ICING ON THE CAKE: SURPRISE BENEFITS OF SURFACE CONTROLLED GAS LIFT

Joel Shaw

Silverwell Energy

INTRODUCTION

Gas lifted wells have been dominated by Injection Pressure Operated (IPO) valves over the last half century. The technology is well known and offers some great benefits over other forms of artificial lift in some wells and in some fields. Advancements in electronics, manufacturing process, and technology are delivering breakthroughs that offer more intelligence and functionality downhole. Surface controlled gas lift is one of the most recent of these breakthroughs.

Surface controlled gas lift is exactly as it sounds. It is a gas lift system that allows an operator real time control of downhole gas lift valves from the surface. From anywhere on the surface. This might not seem like much of an advantage over IPOs, but it allows for some very predictable benefits such as increased production due to deeper injection. This is an obvious benefit that can be modeled, accurately predicted, is generally accepted, and a value can be easily calculated. Continuous optimization with intervention is another benefit that is accepted but much harder to put a value on. Many benefits are less obvious, and those will be addressed in this paper.

This document will start by describing what a surface controlled gas lift system is, and how it relates to traditional IPO completion. Then it will briefly touch on the obvious advantages of surface controlled gas lift. These are the types of advantages that would go in a business case showing immediate value added to production. Then it will discuss field experiences proving unanticipated benefits… surprises… “icing” on the “cake” of increased production.

GAS LIFT AND SURFACE CONTROLLED GAS LIFT COMPARISON

Gas lift is an artificial lift process that uses gas injected into the production string to reduce the hydrostatic column that the reservoir sees. This reduction in hydrostatic pressure allows the available reservoir pressure to push oil out of the formation (see Figure 1). Over the last 50 years the industry has focused on the use of IPO valves. These are devices that allow gas to flow from the annulus to the tubing based on the pressure in the annulus. These are placed along the length of the production string. It is beyond the scope of this paper to explain the details, but Figure *2* is included to give the reader a basic idea of the implementation of a gas lift system. In general valves close as the annulus pressure drops. This allows the well to gradually reduce the hydrostatic pressure to the formation as each IPO closes and forces more lift into subsequently deeper IPO stations as represented by the steps in Figure *3*. Each of these stations acts autonomously based roughly on the pressure in the annulus. This system works well at producing some level of oil production, but there are shortcomings.

From a design perspective, the pressure and temperature related opening and closing pressure of each IPO valve must be set before installation. This requires a good understanding of the well behavior at initial completion as well as for the life of the well. Optimization requires the assumption that the well will be stable over time, the reservoir characteristics are completely understood before completion, and the infrastructure not to change over time. None of these assumptions are valid, especially in unconventional fields. Correction for poor misassumptions or dynamic factors requires intervention.

The design of a well to utilize IPOs also requires some concessions. One that affects production is the pressure drop required in the design of each station. To guarantee that a station will close and drive gas flow to a lower station, an extra pressure reduction is required for each station. A good rule of thumb is a 20-50 psi pressure drop for each additional station. If 10 stations are required to get to the desired injection depth, 500 psi is lost in the design. That 500 psi could be used to inject even deeper, increase the drawdown, and increase production.

Surface controlled gas lift provides a solution to this dilemma. It offers absolute control over where gas is injected and at what rate at any time in the life of the well. It also offers instant adjustment of gas injection without any sort of intervention.

Three main components are required for surface controlled gas lift: downhole flow control devices, a way to communicate with the downhole flow control devices, and the surface system to communicate with the downhole devices. Figure 4 shows such a system. It includes the downhole surface controlled gas lift valves, a communication line to the surface, and a surface control system to relay communications. This control system is typically communicably attached to the operator's SCADA (Surface Control and Data Acquisition) system.

This is a very simplistic summary of the IPO and surface controlled gas lift systems, but along with the figure it offers enough of a framework to present the ideas in the remainder of this paper.

SURFACE CONTROLLED GAS LIFT APPARENT ADVANTAGES

One of the most basic advantages of many surface controlled gas lift systems is the ability to inject gas deeper because the available pressure is not lost to guarantee the operation of IPO valves. This leads to more drawdown at the formation and increased production as shown in Figure 5 (Faux et al 2016).

IPO completions must be designed to function when the available gas lift injection pressure is at its lowest. That provides a very conservative design that cannot then utilize increased injection pressure to increase drawdown and production.

These two benefits are often predicted and quantifiable. They are straight forward. They can be included in business cases, measured, and compared to other wells.

Surface controlled gas lift also enables some completions that would not otherwise be viable. Two examples are in situ gas lift and dual string gas lifted completions.

In situ gas lift (also called auto gas lift) describes wells extending through both gaseous formations and oil producing formations as shown in Figure 6. In them, surface controlled gas lift valves allow gas to controllably enter a production string that is also open to an oil formation. As gas is allowed to enter the production string, the hydrostatic column is reduced which aids production from the oil formation. IPOs and Interval Control Valves have been utilized for such completions, but neither offer the level of control that surface controlled gas lift valves offer.

Commented [JS1]: Reference paper on In situ, with ICVS or IPOs or DIALs

Surface controlled gas lift is also an enabling technology for dual string gas lift wells (Figure 7). While these types of wells have been completed for decades by using IPOs on one of the strings and PPOs on the other, most operators have given up on them because they end up being uncontrollable. In theory, the annulus pressure can be used to control gas injection in one string and production pressure can be used to control the other. In practice, it is a continuous balancing act and one well always ends up taking the vast majority of the gas. Surface controlled gas lift is driving regained interest in dual string gas lifted completions because it allows absolute control of each string regardless of annulus or tubing pressures (Salleh et all 2022, Alshmakhy et al, 2020, Kumar et al, 2021).

