

Novel Well Flow-control Valve for Flexible Well Completion and Application in Commingled Production of Oil and Gas in West Africa*

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Abstract

This paper presents the development, qualification, and field trial of a novel well flow valve that delivers unlimited zonal selectivity in single skin lower completion without the use of control lines. Control lines have limitations and risks due to complexity during deployment, restrictions on the number of zones, complications with liner hanger feed thru, and associated wet connects. It is desirable to remove the control lines whilst maintaining the functionality of multi zone, variable choke flow control. The well flow valve is a full-bore, reliable, and robust mechanically operated sleeve, qualified in accordance with ISO14998 including multiple open/close cycles, at a sustained unloading pressure of 1,500 psi, with highly customizable flow ports. The need for such a solution was identified by an operator in West Africa. The well objective was elevated from a gas producer to a well that required the flexibility to produce gas or oil with gas lift capability. The well flow valve was selected and required on site variable choke capability for both oil and gas production, with choke position verification, ability to handle dirty gas production without risk of plugging, compliant with a high rate and high pressure proppant frac along with ease of operation and long term reliability. The field trial included a high pressure proppant frac in the oil zone. In the shallower gas zone, three well flow valves were used to deliver variable choking capability from maximum gas flow rate with minimal delta P adjusting down to a choke size suitable for gas lift. The well flow valves were operated using a high expansion shifting key conveyed on e-line through the 3 ½' production tubing. The shifting key expanded in the 4 ½' lower completion to open/close individually all the well flow valves in a single trip. Incorporating this new product overcame the challenges presented and met the objective of

commingled production of oil and gas. The well flow control valve demonstrated flexibility through design, supply chain, manufacturing, and operations. This paper will also outline the future road map covering further developments of the well flow valve and its incorporation into an enhanced flexible lower liner solution aimed at lowering well completion costs and risks.



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The Challenge

- Oil found during gas field development
- Need to investigate the oil zone with proppant fracturing
- High burst and collapse requirement for fracturing
- In-situ gas lift to lift the oil if commercial
- Up to 70° deviation
- Flexible solution to adapt to limited knowledge of the fluid properties
- Limited time to deployment
- Simplicity of solution

Solutions Investigated

Gas-Lift Valve

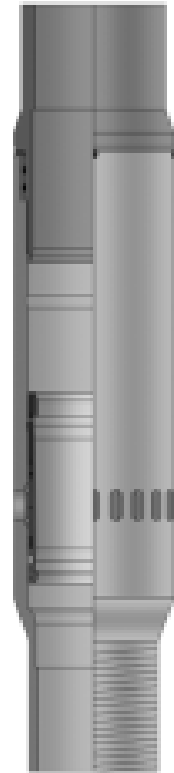
- Advantage
 - Adjustable flow rate
- Disadvantages
 - Limited to deviation $< 50^\circ$
 - Cannot handle dirty gas
 - Complex operation
 - Burst/collapse rating

SSD

- Advantage
 - Simple design
- Disadvantages
 - Not fullbore
 - Sealing reliability
 - High shifting force required
 - Flow ports not configurable

Selected Solution: Well Flow-Control Valve

- Fixed choke with 2 positions: fully open / fully closed
- Choke achieved with multiple valves in the same zone
- Full bore design with smooth flow area to minimize Delta P loss
- Configurable flow ports to deliver Delta P / Flow needs
- Inlet flow geometry to minimize erosion
- Robust seal design for manipulation under Delta P
- High burst, collapse and torque capability



