LONG TERM JET LIFT

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BACKGROUND

Jet lift is often seen as a short-term solution or last case lift option by many users. In a horizontal well, where decline rates are high and production mix varies throughout the life of the well, a downhole jet pump has many benefits as a long-term lift option. This paper aims to showcase these benefits by looking at two examples: one from the Delaware Basin with a depth of 10,400' and another from the Northern Denver-Julesburg (DJ) Basin with a depth of 7000'. Both wells have 5.5" casing to depth with 2.875" tubing and 2.375" tubing respectively.

Please note that throughout this paper jet lift will refer to the artificial lift system while jet pump will refer to the downhole component only.

Both wells examined in this paper are horizontal shale wells with high decline rates. The Delaware Basin well also has a high concentration of H_2S and some solids debris that makes other forms of lift more challenging to produce. To counter these decline rates and corrosion, these operators chose a standard flow jet lift system, which allows for hydraulic retrieval of the downhole jet pump to make design changes and repairs onsite. Please see Figure 1 for the downhole completion of a standard flow jet pump. Also, different software versions of the jet pump modeling software result in performance graphs with different color pallets. This does not affect the calculations performed.

SOLUTION

As these wells declined over time, optimization of the jet lift system was preformed and monitored. For a jet lift system there are two main changes that occur during optimization: injection pressure / rate and nozzle / throat combination changes.

The downhole jet pump houses a tungsten carbide nozzle and throat under the upper seal of the jet pump. This combination creates the localized pressure drop that draws in the reservoir fluid. Figure 2 shows the general pressure and velocity changes that occur in the nozzle / throat area of the jet pump, which is taking advantage of the Venturi Effect to create the required drawdown. As the area ratio of the nozzle to throat changes, the effective drawdown changes. As a well declines, the produced stream changes properties, or as solids erode components, the nozzle and throat can be hydraulically retrieved and changed onsite to accommodate for the changing downhole conditions by reverse circulation.

Increasing or decreasing the injection rate / pressure is another way to control the drawdown of a jet pump. Power fluid, either produced water or oil, is injected down the tubing to the jet pump nozzle by using a high-pressure high-rate pump, either a positive displacement plunger pump or horizontal surface pump. If more injection rate and pressure is delivered to the nozzle, the pressure drop becomes larger. Often a jet lift installation will start at a lower injection pressure than it's designed for to accommodate for flush production from well downtime. Then slowly the injection pressure is increased to the design pressure for long term operation. As the well declines, this injection pressure can be increased to compensate for declining flowing bottom hole pressure until a new combination is needed.

RESULTS

As mentioned earlier, the Delaware Basin operator installed a jet lift system to counter high decline rates and corrosion in their well. Initially installed in April of 2020, the target production rate of 1500 BPD was achieved using a jet lift system. Figure 3 shows the initial production, injection pressure, injection rate, hydraulic horsepower, and pump intake pressure.

By November of 2020 the production had fallen to 1400 BPD, and a jet lift optimization design was requested. It was determined that no combination change was needed, but injection pressure increased from 3700psi to 3900psi to keep up with expected decline (Figure 4).

Two years later in September 2022 another jet lift optimization design was requested, and the combination was changed, decreasing required injection pressure, injection rate, and horsepower (Figures 5 and 6).

Although the optimization report shown keeps the production rate the same, the operator can choose to increase injection pressure to make ~450 BPD with a pump intake pressure of ~820psi.This is shown in the graph of Figure 6 represented by the 4200psi injection pressure outflow curve crossing the well inflow performance relationship (IPR).

This well has continued to produce with the same combination since September 2022 as the decline rate has stabilized. No workover rig has been needed since initial installation and all optimization has been done onsite or remotely. Stainless steel downhole tools were run to withstand corrosion over carbon steel components and nozzle / throat material are standard tungsten carbide to withstand solids production. Please see Table 1 for more details.

The Northern DJ Basin operator Installed a jet lift system to counter similar decline rates starting in June of 2017 producing 2000 BPD (Figure 7). The jet lift system ran continuously for 10 months with the original nozzle / throat combination, only increasing injection pressure to maintain expected decline.

After 10 months of production, the well had declined to 834 BPD (Figure 8) in April 2018 and the nozzle / throat combination needed to be changed to avoid cavitation. After another combination change in October of 2018, the well was producing 450 BPD (Figure 9) and the decision was made to convert the well to a rod lift system.

Over a 405-day period the rod pump had eight downhole failures and workovers ranging from gas locking to rod load related failures totaling 43 days of downtime and lost production. In February 2020, one year and four months later, the well was converted back to jet lift and started producing an average of 390 BPD (Figure 10).

A jet lift optimization was performed in March 2020 to increase the average production rate to 550 BPD (Figure 11). The last production test on file for this well was in August 2022 at 173 BPD. This well has been producing on jet lift for a total of 4.5 years and has had only one workover during the jet lift operation due to a hole in tubing. Please see Table 2 for more details.

Figures 12-15 chart the production and pump intake pressure over time for each well.

