Artificial Lift R&D Council

2024 Gas Lift Workshop

June 3-6, 2024

First deployment in Middle East of Digital gas lift in dual string offshore well

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silverwell
ARTIFICIAL LIFT INTELLIGENCE

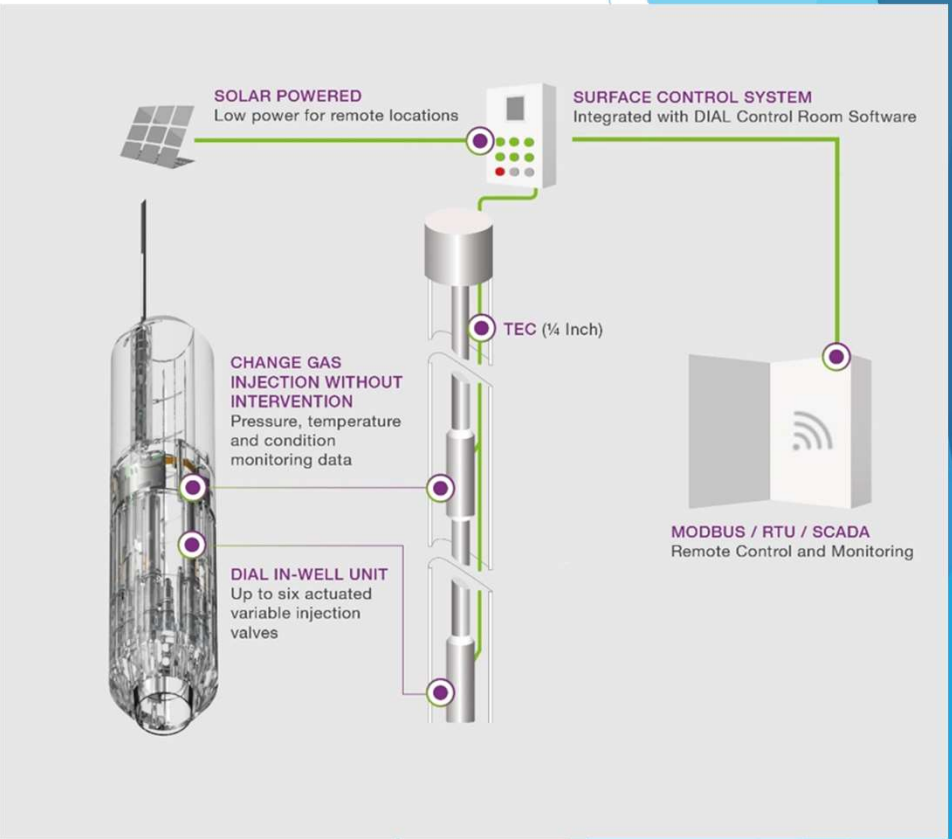
ADNOC

AGENDA

- TECHNOLOGY
- INSTALLATION
- WELL-UNLOADING AND PRODUCTION START UP
- DATA TO TROUBLESHOOT WELL CONDITION
- SUMMARY OF BENEFITS ACHIEVED

TECHNOLOGY
DIAL – DIGITAL INTELLIGENT ARTIFICIAL LIFT

Features	Benefits
•Variable orifice size at any depth •Deeper injection •No deviation limitation •No well intervention •Pressure and temperature data •Remote monitoring and control •Intelligent field-wide management	Eliminate intervention Reduce OPEX Mitigate instabilities Enhance recoveries Optimize production Reduce HSE risk

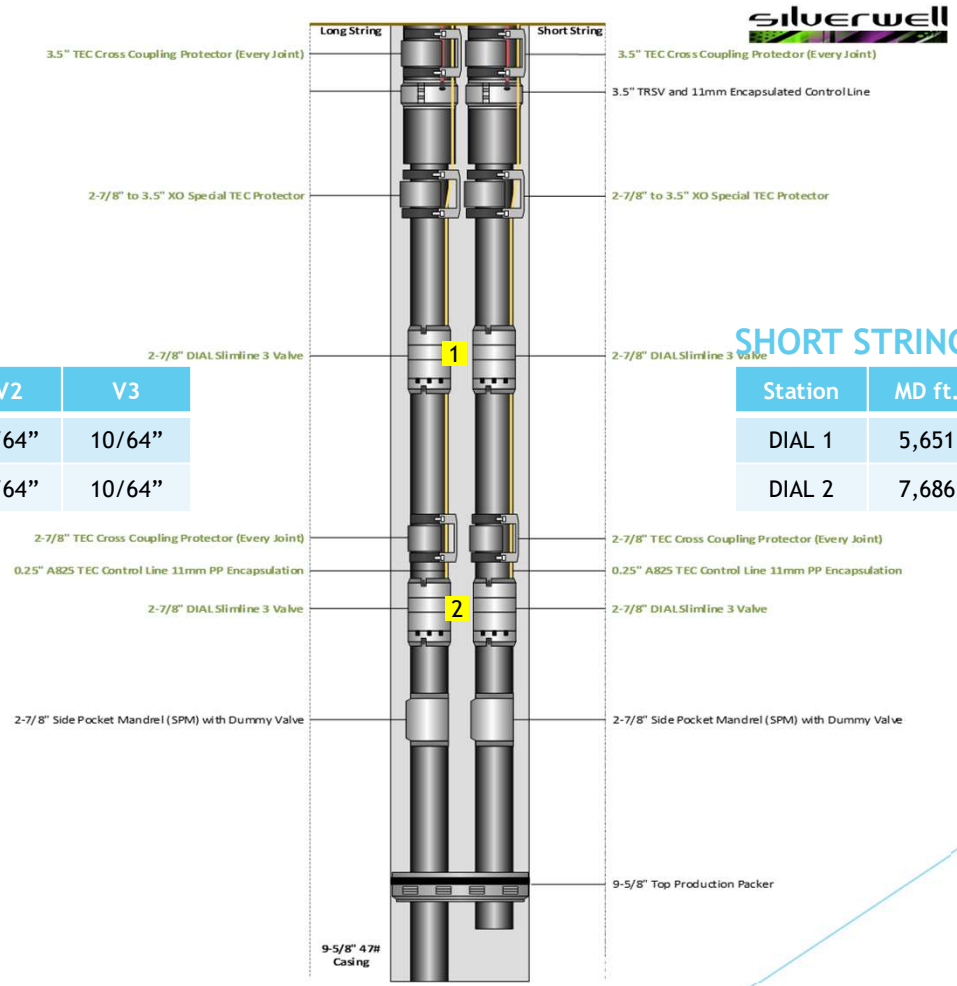


TIMELINE OF EVENTS

Date	Event
Jan 2023	Delivery of equipment to UAE and System Integration Testing (SIT)
Mar 2023	Well completed.
Apr 2023	SCADA integration completed.
Jun 2023	Short and Long String flowed naturally.
	Well unloading started.
	Well unloading completed.
	Well shut-in (Platform Maintenance).
	Well start-up completed.
	DIAL System user training provided to platform Operators.
Aug 2023	Well continues in production. SS 2905 BOPD / LS 2386 BOPD
Sep 2023	Short String experiences lower production following platform emergency shutdown.
Oct 2023	Troubleshooting using DIAL system enabled to quickly identify an issue with the SSV and fix it.
June 2024	Both string gas lifting from deepest DIAL unit and producing in stable manner.

