



Integrated Petroleum Technologies, Inc.



02618392

April 14, 2015

Mr. Stuart Ellsworth  
Engineering Manager  
Colorado Oil & Gas Conservation Commission  
1120 Lincoln Street, Suite 801  
Denver, Colorado 80202

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Re: Injection Pressure Request – DJINJ Injection Well  
NGL C6A (API# 05-123-40968)  
NGL Water Solutions DJ LLC  
SHL: 894 FSL x 2440 FEL / SWSE-30-T3N-R65W  
Weld County, Colorado

Dear Stuart,

NGL Water Solutions DJ LLC, operator of the subject well, requests an injection pressure assignment of **2,250 psig** and a maximum daily injection rate of **19,440 bwpd** for the subject well based on the results of the step rate test. A mechanical integrity test was conducted to 2,500 psig.

The Step Rate Test ("SRT") and Pressure Fall-Off Test ("PFOT") report is attached and the data indicates a fracture gradient of 0.61 psi/ft. The table below shows the estimated operating conditions for the well as completed with 4-1/2" coated injection tubing.

Rate (bpm)	Rate (bpd)	BH Pressure (psig)	BH Pressure Gradient (psi/ft)	Calculated Pipe Friction <sup>1</sup> (psi)	Est. Surface Injection Pressure (psig)
2.4	3,456	4,570	0.51	18	691
5.0	7,200	4,843	0.54	101	1,046
7.5	10,814	5,103	0.57	211	1,416
10.0	14,400	5,259	0.58	367	1,728
12.4	17,856	5,434	0.60	504	2,041
13.5	19,440	5,500	0.61	647	2,250
15.1	21,744	5,531	0.61	752	2,386
21.0	30,240	5,704	0.63	1,467	3,274
29.8	42,912	5,824	0.65	2,751	4,678
39.9	57,456	5,971	0.66	4,585	6,659

<sup>1</sup> Calculated pipe friction for normal operations based on 4-1/2" IPC set at 9,170' MD.



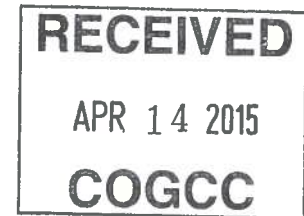
The top of the Lyons formation is at 9,294' MD (9,001' TVD) and the injection packer is set at 9,170' MD, 54' above the liner top.

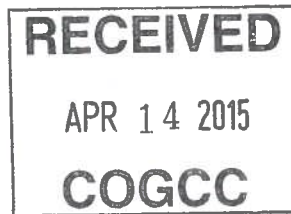
Please contact me at +1 303 947-9402 if you have any questions.

Kind Regards,

Neel L. Duncan, PE  
Vice President, Operations

Attachment: *Step Rate Test and Pressure Falloff Test Analyses.*





## 1.0 Executive Summary

IPT analyzed and evaluated the step rate test (SRT) and pressure falloff test conducted on the completion from the Lyons formation to the Atoka formation in the NGL C6A well. This analysis was performed to determine the fracture propagation pressure and reservoir parameters of this interval. The results of the analysis are shown in Table 1 and Table 2.

The step rate test was conducted through perforations from 9,294'-9,320' MD (9,001'-9,027' TVD) and the slotted liner from 9,350'-10,963' MD (9,057'-10,669' TVD) and was performed by starting injection at 2.4 bpm and stepping up to a final rate of 39.9 bpm down 7" casing into the 4-1/2" slotted liner. The bottom-hole gauge was set at 9,223' MD (8,931' TVD) so gauge pressures were adjusted to the top of the Lyons. Tubing friction pressures were calculated at each injection rate to determine the maximum surface injection pressure based on the recorded bottom-hole pressure (Table 2).