CONCLUSION

Jet lift is believed to be a short term or last form of lift when others cannot perform. This paper proves jet lift can perform throughout the life of a well, meet production targets, and keep costly workover operations away in challenging environments. This author is aware of the inherent inefficiencies in a jet lift system but believes that jet lift is a viable option for many operators experiencing workovers due to deviation, gas handling, solids handling, or corrosive environments.

SOURCES

- Figures 1-2; 12-15, ChampionX
- Figures 3-11, SNAP and ChampionX
- Tables 1-2, ChampionX

TABLES

Table 1 – First jet lift system results

Delaware Basin Well							
Date	Production (BPD)	GOR (SCF/BOPD)	Injection Pressure (psi)	Injection Rate (BPD)	PIP (psi)	Hydraulic Horsepower	N/T Combination
Apr-20	1513	1147	3716	3175	3000	217	.213"/.35"
Nov-20	1421	1528	3928	3352	2548	240	.213"/.35"
Sep-22	390	1295	3858	3533	1798	234	.213"/.35"
Oct-22	390	1295	2176	2948	1792	165	.199"/.293"

Table 2 – Jet lift system results

Northern DJ Basin Well							
Date	Production (BPD)	GOR (SCF/BOPD)	Injection Pressure (psi)	Injection Rate (BPD)	PIP (psi)	Hydraulic Horsepower	N/T Combination
Jun-17	1997	376	2657	2207	2485	127	.199"/.350"
Apr-18	834	600	3617	2274	840	148	.175"/.292"
Oct-18	450	927	3568	2058	520	127	.164"/.280"
Feb-20	392	931	3442	2043	602	121	.164"/.293"
Mar-20	550	1326	3779	2110	549	140	.164"/.293"

