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Presentation Outline

Topic	Description
1	Intelligent Gas Lift System Introduction
2	Difference compared to conventional Gas Lift
3	Intelligent Gas Lift System Applications
4	Intelligent Gas Lift System Design and Spacing
5	Well Unloading
6	Production Optimization

The course will conclude with a summary and Q&A

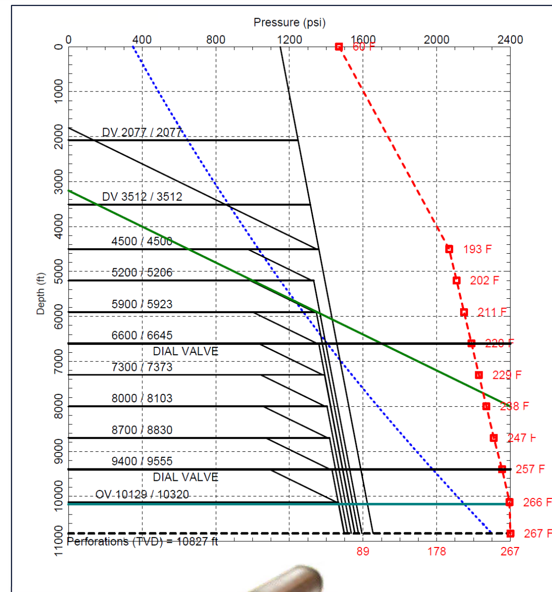
Topic #1

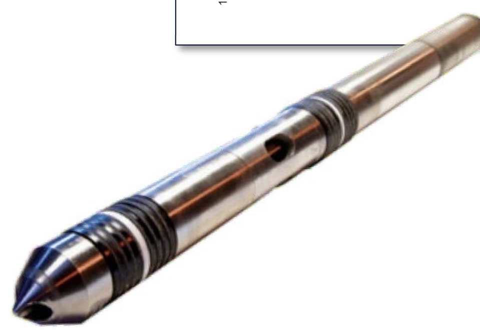
Intelligent Gas Lift System Introduction

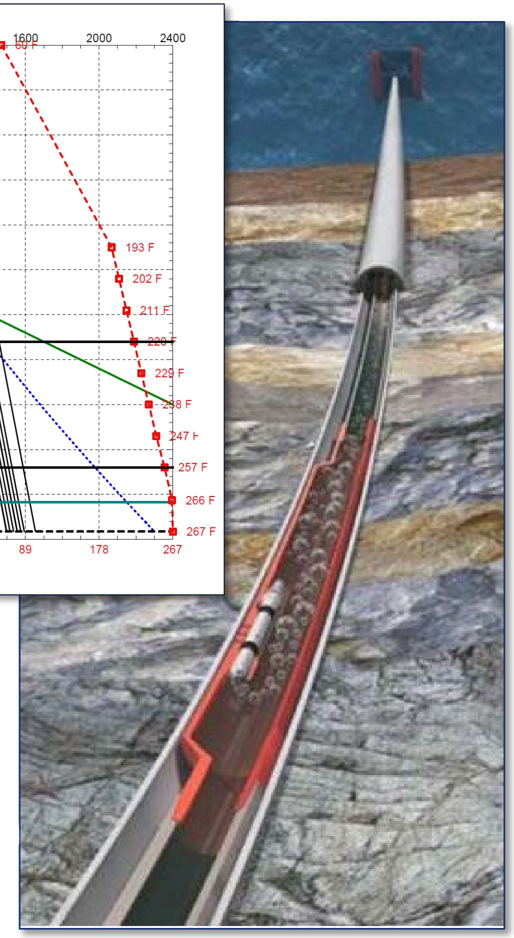
Gas Lift Production Optimization is Difficult

Conventional Gas Lift Challenges

- 70-years-old technology.
- Mechanically driven, sensitive to pressure.
- Inability to change gas injection rate or depth.
- Safety factors required for gas lift spacing design.
- Prone to multipoint injection.
- Flowing Gradient Surveys (FGS) required.
- Frequent well intervention required.
- Typically, 10-20% under-optimum.



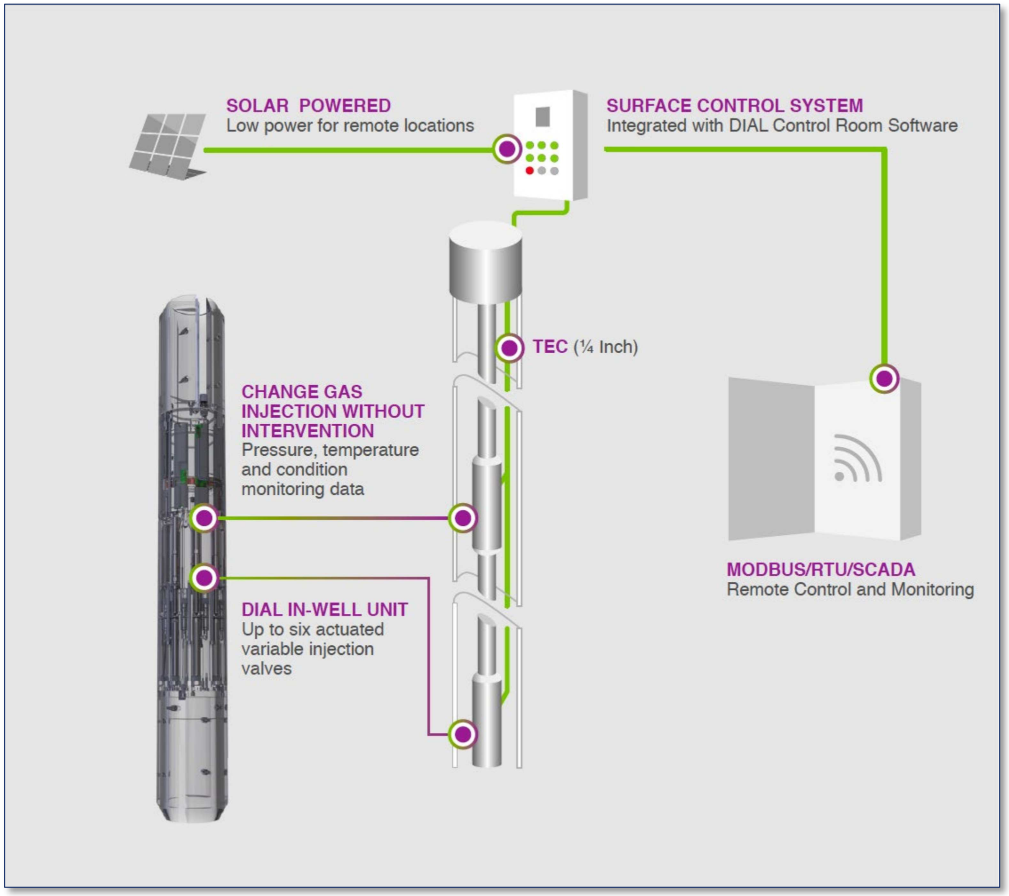




Addressing the Challenges

Intelligent Gas Lift System

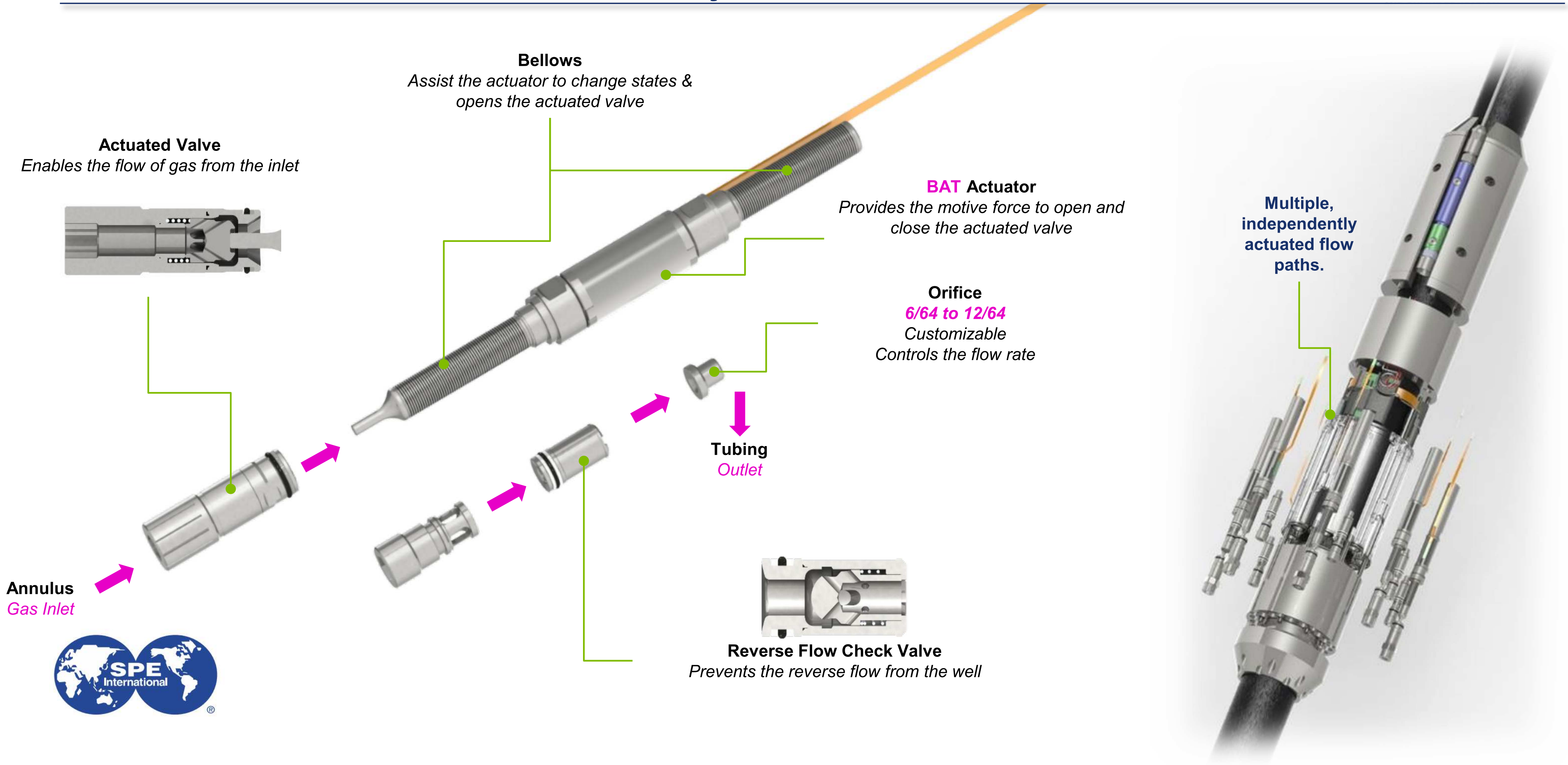
- Designed for the digital oilfield.
- Digitally controlled from the surface.
- Not effected by pressure or temperature.
- Multiple ports at each depth.
- Real-time pressure and temperature data.
- Simplified gas lift design.
- Interventionless technology.
- Deeper, single point injection.
- Continuous production optimization.



Intelligent Gas Lift System Specification

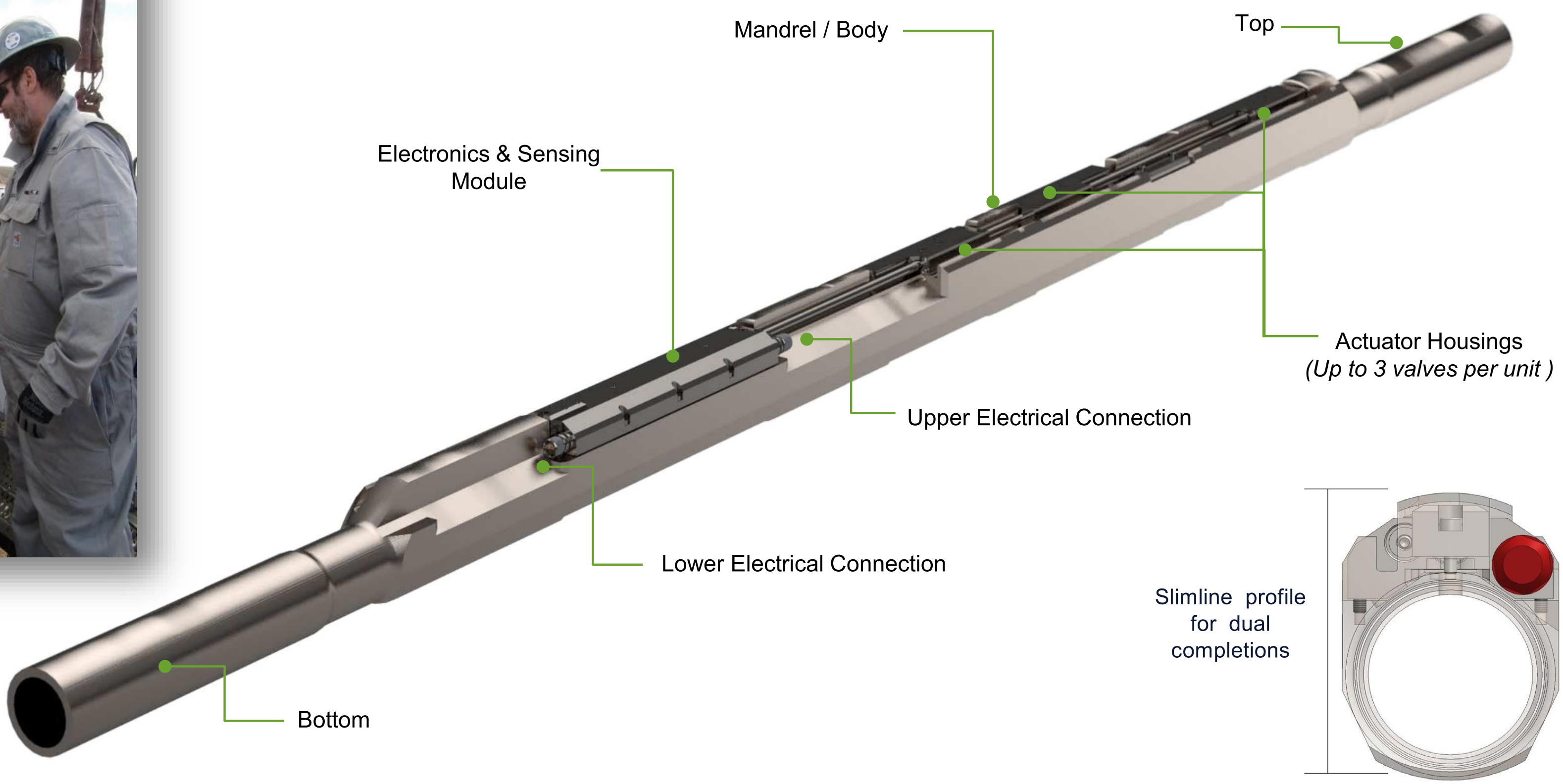
- Multiple mandrel units per well from one single TEC cable.
- 6,000psi Max. Working Collapse Pressure.
- 10,000psi Max. Working Burst Pressure.
- 2-7/8", 3.5", 4.5" and 5.5" tubing configurations.
- 125°C Max. rated Temperature.
- Fully MR0175 / ISO 15156 compliant Materials.
- Hermetically sealed with Electron Beam Welded construction.
- Strain gauge sensors for annulus and tubing pressure and tubing temperature.