INSTALLATION

DIAL Configuration Schematic



LONG STRING

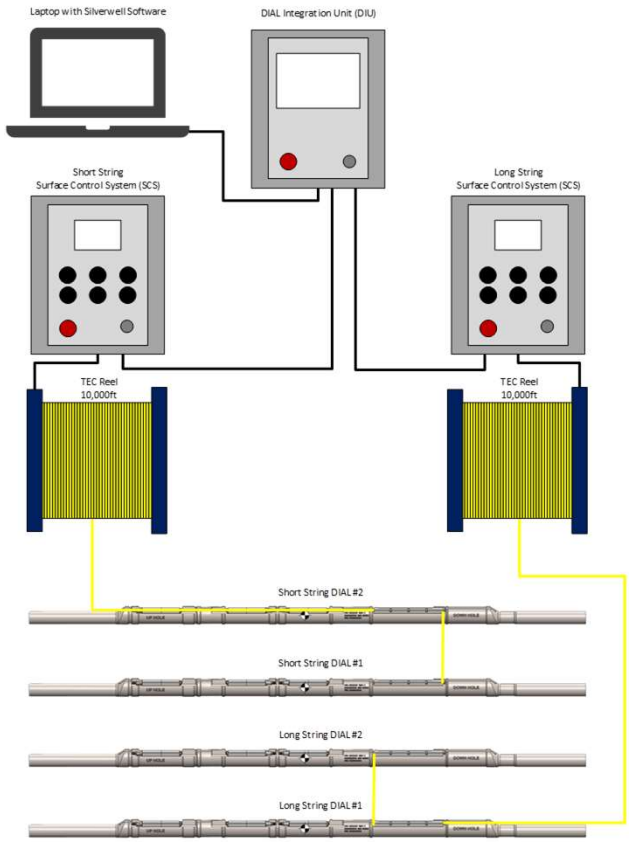
Station	MD ft.	TVD ft.	V1	V2	V3
DIAL 1	5,629	5,500	6/64”	8/64”	10/64”
DIAL 2	7,714	7,475	6/64”	8/64”	10/64”

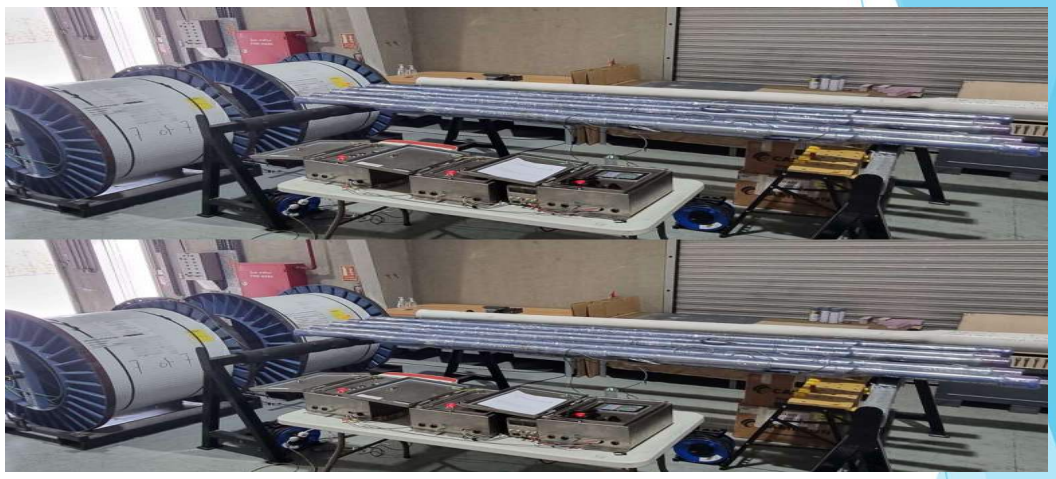
SHORT STRING

Station	MD ft.	TVD ft.	V1	V2	V3
DIAL 1	5,651	5,470	6/64”	8/64”	10/64”
DIAL 2	7,686	7,455	6/64”	8/64”	10/64”