These are all obvious examples of surface controlled gas lift advantages such as increased production or enabling a special type of completion. There are many more, but the next section surprise discusses benefits that might be a little less clear without the benefit of field experience and hindsight.

SURPRISE BENEFITS

The above-listed benefits are understood and predicted. They show production increases that can be used to justify installation as well as some softer benefits. In some cases, they are enablers for new well configurations such as In Situ or Dual String. Many benefits have come to light through experience and real-life applications. Some of these include:

- Diagnosing and Correcting Downhole Hardware Problems
- Quick Production Recovery After a Frac Hit or Shut-In
- Fracking Operations
- Debris Identification and Recovery
- Benefits Anticipated but Not Obvious

The first several items are fairly straightforward from the description and represent unanticipated or *under*-anticipated benefits of surface controlled gas lift, and the results are based on actual wells. The last item refers to benefits that were eventually anticipated but were not initially obvious.

The following subsections elaborate on each of these subjects.

Diagnosing and Correcting Hardware Problems

While many more problems have been diagnosed and corrected in place using surface controlled gas lift, a few specific instances are indicative of its benefits. This subsection will highlight:

- Sensing and correcting Injection Pressure Operated (IPO) Valve Chatter
- Finding a Malfunctioning Safety Valve
- Discovering incorrect readings from the Surface flowmeter
- Incorrect pressure gradient reveals gas process issue
- Debris Identification

Wells have occasionally been hybridized with IPO and surface controlled gas lift valves to reduce cost or as a contingency. While these wells make sense in some limited cases, they do not provide the full benefit of surface control. The IPOs are susceptible to the same shortcomings they traditionally see, namely multipointing and chatter. One difference is that the monitoring and control offered by the surface control valves in the hybrid system allow the operator some options. This was evident in a hybrid West Texas unconventional well which was seeing some production anomalies. The pressure data indicated that the upper IPO was chattering. Rather than blindly dropping the gas injection rate, the surface control valves were adjusted to maintain steady and optimized injection without multipointing or chatter.

Surface controlled gas lift was also helpful in diagnosing a Middle Eastern well that experienced a drastic drop in production when brought back online after being shut in. In this case, it was unclear if there was a gas obstruction downhole, a tubing restriction, a wellhead restriction, or any other number of culprits. The well had multiple surface controlled gas lift valves offering the operator a tubing and annulus pressure profile. This profile in conjunction with the flowing wellhead pressure was used to calculate a density profile by which it became obvious the restriction was in the subsurface safety valve. With the problem identified, the operator was able to assemble and implement a plan focused on repairing that specific item.

Problems have also been identified with Surface equipment by comparing surface readings with those from the surface controlled gas lift system. For example, the pressure readings and flow coefficients in a surface controlled gas lift system are used to calculate the flow rate at each gas lift station. In one Middle Eastern application, flowmeter readings from the surface disagreed with the downhole flow calculations from the surface controlled gas lift system which led to re-calibration of the surface flow meter.

In another application from the same region, the pressure profile shown by the surface controlled gas lift differed from what was expected. The gas appeared to be more dense than anticipated, which lead to process checks in the gas separation and cleaning process.

Both cases show that collecting cross-checking multiple data sources is useful for maintaining optimal production.

Debris can create problems with many kinds of downhole jewelry, and this is especially true of gas lift valves since they have a metal-to-metal seal, low initial interfacial force, and act like a vacuum cleaner as the well is unloaded through their orifices. Luckily, surface controlled gas lift offers some mechanisms to detect debris. One prime example was a well in the Middle East that could not pass a tubing test. This particular well included a fiber optic line, but even Distributed Acoustic Sensing (DAS) was unable to determine the locale of the leak. However, the surface controlled gas lift valves that were installed in the well included a position indicator. That sensor was able to determine that there might be a poorly seated valve at one of the gas lift stations. Armed with this knowledge, the operator utilized some of the interventionless debris recovery methods that will be mentioned below to clear the debris and get a good tubing test.

Debris issues are the same for IPOs and surface controlled gas lift valves, but debris issues seem to be noticed more often with surface controlled gas lift because they can often be detected. Luckily there are interventionless options to correct debris in surface controlled wells that are not available with IPO valves. The following subsection describes debris remediation more thoroughly.

Debris Detection and Remediation

Well cleanliness is paramount for gas lift systems in general. The small ports are a point through when everything in the well annulus must pass, and the oilfield is rife with stories of things that have been found in gas lift valves. This can even extend beyond just debris to include buildups such as scale or paraffin (Sompopsart et al 2018).

Surface controlled gas lift systems include tools to determine if there is a debris issue including temperature and pressure profiles of the tubing and annulus, position indicators, and adjusting the well to see how it reacts. Ironically, this might make it seem debris is more of an issue in surface controlled gas lift systems. Rather, it is just more detectable. Luckily surface controlled gas lift offers solutions for debris that are not available to more traditional forms of gas lift or are simply better suited to surface control. Some of these include:

- Rock the Well
- Hot Oil
- Multiple shifts
- High-Pressure Flow
- High-Pressure Opening

Rocking the Well is a gas lift valve unplugging procedure that consists of first closing the tubing until the well reaches steady state with pressure in both the tubing and annulus. Then, quickly venting either the tubing or the annulus to dislodge any foreign material. This is a common practice utilized over decades for conventional gas lift. Selectively focusing the stored energy by opening certain valves means it can even more successfully be applied to DIAL completions.