FIGURES

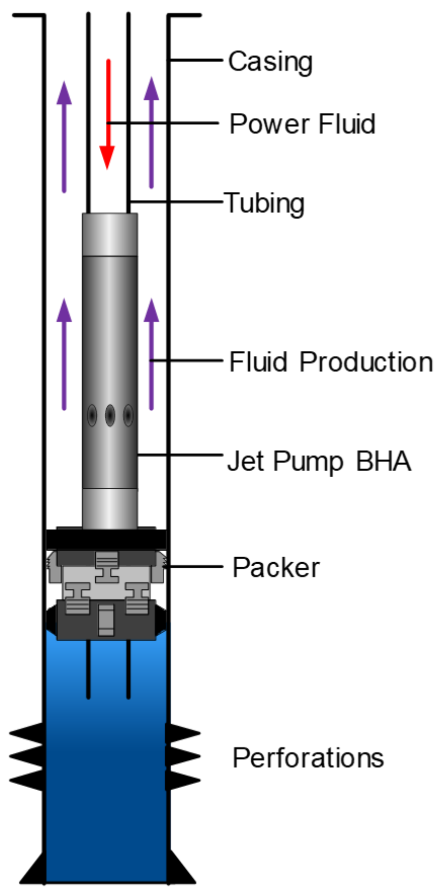

Figure 1 - Downhole completion of a standard flow jet pump

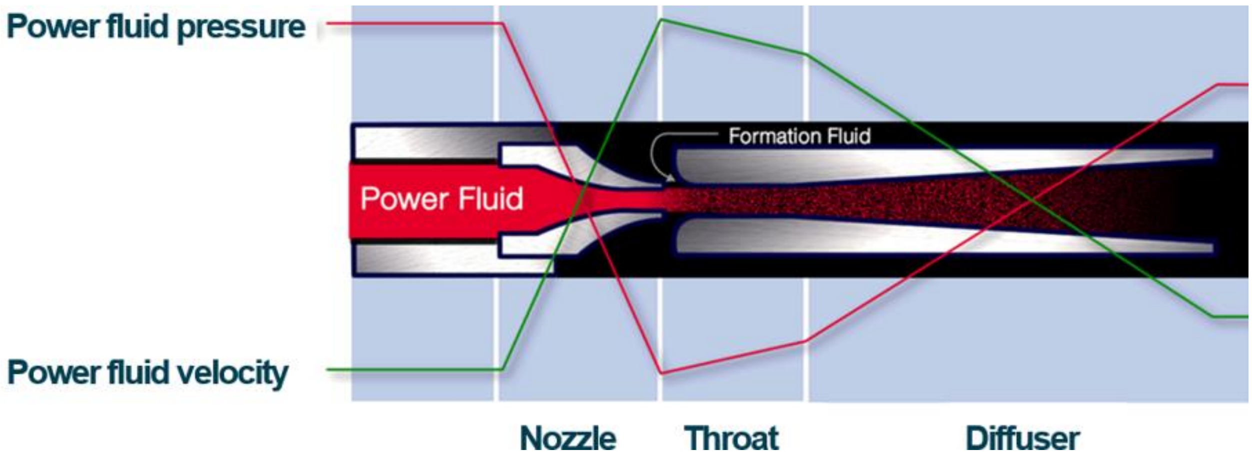

Figure 2 - Venturi Effect

```
Custom Nozzle (0.213) and Throat (0.350) diameters Pump Performance Summary
    Target Production Rate : 1513 BLPD @pump intake pressure : 3000 psia
    Predicted Surface Power Fluid Injection Pressure =   3716 psia
    Predicted Surface Power Fluid Injection Rate     =   3175 bpf/d
    Predicted Pump Intake Pressure                   =   3000 psi
    Predicted Pump Discharge Pressure                =   4917 psia
    Predicted Power Fluid Pressure at Pump depth     =   8142 psia
    Predicted Horsepower requirement                 =    217 HP
=====================================================================================
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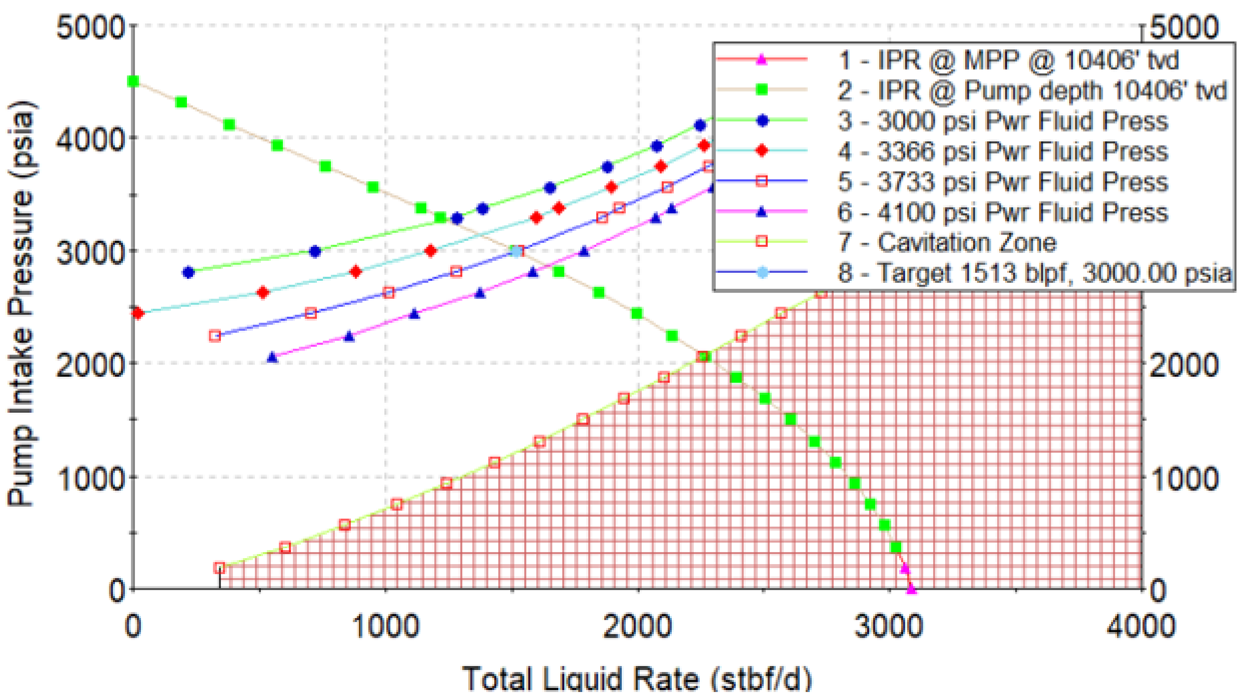

Figure 3 – April 2020 jet lift results

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Custom Nozzle (0.213) and Throat (0.350) diameters Pump Performance Summary
    Target Production Rate : 1421 blpd @pump intake pressure : 2548 psia
    Predicted Surface Power Fluid Injection Pressure =   3928 psia
    Predicted Surface Power Fluid Injection Rate     =   3352 blpd
    Predicted Pump Intake Pressure                   =   2549 psia
    Predicted Pump Discharge Pressure                =   4788 psia
    Predicted Power Fluid Pressure at Pump depth     =   8316 psia
    Predicted Horsepower requirement                 =    240 HP
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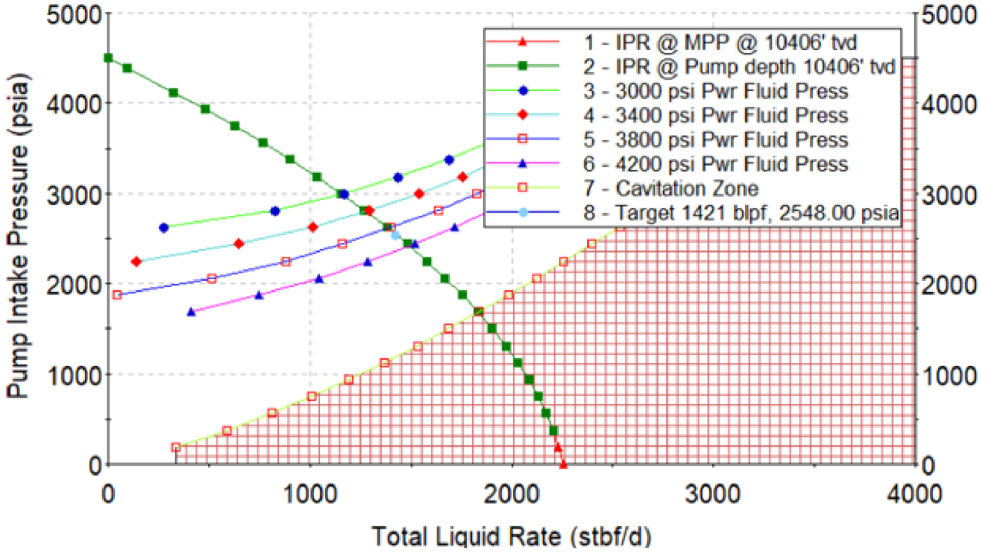

Figure 4 - November 2020 jet lift results

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Custom Nozzle (0.213) and Throat (0.350) diameters Pump Performance Summary
    Target Production Rate : 390 blpd @pump intake pressure : 1798 psia
    Predicted Surface Power Fluid Injection Pressure =   3858 psia
    Predicted Surface Power Fluid Injection Rate     =   3533 blpd
    Predicted Pump Intake Pressure                   =   1798 psia
    Predicted Pump Discharge Pressure                =   3521 psia
    Predicted Power Fluid Pressure at Pump depth     =   8204 psia
    Predicted Horsepower requirement                 =    234 HP
```

