FLAGS PIPELINE IN-LINE INSPECTION

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- Ram Subramanian, Pipelines & Subsea Technical Support Engineer, Shell
- Tom Steinvoorte, Business Development, ROSEN

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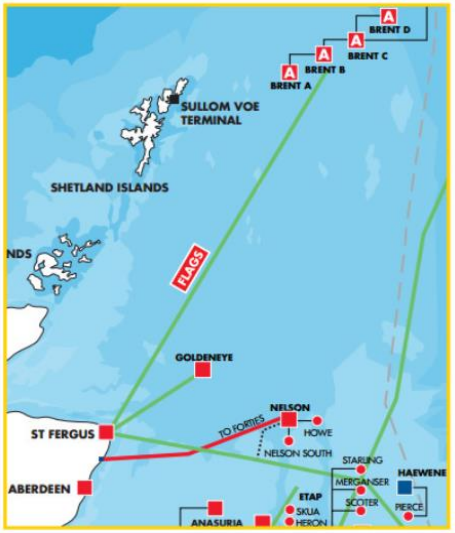
BACKGROUND

FLAGS (Far North Liquids and Associated Gas) pipeline system

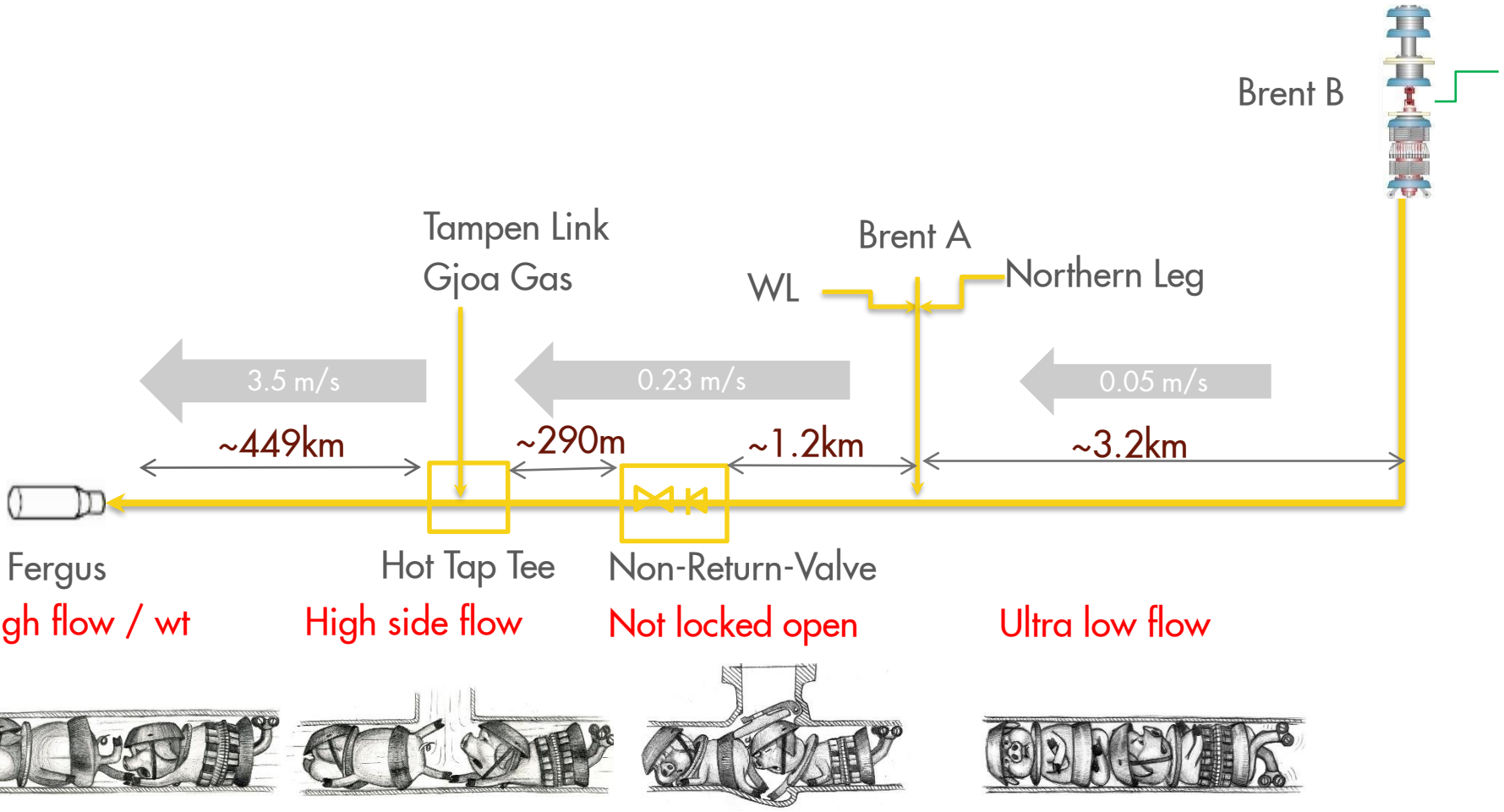
- Shell UK operated 36" x 450 km offshore dry gas pipeline that runs from Brent Bravo to St Fergus gas terminal
- Pipeline transports processed gas from UK and Norwegian North Sea platforms
- Operated in dense phase mode between 120 – 135 barg and 15-25 deg C
- Supplies about 15% of UK's gas consumption and a strategic asset for Shell UK

