GAS LIFT - JET PUMP HYBRID COMPLETION REDUCES NONPRODUCTIVE TIME DURING UNCONVENTIONAL WELL PRODUCTION

Osman A. Nuñez-Pino, Weatherford International Inc.
Toby Pugh, Weatherford International Inc.
James Hubbard, Weatherford International Inc.

ABSTRACT

Gas lift is a preferred lifting method to produce unconventional wells across the world. During specific stages of the well life, however, it might happen that water percentage raises enough to make the tubing flow gradient too high for lifting with the maximum operating pressure and rate of injection gas. This results in unplanned nonproductive time. A slickline-deployable jet pump can be a cost-effective alternative to effectively unload the well and resume production with gas lift.

The addition of a sliding sleeve door (SSD) to the tubing string, installed between the deepest gas lift mandrel and the annular packer, will allow the deployment of a wireline-set jet pump. The backup jet pump provides a valuable and cost-effective alternative in three potential scenarios: when unloading fracking fluids before beginning gas-lift production, when restoring production after an unpredicted shutdown of the gas-lift compression system, and when the producing water cut becomes higher than expected.

An operator in Logan County, Oklahoma, installed the gas lift-jet pump hybrid completion in five wells. The completion was basically designed for gas lift with a standard "X" profile SSD installed between the packer and the operating gas-lift valve. The dual-purpose tubing string was installed in each well in one trip. To produce fracking fluids left in the wellbore, standard-flow jet pumps were set in the SSD, mobile hydraulic-lift surface units were hooked up to the Christmas tree and jet pump production operation started. On average, fracking water was produced 66% faster than by swabbing and rod pumping, and 33% faster than with nitrogen lift. Upon recovery of the fracking fluids, the wells were producing enough gas to successfully start the gas lift systems in approximately 6 days.

This simple but ingenious dual-purpose completion approach has already proved to solve the problem of unconventional well production load-up during the early production stage of gas lifted systems. The information provided in this paper will help operators plan, design, deploy, and operate a dual-purpose gas lift-jet pump well completion.

INTRODUCTION

During the productive life of a gas lifted well, there might be unplanned circumstances that can make the producing process to become both technically and economically challenging and sometimes even not feasible. Typical causes that make difficult producing gas lift wells are, among others: Low flowing bottomhole pressure, lack of produced gas to be used as working fluid, temporary or permanent failure of the gas compression/piping facilities and, the increase of produced water percentage of the well above maximum levels.

In unconventional reservoir stimulation processes (i.e. fracking), large volumes of liquids are pumped down the well and along with the proppant and other substances, are forced to enter and flow through the fractured rock in the well's formation. In the United States of America, the volume of water used for fracturing per well, ranges between 70,000 and 130,000 barrels, depending on what unconventional development (shale play) the well is located.

Unconventional reservoir wells that have been just fracked will typically flow to the surface by means of its reservoir's own energy (sometimes they don't flow). Their flowing bottomhole pressure is high enough to overcome the hydrostatic head, flow losses and wellhead pressure. During this stage of relatively high production rates, frac water will be the predominant component of the producing multiphase flow; gas and oil will usually be present on minimal fractions of the flow at the very beginning, however their mass rate percentage in the flow of fluids will be progressively increasing with time.

Shale reservoirs typically show a steep decline on their producing pressures. In the United States shale fields, it is typical to see 60-80% of unchocked decline rate, just during the first year. That said, most of the fracked wells in unconventional developments cease their self-flowing production stage (flow back) within the first year after they are drilled and fracked; more over 80% of the shale play wells stop flowing within the first 6 months of self-flowing production. It is important to mention that there have been many cases where fractured wells do not flow by their reservoir own pressure, and consequently the artificial lift strategy needs to be put in place before than expected.

When a well is loaded-up with frac water, probably it will not be possible to “kick it off” using gas lift, even by using the highest pressure that the gas compression facility can deliver. A similar scenario might occur when eventually the percentage of produced water becomes higher than the maximum value considered for the gas lift system analysis/design.

