SLOFEC™ LS150 & ULTRASONIC VESSEL INSPECTION

Client: Client

Facility: Client’s Facility

Items Inspected: BT Vessel

Inspection Method: SLOFEC™ & Ultrasonic's

Date Commenced: 13th January 2014

Date of Completed: 18th January 2014

Type of Report: Final Report

Report Number: K0xx-13/Jxx22
<table>
<thead>
<tr>
<th>Client/ Facility</th>
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</tr>
</thead>
<tbody>
<tr>
<td>BT Vessel</td>
<td>Final Inspection Report</td>
<td>K0xx-13/Jxx22</td>
</tr>
</tbody>
</table>

**SLOFEC™ LS150 & MANUAL ULTRASONIC VESSEL INSPECTION REPORT**
Executive Summary

As requested by Client; Innospection has carried out a SLOFEC™ (Saturation Low Frequency Eddy Current) inspection, on the Vessel identified as BT.

The inspection was conducted at the Client’s Facility, from the 13th of January 2014 and completed on the 18th of January 2014.

This inspection report documents in detail the specific inspection that has been conducted; the individual technique and equipment utilised, and the results, observations and conclusions obtained.

This SLOFEC™ inspection indicated internal indications primarily at the 5-7 o'clock locations; with wall losses indicated up to and greater than 50%, of the original nominal manufactured wall thickness.

The corrosion appeared to be that of internal pitting, that was noted wide spread and most severe across the middle lower sections of this vessel. Random spot checking with Ultrasonic around the dome ends, nozzles, branches, take offs and SLOFEC™ scanner dead zones, also showed areas of wall loss present.

The lowest ultrasonic wall thickness measured, was found in zone 2 (please see the included appendix mapping), where a result of 3.6mm remaining wall was indicated.
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## Appendix

Appendix 1 : Section Track Scan Overview & Zone Scan Reports
Appendix 2 : Ultrasonic Thickness Results
1. **Test Object Data**

   Object Identification : BT Vessel

   Location of Object : Client’s Facility

   Orientation of Scan : Longitudinal

   Wall Thickness : Nominal 9.5 mm

   Material : Carbon Steel with a painted coating.

   Surface Condition : Generally clean and free from loose debris.

2. **Inspection Task**

   As requested by Client, a SLOFEC™ (Saturation Low Frequency Eddy Current) inspection was performed on the BT Vessel located at the Client’s Facility from 13/01/14 to 18/01/14.

   The inspection was performed with a SLOFEC™ technology scanner, type LS150.

   SLOFEC™ is regarded as a fast corrosion screening technique, detecting corrosion on either side of the wall inspected. This method of testing makes it practical to inspect storage vessels from the external surfaces, whilst they are still in service and at operating temperatures.

   The SLOFEC™ inspection team consisted of qualified engineers from Innospection Ltd.

   All areas described in Section 4 – Inspection Volume were inspected with the SLOFEC™ Scanner.

   The inspection was to survey for evidence of internal and external corrosion.

3. **Inspection Personnel**

   Lead
   Inspection Technician : Technician a, ET PCN level 2, UT PCN level 2 / 000000

   Inspection Technician : Technician b, ET PCN level 2, UT PCN level 2 / 000001

   Assistant : Technician c, ET PCN level 2 / 00002
4. **Inspection Volume**

The SLOFEC™ Scans were intended to be taken over 360º coverage of the general vessel body. Weather and time constraints lead to 6 specific zones being inspected (as per the appendix). The seam welds including the heat affected zones were not scanned.

All accessible areas of the vessel were targeted for inspection with the exception of specific dead zones, which could not be inspected due to the design of the scanner (i.e. the wheels of the scanner butted against weld beads).

The Dead Zone refers to the following areas:

a. 15 mm on either side of any weld
b. 15 mm on either side of any nozzles/off takes

5. **Inspection Equipment**

5.1 **SLOFEC™ Equipment**

The inspection system consisted of the following SLOFEC™ equipment and accessories:

