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Selective Fracturing of a Series of Perforations in a Horizontal Well Using a Resettable Straddle System

SPE 130689

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ICoTA

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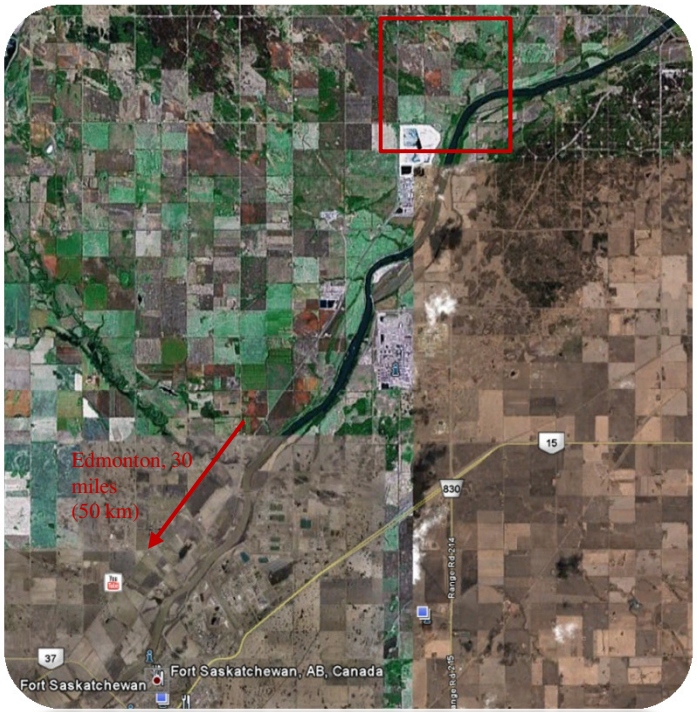
Field Location

- Viking Formation
- Redwater Operations Area
- Approximately 50 km NE of Edmonton
- Discovered in 1948



Well Profiles

- Typically either vertical with the zone being fractured to enhance productivity
- Horizontal with slotted liner completions
- Some selective fracturing operations in low deviation wells using cup style straddles
- With increased deviation they have proved to be unreliable when more than one zone is to be treated on the same run in the well
- stuck straddle assemblies are not uncommon

The Jet Straddle System

- Conventional System
  - Used for Acid Stimulations
  - Multiple Set capable
  - No pipe movement required to set
    - Pack of force created by fluid velocity through orifice
    - Ideal for setting in deviated wells
  - Adjustable straddle lengths
  - 5000 psi differential rating
  - Sets with as little as .5 bpm
  - Up to 17 bpm flow rate (CT dependant)

The Jet Straddle System

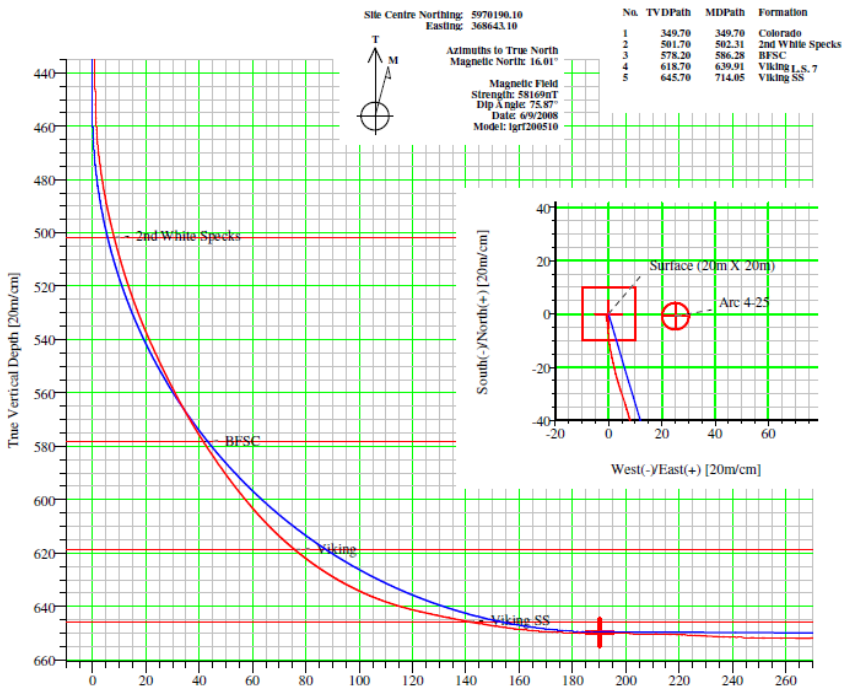
- Reverse Circulation System
  - Used for Proppant Stimulations
  - Multiple Set capable
  - Tension set
    - Pack off force created by overpull
    - Suitable for setting in deviated wells
  - Adjustable straddle lengths
  - 5000 psi differential rating
  - Up to 17 bpm flow rate (CT dependant)
  - Allows for reverse circulation (clean-up)