As in most areas, swabbing or nitrogen lift are typically used to unload wells, while the jet pumping implementation in unloading operations is growing in number of installations, it has not reached yet the level of usage of the traditional unloading procedures. The authors of this paper, knowing the benefits that a jet pump can provide on wells unloading operations, put together a frame of technical knowledge and proposed the solution to an unconventional wells operator in the State of Oklahoma. After applying the technology in five wells, the results were positive, and the operator unloaded its wells effectively and immediately putting them back on production using the gas lift system, without incurring on expensive traditional procedures like workover, swabbing or nitrogen injection, but just by deploying a jet pumping system on temporary basis.

The proposed solution consisted on installing a standard sliding sleeve door (SSD) with landing profile to the gas lift tubing completion; the SSD is located between the annular packer and the last (deepest) gas lift mandrel/valve. Once it was time to unload the well and this was not possible to do it by injecting gas, the SSD is set in open position and a jet pump is landed in it, these two operations are completed using slick-line standard procedures. Immediately later, hydraulic lift power fluid (produced water or oil) is pumped down the tubing to the jet pump, and this produces the fluids from the reservoir (frac water, formation water, oil and gas); mixing them with the spent power fluid and then discharges commingle return fluid to the surface through the casing-tubing annulus conduit. At the moment that produced gas rate reaches a minimum required level, the jet pump is pulled and SSD closed, gas lift system is set into operation to produce the well as it was originally designed. The proposed hybrid completion design can also be used as a backup production system given the case of a disruption of the pressurized gas system (compressor) or its related facilities.

Finally we would like to clarify something: It is not the intention of this paper to explore in the deepness of the currently used gas lift technology, but on the application of the jet pump as a “backup/unloading” artificial lift system.

THE JET PUMP: WHAT IS IT AND HOW DOES IT WORK?

The jet pump is a hydrodynamic device that transfers energy from a stream of liquid or gas primary fluid to a secondary stream of fluid that can be liquid, gas or the combination of both. A jet pump offers significant advantages over other types of artificial lift systems. Having no moving parts makes this technology quite reliable; its high adaptability to different completion geometries is practically unmatchable, simple and low cost.

In this device, a stream of fluid (power fluid) with relatively high potential energy (in form of pressure) is entrained to a nozzle; here the potential energy is transformed into kinetic energy in form of a high velocity/low pressure stream of fluid (jet core). Due to the low pressure environment induced at the tip of the nozzle, formation fluids (water, gas, oil) and many times solids, are enabled to enter the jet pump to commingle with the high speed jet core. The jet core drags the produced fluids into the mixing tube (throat), and is across this constant diameter passage where the transfer of energy (momentum transfer) is accomplished. At the end of the throat, there should be a homogeneous stream of fluid (power fluid and produced fluid). The commingled fluid is now directed to a diffuser for an additional and final energy conversion; the remaining and still considerable kinetic energy is transformed into potential energy (pressure) in order to lift the commingled return fluid up to the surface (Figure 1).

HOW A JET PUMP IS TYPICALLY INSTALLED AND OPERATED TO PRODUCE A WELL?

The most common type of jet pump downhole system (most used configuration, among several ones) is installed using a tubing string, a housing (SSD or jet pump bottomhole assembly) to land the jet pump, and an annular packer that is installed right above the perforation's top. For these wells, a 1.875'' standard circulation jet pump was landed in the SSD, using an X profile lock. The jet pump/lock mandrel assembly seals at the two seal-bore areas of the SSD, so three pressure chambers are defined: I high pressure chamber (where the power fluid acts), a low pressure chamber (producing bottomhole pressure at pump intake) and medium pressure chamber (fluids discharge).

