ONE-TIME DEPLOYED-DUAL PURPOSE WELL COMPLETION PROVES TECHNICAL AND ECONOMIC SUCCESS THROUGHOUT THE ENTIRE PRODUCTIVE LIFE OF WELLS USING JET PUMP AND HYDRAULIC PISTON PUMP

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ABSTRACT

A single-time deployed, multi-purpose well completion can be designed and installed to successfully produce certain particular wells, from the time of their initial clean-up stage all the way to their reservoir depletion. This ingenious and particular type of downhole configuration offers the advantage of producing medium to high rates at considerably high flowing pressures using a hydraulic jet pump, to lately accept a hydraulic piston pump, which will produce relatively low flow rates at very low producing pressures, with absolutely no modifications to the original completion.

When properly engineered, either a jet pump or a piston pump can perfectly work in the same downhole bottom-hole assembly (BHA), as well as be circulated in and out of the well. As consequence of this important flexibility, operational expenses related to well repairs are literally taken out of the equation, only one work-over job is needed, at the very beginning of the well's artificially lifted stage. Initially, the jet pump will effectively clean-up the well and produce medium to high rates, then when producing pressures are substantially lower, the jet pump is circulated out from the well, and a piston pump is immediately installed ("dropped") using the same tubing completion to continue producing the well down the road. Again, a work-over job is not required to carry on with this lifting method transition.

This hydraulic jet – piston pump dual completion approach has proved to reduce significantly well repair expenses as well as nonproductive times during pump retrievals. The technical knowledge provided in this paper will help oilfield operators on the well selection, planning, completion design, installation and operation of this simple but highly effective advantageous completion configuration.

INTRODUCTION

In today's challenging oil and gas industry economic conditions, both equipment performance improvements and operating cost reductions are topics of capital importance for all producer companies around the world. These economically imposed difficulties in the current market environment have been seen as an almost imperative need for the engineering of more reliable equipment with longer run-lives, easy of repair, with standardized parts and capable of satisfactorily handle a wide spectrum of working conditions.

From few years ago, unconventional reservoirs exploitation have indeed attracted the attention of the oil and gas industry, and is a fact that fracturing operations budget is surpassed only by drilling activities budget. This proves the importance and seriousness of the unconventional production business. 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 treatment per well, ranges between 70,000 barrels (11129 m^3) and 130,000 barrels (20668 m^3), depending in what unconventional development (shale play) the well is located.

Shale reservoirs typically show a steep decline on their producing pressures. In the United States different shale fields, it is typical to see 60-80% of unchocked decline rate, just during the first year. That said most of the fractured wells in unconventional developments cease their self-flowing production stage (flow back) within the first year after they are drilled and fractured. Moreover, 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.

Unconventional wells might start its production life with considerably high rates and high flowing bottomhole pressures and then, in less than three years, become a low rate producer with considerably low bottomhole producing pressures. This productivity's decline is typically very uncertain, and it can widely vary not only between different shale plays, but also between wells drilled in the same reservoir. This fast/steep decline in production rate imposes challenges to the conception of a technically/economically viable artificial lift strategy. The well work-over strategy to change lifting method according to the rapid moving well productivity has been the most used way to go and there was no problem with it, whenever the oil price was at such high/sustained levels. During the past two years with an oil average provide of around 50% lower, costs related rig interventions and artificial lift changes are way more under scrutiny than before; producer companies are actively looking for reducing these associated costs to their minimum.

The proposed solution consisted on engineering and installing a well completion with capabilities to function with two lifting methods alternatively. This completion design was appropriate for installing and operating a hydraulic jet pump during the fracturing flow recovery/clean up stage, where producing rates are considerably high, between 1,000 – 4,000 bpd (159 – 636 m^3/d); through medium rates using the same jet pump and finally, when the well is depleted, retrieve the jet pump (no work-over is needed to do this) and run a hydraulic piston pump, where production rates of around 20 bfpd (3.2 m^3/d) are possible. Where jet pump are excellent for handling high rates at medium to high flowing bottomhole pressures, the hydraulic piston pump is quite efficient handling low rates at very low pump intake pressures.

