GETTING AROUND THE GAS

A Comprehensive Guide to Gas Management for ESPs

VALIANT
Artificial Lift Solutions

Energy Providing Energy

TABLE OF CONTENTS

Introduction 1

How Gas Affects ESPs 2

Four Phases of Gas Management 3

Avoid 5

Separate 7

Process 9

Control 12

Factors in Gas Management 14

Equipment Descriptions 16

Application Guidelines 17

FAQ 18

INTRODUCTION

In response to the boom of horizontal plays in the U.S., operators require artificial lift systems capable of providing reliable production in these wells often characterized by harsh, abrasive, and turbulent conditions.

Due to the versatility and production capabilities of Electric Submersible Pumps, these systems have become widely adopted in unconventional applications. While ESPs provide several advantages in terms of flow capacity, lift efficiency, and setting depth, gas production can result in unstable pump operation and increase operating costs due to premature equipment failure.

Therefore, solutions that extend system run life and ensure efficient, uninterrupted operations are an essential part of a successful ESP strategy in unconventional applications.

This guide has been developed to provide an in-depth understanding of the challenges associated with oil production in wells with a high gas-to-liquid ratio (GLR) and to recommend technological solutions that enhance ESP performance in these conditions.

By the end of reading this, you will have a foundational knowledge of the mechanics, design considerations, and applications for each product within Valiant's suite of gas solutions.

HOW GAS AFFECTS ESPs

Unlike conventional, vertical wells, unconventionals are drilled with a lateral section that can reach up to several miles long. Due to pressure differences in the rock formation and slight variations in the position of the drillbit, drilling longer laterals results in the horizontal section of the wellbore diverging from a perfectly straight path. These undulations create hills and valleys where gas is able to accumulate until it is forced out by the production fluid.

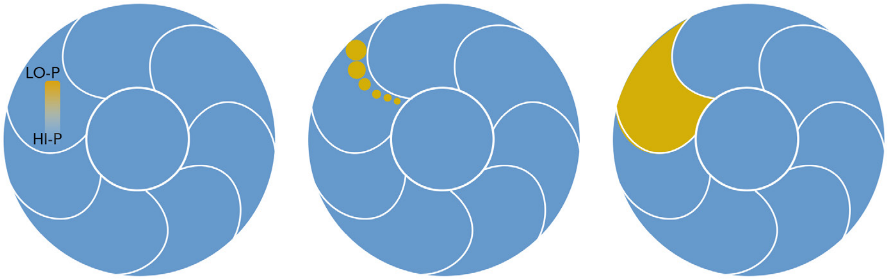
These pockets of free gas - gas not dissolved in the production fluid - can manifest in different ways, ranging from entrained bubbles to large gas slugs in the production string, and they pose a significant challenge for ESPs. The most detrimental outcome of unmanaged gas production is gas locking.

What is Gas Locking?

ESPs rely on centrifugal force to move fluid through the pump, which creates high- and low-pressure areas within the pump stage vanes as they rotate. When gas enters the pump, the low-density gas separates from the higher-density fluid and accumulates on the low-pressure side of the blade until it blocks the passage of the entire vane in the pump stage, leading to gas-locking.

This stops the flow of liquid, resulting in a sharp increase in motor winding temperature and an abrupt decrease in load on the motor. Without some sort of intervention or shutting down the system, prolonged operation in this state will destroy the ESP, forcing the entire string to be pulled out, the motor to be replaced, and costing the operator millions of dollars in lost production time.

Standard ESPs are designed to handle up to 10%-20% free gas



Process of gas locking in ESP stage vanes

VALIANT Artificial Lift Solutions

FOUR PHASES OF GAS MANAGEMENT

While there is a spectrum of technologies available to help operators mitigate the deleterious effects of gas production in ESP applications, all of these solutions can be categorized into one or more of the four phases of gas management: Avoid, Separate, Process, and Control.

