Case study of challenging inspection of Offshore gas pipeline in the Black Sea

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GE Oil & Gas
PII Pipeline Solutions
BSPC - Pipeline Details

• 56” & 48”
• 24” Interconnector Pipelines 380 & 387 Km
• Depth max 2140m (7021’)
• Pressure 250 bar (3625psi)
• 7D bends
• 32mm wall thickness
• Ball Valves
• Barred Tees
• Reduced bore Tees – dia 505mm (83% of OD)
• Buckle arrestors 47mm WT
• Internal epoxy coating
• Flow ~ 2.5m/s
Blue Stream Pipelines Layout

Transportation System

- 2 Lines x 24” – Built 2001
- Overall Length 768 km
- Max Depth 2150 m
How the Key project issues were addressed

The BSPC Pipeline

Main challenges …
• Wall Thickness of 32mm
• Reduced bore passing – Flow Tee near receive (83% of OD)
• Pressures ~Pipeline Operating Pressure 250bar (Tool Design of 400Bar)

Client concerns …
• NO STUCK TOOLS!
• NO damage to internal coating
• Durability for >385Km

Project Scope of Work
• Cleaning
• Caliper
• Mapping/Strain
• MFL inspection
• Pig RECOVERY TOOL or Rescue Pig

Feasibility Study, Engineering Proof & Tool Build, Project Execution
## Problem Statement

Snamprogetti S.p.A contracted as Lead Engineers responsible for engineering support for the IM programme by the Blue Stream Pipeline Company (BSPC)

<table>
<thead>
<tr>
<th>Caliper</th>
<th>Mapping</th>
<th>Inspection System</th>
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</thead>
<tbody>
<tr>
<td>• Pressure</td>
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<tr>
<td>• Pressure vessel integrity</td>
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<td>• Wall Thickness</td>
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<tr>
<td>• Hall Effect sensors</td>
<td></td>
<td>• Buckle arrestors</td>
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<tr>
<td>• Data storage range</td>
<td></td>
<td>• Range</td>
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<tr>
<td>• Capacity</td>
<td></td>
<td>• Bore passing</td>
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<td>• Power range</td>
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<td>• Flow velocity</td>
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<tr>
<td>• Capacity</td>
<td></td>
<td>• Trap Dimensions</td>
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</table>
Experience from PII subsea projects.

- **Client:** Statoil Asgard  
  **Project:** MDPT 715Km 28-42"

- **Client:** Statoil Vesterled  
  **Project:** MFL 360Km 32"

- **Client:** Shell Flaggs  
  **Project:** MFL 450Km 36"

- **Client:** Conoco Phillips  
  **Project:** MFL 354Km 34"

- **Client:** Statoil Europipe1  
  **Project:** XHR 620Km 40"

- **Client:** Franpipe  
  **Details:** XHR 840Km 42"

- **Client:** Interconnector  
  **Project:** MFL 238Km 40"

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Up Front Feasibility Study

- Identification of all pipeline data, plus any assumptions caused by missing data.
- Identification of proposed solutions
- Identification of predicted inspection specification, to be ratified by testing.
- Identification of pigging resources and any testing requirements.
- Identification of possible cleaning pigs/tools available.
- Suggested pigging methodology/schedule. Site Surveys completed in Russia & Turkey
- Identification of cost/timeline to undertake modifications and testing.
  - Cleaning
  - Geometry & Mapping (Strain or Out of Straightness assessment)
  - MFL Inspection
  - ALL above with Pig Recovery Strategy

- Costs and timescale for the BASELINE & subsequent INSPECTION
Engineering proof of Challenges

- Drive & Sealing
- CAD simulation and Magnetic Modelling
- Pig Recovery Strategy
- Location & Tracking (New Concern from the site survey)
- Pipeline Pressure
- Design Verification Testing
- Software & Pipeline Sentencing

Milestones with agreed testing criteria at every stage
Drive & sealing

• Bypass & blow over tests required to ensure the multi diameter sealing arrangement is effective is all pipe sizes
• Designed in provision for a secondary drive element behind the MV on the BV to improve Drive Reliability
• Magnetiser locked down in 24” mode to suit BSPC application
CAD simulation

- Skeleton modelling completed to allow flexible MV - quick change approach modelling & simulation through the bends & Tees
- Magnetic modelling of FLUXBLOCKER return path to optimise magnetic circuit
Blue Stream Magnetic Modelling

CAD 3D Model of BSPC Magnetic Vehicle

Model prepared for Finite Element meshing and analysis in 24” configuration

UNITS
- Length: cm
- Magnetic Flux Density: gauss
- Electric Field: V/cm
- Conductivity: S/cm
- Current Density: A/cm²
- Force: N
- Energy: J

