

## Artificial Lift for Subsea Applications

The natural decline in the reservoir energy will impact the flowrate of oil, gas or water, thereby creating instabilities and resulting in decreased production. Artificial lift is used in oil-dominated or liquid-loaded gas systems to increase and stabilize hydrocarbon production, as well as to minimize flow assurance and operational risks, such as slugging in the subsea production system. Artificial lift methods transfer energy to the produced fluid with the objectives of reducing the fluid density and the pressure head or boosting the flowing pressure.

### Methods of Artificial Lift for Subsea Applications

Several artificial lift methods have been developed for subsea applications, and each method is designed to meet specific lifting requirements and operational constraints. Selection of the artificial lift system depends on subsea production system characteristics such as reservoir and fluid properties, well parameters, architecture, field development strategies and economics. Figure 1 shows impact of artificial lift in extending field life and recovery of reserves. The three most commonly used methods of artificial lift in subsea environments include:

- Gas Lift
- Subsea Boosting (Single and Multiphase Pumping)
- Electric Submersible Pumps (ESP)

### Gas Lift

Gas lift employs high pressure gas that is injected from a topside facility to a specific subsea location. The injected gas commingles with the produced reservoir fluid, resulting in a changed fluid mixture that is less-dense and contains richer-composition gas, thus reducing the hydrostatic column. This resulting lower density fluid column effectively reduces the back pressure on the well, increasing the fluid velocity and flowrate. Particularly for subsea developments, lift gas can be injected at two distinct locations, the wellbore and the flowline-riser. In these cases, a dedicated gas lift flowline is required; however, there are some instances where lift gas is injected via umbilicals. Figure 2 shows a simplified gas lift system and topside components for offshore application.

### Wellbore Gas Lift

Injection of gas into the wellbore is accomplished through the installation of special gas lift valves positioned at specific depths in the annular space between the production tubing and production casing. The pressure gradient is reduced from the injection point to the surface by the reduced pressure head. This bottomhole pressure reduction creates a pressure differential that affects fluid velocities and flowrates.

Another option is to have a single valve, commonly referred to as a Downhole Gas Lift Flow Control valve, set at a particular depth. This valve essentially acts as a choke to control the amount of gas introduced into the wellbore. The increase of flowrate in the tubing and flowlines increases frictional losses, effectively reducing some of the benefits obtained by reducing static head. Therefore, the determination of an adequate gas injection rate is necessary for an optimum performance of the gas lift system.

Figure 3 shows an example of a gas lift performance plot where casing pressure or "A-annulus" pressure and liquid flowrate is a function of the lift gas flowrate. Sensitivities are shown for the outflow curves for various downhole gas lift valve orifice openings. Different parameters such as depth of well, wellbore configuration (i.e. deviation, casing size, and perforation interval), mechanical skin, sands and solids production, corrosive fluids, well temperature and paraffin build up, and scale deposition are important factors that must be considered.

Mechanical conditions often impose severe constraints, particularly in wells that are initially completed for normal natural flow without consideration of the introduction of artificial lift equipment necessary for production in late life conditions. Production casing pressure limits and gas lift valve pressure ratings are sometimes limiting factors in determining the injection pressure of the lift gas.

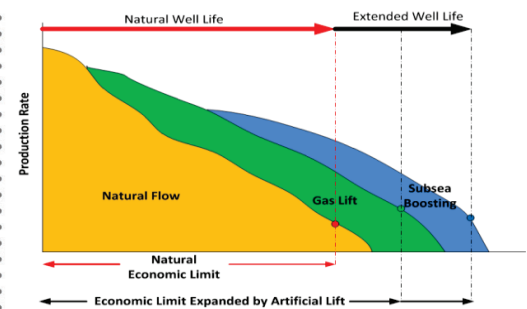


Figure 1: Artificial Lift Impact on Well Life & Economics <sup>1</sup>

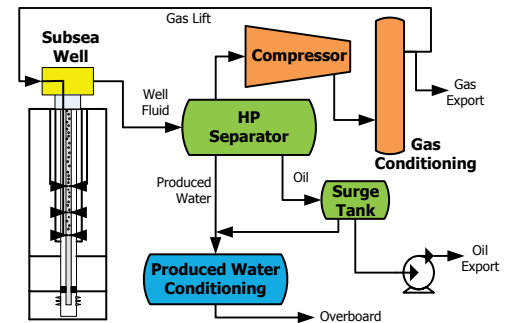


Figure 2: Simplified Typical Offshore Gas Lift System

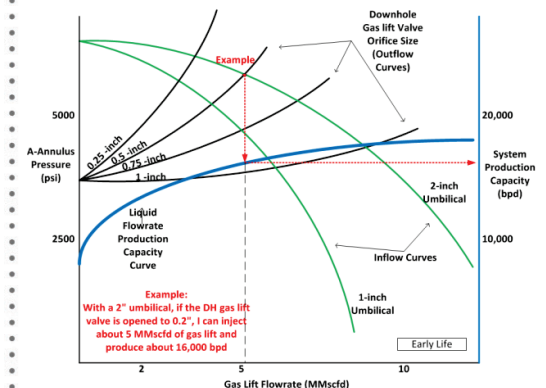


Figure 3: Generic Gas Lift Performance Plot for Various Umbilical Tube Sizes and DH Gas Lift Valve Orifices Topside Pressure Constant

## Artificial Lift for Subsea Applications

### Flowline-Riser Gas Lift

Gas injected into the flowline-riser is designed to alleviate the continuous accumulation of liquids in low points of the production system. Accumulated liquids can create conditions for slug flow that can be detrimental for the optimum performance of the topsides facilities. The most critical location for liquid accumulation in the subsea production system is at the riser base. Therefore, gas injection at the riser base is one of the techniques used to control severe slugging conditions.