Actuator and Valve System



Concentric System | 3.5”, 4.5” and 5.5”

Slimline System | 2.875”and 3.500”



Surface Control System (SCS)

24VDC or 230 VAC Configurations | IP 66 Rated | Ex-D & Ex-nR Enclosure Options

Gas Lift for the Digital Era

Data Driven and Production Automation

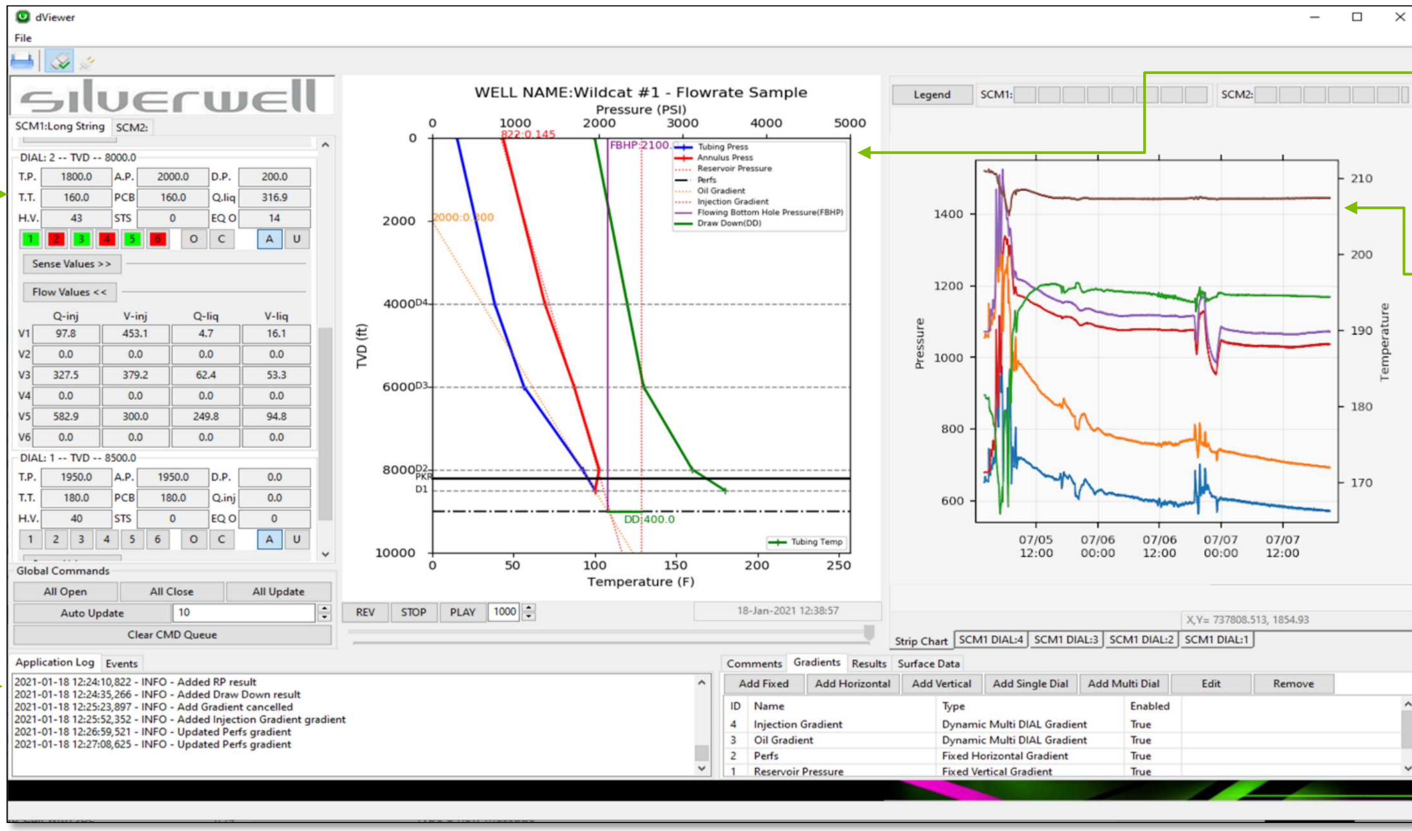
Control Panel

Digital values & valve status for each unit in the string.

Control valves using this interface.

Comments & Events Panel

List of events that occurred during logging operation.



Profile Panel

Cross-plot with pressure and temperature versus depth for each unit in the string.

Strip Chart Panel

Plot of data from each unit versus time.

Separate & combined plots available.

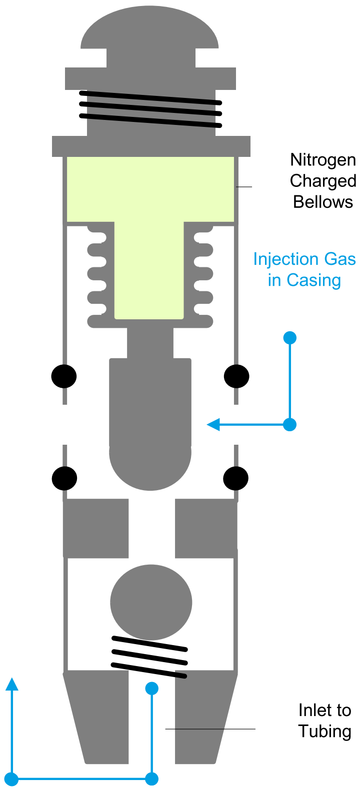
Analysis Panel

Enables user to set up various analysis.

Topic #2

Differences Compared to IPO/PPO

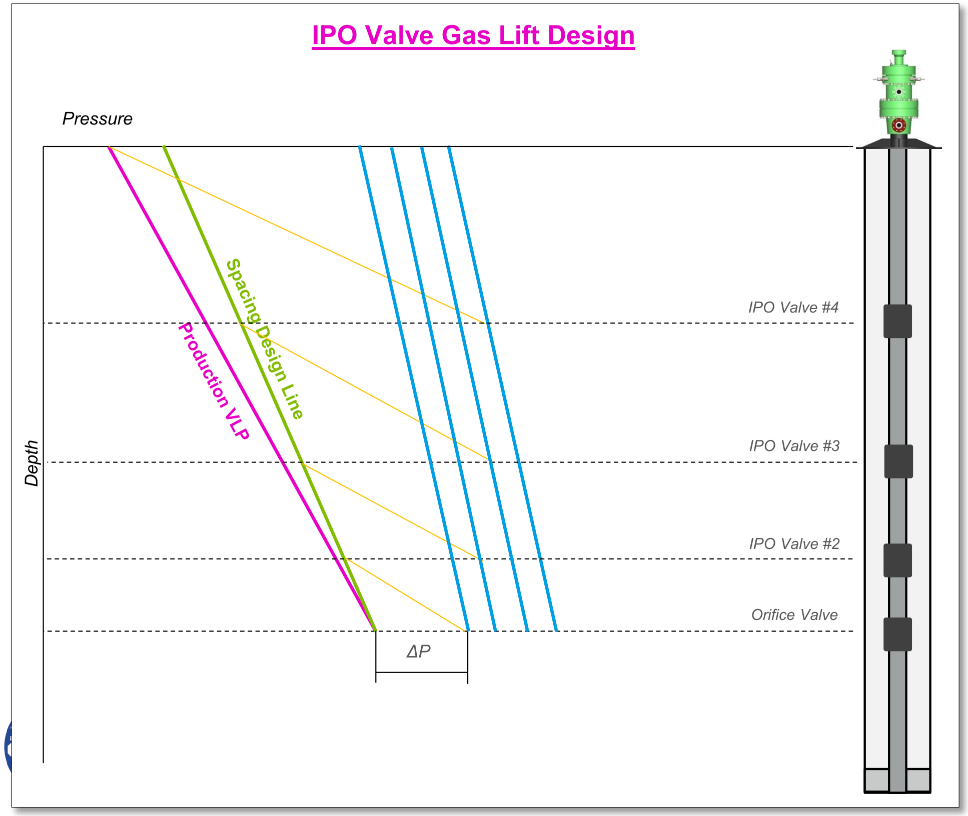
Differences Compared to IPO/PPO

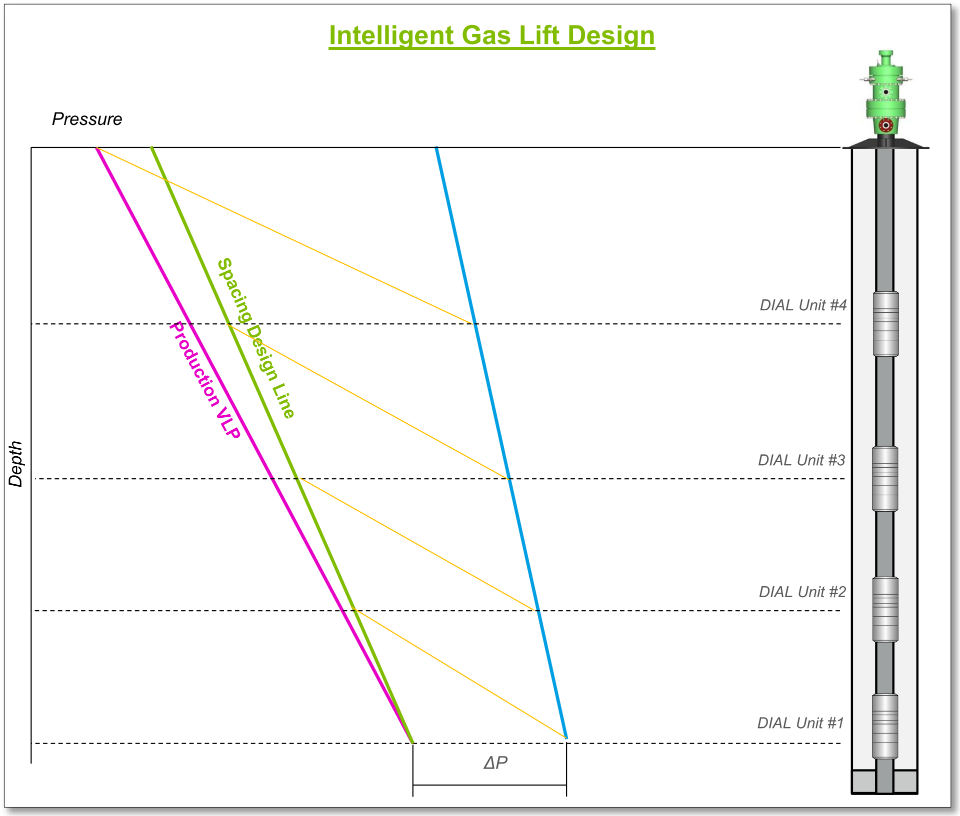


IPO / PPO	Intelligent Gas Lift System
▪ Nitrogen pressure charged. Set-up and calibration required for each specific well design.	▪ Surface control and operation independent of well pressure and temperature.
▪ No data. No downhole knowledge of injection point(s) or wells vertical lift performance.	▪ P/T data at every mandrel unit. Injection point, rate and well vertical performance known in real time.
▪ Pressure driven operation causes valve chattering, shallow and/or multipoint injection.	▪ Surface operation and valve design ensure no valve chattering, shallow and/or multipoint injection.
▪ IPO valve require casing pressure drops to transfer injection to deepest valve.	▪ Surface operation ensures that full casing pressure can be used to deepest point.
▪ Single injection port at depth leading to minimal scope to adjust or optimize injection rate.	▪ Multiple ports within each mandrel provide incremental increase/decrease of injection rate.
▪ Well intervention required to optimize production.	▪ No well intervention required to optimize the production.