- Pipeline previously in-line inspected in1991 & 2006.
- Opportunity identified to bring in-line inspection using Magnetic Flux Leakage (MFL) forward to 2017 to:
  - Avoid significant complexity, cost and risk associated with subsea pig launch post Brent Bypass Phase 2 (~$$10MM savings)
  - Demonstrate integrity to stakeholders to retain and attract future business for Northern Systems and Plant (NSP) asset



PIGGING CHALLENGES

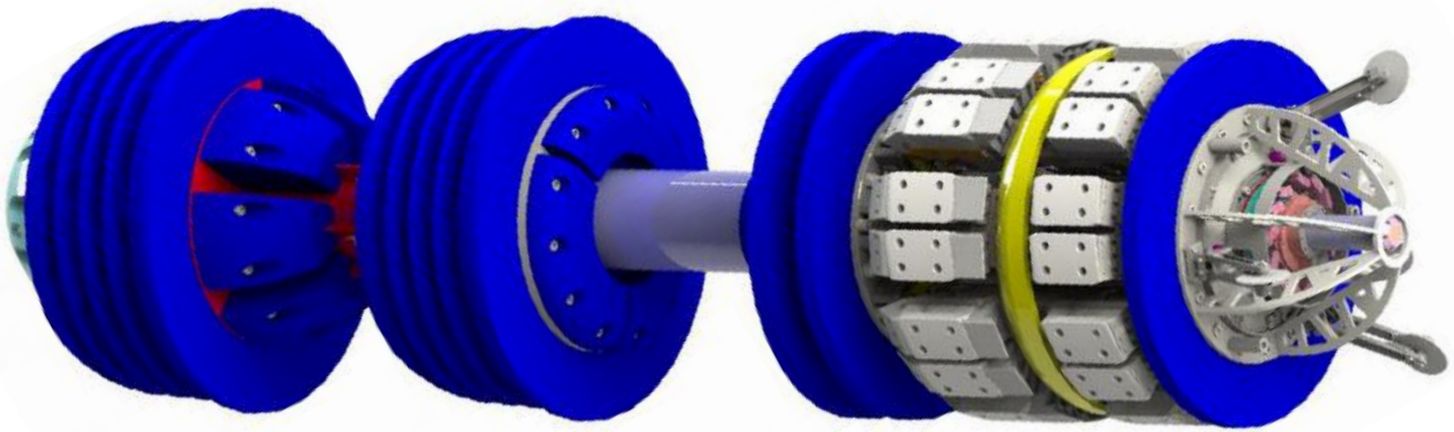
Why pigs don't like this pipeline



SOLUTIONS

- 4 x sealing capacity / low friction vs normal pig to ensure sealing at **ultra low flow*** conditions.
- Bespoke design to open and traverse check valve without damage to pig
- Dual module design with each module capable of driving on its own
- Reduced flow through hot tap tee to safeguard mechanical integrity of pig
- Maintain minimum landing pressure at St. Fergus to ensure dense phase gas throughout pigging operations (prevent liquid drop out).