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

The jet pump is a hydrodynamic device that transfers kinetic 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 in many occasions solids, are enabled to enter the jet pump to commingle with the high velocity jet core. The jet core drags the produced fluids into the mixing tube (throat), and is across this constant diameter passage 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 fluids). 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 cavity (jet pump bottomhole assembly or BHA) to land the jet pump, and an annular packer that is typically installed right above the perforation's top. For these wells, a 2.5-in standard circulation jet pump was landed in the BHA. The jet pump assembly makes seal at the top polished are of the BHA and at the bottom of it, on a metal-to -metal tapered seal with the standing valve. Then three pressure chambers are defined: I high pressure chamber (where the power fluid acts), a low pressure chamber below the standing valve (producing bottomhole pressure at pump intake) and medium pressure chamber (return fluids discharge) (Figure 2).

In the standard circulation configuration (which is the jet pump configuration used in these wells), clean power fluid (high pressure flow), 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 created by the nozzle exit pressure, 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 lift commingled returns to the surface.

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 (or a vessel cleaning unit) to complete the surface equipment (Figure 3).

THE HYDRAULIC PISTON PUMP: WHAT IS IT AND HOW DOES IT WORK?

The hydraulic piston pump basically is a positive displacement pump used to transfer energy from a pressurized volume of liquid to a lower pressure volume of fluids, either liquid and/or gas. Because this is a positive displacement device, it typically transmits energy efficiently, using lower horsepower levels than a jet pump, if we compare them under the same producing conditions. The advantage of the piston pump is in its capacity to pump fluids in wells which bottomhole pressure are low. Hydraulic piston pumps can definitely pump-off a well; contrary to jet pumps that need a minimum pump intake pressure in order to operate appropriately.

The piston pump that we proposed and installed in these wells is a single-displacement piston pump. This pump displaces produced fluids during its up-stroke only. This hydraulic piston pumps is basically composed of an engine barrel, an engine piston, a reversing valve, a pump barrel and a pump piston. The reversing valve is shifted by hydraulic action and makes the pump piston reciprocate up and down withdrawing the energy provided by the power fluid which is pumped from the surface. During the down-stroke pump barrel is filled with production fluid from the formation, when the end of down-stroke is reached, the reversing valve shifts piston movement direction to start the up-stroke, where fluids is the pump chamber are discharged to the annulus and lifted to the surface (Figure 4).

HOW TO MAKE A WELL TUBING COMPLETION SUITABLE TO ALLOW EITHER A JET PUMP OR A PISTON PUMP TO BE INSTALLED AND OPERATED?

A typical hydraulic lift-free style completion includes the following equipment (from bottom to top):

- An entry guide (mule shoe).
- A no-go profile landing nipple (typically a “XN” or “F” profile nipple).
- An annular packer (this can be retrievable or permanent, according to the application and preferences).
- A hydraulic lift bottom-hole cavity commonly referred as BHA (bottom-hole assembly).
- Tubing joints and pup-joints to surface.

A jet pump requires a cavity (BHA) 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 hydraulic lift completion with the capacity of receiving a jet pump and a piston pump, a BHA is installed, above the annular packer (Figure 4).

Considerations about the Bottom-Hole Assembly

The BHA needs to serve as production housing for both the jet and piston, at any time of the productive life of the well and requiring no work-over rig or whatsoever. The BHA to be installed must be appropriated to accept the length of the piston pump (piston pumps are typically longer than jets) and the seal-bore diameters specification of both systems. To simplify the process of the completion of the well, a 2-7/8-in (73.025-mm) piston pump BHA was installed. The jet pump pitch length (distance between seals) was adjusted to the length of these BHA by installing an extension between the jet pump cross-over body and its bottom plug (Figure 5).

HOW THESE OPERATORS TRADIONALY PRODUCED THEIR WELLS?