Hot Oil refers to pumping produced condensate, diesel, xylene, or other solvents down the annulus and through the downhole valve to eliminate deposits. As with Rocking the Well, this is a well-proven technology in gas lift applications.

Multiple Shifts: DIAL systems are unique in that the valves installed in the units can be shifted opened or closed on command. If there seems to be a problem with one of the valves, multiple shifts can dislodge a blockage or remove debris from a sealing surface.

High Pressure Flow: DIAL systems are also a huge improvement from traditional systems in that the pressure can be increased to clean valves and dislodge material. In traditional gas lift systems, increasing the pressure would tend to open upper gas lift stations. DIAL systems will not open unless commanded to do so from the surface.

High Pressure Opening is another remediation option unique to DIAL Systems. Traditional Gas lift valves open uncontrollably as the pressure changes. Conversely, the DIAL system can be held shut while the pressure is increased. High Pressure Opening refers to building up a pressure differential across a DIAL Valve while it is closed. Opening causes a flow surge that can dislodge foreign material.

Each well and situation is different, so combinations of these remedial options are typically applied. Their order would normally be based on the ease of accessibility of the elements required to conduct the procedure. Table *1* offers a comparison of some of these options relative to surface controlled gas lift and more traditional IPO systems.

There have been many examples of these debris remediation methods being utilized. In West Texas, a restriction was found and overcome by using hot oil focused on a particular valve. In Malaysia, a tubing leak was found and corrected by opening under pressure and flowing through a specific valve (Zaidi et al, 2021). There have also been Alaskan wells utilizing surface controlled gas lift systems that would not fully seal due to well debris in the valve. These were recovered by selectively flushing individual valves.

Wells completed with IPO valves offer no way to detect these issues or resolve them without randomly pulling valves until the problem is discovered. Detecting and correcting each of these well problems without intervention was directly enabled by the surface controlled gas lift system.

Fracking Operations

Fracturing wells has become a necessity as more energy demands and depleting reservoirs have driven new completion and production technologies. Competition that drives down oil prices to consumers also requires more to be accomplished more quickly as wells are drilled, fracked, and completed. This means equipment needs to do more jobs more quickly and with less intervention, and it is advantageous to able to frac through the same downhole jewelry used to complete the well for production.

Fracturing through a traditional gas lift would historically use side pocket mandrels with dummy valves installed for the frac. Slickline, wireline, or tractor operations are utilized after the frac to replace these dummy valves so that production could go online. This took extra time, added risk, and increased unpredictability. Fracking through surface controlled valves does not require additional intervention, so lab testing was conducted to verify surface controlled gas lift valve's ability to function after a frac.

The area between the closed valve and the tubing is a blind volume, so little debris is likely to flow into that area during a frac, but lab testing included loading the valve in the worst case scenario. Various grades of proppants and fine sand were crammed between the production check valve (also known as the back check valve) and the simulated inner diameter of the production tubing. Then, hydrostatic pressure was introduced to simulate a frac. Finally, water was circulated through the production check valve to simulate flow from the annulus to the tubing. Testing showed that the check valve opened, water cleared the packed proppant and fines from the system, and the check still held pressure after the test.

Multiple wells have been fracked through surface controlled gas lift valves since successful lab testing, and the system performed nobly. If these wells utilized side pocket mandrels, a cleanout run would be required to remove debris from the mandrel and intervention to replace the dummy valves. If this had been a tubing conveyed IPO, it would have been impossible to selectively flow through certain valves to clear debris. With surface controlled gas lift, no intervention was required to selectively flow through and clean out individual valves.

Quick Production Recovery

Fracking poses another issue in unconventional fields with dozens or hundreds of wells in close proximity. Fractures can sometimes communicate pressure from a well being fracked to one under production. This translates to proppant or sand production and a pressure spike in the well under production. These frac hits are detrimental to an Electrical Submersible Pump (ESP), can destroy surface chokes and equipment, and can disrupt gas lift production. After such an event, wells must be shut in and brought back online after things settle. IPOs require a strict procedure to ensure that each well comes online predictable, and that takes slowly building up gas injection as if the well was initially unloading and coming online. This can take days or weeks for an entire pad of wells.

Surface controlled gas lift offers an alternative. With real-time individual control of each valve and reporting of the pressure sensors, the operator can use the measured pressure profile to determine which stations should be opened or closed. Wells can recover from a frac hit in hours or minutes rather than days or weeks, leading directly to improved production.

An unconventional well in West Texas (Visser et al 2020) showcased this benefit. Surface controlled gas lift was utilized in a well on a pad that took a nasty frac hit. Afterward, the surface controlled gas lift well was back online days before the proximal wells.

Returning to steady state production after a shut in is beneficial for all wells, not just those in unconventional fields that might take a frac hit. Most wells are shut in periodically. It could be for a log, it could be for stimulation, it could be to work on surface equipment or flow lines, it could be for any reason. It could even be because a nearby well needs work. With surface controlled gas lift, a remote flip of a switch is almost all that it takes to get those wells back to production.

Any number of algorithms can also be used to automate bringing a well back online. These algorithms can be implemented onsite at the edge of the network, they can be implemented in the cloud, or they can be implemented at a central processing facility. Furthermore, a combination of algorithms may be used. A processor in the field could be encoded to act like an optimized and idealized IPO to automatically account for minor aberrations, and a central processor might be used to send commands overriding that functionality based on field needs.