The following are the general conclusions and observations of these evaluations:

- The step rate test indicates the fracture propagation for the injection formations occurred at ~5,500 psi (0.61 psi/ft) at a rate of 13.5 bpm (19,440 bpd). Accounting for tubing friction effects at 13.5 bpm in 4-1/2" IPC tubing, this bottom-hole pressure should be realized at a surface injection pressure of 2,240 psi (Table 2).
- The pressure falloff analysis suggests the injection interval has high reservoir permeability. Based upon the analysis of the late time pressure data trends, average reservoir permeability is estimated to be 6.9 md and reservoir pressure is calculated to be 4,121 psi (0.46 psi/ft pressure gradient). The character of the pressure falloff derivative suggests an undamaged completion with a skin factor of -6.0.
- Utilizing the injection rate calculation below and the parameters from Table 1 for the falloff test, the injection rate is calculated to be approximately 9.6 bpm at the fracture propagation pressure. This is significantly lower than that observed during the step rate test and is likely due pressure effects from the offsetting NGL C6 wellbore. Several of the same formations are completed in both wells, which could be affecting the pressure response during the falloff and resulting in a higher average reservoir pressure.

$$q = \frac{kh\Delta P}{141.2\beta\mu \left[ \ln\left(\frac{r_e}{r_w}\right) - \frac{3}{4} + s \right]} = \frac{2190 * (5496 - 4121)}{141.2 * 1 * 1 \left[ \ln\left(\frac{1320}{0.333}\right) - \frac{3}{4} - 6.0 \right]} = 13,893 \text{ bpd} = 9.6 \text{ bpm}$$



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**Table 1: Reservoir parameters.**

Reservoir Parameter	Pressure Falloff Test
Effective reservoir permeability (md)	6.9
Flow capacity (md-ft)	2,190
Net pay thickness (ft)	318
Skin factor (-)	-6.0
Reservoir pressure (psi)	4,121
Reservoir pressure gradient (psi/ft)	0.46

**Table 2: Injection rates and pressures.**

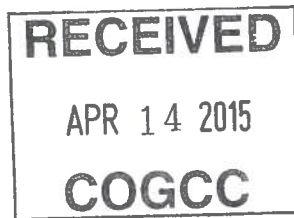
Rate (bpm)	Rate (bpd)	Surface Pressure <sup>1</sup> (psig)	BH Pressure (psig)	BH Pressure Gradient (psi/ft)	Calculated Pipe Friction <sup>2</sup> (psi)	Hydrostatic Pressure <sup>3</sup> (psig)	Est. Surface Injection Pressure (psig)
2.4	3,456	613	4,570	0.51	18	3,897	691
5.0	7,200	922	4,843	0.54	101	3,897	1,046
7.5	10,814	1,154	5,103	0.57	211	3,897	1,416
10.0	14,400	1,355	5,259	0.58	367	3,897	1,728
12.4	17,856	1,496	5,434	0.60	504	3,897	2,041
13.5	19,440	N/A	5,500	0.61	647	3,897	2,250
15.1	21,744	1,622	5,531	0.61	752	3,897	2,386
21.0	30,240	1,825	5,704	0.63	1,467	3,897	3,274
29.8	42,912	2,124	5,824	0.65	2,751	3,897	4,678
39.9	57,456	2,508	5,971	0.66	4,585	3,897	6,659

<sup>1</sup> Step rate test pumped down 7" casing.

<sup>2</sup> Calculated pipe friction for normal operations based on 4-1/2" IPC set at 9,170' MD.

<sup>3</sup> Fresh water used during the step rate test (8.33 ppg).

<sup>4</sup> Requested injection pressure based on estimated fracture gradient and calculated pipe friction. Rate not used during SRT.



## 2.0 Review of step rate test

The step rate test in the SWD C6A was performed on March 16, 2015. Rates of 2.4, 5.0, 7.5, 10.0, 12.4, 15.1, 21.0, 29.8, 39.9 bpm were utilized during the test. A total of 2,136 bbls of fresh water was pumped during the test.

The following figures are used in the analysis:

**Figure 1:** SRT time chart.

**Figure 2:** SRT rate chart.

Observations from the step rate test (SRT) evaluation are shown below:

- The change in the bottom-hole pressure trend with increasing rate (Figure 2) at ~13.5 bpm indicates that the fracture propagation pressure is approximately 5,500 psi. This corresponds to a fraction propagation gradient of 0.61 psi/ft based on the top of the Lyons formation.