- **Scanner:** SLOFEC™ Scanner LS150 (width 150mm)
- **Description of Scanner:** The SLOFEC™ Scanner LS150 is a handheld system equipped with permanent magnets and multiplexed electronics. 8 sensors each with a width of 18.75mm are located between the pole shoes. A trigger encoder is connected via a belt drive to one wheel. 2 wheels at the front and 2 wheels at the rear are adjustable in height for lift off.
- **Scanning Speed:** 100% (approx.: 24m/min)
- **Eddy Current Instrument:** IBM-AT-compatible computer with 2-frequency Eddy current plug-in cards.
  - **Type:** eddyMax - EMC07/08.03
- **Eddy Current Sensors:** 8 x EC-B-18.75mm
- **Software Version:** EddyMax Eddy Current Multiplex Software With trigger use – SN 20000997 TMT
  - **Version:** 5.07.07.20
- **Cable:** 30 metres of specific cable connection between the computer eddy current instrument and SLOFEC™ Pipe Scanner LS150
- **Reference Plate:** 9.5mm from Innospection – S/N 265
- **Reference Defect:** 20%, 40%, 60%, 80% FBH
5.2 Ultrasonic Equipment

The Ultrasonic Equipment consisted of the following accessories:

GE – USM GO Ultrasonic Flaw Detector capable of both “A” scan display and digital thickness readout - USMGO09110981
5 MHz 10mm Ø twin crystal transducer
2mm – 12mm carbon steel calibration step wedge

6. SLOFEC™ Equipment Setting

In general, the SLOFEC™ system is calibrated using sample test samples with artificial reference defects. The reference samples should be of the same material and thickness as the surface to be inspected.

In the case of a coating being present on the surface to be inspected, the average thickness of the coating (if applicable) should also be simulated on the reference sample for the calibration.

Typical reference defects that are used are flat bottom holes or conical bottom holes are with a diameter of 5mm, 10mm and 20mm.

The depths of the artificial reference defects are typically 20%, 40%, 60%, 80% and 100%.

For calibration, the SLOFEC™ system is driven over the reference defects and the channels are set (one sensor per channel) to give a sufficient sensitivity level for the detection of topside and underside corrosion defects.

The calibration is performed at beginning, after breaks, at the end of every shift or in the case of changes to the equipment.

The calibration results and reference defect data from the calibration sample, is always stored in the system.

The Eddy Current signal analysis is done online. The computerised equipment and the software allow the analysis of the signal amplitude [in div.] and signal phase [in °].

In discussion with the individual client, indications comparable with the reference defect indications can be marked on the floor and are usually recommended to be re-inspected by Ultrasonic examination.
7. **SLOFEC™ Equipment Calibration**

7.1 **Equipment Calibration**

For internal corrosion detection, the differential mode was used. The frequency setting used for Channel 1-4 (differential mode) was 80 - 100 KHz.

The amplitude of the signals was set so that the artificial reference defect (Ø 8mm 80% depth) was set to 8 screen divisions. This is only classed as the initial pre-calibration setup and may then be further adjusted when the first true indication is detected and evaluated for depth, this by utilising the Ultrasonic pulse echo technique.

Optimum signal/noise ratio and signal phase separation between the internal defect indications and other indications were considered when selecting a suitable test frequency.

The differential channels of all the sensors were set so that internal defects were indicated in the vertical signal phase direction as shown in the diagram below. By moving the scanner in the positive forward direction, the internal defect signal would show the first peak down, followed by the second peak up with an upward movement.

![Sample signal display of internal defect](image)

7.2 **Calibration Control**

The general setting and calibration was performed at the beginning of the inspection, with all calibration data being stored digitally. Calibration controls were performed at the beginning and end of each working shift and after any other significant interruption (i.e. breaks or lunch). Re-calibration is also deemed necessary when significant changes are made to the settings of the equipment.

Calibration samples are used for the initial set-up and for the random check of operator’s settings. Accuracy of sensitivity settings can only be evaluated and achieved, when the first true indication found on the item undergoing the test is verified by a U/T operator, with the corresponding depth of indication and SLOFEC™ sensitivity being adjusted accordingly. With this setting, external corrosion defects would be detected and distinguished by phase separation from the internal defects.
7.3 **Calibration Samples**

The calibration samples are manufactured by Innospection Ltd in accordance to the setting standard requirements.

7.4 **Change of Settings**

In the event of any scanner adjustment, re-calibration is performed.

8. **Inspection Procedures**

The inspection was performed according to the following valid procedure:

SLOFEC Vessel Procedure No. InnoVSloVes-001-08 – Current Issue

9. **Inspection Performance**

9.1 **Scanner Movement**

The scanner assistant, who was in permanent communication with the SLOFEC™ operator, was responsible for positioning and moving the scanner on the pipe surface. The SLOFEC™ Scanner LS150 is marked clearly on the top with the FORWARD and BACKWARD directions so that all scan directions are made clear to the operator and assistant at all times. In addition, some visual contact between the operator and assistant was established during the inspection.