Anticipated But Not Initially Obvious

Many of the softer benefits or factors of surface controlled gas lift were not surprises discovered *after* wells were installed. They were anticipated ahead of time, but they were not obvious. Some have been anticipated but not yet proven:

- Creative Elimination of Scale, Parafin, Asphaltine, etc
- Packer Test
- Extended Reach
- Handle and Utilize Variations in Lift Gas Supply Pressure
- PPOs in Hybrid Systems
- Carbon Reduction

Material buildup (scale, asphaltene, etc.) is a problem in wells around the world. This can be exacerbated by cooling as is common when gas expands through a gas lift valve or a surface choke. With surface controlled gas lift, the operator is armed with the real-time pressures and temperatures of the liquids and gases. They can utilize that in conjunction with characteristics of the various chemical constituents and downhole flow control to steer clear of dangerous areas on the Pressure Temperature chart that might create precipitates.

Offshore wells are another arena subject to buildups in the flow lines. Their lift gas infrastructure is often on the ocean floor and at low temperatures, and choking on the cold ocean floor leads to even more problems. Even worse, inaccessibility exacerbates the problem if there ever, and some have not yet been proven in the field, and some have not yet been proven in the field is an issue. Surface controlled gas lift eliminates the problem by reducing or removing choking on the ocean floor and moving it downhole where there is elevated temperature.

Surface controlled gas lift offers operators more options for setting and testing a completion. One example is an annulus test after a completion has been landed and the production packer is set. If tubing conveyed IPOs are used, it is impossible to test the packer by pumping up on the annulus. If side pocket mandrels are used, dummies must be installed during the packer test. Surface controlled gas lift valves can simply be closed for the test and reopened once the packer integrity is verified. This has become the common practice for surface controlled gas lift valves.

Surface controlled gas lift has also become the standard for highly deviated and extended reach wells. As the deviation increases, it becomes more difficult to access side pocket mandrels with slickline and eventually downhole tractors are required. But tractors are expensive, and using kickover tools gets risky as wells deviate more and more from vertical. Surface controlled gas lift does not require any intervention for sealing and optimization, so it is becoming a standard in regions such as the North Slope and the Gulf of Oman where extended reach wells benefit from gas lift deep into the build section.

Gas supply to gas lifted wells can be unreliable. They can fluctuate wildly based on issues like new wells coming online, leaks, and compressor failure or maintenance. A PPO system must be designed to operate at the lowest possible injection pressure. Unfortunately, this means that additional injection pressure cannot be utilized when it is available. Surface controlled gas lift allows the operator to optimize both when little pressure is available as well as when excessive pressure is available, so long as there are no IPOs in the string (such as with a hybrid system). That leads to the next point.

Yet another surprise with surface controlled gas lift is that hybrid gas lift systems are sometimes better off using Production Pressure Operated (PPO) gas lift valves than Injection Pressure Operated (IPO) valves. This is surprising as PPO's disadvantages to IPOs have almost completely discouraged the use of PPOs: reduced flow capability, no feedback as to where injection is occurring, prone to multipointing, and less accurate opening/closing pressures. All of these shortcomings are overcome when they are used for unloading a hybrid surface controlled gas system.

If there are large injection gas fluctuations in a field, IPOs must be adjusted to operate at the lowest possible injection pressure. If the available pressure increases and the operator desires to use that pressure to inject deeper, the upper IPO will open and cause multipointing. PPOs do not have this problem (Shaw 2022). PPOs rely on tubing pressure, so increasing the injection pressure to increase production by increasing injection depth will not open upper valves and have a deleterious effect on the system.

One final surprise is Surface Controlled Gas Lift's ability to reduce the Carbon Intensity of oil production. It can reduce methane in ways such as reducing slugging, flaring, and exhausting from blow off valves. These are often unpredictable events, but surface controlled gas lift also reduces emissions in a predictable manner. Gas is compressed before injection, and much of that pressure is lost in surface chokes and not utilized to inject deeper. The carbon intensity reduction is based on increased production from injecting deeper while using the same or less gas (Figure 8). Optimization of a surface controlled gas lift well in Bahrain showed an 18% production increase and a 25% gas injection reduction. This represents a 36% reduction in ongoing carbon intensity for that well as shown in Figure *9*.

CONCLUSION

The emergence of surface controlled gas lift represents a significant advancement in artificial lift technology, offering a host of benefits over traditional Injection Pressure Operated (IPO) valves. While IPO valves have long been the dominant method for gas lifted wells, surface controlled gas lift systems provide operators with unprecedented real-time control and flexibility from the surface, leading to numerous advantages in optimizing production and addressing operational challenges.

Surface controlled gas lift systems allow for deeper gas injection, leading to increased drawdown at the formation and subsequently higher production rates. This deeper injection capability, coupled with real-time control, enables operators to optimize production continuously without the need for intervention, a significant departure from the limitations of IPO valves. Additionally, surface controlled gas lift facilitates the implementation of specialized completions such as in situ gas lift and dual string gas lift wells, offering enhanced control and efficiency in complex reservoir environments.

The unforeseen benefits of surface controlled gas lift systems, such as diagnosing and correcting downhole hardware problems, quick production recovery after frac hits or shut-ins, and improved efficiency in fracking operations, underscore the transformative potential of this technology. Surface controlled gas lift not only enables proactive maintenance and problem-solving but also streamlines production processes, leading to significant time and cost savings for operators.