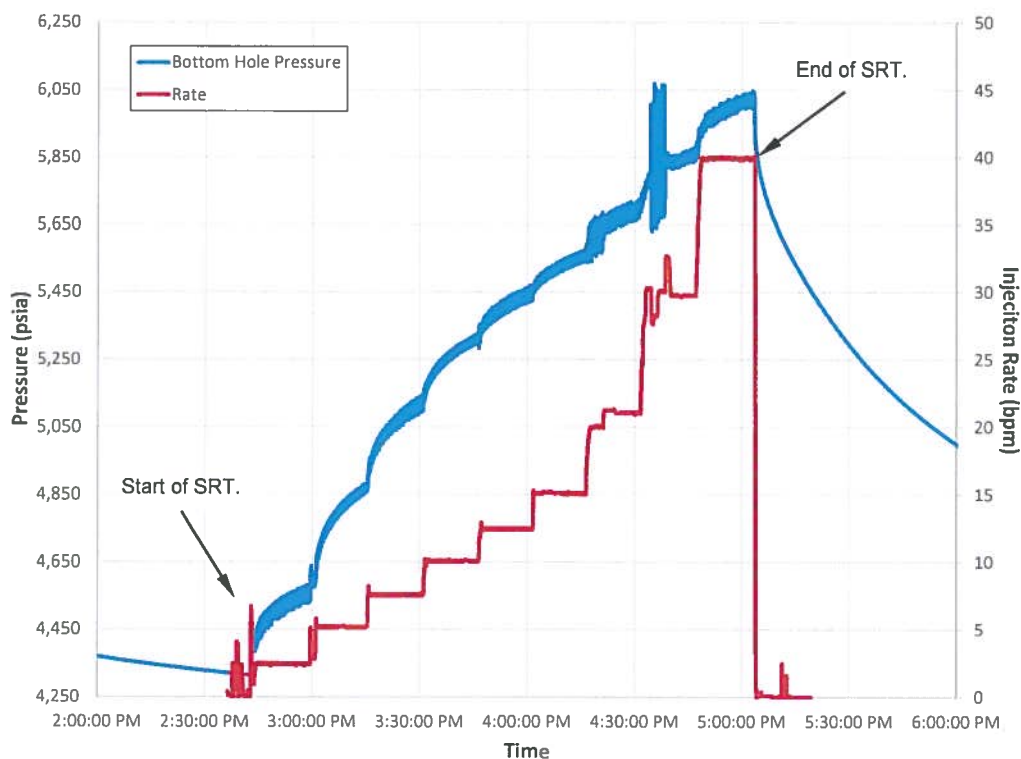


Figure 1: SRT time chart.

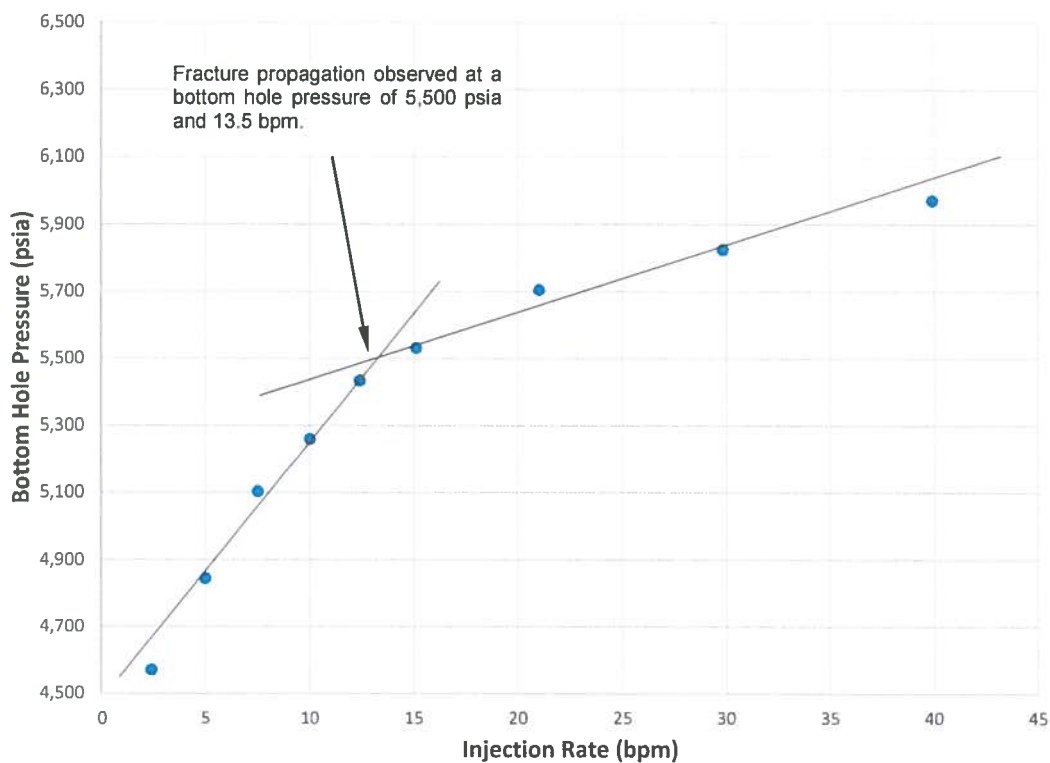
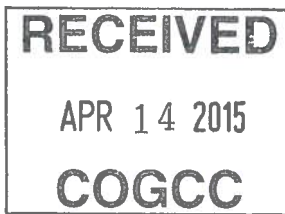


