Shell Exploration & Production

High Reliability Gas Lift Flow Control Devices Increase Well Safety and Reduce Well Intervention Frequency

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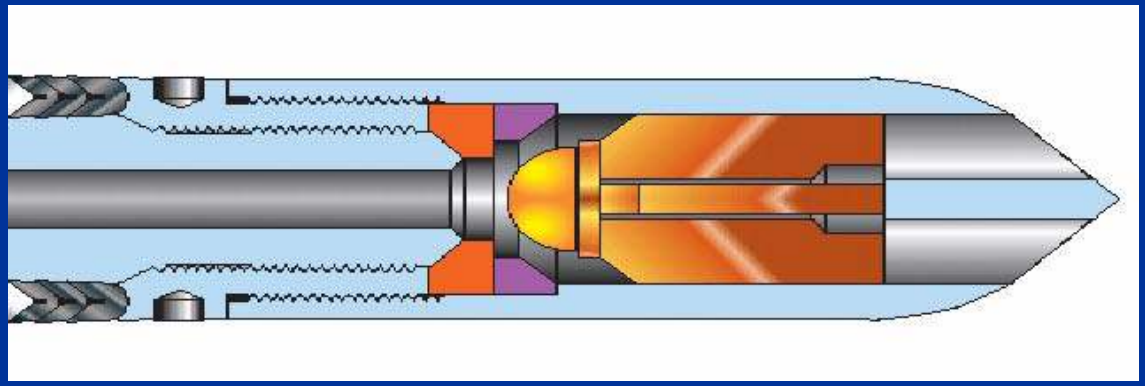
Need for High Reliability Gas Lift Valves

- Regulatory requirement is much higher than other parts of world
- Subsea/TLP completion where the risk and the cost for intervention or to change failed reverse-flow valve are high
- Waterflood with seawater as a source commonly results in reservoir souring. Sour produced fluids must not be allowed into the casing annulus
- HSE case requires a zero-leak check valve
- Viable for any gas-lift well

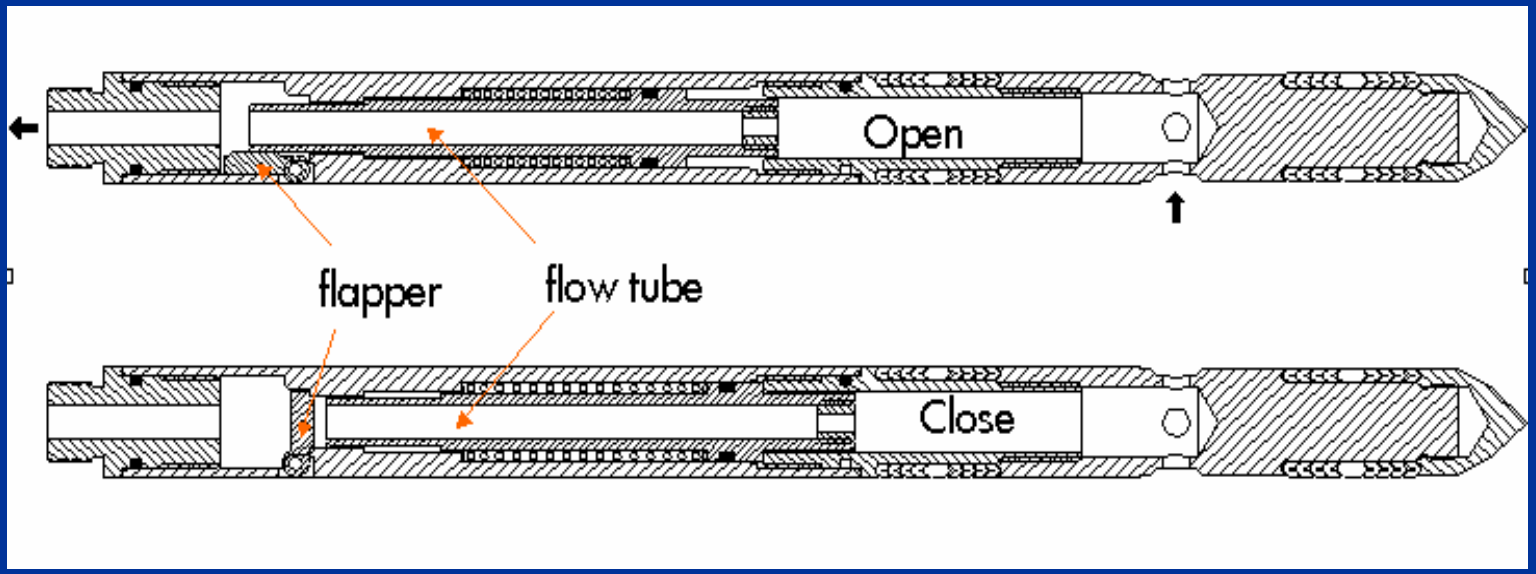
Problems to Commonly Used Gas-lift Valves

