2022 GAS LIFT WORKSHOP

Hebron Gas Lift Case Study – Dual Pocket GLM

Amy Seward, ExxonMobil Wells Engineer

ALRDC Gas Lift Workshop

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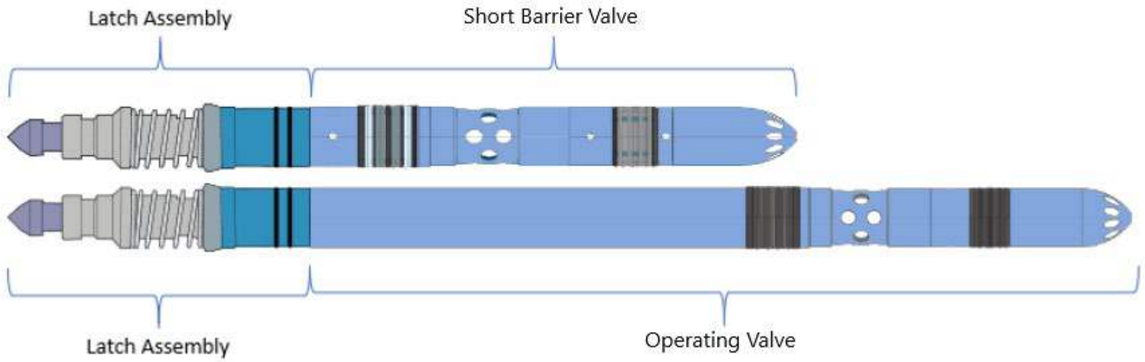
Hebron