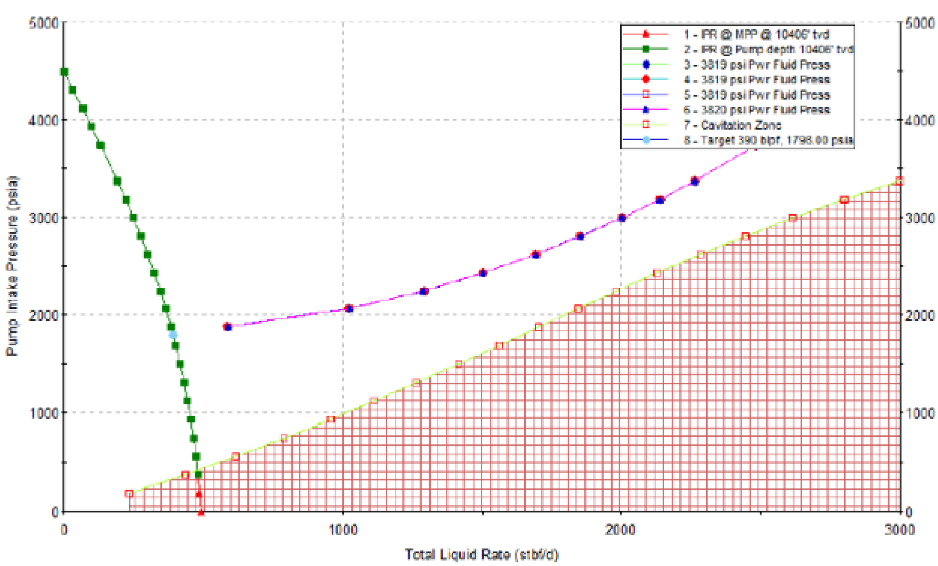

Figure 5 - September 2022 jet lift results

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Custom Nozzle (0.199) and Throat (0.293) diameters Pump Performance Summary
    Target Production Rate : 390 blpd @pump intake pressure : 1798 psia
    Predicted Surface Power Fluid Injection Pressure =    3176 psia
    Predicted Surface Power Fluid Injection Rate     =    2948 blpd
    Predicted Pump Intake Pressure                   =    1792 psia
    Predicted Pump Discharge Pressure                =    4784 psia
    Predicted Power Fluid Pressure at Pump depth     =    7644 psia
    Predicted Horsepower requirement                 =     165 HP
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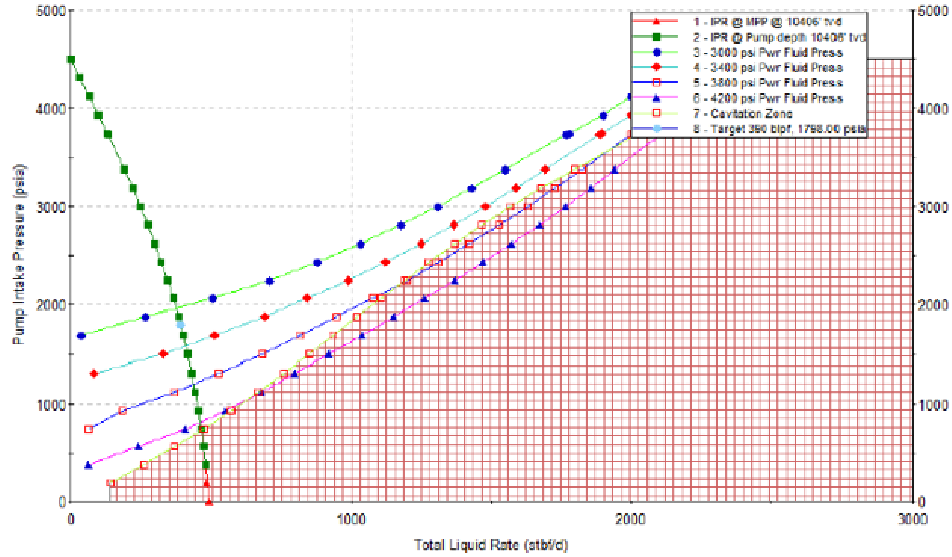