- Standard gas lift hardware compromises the well integrity envelope
- The check valve/“check dart” is prone to failure due to high velocity flow cut and is not a reliable barrier
- It is common for the reverse-flow valve to leak at low pressure
- A gas lift mandrel with an open pocket allows flow from the tubing to the casing



Solution

- Protect the check valve sealing surfaces from exposure to high velocity fluids
  - Redesign the gas lift flow control device to use a flapper and flow tube
- Prevent flow of tubing contents into the casing annulus when the mandrel pocket is open
  - External mounted check valve

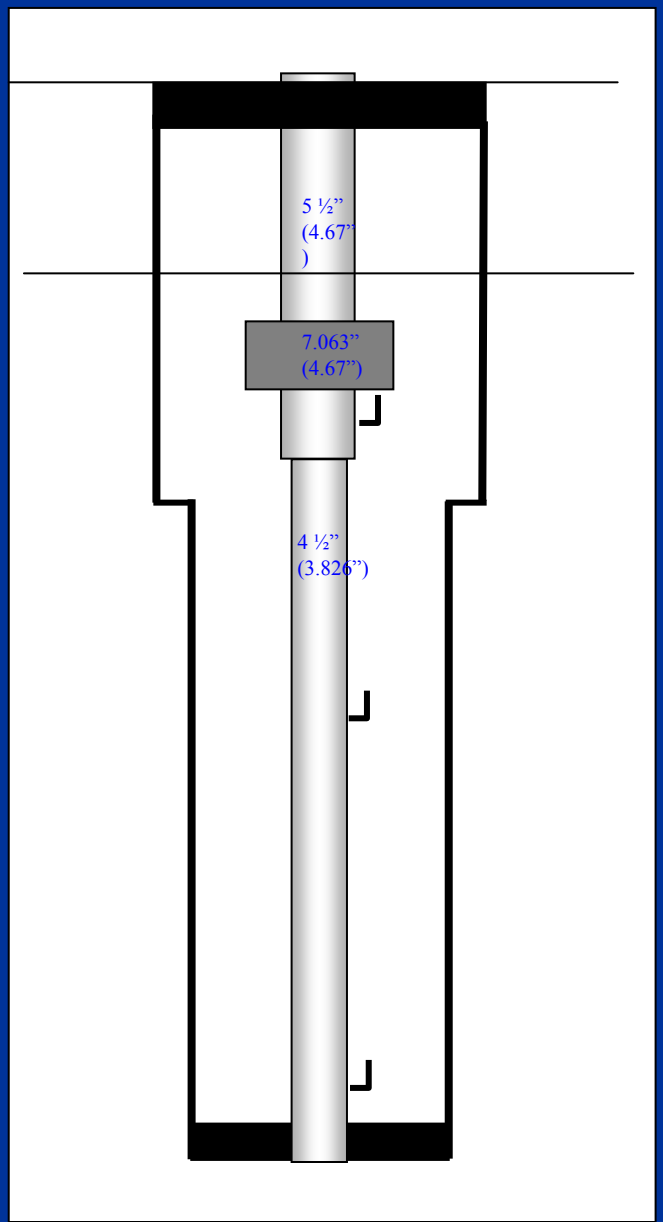


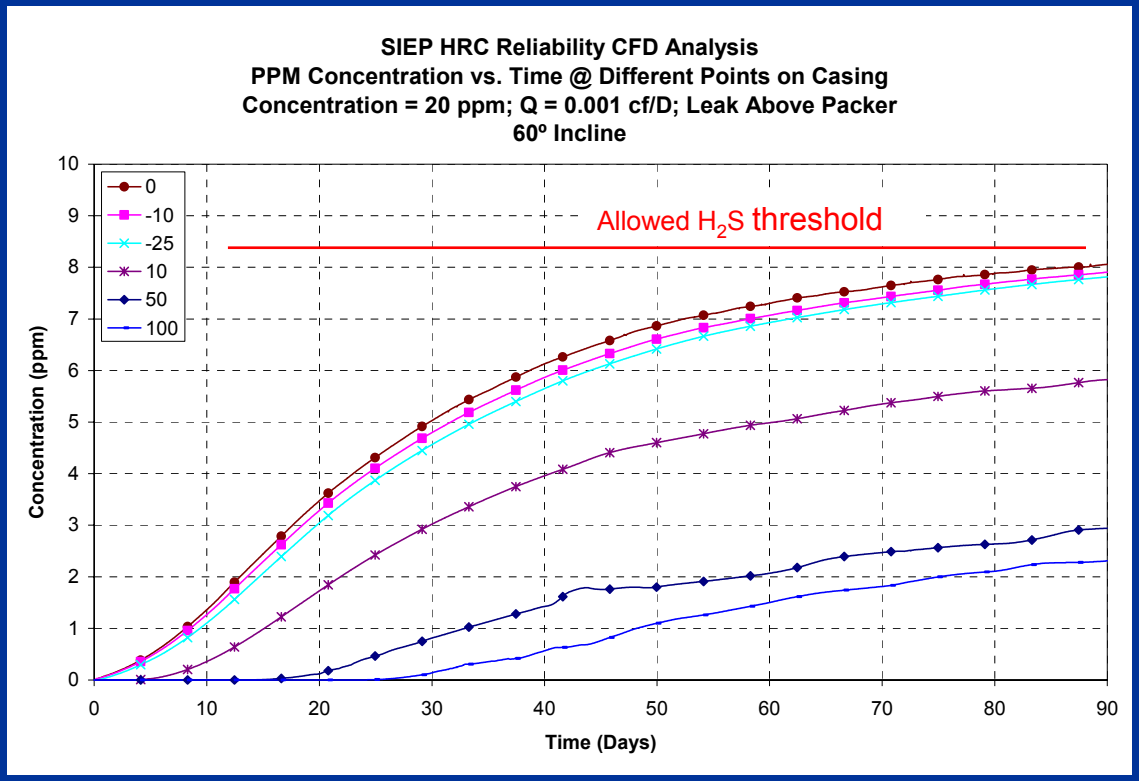
External Mounted Check Valve (FAST-TEC™)

Design and Qualification Procedures

- CFD (computational fluid dynamics) modelling as assessment, design and optimization tool
- Acceptance criteria
- Low pressure leakage tests (individual and dowhole sub-assembly system)
- Static and cyclic high pressure tests
- Explosive decompression test for elastermer used as seating o-ring material
- Fatigue performance tests for moving parts
- Erosion resistance tests with water
- Gas flow performance tests
- Field trials