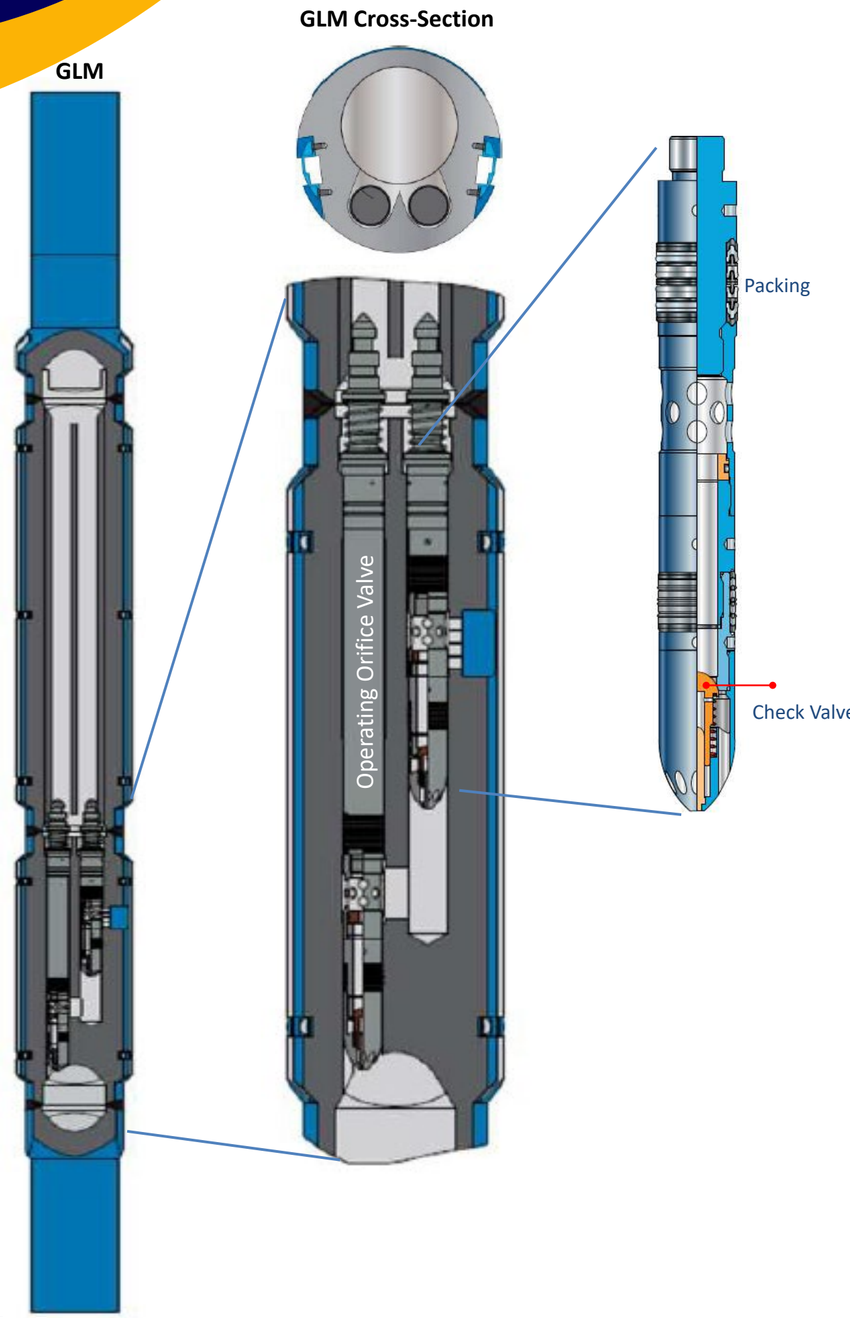
Agenda

- Gas lift equipment background
- Hebron well design overview
- Case Study summary
- Wellwork operations and learnings journey
- Wrap up & recommendations

Barrier Series Dual Side Pocket Mandrel

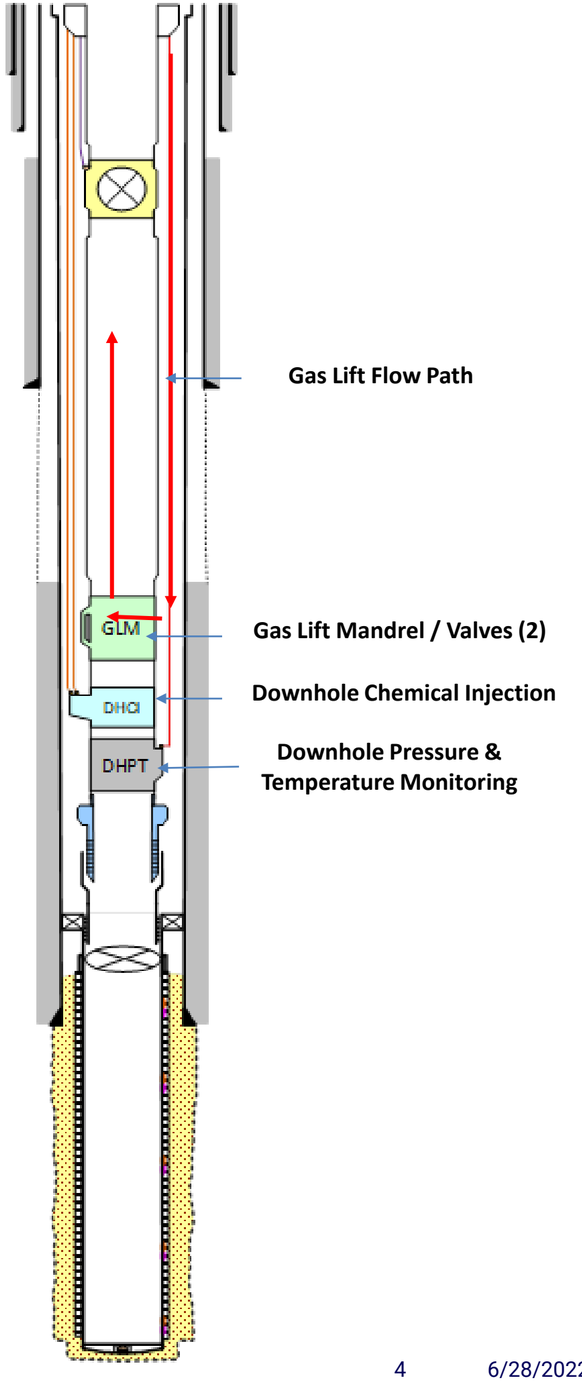
- Dual side pocket GLM; 2 valves w barrier qualified check assemblies
  - Outer Tubing-Casing Barrier Valve (Short valve)
  - Inner Operating Orifice Valve (Long valve)
- Barrier qualified GLM / GLV replaces Annular Safety Valve (ASV)
- Short valve eliminates annulus flooding during long valve replacement
  - Mitigates most frequent event (valve damage during unloading liquid filled annulus)