Figure 6 - September 2022 jet lift results

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Custom Nozzle (0.199) and Throat (0.350) diameters Pump Performance Summary
    Target Production Rate : 1997 BLPD @pump intake pressure : 2485 psia
    Predicted Surface Power Fluid Injection Pressure =    2657 psia
    Predicted Surface Power Fluid Injection Rate     =    2207 bpf/d
    Predicted Pump Intake Pressure                   =    2480 psi
    Predicted Pump Discharge Pressure                =    3301 psia
    Predicted Power Fluid Pressure at Pump depth     =    5577 psia
    Predicted Horsepower requirement                 =     127 HP
==============================================================================
```

Helis - Hodges 6CH | Helis - Hodges 3-33-28-6CH - New well 200hp 2 plungerPump Design
Diameters : NozzleID 0.199 ThroatID 0.350 | 05-Jan-18 16:22:20
Pump Depth = 7000

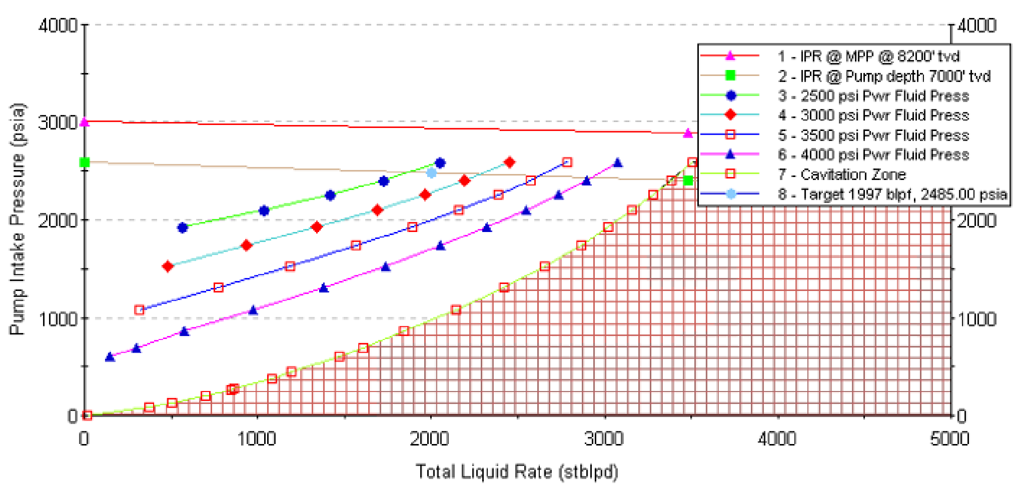

Figure 7 – June 2017 jet lift system results

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Custom Nozzle (0.175) and Throat (0.292) diameters Pump Performance Summary