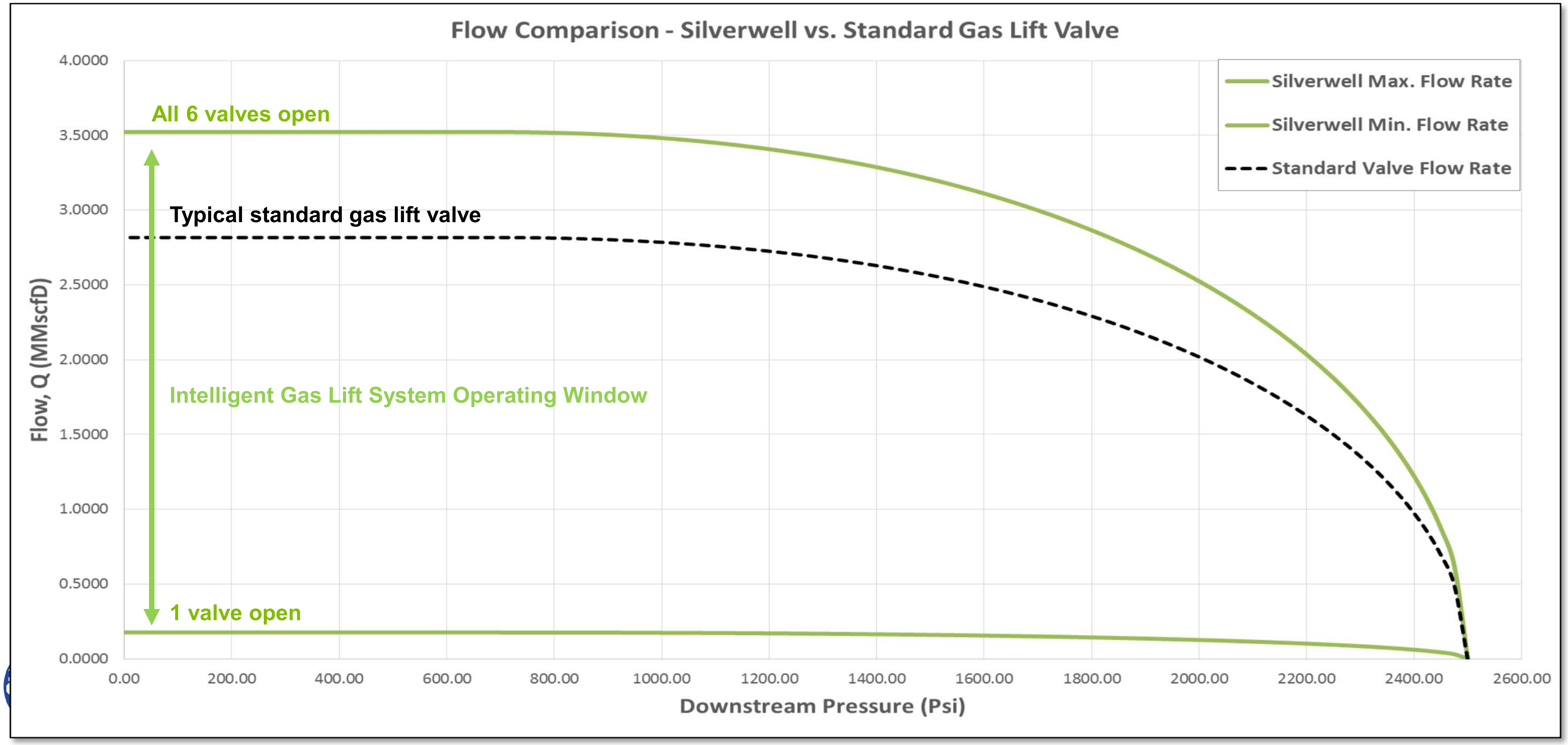
Intelligent Gas Lift vs IPO Valve Well Design Comparison

Full Casing Pressure | Wider Spacing | Less Stations | Deeper Injection | Increased Production and Stability





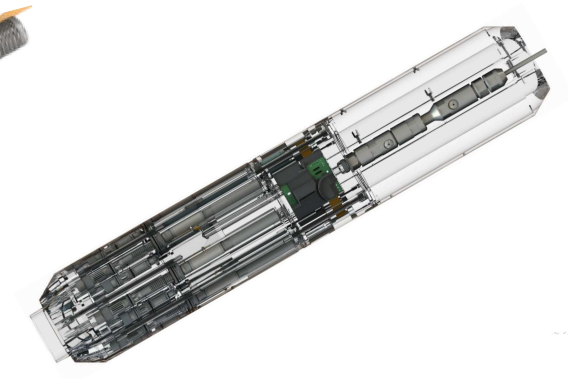
Conventional Valve Inj. Rate Comparison



Topic #3

Intelligent Gas Lift System Applications

Technology Performance Metrics



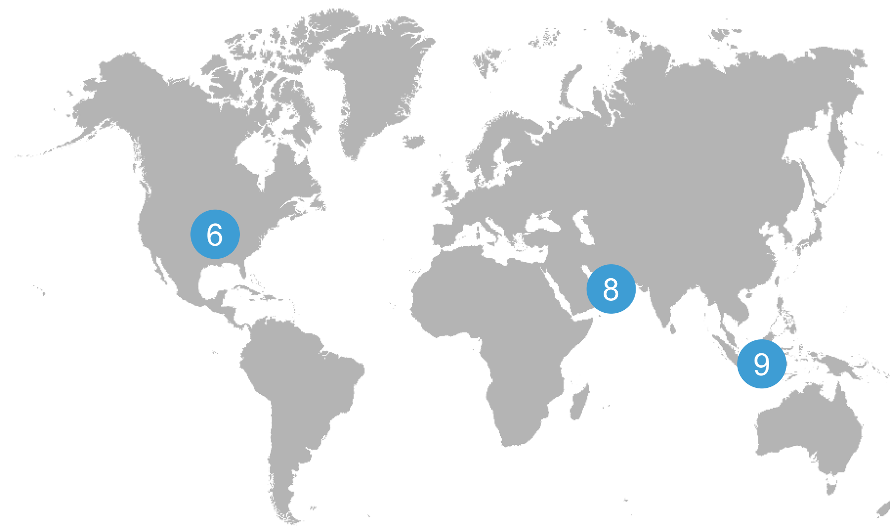
150
actuators ran

192
Combined Operating Years

43
Units ran

21
Combined Operating Years

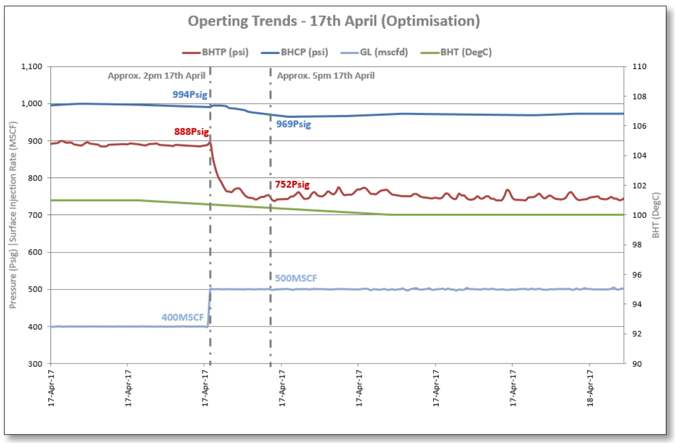
23 Wells by Q1'22



Value Delivered to Operators

Webinars

Well Optimization



Through downhole gauge measurement, the operator recognised the opportunity to **increase gas injection rate from 400 to 500MCFD**.

Intelligent Gas Lift valves were opened, increasing the drawdown from the reservoir.

Net Oil Production increased 10%.

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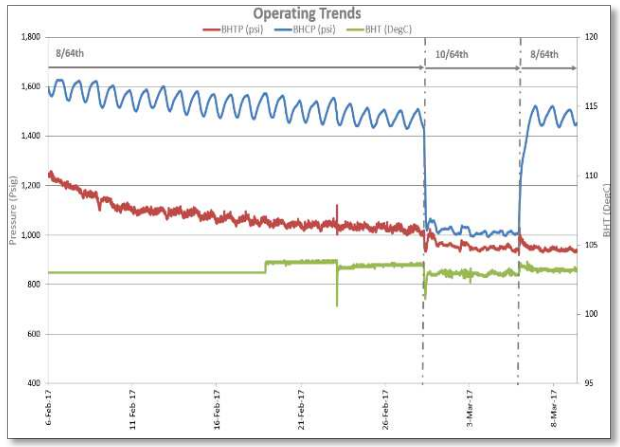
Mitigating Instability



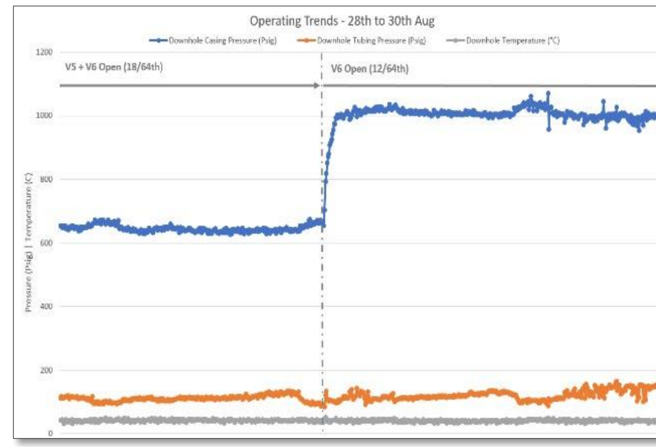
8/64th orifice size causing **multi-point injection** and well instability.

Upper IPO valve continuously **opening and closing**.

Operator **increased the port size** to 10/64 by opening an additional valve. **Well stability achieved**.

Valve closed to replicate issue & confirm Intelligent Gas Lift action.

Gas Management

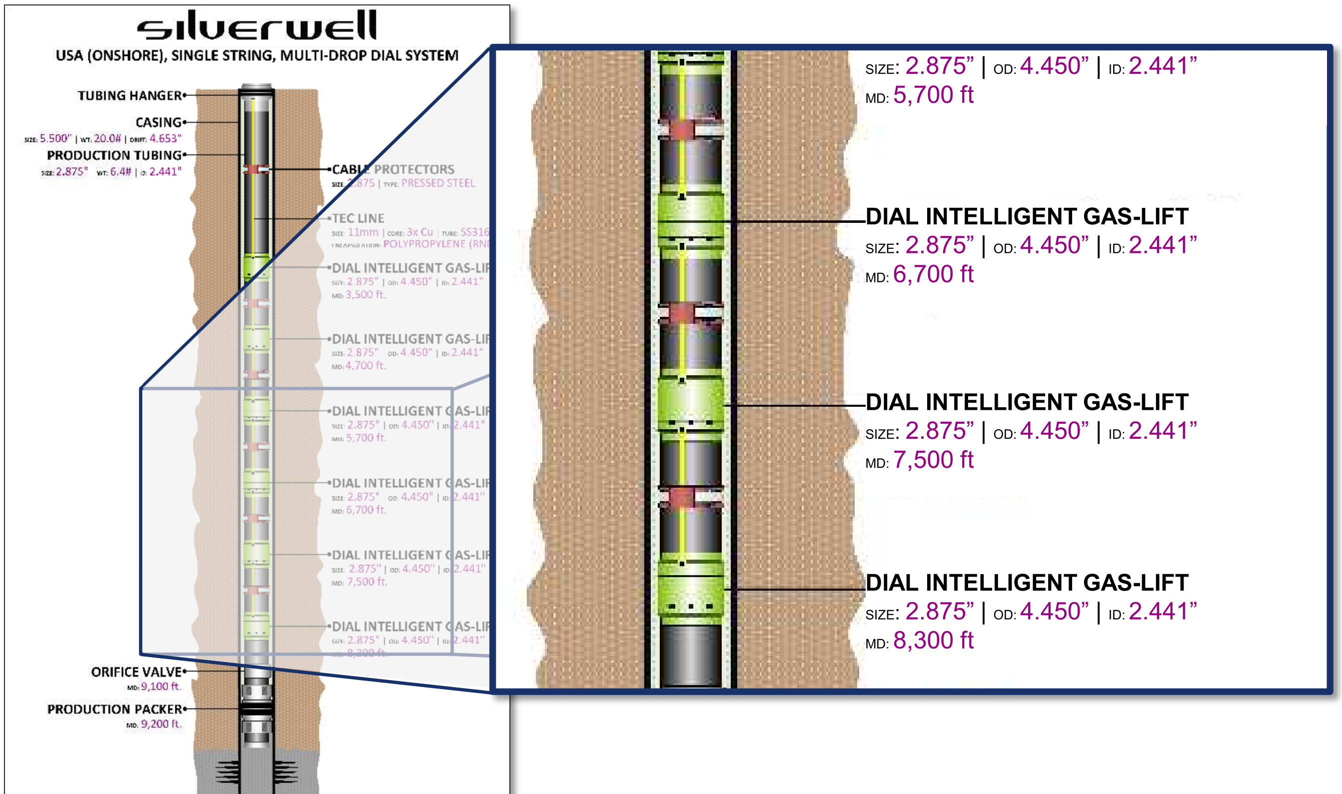


Through downhole gauge measurement, the operator recognized the opportunity to **reduce the gas injection rate**.

The **valve combination** was changed from **18/64** to **12/64ths**.

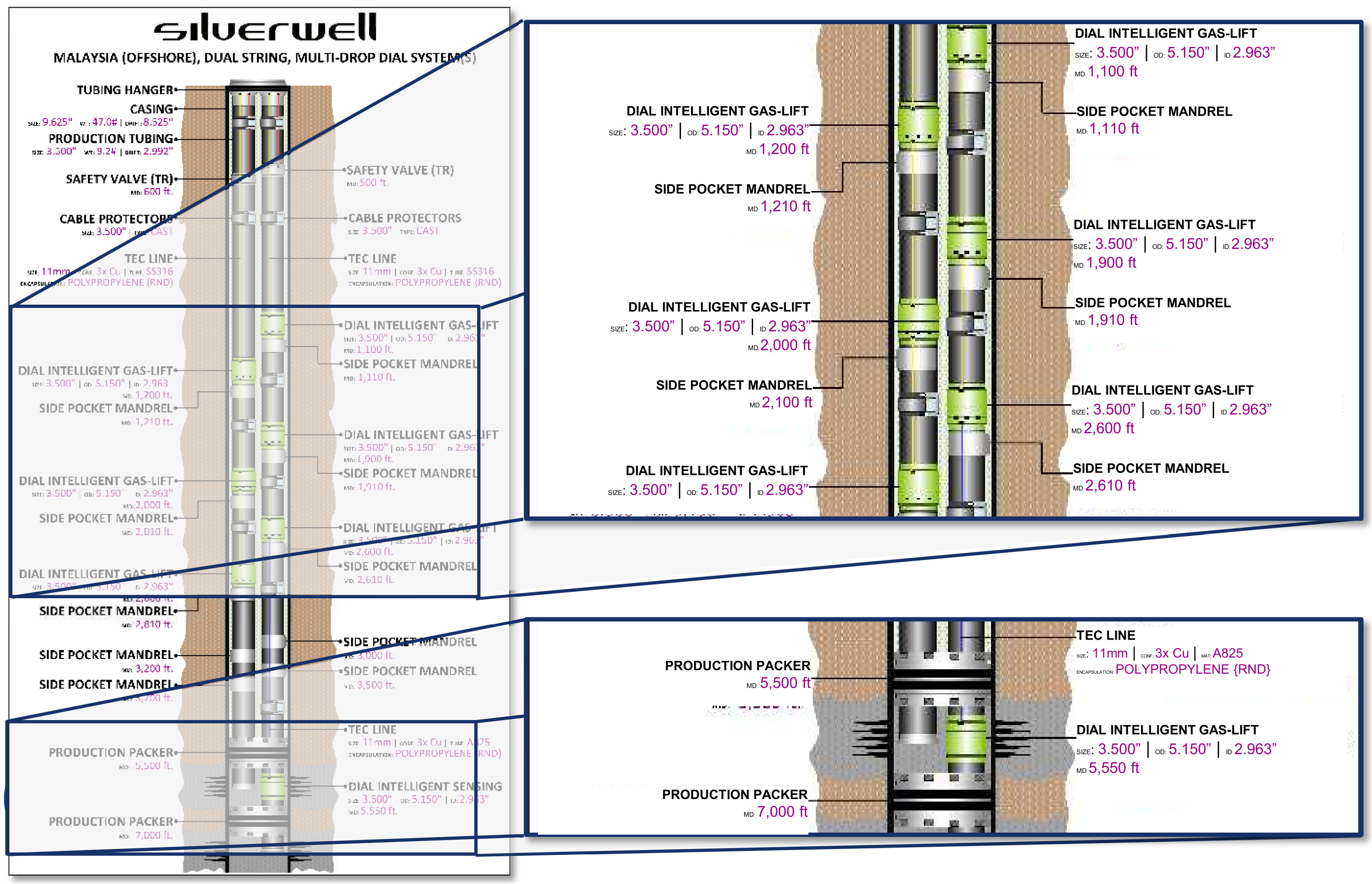
The operator **reduced gas injection by 25%** and **increased Net Oil Production by 18%.**