In the standard circulation configuration (which is the jet pump operation style applied on these wells), clean power fluid, typically produced water or oil, is pumped to the well Christmas tree and then down the tubing to the jet pump nozzle. As consequence of the induced drawdown, produced fluids enter the jet pump admission from below (formation fluids usually flow through a standing valve before getting to the jet pump intake). Through the jet pump side discharge ports, both expended power fluid and produced fluids are flown to the casing-tubing annulus. This discharge flow should be at a high enough static pressure to be lifted to the surface (Figure 2).

The hydraulic lift surface equipment can also be installed using a variety of configurations, however there are two common elements that are present in one way or another in all the possible arrangements: The power fluid reservoir and the power fluid pump. The power fluid reservoir might be a pressurized vessel, an upright storage tank or a frac tank. In the other hand, to energize the power fluid (increasing its potential energy in form of static pressure), multiplex plunger pumps (triplex or quintuplex), surface multistage centrifugal pumps or surface progressing cavity pumps can be utilized. The authors proposed and installed the surface equipment using a power unit (triplex pump) and several upright tanks to complete the temporary surface equipment facility (Figure 3).

HOW TO MAKE A GAS LIFT COMPLETION SUITABLE TO ALLOW A JET PUMP TO BE INSTALLED ON A TEMPORARY BASIS?

A typical gas lift completion includes the following equipment (from bottom to top):

- An entry guide (mule shoe).
- A no-go profile landing nipple (typically a "XN" profile nipple).
- An annular packer (this can be retrievable or permanent, according to the application and preferences).
- Gas Lift Mandrels along the tubing string. These might be conventional or side-pocket mandrels.
- Tubing joints, pup-joints, downhole gauges, safety valves and any other flow control/safety device as required.

A jet pump requires a cavity (or housing) to be installed, so injection pressure, intake pressure and discharge pressure are all isolated from each other. These pressure chambers isolation is achieved combining seal-bore areas and seals; the seals can be pressure activated (i.e. v-packings, thermoplastic ring seals and similar) and/or tapered metal to metal seals. That said, to have a gas lift completion with the capacity of receiving a jet pump, a Sliding Sleeve Door (or Sliding Side Door) is installed, above the annular packer and below the deepest gas lift mandrel (Figure 4).

Considerations about the Sliding Sleeve Door (SSD)

A sliding sleeve door represents one of the most commonly used flow control devices in well completions. It is typically installed as an equalization device between tubing and casing, and as equipment that will allow flow circulation from casing annulus to tubing and vice-versa, whenever it is needed. The SSD that was installed in these gas lift/jet pump hybrid completions had to fulfil with three main requirements: A landing profile (usually "X" or "XN"), polish bore surfaces and an inner sleeve that can be opened or close by purpose.

On this specific application (jet pump used as back-up artificial lift) the jet pump equipment is implemented in a temporary basis, then the SSD will need to be open when the jet pump inside it and operating, and needs to be closed after the jet pump has achieved the unloading operation (or back-up production method task), so the gas lift can resume to its normal operating process.

HOW THE OPERATOR UNLOADED WELLS BEFORE USING JET PUMPS?

Common well unloading methods still widely implemented, not only in North America but in the majority of the oilfields worldwide, are the injection of nitrogen (nitrogen lift) and swabbing; and these were also the unloading strategy used for this operator before they used jet pumps.

In a nitrogen lift operation, liquid nitrogen is transported from nearby storage facilities to the well location. Nowadays portable nitrogen generation units are also available; these units can harvest nitrogen from the air so can then be injected to the well. Nitrogen is pumped at considerable pressure down the tubing at a specified depth, typically using a coiled tubing string. The injected inert gas flows down the coiled tubing (which has been ran in the well through the existing tubing completion), and once it exits the coiled tubing string end, it will flow back to the surface, through the annulus space between the tubing string inner surface and the coiled tubing outer surface. Eventually the well is "kicked-off" and enabled to produce, while the nitrogen injection continues for the required time.