Gas injected into the riser base continually lifts liquid out of the riser, preventing the build-up of liquid by reducing the pressure head in the riser and increasing the superficial velocity of the gas, which diminishes the severity and cycle time of the slugging condition.

The need for gas lift into the flowline-riser must be assessed during the design stage of the project, and provisions made for its implementation.

### Subsea Pressure Boosting

Artificial lift methods using pressure boosting aims to increase the flowing pressure in the production system when the reservoir pressure is insufficient to transport produced fluids at an optimum rate. Mechanical means such as downhole single/multiphase pumping or a combination of subsea separation and pumping may be used for this purpose. Pressure boosting may be necessary at any given stage of the project development; therefore, it is an important consideration in the design stage of the project.

### Subsea Multiphase Pumps & Electric Submersible Pumps (ESPs)

Multiphase pumps can be classified as either rotodynamic pumps or positive displacement pumps. Rotodynamic pumps have larger capacities, but are much more affected by changes in gas volume fraction, suction pressure, and differential pressure. Reaching erosional velocities is a risk, making proper material selection for the pump design important. Figure 4 shows a typical rotodynamic pump. The differential pressure achievable by positive displacement pumps is limited by the ability of the pump to withstand system pressure and the effect of the differential pressure on the internal pump leakage.

An ESP is a multistage centrifugal pump installed downhole and driven by an electric motor powered by cable from the surface. ESPs work efficiently for higher water-cut, low Gas to Oil Ratio (GOR) wells.

### Flow Assurance Problems Associated with Subsea Artificial Lift

Typical flow assurance problems associated with subsea artificial lift systems include scaling, asphaltenes, emulsions and slug flow.

### Scaling & Asphaltenes

Scales are likely to form in a system where the fluid composition or temperature is changing rapidly; hence, the injection valve port in a gas lift system is a potential location for scale build up. Anti-scaling chemicals can be injected downhole to inhibit the formation of scale deposits driven by the injected gas; however, the primary challenge is to make sure proper treatment is achieved at the injection point.

Flocculation and precipitation of asphaltenes may also be triggered by gas lift. The decrease in the resulting fluid density and reduction of viscosity creates the conditions for asphaltene micelles destabilization. This can lead to subsequent plugging of the near wellbore region and gas lift equipment.

### Emulsions & Slug Flow

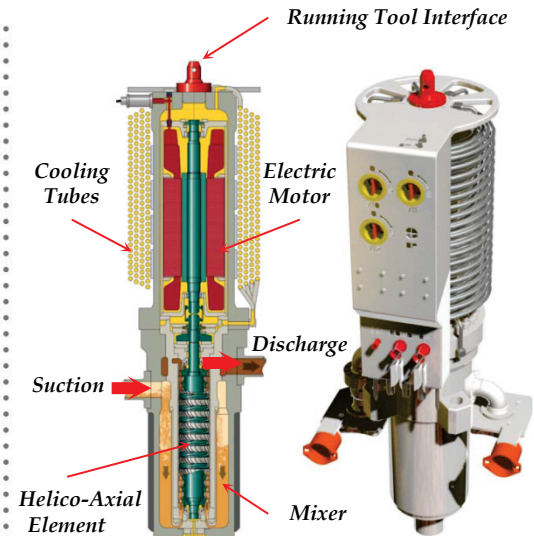
Emulsions may form when the fluid is subjected to shear forces and pressure changes. The greater the shear force the more likely an emulsion will be formed. Gas lift wells present situations where the fluid is subjected to external shear forces, and thus gas lift is known to increase the problems of an emulsion producing well. The amount of shear force created in a gas lift well, however, is considerably less than that generated by a downhole pump and, for this reason, downhole pumps are less suitable for artificial lift when emulsions are a potential risk.

Slug flow can be controlled efficiently in properly designed gas lift systems by increasing the fluid velocities, and reducing the liquid holdup along the production system. Ineffective gas lift systems can be the source of such flow instabilities, particularly when the design is not sufficiently robust to account for changes in reservoir and fluid conditions that occur late in field life.

### Conclusions

Several artificial lift methods for subsea application have been introduced. Artificial lift methods work well if systems are designed and installed properly. Changing reservoir and well conditions need to be anticipated so that proper equipment is selected and installed in order to ensure flexibility throughout the life of a field. Availability of data is important to achieve good designs that work effectively in the field. Applications and limitations of each artificial lift method must be thoroughly assessed in order to deploy the most effective, optimized and robust production methodology throughout the field life.

Selection of the right artificial lift method for the subsea production system is a process primarily driven by parameters of reservoir performance, fluid properties, well configuration, subsea system architecture, associated flow assurance challenges, operating philosophy and processing capabilities. Furthermore, the availability of resources such as electrical power and gas, and the economic targets that impact the CAPEX, OPEX and rate of return of a given development must be taken into account. All these considerations should be incorporated into the analysis of alternatives for implementing subsea artificial lift.



**Figure 4: Typical Helico-Axial Pump Type of Rotodynamic Subsea Multiphase Pump<sup>2</sup>**

### References

1. Fleshman, R. Obren, H. "Artificial Lift for High Volume Production". Oil Field Review Spring 1999, Schlumberger. USA. (Modified)
2. <http://www.onesubsea.com>



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