CFD Model for Acceptable Leakage



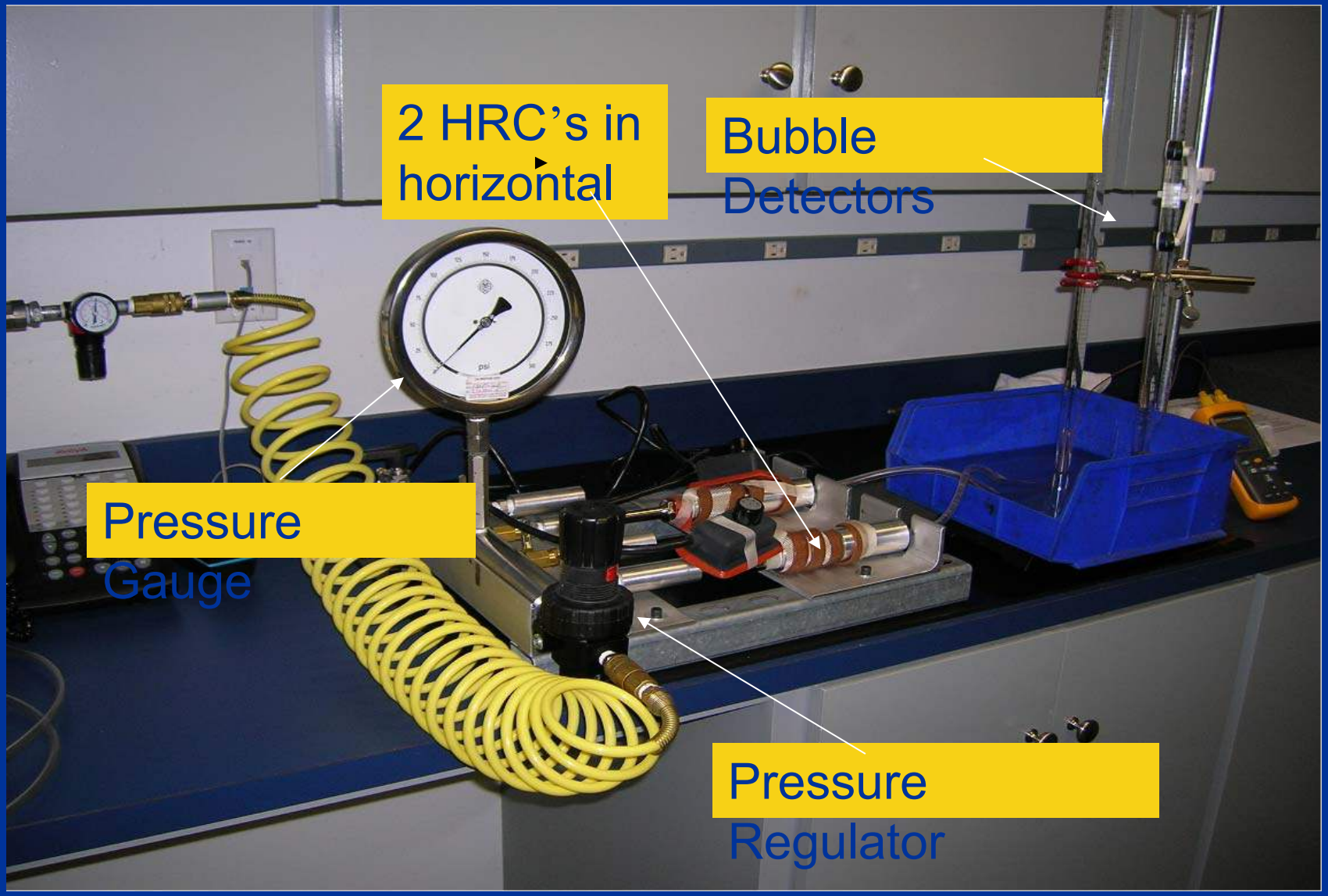


- The simulation scenarios were carefully considered and arranged to cover the worst case scenarios so that overall results can be supported by the reasonably high safety factor for confidence