In the other hand, unloading wells implementing a swabbing strategy, was also tried up to extent, it resulted to be laborious and costly because of the extended working periods of a slick-line truck and crew. In this operation, a swab cups assembly is run down the tubing until it reaches a certain depth, then it is pull back to the surface in order to achieve a "piston displacement effect" to move a specific volume of well fluid to the surface. The same operation is repeated over and over until it is considered that the well has been unloaded.

THE JET PUMP USED AS WELL UNLOADING ARTIFICIAL LIFT SYSTEM THAT ENABLED THE OPERATOR TO CONTINUE PRODUCING ITS UNCONVENTIONAL WELLS WITHOUT ABANDONING THEIR ORIGINAL GAS LIFTING STRATEGY

Sometimes it is assumed that every fracked well will flow on its own with relatively high rates, and that all injected frack water will be expelled from the formation during this flowing period. Unfortunately, this is not always the case. Sometimes, the stimulated formation will make the well to flow for just few days or hours, or even worse, it might not flow.

Before using the backup jet pump strategy, this client used to install gas lift completions (without an SSD), immediately after the wells stopped their self-flowing stage. Then they tried to "kick-off" the well with gas injection as the gas lift infrastructure was already in place. In those wells where a considerable percentage of injected frack water was still in the formation, it was not possible for the gas injection system to "kick them off", because of the column high gradient in the tubing string. Moreover, assuming that the gas lift system were capable to start lifting the well fluids, its gas production rate might be not enough to keep the system working on continuous gas injection. Here is where the operator typically used the services of a nitrogen lift system or a swabbing truck, or if nitrogen didn't work, Workover the well to install an ESP system.

It was then, after listening to recommendations and looking at other jet pump experiences in surrounding fields, the operator decided to install an appropriate SSD, located below the deepest gas lift mandrel and above the annular packer to all the upcoming gas lift completions.

The time arrived for the first fracked well not able to produce with its deployed gas lift completion. The operator installed a standard circulation jet pump and landed it at the sliding sleeve door at approximately 5,200 ft MD, using a lock mandrel. A skid mounted 165 horsepower hydraulic lift power unit (commonly known as "frack fluid recovery unit"), was brought to the location and properly hooked up to the well Christmas tree, to one of its tubing string wing valves. The Christmas tree annular conduit exit valve was connected through 2'' hammer union pipes to a battery of tanks. Power fluid (water) at a pressure of 2,000 – 3,500 psig was pumped from the multiplex pump downstream tubing to the jet pump.

In order to maximize the utilization of the available surface installed horsepower, we equipped the jet pump with a nozzle/throat area ratio that enables us to lift the maximum production flow rate from that well. During this early production stage, a standard jet pumping system will typically produce between 500 and 1,500 bfpd (with a 2-3/8'' jet pump), depending on the flowing bottomhole pressure at the jet pump intake.

RESULTS

At the time that the operator has had equipped these gas lift-jet pump hybrid completions in 5 wells, the tangible benefits that this process has brought are:

1. Saving on work-over expenses: In many opportunities, the operator installed Electric Submersible Pumps (ESP) and in a much lower frequency, Reciprocating Rod Lift (RRL), in order to carry on with the Frack

Fluid Recovery (FFR). Once the FFR was considered completed, they pulled this temporary completion to install the long term gas lift completion. Just adding the SSD to the gas lift completion, the operator could complete the FFR process and switch to gas lift production mode, without making a rig intervention to the well (Table 1).

2. According to the producer company estimations, the saving on one rig intervention by doing the combined installation of the jet lift and the gas lift in one tubing string trip, covered the entire cost of gas lift valves.
3. Production downtime caused for the completion change from ESP or SRP to gas lift was reduced in approximately 50% as an average of all five wells.
4. From production data collected on five wells where the dual system was installed, fracking water was produced 66% faster than swabbing and sucker rod pumping, and 33% faster than nitrogen lift.
5. Upon recovery of the fracking fluids, the wells were producing enough formation gas so the operator was enabled to start the production operation with gas lift in approximately six days.
6. Jet Pumps resulted to be more tolerant than ESPs when handling frac sand (proppant). Up the date, no jet pump nozzle and/or throat have been replaced because of proppant erosion damages (Figure 5).

