



November 17, 2015

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

Re: Injection Pressure Request – DJINJ Injection Well
NGL C5A (API# 05-123-40973)
NGL Water Solutions DJ LLC
SHL: 1974 FSL x 2431 FWL / NESW-29-T2N-R64W
Weld County, Colorado

Dear Stuart,

NGL Water Solutions DJ LLC, operator of the subject well, **requests an injection pressure assignment of 2,500 psig and a maximum daily injection rate of 40,320 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 0.53 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 ¹ (psi)	Est. Surface Injection Pressure (psig)
1.5	2,160	3,283	0.37	9	0
3.0	4,320	3,394	0.39	18	0
5.0	7,200	3,577	0.41	97	0
7.5	10,800	3,796	0.43	194	175
10.0	14,400	3,895	0.44	352	432
12.5	18,000	3,950	0.45	529	663
15.0	21,600	4,007	0.45	731	923
20.0	28,800	4,239	0.48	1,234	1,657
28.0	40,320	4,640	0.53	2,379	3,204
30.0	43,200	4,663	0.53	2,643	3,491
40.0	57,600	4,905	0.56	4,406	5,495

¹ Calculated pipe friction for normal operations based on 9,209 ft of 4-1/2” IPC.



The top of the Lyons formation is at 9,383 ft MD (8,811 ft TVD) and the injection packer is set at 9,189 ft MD, 15' above the liner top.

Please contact me at (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 of the Lyons through Atoka formations in the NGL C5A 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 slotted liner from 9,383 ft to 11,130 ft MD (8,811 ft to 10,558 ft TVD) and was performed by starting injection at 1.5 bpm and stepping up to a final rate of 40.0 bpm down the 7" casing into the 4-1/2" liner. The bottom-hole gauge was set at 9,215' MD (8,643 TVD) so gauge pressures were adjusted to the 9,383 ft MD (8,811 ft TVD), which is the top of the Lyons formation. 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 ~4,640 psi (0.53 psi/ft) at a rate of 28.0 bpm (40,320 bpd). Accounting for tubing friction effects at 28.0 bpm in 4-1/2" IPC tubing, this bottom-hole pressure should be realized at a surface injection pressure of 3,207 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 116 md and reservoir pressure is calculated to be 3,207 psi (0.36 psi/ft pressure gradient). The character of the pressure falloff derivative suggests an undamaged completion with a skin factor of -5.2
- Utilizing the injection rate calculation below and the parameters from Table 1 from the falloff test, the injection rate calculated from the bottom-hole pressure at 24.0 bpm agrees closely with the actual rate. A skin of 2.2 was utilized as it match the injection period more accurately and would be more representative of actual injection conditions.

$$q = \frac{kh\Delta P}{141.2\beta\mu \left[\ln\left(\frac{r_e}{r_w}\right) - \frac{3}{4} + s \right]} = \frac{20,880 * (4,640 - 3,207)}{141.2 * 1 * 1 \left[\ln\left(\frac{1320}{0.333}\right) - \frac{3}{4} - 2.2 \right]} = 39,720 \text{ bpd} = 27.6 \text{ bpm}$$



Table 1: Reservoir parameters.

Reservoir Parameter	Step Rate Test	Pressure Falloff Test
Fracture propagation pressure (psi)	4,640	N/A
Propagation pressure gradient (psi/ft)	0.53	N/A
Effective reservoir permeability (md)	N/A	116
Flow capacity (md-ft)	N/A	20,880
Net pay thickness (ft)	N/A	180
Skin factor (-)	N/A	-5.2
Reservoir pressure (psi)	N/A	3,207
Reservoir pressure gradient (psi/ft)	N/A	0.36

Table 2: Injection rates and pressures.