- Based on on the worst case scenarios evaluated by CFD, the acceptable leaking rate should be limited to 0.001scf/D without imposing a H_2S critical threat to the casing

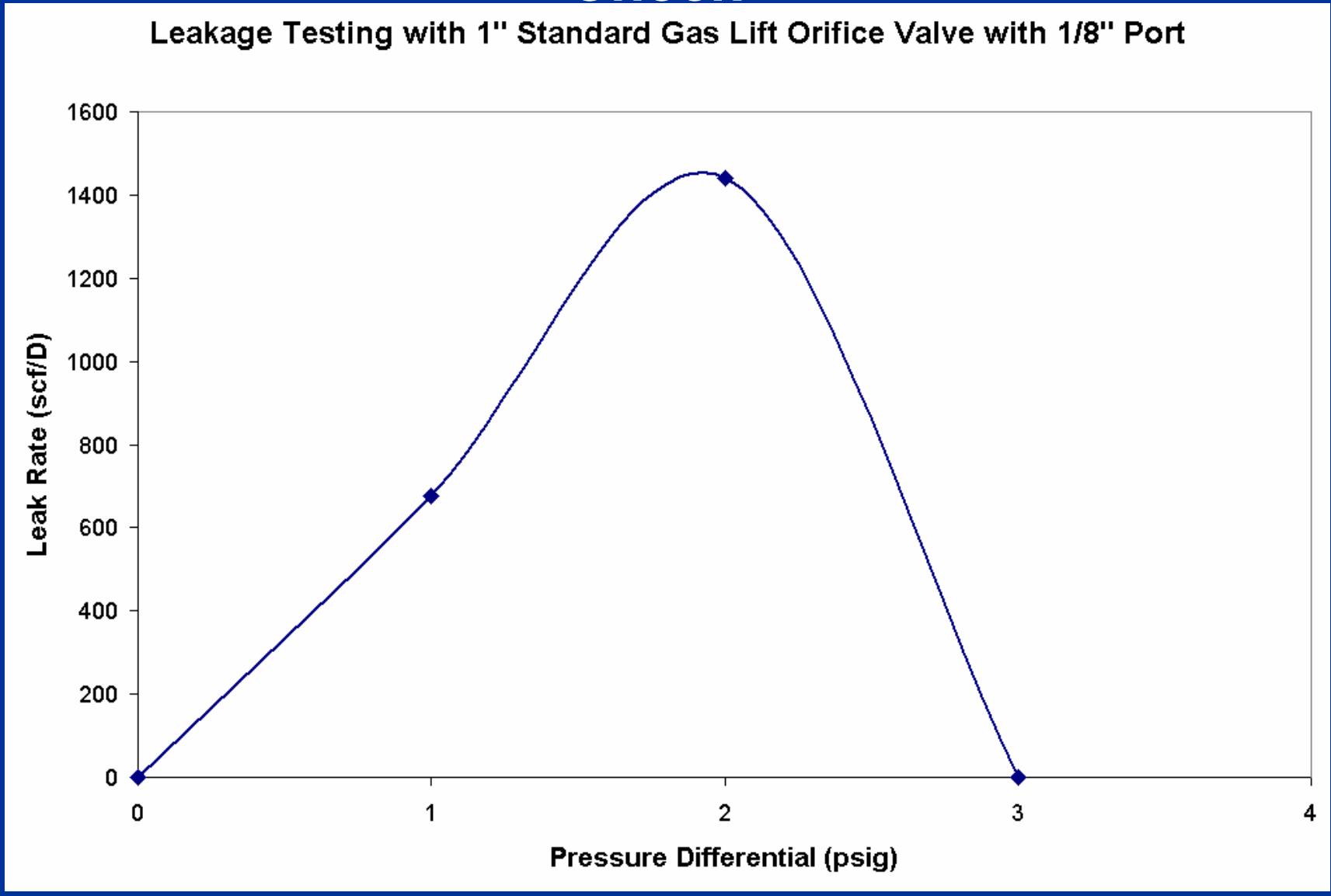
Acceptance Criteria for High Reliability Gas Lift Valve