DIAL SIT

Testing of Primary and B/U DIAL, TEC, SCS and DIU

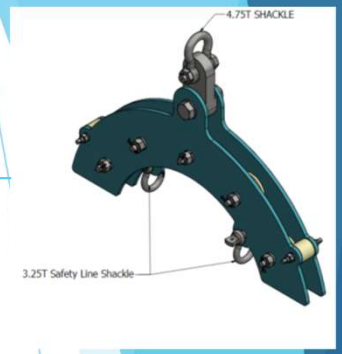




RIH Monitoring Layout

Rig Power

Rig Airline



Silverwell Container

RIH Monitoring

TEC Spooler

Test Cable

TEC Cable

Long String

Short String

Test Cable

TEC Cable

Rig Floor

Spreader Bar/ Sheave Wheels

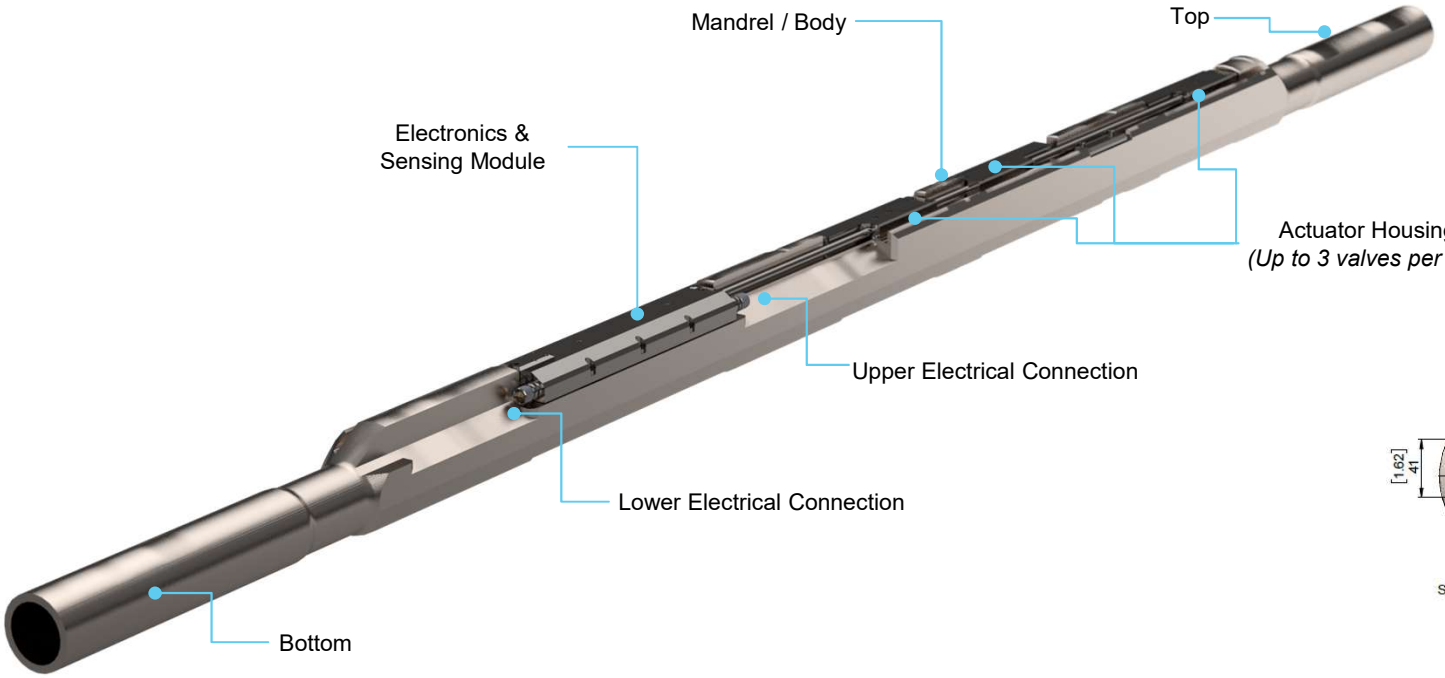
10ft DNV Certified

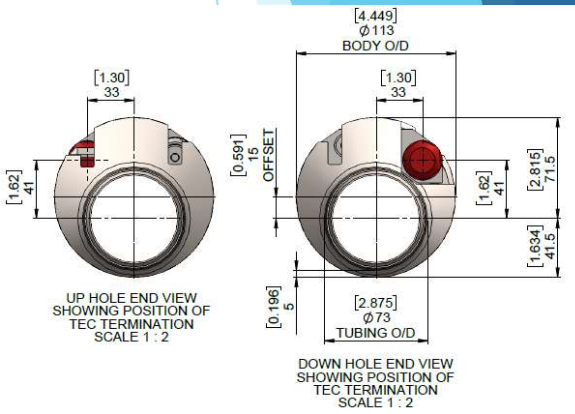
DNV Certified TEC Spooler

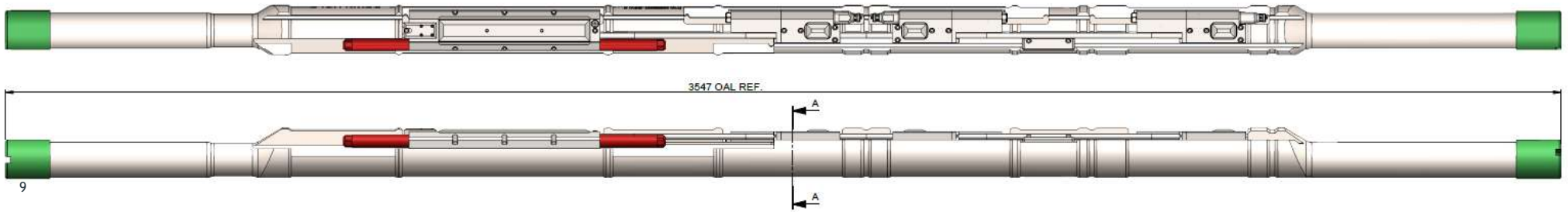
Rig Airline

Length	2412 mm
Breadth	2458 mm
Height	2485 mm
Maximum gross mass	10,000 Kg apx.
Tare mass	3,000 Kg apx.

DIAL Unit Assembly







TEC Cable

ENCAPSULATION
MATERIAL: POLYPROPYLENE
PROFILE: 0.433"
TEMP. RATING: 302°F/150°C
WEIGHT PER FOOT: 0.038 LBS

150°C RATED TEC
LAYER: CONDUCTOR
MATERIAL: 3/C 18 AWG 7/s TINNED COPPER
DIAMETER: 0.048"

LAYER: INSULATION
MATERIAL: FEP
DIAMETER: 0.079"
CABLE: 2" LEFT HAND LAY

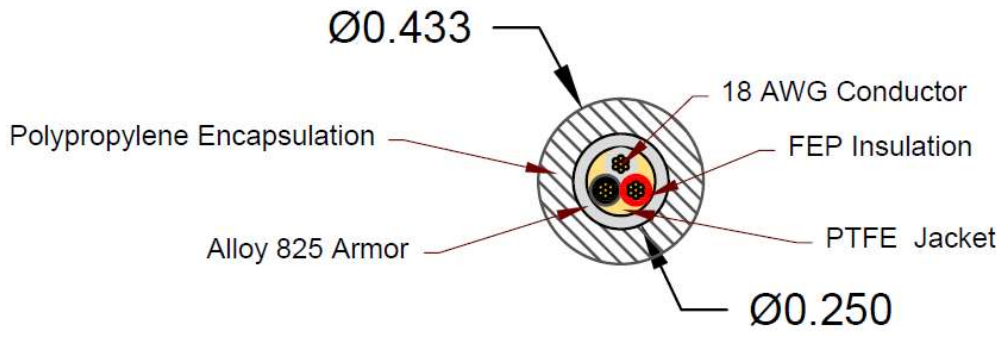
LAYER: FILLER
MATERIAL: PTFE TAPE
DIAMETER: 0.180"

LAYER: ARMOR
ALLOY: A825
PROFILE: 1/4" x 0.035"