CONCLUSIONS

1. A slight modification to the traditional gas lift completion, by adding an SSD to it, transforms this tubing string in a dual purpose or hybrid completion that allows the well owner to install a jet pump. Further changes or additions to the completion design are not required.

2. Jet Pumps demonstrated to be more tolerant to frac sand production (proppant handling) than ESP systems. Typical frac sand grains have a “quasi” spherical shape and usually no sharp or irregular edges. Jet pump’s nozzle and throat are made out of tungsten carbide (sometimes with silicon carbide), so typically they don’t get eroded by frac sand produced along formation fluids.

3. It was clear that in most cases, a jet pump can unload this operator wells faster than rod pumps, nitrogen lift and swabbing.

4. With the deployment of the gas lift – jet pump hybrid completion, the operator saved the entire cost of a work-over operation. The amount of this saving was enough to payback the gas lift valves cost.

REFERENCES

1. Pugh, T.S. 2015. Overview of Hydraulic Pumping. Fort Worth, TX.
2. Chokshi, R. and Lane, W. 2014. Considerations for Optimizing Artificial Lift in Unconventionals. URTeC 1921823.
3. King, G. 2012. Hydraulic Fracturing 101. SPE 152596.

ACKNOLEDGEMENTS

The author would like to acknowledge Mr. Toby Pugh for his technical support and dedicated mentoring, to Mr. James Hubbard and his Hydraulic Lift Operations Team, for their unconditional support and outstanding job in the field.

Table 1 – Switch-over of systems comparison table

	Operation Description	ESP	Rod Pump	GL - JP Hybrid
Installation of the unloading system completion	Rig Move-in Time [hours]	13	13	13
	Rig Up Time [hours]	3	3	3
	Running Tubing [hours]	12	10	10
	Running Pump [hours]	0	0	1*
	Running Sucker Rods [hours]	0	7	0
	Rig Down Time [hours]	2	2	2
	Surface work [hours]	4	6	4
Pulling of unloading completion - Installation of long term completion system (Gas Lift)	Rig Move-in Time [hours]	13	13	0
	Rig Up Time [hours]	3	3	0
	Pulling Tubing [hours]	6	5	0
	Pulling Pump [hours]	0	0	1*
	Running Tubing GL Completion [hours]	10	10	0
	Surface work [hours]	3	3	3
	Total work-over time [hours]**	**36**	**40**	**15**
	Total ALS switch-over [hours]***	**69**	**75**	**37**

* Wireline job

**Based on a 5,200 ft well. ESP and RP are tubing pumps. Wireline set Jet Pump.
***Average time to install/ uninstall unloading system, and to install Gas Lift System.