Rate (bpm)	Rate (bpd)	Surface Pressure ¹ (psig)	BH Pressure (psig)	BH Pressure Gradient (psi/ft)	Calculated Pipe Friction ² (psi)	Hydrostatic Pressure ³ (psig)	Est. Surface Injection Pressure (psig)
1.5	2,160	0	3,283	0.37	9	3,815	0
3.0	4,320	0	3,394	0.39	18	3,815	0
5.0	7,200	0	3,577	0.41	97	3,815	0
7.5	10,800	0	3,796	0.43	194	3,815	175
10.0	14,400	63	3,895	0.44	352	3,815	432
12.5	18,000	131	3,950	0.45	529	3,815	663
15.0	21,600	210	4,007	0.45	731	3,815	923
20.0	28,800	407	4,239	0.48	1,234	3,815	1,657
28.0	40,320	N/A	4,640	0.53	2,379	3,815	3,204
30.0	43,200	938	4,663	0.53	2,643	3,815	3,491
40.0	57,600	1,476	4,905	0.56	4,406	3,815	5,495

¹ Step rate test pumped down 7" casing.

² Calculated pipe friction for normal operations based on 4-1/2" IPC set at 9,209' MD (8,637' TVD).

³ Fresh water used during the step rate test (8.33 ppg).

⁴ Requested injection pressure based on calculated matrix injection rate and the calculate pipe friction. Rate not used during SRT.



2.0 Review of step rate test

The step rate test in the NGL C5A was performed on November 7, 2015. Rates of 1.5, 3.0, 5.0, 7.5, 10.0, 12.5, 15.0, 20.0, 30.0, and 40.0 bpm were utilized during the test. A total of 2,462 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 ~28.0 bpm (extrapolated) indicates that the fracture propagation pressure is approximately 4,640 psi at the top of the Lyons formation. This corresponds to a fracture propagation gradient of 0.53 psi/ft.

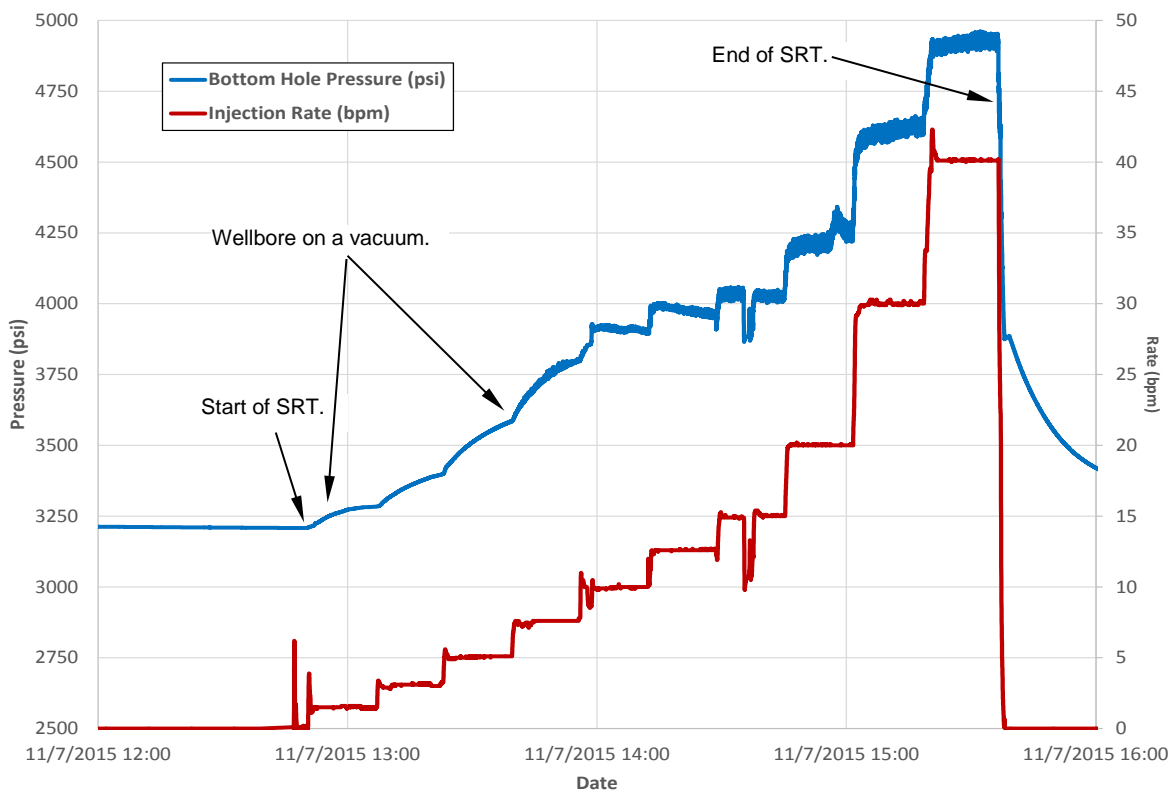


Figure 1: SRT time chart.