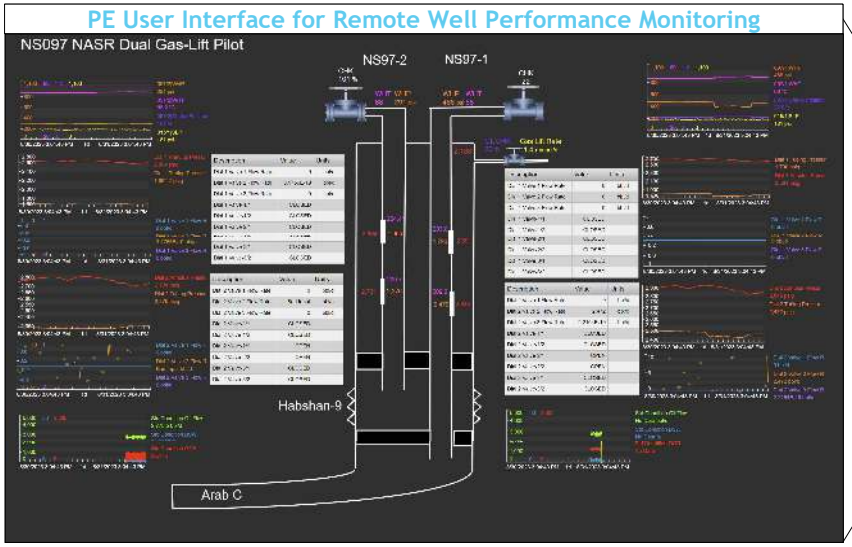
CONDUCTOR RESISTANCE: 6.8 Ohms/1000' maximum @ 20°C
INSULATION RESISTANCE: 6,500 MOhms-1000' min
ARMOR RESISTANCE: 25.5 Ohms/1000' max @ 20°C
CAPACITANCE: 30.0 pF/ft Nominal @ 20°C
VOLTAGE RATING: 1000 V
ESTIMATED WEIGHT PER FOOT: 0.115 LBS