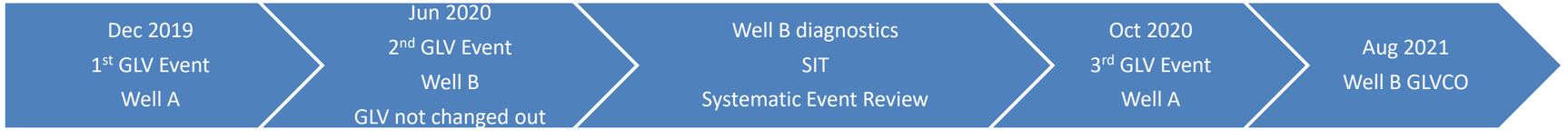




Typical Hebron Oil Producer Well Design

- ~1400 m horizontal open hole gravel pack
- 7” tubing w 5.5” completion assemblies; TR-SCSSV, GLM, DHCIM, DHPT
- No ASV
  - Installed in 3 wells prior to regulatory approval of only barrier qualified GLM
- Single point injection with 5.5” dual pocket gas lift mandrel.
- GLM @ <65° inclination to allow for SL intervention
- Gas lift system designed to operate at 3000 psi and 10 MMscfd
  - Eliminates requirement for unloading valves
  - Operating above industry standard GL operating pressure 2000 psi





Gas Lift Case Study Summary

- **Case Study #1 – Well A (Dec 2019)**
  - Event occurred ~ 4 months after completion installation
  - Initial finding pointed towards improper onshore installation by vendor, of latch shear pin. Further review of well data identified that this event was most likely triggered by pressure cycles during ramp up/down event.
  - Corrective actions implemented on subsequent wells; improved shop procedures and borescope confirmation of proper valve/latch installation.
- **Case Study #2 – Well B (Jun 2020)**
  - Event occurred ~ 2.5 years after completion installation
  - Camera diagnostics confirmed short valve out of pocket, sitting on top of long valve
  - Well contained functioning ASV therefore returned to production; Injection through empty pocket
  - Collaborative review of data points including design, installation and operating conditions
    - Focus on unbalanced pressure/force load on short valve that allowed valve to cycle in pocket under varying well operations
  - Reconfigured valves to operate as a single pocket mandrel which eliminated pressure imbalance that led to early GLV change outs
- **Case Study #3 – Well A (Oct 2020)**
  - Event mechanism believed to be consistent with case study # 2; valve cycling / pressure imbalance

Gas Lift Operations – Cause of Valve Cycling

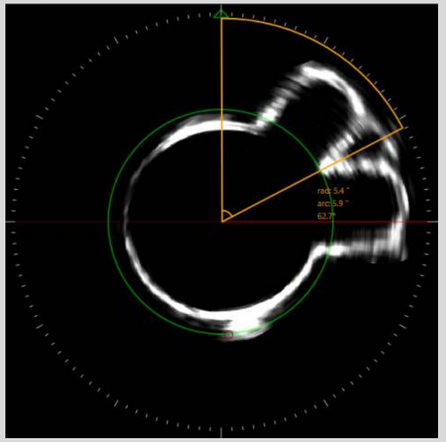
- Rapid bleed down and startup of gas lift injection likely caused the short valve shuttling/cycling inside pocket
- Cycling test proved valve has potential to move back and forth inside pocket with significant force

Case Study #1 – Well A GLV Replacement

- Planned to confirm GLM orientation and consider use of orientation sub with KOT during GLV changeout
- Wireline junk basket prior to logging
  - Became stuck in GLM; unable to pull free; electronically released BHA in GLM
- Slickline fishing of BHA left downhole
  - Short valve recovered in junk basket
  - Suspect GLV protruding into GLM became wedged during junk basket run (cause of bending)
- Wireline orientation log
  - Determine GLM orientation; onshore SIT completed to support interpretation
- Replace short valve with WL
  - KOT with orientation sub