Single String Intelligent Gas Lift Completion



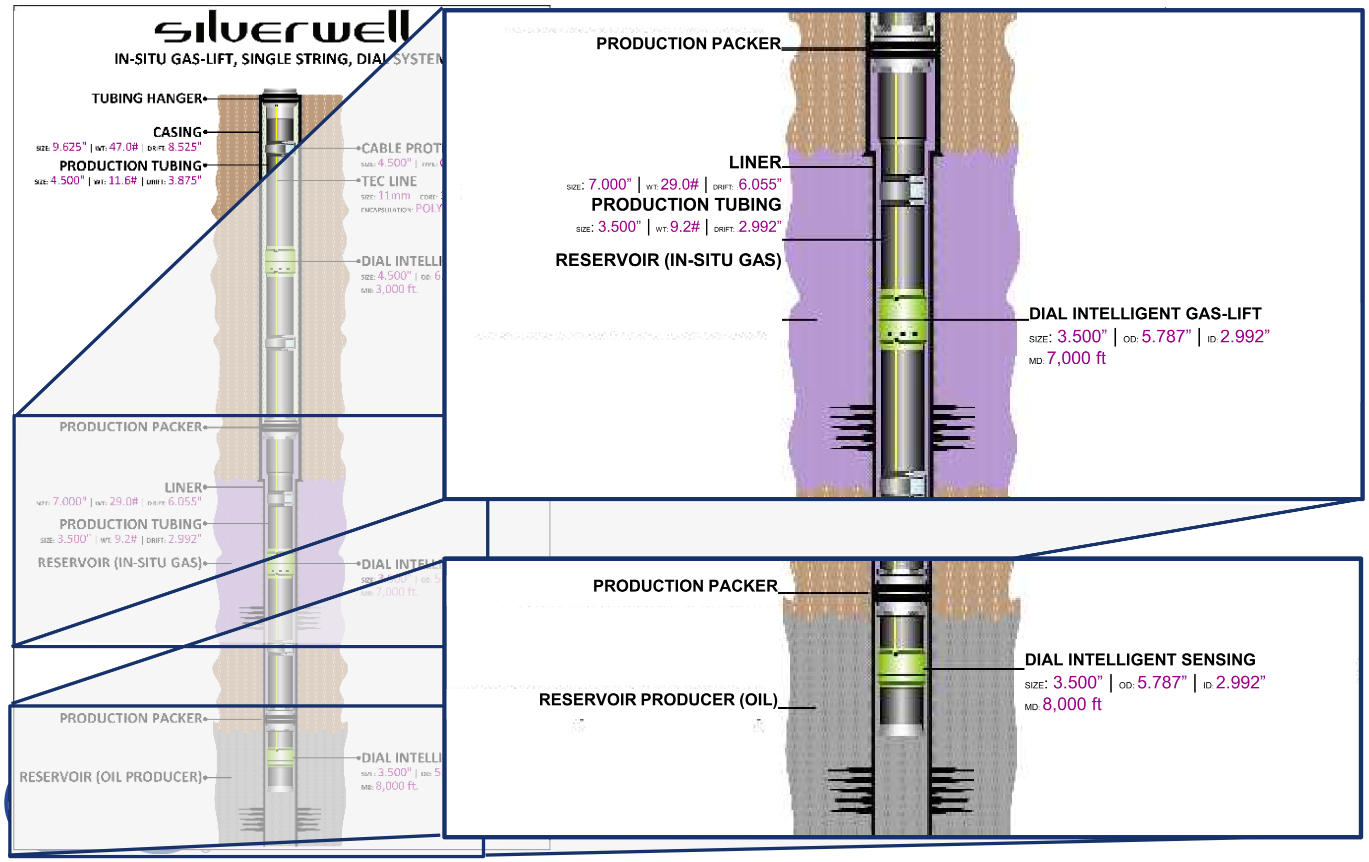
- Multiple Intelligent Gas Lift Units Using a single TEC.
- Pressure sensing on each Intelligent Gas Lift giving well pressure profile and FBHP analysis.
- Real time control and optimization.
- Slimline Intelligent Gas Lift for small casing.
- Concentric Intelligent Gas Lift for increased flow.

Dual String Completion



- Two slimline production strings in single casing.
- Complete Individual Control of each reservoir/zone with efficient gas lift distribution.
- Eliminates multi-pointing and gas robbing; problematic with IPO/PPO.
- Increased ROI as two zones can be produced through one drill.
- Dual sensing unit allows dual measurement of both producing zones.

In-Situ (Auto-Gas) Lift Completion



- Upper (or lower) gas zone provides lift gas for the oil zone.
- Intelligent Gas Lift allows real time adjustment of drawdown as reservoir characteristics vary.
- Intelligent Gas Lift sensing unit can provide pressure / temperature readings in oil zone.
- Eliminates surface gas lift infrastructure.
- Speeds up field completion and production schedule.

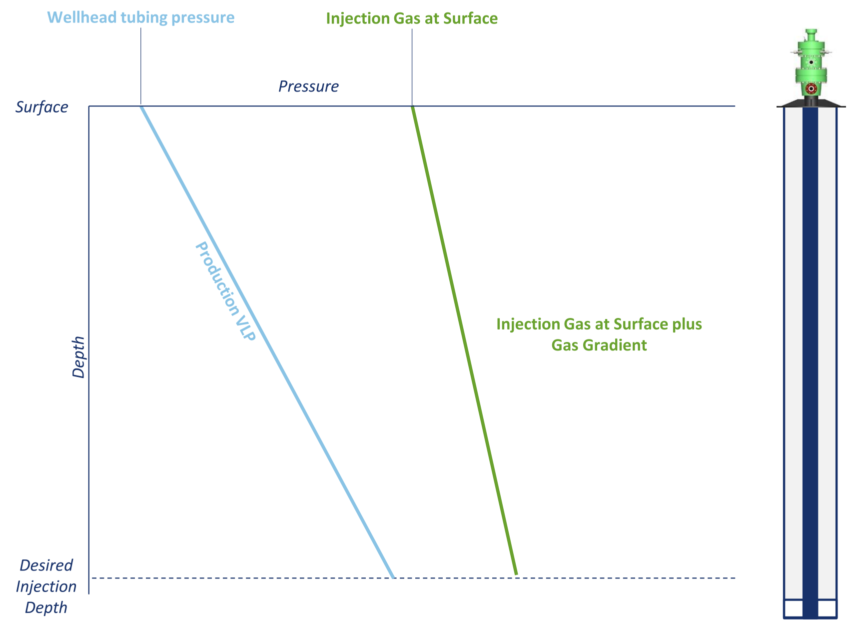
Topic #4

Intelligent Gas Lift System Design and Spacing

Intelligent Gas Lift Design and Spacing

Step #1

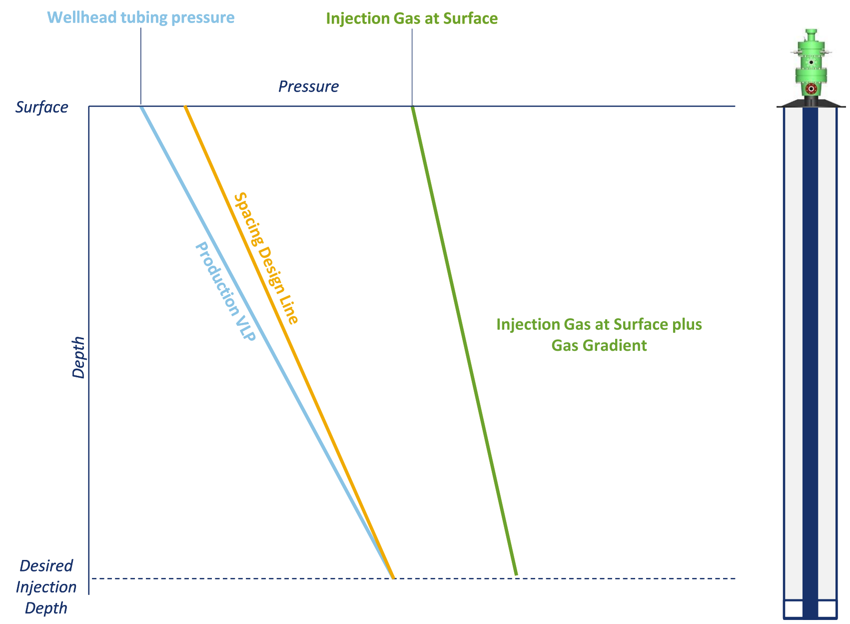
- As with the IPO spacing design, production VLP can be plotted on pressure vs depth chart for the well.
- The VLP can be determined using nodal analysis software such as Prosper.
- The injection pressure and gas gradient can also be plotted.
- These are the two boundaries in achieving the desired injection depth.
- The target differential pressure at the desired injection depth should be ≥100Psi.



Intelligent Gas Lift Design and Spacing

Step #2

- The spacing design line is constructed between two points:
- Surface = Pwh + (SF * (Pc – Pwh)).
- Injection Depth = Pt @ depth.



Where:

Pwh = Tubing pressure at wellhead

SF = Safety factor (varies depending on well PI)

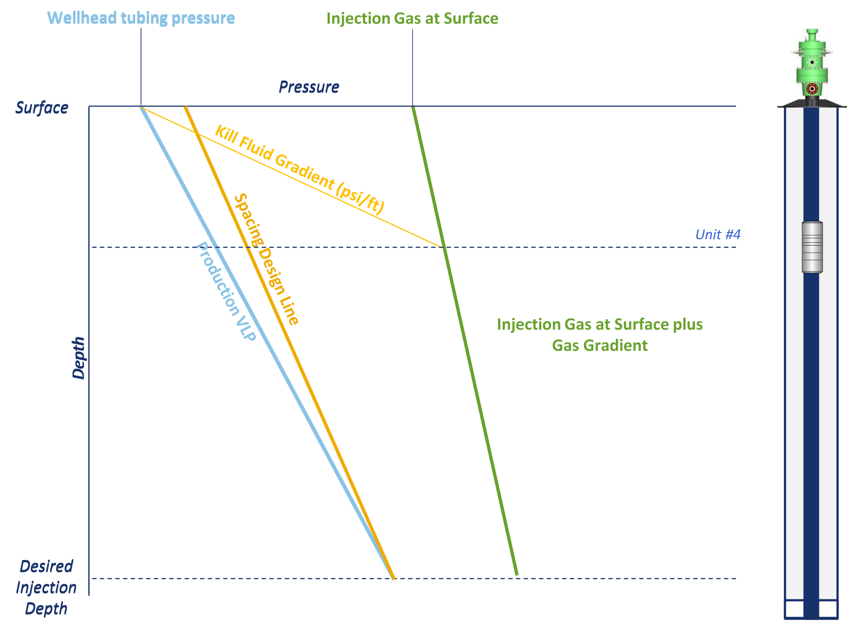
Pc = Casing Pressure

Pt @ depth = Tubing pressure at depth

Intelligent Gas Lift Design and Spacing

Step #3

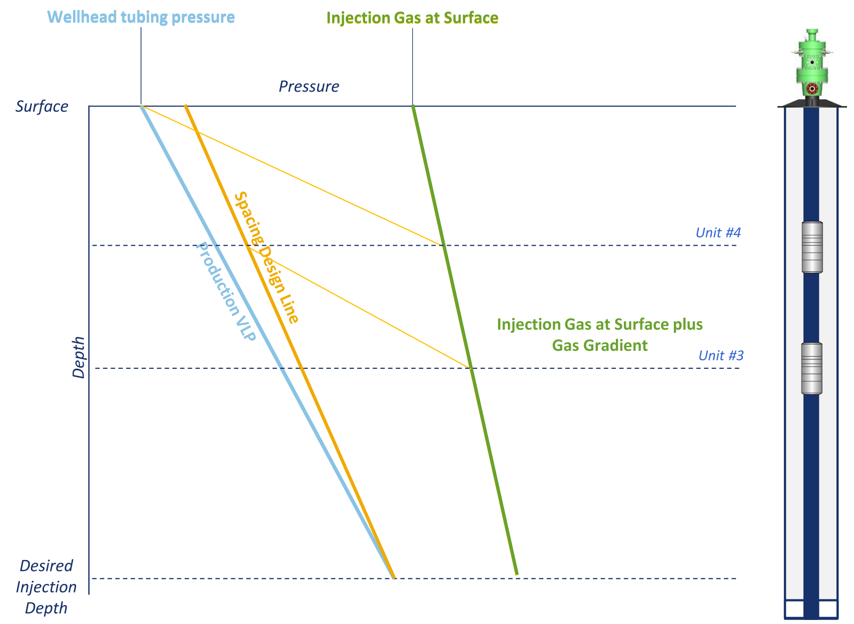
- The first unloading Intelligent Gas Lift unit depth is placed at the kill gradient pressure (Psi/ft.) from the wellhead pressure



Intelligent Gas Lift Design and Spacing

Step #4

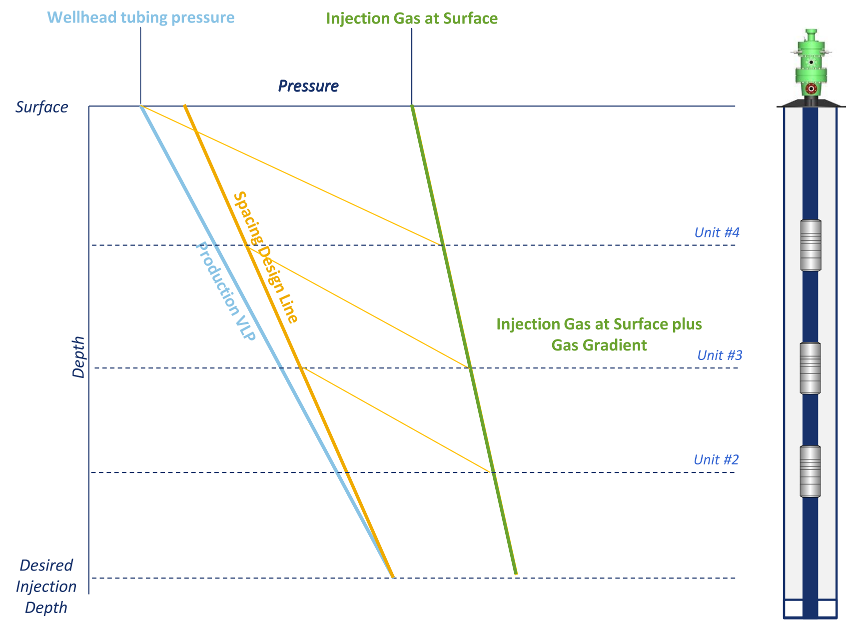
- The second Intelligent Gas Lift unit depth is placed at the kill gradient pressure (Psi/ft.) from the first Intelligent Gas Lift unit at the spacing design line.
- Unlike with the IPO valve design, a pressure drop isn't required to close the upper valves at the first Intelligent Gas Lift unit.