Figure 2: SRT rate chart.



### 3.0 Review of first pressure falloff test analysis

The NGL 6A was monitored for ~15 hours utilizing a bottom hole pressure gauge. A total of approximately 2,438 bbls of fluid was pumped prior to the shut-in on March 14, 2015. The pressure response was analyzed to determine the relevant reservoir characteristics. The reservoir pressure calculated from the pressure fall-off analysis (PTA) of the injection/falloff test are shown in Table 1.

The following figures are used in the analysis:

**Figure 3:** Cartesian plot of bottom hole pressure and temperature.

**Figure 4:** Diagnostic log-log plot.

**Figure 5:** Superposition plot.

**Figure 6:** Model match of pressure history.

Observations from the pressure fall-off (PTA) evaluation are shown below:

- The PTA log-log diagnostic plot (Figure 4) indicates several changes: 1.) Initial wellbore storage effects 2.) Appears to reach infinite acting radial flow.
- The type curve match of the late-time pressure trends (Figure 4) suggests a reservoir flow capacity of 2,190 md-ft. Based upon 318 feet of net pay, average reservoir permeability is calculated to be 6.9 md.
- The character of the pressure derivative (Figure 4) suggests an undamaged completion with a skin factor of -6.0.
- Based upon the late time pressure trends (Figure 4 and Figure 6), current reservoir pressure is approximately 4,121 psia (0.46 psi/ft).



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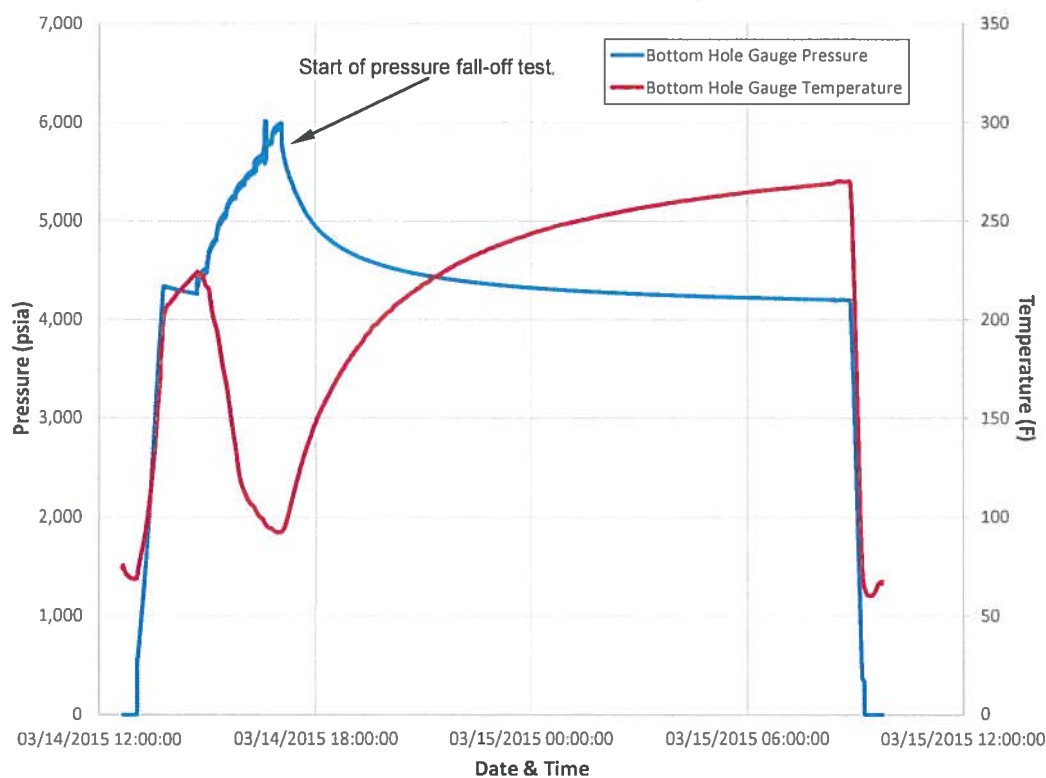


Figure 3: Cartesian plot of bottom hole pressure and temperature.