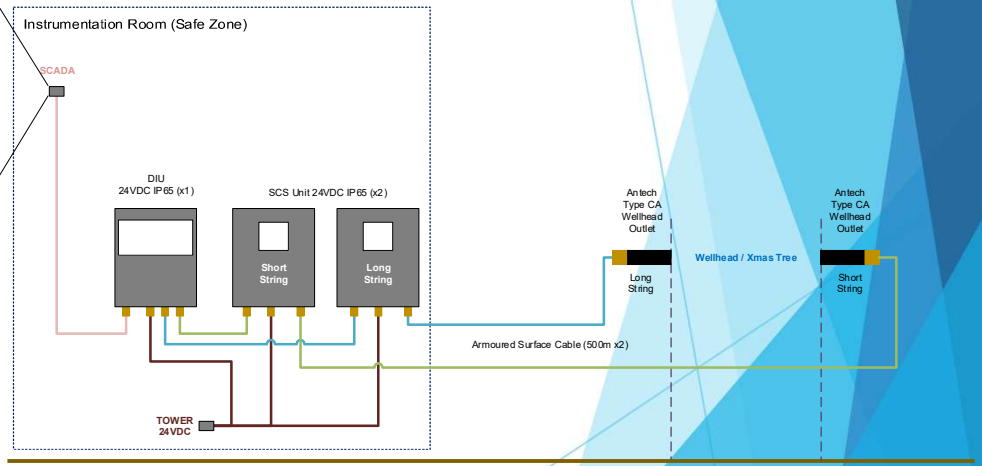
TOTAL WEIGHT PER FOOT: 0.153 LBS

MSCL P/N: 105019



Surface Equipment Arrangement and Data Visualization

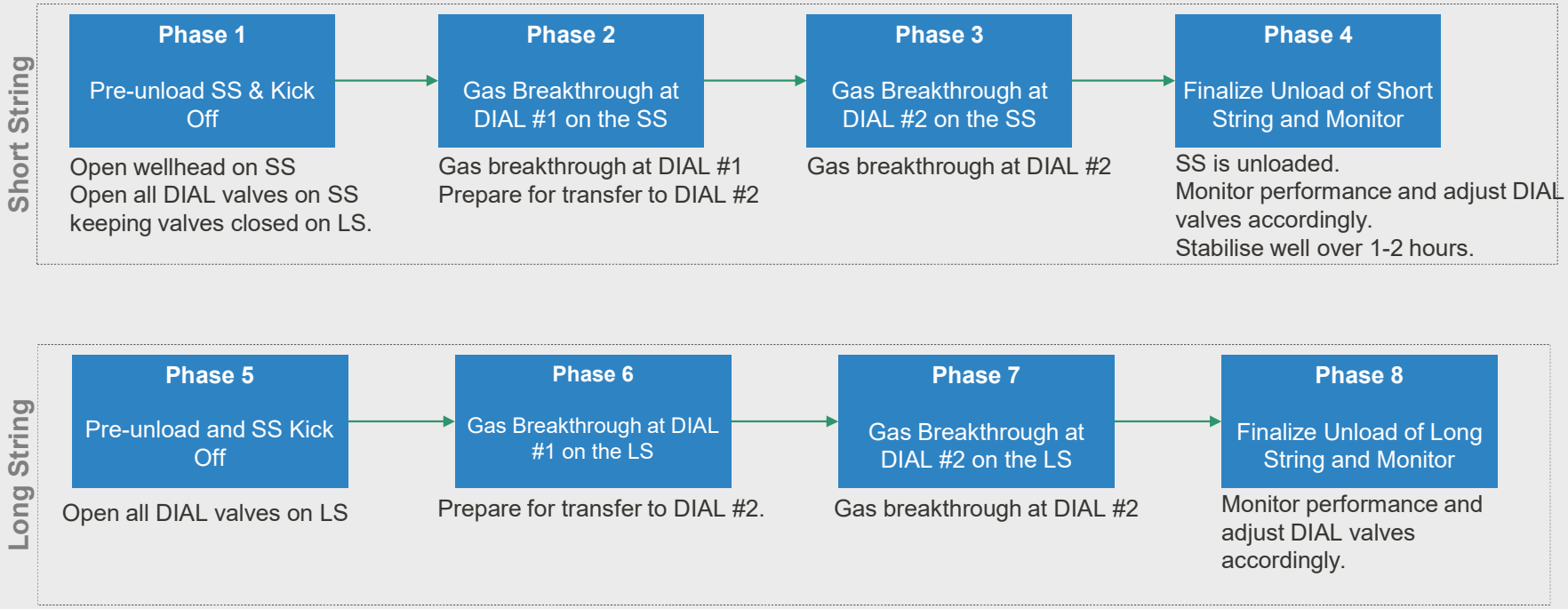




WELL UNLOADING

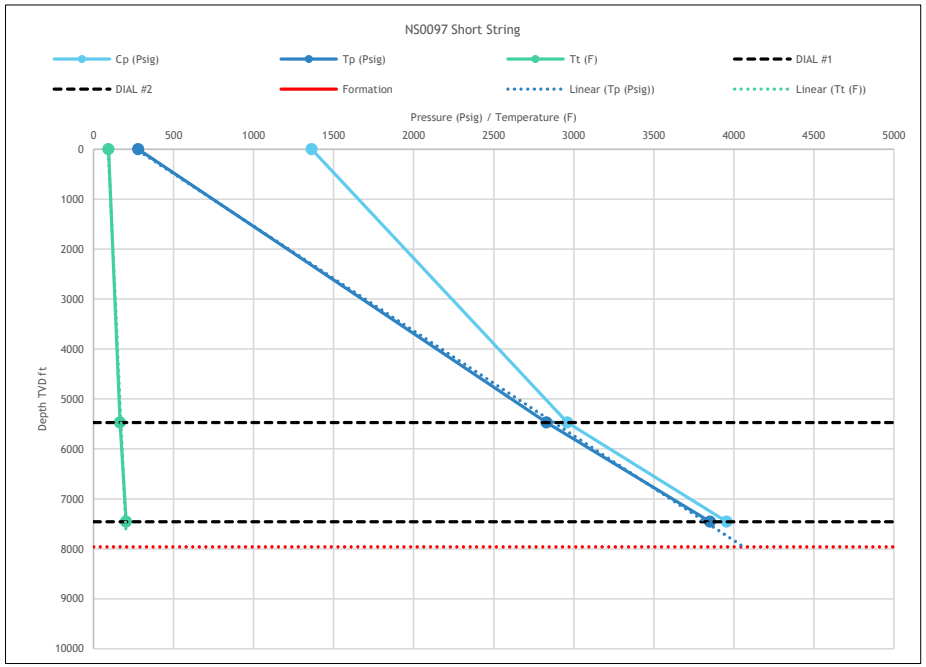
Unloading workflow

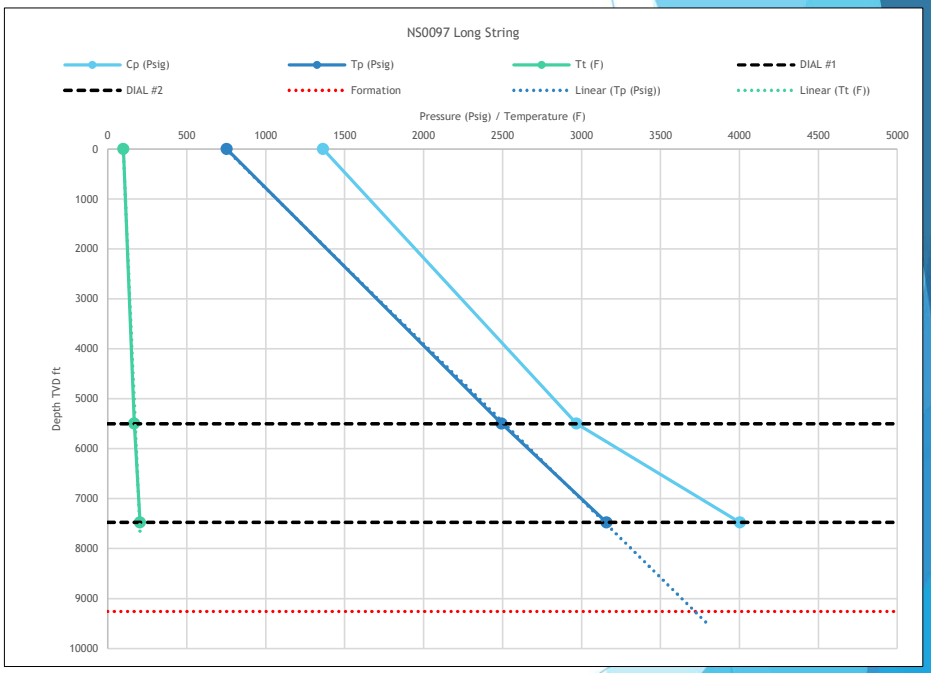
The gas injection surface choke was adjusted initially at 50 psig/10 minutes up to 400 psig; then at 100 psig/10 minutes until the Casing Kick Off Pressure of 2900 Psig was reached.



Start Unloading | 17th Jun 2023

S String Valves open at DIAL #1 and #2. Increase GL Inj. Pressure. Start u-tubing completion fluid.
L String DIAL valves closed. Flowing naturally.