- The test criteria set by Shell safety case and evaluated by the CFD modeling requires every check valve hold pressure tight from 1 psi up to 8000 psi.
- Industrial standards for Acceptable leakage for gas lift
  - 35 SCF/D (1 SCM/D) gas leakage for gas lift devices (API API11V1)
  - 35 SCF/D (1 SCM/D) gas leak rate (ISO Standard 17078.2)
  - 1 bubble per minute (0.15cc/min) at 50 psi differential for Class VI control valve
- Almost all reverse-flow gas lift valves in the market do leak in a small amount at low pressure (1 to 15 psi)
- Critical challenge to HSE case where souring fluid is not allowed into the casing

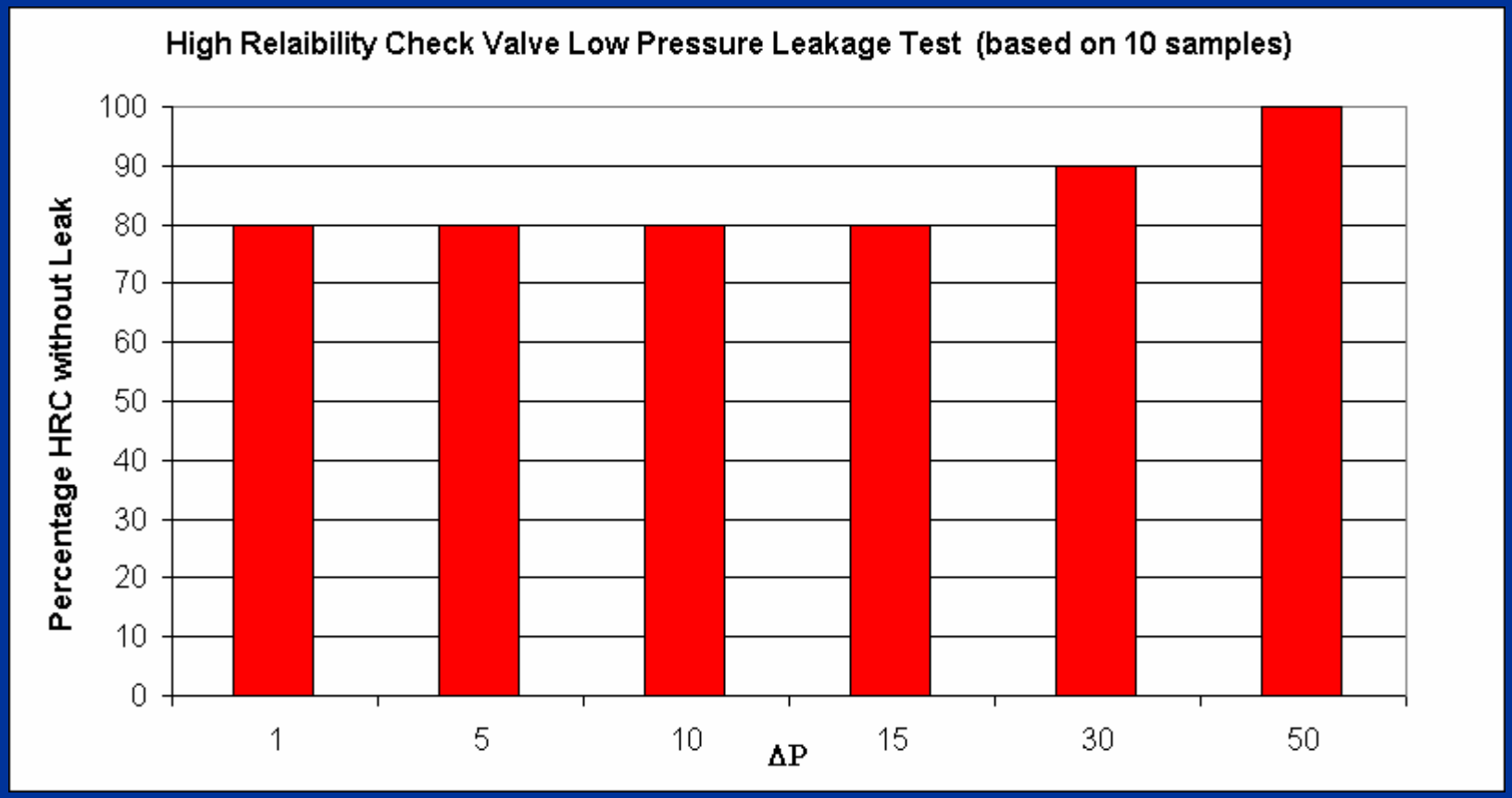
Low Pressure Test Apparatus for HRC/HRO



Leaking Behavior for Typical Reverse-flow Check



Low Pressure Reverse-Flow Sealing Performance



Testing with 10 samples with optimized design, 80% originally assembled HRCs are able to meet zero leakage at 1 psi. Only 2 out 10 checks did leak at 1 psi until 30~40 psi to seal