AVOID

Diverts gas in wellbore from entering the ESP to reduce stress on the system and minimize production obstacles

PROCESS

Homogenizes gas-fluid mixture to improve production through pump via different mechanisms

SEPARATE

Separates gas from fluid mixture inside the ESP and guides free gas back out into the casing annulus

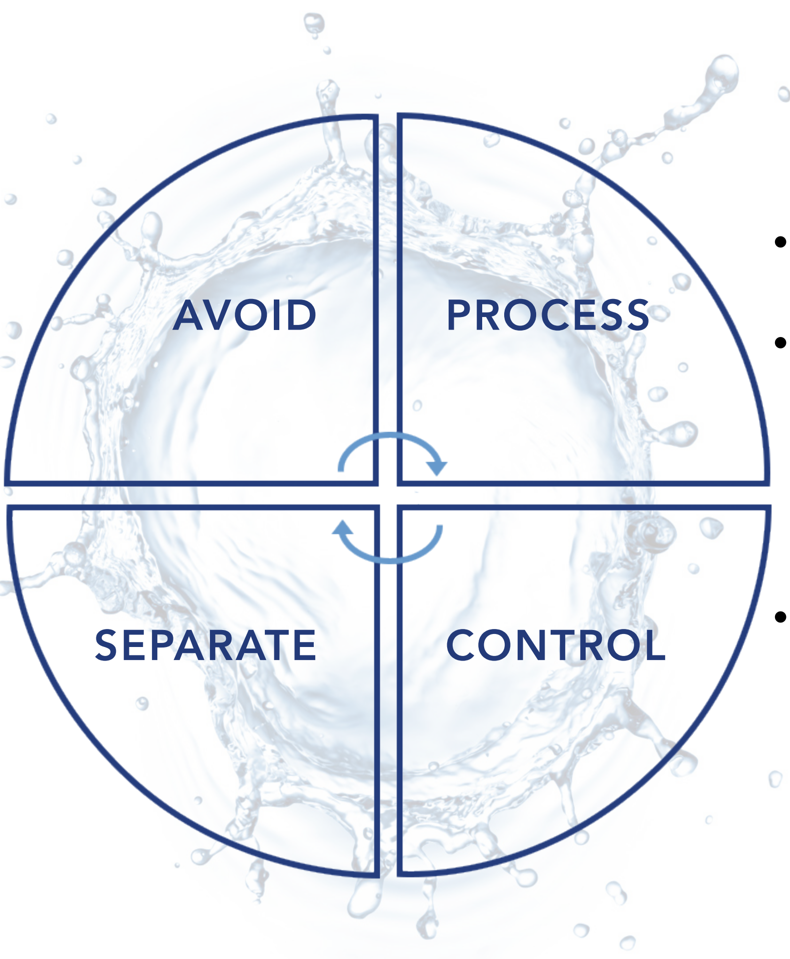
CONTROL

Monitors downhole conditions and adjusts system operation to reduce cycling during gas production

SOLUTIONS AT EVERY PHASE

Valiant offers a comprehensive suite of ESP solutions to address each phase of gas management. In the next section, we will provide a complete overview of the various gas solutions technologies and the proper applications for each product.

- Inverted Shroud
- Positive Seal Shroud



- Helico-Axial Stages (Gas Handler)
- Tapered Pump

- Vortex/Rotary Gas Separators

- Pulse® VSD Gas Lock Prevention Software

AVOID

The Avoid phase involves using different mechanisms to prevent gas in the annulus from entering the production string. Gas Avoidance can involve redirecting the flow of wellbore fluid or implementing special ESP components designed to minimize gas intake.

SHROUDS

One of the most widely implemented devices for gas avoidance is a shroud. The standard assembly is made up of a jacket, a hanging clamp and sealing retainer for the top, and a centralizer for the bottom. In a standard application, perforations are positioned above the motor. This configuration works by leveraging the natural separation of production fluid and gas via differences in density, allowing gas to follow the path of least resistance towards the top of the annulus while drawing down fluid to the shroud opening and back up into the pump intake. This serves two purposes: discourage gas from entering the pump intake and direct production fluid past the motor for cooling. Depending on the wellbore geometry, variations on the standard shroud can also be implemented.

POSITIVE SEAL SHROUD

Similar to a standard shroud, a positive seal shroud includes a rubber cap to ensure fluid enters at the bottom of the shroud rather than through openings at the top.

INVERTED SHROUD

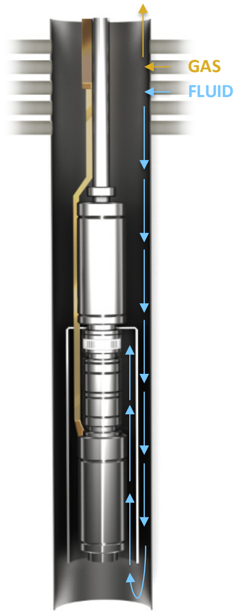
When perforations are positioned below the motor, an inverted shroud can be used. This device works in essentially the same way as the standard shroud, but the configuration is upside-down. An inverted shroud can either be designed where the bottom of the shroud starts at the pump intake (motor not encapsulated) or below the bottom of the entire equipment string (motor encapsulated).