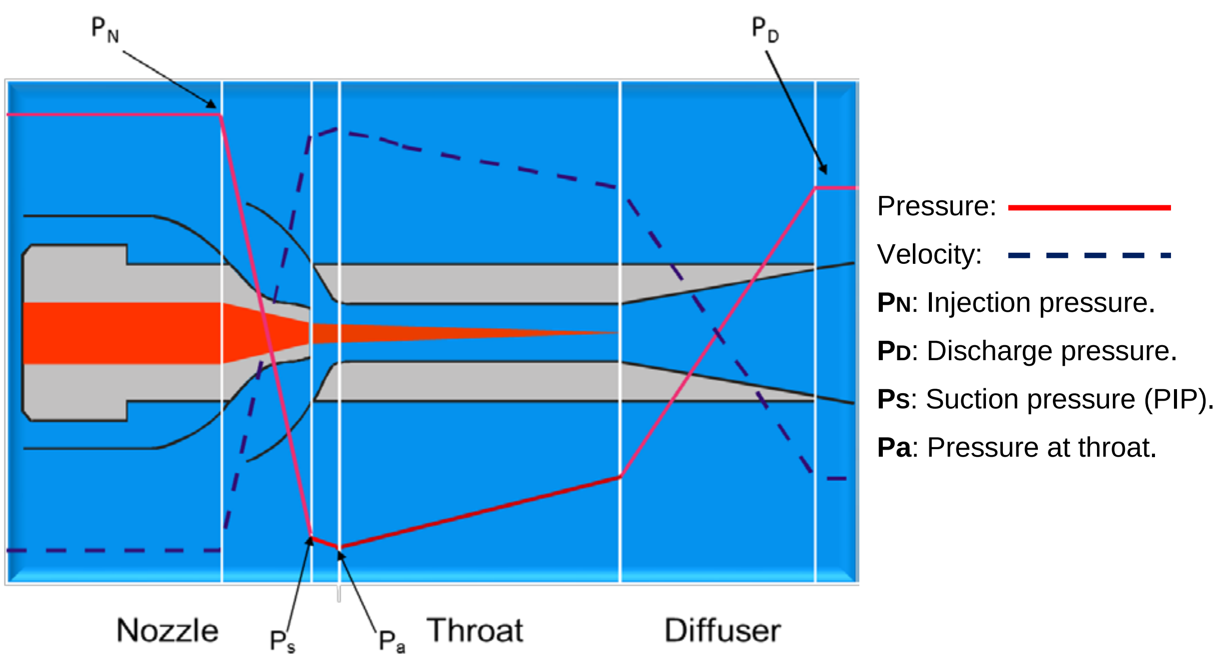

Figure 1 - Schematic of Flow Velocity and Static Pressure in a Jet Pump

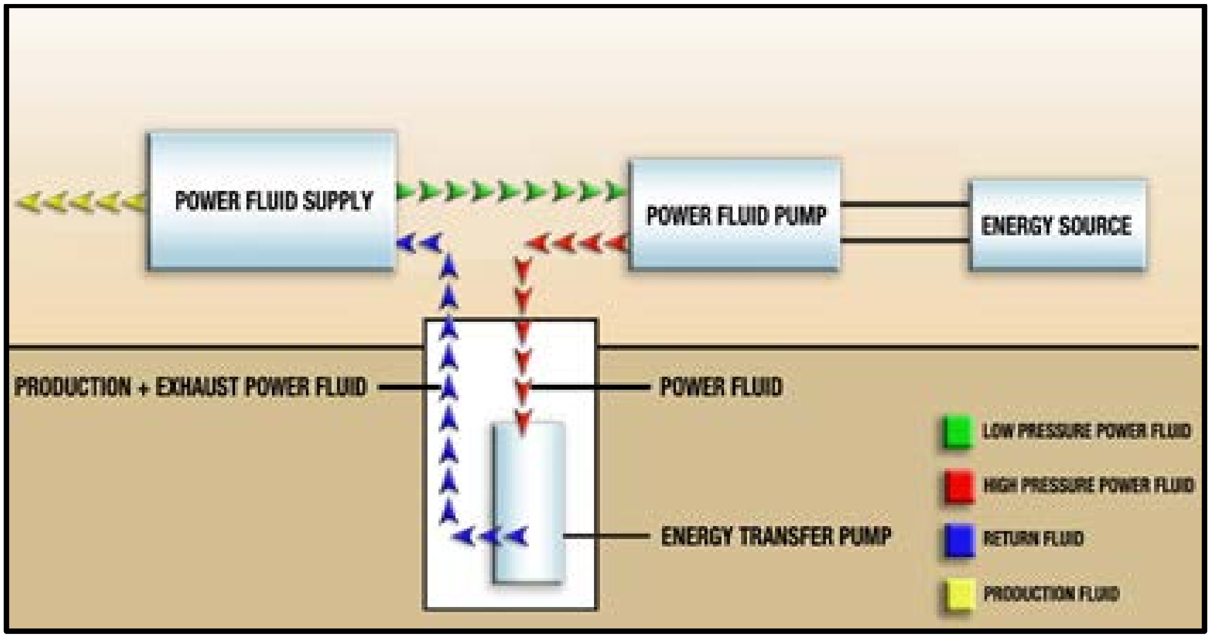