Intelligent Gas Lift Design and Spacing

Step #5

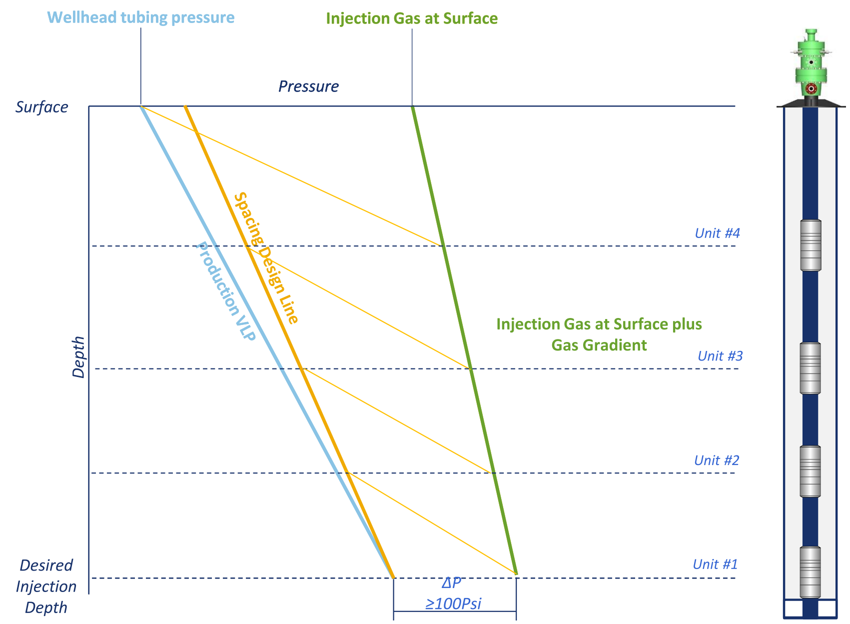
- The same process is followed to achieve the spacing for the third Intelligent Gas Lift unit.



Intelligent Gas Lift Design and Spacing

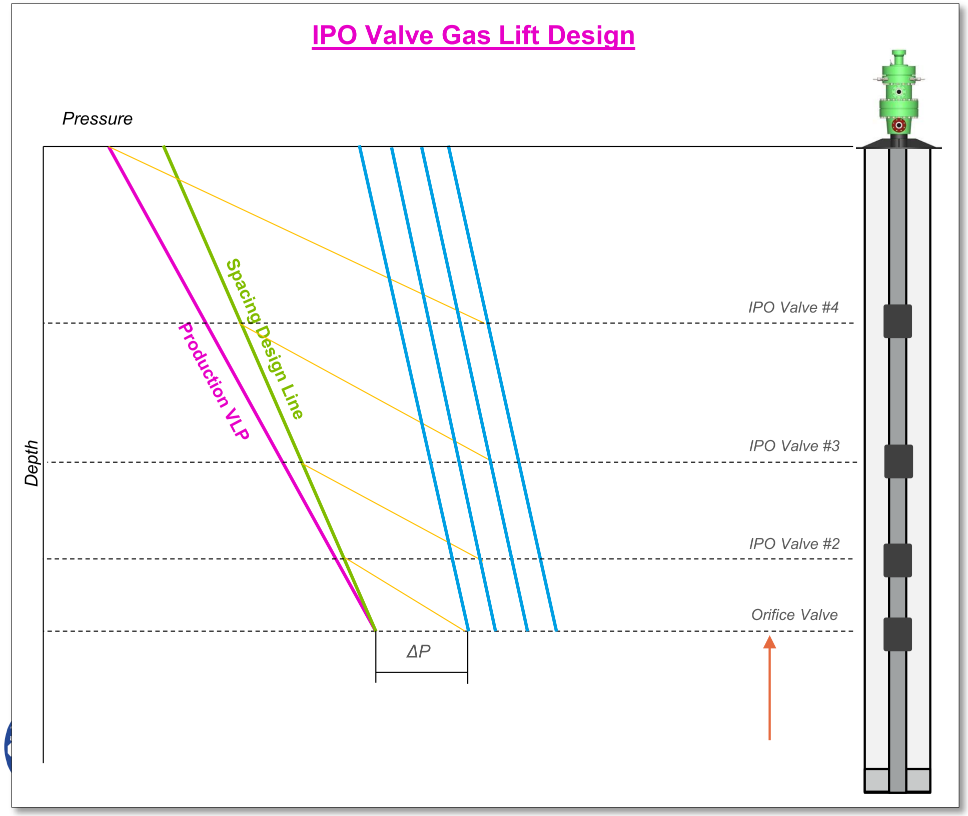
Step #6

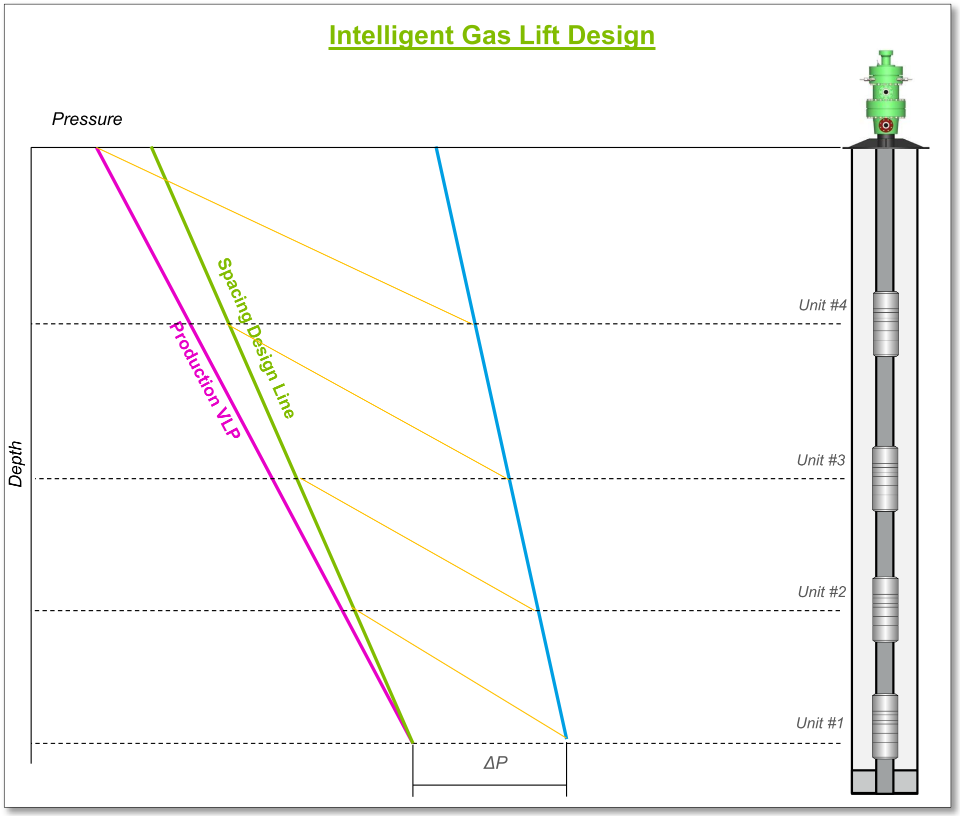
- The same process is followed to achieve the spacing for the fourth Intelligent Gas Lift unit and final injection depth.
- Intelligent Gas Lift can achieve the desired injection depth:
    - Without lowering casing pressure.
    - With less unloading stations compared to the IPO design.
    - With a higher differential pressure at the injection depth.
    - As the valves are active and not pressure operated, no nitrogen charge is required to set the opening and closing pressures.



Intelligent Gas Lift vs IPO Valve Well Design Comparison

Full Casing Pressure | Wider Spacing | Less Stations | Deeper Injection | Increased Production and Stability

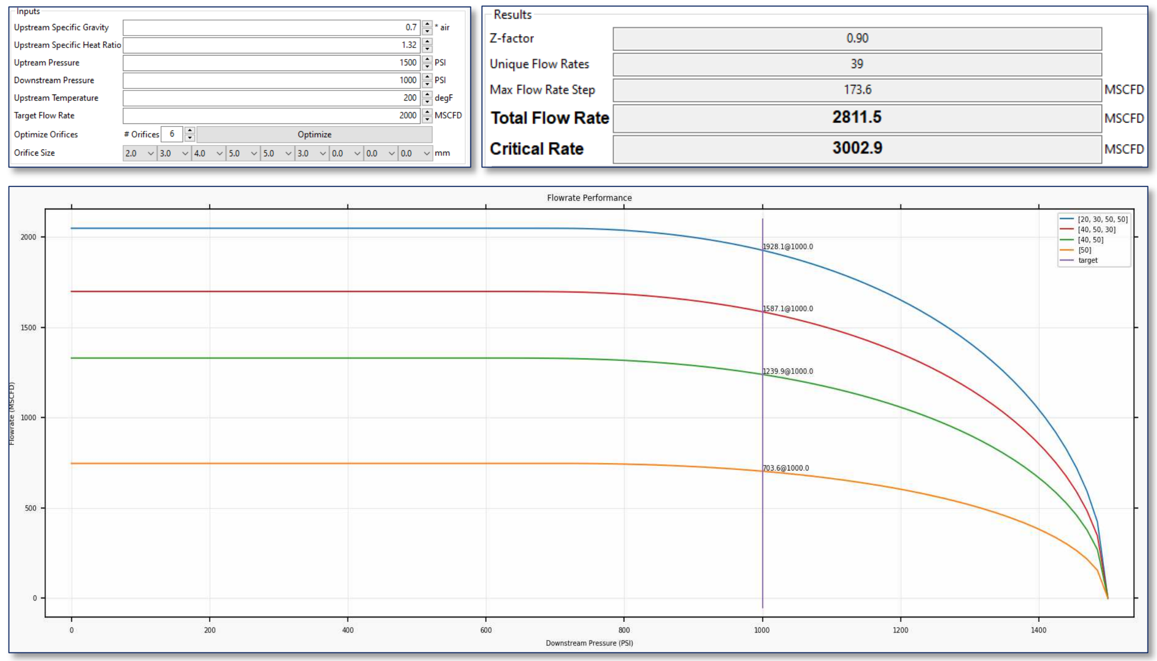




Intelligent Gas Lift System Orifice Selection

Step #7

- Select the port sizes which achieve the design gas lift injection rate.
- Consider incremental sizes to ensure the gas lift injection rate can be adjusted to ensure the optimum state can be achieved as well conditions change (i.e. increased water cut, lower reservoir pressure etc.)



Topic #5

Well Unloading

Unloading Workflow and Philosophy

Input gas sg and unit depths

Open all valve at all units

Start gas injection via casing

When gas gradient present between surface and unit #4, close valves.

Unit #4 unloaded

When gas gradient present between unit #4 and unit #3, close valves.

Unit #3 unloaded

When gas gradient present between unit #3 and unit #2, close valves.

Unit #2 unloaded

When gas gradient present between unit #2 and unit #1, close valves.

Unit #1 unloaded

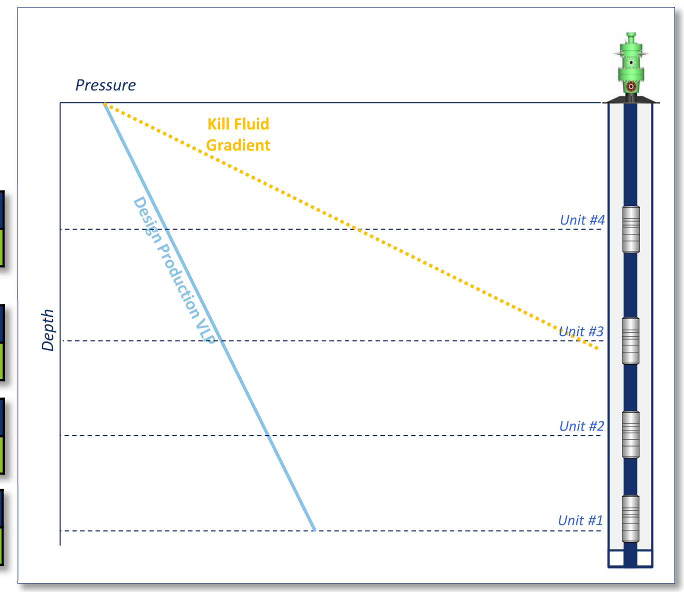
Well unloaded. Configure for optimum gas lift.

V1	V2	V3	V4	V5	V6
Open	Open	Open	Open	Open	Open

V1	V2	V3	V4	V5	V6
Open	Open	Open	Open	Open	Open

V1	V2	V3	V4	V5	V6
Open	Open	Open	Open	Open	Open

V1	V2	V3	V4	V5	V6
Open	Open	Open	Open	Open	Open



Unload to Unit #4 from Surface

Unit#4 is unloaded when:

Unit #4 Cp ≤ CHP + Depth to Unit #4 (ft. TVD) * Gas Gradient

Then the Intelligent Gas Lift System reconfigures the valves.