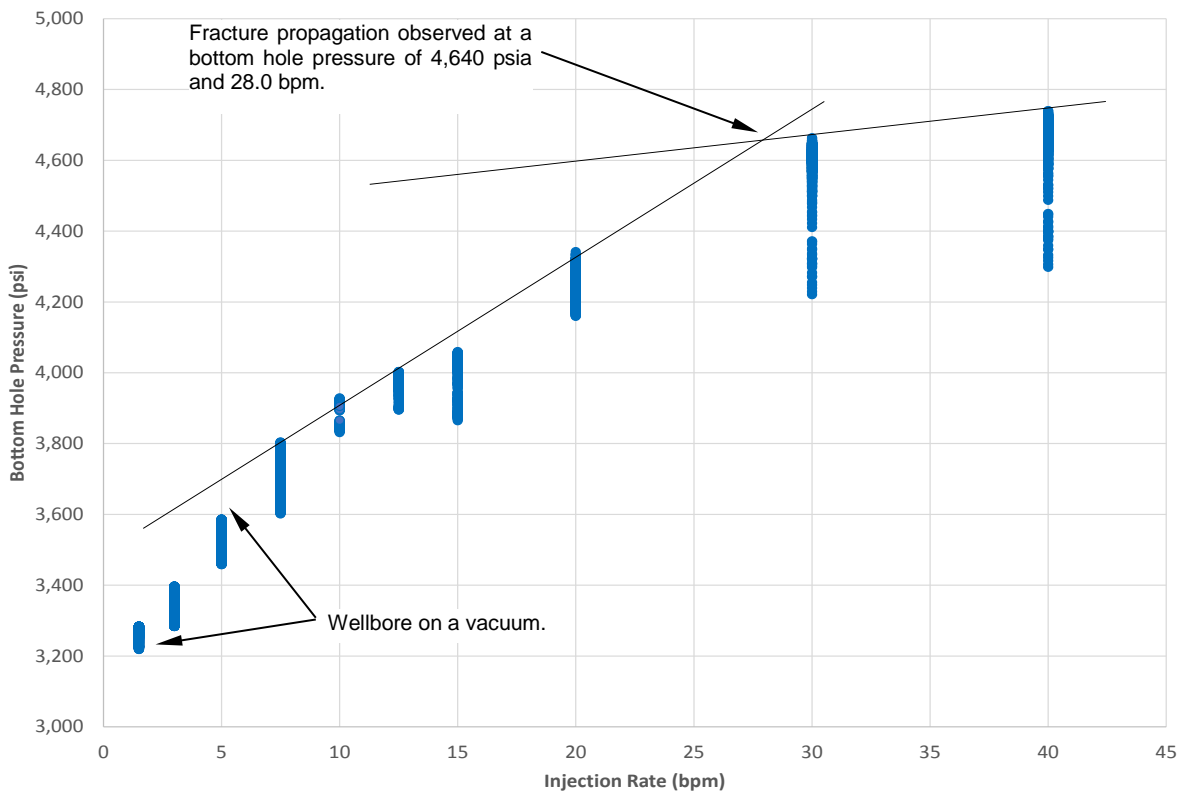


Figure 2: SRT rate chart.