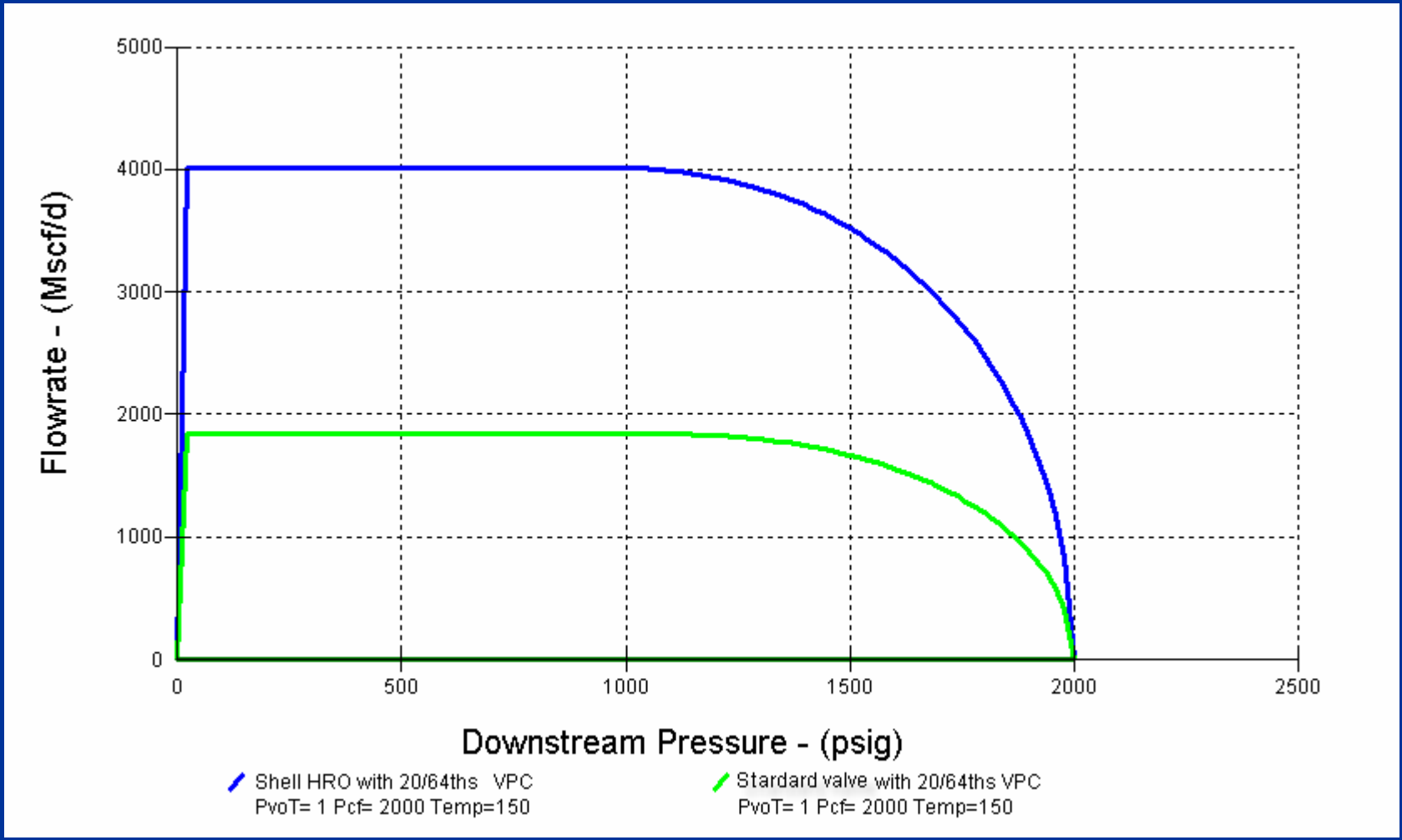
High Pressure Static and Cyclic Tests

- High pressure static test
  - hold 8000 psig for 10 to 18 hours
- High pressure cyclic test
  - being cycled 15 times with 15 minute minimum hold times
  - no nibbling or visual damage of any sort on either of the o-rings

O-ring Material ED Test