Surface controlled gas lift benefits that are not initially obvious highlight the forward-looking nature of surface controlled gas lift design, including creative elimination of scale and paraffin, extended reach capabilities, and reduced carbon intensity of oil production, by leveraging real-time data and advanced control mechanisms, surface controlled gas lift systems offer a pathway to more efficient and sustainable oil production practices.

The adoption of surface controlled gas lift represents a paradigm shift in artificial lift technology, offering operators greater control, flexibility, and efficiency in optimizing production and addressing operational challenges. As the industry continues to evolve, surface controlled gas lift systems are poised to play a central role in maximizing the potential of gas lifted wells while minimizing environmental impact and operational costs.

References:

Faux, Stephen , and Thomas Glenday. "The Benefits of Introducing Intelligent Gas Lift Management to Create a Smart Field." Paper presented at the SPE Middle East Artificial Lift Conference and Exhibition, Manama, Kingdom of Bahrain, November 2016. SPE 184184-MS doi: https://doi.org/10.2118/184184-MS

Salleh, Nurfarah Izwana, M Ghazali, M Haziq, Rozlan, M Rizwan, Wan Mat, Syarifah Suliza, Ismail, Mohamad Sazwan, Amsidom, Amirul Adha, Roh, Cheol Hwan, Bakar, M Farris, and M Faizatulizuddin ishak. "The World's First Successful Digital Intelligent Artificial Lift (DIAL) for Dual String Application - A Paradigm Shift for Gas Lift System in Offshore Malaysia." Paper presented at the SPE Middle East Artificial Lift Conference and Exhibition, Manama, Bahrain, October 2022.
doi: https://doi.org/10.2118/206903-MS

Alshmakhy, Ahmed, Punnapala, Sameer, AlShehhi, Shamma, Ben Amara, Abdel, Makin, Graham, and Stephen Faux. "First Digital Intelligent Artificial Lift Production Optimization Technology in UAE Dual-String Gas Lift Well – Completion and Installation Considerations." Paper presented at the International Petroleum Technology Conference, Dhahran, Kingdom of Saudi Arabia, January 2020.
doi: https://doi.org/10.2523/IPTC-19620-MS

Kumar, Suman , Ismail, Mohamad Sazwan, Salleh, Nurfarah Izwana, Amsidom, Amirul Adha, M Ghazali, M Haziq, Rozlan, M Rizwan, and M Azan A Karim. "First Successful Application of Digital Intelligent Artificial Lift DIAL System in Dual Strings in B Field Applying Lessons Learnt from its First Pilot Application in Different Field in Same Offshore Malaysia." Paper presented at the International Petroleum Technology Conference, Virtual, March 2021. doi: https://doi.org/10.2523/IPTC-21201-MS

Sompopsart, Suwin , Toempromraj, Wararit , Nadoon, Apiwat , Chandakaew, Rossawan , Weeramethachai, Deephrom , Kiatrabile, Thanita , Ben Amara, Abdel , Makin, Graham , Faux, Stephen , and Peter Watson. "Pilot Installation of In-Well Digital Gas Lift System in PTTEP Sirikit Oilfield." Paper presented at the SPE Middle East Artificial Lift Conference and Exhibition, Manama, Bahrain, November 2018. doi: https://doi.org/10.2118/192463-MS

Zaidi Awang Mohamed, Zaidi , Selladurai, Jagaan , Mohd Zain, Siti Nur Mahirah, Yang, Juhari , Bahar, Badroel Rizwan, Ben Amara, Abdel , Shaw, Joel , Patterson, Gerry , and Stephne Fauz. "Successful Pilot of DIAL Digital & Interventionless Gas Lift Production Optimization System Offshore Malaysia." Paper presented at the SPE/IATMI Asia Pacific Oil & Gas Conference and Exhibition, Virtual, October 2021.
doi: https://doi.org/10.2118/205763-MS

Visser, Johannes , and Tomislav Basic. "Pilot Application of Remotely Operated Gas Lift Valves in Permian Basin Unconventional Wells." Paper presented at the SPE Artificial Lift Conference and Exhibition - Americas, Virtual, November 2020. doi: https://doi.org/10.2118/201140-MS

Shaw, Joel; US Patent 11,441,40; Hybrid gas lift system; 2022-09-13

Table 1: Debris and Buildup Contingency Comparison for Traditional and Surface Controlled Gas Lift

Scenario	Traditional GLV	Surface Controlled GLV
Rock the Well	GL Stations opened / closed based on hydrostatic pressure; may change as pressures change dynamically in the tubing or annulus	Operator selects which actuators are opened or closed, These setting will not change as the pressure changes
Hot Oil	Injected solvent may change hydrostatics and open or close the desired valves limiting effectiveness	Specific valves can be opened or closed based on the well needs
High-Pressure Flow	As the pressure increases to create more flow through the valve, it can open gas lift valves near the surface	Upper valves can be maintained closed regardless of the injection pressure
High Pressure Opening	Conventional gas lift valves open gradually, so they cannot be instantly opened against high pressure	DIAL valves can be closed from the surface while annulus pressure builds. Then any valve can be instantly opened to dislodge material.