Between the several operators that are in this time implementing this strategy, basically two production system changing-processes where implemented:

- After the well hydraulic fracturing and fracturing fluids flow-back (by its own reservoir pressure), electric submersible pump for the high production rate stage and then later, a reciprocating rod pump.
- Following the well flowback, gas lift and reciprocating rod pump.

As it can be seen, work-over rigs are required at least twice in order to install the first ALS (artificial lift system) for higher rates, and for the second (medium/low rates) ALS.

Our solution is designed to eliminate one of these work-over jobs, by deploying one completion that will allow the operation of two different systems, one at a time.

HYDRAULIC LIFT PUMPS (JET AND PISTON) USED AS ALTERNATING PRODUCTION SYSTEMS THAT ENABLED OPERATORS TO CONTINUE PRODUCING THEIR WELLS WITHOUT BRINGING A WORK-OVER RIG TO LOCATION TO RE-COMPLETE THE WELL

Once an unconventional well ceases to flow by its own reservoir pressure or this flow is close to nothing, a dual purpose hydraulic lift completion is installed. Hydraulic Lift surface equipment was installed according to the technical requirements of the downhole hydraulic pump. During the well natural flowback period of time, pressures and rates data was collected in order to estimate the well current IPR (inflow performance relationship) and also to estimate rate/pressure declining vs time. With this data on hand, it was possible to make an analysis and predict the jet pump performance and its required surface power requirements.

Once both completion and surface facilities were completed and ready to start the first ALS production stage, the jet pump was deployed and high rate production stage began. As it was previously mentioned, the average production of these wells at the very beginning of jet pump operation is around 2,500 bpd (397 m^3/d) with FBHP (flowing bottomhole pressure) of 2,400 psi (16.5 x 10^6 Pa). The jet pump continuously operated for approximately 3 to 6 months before the production rate declined to 300 bpd (48 m3/d) and FBHP at pump intake below 500 psi (3.45 x 10^6 Pa). When this barrier of low production rate/intake pressure was achieved, the jet pump production strategy demonstrated to be considerably un-economical, because generated profits from net production of oil was considerably reduced, based on the input power that the jet pump required.

It was at this moment where is decided to reverse the jet pump to the surface (by hydraulic circulation) and installed the hydraulic piston pump. These 2.5-in (63.5-mm) Piston pumps can effectively produce rates that range between 20 bpd (3.2 m^3/d) all the way up to 350 bpd (56 m^3/d). For this type of completion, the produced free gas is handled by the pump, the jet or piston, so both pump performances will be affected by the gas rate. This last topic is of extreme importance at the moment of deciding the deployment of these dual purpose hydraulic lift completion.

RESULTS

At the time that several operators have had equipped these dual-purpose hydraulic lift completions in 10 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 implementing the dual purpose hydraulic lift completion, the operator could carry on with the high rate production stage and later switch to piston pump 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 hydraulic piston in one tubing string trip, reduced the first year OPEX by approximately 50%.
3. Production downtime caused for the completion change from ESP or gas lift to RRP (reciprocating rod lift) was reduced in approximately 80% as an average of all ten wells.
4. Jet Pumps resulted to be way 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 6).

CONCLUSIONS

1. A slight modification to the traditional well completion, by adding a BHA to it, transforms this tubing string in a dual purpose hydraulic lift completion that allows the well owner to install either a jet pump or a piston 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 easily eroded by frac sand produced along formation fluids.

3. With the deployment of the dual-purpose hydraulic lift completion, the operator saved the entire cost of a work-over operation. The amount of this saving was enough to reduce time for ROI (return of investment) by approximately 50%.