Figure 2 - Flow Schematic for a Typical Hydraulic System

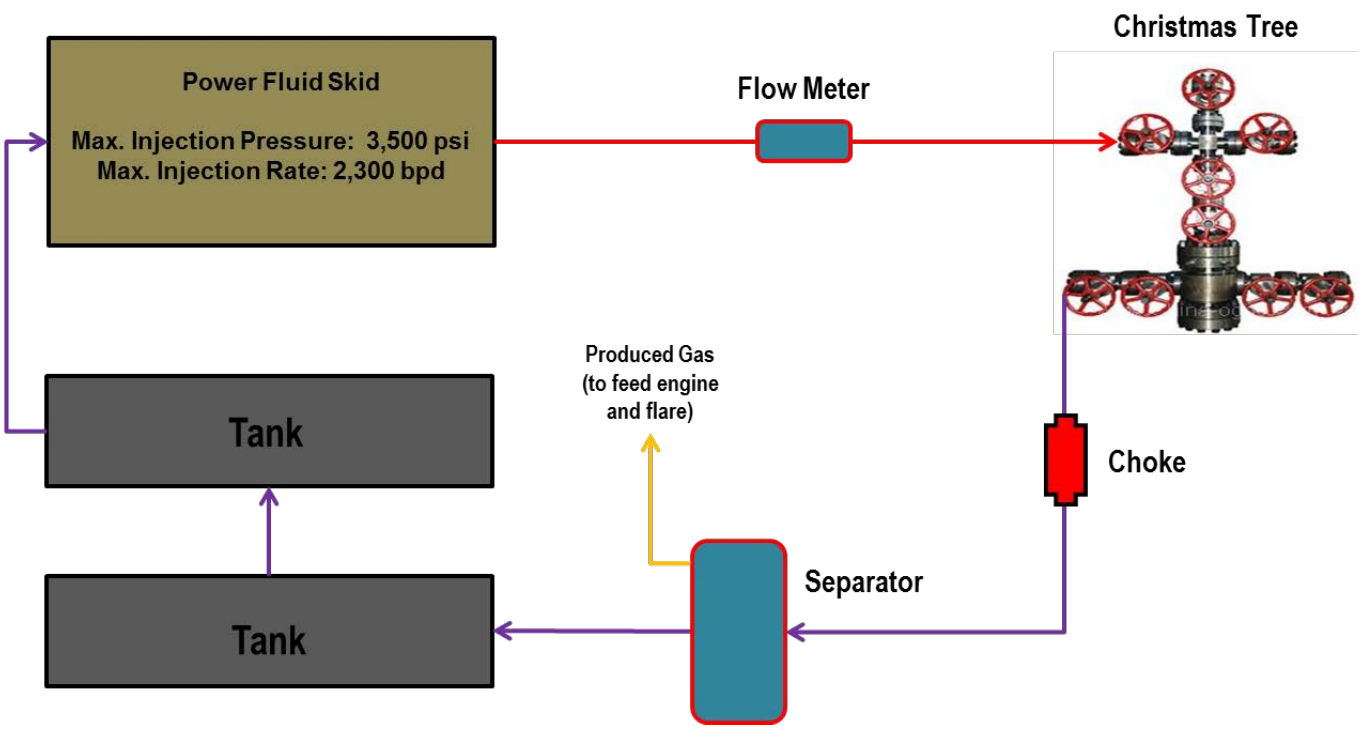

Figure 3 – Jet Pump Frac Fluid Recovery Surface Layout

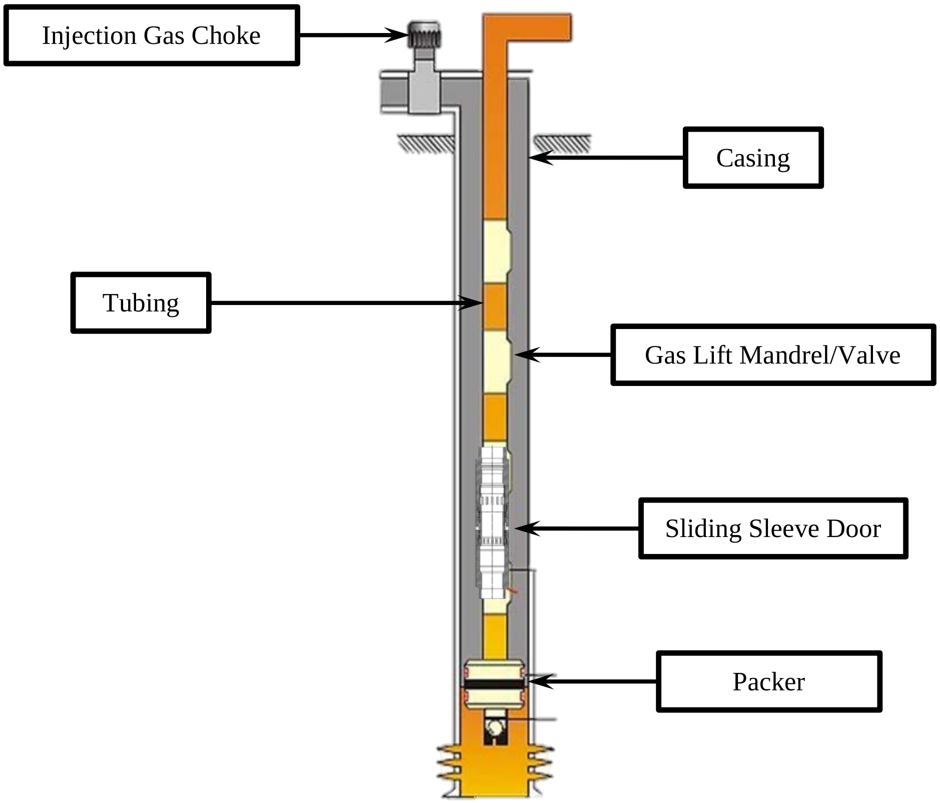