The primary advantage of using a shrouded ESP configuration is the ability to prevent free gas from entering the pump, thus eliminating challenges associated with gas production and ensuring stable, reliable operation.

However, one of the most significant limitations to this approach can be the diameter of the wellbore. Not only must the shroud be designed with an inside diameter (ID) large enough to accommodate the ESP and provide flow clearance, but the outside diameter must also have clearance in the casing ID to be deployed and ensure flow from well perforations to the pump intake.

INTERCEPT™ SHROUDS

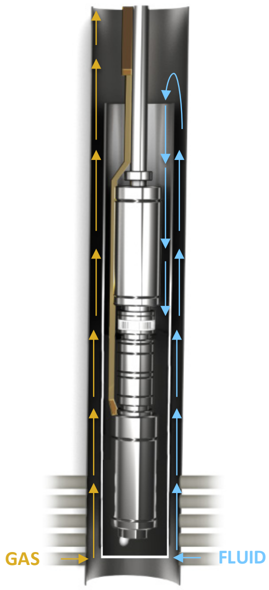
Standard/Positive Seal Shrouds



DESCRIPTION	OD	CASING ID	ESP OD
Positive Seal Shroud in Carbon Steel	5 1/2"	7"	All 400 Series ESP
Positive Seal Shroud in Stainless Steel	5 1/2"	7"	All 400 Series ESP
Standard Shroud	4 1/2"	5 1/2"	400 Series Pump, 300 Series Seal & Motor
Positive Seal Shroud in Low Carbon Steel	4 1/2"	5 1/2"	400 Series Pump, 300 Series Seal & Motor

Inverted Shrouds

OD	CASING ID	ESP OD
5 1/2"	7"	All 400 Series ESP

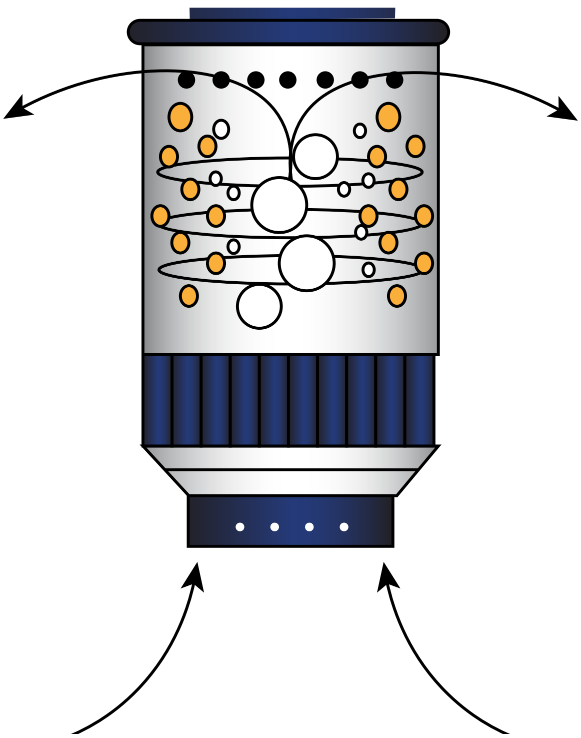


FEATURES:

- Valiant proprietary software to calculate and monitor motor heat rise risk
- Eliminates the need of re-circulation System
- Provides a reservoir of fluid to help pump ride-though larger gas slugs

SEPARATE

The Separate phase involves allowing the gas-fluid mixture to enter a device which isolates production fluid and directs gas bubbles to flow back out into the annulus. Gas Separation uses mechanical methods to physically separate free gas from fluid mixtures.



GAS SEPARATORS

Installed at the pump intake, gas separators use centrifugal force to separate gas from the production fluid before entering the primary pump. Heavier fluids, which naturally migrate to the outer circumference, are delivered to the intake, while larger gas bubbles are isolated towards the middle and directed out into the wellbore annulus. These devices utilize an auger vein to pressurize and energize production fluid while expelling gas into well annulus.