The scanner was moved manually with the scanned tracks being overlapped at all times.

All scans for the inspection were recorded in the forward position.

9.2 **Scan Track Positioning**

The six vessel zones inspected were marked circumferentially into equal tracks.

9.3 **Parameter Storage**

The Eddy Current testing parameter was set during the calibration and digitally stored according to the scan direction and lift off.
10. **Defect Analysis**

All indications which showed a clear signal phase direction similar to that of the reference defects and had signal amplitude equivalent to that of the test piece were subjected to analysis. Signals that are clearly out of the corrosion phase direction were not reported.

11. **Comments to Inspection**

It is recommended for future inspections that a canopy be erected over the vessel, before the inspection start date. The weather caused significant delays during this particular inspection. Also preferably the vessel bund area should also be emptied of water before inspection. The cleaning status of the vessel surfaces was found suitable for inspection. The general external surface was painted and in very good condition.

12. **Sensitivity Setting**

The general overview of the inspected areas with the results is presented in the attached colour scan reports with wall loss being represented in colour classes as shown in the Wall Loss Legend below:

![Wall Loss Legend]

- Below 20% wall loss - Grey
- 20-30% wall loss - Green
- 31-40% wall loss - Blue
- 41-50% wall loss - Yellow
- Above 50% wall loss - Red

**Note**

Eddy Current inspection is an evaluation method of NDT; hence all results obtained are based upon the test piece used. Material and wall thickness of the test piece should be as near as reasonably practicable to the item under inspection. Artificial defects should be as near in size and shape as to the type sought.

Because SLOFEC™ signal amplitudes are an indication of defect depth and volume, the defect depth analysis by signal amplitude can only be done in comparison with artificial reference defects having varying depths.
13. **Inspection Summary**

Significant internal corrosion was discovered during this vessel inspection.

The maximum wall loss found present was 50%>, with the minimum ultrasonic wall thickness result recorded in zone 2 being 3.6mm remaining wall.

The most severe wall loss was seen in the bottom half (5-7 o’clock) of the vessel and concentrated in the middle inspected section. The characteristic of the corrosion was determined to be corrosion pitting.

14. **Documentation**

The inspection result, parameters and data are stored in the Innospection Limited archive database system.

15. **Signature**

Lead Inspection Technician a
Inspection Technician
Innospection Limited

Senior Engineer Level 3
Inspection Technician
Innospection Limited
APPENDIX 01

SLOFEC Scan Report
# SLOFEC™ Vessel Scan Report

<table>
<thead>
<tr>
<th>Client Plant</th>
<th>Client Facility</th>
<th>Date</th>
<th>Subject Identification</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>BT Vessel</td>
<td>Innospection limited</td>
</tr>
</tbody>
</table>

**Inspected Areas**

**BT Vessel Viewed from the North**

- **Zone 1**
- **Zone 2**
- **Zone 3**
- **Zone 4**
- **Zone 5**
- **Zone 6**

**LOWEST RECORDED ULTRASONIC THICKNESS MEASUREMENT, TAKEN WITHIN THIS ZONE**

3.6mm REMAINING WALL THICKNESS

(ORIGINAL NOMINAL WALL THICKNESS 9.5MM)

---

(Plan) Full Circumferential Internal Opened Out View (BT Vessel)

Not to Scale
**Client Location**

<table>
<thead>
<tr>
<th>Section</th>
<th>Zone 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>13 to 18 January 2014</td>
</tr>
<tr>
<td>K-No.</td>
<td>0xx-13</td>
</tr>
</tbody>
</table>

**Signal Y-component / angle analysis window**

Set for indication of internal defects with approx. depth information.

![Image of signal analysis window]

The SLOFEC™ Zone Scan Report includes a zone scan of a vessel section from 12 o'clock to 6 o'clock, covering a range of 2950mm.

**Zone 1**

- **North Side**
- **2950mm**

**Signal Amplitude [div]**

- < 20%
- 20-30%
- 30-40%
- 40-50%
- > 50%
Signal Y-component / angle analysis window set for indication of internal defects with approx. depth information.

Zone 2

Client: Client
Location: Facility
Vessel: BT
Identif.: 
Section: Zone 2
Date: 13 to 18 January 2014
K-No.: 0xx-13
Signal Y-component / angle analysis window set for indication of internal defects with approx. depth information.