Well Flow-Control Valve Extended Qualifications

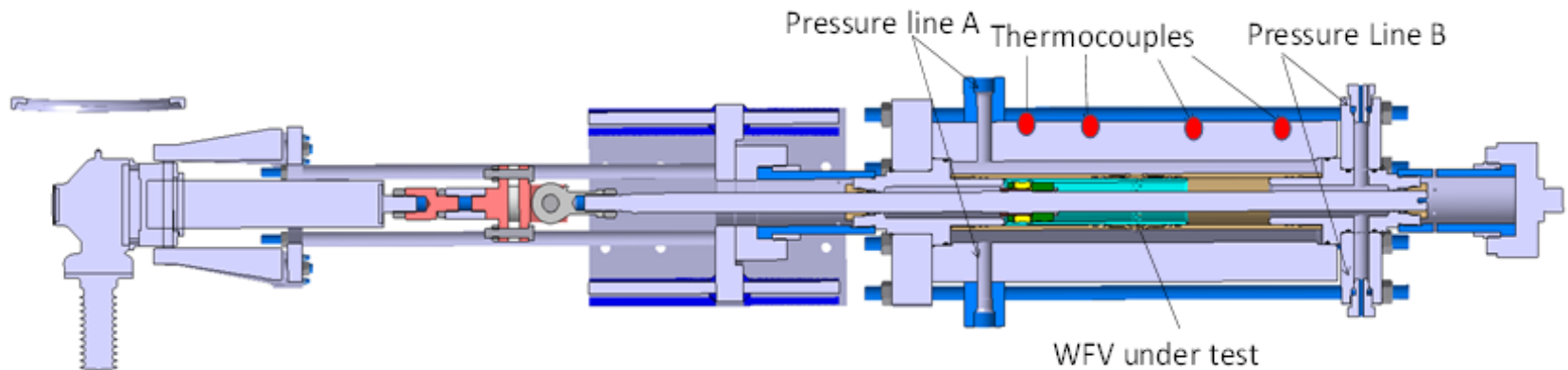
In summary the ISO14998 requires

- Multiple open/close liquid test
- Pressure + axial load + one temperature cycle
- 1% drop in differential pressure over 15 minute hold period
- Unloading pressure tested at the maximum rated unloading pressure when opening, gas cap charge volume at the unloading pressure to be at least the internal volume of the tested product
- After the opening/closing cycles, products pressure tested to one pressure reversal (1% drop over 15 min)

Additional qualifications to include

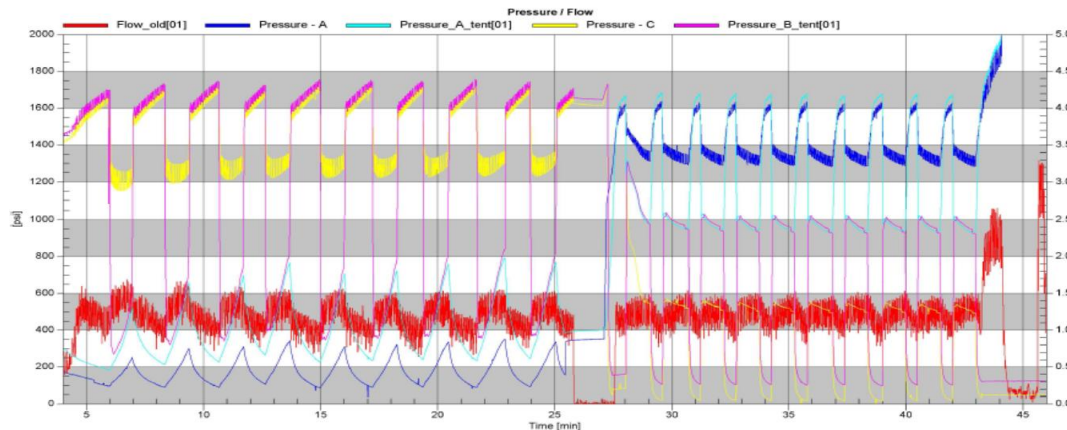
- Burst and collapse testing at temperature
- Multiple open/close liquid test with differential pressure at high flow rate using cement pumps
- Tension and Compression tests
- Flow / Delta P Curve Generation (Cv)
- Acid soak tests

Test Apparatus



Specifications of Well Flow-Control Valve

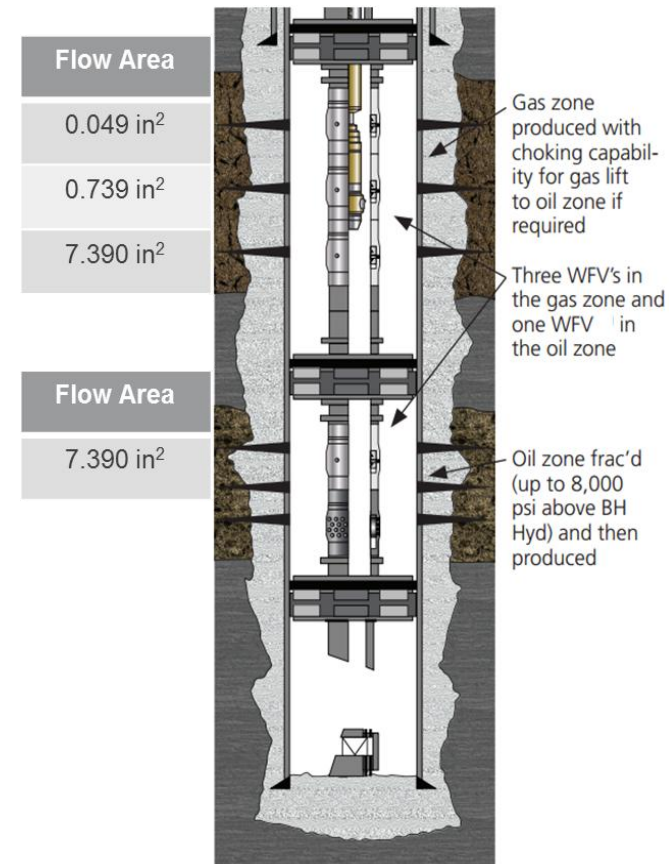
Specification	Value
Basepipe size	4.5"
Basepipe weight	12.6ppf
Torque limit	6000 ft-lbf
Rated burst pressure	8000 psi
Rated collapse pressure	4000 psi
Rated tensile/compressive load	200klbf
Rated temperature	135C
Max differential pressure while opening sleeve from fully closed position	1500psi
Metallurgy (Valve body and sleeve)	Super 13Cr-110Ksi
Seal material	PTFE, 10% Carbon fibre, Peek, HNBR
Sleeve positions	2 (Fully open/closed)
Flow area	Configurable prior manufacturing
Max OD	5.57"