***Shell Group first / potential industry first**

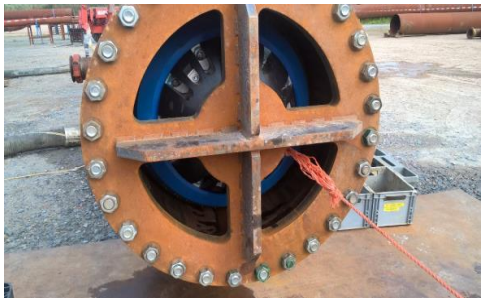


FACTORY ACCEPTANCE TEST (FAT)

Comprehensive FAT was carried out to demonstrate tool performance

1. Mechanical Test wrt. Passage Capability / Impact Resistance

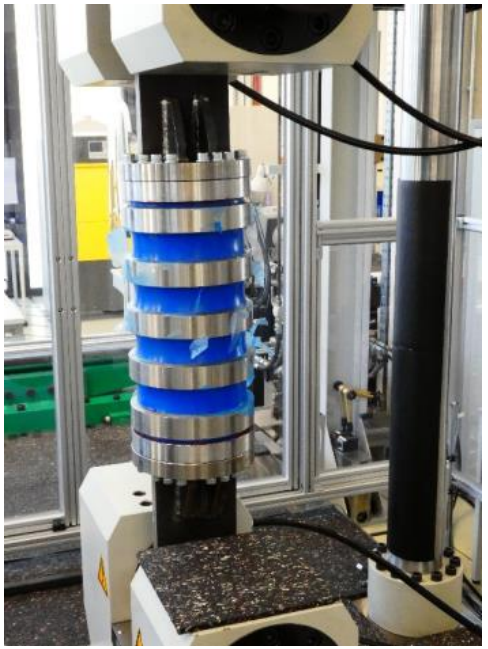
- Check Valve Simulation (Cleaning Tool/MFL tool)



2. Differential Pressure Evaluation / Propulsion Forces / Seal performance

- Propulsion Forces for Cleaning Tool & MFL modules (front / rear)
- Sealing performance and bypass behaviour (flip over test) for all pig modules

3. Tensile strength test of newly developed semi stiff joint to proof it can withstand force resulting from side flow (>60 tons) .



4. Side Flow Simulation (Hot tap tee passage)

Shell

EP201706207747

FAT – MFL SIDE FLOW TEST RESULTS

Side Flow Simulation (HTT Passage)

- Passage of both tools with side flow of 300 L/s water @ ~1cm/s

  $E \propto mv^2$, $v_g = 2.87 \times v_w$

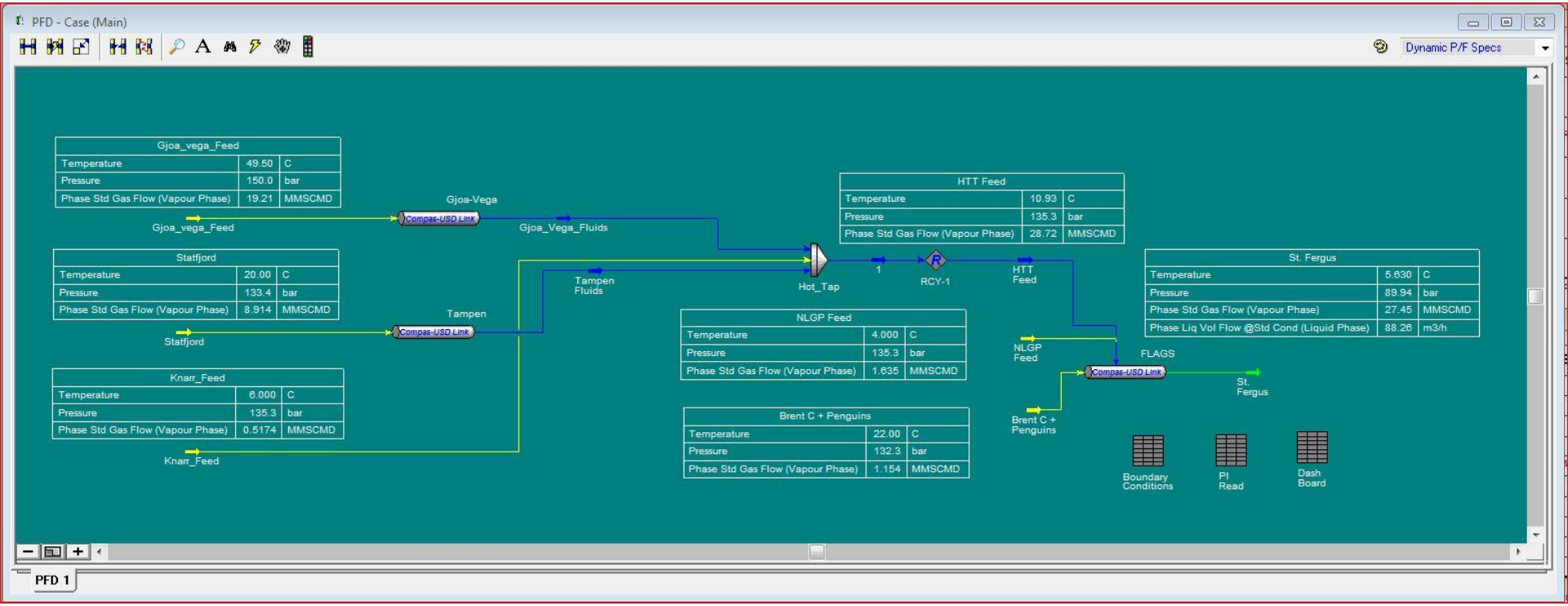
  for 16" side port, $v_w = 2.1$ m/s, $v_g = 6$ m/s

