2501.13	74.51	762329.17	139197.63	0.00
3751.00	74.55	789276.67	139200.00	0.11
5003.58	74.52	816330.67	139215.63	0.07
6254.67	74.56	843369.00	139199.25	0.23
7504.65	74.49	870437.67	139206.50	0.21
8753.70	74.60	897457.83	139167.13	0.18
9996.95	74.53	924431.83	139171.63	-0.20
13.15	93.84	708816.17	133866.00	-0.39
506.86	93.81	719010.00	133872.00	-0.29
1001.03	93.86	729220.33	133886.00	-0.29
2501.12	93.83	760262.17	133909.25	-0.20
3751.00	93.87	786169.50	133911.00	-0.08
5003.58	93.83	812177.17	133928.25	-0.23

Figure 2: Temperature and Pressure Test Points

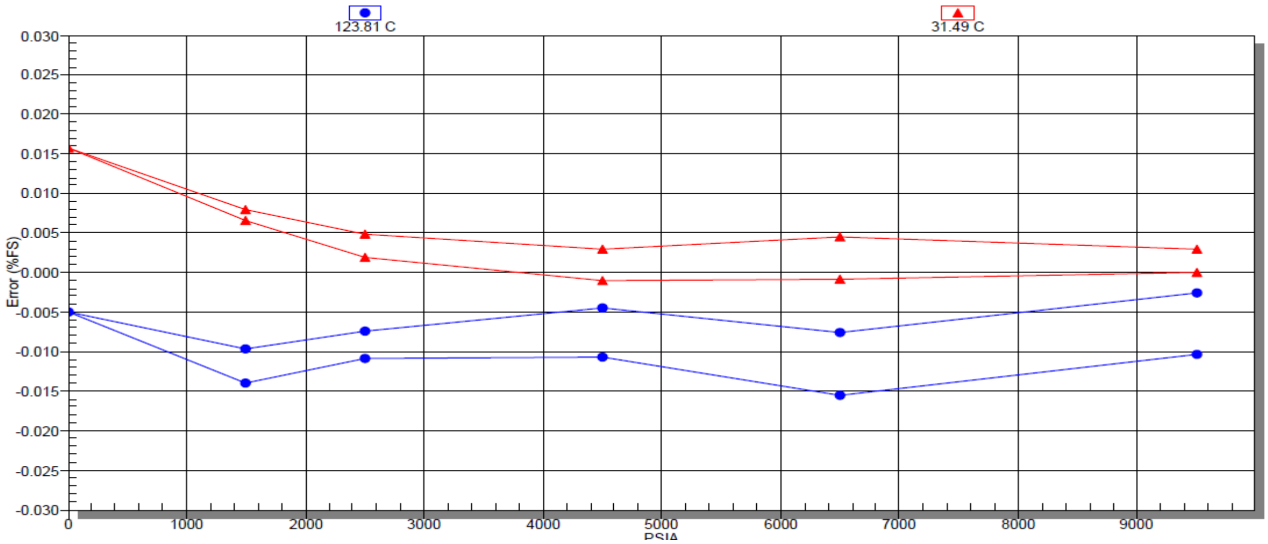


Figure 3: Pressure Gauge Certificate of Conformance

As shown in the graph above, this Gauge conformed to within +/- 0.030 %F.S. of the pressure standard used in calibration, which is accurate to within +/- 0.01% of reading. This gives an overall accuracy of +/- (0.030%F.S. + 0.01% of reading).

Slickline survey capturing the problematic conditions of well.

There is a decline in liquid production hence acquiring the P/T reading at each valve is integral to recording the problematic well conditions. The survey must be run on the well in as-is conditions with no choke management in play. Also, gas injection pressure and rate should be consistent and should be equal to the value which was giving the problem of compromised liquid rate production. This will help maintain the survey's integrity and help monitor the actual temperature and pressure in the latter times of the unloading process. Also, the preferred line speed of the wireline job for recording and sampling must be around 75 ft/min consistent during down-pass and in up-pass.

Discussion on survey results

After analyzing Figure 4, Figure 5 and Figure 6 we can say that there is a cooling effect @ 5218ft during both the runs (i.e., down-pass & up-pass) which is giving indication, that GLV # 4 is injecting gas. Also, there is some differential and gradient change at 6742ft, indicating GLV # 2 is injecting gas. As identical P/T signatures at similar depths during both runs are very important. It looks like the well is filled up to 5218ft with liquid phase as the pressure is very consistent and almost has a unit slope.