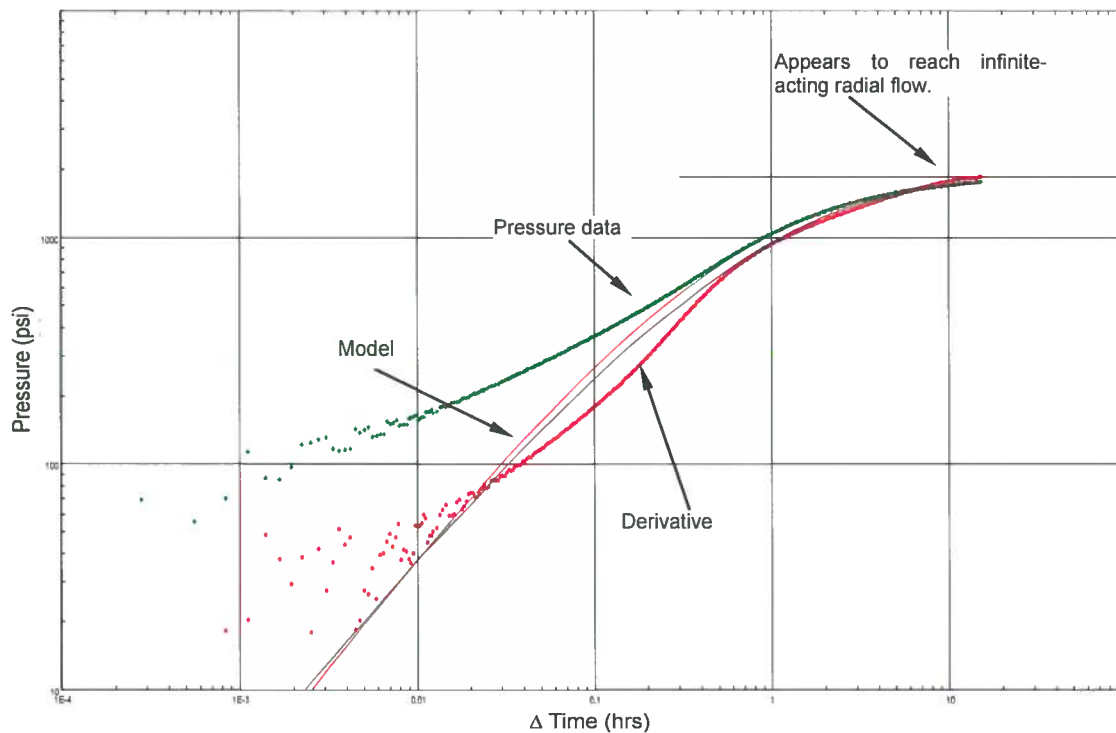


Figure 4: Diagnostic log-log plot.



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NGL Water Solutions DJ LLC  
NGL C6A - DJ Basin Combined Disposal Zone  
Step Rate Test and Pressure Falloff Test Analyses