Orientation Sub

Bent GLV retrieved from Well A

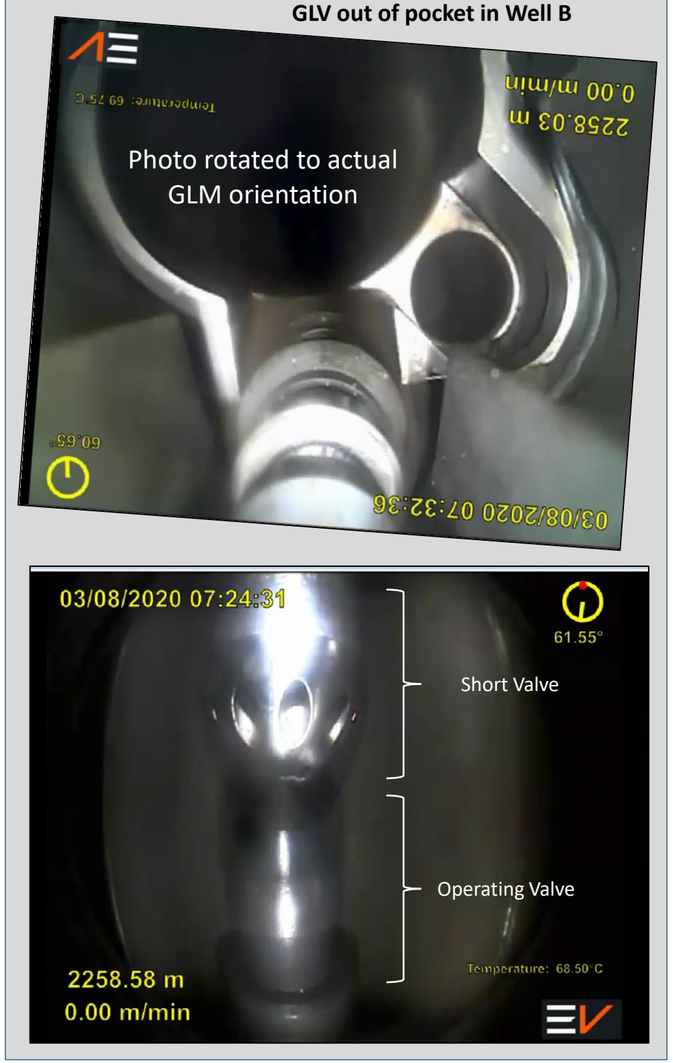


GLM orientation log

Case Study #2 – Well B - Diagnostics

- Well B contained functional ASV
  - Continued production
- Camera run
  - Well displaced to N2; camera run to determine GLV status
  - Short valve found completely displaced from pocket sitting on top of long valve
- Well returned to production
  - Initiated SIT planning
  - Injection through empty pocket