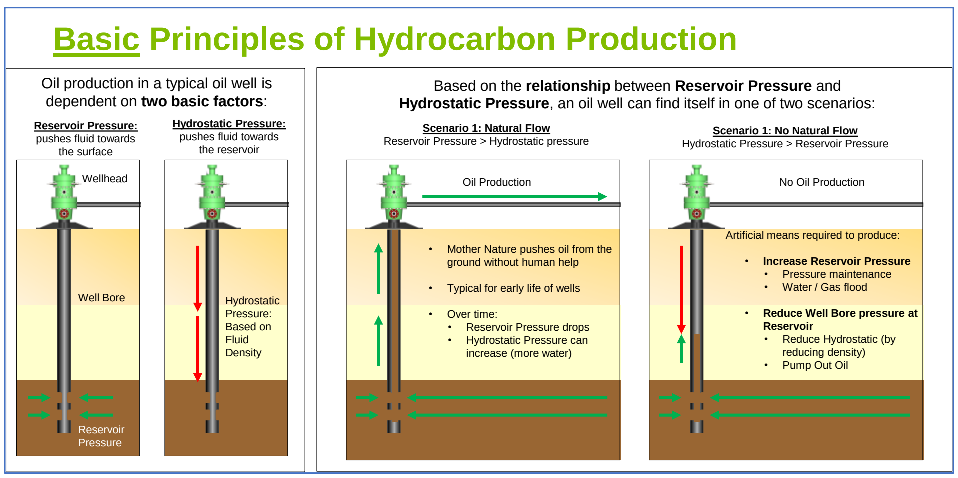

Figure 1: Hydrostatic and Reservoir Pressures as They Relate to Oil Production

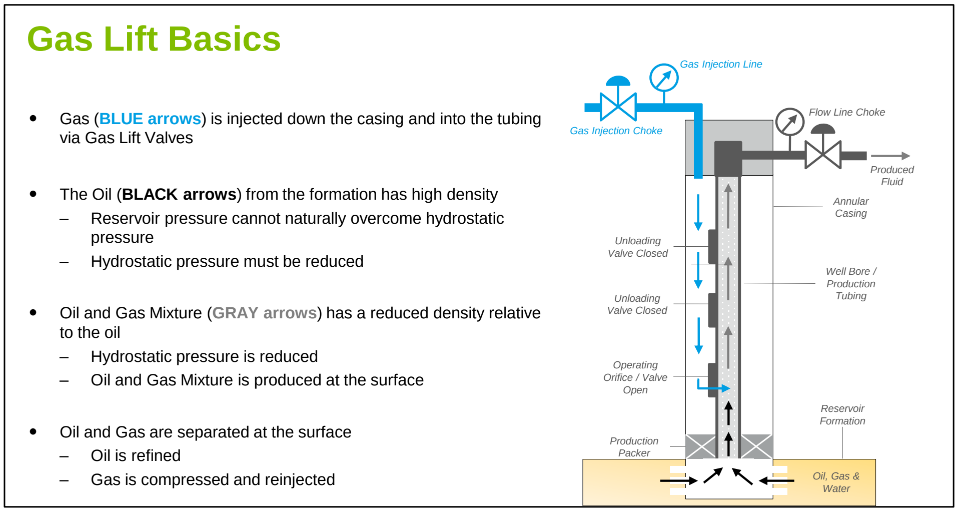

Figure 2: Typical Gas Lift Well Components

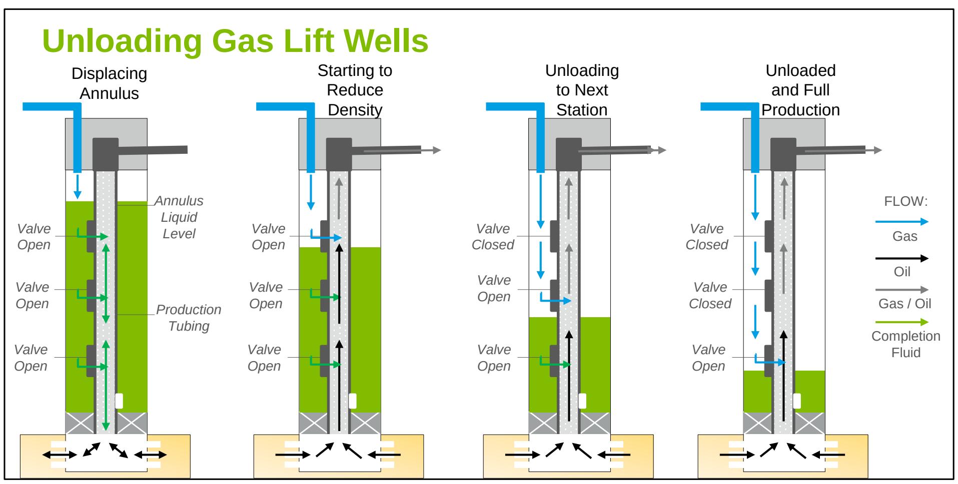

Figure 3: Gas Lift Well Unloading and Production

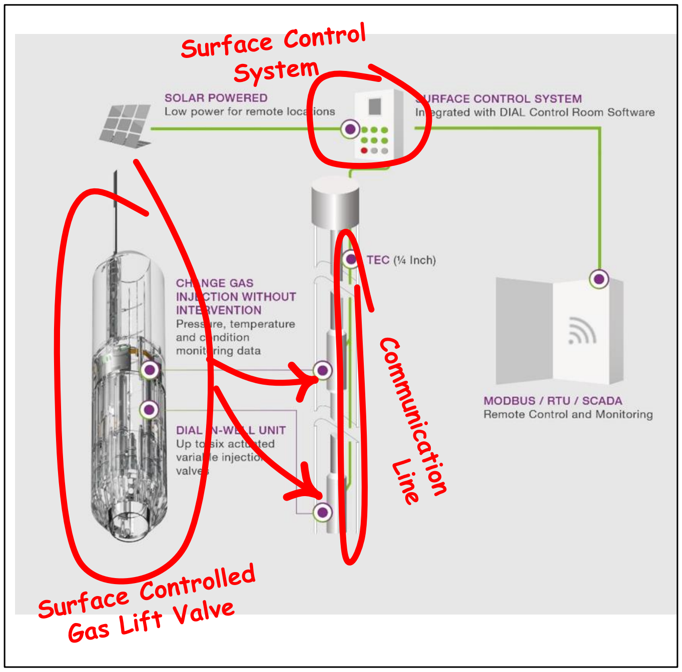

Figure 4: Surface Controlled Gas Lift System Essential Components (in red)