A recommended strategy is a survey run immediately after valve installation, which will serve as a baseline for future comparison and as a method to evaluate valve design efficiency using the current survey. As Joules-Thompson cooling effect comes into play in survey readings where if gas pressure changes, temperature changes with it. And if the total pressure drop was achieved in one stage, that may cause hydrates to form in a flowing medium. Also, to determine the lift point, it is necessary to observe the cooling behavior in both runs at a similar depth.The tool stopped at a depth of 7550ft collecting all the downhole logging parameters at this depth for 30minutes. Gas Lift injection pressure recorded during this survey averaged 350 psia with a flowing tubing pressure of 120 psia. Data was put on depth to the last lift station and the remaining valve depths were confirmed by the logging tool.

The new pressure and temperature will be the foundation for the simulations.

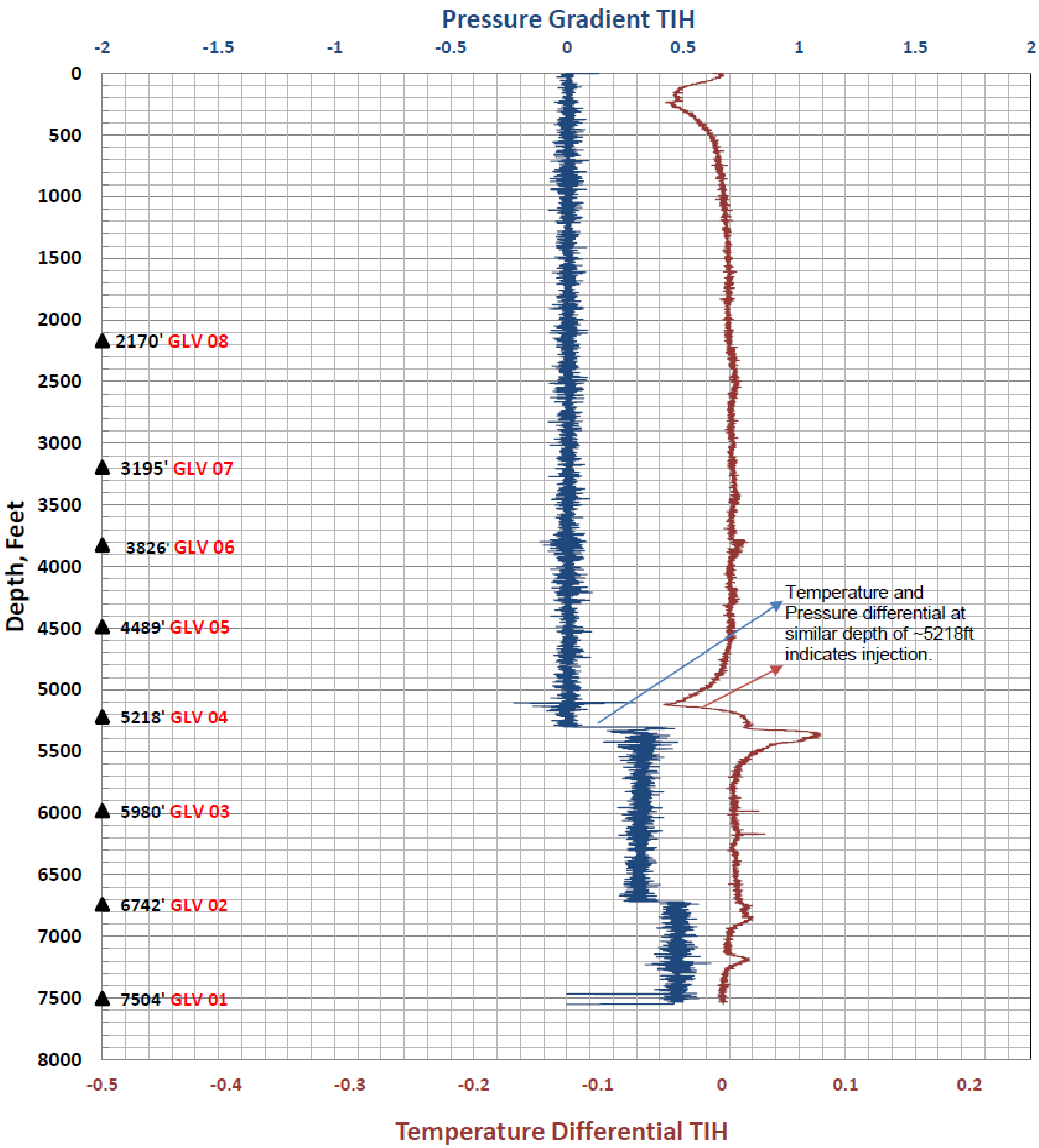


Figure 4: Pressure Gradient and Temperature Differential Plot (Down-Pass)