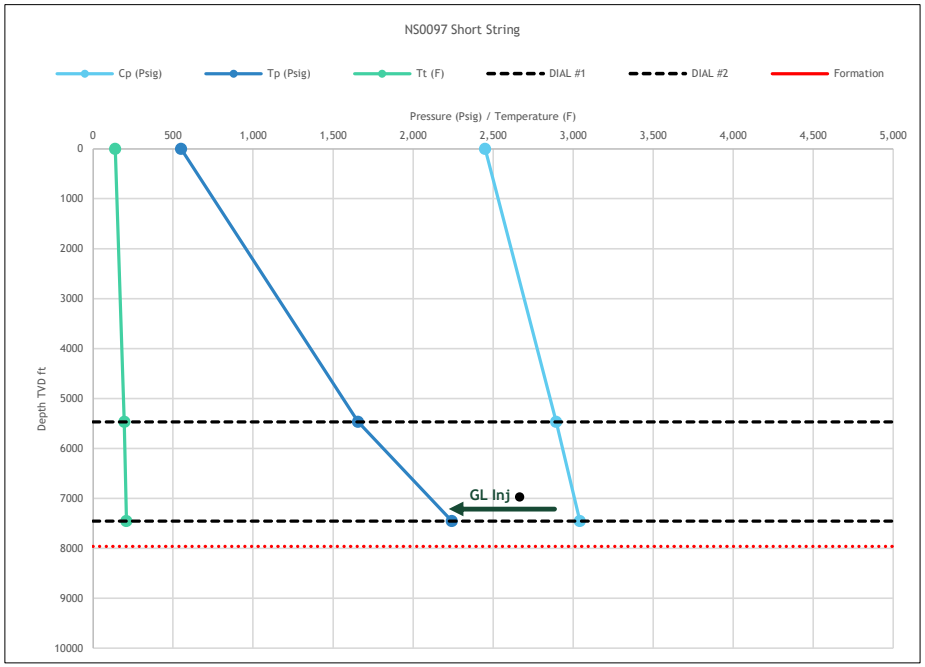


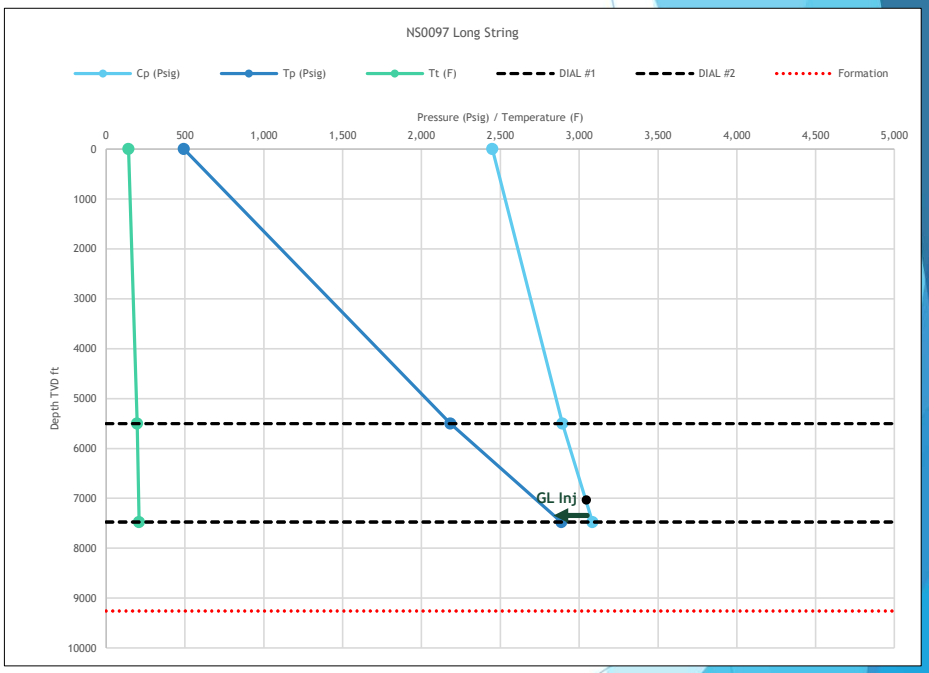
NS0097 - Short String											
DIAL	Depth TVD ft.	Cp (Psig)	Tp (Psig)	dP (Psi)	Tt (F)	V1 (6/64")	V2 (8/64")	V3 (10/64")	Cp Grad (Psi/ft.)	Tp Grad (Psi/ft.)	Tt Grad (F/ft.)
Surface	0	1363	279	-	93	-	-	-	-	-	-
#1	5,470	2,961	2,831	130	165	OPEN	OPEN	CLOSED	0.29213894	0.46654479	0.013162706
#2	7,455	3,956	3,852	104	203	OPEN	OPEN	OPEN	0.501259446	0.514357683	0.019143577
Formation	7,960	-	*4,112*	-	*213*	-	-	-	-	-	-

NS0097 - Long String											
DIAL	Depth TVD ft.	Cp (Psig)	Tp (Psig)	dP (Psi)	Tt (F)	V1 (6/64")	V2 (8/64")	V3 (10/64")	Cp Grad (Psi/ft.)	Tp Grad (Psi/ft.)	Tt Grad (F/ft.)
Surface	0	1363	754	-	100	-	-	-	-	-	-
#1	5,500	2,969	2,494	475	169	CLOSED	CLOSED	CLOSED	0.292	0.316363636	0.012545455
#2	7,475	4,005	3,160	845	205	CLOSED	CLOSED	CLOSED	0.524556962	0.33721519	0.018227848
Formation	9,258	-	*3,761*	-	*238*	-	-	-	-	-	-

Gas Lifting on Both Strings | 18th Jun 2023

S String Valve #2 (8/64”) DIAL #2 open. Gas injecting at DIAL #2. Calculated gas lift rate 0.85MMscf/d.
L String Valve #1 (6/64”) DIAL #2 open. Gas injecting at DIAL #2. Calculated gas lift rate 0.36MMscf/d.





NS0097 - Short String											
DIAL	Depth TVD ft.	Cp (Psig)	Tp (Psig)	dP (Psi)	Tt (F)	V1 (6/64")	V2 (8/64")	V3 (10/64")	Cp Grad (Psi/ft.)	Tp Grad (Psi/ft.)	Tt Grad (F/ft.)
Surface	0	2,450	551	-	138	-	-	-	-	-	-
#1	5,470	2,895	1,657	1,238	196	CLOSED	CLOSED	CLOSED	0.081352834	0.202193784	0.010603291
#2	7,455	3,042	2,242	800	208	CLOSED	OPEN	CLOSED	0.074055416	0.294710327	0.00604534
Formation	7,960	-	-	-	-	-	-	-	-	-	-

NS0097 - Long String											
DIAL	Depth TVD ft.	Cp (Psig)	Tp (Psig)	dP (Psi)	Tt (F)	V1 (6/64")	V2 (8/64")	V3 (10/64")	Cp Grad (Psi/ft.)	Tp Grad (Psi/ft.)	Tt Grad (F/ft.)
Surface	0	2,450	493	-	143	-	-	-	-	-	-
#1	5,500	2,895	2,184	711	197	CLOSED	CLOSED	CLOSED	0.080909091	0.307454545	0.009818182
#2	7,475	3,085	2,888	197	210	OPEN	CLOSED	CLOSED	0.096202532	0.356455696	0.006582278
Formation	9,258	-	-	-	-	-	-	-	-	-	-

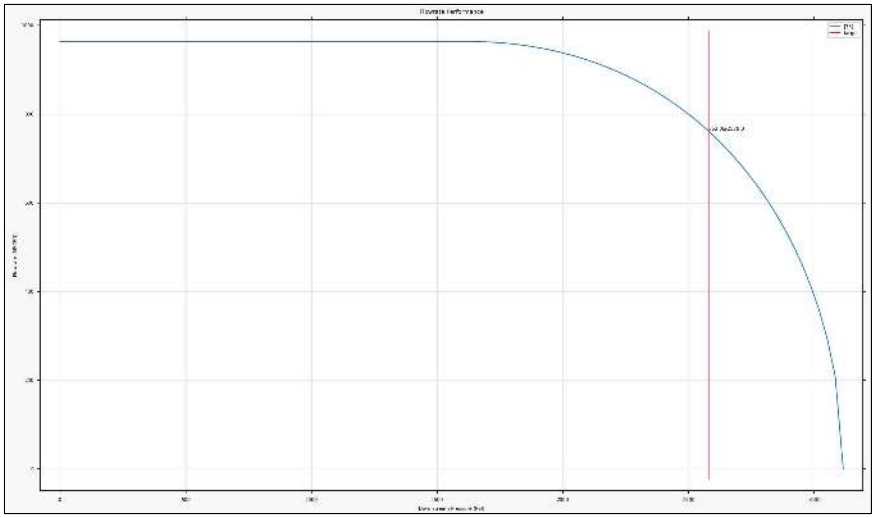
Gas Lift Inj. Rate Analysis | 29th Jun 2023

Gas Lift Injection Meter Measures 1MMscf/d | Downhole Calculated Rate 1.02MMscf/d

Short String

Valve #2 (8/64”) DIAL #2 open.