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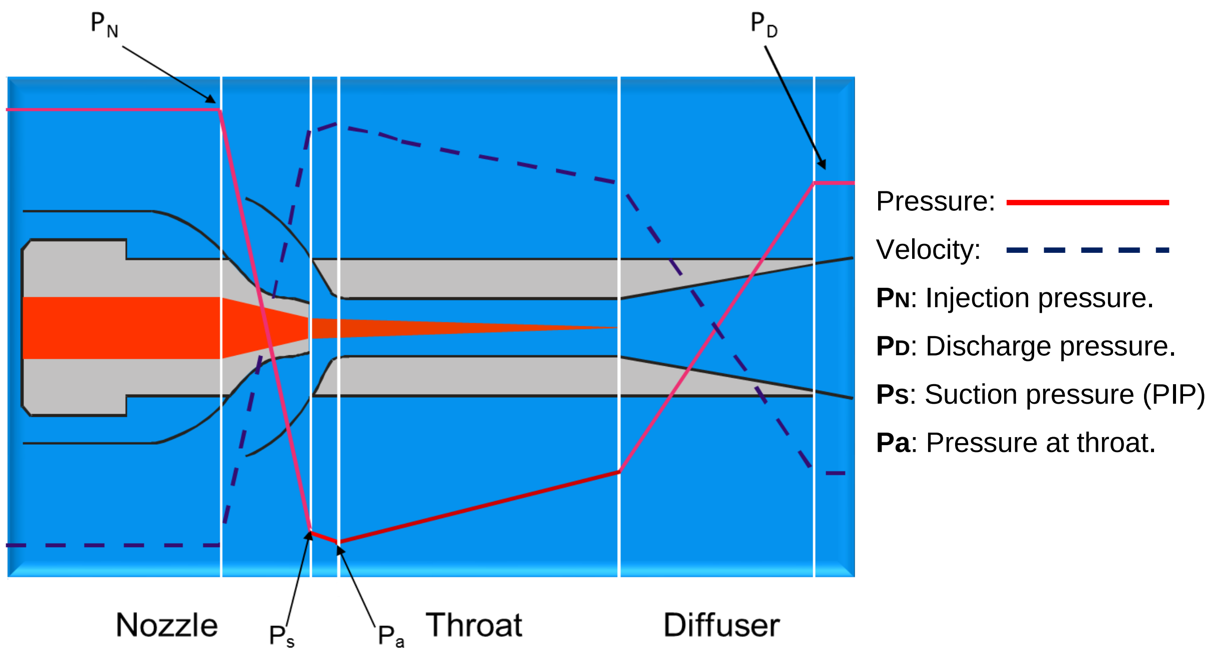