GLV out of pocket in Well B



Short Latch - sheared

Operating valve latch - not sheared

Downhole view of empty short valve pocket and installed operating valve

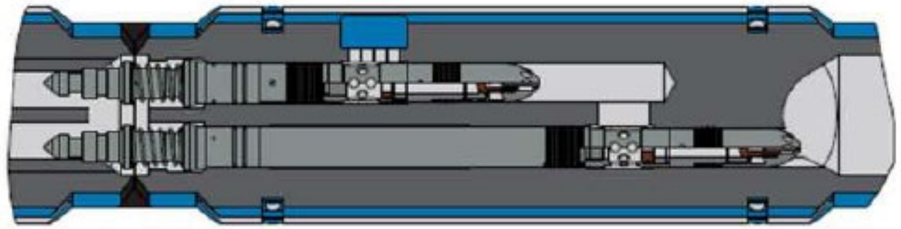
Latch Lug profile mandrel

Slot in Mandrel

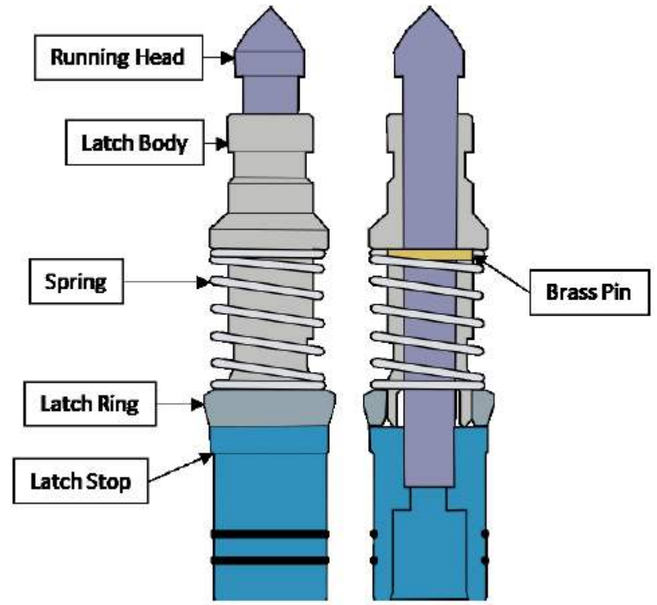
Systematic event review

- Suspected root cause following first event
  - Suspected improper shop assembly and installation by vendor
  - Procedures and checks implemented following first event
- Primary root cause suspected following second event
  - Latch shear pin fatigued due to valve cycling / pressure imbalance
    - Interstitial space between two check valves results in pressure imbalance
    - Bleeding down and ramping up injection pressure forced short valve to shuttle back and forth repeatedly; Not operating gas lift system in stable continuous manner
  - System modeling and dynamic testing replicated valve cycling
  - Confirmed latch shock loads but unable to replicate latch premature shear during cyclic testing
    - Momentum testing result confirmed shear pin fatigue
    - Well conditions difficult to replicate in shop/lab testing
- Forward Plan
  - Reconfigured valve arrangement; GLM to function as single pocket mandrel
    - Implemented in new drill wells and subsequent GLV changeouts
  - Automated annulus bleed down and ramp up process

GLM Cross section



GLV Latch



Reconfigured GLVs

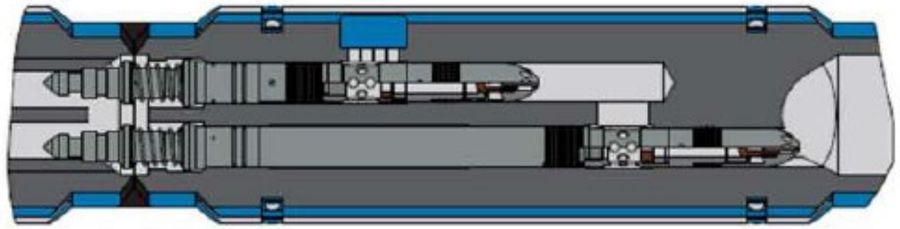
Short Pocket (Operating)

- Short Valve
  - Orifice Style: Venturi
  - Orifice Size: Per Injection Rate Design
- RK Latch
  - Shear Pin: Inc 925
  - Remove O-rings

Long Pocket

- Long Valve (Non-operating)
  - Orifice Style: Square Edged
  - Orifice Size: 51/64
  - Backcheck Variation: Check Dart Removed
- RK Latch
  - Shear Pin: Inc 925

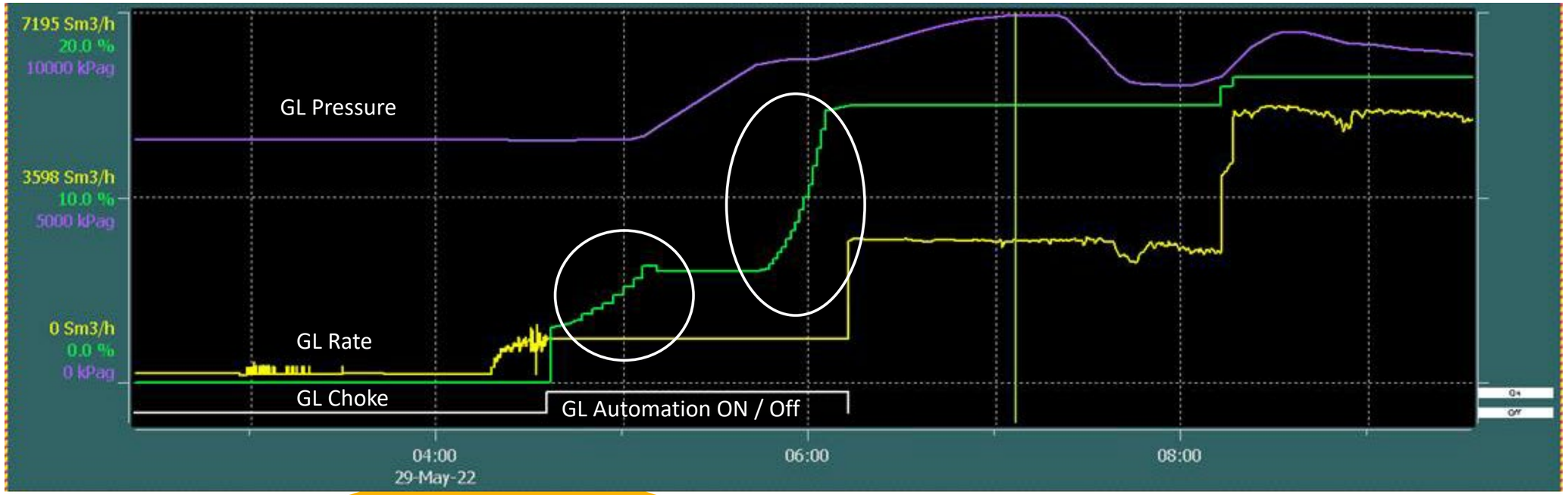
- Two check valves in two valve design.
  - One in each valve
  - Pressure imbalance created.
- New Configuration removes long valve check dart.
  - Combines barrier valve and operating orifice into a single Barrier