INTERCEPT™ GAS SEPARATORS

Intercept™ gas separators are available in Rotary or Vortex designs and can be run in single or tandem configurations.

- Rotary Gas Separators provide better separation at lower-to-moderate flow rates with viscous well fluids
- Vortex Gas Separators are better for higher flow rates with low-to-moderate gas content and are constructed with enhanced radial bearing support for added durability in abrasive, solid-laden well conditions

SERIES	MODEL	MAX PRODUCTION RATE[1]	PRODUCTION EFF. IN 25% GVF[2]
338	Rotary	2,700 bpd	1,850 bpd / 89.2%
400	Rotary	2,000 bpd	1,400 bpd / 89.4%
400	Vortex	4,800 bpd	2,500 bpd / 86%
513	Vortex	9,000 bpd	5,000 bpd / 86.4%

[1] Range based on production of water with no gas content; Production will vary based on fluid viscosity and gas content
[2] Based on water production under nominal testing conditions

PROCESS

The Process phase encompasses what the industry commonly refers to as "gas handling." Perhaps the most widely misrepresented category of gas management solutions, Gas Processing consists of more than just one piece of equipment. While the term "gas handler" has become a popular pseudonym for gas processing technologies, this leads to subjective interpretations and general miscommunication in the ESP community. Instead, we define gas processing as a collection of distinct solutions which are designed to ease the flow of gas through the pump and reduce gas locking.

Up to this point, we have discussed gas solutions in terms of avoidance and separation - essentially, keeping gas out of the pump as effectively as possible. However, it should be noted that there is a tremendous benefit of getting gas through the ESP inside the tubing. While this approach requires some extra energy to be spent to sufficiently condition the gas-fluid mixture, there is an advantage to gaining natural buoyancy in the production fluid: improved lifting efficiency.

HELICO-AXIAL STAGES

The devices commonly referred to as "gas handlers" are actually a specific type of stage design known as helico-axial stages. (When gas handlers are referred to in this guide, we are talking about helico-axial stage configurations.) The design of these stages feature a specialized geometry which serves to condition the fluid by compressing and chopping up gas bubbles before they enter the production pump.

By design, helico-axial stages have a high horsepower requirement and a low lift-per-stage ratio. Their primary role is to homogenize the gas-fluid mixture below the production (upper) pump. By adding axial velocity to the fluid, helico-axial stages reduce gas accumulation within the primary pump while maintaining natural lift energy of gas entrained in the now-homogeneous mixture.

TAPERED PUMP

Tapered pumps are another method of gas management that has been around for years, but this configuration is not quite as effective as helico-axial stages. The tapered pump design is comprised of standard ESP mixed-flow stages configured in a volumetric tapered design. Because the total volume decreases as fluid moves upwards through the pump, there is a higher flow rate at the entrance and lower flow at the top, gradually compressing the gas-fluid mixture as it is pushed further up the pump.

INTERCEPT™ GAS HANDLERS

Valiant offers a selection of gas handlers (a.k.a. helico-axial stage configurations) in the Intercept™ gas solutions portfolio. Each model is designed with a fixed stage count and can be run with or without a gas separator. When used in conjunction with a gas separator, Intercept™ Gas Handlers can handle well over 50% GVF.

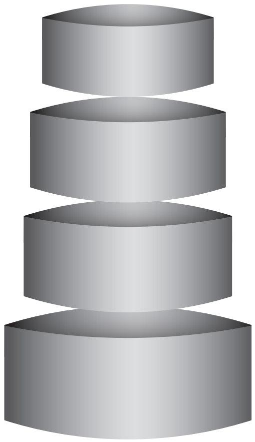
FEATURES

- Compression construction with tungsten carbide/abrasion-resistant support bearings
- Inconel shaft with shim set screw
- Carbon steel housing, head and base; center tandem
- Integrated with Valiant's Zone™ ESP sizing software

SERIES	MODEL	OPERATING RANGE
400	VCGH 1550	380-1550 bpd
400	VCGH 2300	750-2300 bpd
538	VEGH 4500	2250-4500 bpd
538	VEGH 9500	4500-9500 bpd

INTERCEPT™ TAPERED PUMPS

The Intercept™ tapered design utilizes a higher flow abrasion-resistant modular (ARM) pump as the lower pump, and a lower flow ARM pump is selected for the production (upper) pump. This configuration can be run with or without a gas separator, which may be required in certain applications to achieve a suitable GVF.