**SLOFEC™ Zone Scan Report**

**Zone 3**

**Client**

**Location**

**Vessel**

**Identif.**

**Section**

**Date**

**K-No.**

**Client Location**

**Vessel Identif.**

**Zone 3**

**13 to 18 January 2014**

**0xx-13**
Signal Y-component / angle analysis window set for indication of internal defects with approx. depth information.

Client: Client
Location: Facility
Vessel: BT
Identif.: Zone 4
Date: 13 to 18 January 2014
K-No.: 0xx-13

Zone 4

12 o'clock

South Side

6 o'clock

2950mm

4350mm

Zone 4
Signal Y-component / angle analysis window set for indication of internal defects with approx. depth information.

Client: BT
Location: Facility
Identification: 0xx-13

Zone 5

Client Location Vessel Identif.
Zone 5
Date 13 to 18 January 2014
K-No. 0xx-13

12 o'clock
South Side
6 o'clock

Zone 5

4370 mm
Signal Y-component / angle analysis window set for indication of internal defects with approx. depth information.

Client Location
Facility BT

Section Zone 6
Date 13 to 18 January 2014
K-No. 0xx-13
APPENDIX 02

Ultrasonic Thickness Results
**Report No**
K-No 0xx-13

**Customer**
Client

**Location**
Plant, UK

**Project**
BT Vessel

**Line No**
N/A

**Description**
Ultrasound Thickness Inspection On Areas of SLOFEC Dead Zones

**Test Date**
13-18 Jan 2014

**Procedure No**
InnoUTSD-001-12

**Material**
Carbon Steel

**Standard**
BS EN 1714

## Equipment

<table>
<thead>
<tr>
<th>Couplant</th>
<th>Equip. Manufacturer</th>
<th>Model</th>
<th>Serial No.</th>
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<tbody>
<tr>
<td>Water Based Gel</td>
<td>GE USM</td>
<td>GO</td>
<td>USMG009110981</td>
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<table>
<thead>
<tr>
<th>Visual</th>
<th>Time Base Linearity</th>
<th>Amplifier Linearity</th>
<th>Calibration Block No</th>
<th>Timebase Range</th>
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<td>✔️</td>
<td>✔️</td>
<td>3536738</td>
<td>0-25</td>
</tr>
</tbody>
</table>

**Serial No**
26751

**Type**
Twin Crystal

**Angle**
0°

**Crystal Size (mm)**
10

**Freq (MHz)**
5

**Basic Sens (db)**
58

**Test Restriction/Limitations:**
Uneven covering of paint made some areas of UT inspection not possible.
Scaffold prevented some areas of deadzones to be inspected with UT.

## Ultrasonic Inspection Results

### Dome Ends

A UT reading was taken on the barrel, the knuckle of the dome end and 3 readings for each clock position as depicted

<table>
<thead>
<tr>
<th>East Dome End</th>
<th>Barrel</th>
<th>Knuckle</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>(mm)</td>
<td>(mm)</td>
<td>(mm)</td>
<td>(mm)</td>
<td>(mm)</td>
</tr>
<tr>
<td>1 o’clock</td>
<td>12.7</td>
<td>12.0</td>
<td>12.5</td>
<td>11.8</td>
<td>11.2</td>
</tr>
<tr>
<td>2 o’clock</td>
<td>12.8</td>
<td>12.7</td>
<td>12.7</td>
<td>11.7</td>
<td>11.2</td>
</tr>
<tr>
<td>3 o’clock</td>
<td>12.0</td>
<td>12.0</td>
<td>11.8</td>
<td>11.7</td>
<td>11.4</td>
</tr>
<tr>
<td>4 o’clock</td>
<td>9.9</td>
<td>11.0</td>
<td>9.5</td>
<td>11.1</td>
<td>11.2</td>
</tr>
<tr>
<td>5 o’clock</td>
<td>11.7</td>
<td>9.6</td>
<td>12.4</td>
<td>11.4</td>
<td>11.3</td>
</tr>
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<td>6 o’clock</td>
<td>12.2</td>
<td>12.1</td>
<td>11.5</td>
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<td>11.2</td>
</tr>
<tr>
<td>7 o’clock</td>
<td>12.4</td>
<td>11.8</td>
<td>12.2</td>
<td>11.4</td>
<td>11.2</td>
</tr>
<tr>
<td>8 o’clock</td>
<td>12.5</td>
<td>11.4</td>
<td>11.3</td>
<td>11.4</td>
<td>11.2</td>
</tr>
<tr>
<td>9 o’clock</td>
<td>11.8</td>
<td>11.0</td>
<td>11.4</td>
<td>11.6</td>
<td>11.2</td>
</tr>
<tr>
<td>10 o’clock</td>
<td>12.1</td>
<td>11.2</td>
<td>11.6</td>
<td>12.1</td>
<td>11.5</td>
</tr>
<tr>
<td>11 o’clock</td>
<td>12.1</td>
<td>11.6</td>
<td>12.2</td>
<td>11.6</td>
<td>10.9</td>
</tr>
<tr>
<td>12 o’clock</td>
<td>12.3</td>
<td>13.1</td>
<td>12.5</td>
<td>6.0</td>
<td>11.3</td>
</tr>
</tbody>
</table>
Ultrasonic Inspection Results