  for 6" side port, $v_w = 15$ m/s, $v_g = 43$ m/s

- Acceptance criteria:
  - The foreseen acceptance criterion is two consecutive instrument passages without functional damage.
- Results:
  - Two sensors at the 12:00 position found to be "clicked into" a gap underneath the magnets.
  - Consequence during actual run would be loss of these two sensors

ROSEN determined this as a design flaw and re-positioned the sensor ring to eliminate this problem. Subsequent test proved this design to be optimal.

UNISIM DESIGN MODEL SETUP

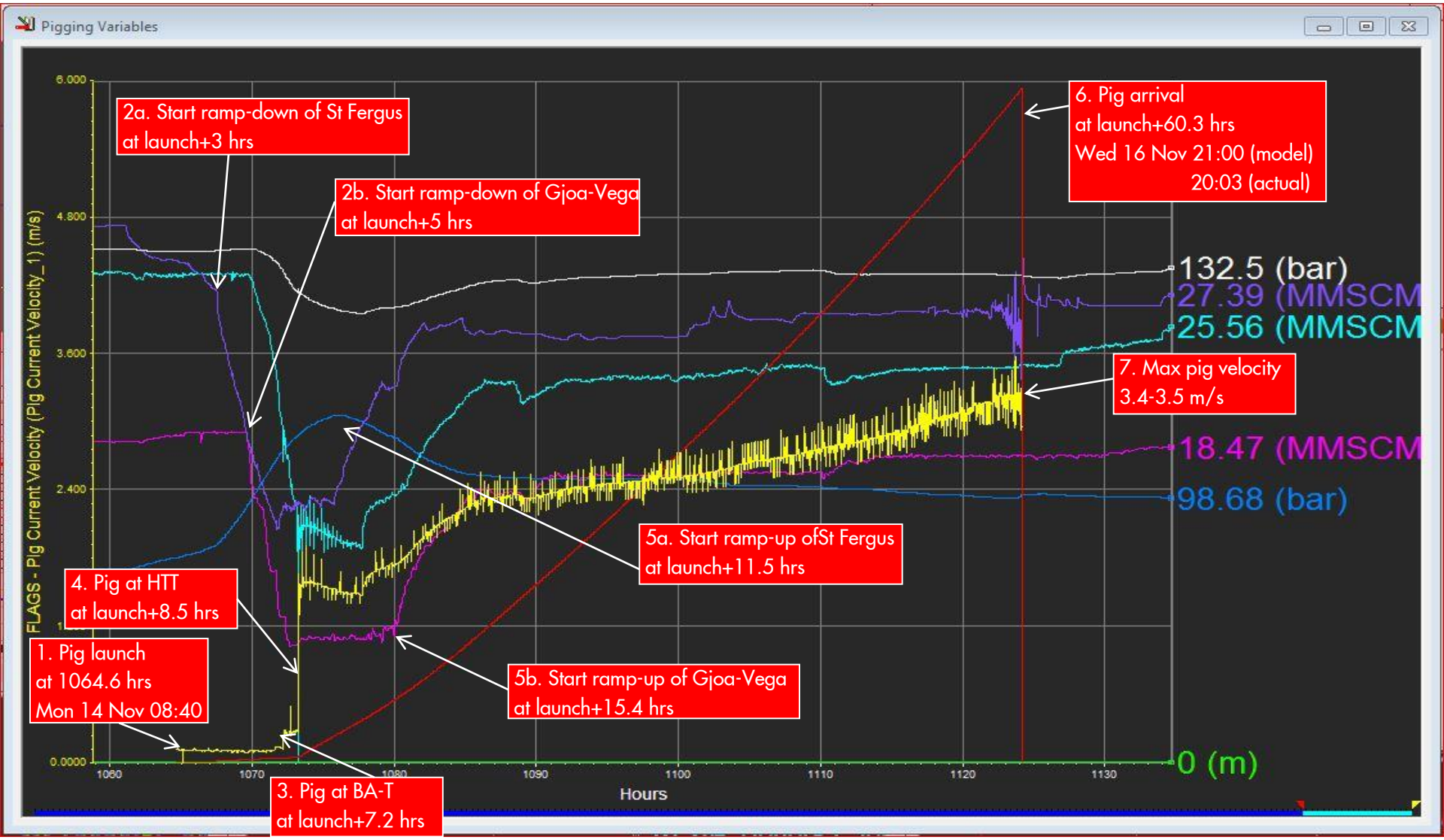


- Key Model Components:
  - FLAGS Pipeline (compas)
  - Gjoa-Vega Pipeline (compas)
  - Tampen Link Pipeline (compas)
  - PI Read (USD spreadsheet)
  - Boundary Conditions (USD spreadsheet)
  - Dash Board (USD spreadsheet)

- Benefits of model in this case:
  - Live tracking of pig travel
  - Used as a basis for reducing HTT flow
  - Helps quickly identify anomalous condition (i.e. stuck pig scenario)
  - Monitor system flows

SIMULATIONS – LIVE PIG TRACKING

Live Pig Tracking Simulation Trends for Cleaning Pig Run (Brent B flow 1.0-1.1 MMSm^3/d)



PIGGING RESULTS

Cleaning pig

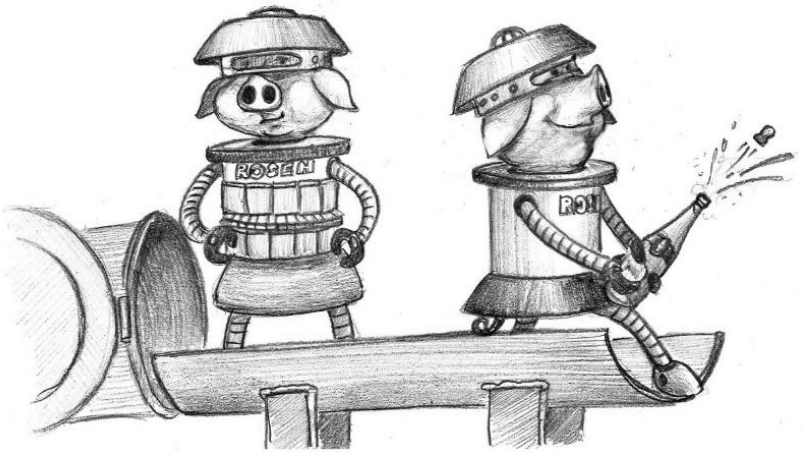
- Overall tool condition good upon receive
- Tool removed minimal dust / ferrous debris
- Gauge plate had a small deflection of 2mm likely to be caused by mechanical pig signaller
- No further cleaning / gauging runs were required prior to MFL tool

MFL pig

- Tool in good condition upon receive
- Ferrous material collected on magnets upon recovery
- Minimal wear to front seals
- Sludge type debris received in front of tool
- In-line inspection (ILI) data acceptance criteria was met
- ILI final report received with presence of no significant internal corrosion

CONCLUSION

- The IP Project was successfully completed safely and under budget.
- Planning key to getting it right first time.
- Complexity of low flows and presence of in-line components meant a comprehensive FAT was required with adequate Factors of Safety (test medium – water)
- Early engagement with stakeholders, especially for reducing HTT flow.
- Shell and ROSEN teams operated as “one team” right from the start
- My reflections:
  - Establishing key success factors: Pig launcher / receiver readiness, Site visits, HAZID, Pig on Paper, Pro-active stakeholder management, Go/No-go meeting, facilitating behaviours, contingencies, risk management, controls, incident management



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