Figure 4 – Gas Lift – Jet Pump Hybrid Well Completion Illustration

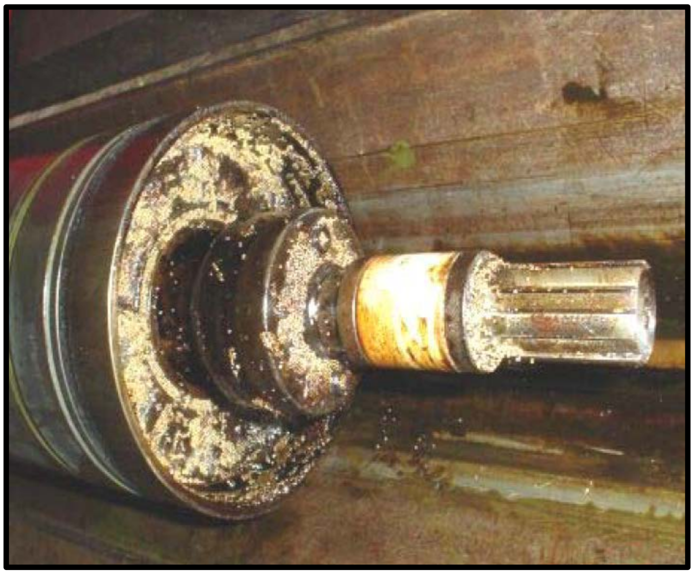

Figure 5 – Pulled ESP. It failed because of frac sand (proppant) accumulation