GLM Cross section

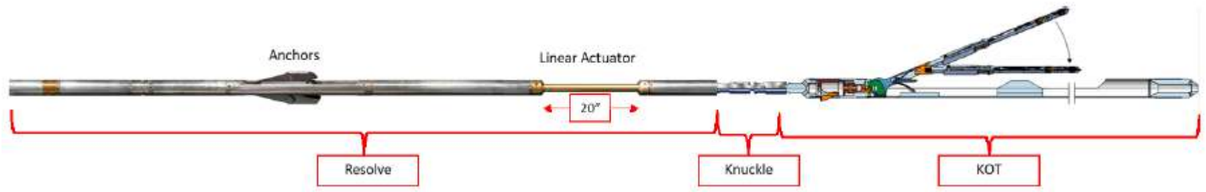
Automated Annulus Ramp Up

- Controlled choke opening / closing sequence to mitigate rapid pressure increase / decrease
- Mitigates valve shuttling/cycling inside pocket



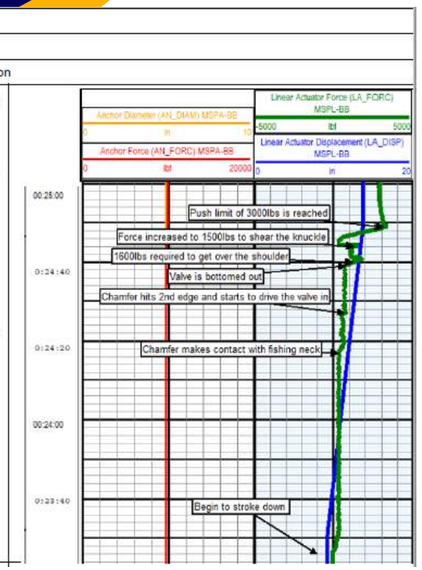
GLV SIT

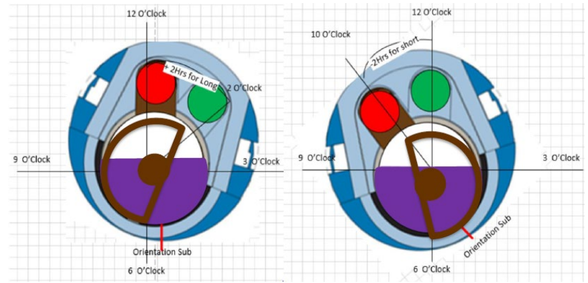
- Developed strategy for recovering short valve on top of long valve
  - Fish w WL stroker tool w KOT and modified JDS pulling tool
- Developed strategy for GLV changeouts w WL
  - Facilitate WL camera diagnostics between runs
  - Simulated KOT motions using WL stroker while logging forces and tool travel distance
  - Signatures documented for each KOT function; helix orientation, valve latch, shearing latch pin, etc.