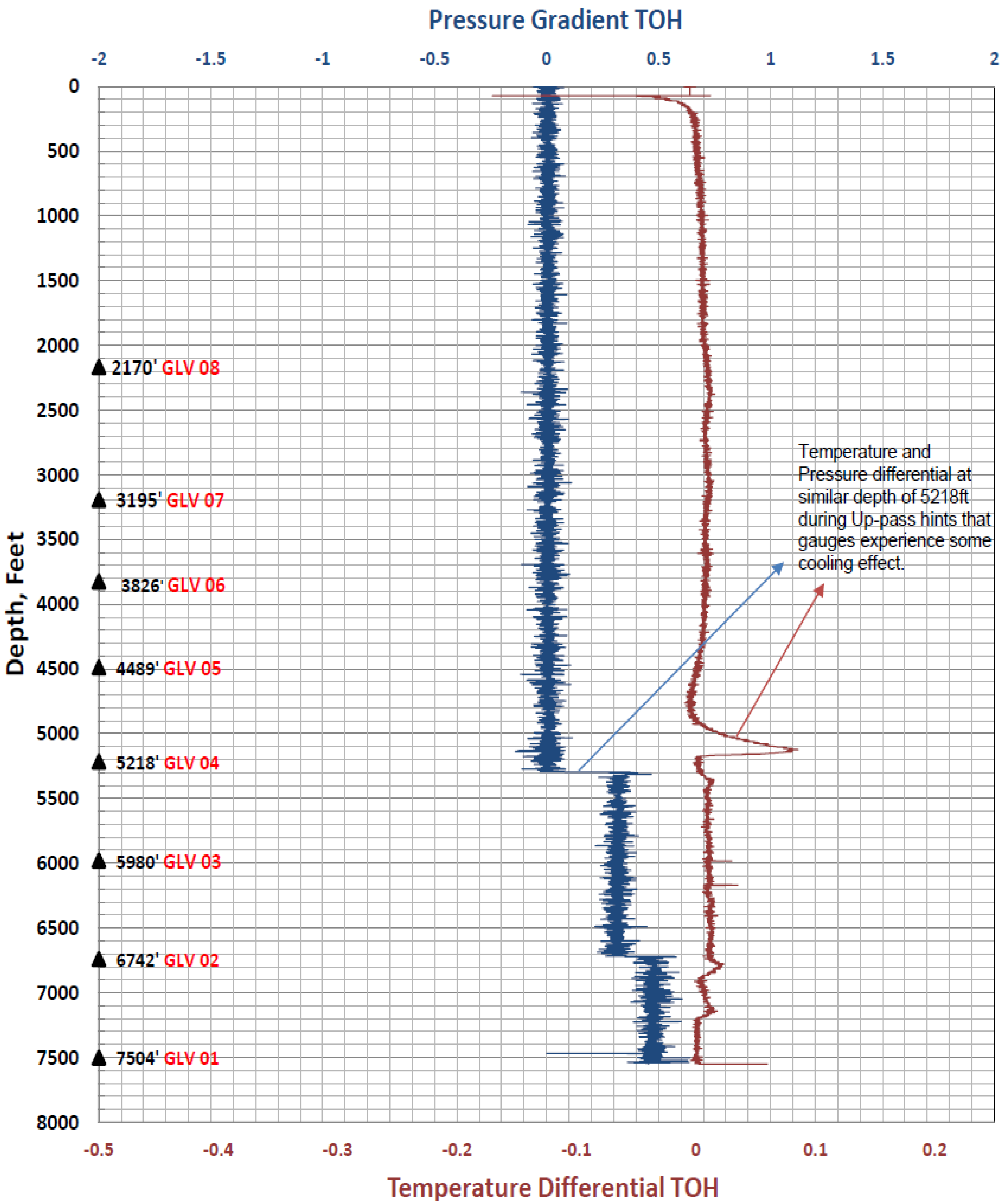


Figure 5: Pressure Gradient and Temperature Differential Plot(Up-Pass)