3.0 Review of first pressure falloff test analysis

The NGL C5A was monitored for ~41 hours utilizing a bottom hole pressure gauge. A total of approximately 3,006 bbls of fluid was pumped prior to the shut-in on November 7, 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.) Reaches infinite acting radial flow.
- The type curve match of the late-time pressure trends (Figure 4) suggests a reservoir flow capacity of 20,880 md-ft. Based upon 180 feet of net pay, average reservoir permeability is calculated to be 116 md.
- The character of the pressure derivative (Figure 4) suggests an undamaged completion with a skin factor of -5.2.
- Based upon the late time pressure trends (Figure 4 and Figure 6), current reservoir pressure is approximately 3,207 psia (0.36 psi/ft).

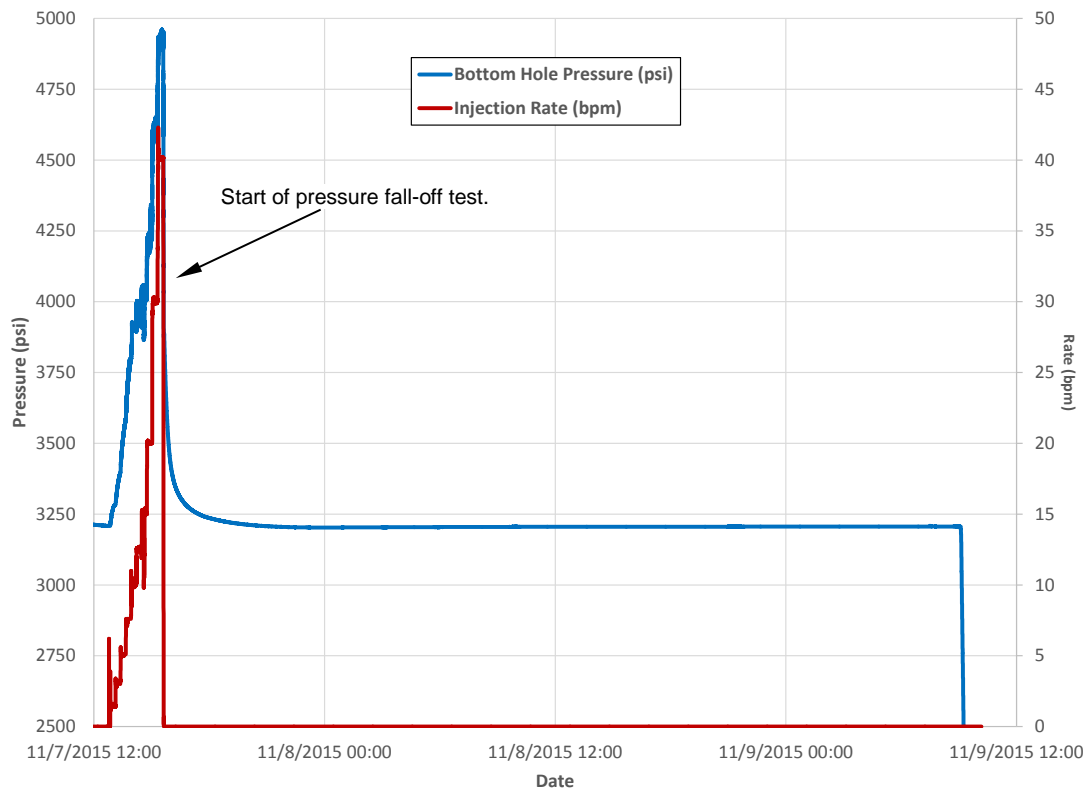


Figure 3: Cartesian plot of bottom hole pressure and temperature.