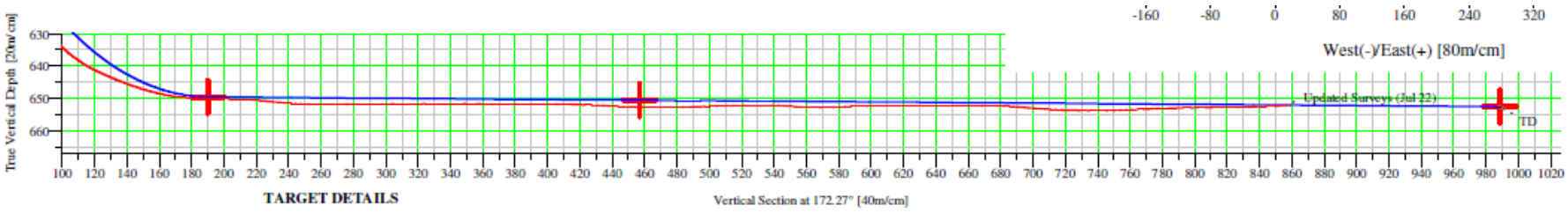
Background

- New horizontal well drilled early in 2009
  - cement casing through the productive zone, perforate several intervals and fracture them in an attempt to improve productivity.
- Research done to find new approach to selective treatment of each set of perfs
- Desired approach would allow for;
  - Set across the zone
  - fracture,
  - unset,
  - circulate the well clean,
  - move to next interval

Operational Details

- Well Schematic
  - TVD 2,133ft (650m)
  - MD 4,859ft (1,481m)
  - Max inc. 91°
  - 4-1/2” 11.6lb/ft casing
  - Six (6) sets of perfs
    - 1 m in length
    - From 2,681-4,813ft (817-1467m)





Operational Details

Areal photographs of location

CT Stretch

TABLE 1.1

Zone	Perforations	Anchor Asm. Travel	CT Stretch	RIH Distance	POOH Distance
1	1466mKB - 1467mKB	0.2 m	0.38 m	0.58 m	0.58 m
2	1344mKB - 1345mKB	0.2 m	0.30 m	0.50 m	0.50 m
3	1234mKB - 1235mKB	0.2 m	0.25 m	0.45 m	0.45 m
4	1095.5mKB - 1096.5mKB	0.2 m	0.17 m	0.37 m	0.37 m
5	945mKB - 946mKB	0.2 m	0.11 m	0.31 m	0.31 m
6	817.5mKB - 818.5mKB	0.2 m	0.07 m	0.27 m	0.27 m