Dome Ends

A UT reading was taken on the barrel, the knuckle of the dome end and 3 readings for each clock position as depicted.

<table>
<thead>
<tr>
<th>West Dome End</th>
<th>Barrel (mm)</th>
<th>Knuckle (mm)</th>
<th>1 (mm)</th>
<th>2 (mm)</th>
<th>3 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 o'clock</td>
<td>12.1</td>
<td>11.7</td>
<td>12.4</td>
<td>11.7</td>
<td>11.3</td>
</tr>
<tr>
<td>2 o'clock</td>
<td>11.8</td>
<td>12.0</td>
<td>11.4</td>
<td>11.5</td>
<td>11.3</td>
</tr>
<tr>
<td>3 o'clock</td>
<td>11.4</td>
<td>11.3</td>
<td>12.4</td>
<td>11.1</td>
<td>11.4</td>
</tr>
<tr>
<td>4 o'clock</td>
<td>10.8</td>
<td>11.0</td>
<td>11.6</td>
<td>11.2</td>
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<td>5 o'clock</td>
<td>12.0</td>
<td>11.7</td>
<td>12.0</td>
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<td>11.3</td>
</tr>
<tr>
<td>6 o'clock</td>
<td>11.8</td>
<td>11.2</td>
<td>11.8</td>
<td>11.4</td>
<td>11.4</td>
</tr>
<tr>
<td>7 o'clock</td>
<td>11.7</td>
<td>11.2</td>
<td>11.7</td>
<td>9.5</td>
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<td>11.5</td>
<td>11.0</td>
<td>10.3</td>
<td>10.8</td>
<td>11.4</td>
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<tr>
<td>9 o'clock</td>
<td>11.5</td>
<td>11.1</td>
<td>11.4</td>
<td>11.5</td>
<td>11.5</td>
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<tr>
<td>10 o'clock</td>
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<td>11.6</td>
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<td>11.7</td>
<td>11.9</td>
<td>11.7</td>
<td>11.4</td>
</tr>
<tr>
<td>12 o'clock</td>
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<td>11.8</td>
<td>12.0</td>
<td>11.5</td>
<td>11.7</td>
</tr>
</tbody>
</table>

Dome End Scan Number Positioning

12 o'clock

9 o'clock

3 o'clock

6 o'clock
Ultrasonic Inspection Results

Slofeco Deadzones around Nozzle/Manway

A UT reading was scanned 180mm around all nozzles and manways as depicted below.

<table>
<thead>
<tr>
<th>Nozzle/Manway</th>
<th>UT Reading (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1</td>
<td>8.8</td>
</tr>
<tr>
<td>Area 2</td>
<td>8.3</td>
</tr>
<tr>
<td>Area 3</td>
<td>8.0</td>
</tr>
<tr>
<td>Area 4</td>
<td>7.7</td>
</tr>
<tr>
<td>Area 5</td>
<td>8.4</td>
</tr>
<tr>
<td>Area 6</td>
<td>8.2</td>
</tr>
</tbody>
</table>
**Ultrasonic Inspection Results**

Slopec Deadzones around Circumferential Weld and Saddle

A UT reading was scanned 180mm around all circumferential welds and welds of the vessel saddle as depicted below. No body of welds were scanned using shear wave. Due to time constraints only from 3 o’clock to 9 o’clock were scanned (underside of vessel).

<table>
<thead>
<tr>
<th>Weld No.</th>
<th>UT Reading (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.3</td>
</tr>
<tr>
<td>2</td>
<td>5.2</td>
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<tr>
<td>3</td>
<td>6.7</td>
</tr>
<tr>
<td>4</td>
<td>7.7</td>
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<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Saddle</td>
<td>5.2</td>
</tr>
<tr>
<td>Western Saddle</td>
<td>5.0</td>
</tr>
</tbody>
</table>