    Target Production Rate : 834 BLPD @pump intake pressure : 840 psia
    Predicted Surface Power Fluid Injection Pressure =   3617 psia
    Predicted Surface Power Fluid Injection Rate     =   2274 bpf/d
    Predicted Pump Intake Pressure                   =    840 psi
    Predicted Pump Discharge Pressure                =   3055 psia
    Predicted Power Fluid Pressure at Pump depth     =   6340 psia
    Predicted Horsepower requirement                 =    148 HP
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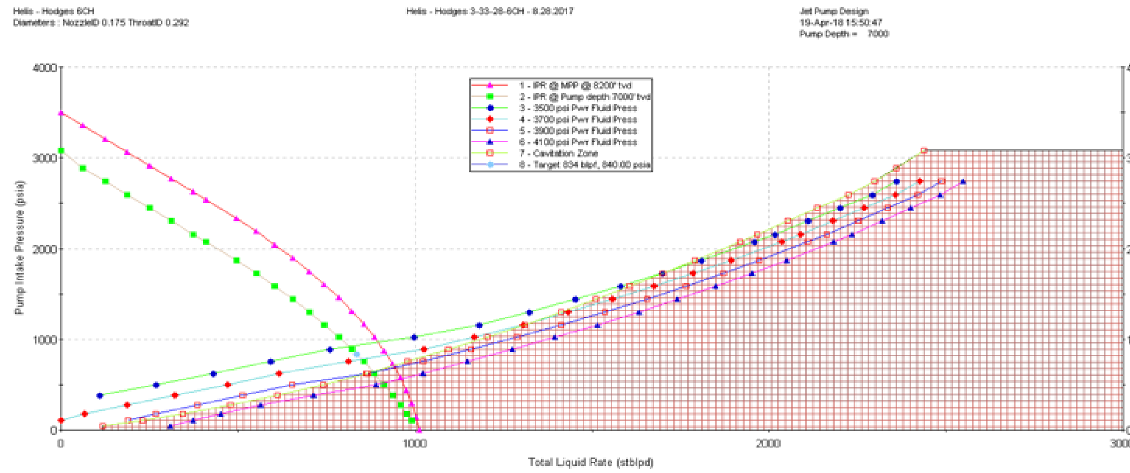

Figure 8 – April 2018 jet lift system results

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Custom Nozzle (0.164) and Throat (0.280) diameters Pump Performance Summary
    Target Production Rate : 450 blpd @pump intake pressure : 520 psia
    Predicted Surface Power Fluid Injection Pressure =   3568 psia
    Predicted Surface Power Fluid Injection Rate     =   2058 blpd
    Predicted Pump Intake Pressure                   =    504 psia
    Predicted Pump Discharge Pressure                =   2973 psia
    Predicted Power Fluid Pressure at Pump depth     =   6346 psia