Test 4	Pulling TCBV Valve
Orientation	3 O'clock
Pulling tool	Good DJD tool + 6 in extension

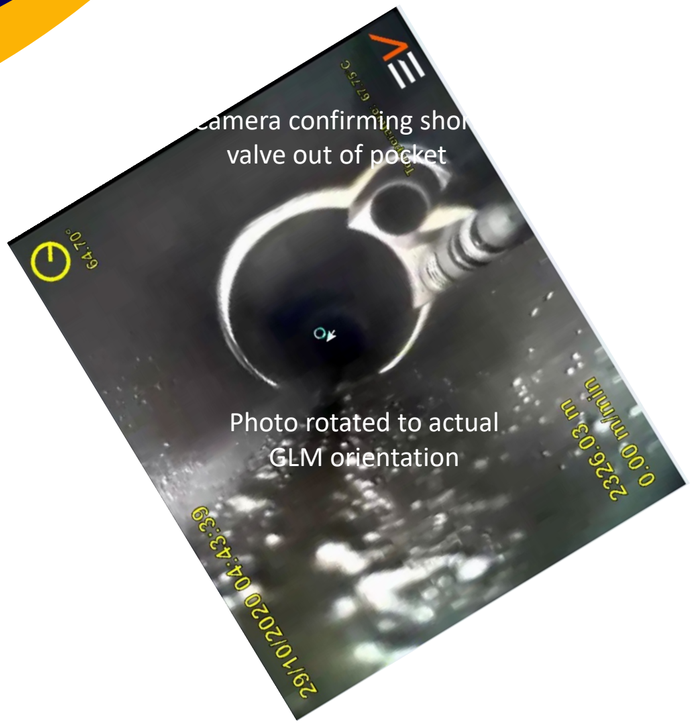
- DJD begins to travel down over the latch assembly
- Once the chamfer of the DJD skirt reaches the lower shoulder on the latch body the DJD pushes the latch down until it bottoms out
- After 1600lbs of push force is seen the DJD makes it over the shoulder, the dogs latch, and the knuckle shears all within a second
- The DJD continues to move down until a push limit of 3000lbs is seen and the tool stops.