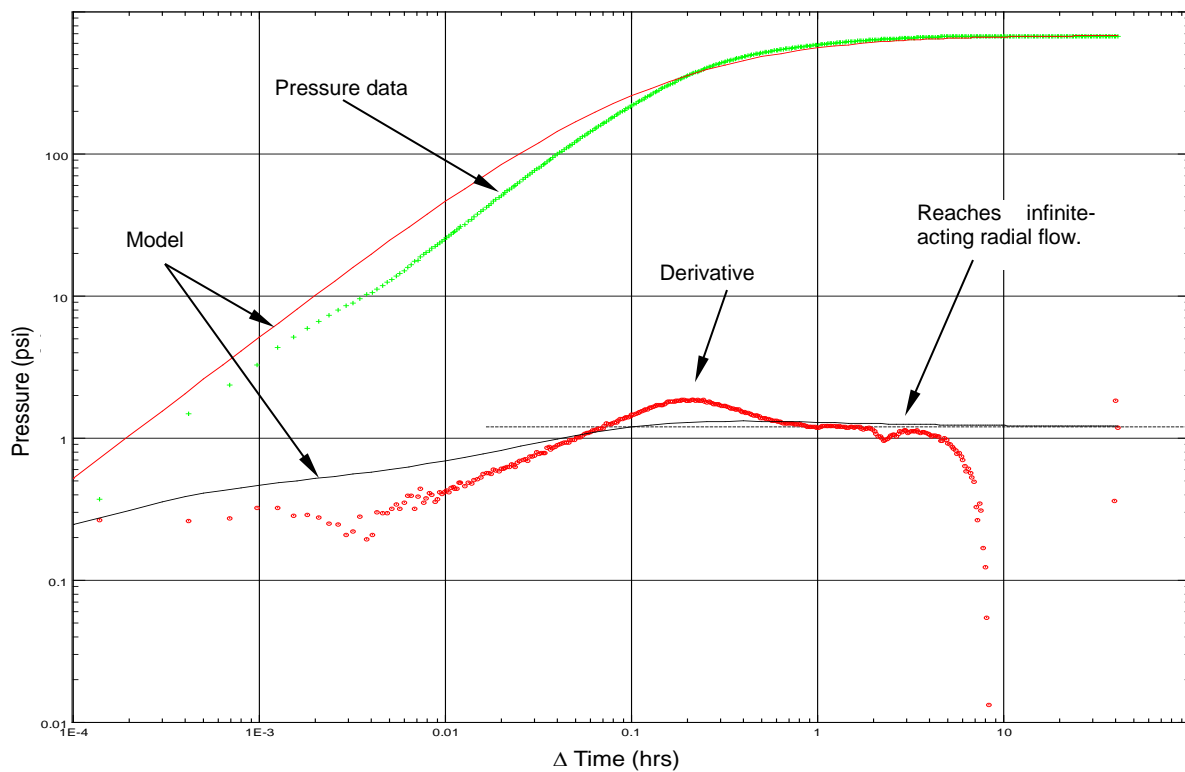


Figure 4: Diagnostic log-log plot.