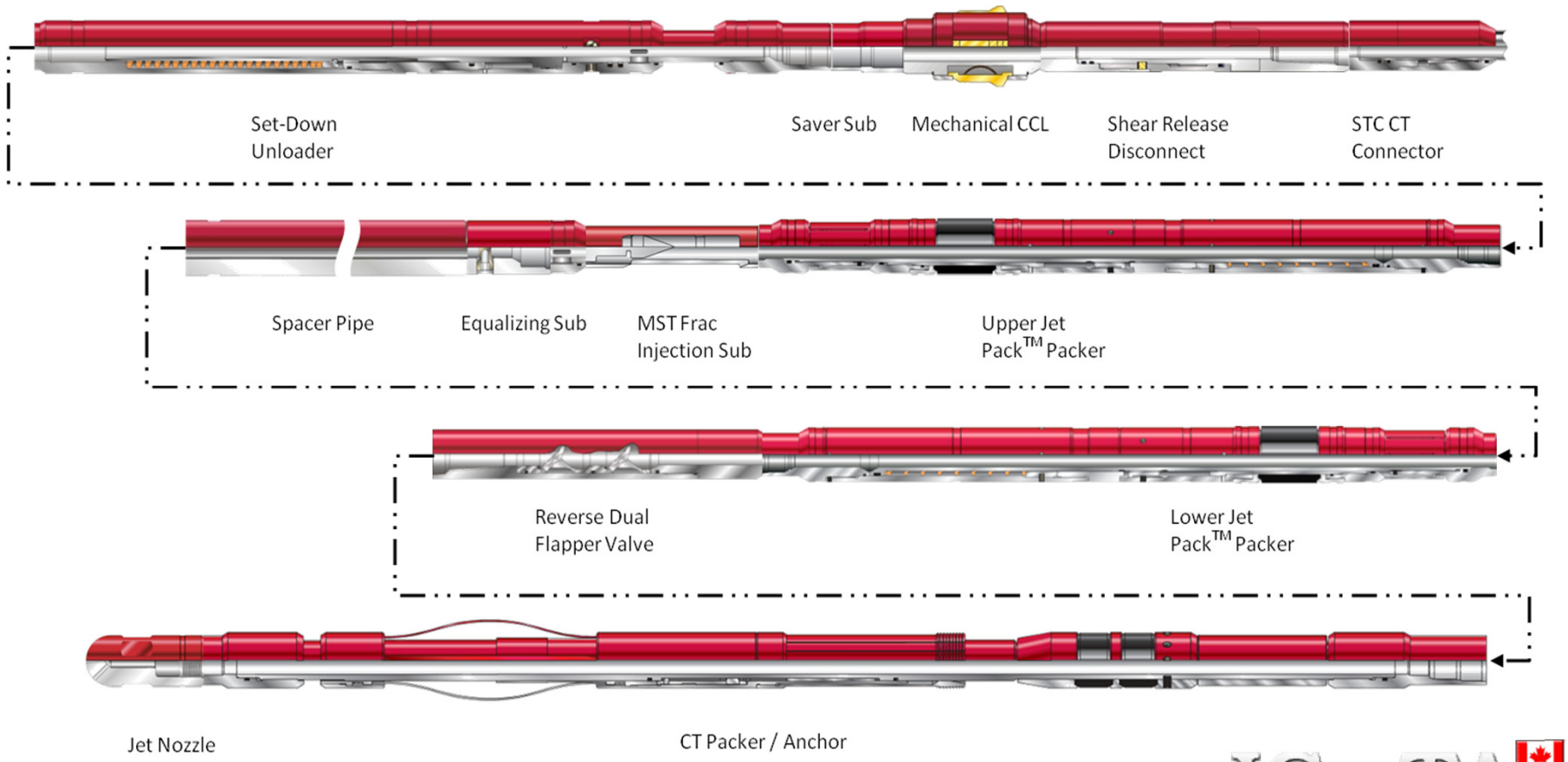
Required Setting Loads

TABLE 1.2

		Overpull DH		Overpull at Surface	
Zone	*Perforations*	*Min.*	*Max.*	*Min.*	*Max.*
1	1466mKB - 1467mKB	700	900	1117	1453
2	1344mKB - 1345mKB	700	900	1074	1401
3	1234mKB - 1235mKB	700	900	1028	1344
4	1095.5mKB - 1096.5mKB	700	900	964	1257
5	945mKB - 946mKB	700	900	900	1182
6	817.5mKB - 818.5mKB	700	900	796	1068

Operational Details

- BHA Configuration



Operational Details

- Case History
- Run 1
  - RIH to 705 ft. (215 m), anchor set and a surface load (CT weight plus applied tensile load) of 10.3K lbs (4.6 kdaN) applied to set straddle in blank pipe
  - Successful pressure test to 4,350psi (30MPa) for 5 min
  - Straddle moved to 3,031 ft (924m)
  - Successful blank pipe test was carried out (26,976 lbs (12 kdaN) surface load applied to test in horizontal.
  - POOH to prepare for fracturing operations the next day.

Operational Details

- Case History
- Run 2
  - Next day, same assembly RIH
  - Objective of fracturing zone 6
  - Casing collar @ 1467.2 meters (4814 ft.)
  - Pulled up to set at 1462.6meters (4799 ft.) with a surface load of 14 kdaN (31,472lbs).
  - Leak appeared at pressure of 9 MPa (1305 psi)
  - Pumps were shut off and a surface load of 16.8kdaN (37,766lbs) applied
  - leak returns

Operational Details

- Case History
- Run 2 (Cont)
  - Straddle unset and then reset at a depth of 1459.9 meters (4790 ft)
  - load of 15kdaN (33,729 lbs) applied
  - Indications were that the safety shear release on the anchor had been activated
  - POOH to inspect the assembly
  - packer elements damaged and the anchor had sheared
  - Conclusion that the straddle had been set across the perforations

Operational Details

- Case History
- Run 3
  - logging run was made with a memory tool on CT
  - Perforations found to be off by 1m (3.3ft).
  - 62cms (2.03 ft.) of spacer added between the packers
  - total length of 10.16m (33.3ft)
    - (longest that could be accommodated in the lubricator)
  - RIH and set at a depth of 1461.5 meters (4795 ft.) with a surface load of 14.5 kdaN (32,596 lbs)
  - Straddle zone 6

Operational Details

- Case History
- Run 3 (Cont)
  - Zone successfully fractured
    - breakdown pressure of 22 MPa (3190 psi)
    - total of 84 m^3 of gelled fluid
    - 45 metric tonnes (99,180 lbs) of sand
  - RIH to 1464 meters (4803 ft.) to unset the anchor and packers
  - after a short wait to allow the packing elements to retract, reverse circulation was established to flush the CT and the surface lines.
  - POOH to inspect - packers found to be in good condition with no evidence of any damage.