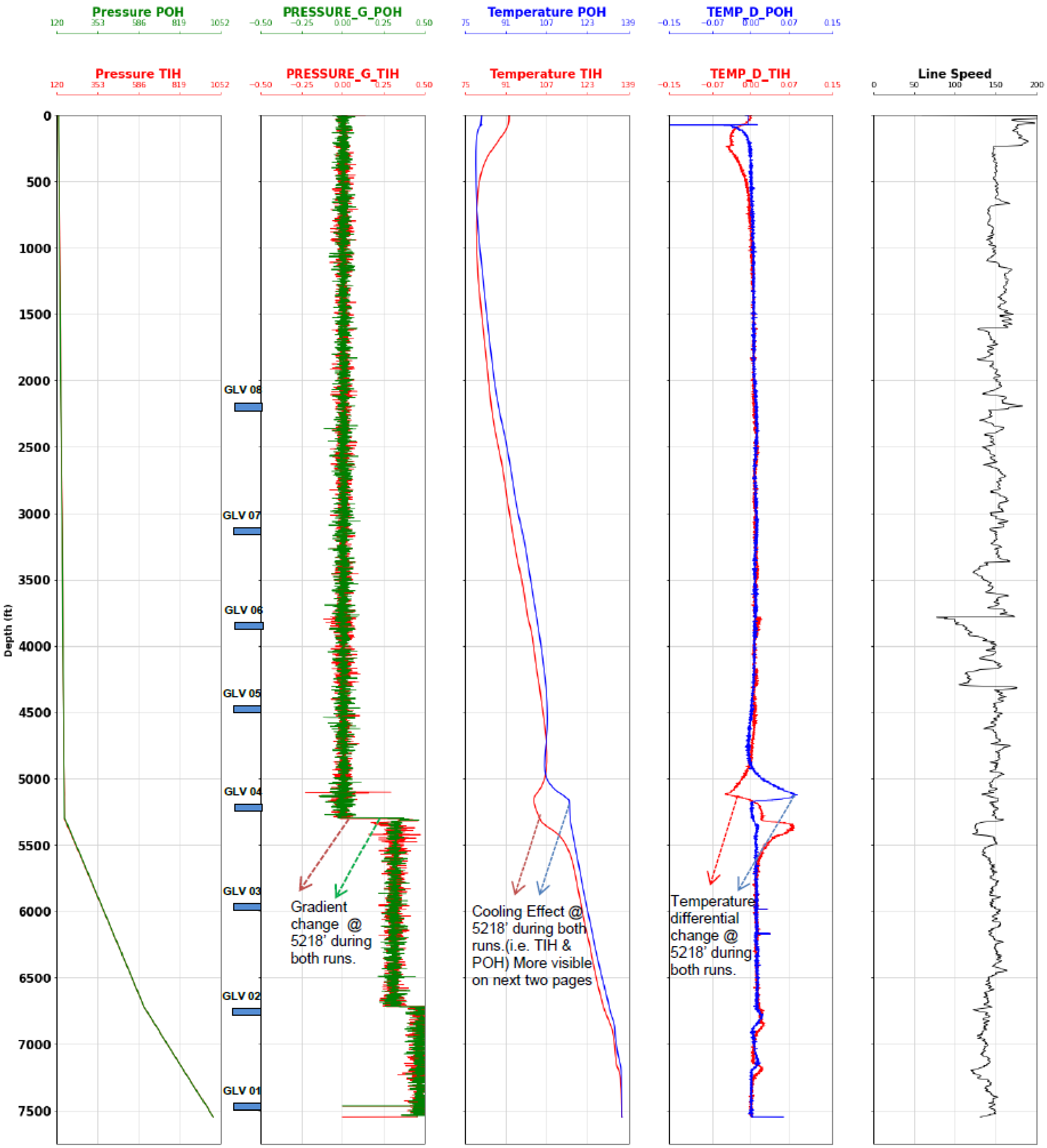


Figure 6: Gas Lift Survey Integrated Plot

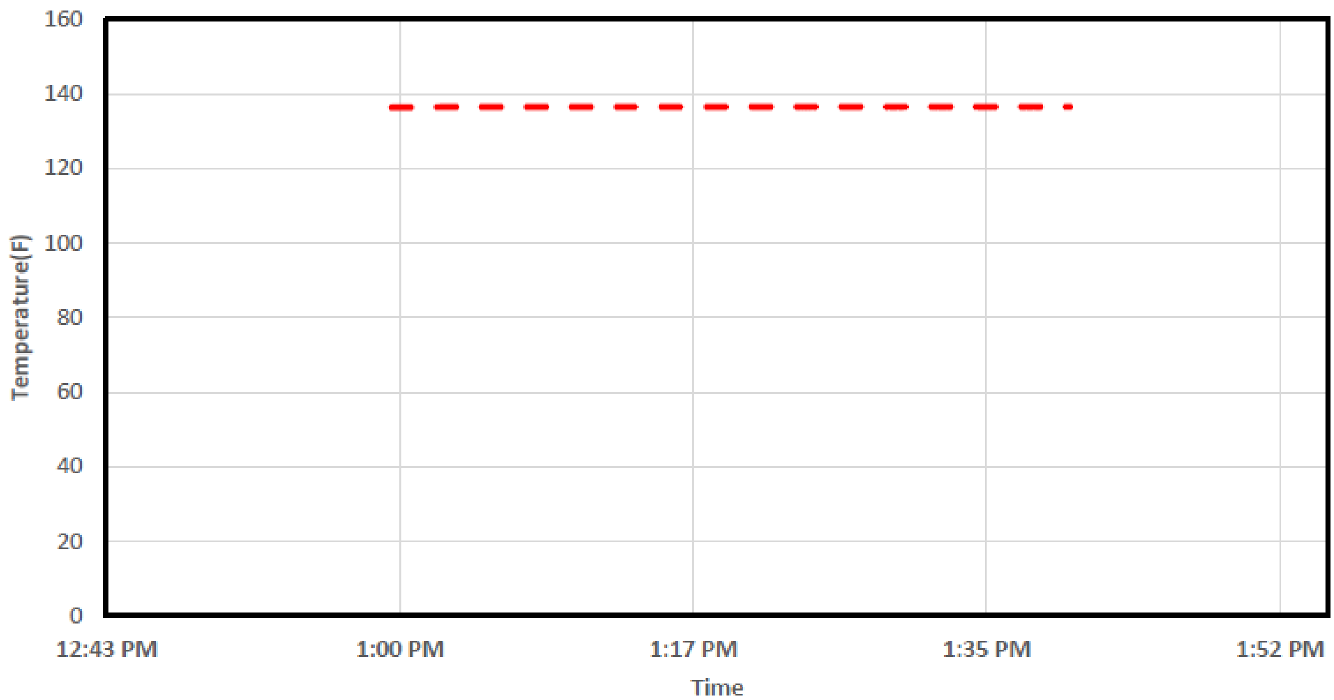


Figure 7: On-Bottom Temperature

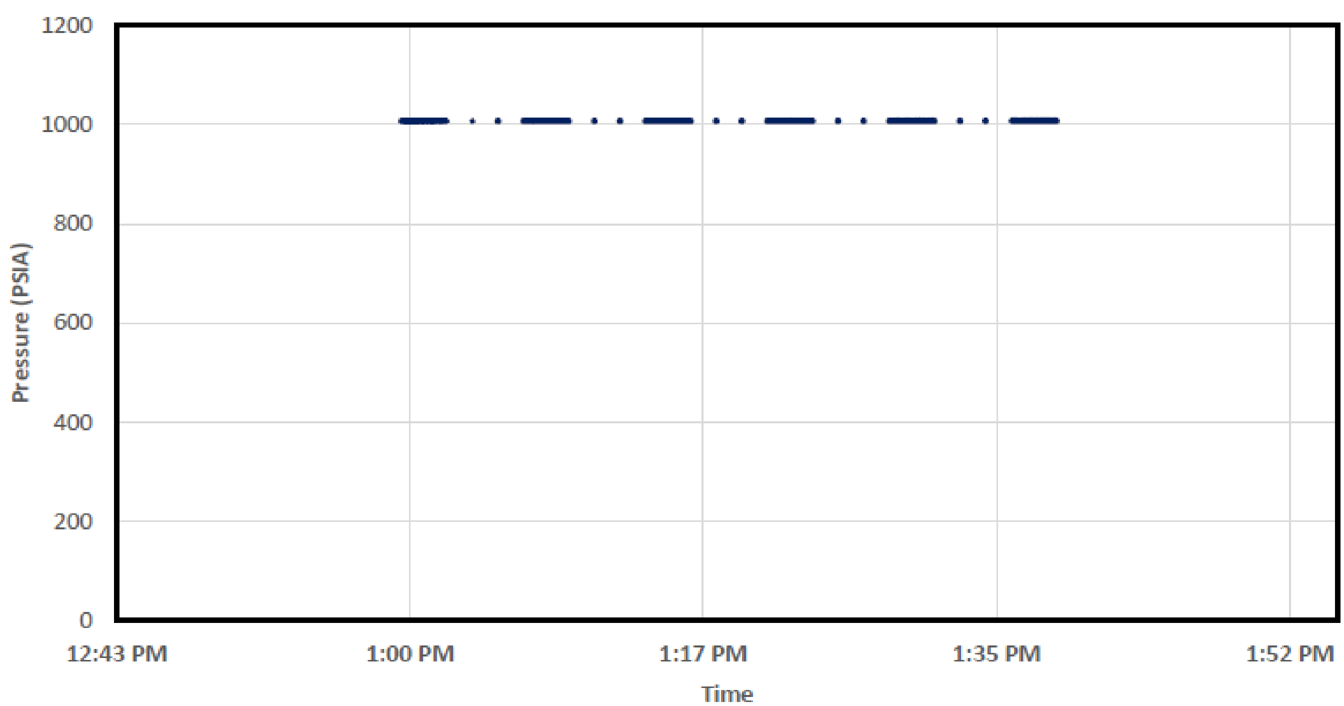


Figure 8: On-Bottom Pressure

Comparative analysis between the gas lift design and P/T survey

We will now compare the survey-measured pressure and temperature at each valve depth with the P/T points assumed in the gaslift design for troubleshooting and analysis. Below is the comparative analysis between the gas lift design and P/T survey on our well .