Representation of tapered pump stages

Valiant's ARM pumps are reinforced with tungsten carbide for enhanced radial support and downthrust protection

4.00" ARM	
VC700	100-925 bpd
VC1050	300-1500 bpd
VC1750	500-2150 bpd
VC3000	1000-3700 bpd
VC4300	2000-5200 bpd

5.38" SERIES ARM	
VE1500	400-2240 bpd
VE3300	110000-4500 bpd
VE5500	1750-7300 bpd

CONTROL

Methods of Controlling Gas during production involve manipulating ESP operation to protect system stability and reduce wear on the equipment when free gas is present. At the most basic form, this can be performed by automatically shutting down the system when gas-locking conditions are detected to prevent equipment failure. However, variable speed drives are capable of implementing much more sophisticated programming and are therefore an integral part of an effective gas management strategy.

By monitoring various inputs from the ESP, a VSD can recognize hazardous production conditions and help return the system to normal operation.

PULSE® VSD GAS LOCK PREVENTION

As part of the control phase of gas management, Valiant Pulse® Variable Speed Drives are programmed with proprietary gas lock prevention software. By integrating with downhole monitoring, the drive can automatically recognize and respond to changing production conditions.

Valiant's Gas Lock Prevention programming is designed to monitor key ESP inputs - motor amperage, temperature, and intake and discharge pressure - and automatically reduce frequency of the drive to allow gas slugs to move through the pump when potential gas-locking conditions are detected.

By helping to prevent gas locking and shut-downs, Valiant's gas lock prevention software minimizes cycling and maximizes production for improved ESP performance in challenging wells.

HOW IT WORKS:

- Once current drops below the underload set point (or a separate dedicated set point) and Gas Lock Prevention mode has been enabled, the Reaction Delay timer will begin its countdown.
- After the Reaction Delay timer completes its countdown, it will slow down to the Reaction Speed.
- Once it slows down to the set Reaction Speed the Gas Lock Prevention run timer will begin its countdown.
- Once the GLP run timer elapses the unit will speed back up to its original run state i.e. frequency mode, PIP, and current limit.
- If the unit does not catch a load when it returns to its normal mode of operation, it will start the process over with the Reaction Delay timer, and it will trigger one attempt with the GLP Attempts counter.
- If the unit never catches a load and reaches the GLP Attempts counter (usually 3 attempts), the unit will shut down on underload or Gas Lock Prevention failure.
- If it catches a load, it will start the Reset Delay Timer. Once the Reset Delay Timer elapses without going into a gas lock situation, it will reset the GLP Attempts counter.

FACTORS IN GAS MANAGEMENT

In this guide, you have been introduced to various technologies that can be applied to the four phases of gas management. However, all solutions are not created equal in all applications. Because wells are dynamic (unconventional wells in particular), no configuration is going to be one-size-fits-all. Therefore, the best solutions must be tailored to each customer's specific application and production requirements to achieve the desired outcome.

The following section presents some important considerations when it comes to selecting the right solution for your application.

ROLE OF FREE GAS INTO PUMP

The percent of free gas into the pump is an important calculation when designing ESPs with gas-optimized configurations.

As a general rule of thumb:

- Radial flow stages can handle up to 10% free gas
- Mixed-flow stages can handle up to 25% free gas

WHAT DOES THIS MEAN FOR DESIGN?

ESP designs are based on intake conditions, stage geometry, and the rule of thumb for the percentage of free gas a pump can handle (above).

Two calculations, the Turpin (1986) correlation and the Dunbar (1989) curve, have become widely accepted as the industry standards for determining ESP pump stability when free gas is present in the fluid.

Turpin Correlation:

$$\Phi = \frac{2000 \dfrac{q_{ing}'}{q_l'}}{3\ PIP}$$

Φ equals the Turpin function, 1/psi

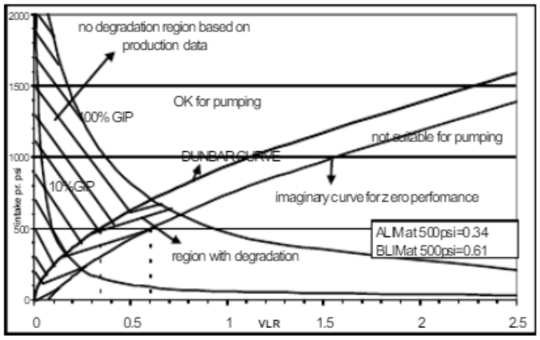
q_{ing}' equals the gas volumetric rate ingested by the pump (bpd)

q_l' equals the liquid volumetric rate at suction conditions (bpd)

PIP equals the pump intake pressure (psia)

According to this calculation, when Φ <1.0, stable pump operation can be expected, and when Φ >1.0, severe gas interference occurs and pump performance begins to deteriorate.