Figure 1 - Schematic of Flow Velocity and Static Pressure in a Jet Pump

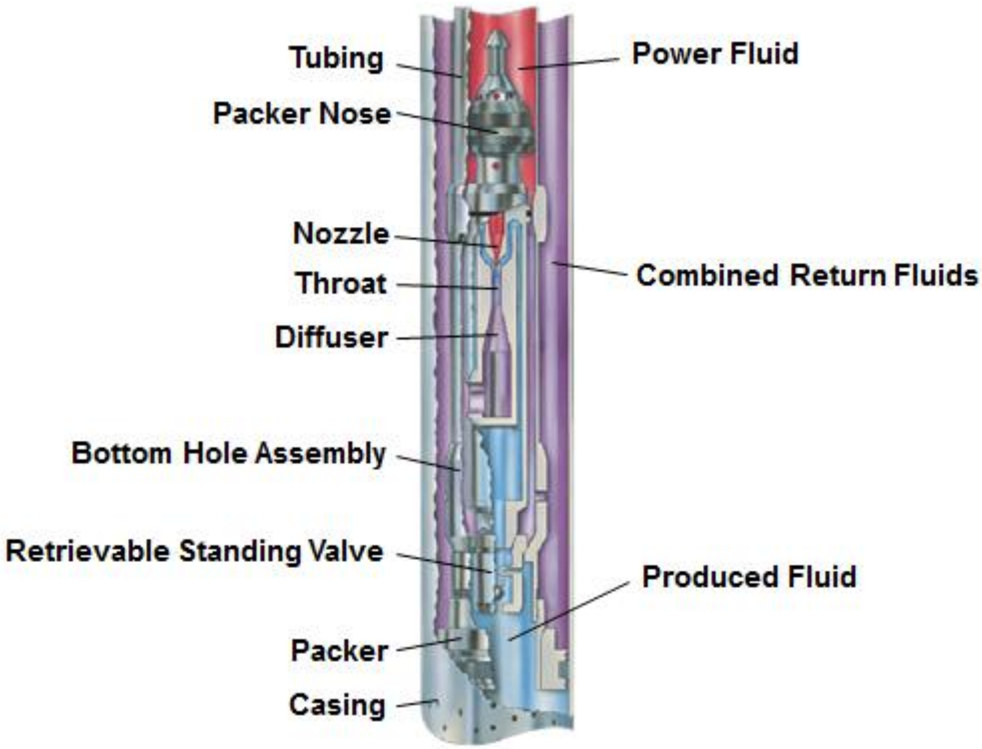

Figure 2 - Schematic of a Standard Flow in a Jet Pump (hydraulically retrievable)

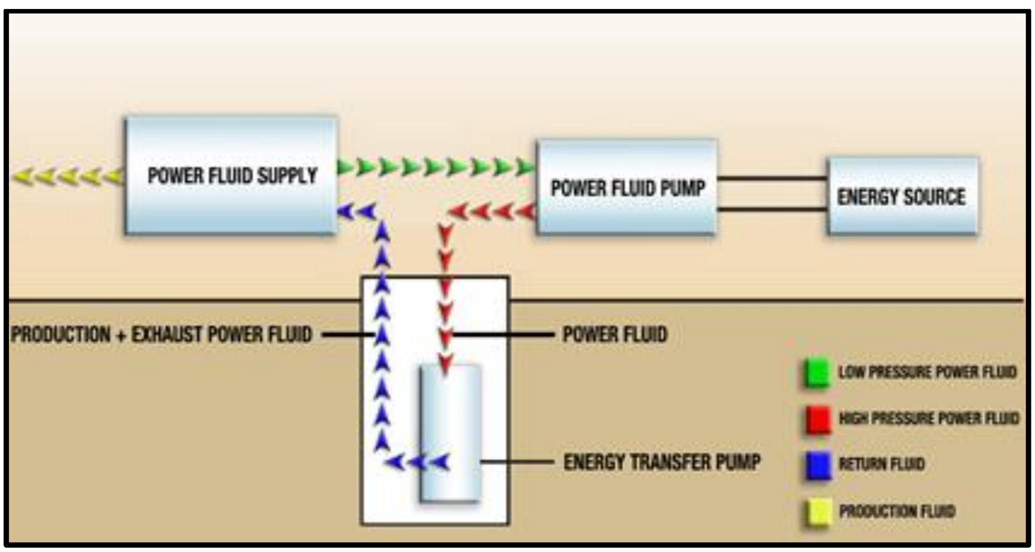

Figure 3 – Surface Power/Produced Fluids Flow Schematic for a Typical Hydraulic System

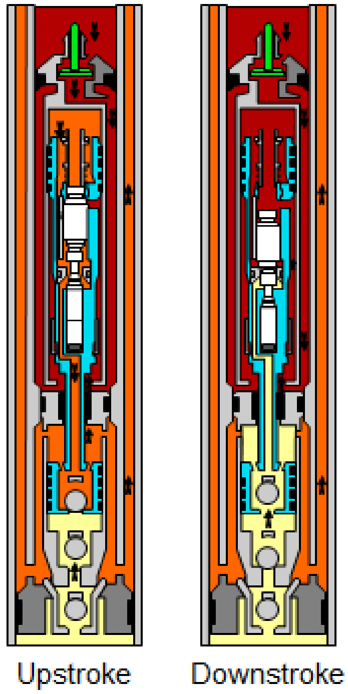

Figure 4 - Schematic of a Hydraulic Piston Pump (hydraulically retrievable)