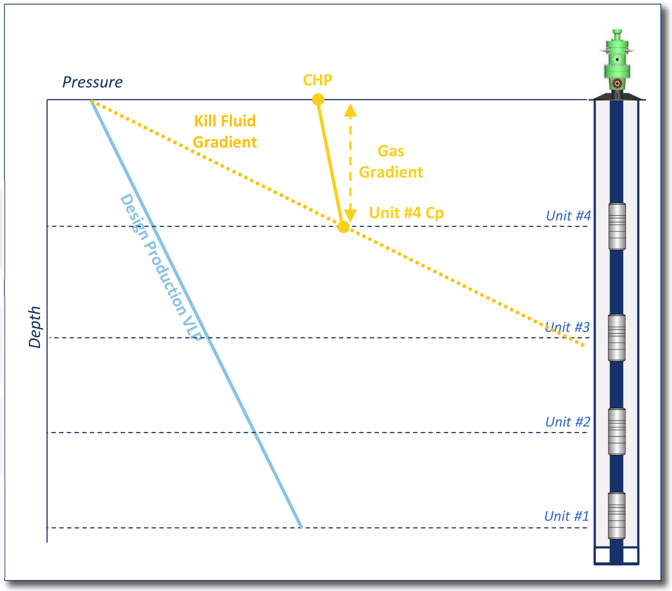
This act allows for a soft transfer of the injection gas to Unit #3, whilst continuing well flow with gas injection at Unit #4.

V1	V2	V3	V4	V5	V6
Close	Close	Close	Close	Close	Open

V1	V2	V3	V4	V5	V6
Open	Open	Open	Open	Open	Open

V1	V2	V3	V4	V5	V6
Open	Open	Open	Open	Open	Open

V1	V2	V3	V4	V5	V6
Open	Open	Open	Open	Open	Open



Unload to Unit #3 from Unit #4

Unit#3 is unloaded when:

Unit #3 Cp ≤ CHP + Depth to Unit #3 (ft. TVD) * Gas Gradient

Then the Intelligent Gas Lift System reconfigures the valves.

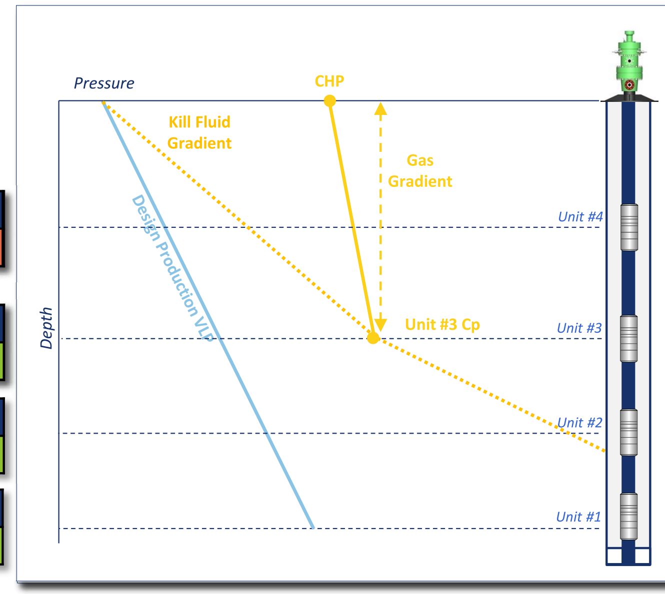
This act allows for a soft transfer of the injection gas to Unit #2, whilst continuing well flow with gas injection at Unit #3.

V1	V2	V3	V4	V5	V6
Close	Close	Close	Close	Close	Close

V1	V2	V3	V4	V5	V6
Close	Close	Close	Close	Close	Open

V1	V2	V3	V4	V5	V6
Open	Open	Open	Open	Open	Open

V1	V2	V3	V4	V5	V6
Open	Open	Open	Open	Open	Open



Unload to Unit #2 from Unit #3

Unit#2 is unloaded when:

Unit #2 Cp ≤ CHP + Depth to Unit #2 (ft. TVD) * Gas Gradient

Then the Intelligent Gas Lift System reconfigures the valves.

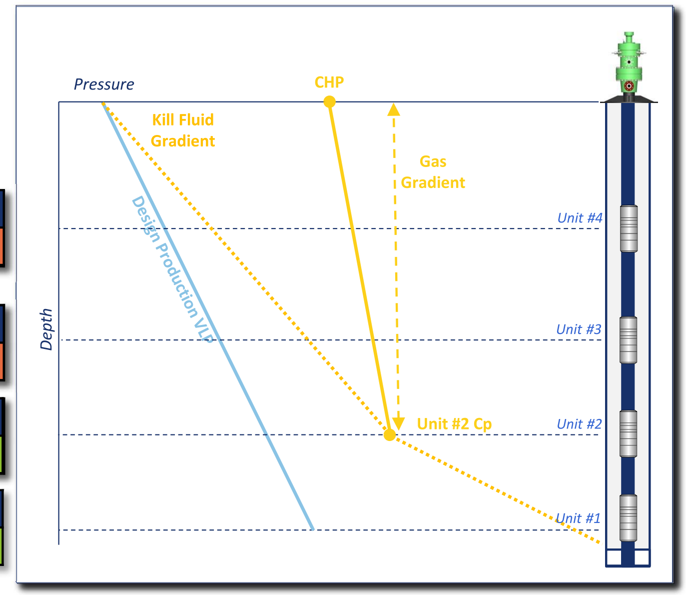
This act allows for a soft transfer of the injection gas to Unit #1, whilst continuing well flow with gas injection at Unit #2.

V1	V2	V3	V4	V5	V6
Close	Close	Close	Close	Close	Close

V1	V2	V3	V4	V5	V6
Close	Close	Close	Close	Close	Close

V1	V2	V3	V4	V5	V6
Close	Close	Close	Close	Close	Open

V1	V2	V3	V4	V5	V6
Open	Open	Open	Open	Open	Open



Unload to Unit #1 from Unit #2

Unit#1 is unloaded when:

Unit #1 Cp ≤ CHP + Depth to Unit #1 (ft. TVD) * Gas Gradient

Then the Intelligent Gas Lift System reconfigures the valves.

The well has been fully unloaded.

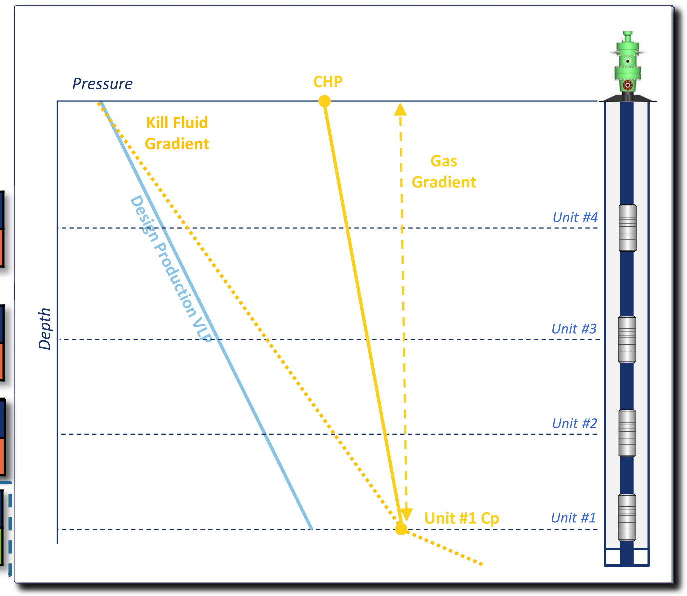
The well can now be configured for gas lift by adjusting the valve depending on the optimum gas injection rate at Unit #4.

V1	V2	V3	V4	V5	V6
Close	Close	Close	Close	Close	Close

V1	V2	V3	V4	V5	V6
Close	Close	Close	Close	Close	Close

V1	V2	V3	V4	V5	V6
Close	Close	Close	Close	Close	Close

V1	V2	V3	V4	V5	V6
Open	Open	Open	Open	Open	Open



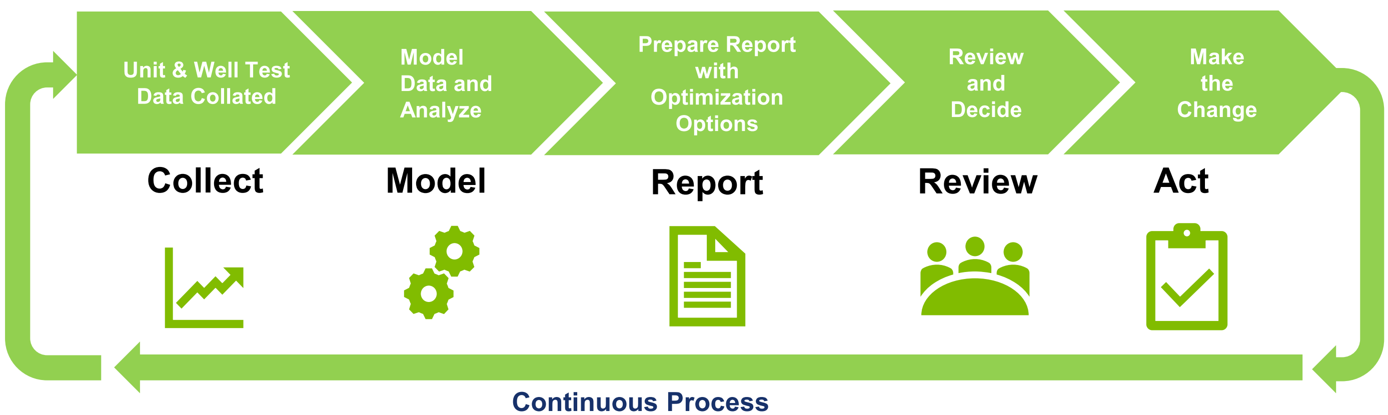
Topic #6

Production Optimization

Intelligent Gas Lift Production Optimization

From Months to Minutes

- Intelligent Gas Lift System's real-time data analysis and surface control enables production optimization in minutes.
- Conventional gas lift optimization can sometimes takes months due to the need for scheduling of flowing gradient surveys and well intervention to change valves.