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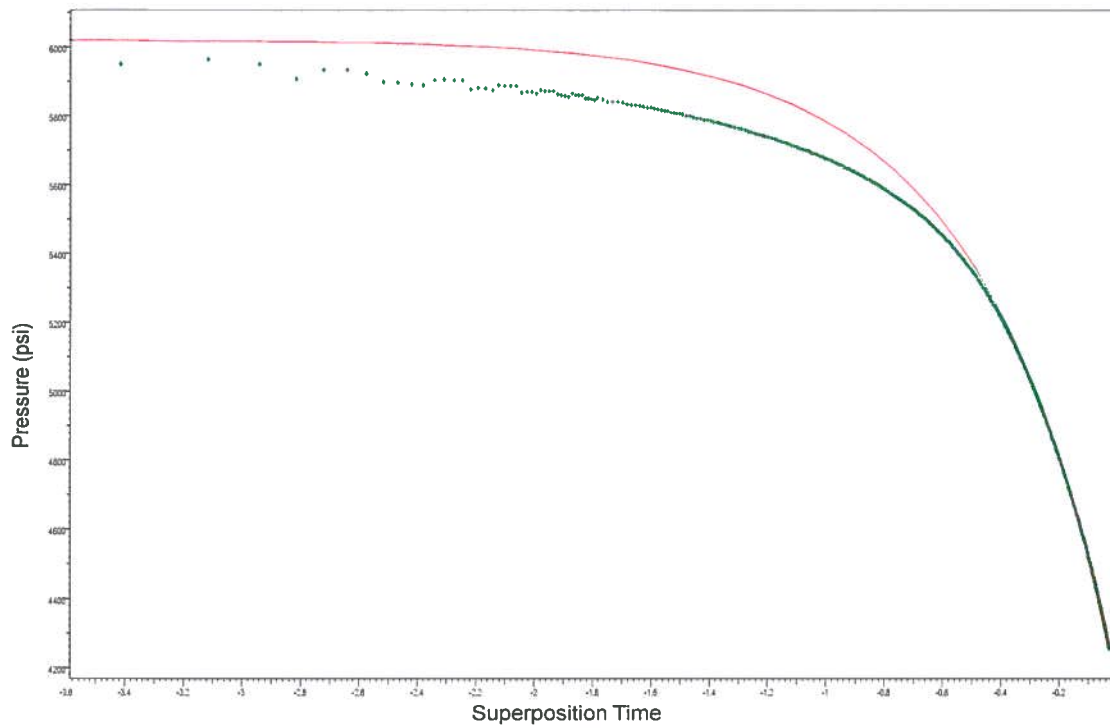


Figure 5: Superposition plot.

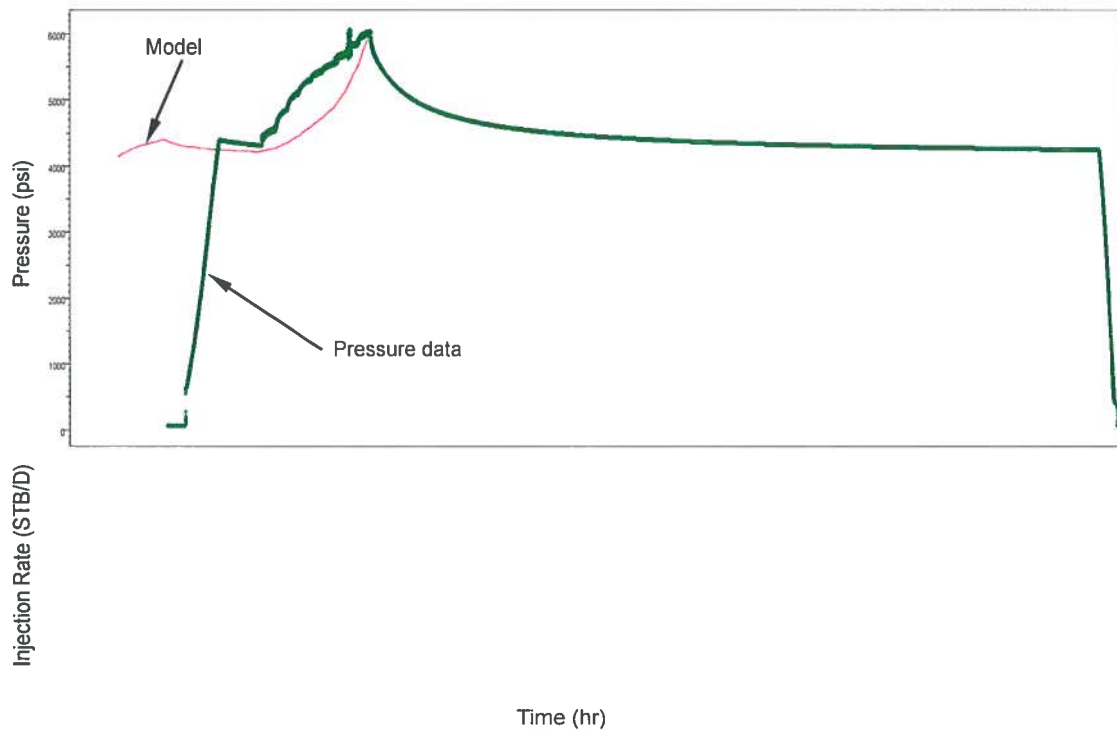


Figure 6: Model match of pressure history.