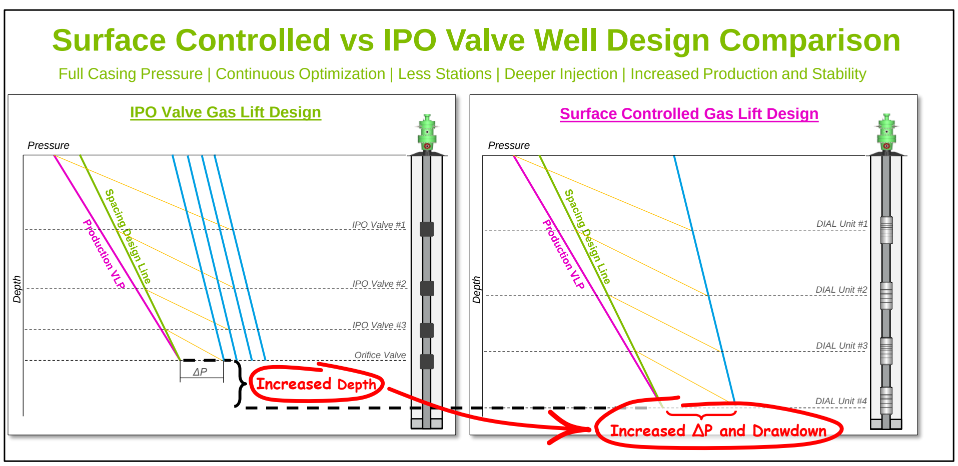

Figure 5: Surface Controlled Gas Lift Comparison to IPOs

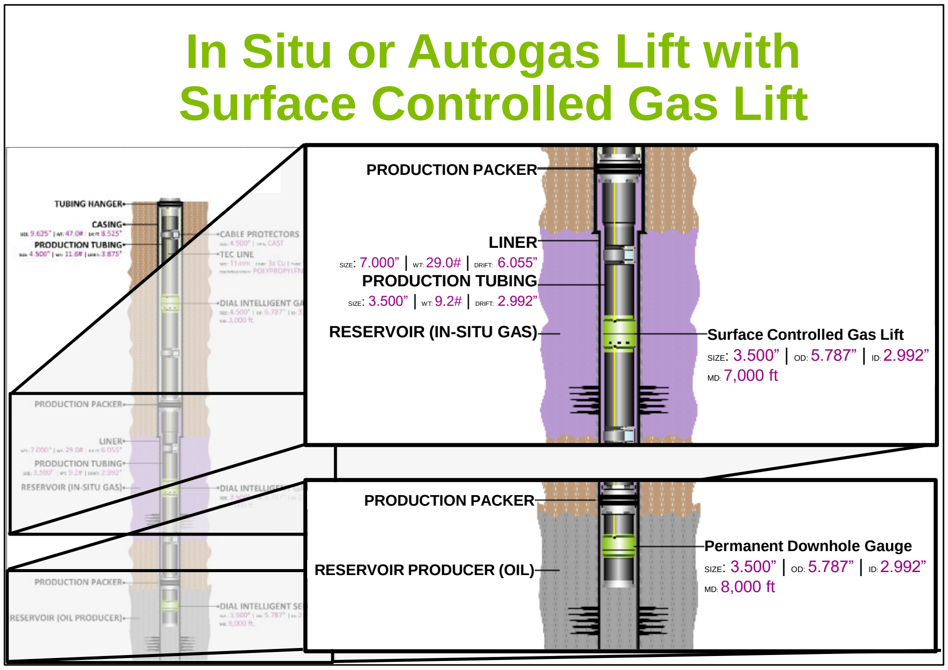

Figure 6: In SItu Surface Controlled Gas Lift Example

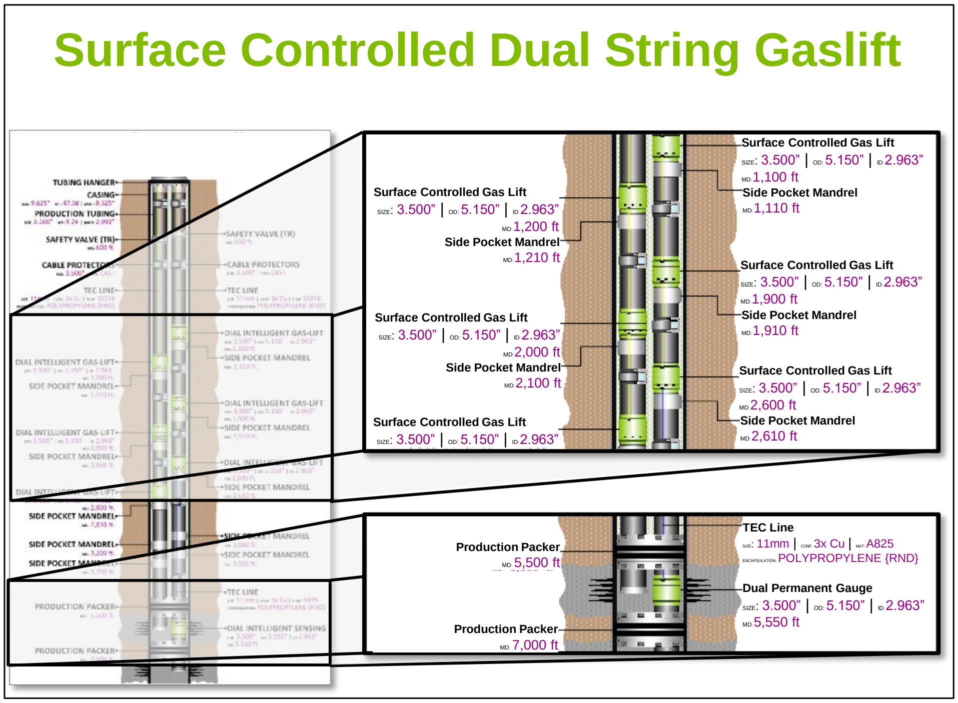

Figure 7: Dual String Surface Controlled Gas Lift

Carbon Intensity Reduction

- Carbon Intensity reduction percentage can be estimated based on increase in production and reduction in gas compression
- Derivation in Silverwell White Paper: SWP-0017 available on website

Carbon Intensity Reduction Ratio	$C_{rr} = 1 - \frac{(1 - \text{[illegible]})}{(1 + P_{ur})}$	EQ 17
Carbon Intensity Reduction Percentage	$C_{r\%} = 100\% - 100\% * \frac{(100\% - G_{r\%})}{(100\% + P_{u\%})}$	EQ 18
Final Carbon Intensity Value	$C_f = C_i \frac{(1 - G_{rr})}{(1 + P_{ur})}$	EQ 23

CO2 Reduction		Reduction in Injection										
		0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
Increase in Production	0%	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
	2%	2%	7%	12%	17%	22%	26%	31%	36%	41%	46%	51%
	4%	4%	9%	13%	18%	23%	28%	33%	38%	42%	47%	52%
	6%	6%	10%	15%	20%	25%	29%	34%	39%	43%	48%	53%
	8%	7%	12%	17%	21%	26%	31%	35%	40%	44%	49%	54%
	10%	9%	14%	18%	23%	27%	32%	36%	41%	45%	50%	55%
	12%	11%	15%	20%	24%	29%	33%	38%	42%	46%	51%	55%
	14%	12%	17%	21%	25%	30%	34%	39%	43%	47%	52%	56%
	16%	14%	18%	22%	27%	31%	35%	40%	44%	48%	53%	57%
	18%	15%	19%	24%	28%	32%	36%	41%	45%	49%	53%	58%
	20%	17%	21%	25%	29%	33%	38%	42%	46%	50%	54%	58%