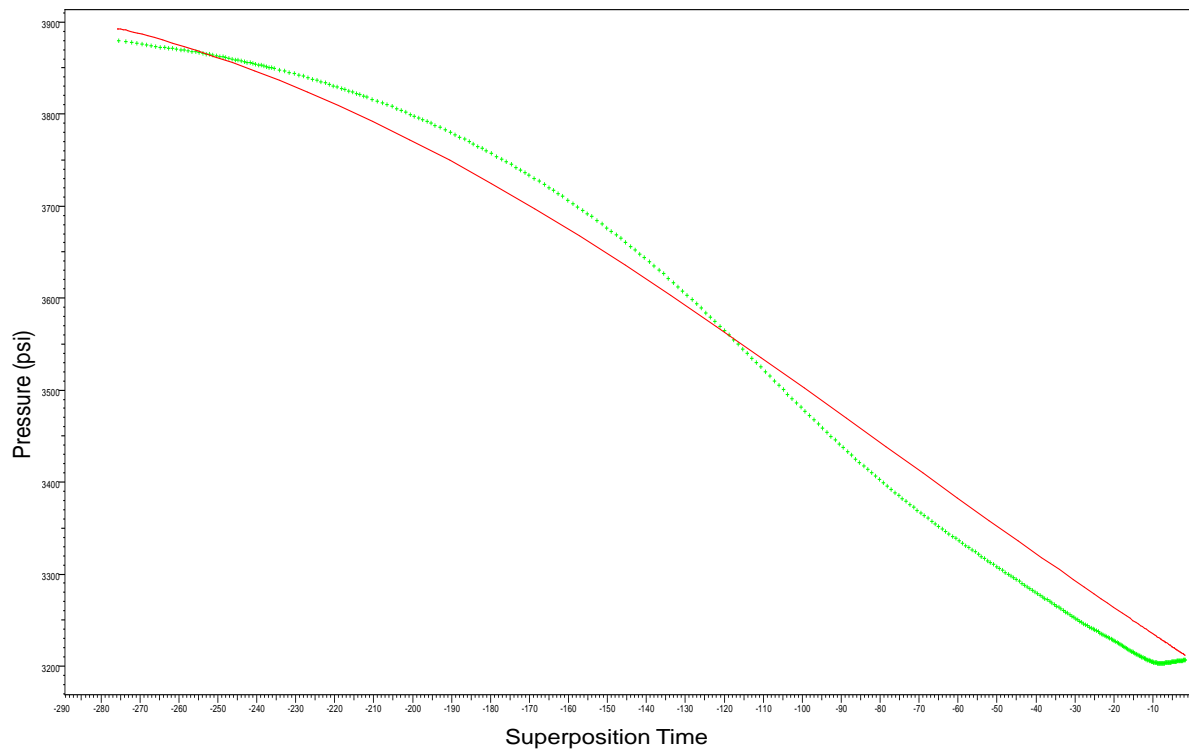


Figure 5: Superposition plot.

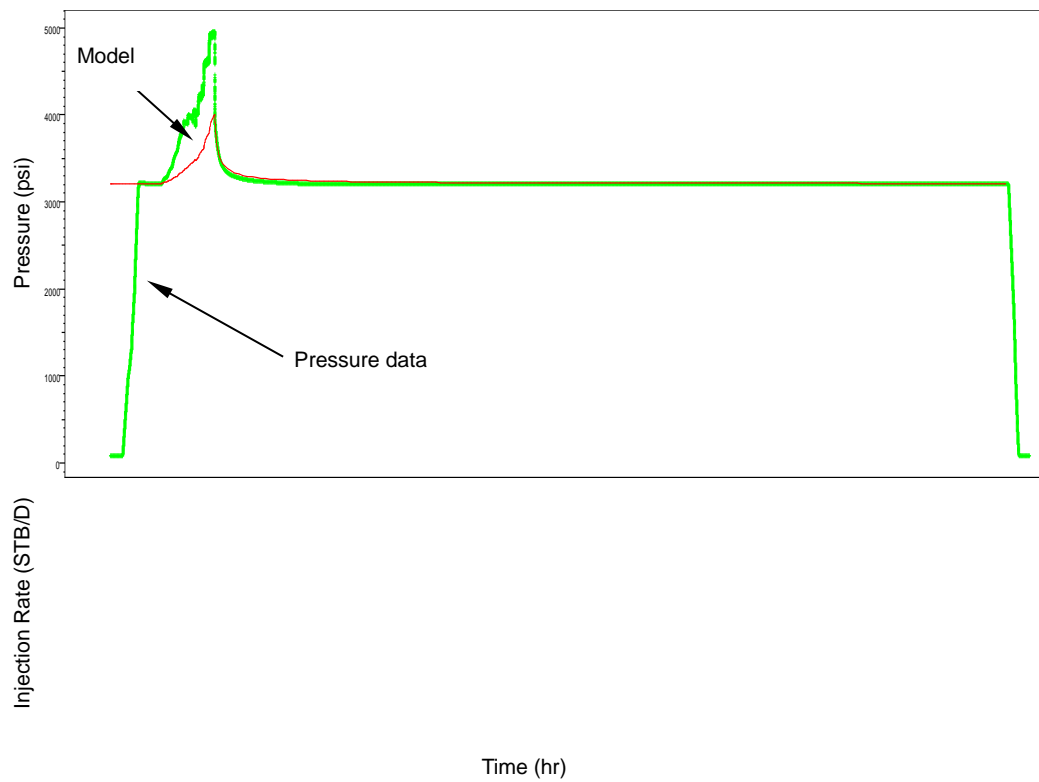


Figure 6: Model match of pressure history.