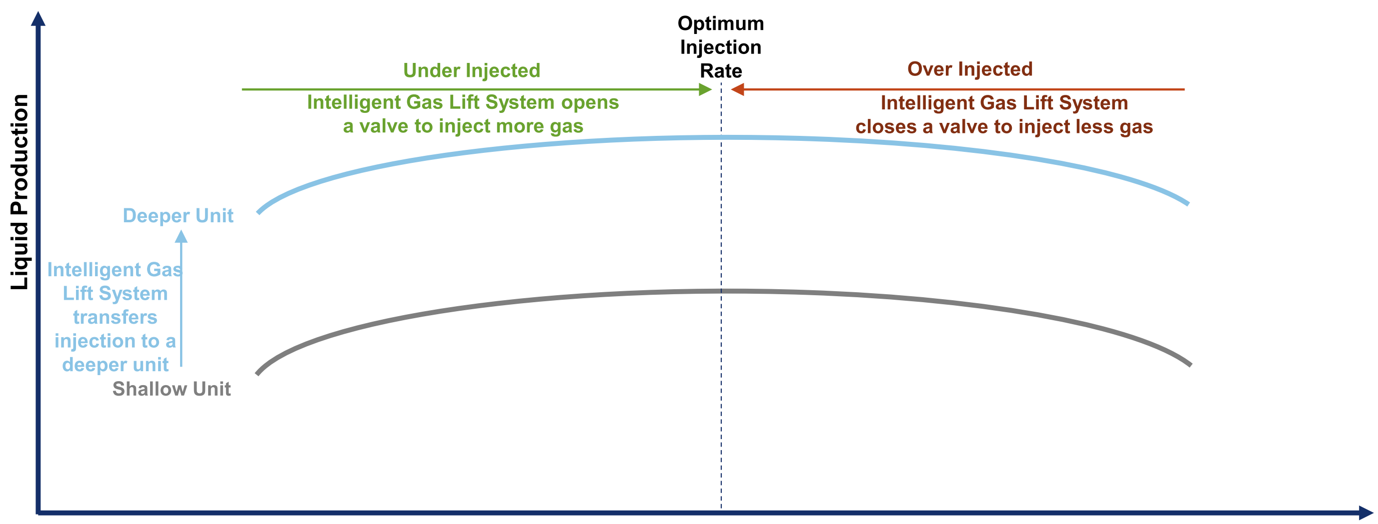
Gas Lift Optimization

Three Scenarios for Gas Lift Optimization

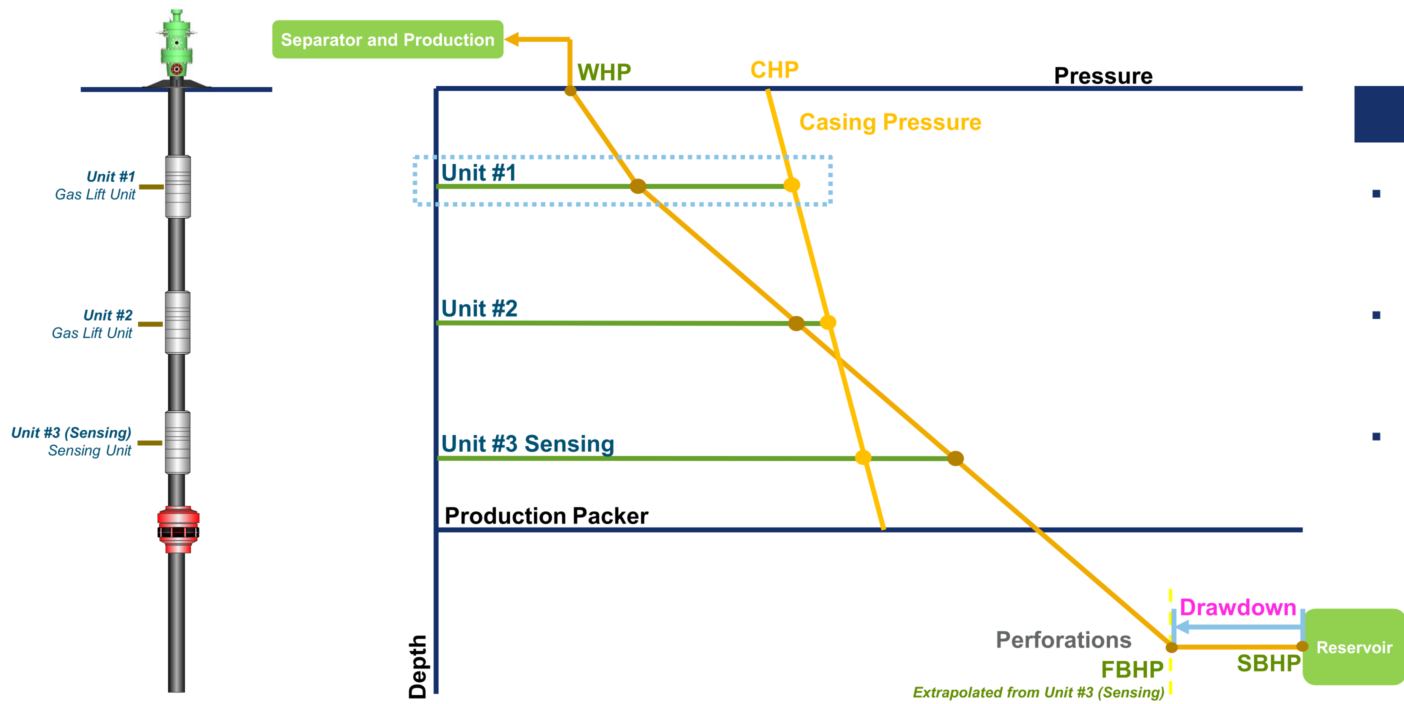
Deeper Gas Injection

Increase Gas Injection

Reduce Gas Injection



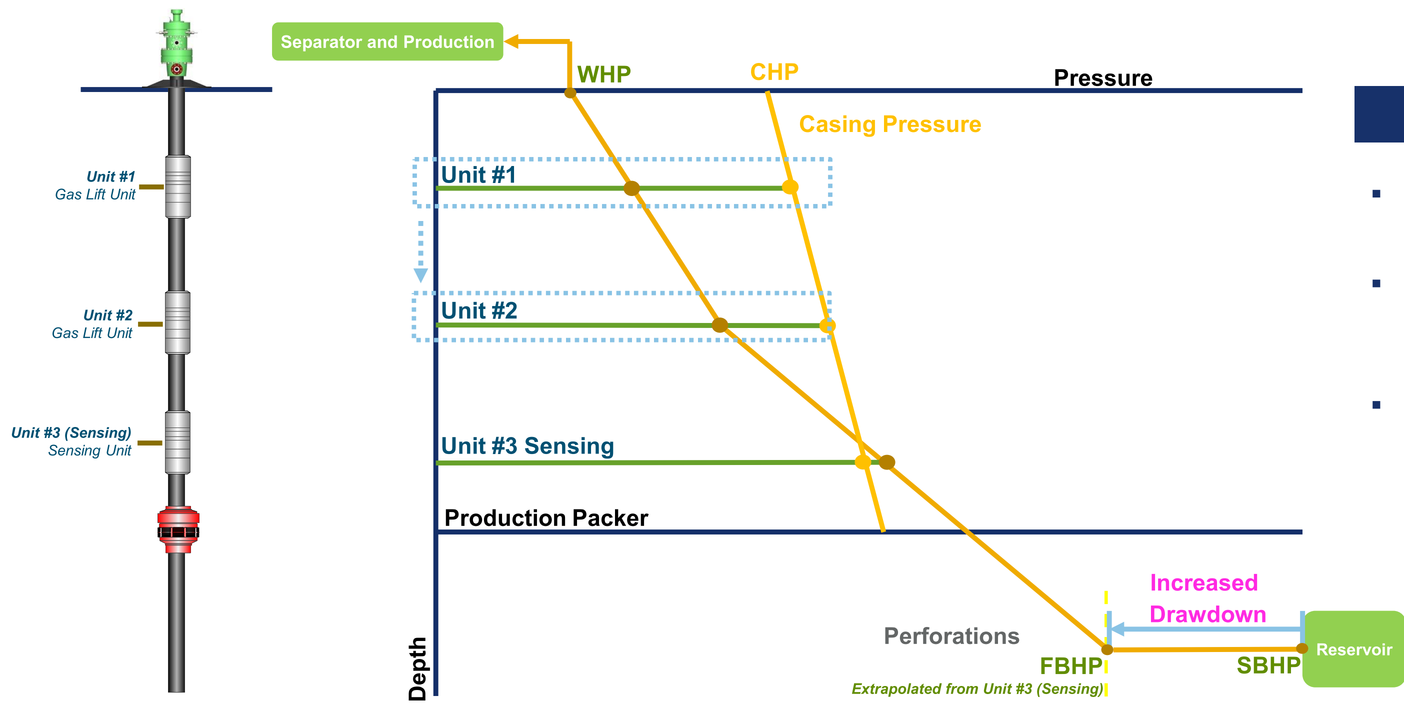
Scenario 1 | Can the Intelligent Gas Lift System Inject Deeper?



Scenario 1 Pre-Optimization

- In this scenario, injection is currently occurring at Unit #1 and the measured FBHP is above the target/setpoint.
- The Intelligent Gas Lift System identifies a deeper unit (#2) with an positive deltaP of ≥100Psi.
- The Intelligent Gas Lift System opens a valve at unit #2 and closes all valves at unit #1 (refer to the next slide for this action).

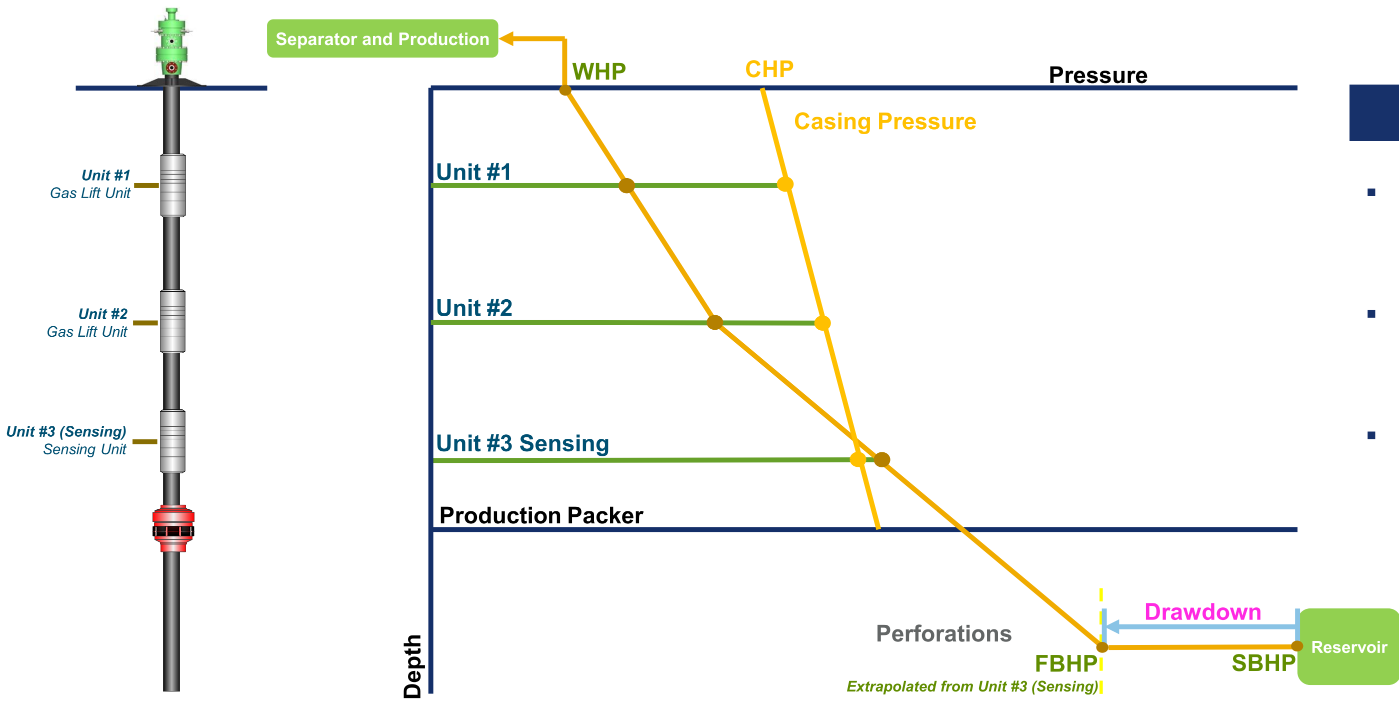
Scenario 1 | Optimization through Deeper Injection



Scenario 1 Post-Optimization

- Injection has now been transferred from Unit #1 to Unit #2.
- The FBHP has decreased and moved closer to target set-point. Drawdown from the reservoir has increased.
- In summary, the Intelligent Gas Lift System has optimized the well and increased the FBHP through deeper injection.

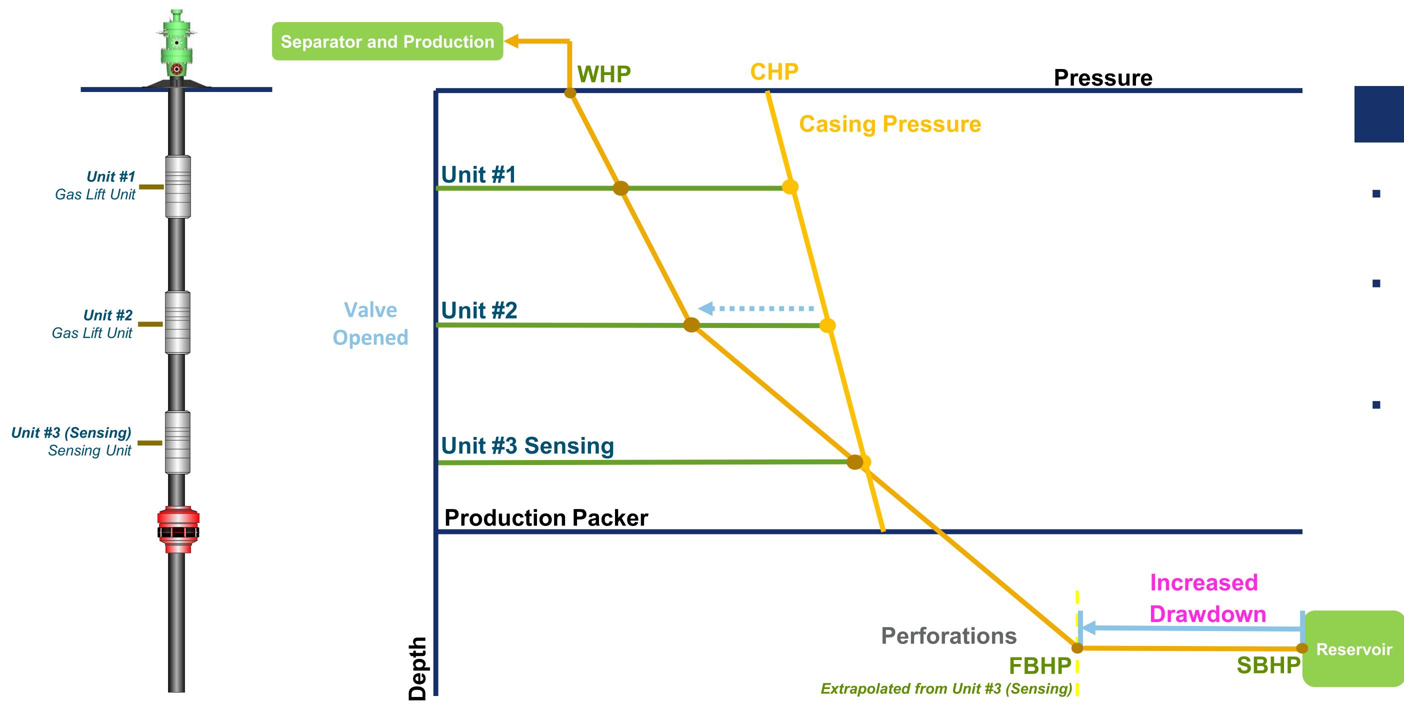
Scenario 2 | Can the Intelligent Gas Lift System Inject more?



Scenario 2 Pre-Optimization

- In this scenario, injection is currently occurring at Unit #2 and the measured FBHP is above the target/setpoint.
- The Intelligent Gas Lift System identifies that another valve can be opened at Unit #2, allowing for increased gas injection.
- The Intelligent Gas Lift System opens a valve at Unit #2 (refer to the next slide for this action).

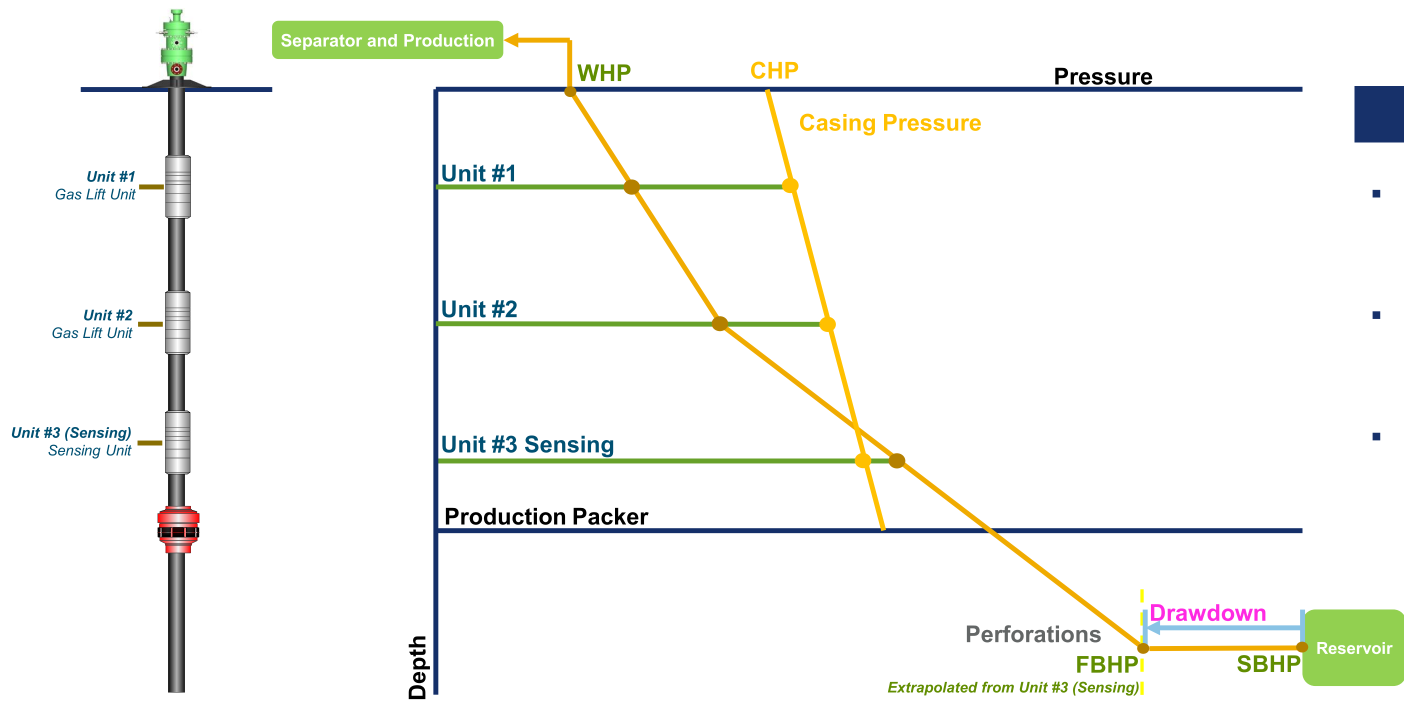
Scenario 2 | Optimization through Increased Injection



Scenario 2 Post-Optimization

- Injection has increased at Unit #2 through the opening of another valve.
- The FBHP has decreased and moved closer to target set-point. Drawdown from the reservoir has increased.
- In summary, the Intelligent Gas Lift System has optimized the well and increased the FBHP through increased injection.