    Predicted Horsepower requirement                 =    127 HP
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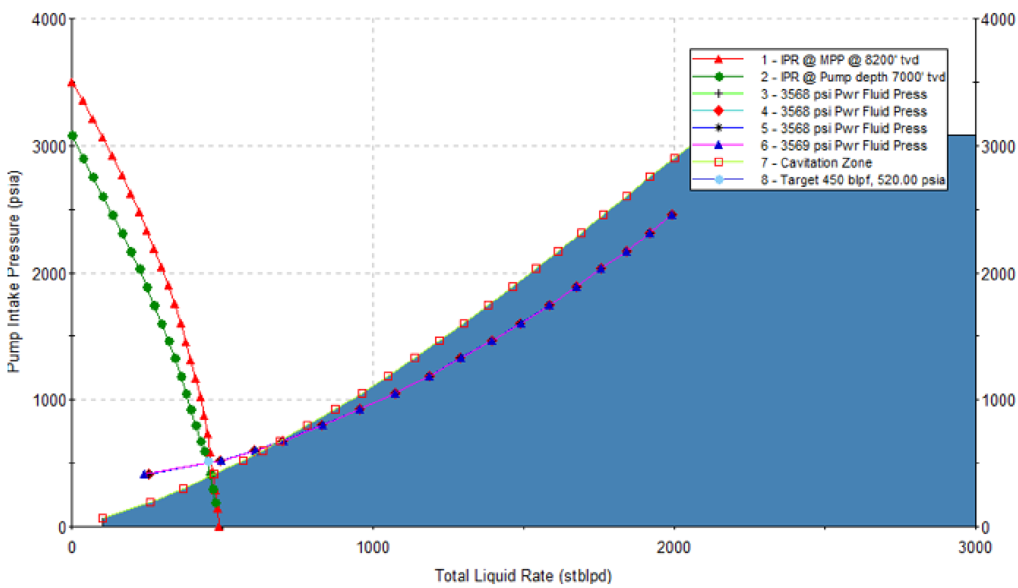

Figure 9 – October 2018 jet lift system results

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Custom Nozzle (0.164) and Throat (0.293) diameters Pump Performance Summary
     Target Production Rate : 392 BLPD @pump intake pressure : 602 psia
     Predicted Surface Power Fluid Injection Pressure =   3442 psia
     Predicted Surface Power Fluid Injection Rate     =   2043 bpf/d
     Predicted Pump Intake Pressure                   =    599 psi
     Predicted Pump Discharge Pressure                =   2929 psia
     Predicted Power Fluid Pressure at Pump depth     =   6376 psia
     Predicted Horsepower requirement                 =    121 HP
=====================================================================================
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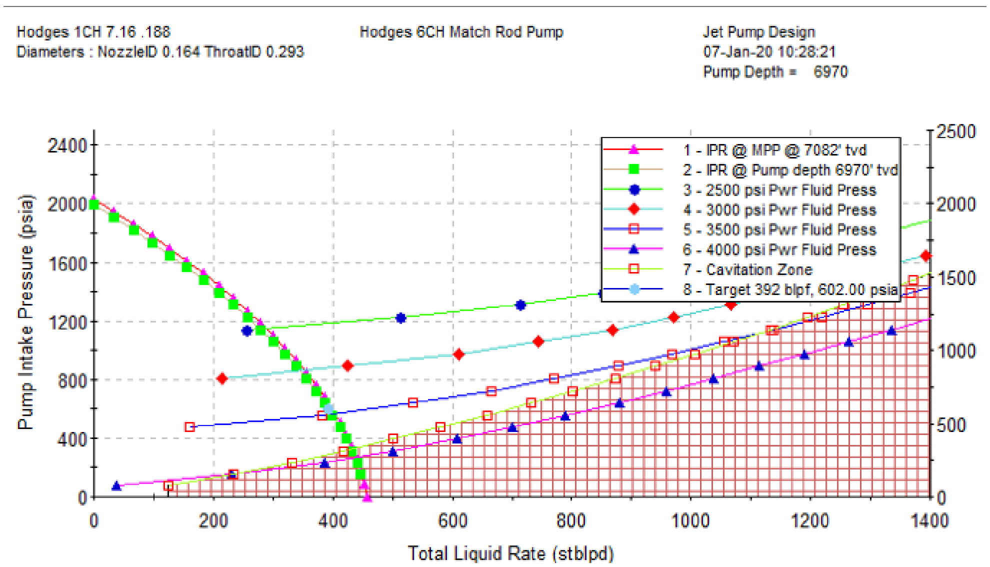

Figure 10 – February 2020 jet lift system results

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Custom Nozzle (0.164) and Throat (0.293) diameters Pump Performance Summary
