ABOVEGROUND STORAGE TANK

API 653 INSPECTION REPORT

FORMAL {insp\_campaign} INSPECTION

{company\_name}

TANK {tank\_no}

{site\_name}

{location}

{insp\_date}

{overview\_pic}

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# Introduction

At the request of {company\_name} for an {insp\_campaign} inspection of

tank {tank\_no} was carried out. The inspection was conducted by a team of inspectors under supervision of certified API 653 inspector. The inspection was carried out on {insp\_date}.

# Scope of work

The {insp\_campaign} inspection in accordance with the API 653 code was

carried out. Paragraph 2.1 summarizes the scope of works carried out. Paragraphs 2.2 displays the details of NDT and survey equipment used. Paragraph 2.3 gives a short

explanation of the techniques used.

## Inspection NDT and surveys carried out

## NDT and survey equipment used

## Equipment/Technique description

The following equipment/techniques are normally used during tank inspections:

**Ultrasonic Thickness Measurements (UTM)**

UTM is one of the techniques used to determine the condition and wall thickness of e.g. the tank shell, bottom, and nozzles. Normally the purpose is to detect erosion/corrosion problems in an early stage. If measurements are repeatedly made on a same location, after a certain amount of time corrosion speeds can be determined and for example be used for Risk Based Inspection purposes.

**Equipment**

Dexon has a big assortment of equipment that can be used for UTM measurement ranging from handheld thickness gauges to more sophisticated A- and B-scan equipment. Most likely to be used is the Panametrics 36/37 DL or other model equipment, which can compensate for the thickness of paint layers and has a B-scan presentation. In addition to that a Dexon operator will have the availability of calibration blocks in at least three different materials (Carbon steel, Stainless Steel and Duplex).

**Magnetic Flux Hand Scan**

The Hand Scan System is designed to compliment the MFL 2000 and Floormap VS2i floorscanners. The latest generation of permanent magnets allows localized magnetic saturation of the floor area under test.

**Equipment**

Dexon has a wide range of equipment that can be used for Magnetic Flux Hand Scan, any signal above the operator controllable threshold is displayed as both a visual and audible alarm. Its low profile and extendable handle allow scanning in otherwise inaccessible areas at storage tanks such as the shell to annular area and under pipe work or heater coils.

# History of tank (inspection and repairs)

{#repair}

| {part} |
| --- |
| {img} |
| Recommendation |
| {recommendation} |

{/repair}

# Tank data

|  |  |
| --- | --- |
| Status | {applicable\_status} |
| Type of tank | {roof\_type} |
| Product | {product\_code} |
| Product specific gravity | {g} |
| Diameter (m) | {diameter\_m} |
| Height (m) | {tank\_height\_m} |
| Safe fill height (m) | {max\_liquid\_level\_m} |
| Design code | {inspection\_code} |
| Date constructed | {installation\_date} |
| Date and type of last inspection |  |
| Bottom nominal thickness (mm) | {bottom\_nominal\_thk\_mm} |
| Annular nominal thickness (mm) | {annular\_nominal\_thk\_mm} |
| Roof nominal thickness (mm) | {roof\_nominal\_thk\_mm} |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Shell Course | Nominal  Thickness  (mm) | Height  (mm) | Tank Material | Material  Type |
| {#shell\_course} {course\_no} | {t\_nom\_plate\_mm} | {height\_of\_course\_m} | {mat\_spec} | {mat\_type}{/shell\_course} |

{new\_page}

# API checklist

{#checklist\_generic}

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| {header\_content} | | Rating | | | | | | Comments: |
| OK | Minor Observation | Evaluation Required | Monitoring Required | Not Acceptable | Not Applicable |
| {#sub\_header}{subheader\_content} | | | | | | | | |
| {#topic}{no} | {topic} | {#result}{OK} | {MinorObservation} | {EvaluationRequired} | {MonitoringRequired} | {NotAcceptable} | {NotApplicable} | {comments}{/result}{/topic}{/subheader} |
| Remarks And Recommendations: | | | | | | | | |
| {#remark\_desc}{remark}{/remark\_desc} | | | | | | | | |

{/checklist\_generic}

# Visual inspection

{#picture\_log}

| Overview | Close-up view |
| --- | --- |
| {overview\_pic} | {close\_up\_view\_pic} |
| Findings | Recommendation |
| {findings} | {recommendation} |

{/picture\_log}

# Thickness

### Roof thickness

- UT measurements were made on 5 examination points per plate.

- A, B, C and D examination point are spacing from weld 25 mm.