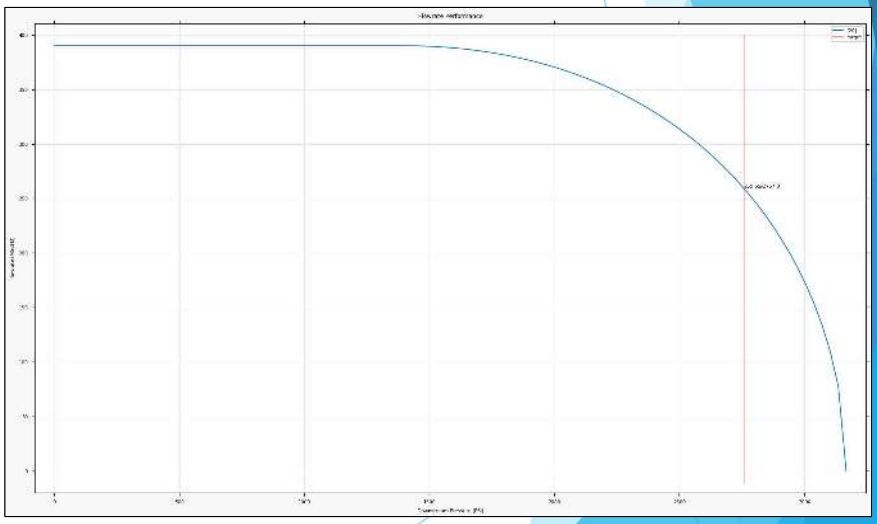
Calculated gas lift rate 0.76MMscf/d.



Long String

Valve #1 (6/64”) DIAL #2 open.

Calculated gas lift rate 0.26MMscf/d.



MPFM Production Data | 29th Jun 2023

Short String	
Oil	1295 STB/Day
Water	264 STB/Day
Gas	1.7 MMscf/d
GOR	1305 Scf/STB
Water Cut	16.3%

Long String	
Oil	2809 STB/Day
Water	12 STB/Day
Gas	1.1 MMscf/d
GOR	404 Scf/STB
Water Cut	0.3%

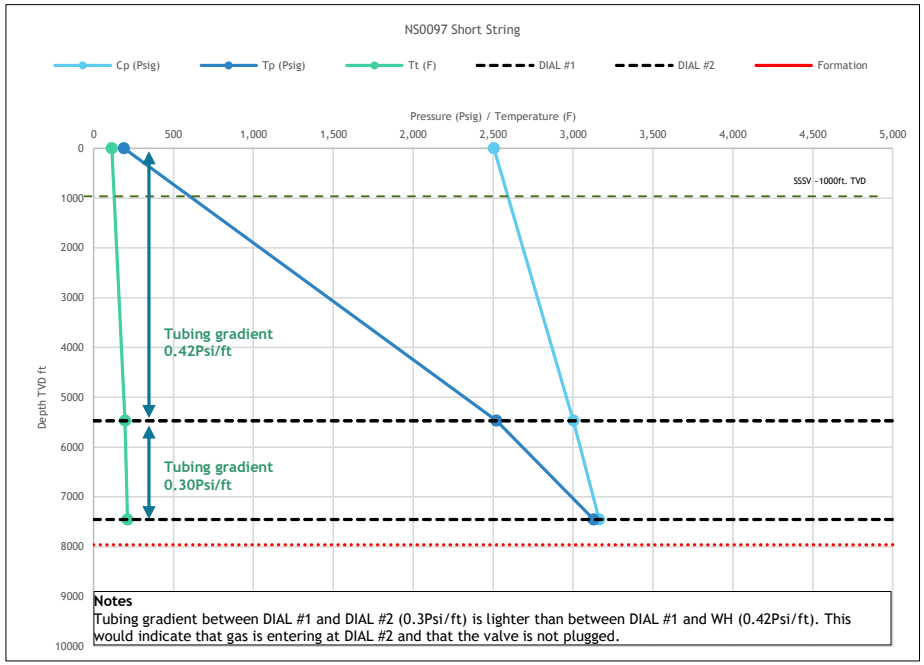
WELL TROUBLESHOOTING

Emergency Shutdown | 19th Sept 2023

- The platform had emergency shut down at 1600hrs on the 19th September. The well was shut-in for 5 hours.
- When the shutdown is initiated, both the wellhead and SSSV are closed.
- Following the shutdown, the Long String continued to flow as before.
- The Short String started to flow but the production rate was only ~200BLPD, compared to ~2700BLPD before shutdown.
- Initially, valve plugging was suspected on the Short String.
- Following this, the operators shut the wellhead in to monitor the reservoir response and to check there are no restrictions from the SSSV to the surface. The WHP pressure increased to 1100Psi. They reopened the wellhead and the pressure decreased to ~200Psi again.
- It still appears that there is a restriction in the well preventing flow. This is evident due to the low WHP, which does not correlate with the higher Tubing pressure at DIAL #1 and DIAL #2.
- At this point, ADNOC requested Silverwell to send an Engineer to site to investigate.

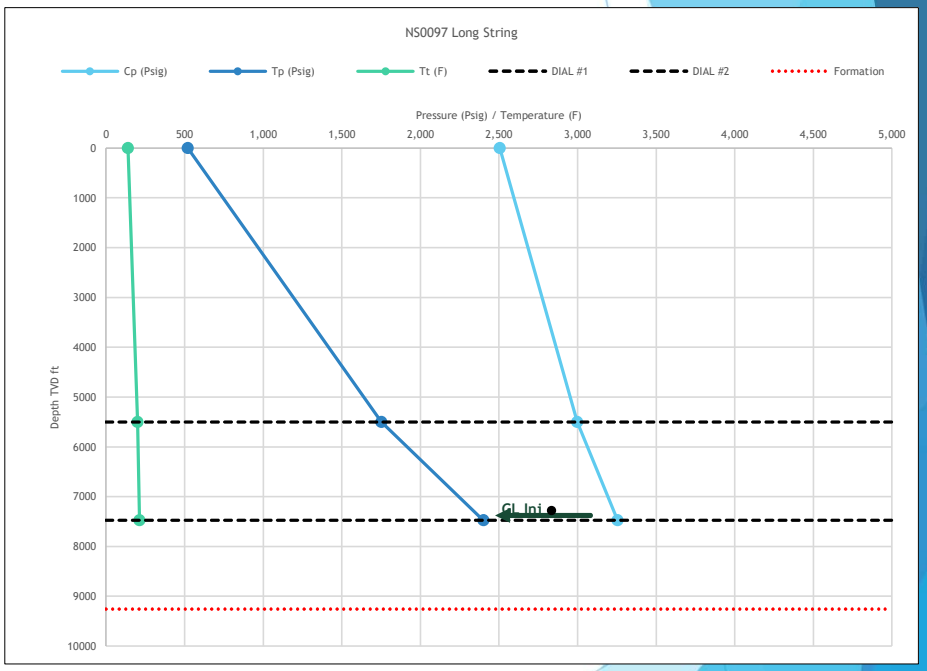
Post Shutdown Performance | 20th Sept 2023