	22%	18%	22%	26%	30%	34%	39%	43%	47%	51%	55%	59%
	24%	19%	23%	27%	31%	35%	40%	44%	48%	52%	56%	60%
	26%	21%	25%	29%	33%	37%	40%	44%	48%	52%	56%	60%
	28%	22%	26%	30%	34%	38%	41%	45%	49%	53%	57%	61%
	30%	23%	27%	31%	35%	38%	42%	46%	50%	54%	58%	62%
	32%	24%	28%	32%	36%	39%	43%	47%	51%	55%	58%	62%
	34%	25%	29%	33%	37%	40%	44%	48%	51%	55%	59%	63%
	36%	26%	30%	34%	38%	41%	45%	49%	52%	56%	60%	63%
	38%	28%	31%	35%	38%	42%	46%	49%	53%	57%	60%	64%
	40%	29%	32%	36%	39%	43%	46%	50%	54%	57%	61%	64%
	42%	30%	33%	37%	40%	44%	47%	51%	54%	58%	61%	65%
	44%	31%	34%	38%	41%	44%	48%	51%	55%	58%	62%	65%
	46%	32%	35%	38%	42%	45%	49%	52%	55%	59%	62%	66%
	48%	32%	36%	39%	43%	46%	49%	53%	56%	59%	63%	66%
	50%	33%	37%	40%	43%	47%	50%	53%	57%	60%	63%	67%

Figure 8: Carbon Intensity Reduction Calculations

Carbon Intensity Reduction Example

Case Study: "DIAL System's Digital Capabilities Enable Lift Gas Efficiency and Production Increase for Middle East Operator" Silverwell website

- Example of Carbon Intensity reduction calculations applied to a previous Case Study
- Very basic completion (single drop Surface Controlled Gas Lift Valve vs. multi drop)
- Surface Controlled Gaslift System allowed the operator to adjust injection rates and monitor downhole pressure conditions
- Optimized gas injection resulted in 18% production increase and 25% reduction in gas injected
- Calculations show
  36% REDUCTION IN CARBON INTENSITY

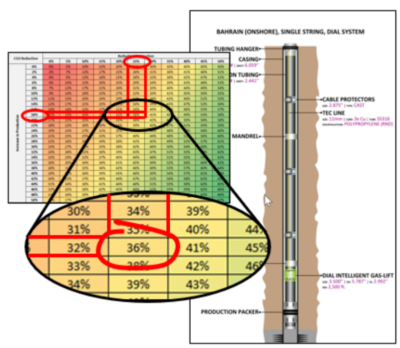

Figure 9: Carbon Intensity Reduction Calculations