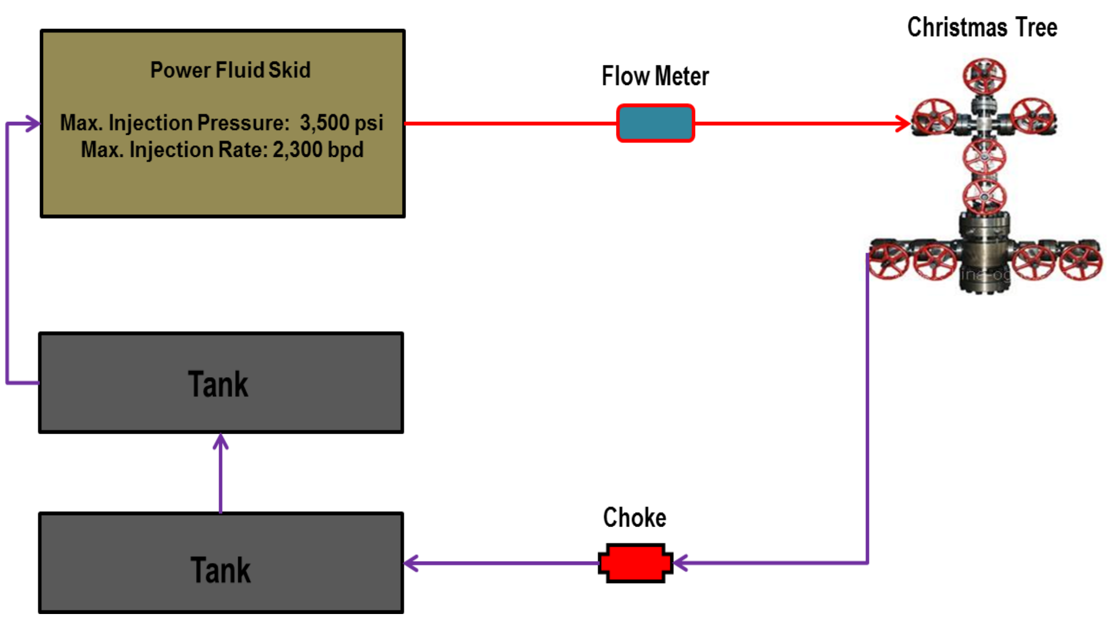

Figure 4 – Surface Equipment Installation Schematic

Figure 5 – Jet Pump BHA (bottom), Standing Valve (middle-left) and Jet Pump (middle-right)

Table 1 – Switch-over of system comparison table

	Operation Description	ESP	RRL	JP-HPP
Installation of the high rate 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 high rate completion - Installation of long term completion system (low rate)	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 Completion [hours]	10	10	0
	Surface work [hours]	3	3	3
	Total workover time [hours]**	**36**	**40**	**15**
	Total ALS switch-over [hours]***	**69**	**75**	**37**

* Hydraulic Circulation (pump circulated out).

**Based on a 10,000 ft well.

***Average time to install/ uninstall unloading system, and to install Gas Lift System.

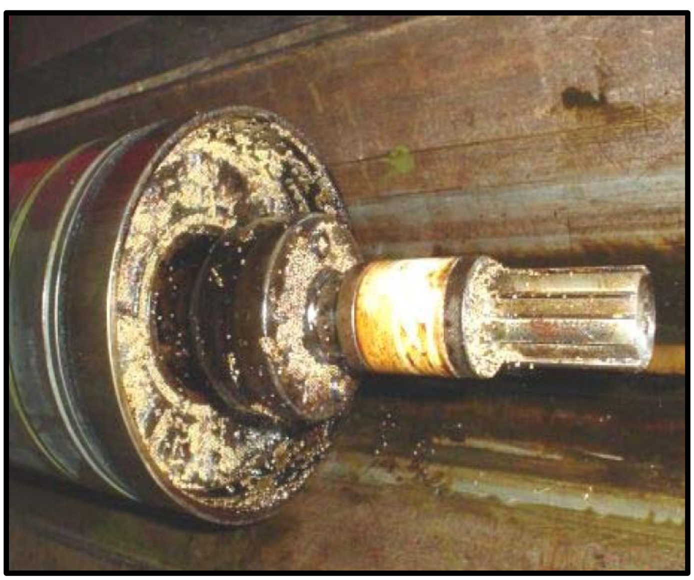

Figure 6 – Pulled ESP. It failed because of frac sand (proppant) accumulation