Hot Unloading Test

Field Deployment

- 4 x well flow-control valves deployed on the 4 ½” inner string in closed position
 - 3 in the gas zone
 - 1 in the oil zone
- Risk assessment performed to replace a failed frac sleeve
- Valve in the oil zone opened on e-line to perform proppant frac
- After clean-up, the three valves in the gas zone were opened in a single descent



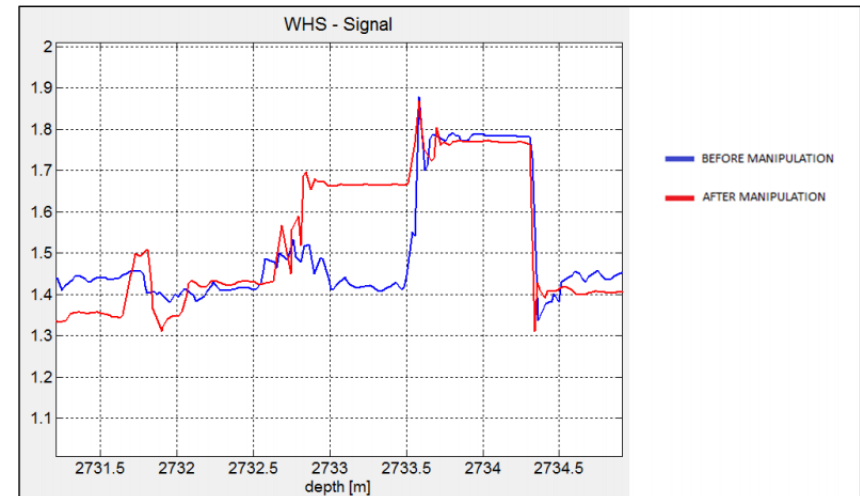
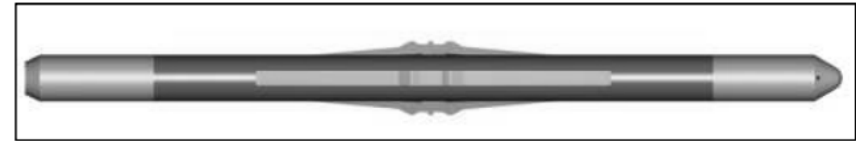
Valve Manipulation on e-Line

- Well conditions:
 - Lower completion: 4 ½”
 - Upper completion: 3 ½”
 - Restriction: 2.75”

- Toolstring:
 - Tractor
 - Stroker
 - High expansion key
 - Scanner

- Shifting force required: 400 Lbs

- Signature for each valve



Value Provided to the Operator

- Enabled oil zone exploration while producing gas zone
- Minimized changes to the original completion
- Variable choke valve with 5-8 positions in the gas zone
- Valves designed, qualified, and delivered within 6 weeks
- Saved more than 2 weeks of rig time
 - Prevented from having to pull the lower completion and re-run it

Choke Positions Achieved in the Gas Zone				
	Small Valve 0.049 in ²	Medium Valve 0.739 in ²	Large Valve 7.390 in ²	Total Flow Area In ²
Position 0	X	X	X	0
Position 1	O	X	X	0.049
Position 2	X	O	X	0.739
Position 3	O	O	X	0.788
Position 4	X	X	O	7.390
Position 5	O	X	O	7.439
Position 6	X	O	O	8.129
Position 7	O	O	O	8.178

Conclusion and Future Road Map

Conclusion

- Robust valve
- Flawless execution
- Precision shifting with signature
- Selectivity achieved in the well
- Exploration of oil zone enabled
- Production of gas zone maintained

Future Road Map

- Expand the size range: 3 ½", 5 ½", 6 5/8"
- Expand multi-position capability:
 - Dual sleeve
 - Single sleeve 5 positions
- Expand applications:
 - Open hole / multi-laterals
 - Sand screens
 - Zonal stimulation
 - Water shut-off / gas shut-off
- Remote operation without control lines

