CASE STUDY:

NINE ENERGY SUCCESSFULLY STIMULATES DIVERT-A-FRAC 50 STAGE SYSTEM IN THE WILLISTON BASIN

SUMMARY

- First successful stimulation with Nine Energy 50 stage Divert-A-Frac Open Hole Multistage Sleeve System
- Increased single-point entry stage count from 35 to 50 for ~10,000 ft lateral
- Achieved through detailed pressure and erosional testing of DAFPS-III frac sleeves
- DAFPS-III sleeves successfully shifted in all 50 stages
- Total stimulation time for job was under 52 hours
- Total of 3.5 MM lb proppant and 52,300 bbl fluid placed

BACKGROUND

The Williston Basin has seen a full evolution of completion technology throughout its development, with increasing levels of science being applied to determine the best methodology. Although often referred to as a shale, the stimulation target is either the Middle Bakken, a dolomite/sandstone/siltstone layer between the upper and lower shales, or the Three Forks dolomite/mudstone/shale formation below. The primary completion method used is open hole, multistage systems, which use packers (hydromechanical or swellable) for external isolation between stages and ball activated frac sleeves for zonal treatment.

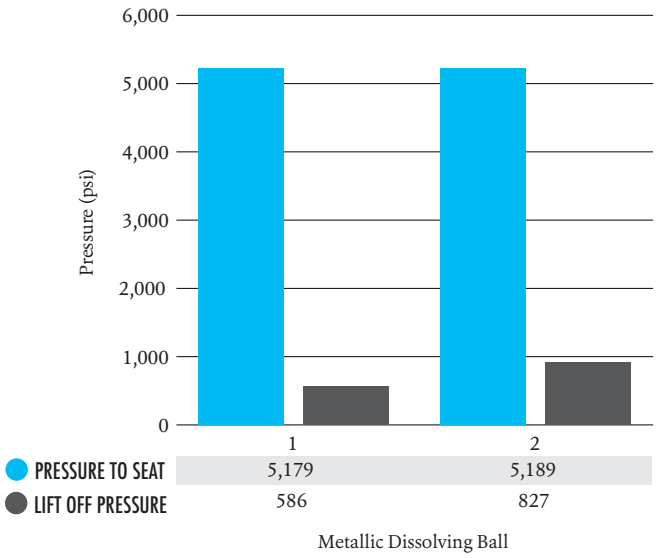
CHALLENGE

A large, global independent operator working in Mountrail county of North Dakota was looking to increase stage counts in their 10,000 ft open hole laterals to optimize reservoir treatment. The goal was to increase stage count from 35 to 50 without resorting to limited entry (cluster) completions. Single-point entry systems enable higher rates per stage and more control over fracture initiation and propagation. However, these systems have inherent stage number limitations due to available ball and seat increments and associated pressure ratings.

SOLUTION

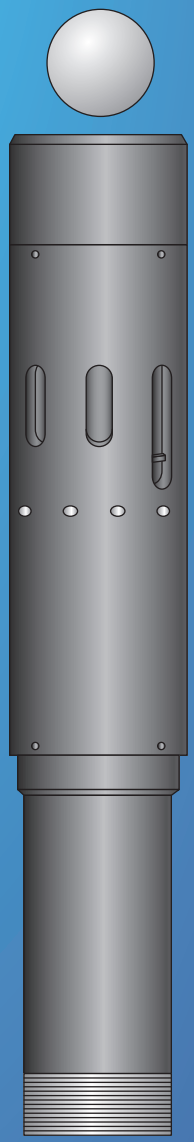
To provide the operator with the desired system requirements, Nine Energy undertook a series of testing programs to validate their ability to provide 50 stages at the required pressure rating. Divert-A-Frac Port Sub (DAFPS)-III frac sleeves were qualified with dissolvable metallic actuation balls for the ability to hold 5,000 psi pressure on ≤1/16-in. increments. This testing focused on the worst case scenarios for each level of ball/seat overlap. The test procedure was to increase pressure to ~5,000 psi and hold for 5 minutes, then determine the pressure required to lift the ball off seat. After this, each case was taken to failure. The successful scenarios were incorporated into the final system design.

PRESSURE AND LIFT OFF OF REPRESENTATIVE BALL ON SEAT



With a total 3MM lb proppant stimulation planned, Nine Energy also determined whether seat erosion from proppant would compromise the ability of the actuation balls to hold pressure. Computational fluid dynamics (CFD) analysis was performed with proprietary software on eight representative seat sizes spanning the 50-stage system. This analysis used an erosional model to determine wall material loss based on impact angle and velocity from 1.5-2.5 million sand particle trajectory calculations that incorporated turbulence. Input variables included sand size, shape, density and volume, fluid density, viscosity and rate, and seat material and geometry.

DIVERT-A-FRAC PORT III SUB



RESULTS

The first 50-stage system was successfully deployed into a 20,580 ft wellbore with a 9,660 ft, 5 ⅞-in. open hole lateral. The 4 ½-in. system included float equipment, 50 DAFPS-III frac sleeves, 50 swellable packers with a 5 ft elastomer length and a PPK Liner Hanger Packer with a 20-ft polished bore receptacle (PBR).

The stimulation job was completed as designed with all 50 DAFPS-III frac sleeves successfully opening and receiving an average of 70,000 lb of proppant (6% 40/70 and 94% 20/40 white sand) for a total of 3.5 MM lb. The proppant was delivered using an average 1,050 bbl per stage of primarily crosslinked gel for a total of 52,300 bbl. The stimulation treatments were pumped at rates of up to 30 bpm, as per the operator's requirements. The total stimulation time for the job was just over 50 hours with less than 9% non-productive time (NPT) unrelated to the system operation.

TABLE 1. SUMMARY OF 50-STAGE STIMULATION

Stage number	50
Liner size	4.5 in.
Lateral length	9,660 ft
Average stage length	193 ft
Total proppant	3.5 MM lb
Average proppant per stage	70,000 lb
Average 40/70 white per stage	4,000 lb (0.5 – 1 lb/gal)
Average 20/40 white per stage	66,000 lb (1 – 4 lb/gal)
Total fluid	52,300 bbl
Acid	1,250 gal (stages 1-5)
FR fluid	13,265 bbl
Linear gel	385 bbl (stages 1-4)
Crosslinked gel	38,640 bbl
Total stimulation time	51.2 hr
Pump time	46.7 hr
NPT	4.5 hr

Although the operator has had 100% success using Nine Energy for their 35 stage open hole systems, this was their first deployment of Nine Energy's 50 Stage Divert-A-Frac Open Hole Multistage Sleeve System. With the successful stimulation of 50 stages and positive production results, they plan to continue using this system design for additional Bakken wells.