Short String Valve #2 (8/64”) DIAL #2 open. Production reduces to ~200BLPD post-shutdown



DIAL	Depth TVD ft.	Cp (Psig)	Tp (Psig)	dP (Psi)	Tt (F)	V1 (6/64")	V2 (8/64")	V3 (10/64")	Cp Grad (Psi/ft.)	Tp Grad (Psi/ft.)	Tt Grad (F/ft.)
Surface	0	2,505	189	-	113	-	-	-	-	-	-
#1	5,470	3,002	2,521	481	197	CLOSED	CLOSED	CLOSED	0.090859232	0.426325411	0.01535649
#2	7,455	3,163	3,130	33	212	CLOSED	OPEN	CLOSED	0.081108312	0.306801008	0.007556675

Long String Valve #2 (8/64”) DIAL #2 open. Production continues as before shutdown.

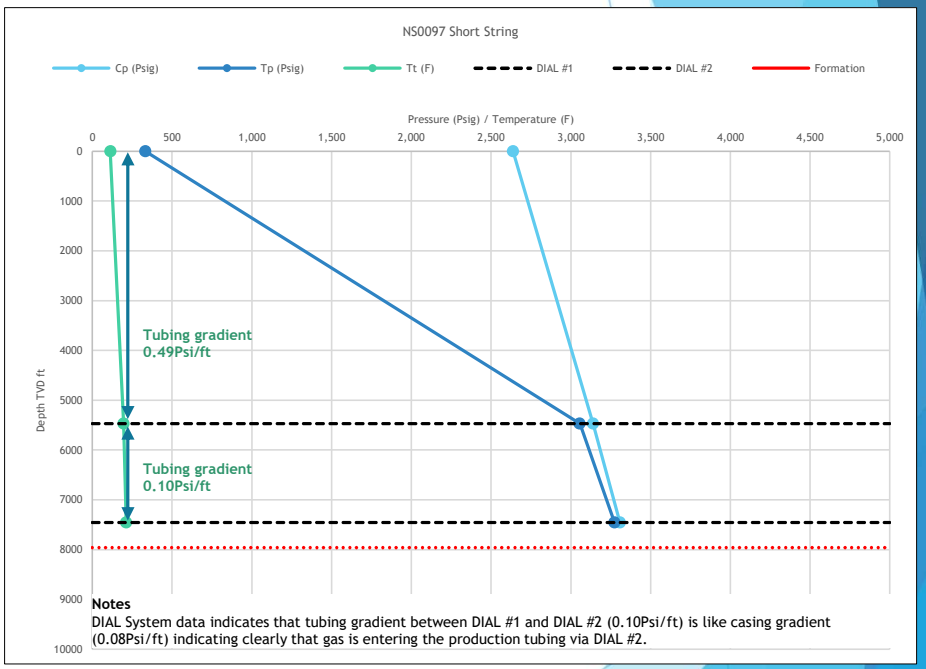


DIAL	Depth TVD ft.	Cp (Psig)	Tp (Psig)	dP (Psi)	Tt (F)	V1 (6/64")	V2 (8/64")	V3 (10/64")	Cp Grad (Psi/ft.)	Tp Grad (Psi/ft.)	Tt Grad (F/ft.)
Surface	0	2,505	520	-	140	-	-	-	-	-	-
#1	5,500	2,998	1,752	1,246	201	CLOSED	CLOSED	CLOSED	0.089636364	0.224	0.011090909
#2	7,475	3,255	2,401	854	213	CLOSED	OPEN	CLOSED	0.130126582	0.328607595	0.006075949

Onsite Investigation | 23rd Sept 2023

Investigation Summary

- Silverwell Engineer mobilized to site on 23rd September.
- CR readings were taken at the SCS cabinets for both strings. Electrically DIAL Systems are good.
- V1 and V2 were in the open position so an attempt was made to increase gas injection rate to monitor the tubing response.
- The SSSV was cycled closed > open.
- Despite the increase in casing pressure, the WHP did not increase. By viewing the graph, it is evident that gas is entering the tubing via DIAL #2 V1 and V2. The tubing gradient is very light between DIAL #1 and DIAL #2 (0.10Psi/ft). Yet the WHP remained very low and the gradient between DIAL #1 and the wellhead is 0.49psi/ft.
- The wellhead was then shut-in to monitor the tubing response. The response was slow (0.6bar/min).
- The SSSV was cycled again, and the casing pressure was increased but was unsuccessful to kick of production.
- On the 1st October, the wellsite Operators depressurized and repressurized the lines on the platform, confirming the issue was related to the SSSV.
- **After this, the Short String flow returned, and production rates were at ~2900 BLPD**



DIAL	Depth TVD ft.	Cp (Psig)	Tp (Psig)	dP (Psi)	Tt (F)	V1 (6/64")	V2 (8/64")	V3 (10/64")	Cp Grad (Psi/ft.)	Tp Grad (Psi/ft.)	Tt Grad (F/ft.)
Surface	0	2,639	333.5	-	113	-	-	-	-	-	-
#1	5,470	3,140	3,056	84	197	CLOSED	CLOSED	CLOSED	0.091590494	0.497714808	0.01535649
#2	7,455	3,309	3,274	35	212	OPEN	OPEN	CLOSED	0.085138539	0.109823678	0.007556675

BENEFITS OBSERVED

Summary of Benefits Observed

Compared to Conventional IPO Gas Lift on One String and Natural Flow on the other String

- Straight forward well unloading process, bringing production online successfully.
- Simultaneous gas lifting of both production strings ensuring the max gross rate.
- Avoidance of multipoint injection or gas robbing.
- Continuous downhole monitoring to enabling VLP data in real time and annular gas gradient.
- SCADA integration enabled monitoring from PE office.
- Ability to continuously update well models without the need for Flowing Gradient Surveys.
- Surface control enabling well production optimization in real time without well intervention.
- Ability to perform PBU test to monitor reservoir response and identifying the requirements for acid stimulation.
- Reduce OPEX (**±400k $**) and optimize production (**extra ±1,000 BOPD per string**).

Artificial Lift R&D Council

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