Gas Lift Valve	MD	TVD	Temperature		Pressure		Line speed
GLV #	(ft)	(ft)	(°F)	(°F/ft)	(psi)	(psi/ft)	(ft/min)
GLV 08	2171	2170	85.17	0.008	143.64	0.041	154.00
GLV 07	3196	3195	94.05	0.008	151.29	-0.004	165.00
GLV 06	3827	3826	100.12	0.013	154.62	-0.040	170.00
GLV 05	4490	4489	105.39	0.008	158.55	0.064	150.32
GLV 04	5219	5218	102.55	0.018	162.86	0.012	151.96
GLV 03	5981	5980	120.79	0.012	382.85	0.329	149.20
GLV 02	6743	6742	129.61	0.017	627.16	0.512	149.99
GLV 01	7505	7504	136.26	0.001	989.76	0.397	121.21

Figure 9: Slickline measured temperature and pressure at each valve

GLV#	TVD	Port	R	TV	TCF	OP	PSC	PVC	PSO	PTRO
		size		°F		psi	psi	psi	psi	
8	2300	3/16"	0.094	123	0.873	1276	1156	1232	1200	1190
7	3300	3/16"	0.094	129	0.863	1275	1136	1248	1163	1190
6	3900	3/16"	0.094	132	0.858	1279	1116	1250	1144	1185
5	4550	3/16"	0.094	136	0.851	1285	1096	1254	1127	1175
4	5250	3/16"	0.094	140	0.845	1292	1076	1259	1109	1170
3	6000	3/16"	0.094	143	0.840	1299	1056	1266	1089	1165
2	6750	3/16"	0.094	147	0.835	1305	1036	1273	1069	1160
1	7500	3/16"	Orifice	150		1217				

Table 1: Currently installed gaslift design

If we choose the second last valve (GLV # 2) for analysis, the survey exposed that the current flowing temperature is much lower (circled in blue) than the design-based temperature (from Shui correlation circled in red).

The new lower temperature, when substituted in the temperature correction equation, will give a greater TCF_{new} value as:

$$TCF_{(new)} = 1.023\left[\frac{1}{1 + 0.0021\left(T_{flowing\ @valve((147\ to\ 136)°F)} - T_{testrack(60°F)}\right)}\right] - 0.025$$

$$TCF_{(new)} = \ 0.857\ (original\ 0.835\ circled\ in\ purple\ in\ above\ picture)$$

This increase in temperature correction factor will decrease gas closing pressure at valve depth as:

$$P_{vc(new)} = \frac{P_{b60}}{TCF_{new}}$$

$$P_{vc(new)} = \ 1226\ psi\ whereas\ design\ base\ Pvc\ is\ 1273\ psi\ circled\ in\ green\ in\ above\ picture.$$

By substituting a new lower value of Pvc_{new}, a lower opening pressure at valve depth than the predicted P_{OP} in the design will be calculated as:

$$OP_{(new)} = \frac{P_{vc(new)} - R * P_{tubing}}{1 - R}$$

$$OP_{(new)} = 1251 \text{ psi}$$

This change (decrease) in the OP with respect to design base OP will decrease the re-opening pressure of the valve at the surface as:

$$P_{so(new)} = OP_{(new)} - (P_{iod} - P_{io})$$

$$P_{so(new)} = 1051\ psi\ whereas\ design\ base\ Pso\ is\ 1069\ psi.$$

And at a given value of Ptro and Pb60, the 2nd valve at 6750ft will hang open or remain open at a pressure lower than its design base surface opening pressure. This analysis can help us understand the premature injection from the valves and the contracting nature of the bellows keeping the valve open.

By comparing table 1 and table 2, we can reach the consensus that a GL survey was required and is the only option to propose a solution according to the problem eliminating guesswork. Also, as the compressor started injecting gas just before running the survey, it looks like the well is in the state of initial unloading. New Ptro set pressures compatible with lower well productivity can be one option. Following is the table (Table # 2) with new surface controlling pressures based on new operating conditions and well productivity.