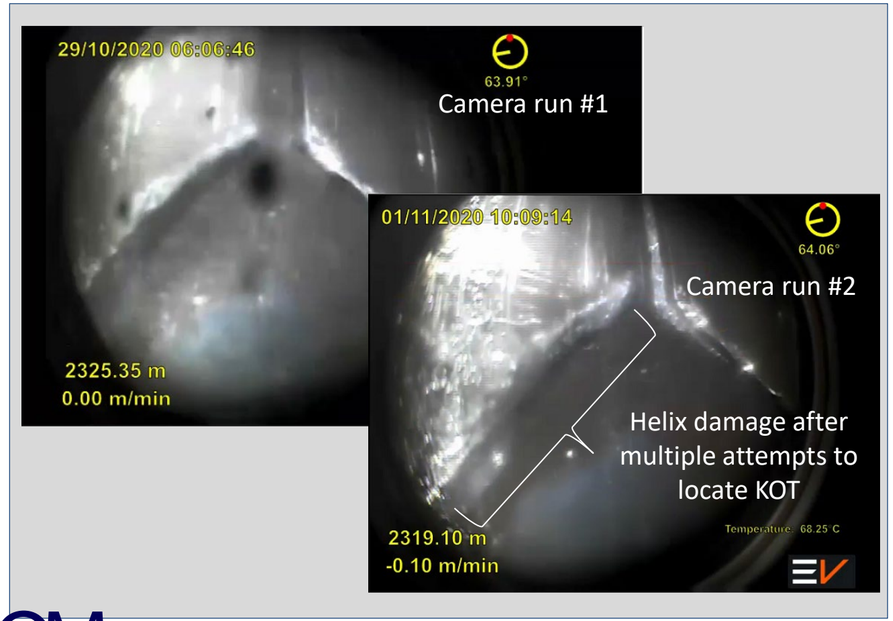




Case Study #3 – Well A GLV Replacement

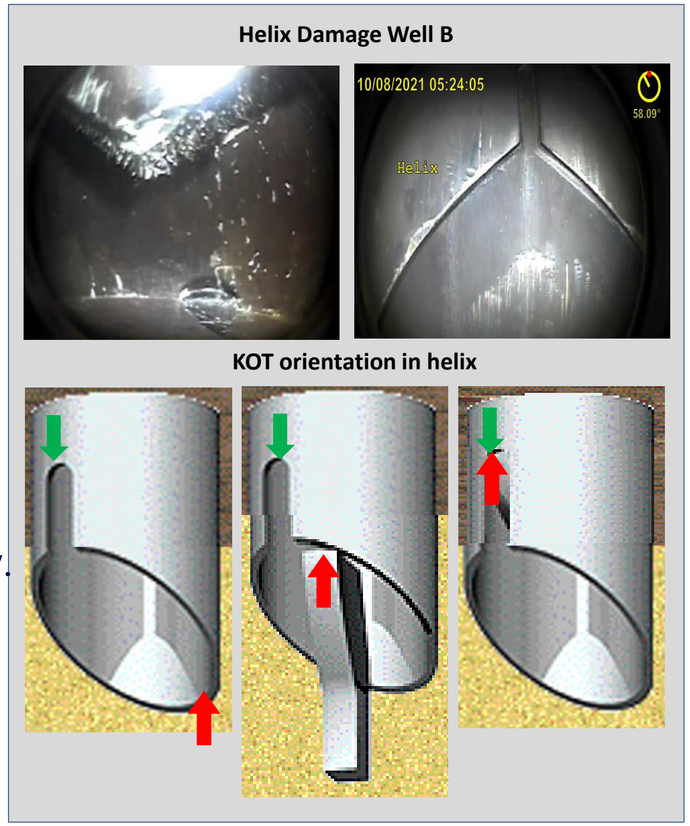
- Second event of Well A GLV
  - Strategy to reconfigure valves to function as a single pocket GLM
    - Further indicates initial root cause of shear pin installed incorrectly not underlying cause
    - Gas lift operation (annulus ramp up and bleed down) causing valve to cycle in pocket
- Camera run
  - Confirmed short valve completely missing from pocket
  - Operating valve in place, latch pin not sheared
- Multiple attempts to recover Operating valve w WL and SL
  - Observed helix damage; KOT likely not fully orienting
  - More favorable success with SL; due to the jarring type motion as compared to the slow controlled motion of WL tools
- Successful changeout and gas lift valves reconfigured



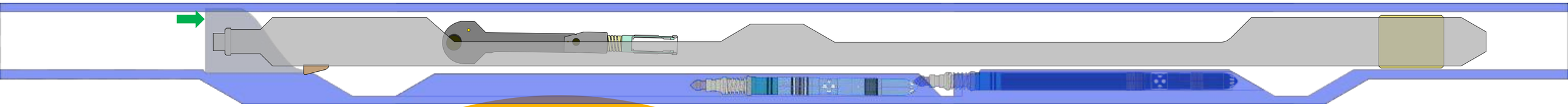


Case Study #2 – Well B – GLV Replacement

- Multiple attempts to recover short valve on top of long valve with WL & SL
  - Plan to recover short valve with WL stroker for 2 reasons:
    - Ability to measure stroke length on initial run to confirm barrier latch vs. operating latch (ie. confirmation barrier valve was still there)
    - Modified JDS to accommodate length of short valve on top of operating valve had the shear release mechanism removed, therefore WL release device added to BHA as a mitigator
  - Observed helix damage comparable to well A (different location)
    - Potential root cause for multiple fishing runs.
    - Another potential root cause was well geometry and its affect on the KOT orientating correctly.
    - KOT modified to reduce centralizer OD and locating top down rather than bottom up proved more effective mitigating helix damage and geometry interface
    - 6:00 GLM orientation proved to be most difficult for orienting KOT



KOT run in hole orientation



Wrap up

- Summary of findings from these events
  - Able to replicate valve cycling and confirm impact loading, unable to release valve in cyclic testing; Momentum testing showed shear pin sheared for low number of impacts
  - Difficult to replicate exact well conditions at valve to obtain conclusive results
  - Implemented automated GL pressure / rate ramp up and ramp down in contrast to original operating conditions
  - No subsequent events since learnings implementation (18 wells with Dual Pocket Mandrel's installed; 12 remain with original valve configuration)

- Wellwork operations
  - Slickline provides optimal downhole tool movement for GLV KOT operation
  - Camera log to confirm downhole conditions proved quite useful in well diagnostics
  - Orienting from top down, and reduced centralizer OD mitigates helix damage and potential geometry interface challenges

Acknowledgements/Thanks & Questions

- Michael Romer, ExxonMobil Principal Artificial Lift Advisor

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