Operational Details

- Case History
- Run 4
  - BHA set at 1341 meters (4400 ft.) with a surface load of 9.4kdaN (21,131 lbs)
  - Top packer leak detected
  - BHA unset and reset at 1340.5 meters (4398 ft.)
  - Another leak (upper element was set across the perforations)
  - Good set at 1340 meters (4397 ft.)
  - zone 5 fractured
    - maximum pressure of 37.5 MPa (5437 psi)

Operational Details

- Case History
- Run 4 (Cont)
  - The BHA run down to 1348 meters (4423 ft) to unset
  - Reverse circulation established to flush the CT and surface lines clean.
  - POOH to be reset across zone 4 but without success
  - POOH for inspection of straddle
    - CT had been perforated by sand
    - Frac. breaking down casing cement establishing communication with Zone 4 (the next zone above) from outside the casing to inside (around the casing annulus).

Operational Details

- Case History
- Run 5
  - RIH to be set at a depth of 1230.65 meters (4038 ft.) to straddle zone 4
  - leak developed (packers maybe set in the perforations)
  - Unset and reset at 1230.2 meters (4036 ft.)
  - Leak detected again (communication with zone 5 below)
  - Zone 4 attempts abandoned
  - BHA was unset reset at 1091.6 meters (3582 ft.)
    - surface load of 13.3 kdaN (29,898 lbs).

Operational Details

- Case History
- Run 5 (Cont)
  - Zone 3 successfully fractured
    - maximum pressure of 15 MPa (2175psi)
    - Job terminated early due to pressure jacking
  - As a result, when the BHA was unset and reverse circulation started, no returns were obtained
  - Attempts to POOH with a surface load of 13 kdaN (29,224 lbs) were unsuccessful
  - BHA worked down to 1103.5 meters (3621 ft) (no returns)
  - Down to 1107.9 meters (3635 ft.) free with a surface load of 9 kdaN (20,232 lbs)

Operational Details

- Case History
- Run 5 (Cont)
  - POOH with a continuous overpull of 4kdaN (8992 lbs)
    - Sand on top of the BHA
    - Packing elements not fully retracted
    - CT packed with sand.
  - Tools shipped to Red Deer Ops shut down for Easter

Operational Details

- Case History
- Run 6
  - Operations resumed five days later
  - RIH to be set across zone 2 at 940.9 meters (3087 ft)
  - Surface load of 11 kdaN (24728 lbs)
  - Zone successfully fractured
    - maximum pressure of 38 MPa (5510 psi).
  - Return line became plugged preventing bleed off
  - BHA unset and RIH to 962 meters (3156 ft)
  - Operations shut down to allow the well to bleed to the formation overnight.

Operational Details

- Case History
- Run 6 (Cont)
  - Next day operations continued
  - After cleaning out the surface lines circulation was established
  - plugged the return line twice
  - The BHA was RIH to 967.5 meters (3174 ft) and with reverse circulation the returns became clean enough to POOH
  - BHA was recovered and found to be in good condition.

Operational Details

- Case History
- Summary
  - 4 of the 6 sets of perforations treated
  - Ceased operations to evaluate the results
    - Total of 6 trips
    - Set and unset successfully 12 times
    - Four (4) zones treated
    - total of 180 Metric tonnes (396,720 lbs) of 20-40 sand
    - combined density of 1000kg/m³ (8.4 lbs/gallon)
    - fluid viscosity of approx 400cp, with no indications of any untoward abrasion of the BHA.

Operational Details

- Case History
- Summary (Cont)
  - After clean up period well was put on production at a rate of 50bbl/day
  - Highest initial rate for any well in the field
  - 4 months of steady production at that rate is also the longest on record.

Conclusions

- Correctly placing the straddle proved difficult
  - Short distance between the element centerlines.
  - Dictated by the maximum assembly length that the lubricator assembly could accommodate.
  - In future operations it would be advisable to make plans for a longer lubricator.
- Stretch and load characteristics of the CT are critical to the operation and the modeling of them is a very important part of job preparation!
- Accurate perf depths very important.
- Properly sized manifold for returns is equally important
- Quality of the cement bond (communication between sets of perfs)
- 24 hour operations is a must for optimizing costs.

Looking Forward

- Our experience has lead us to improvements to optimize performance these improvements include:
  - Increased pressure rating – Up to 54Mpa
  - Improved bottom packer equalization / release – Allowing for quicker movement between zones.
  - Debris barriers designed to “survive screen outs”
  - Improved Operating Procedures

Questions?