PROBLEM DATA
- TOSCA Magnetic Field
- Non-linear materials
- Simulation: 1 of 1
- 16,342,366 elements
- Fixed/Free modes
- Model: interpolated fields

Local Coordinate: 0,0,0,0,0
Local XYZ - Global XYZ
## Wall Thickness Capabilities

<table>
<thead>
<tr>
<th>Pipe Diameter</th>
<th>Predicted Min. WT / mm (Inch)</th>
<th>BSPC Min. WT / mm (Inch)</th>
<th>Predicted Max. WT / mm (Inch)</th>
<th>BSPC Max. WT / mm (Inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 Inch</td>
<td>13.70 (0.539)</td>
<td>25.4 (1.000)</td>
<td>38.10 (1.500)</td>
<td>32.0 (1.260)</td>
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</table>

* Pull Throughs required to verify top inspection speed for 32mm thickness inspection and static field measurements

Test results demonstrated that the Magnetic Circuit was capable of inspecting 32mm WT @ 2m/s
Buckle Arrestor Static Modelling

UNITS
Length cm
Magnetic Density gauss
Magnet izat佛法 cm
Magnetic Field Gauss cm
Magnetic Vector Point Gauss cm
Electric Field V/m
Electric Charge C
Conductivity S/cm
Current Density A/cm²
Power W
Force N
Energy J

PROBLEM DATA
agnet1.cora_3D.magnets.cora
1.000A Magnetization
Non-linear materials
Simulation No 1 of 1
275001 elements
59201 nodes
Nodal interpolated fields

Local Coordinates
Origin 0.0, 0.0, 0.0
Local XZ = Global XYZ

VECTOR FIELDS

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Buckle Arrestor Static Modelling
Buckle Arrestor Static Modelling

- Field level drops significantly in region of Buckle Arrestors
- Inspection not possible
- But … plan is to model and investigate as part of the project
BSPC 24” Magnetic Vehicle

Design to Build…
Dual Diameter drive flaps
Strongest Commercial magnets
BSPC Instrument Vehicle Tool
Battery Vehicle
Pig recovery strategy

• Semi rigid towbars designed & developed to ensure that the 3rd module (rearmost) in the train could push the high drag MV through the bore reduction or in the unlikely event the main drive elements failed.

• Provision to be able to drive the tool from the rear with a Recovery Pig should the main drive elements fail – CRITICAL for successful pig recovery.
Rescue Pig
Location & Tracking

- Electromagnetic Transmitter (22Hz) fitted to the tool as standard
- Magnetic sensitive timer boxes used at strategic positions on the ONSHORE pipeline sections
- Acoustic monitors fitted to both the Launch & Receive sites to enable tracking of the pig position
Pipeline Pressure 250bar

- External harnesses & sensors tested to extremes of pressures & tested & rated to 400 Bar
- Overlapping sensors to optimise the sensor spacing in the various bores
- Magnetic modelling and simulation to ensure overlapping sensors (Circumferential & Axial) were optimised for the magnetic profile
Design Verification Testing

Component & Sub Assembly Testing

• Pump through tests done to successfully demonstrate passage through simulated bore fitting
  – Would have been better performed with an actual flow tee but the mock ups were essential that these tests were done in advance of mobilising
  – Palladin Dock facility used for pump throughs

• Pressure & temperature tests completed on new sensor arrangements

• Sensor dynamics testing
  – Vibration
Reliability Testing

• Pressure testing of sensors and external electronics to ensure suitability
• Vibration & Bump
• Temperature
• ESD* 18Kv
System Testing

<table>
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<tbody>
<tr>
<td>Initial testing done at PII</td>
</tr>
<tr>
<td>FULL SCALE Testing using actual pipeline fittings</td>
</tr>
<tr>
<td>Reliability Testing</td>
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Video
Software & Pipeline Sentencing

• Dynamic sentencing, due to the varying forces on the pipeline.
• Internal Gas Pressure
• External Water Pressure
• Software & Calculations agreed with BSPC & Snamprogetti
Project Summary

• The two pipelines were successfully inspected & reported to BSPC
  – Tracking method using acoustic monitoring at Launch and Receive sites proved successful
    Tools received on time as predicted
    • Credit to Saipem (Technical Project Consultants) for computation of run times
  – Recovery Pig was not required due to the successful running of the other tools

• Lessons Learnt - Licences, Permits, Import & Export time and complexity
• Setbacks - ESD, Sensor & MV Design
• Milestone & Feasibility/Engineering Proof Stages
• Project was successful, credit to the openness & cooperative approach by BSPC & their partners.
References & Many Thanks:

Massimo Volipini, Technical Manager BSPC
Claudio Monda, Project Manager SCS
Bill Herron Chief Engineer GE PII Pipeline Solutions