GLV#	TVD	Port size	R	TV °F	TCF	PSC psi	PVC psi	PSO psi	PTRO
8	2300	3/16''	0.094	85	0.951	384	408	425	1190
7	3300	3/16''	0.094	94	0.935	364	400	387	1190
6	3900	3/16''	0.094	100	0.924	344	387	369	1185
5	4550	3/16''	0.094	105	0.916	324	374	352	1175
4	5250	3/16''	0.094	102	0.921	304	362	333	1170
3	6000	3/16''	0.094	120	0.891	284	351	313	1165
2	6750	3/16''	0.094	129	0.877	264	339	293	1160
1	7500	3/16''	Orifice	136					

Table 2: Updated Psc and Pso with new operating conditions:

CONCLUSION:

The surface controls Psc and Pso in the design are based on the condition which was assumed at the time of creating a design. Evaluating the injection point and performing other troubleshooting activities based on the design conditions will lead us to a dead end. The dynamic measurement through the Quartz RTD gauge at each valve position helped in measuring the gap between design-based and actual valve temperature in our case study. And, This can be used to evaluate the new Pso and Psc of every valve in this gaslift setup. Which in turn will give the justification for why the bellow in the gaslift valve (#2 @ 6742ft) was open at a lesser pressure than their designed opening pressure. Figure 11 also shows force balance analysis endorsed the new lower temperature at each valve will cause the premature opening of gaslift valve.

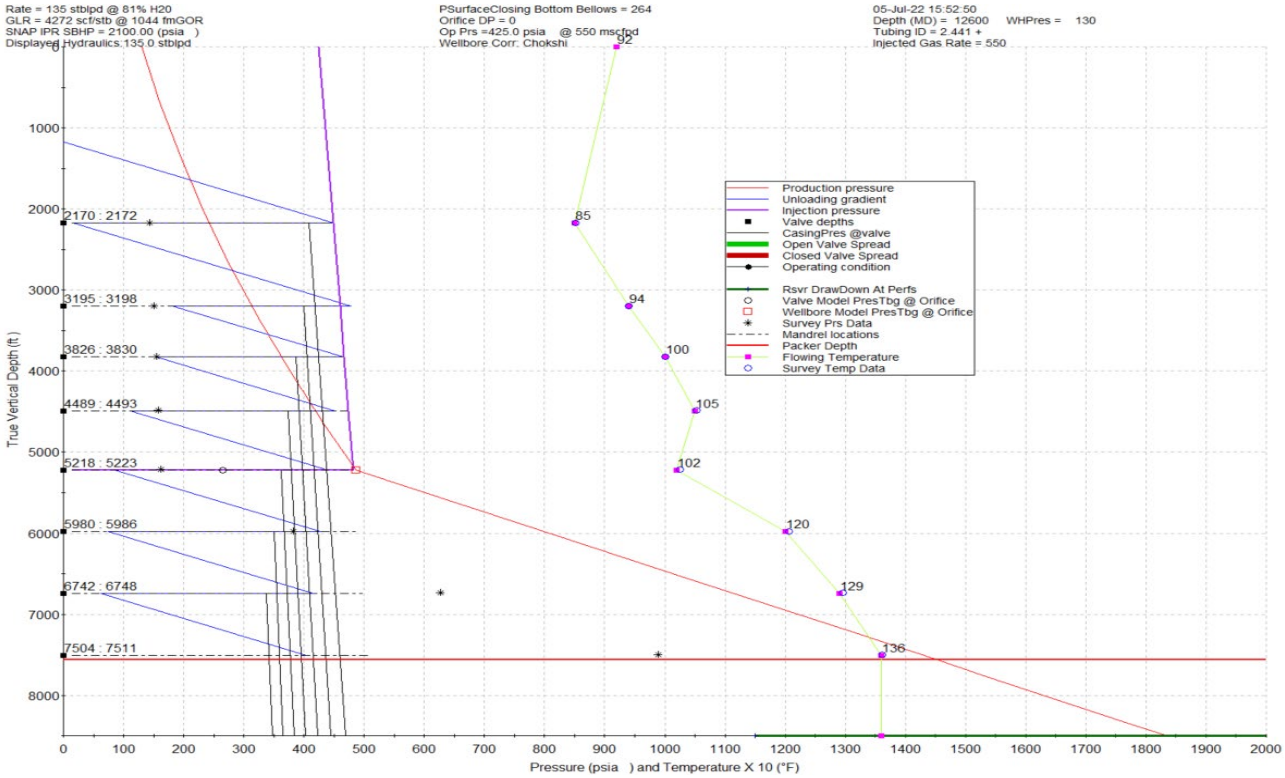
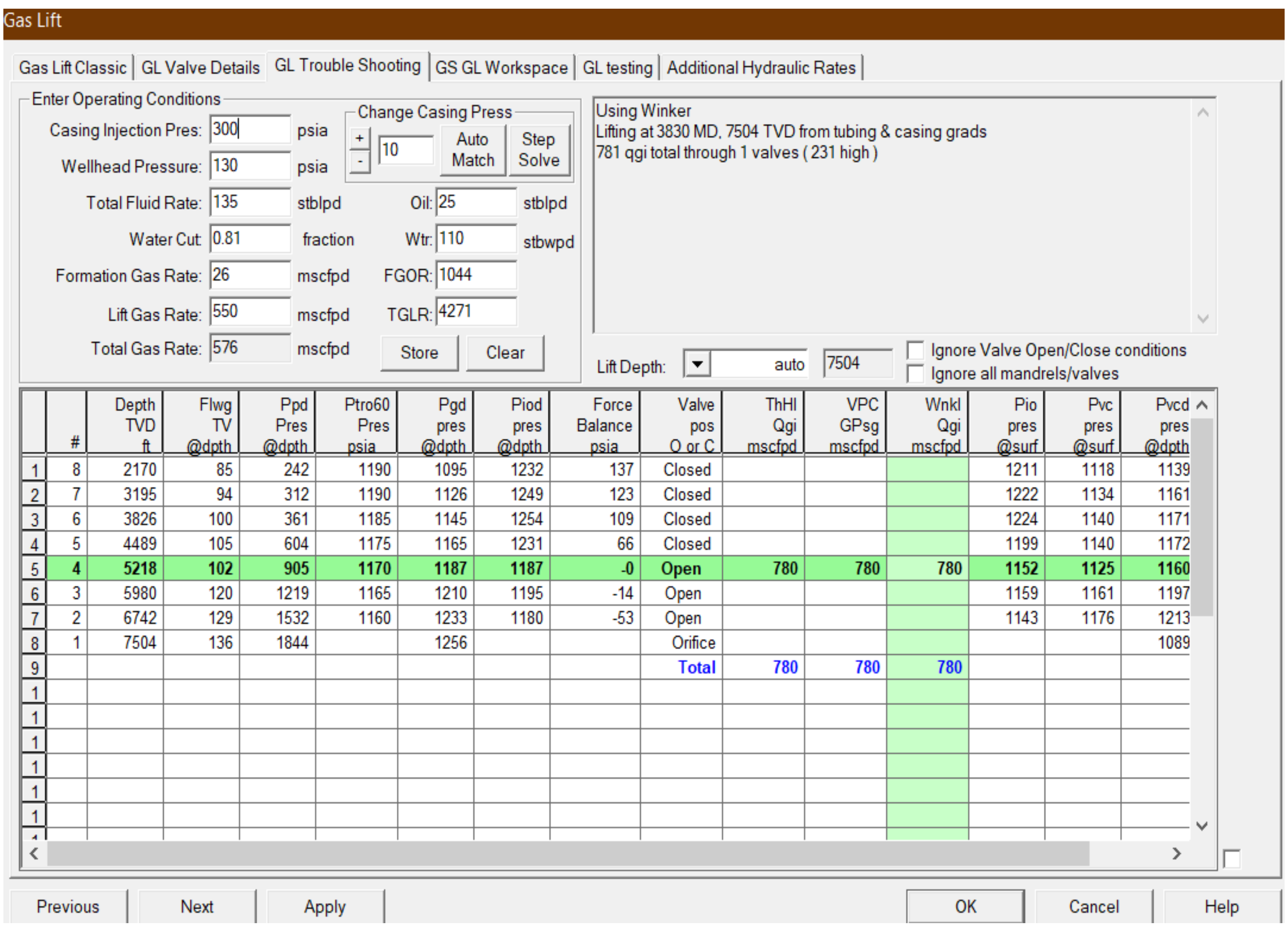