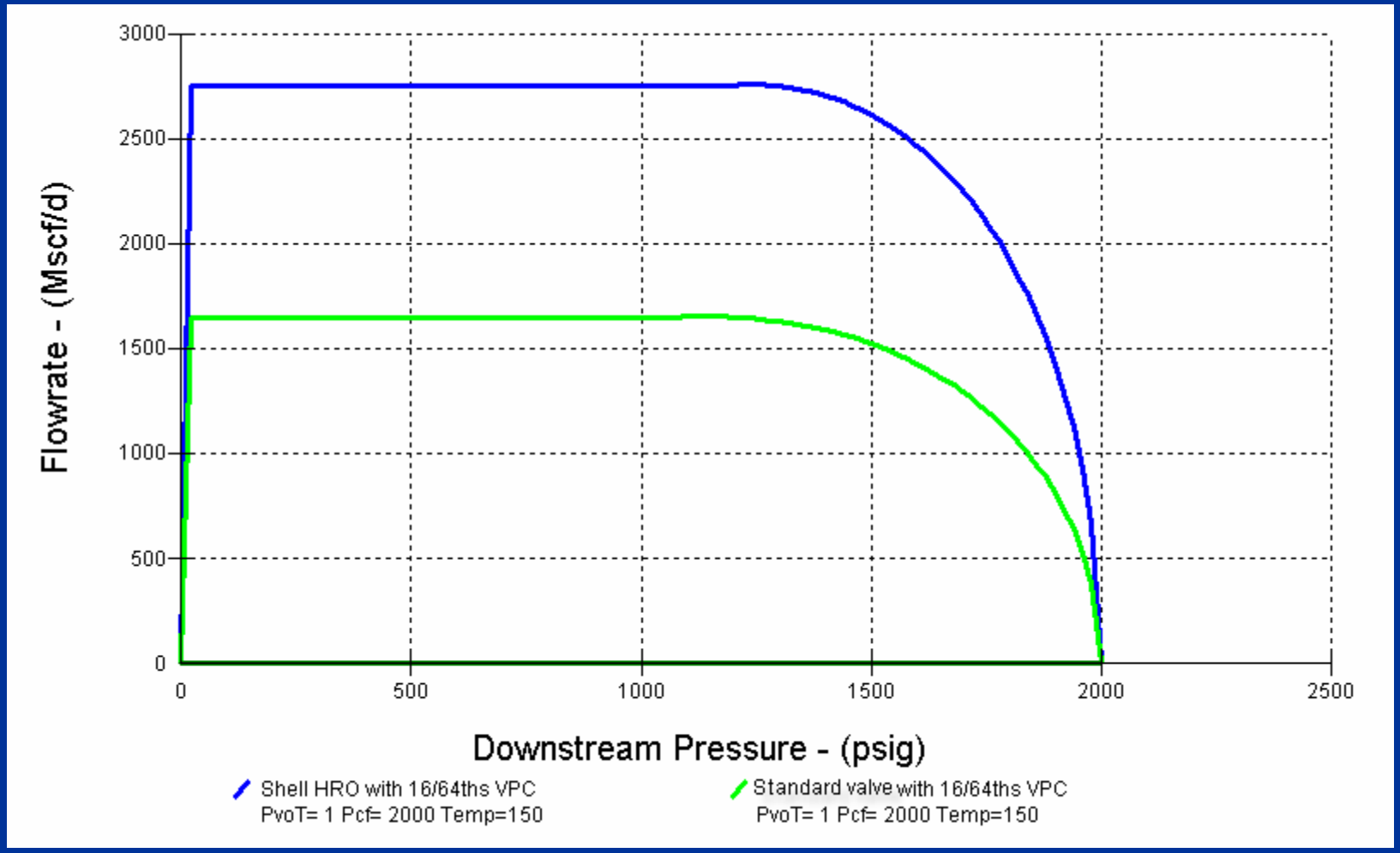
Autoclave number	Test condition						
	samples	Pressure (psi)	Temp (F)	Exposure (days)	Bleed rate (min)	Type gas phase	Results
1	2 Chemraz 510	3500	170	6	14 min (250 psi/min)	Pentane; Methane with 5% CO2	No Blister/ Crack
2	2 Chemraz 510	3500	170	6	7 min (500 psi/min)		No Blister/ Crack

