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KIRBY SOUTH SAGD

2017 WELL INTEGRITY PERFORMANCE

Scheme Approval #11475

April 18, 2018

PREMIUM VALUE. DEFINED GROWTH. INDEPENDENT.

Agenda

1. 2017 Casing Integrity Summary
2. 2017 Casing Integrity Initiatives



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2017 KIRBY SOUTH WELL INTEGRITY SUMMARY

- No intermediate / production casing failures detected on any wells in Kirby South
- One well experienced a hole in the surface casing, at ground level, and the affected section of casing was replaced. Internal surface casing corrosion due to fluid presence inside the annulus was found.
 - Only small amounts of corrosion were noted on the outside of the intermediate casing. Protected with high temperature, metallic, coating before replacement of the surface casing.
 - Annulus filled with bentonite pellets after repairs
- Additional, external, casing inspections did not identify any wells with internal corrosion (UT measurements; compared to laser mapping of surface)



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**2017 KIRBY SOUTH
WELL INTEGRITY INITIATIVES**

- Performed visual checks on surface casing on 4 wells, test-coated in 2016, to verify coating integrity and performance.
 - A few minor coating holidays found, likely due to back-fill, but no degradation or other damage was noted.
- Inspected surface casing on 20 wells found in 2016 to have “high” or “very high” *visual* indication of at-grade external corrosion
 - Measured wall loss ranged from 6.1% to 68%
 - 3 wells found to have 50%+ surface casing wall loss; no internal corrosion noted
 - Rest of wells all <30% wall loss
 - Casings with measured wall loss >10% were coated with protective material over exposed section
- Updated CNRL’s Thermal Well Casing Integrity Protocol document to include SAGD operations.
- Created new CNRL Protocol document to address external, surface / intermediate, casing corrosion risk and its mitigation
- In Q4 implemented procedure to externally coat all surface casing strings on new thermal wells in Kirby S (top ~1.5m)

Example of Holiday on Original Coating

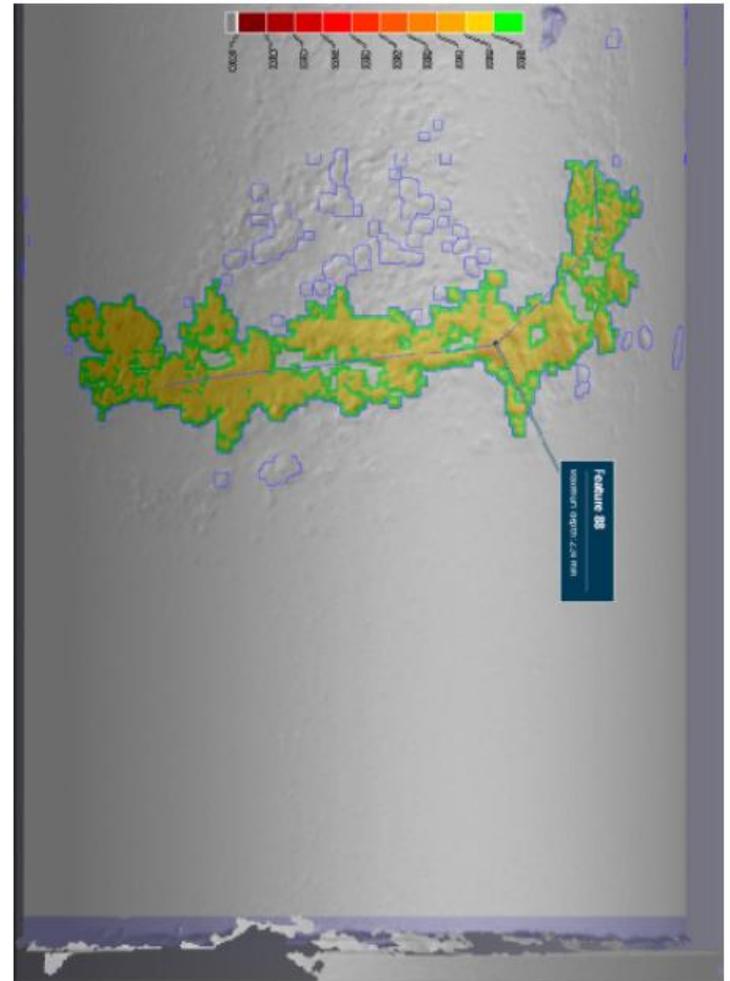
- Largest one of four holidays detected
- Approximately 0.5 x 1cm in size
- No corrosion on exposed surface; possibly caused during excavation
- Remaining holidays barely detectable by visual; confirmed by a holiday detector
- All holidays were re-coated



External Casing Inspection Process

- Excavate to approx. 1.5m to expose conductor top and corrosion-affected section of surface casing
- Abrasively clean surface to expose bare casing metal
- Perform circumferential laser measurement of wall loss over exposed section of casing
- Confirm worst spots with pit gauge and UT probe (the latter, if possible)
- Based on results:
 - Leave casing “as is”, or
 - Protectively coat corroded section, or
 - Cut out and replace affected section (based on allowable wall thickness criteria)

Extent of Corrosion Found



Pit Gauge Measurement



- Updated internal Thermal Well Casing Integrity Protocol document to ensure:
 - preventative casing inspection checks are carried out as appropriate,
 - pressure testing is done to highest operating pressure anticipated,
 - inspection tools are identified and criteria for use set, and
 - repair criteria are established and applied as appropriate.
- Issued new internal Thermal Well External Casing Corrosion Management Protocol document to address preventative inspections and corrective measures for surface-based corrosion risk to establish:
 - inspection frequency of wells,
 - inspection process and methodology,
 - corrosion criteria for mitigation measures to be applied,
 - how mitigation (coating) / repairs are to be done, and
 - future inspection obligations based on prior corrosion history.
- Implemented staff training on new requirements in head office and at field operations.

- Casing connections must reliably seal over repeated thermal cycles:
 - Good industry experience with connection in the required service, or connection qualified for the service
 - Careful monitoring of casing connection torque during make-up, and avoidance of low-cycle fatigue exposure risk (limited, or no, rotation of casing during cementing)
- Appropriate primary cement job design essential to obtaining good cement bond and hydraulic isolation:
 - Cement density vs. risk of lost circulation
 - Pre-flush rate / volume / composition to remove as much mud as possible
 - Cement circulation rate / volume to obtain full circumferential coverage and bond
- Placement of connections in stable formation zones, if localized formation thermal destabilization is a known risk.
 - Avoid connections at formation boundaries
 - Place connections away from known shear or weak zones (to the extent possible)
- Prevent water entry into surface casing annular space
 - Use external shield or pack-off to prevent rainwater / snow from getting in

- Manage well integrity on the basis of the most severe, expected, operating conditions:
 - Pressure-test casing to maximum operating pressure (with thermal de-rating applied)
- Develop an overall Project Well Integrity Management Protocol document that sets out preventative monitoring, inspection, analysis, and repair requirements / procedures:
 - Establish appropriate check frequency for wellbore integrity and corrosion [internal and external]
 - Outline acceptable inspection processes / when to use
 - Outline remedial options based on nature of risk and when to apply
 - Identify frequency of follow-up checks
 - Create a data tracking system for results and next inspection.
- Develop operating procedures to address potential risks to assets:
 - Wellbore warm-up procedure (circulation start-up in SAGD)
 - Minimum wellbore kill fluid temperatures



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