Figure 11: Modified gaslift design after employing survey or actual conditions of the well



	#	Depth TVD ft	Flwg TV @dpth	Ppd Pres @dpth	Ptro60 Pres psia	Pgd pres @dpth	Piod pres @dpth	Force Balance psia	Valve pos O or C	ThHl Qgi mscfpd	VPC GPsg mscfpd	Wnkl Qgi mscfpd	Pio pres @surf	Pvc pres @surf	Pvcd pres @dpth
1	8	2170	85	242	1190	1095	1232	137	Closed				1211	1118	1139
2	7	3195	94	312	1190	1126	1249	123	Closed				1222	1134	1161
3	6	3826	100	361	1185	1145	1254	109	Closed				1224	1140	1171
4	5	4489	105	604	1175	1165	1231	66	Closed				1199	1140	1172
5	**4**	**5218**	**102**	**905**	**1170**	**1187**	**1187**	**-0**	**Open**	**780**	**780**	**780**	**1152**	**1125**	**1160**
6	3	5980	120	1219	1165	1210	1195	-14	Open				1159	1161	1197
7	2	6742	129	1532	1160	1233	1180	-53	Open				1143	1176	1213
8	1	7504	136	1844		1256			Orifice						1089
9									**Total**	**780**	**780**	**780**			

Figure 10: Force balance analysis of gaslift setup based on survey conditions.

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