Gas Flow for 1” HRO vs Standard Orifice Valve



The max rate of HRO w/ 5/16" port is 118% higher than industry standard orifice valve

Gas Flow for 1” HRO vs Standard Orifice Valve



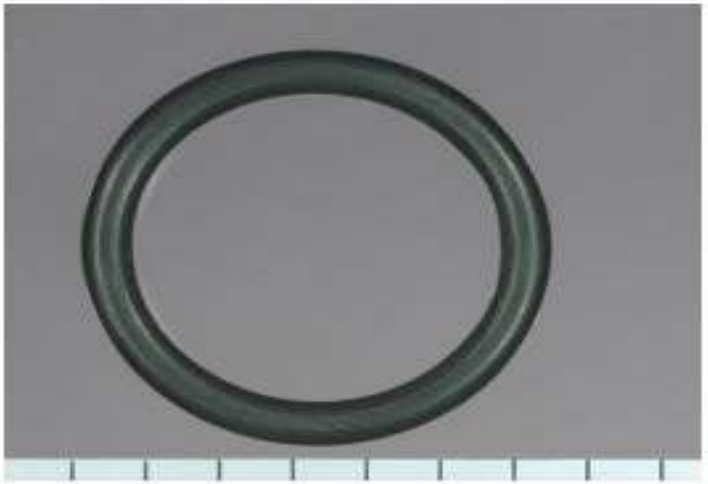
The max rate of HRO w/16/64" port is 67% higher than industry standard orifice valve

HRC/ HRO Erosion Test Summary

Test Samples	Test ΔP	Test Duration	Pumping Rate	Total Volume	Failure Criteria	Result
HRC	1000 psi	7 days	80 gpm	18,000 bbls	Leak Rate > 350 scf/D @ 100 psi diff	Good condition after 7 days test
1/8" port HRO	1000 psi	7 day (168 h)	10 gpm	2400 bbls		No erosion problem after 7 days
1/8" port standard orifice	1000 psi	1 day (24 h) to failure	10 gpm	343 bbls to failure		Severely eroded after 1 day's flow
5/16" port standard orifice	1000 psi	7 day (168 h)	43~ 57 gpm	10,560 bbls		Slightly eroded after 6 days

1” HRO with 1/8” Port Erosion Test (7 day)

HRO w/ 1/8” after 7 days erosion test



Good o-ring in HRO (1/8”)

Flapper of HRO w/ 1/8” with a slight mark caused by sliding of flow tube. The mark is inner side of flapper.

HRO 1/8” flow tube and spring

1” Standard Gas Lift Orifice Erosion Test (1 day)

Dissembled parts

Worn check seal

Eroded check dart

Brand new check dart

Comments and Conclusions

- Clear business case
- High reliability gas lift valves which use the flapper and the flow tube technology meet well safety case and reduce well intervention frequency.
- 80% high reliability check valves achieve bubble tight sealing at low pressure
- High reliability gas lift valves definitely outperform any standard gas lift valves in term of high velocity fluid cut resistance
- High reliability gas lift valve family perform very well in the flow capacity. The maximum gas flow rate for 1” HRO/HRC is averagely 10 ~100% higher than the 1” standard orifice valves given the same port and the pressure

Acknowledgment

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