Dunbar Curve:



The Dunbar curve (above) models the minimum intake pressure that should be attained for a given GLR.

EQUIPMENT DESCRIPTIONS

INVERTED SHROUD	POSITIVE SEAL SHROUD	GAS SEPARATOR	GAS HANDLER	TAPERED PUMP
Perforations should be below the motor	Perforations should be above the motor	Well design must be able to Handle the annulus gas on surface	Originally designed for offshore ESP	Originally used for gassy wells before gas separators and gas handlers were available
Casing should be 7″ or larger	Casing should be 5 $^1/_2$″ or larger	Not easily configured in offshore applications	Now being used in unconventional gassy wells as a fluid conditioner to help prevent gas lock	Can still be run with gas separators and gas handlers
Works well for unconventional wells	Works for conventional wells, not unconventionals	Should be installed above well perforations	Can be run with or without a gas separator	

APPLICATION GUIDELINES

APPLICATION	GLR (CF/B)	SOLUTION
Standard Application	Below 500	Production Pumps with Gas Separator
Moderate Gas	Below 800	Tapered Pump with Gas Separator
High Gas	800 - 1300	Gas Handler Pump with Gas Separator
Extreme Gas	Up to 2000	Shroud System

MAKING THE RIGHT SELECTION - FAQ

When do you run tandem gas separators? Always?

- Dynamic conditions and applications where GLR is continuously increasing
- Using Zone®, GLR may be considered in ESP design to achieve specific gas separation

Why would you run an inverted shroud and not a gas handler?

- You should run an inverted shroud when traditional ESP with gas handler & separator cannot achieve operation
- Inverted shroud forces smaller series of equipment, more jewelry downhole

What is the advantage of setting a pump below the perforations?

- Gain the benefit of natural separation, as fluid comes into the wellbore, gas rises in the wellbore while fluids descend towards the pump
- The lower you set a pump, the more intake pressure you have, leading to more continuous production
- It is important to know that in some cases, the gas bubbles don't rise, and get drawn down with the fluid

Back-pressure on the surface - how does it affect production?

- Increasing the surface tubing pressure will increase the pump intake pressure.
- If the tubing is unloading (unstable fluid flow) because of the free gas in the tubing, this can cause the well to pump off. Adding tubing pressure at the surface can often stabilize the flow in the tubing.
- Note: The back pressure will increase the pump intake pressure, which will reduce the production rate, so the operating Hz should be increased to compensate for the surface pressure that was added to stabilize the tubing.

MOST COMMON GAS-RELATED SHUTDOWNS

UNDERLOAD

During unconventional well gas slugging, you will see a drop in load and go into underload.

Valiant's Gas Lock Prevention software is designed to help restore normal ESP operation once current drops under a set limit. After 3 attempts, the unit will shut down due to underload or GLP failure.

HIGH MOTOR TEMPERATURE

Because the motor depends on liquid passing its outside diameter in order to cool and maintain a winding temperature within range of the insulation system, continued operation at high temperatures runs the risk of burning the motor.

Often, a motor temp shutdown is used instead of an underload shutdown because an underload setting would halt production even though a small amount of flow is keeping the motor temperature at an acceptable level.

With Pulse® Gas Lock Prevention software, the motor continues to run in underload conditions until flow is stopped long enough to cause the motor temperature to rise and the sensor indicates a High Temperature Motor Shut Down caused by gas in the pump.

DON'T LET GAS GET IN THE WAY.

At Valiant, we take the time to understand your goals and challenges before developing solutions tailored to your application. From your initial consultation to servicing your site, we are committed to helping you achieve successful production over the life of your well.

Contact us today to learn how we can make your operations worry-free.

VALIANT
Artificial Lift Solutions

www.valiant-als.com
405.605.4567

LOCATIONS:

Oklahoma City, Oklahoma

Midland, Texas