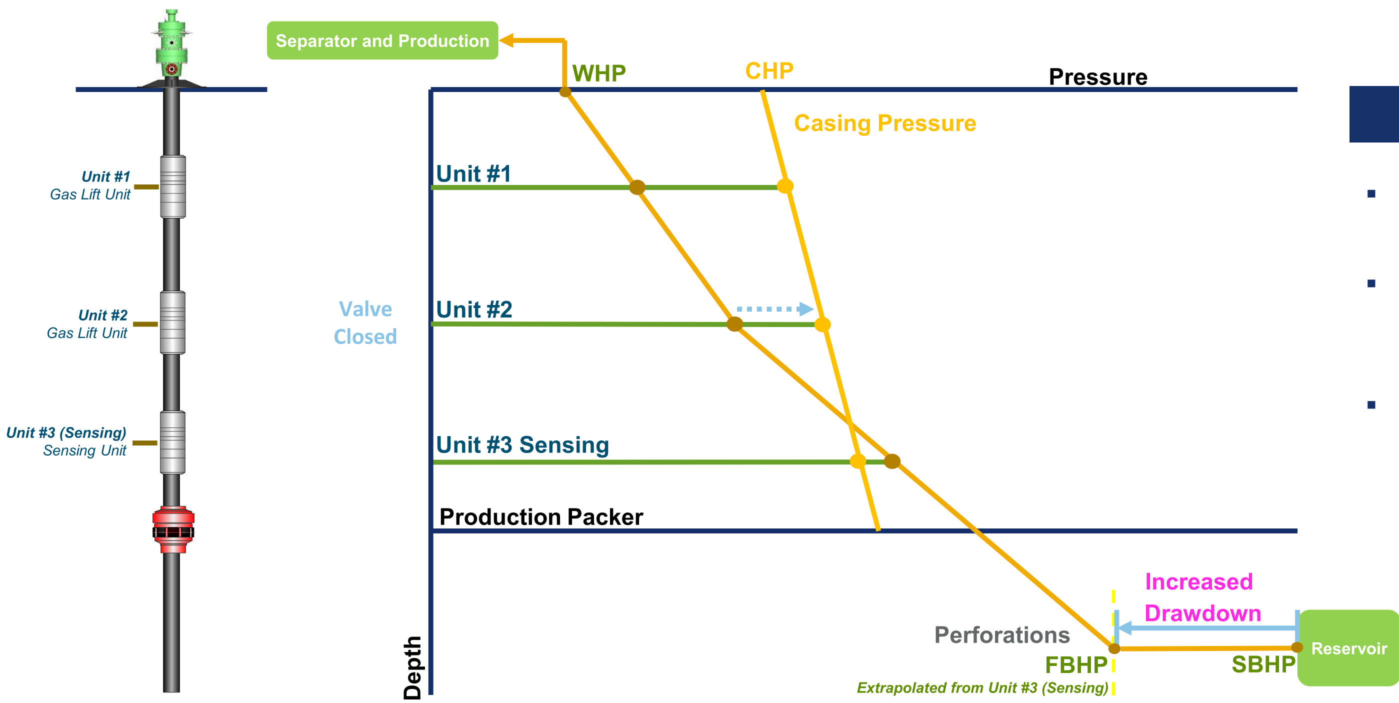
Scenario 3 | Can the Intelligent Gas Lift System Inject less?



Scenario 3 Pre-Optimization

- In this scenario, injection is currently occurring at Unit #2 and the measured FBHP is above the target/setpoint.
- The Intelligent Gas Lift System identifies that a valve can be closed at Unit #2, allowing for reduced gas injection.
- The Intelligent Gas Lift System closes a valve at Unit unit #2 (refer to the next slide for this action).

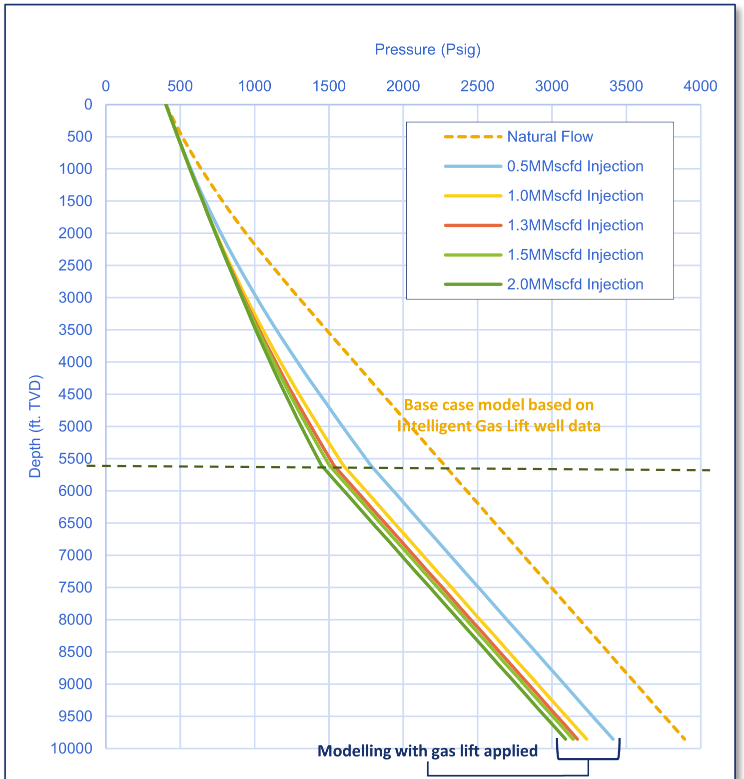
Scenario 3 | Optimization through Reduced Injection



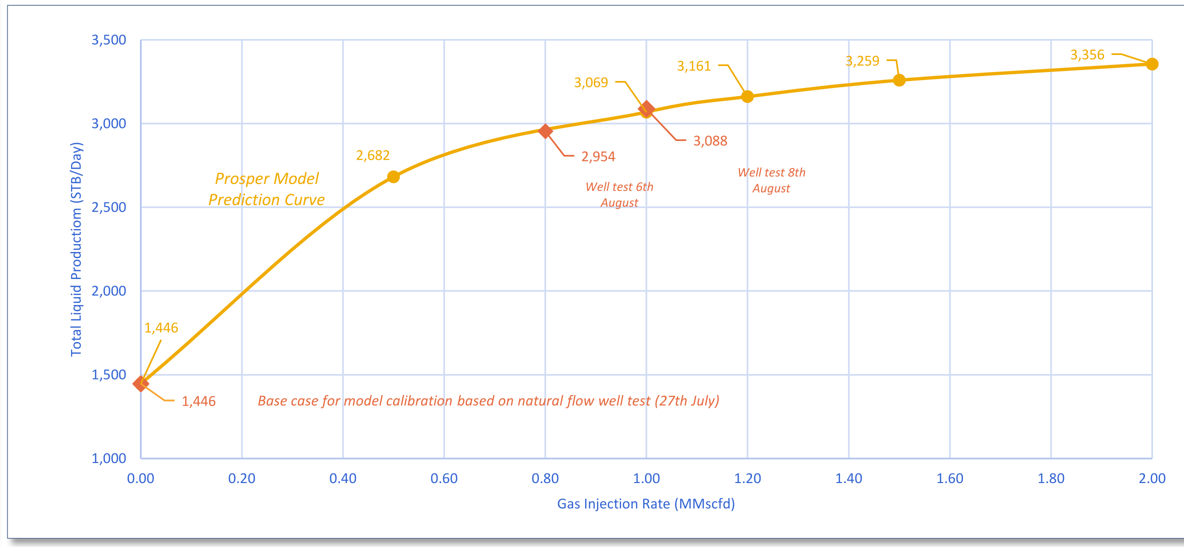
Scenario 3 Post-Optimization

- Injection has reduced at Unit #2 through the closing of another valve.
- The FBHP has decreased and moved closer to target set-point. Drawdown from the reservoir has increased.
- In summary, the Intelligent Gas Lift System has optimized the well and increased the FBHP through reduced injection.

Real Well Optimization Examples

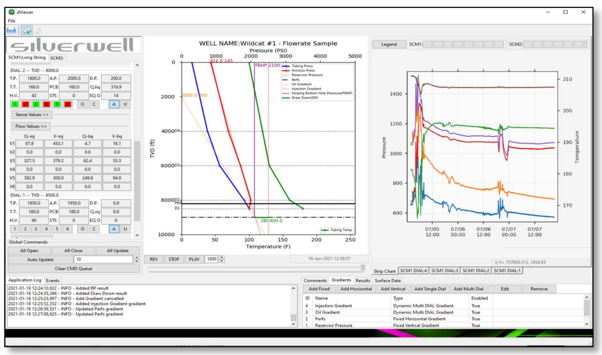


Surface Injection Rate (MMscfd)	~Casing Pressure @ Unit #2 (Psig)	~Tubing Pressure @ Unit 2 (Psig)	Unit #2 Orifice (Open/Closed)						Eq. Orifice Size (/64)
			V1 (6/64)	V2 (6/64)	V3 (6/64)	V4 (11/64)	V5 (11/64)	V6 (11/64)	
0.5	2,080	1,856	C	C	C	O	C	C	11/64
1		1,668	C	C	C	O	C	O	16/64
1.3		1,603	C	C	O	O	C	O	18/64
1.5		1,571	C	C	O	O	C	O	18/64

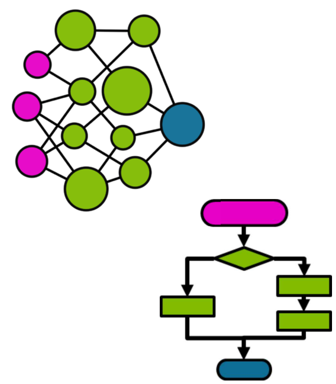


Cluster Wide Optimization and Automation

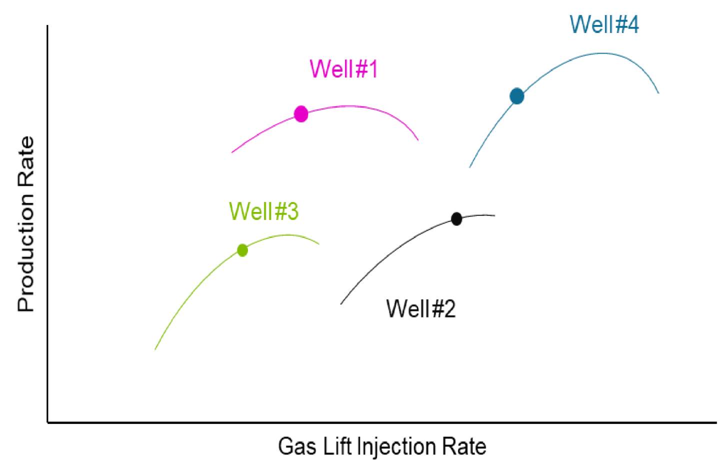
Intelligent Gas Lift System Data and Control



Workflows and Algorithms



Cluster/Field Wide Optimization with Efficient Management of Injection Gas



Summary and Q&A

Intelligent Gas Lift Case Histories | SPE Papers

Year	Paper #	Title
2016	SPE-184184-MS	The Benefits of Introducing Intelligent Gas Lift Management to Create a Smart Field
2016	SPE-184221-MS	Gas Lift - Past & Future
2018	SPE-191885-MS	Ground Breaking Technology in Artificial Lift 1st Installation of Full Digital Intelligent Artificial Lift (DIAL) System at DL field, Brownfield Offshore Malaysia
2018	SPE-192463-MS	Pilot installation of in-well digital gas lift system in PTTEP Sirikit Oilfield
2019	SPE-196146-MS	First Digital Intelligent Artificial Lift Production Optimization Technology in UAE Dual-string Gas Lift Well
2019	MEALF-2019	DIALing in Gas Lift Production Optimization - Unconventional Well Case History
2019	SPE-197824-MS	World's First Digital Gas Lift Application in Dual Completion Technical & Economic Consideration for Successful Implementation
2020	SPE-201140-MS	Pilot Application of Remotely Operated Gas Lift Valves in Permian Basin Unconventional Wells
2020	SPE-205763-MS	Successful Pilot of DIAL Digital & Interventionless Gas Lift Production Optimization System Offshore Malaysia
2021	SPE-206182-MS	Digital Intelligent Artificial Lift DIAL Gas Lift Production Optimization Deployments Across Assets
2021	SPE-206262-MS	Gas Lift Design Optimization Using Intelligent Gas Lift Valves a KJO Case Study

Q&A and Thank You

Webinars

Stephen Faux | Application Engineering Manager | Stephen.faux@silverwellenergy.com

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