     Target Production Rate : 550 BLPD @pump intake pressure : 549 psia
     Predicted Surface Power Fluid Injection Pressure =   3779 psia
     Predicted Surface Power Fluid Injection Rate     =   2110 bpf/d
     Predicted Pump Intake Pressure                   =    540 psi
     Predicted Pump Discharge Pressure                =   2898 psia
     Predicted Power Fluid Pressure at Pump depth     =   6709 psia
     Predicted Horsepower requirement                 =    140 HP
=====================================================================================
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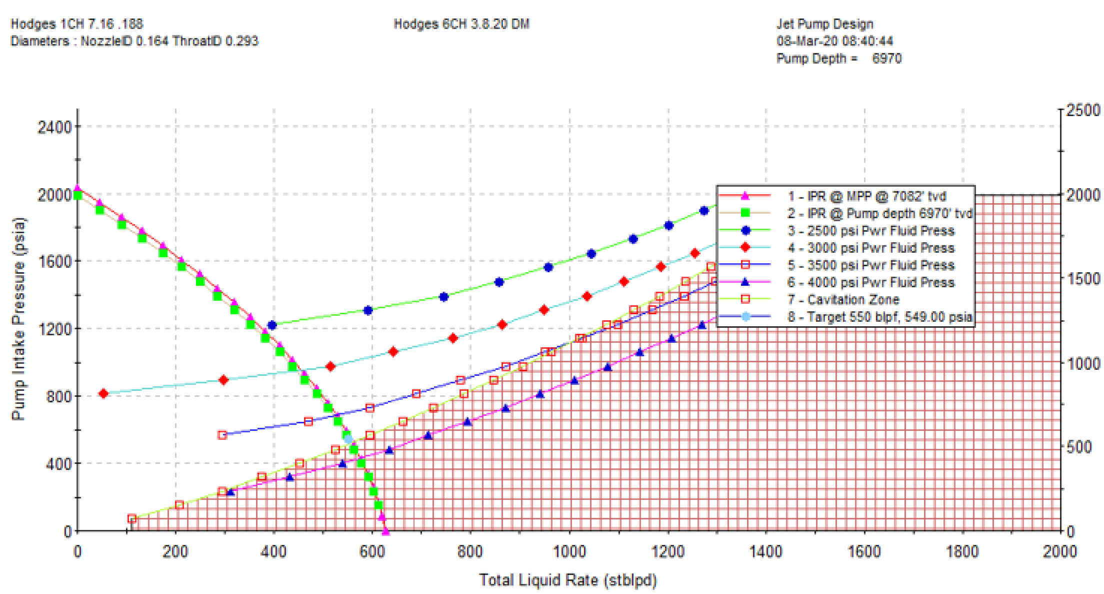

Figure 11 – March 2020 jet lift system results

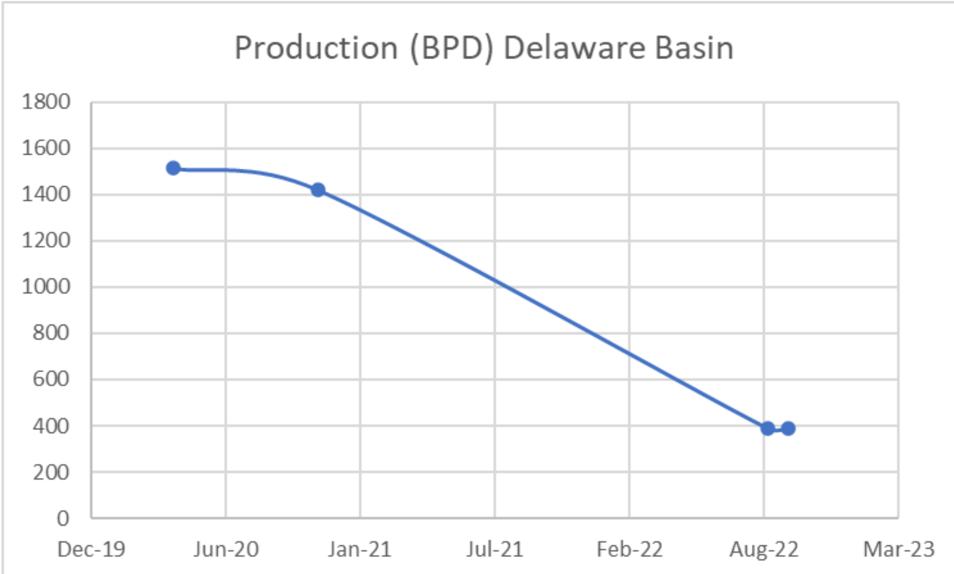

Figure 12 – Jet lift system production of Delaware Basin well

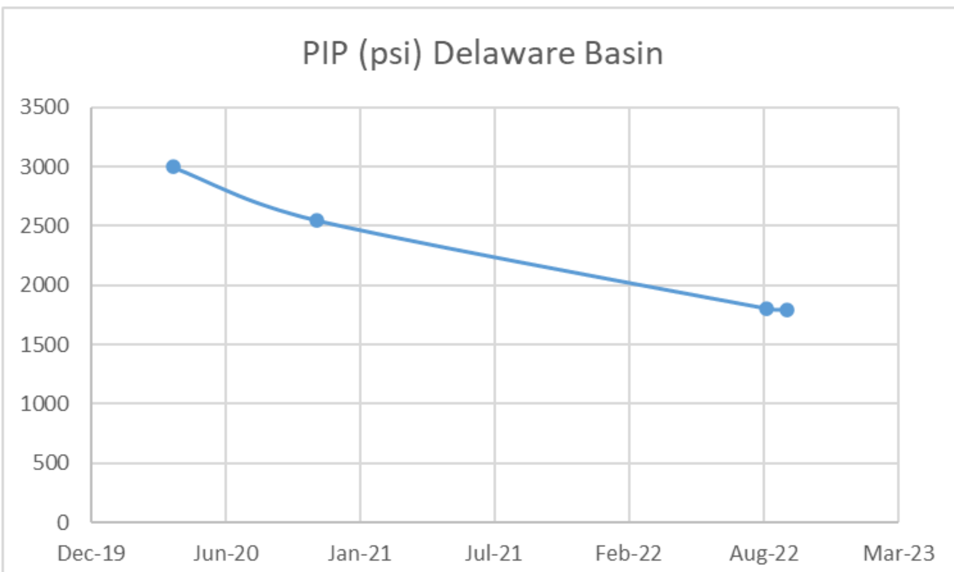

Figure 13 – Jet lift system pump intake pressure of Delaware Basin well

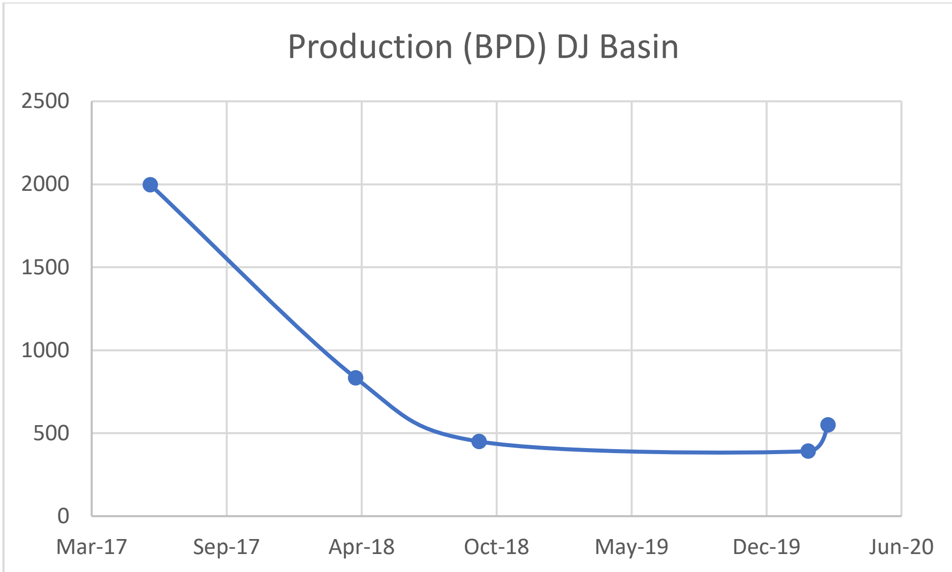

Figure 14 – Jet lift system production of DJ Basin well

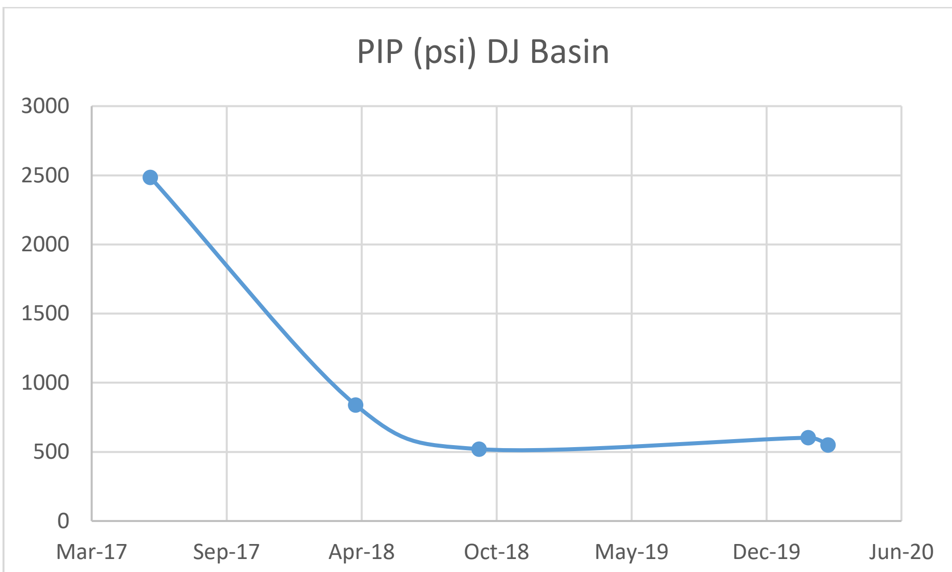

Figure 15 – Jet lift system pump intake pressure of DJ Basin well