- See roof lay-out for plate numbering.

| Roof  Plate No | TP  Name | TP  Desc | tnom  (mm) | tmin  (mm) | Inspection Date | tactual  (mm) | CR  (mm/yr) | RL  (yrs) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| {#roof\_thk}{roof\_no} | {tp\_name} | {tp\_desc} | {t\_nom} | {t\_req} | {inspection\_date} | {t\_actual} | {scr} | {rl}{/roof\_thk} |

### Roof nozzle thickness

| Roof  Nozzle No | TP  Name | TP  Desc | tnom  (mm) | tmin  (mm) | Inspection Date | tactual  (mm) | CR  (mm/yr) | RL  (yrs) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| {#roofnz\_thk}{roofnz\_no} | {tp\_name} | {tp\_desc} | {t\_nom} | {t\_req} | {inspection\_date} | {t\_actual} | {scr} | {rl}{/roofnz\_thk} |

### Shell thickness

- Readings were recorded at 5 examination points per shell course per direction.

- Full Top-to-Bottom scans were made at 4 lines or directions.

- Top and Bottom examination point are spacing from horizontal weld 25 mm.

| Shell  Course | Plate  No | TP  Name | TP  Desc | tnom  (mm) | tmin  (mm) | Inspection Date | tactual  (mm) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| {#shell\_thk}{course\_no} | {plate\_no} | {tp\_name} | {tp\_desc} | {t\_nom} | {t\_req} | {inspection\_date} | {t\_actual}{/shell\_thk} |

### Shell nozzle thickness

| Shell  Nozzle No | TP  Name | TP  Desc | tnom  (mm) | tmin  (mm) | Inspection Date | tactual  (mm) | CR  (mm/yr) | RL  (yrs) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| {#shellnz\_thk}{shellnz\_no} | {tp\_name} | {tp\_desc} | {t\_nom} | {t\_req} | {inspection\_date} | {t\_actual} | {scr} | {rl}{/shellnz\_thk} |

### Bottom thickness

- UT measurements at 5 location per plate were made.

Diagram, shape

Description automatically generated

| Bottom  Plate No | TP  Name | TP  Desc | tnom  (mm) | tmin  (mm) | Inspection Date | tactual  (mm) | CR  (mm/yr) | RL  (yrs) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| {#bottom\_thk}{bottom\_no} | {tp\_name} | {tp\_desc} | {t\_nom} | {t\_req} | {inspection\_date} | {t\_actual} | {scr} | {rl}{/bottom\_thk} |

### Annular thickness

| Annular  Plate No | TP  Name | TP  Desc | tnom  (mm) | tmin  (mm) | Inspection Date | tactual  (mm) | CR  (mm/yr) | RL  (yrs) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| {#annular\_thk}{annular\_no} | {tp\_name} | {tp\_desc} | {t\_nom} | {t\_req} | {inspection\_date} | {t\_actual} | {scr} | {rl}{/annular\_thk} |

### Critical zone thickness

- UT measurements in the critical zone were made at 6 locations per plate.

- In the critical zone 2 rows of 3 measurements per plate were made.

- The critical zone is the part of the bottom within 7.5 cm of the shell.

- The examination point are spacing 5 cm between ACE row and BDF row.

| Critical Zone  Plate No | TP  Name | TP  Desc | tnom  (mm) | tmin  (mm) | Inspection Date | tactual  (mm) | CR  (mm/yr) | RL  (yrs) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| {#critical\_thk}{plate\_no} | {tp\_name} | {tp\_desc} | {t\_nom} | {t\_req} | {inspection\_date} | {t\_actual} | {scr} | {rl}{/critical\_thk} |

### Projection plate thickness

- UT measurements of the projection plate and bottom of shell around the circumference of the tank;

D ≤ 10 m; Examination were made at 1 m interval.

10 m < D ≤ 30 m; Examination were made at 2 m interval.

D ˃ 30 m; Examination were made at 3 m interval.

- The starting of examination is located at North direction and subsequent measurements were made in Clockwise direction.

- Measurements location is spacing from shell to bottom weld 25 mm both at projection plate and bottom of shell.

| TP  Name | TP  Desc | tnom  (mm) | tmin  (mm) | Inspection Date | tactual  (mm) | CR  (mm/yr) | RL  (yrs) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| {#projection\_thk}{tp\_name} | {tp\_desc} | {t\_nom} | {t\_req} | {inspection\_date} | {t\_actual} | {scr} | {rl}{/ projection\_thk} |

### Piping thickness

| Piping No | CML  No | Part | TP  Name | TP  Desc | tnom  (mm) | tmin  (mm) | Inspection Date | tactual  (mm) | CR  (mm/yr) | RL  (yrs) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| {#piping\_thk}{piping\_no} | {cml\_no} | {part} | {tp\_name} | {tp\_desc} | {t\_nom} | {t\_req} | {inspection\_date} | {t\_actual} | {scr} | {rl}{/piping\_thk} |

### Coil thickness

| Coil No | CML  No | Part | TP  Name | TP  Desc | tnom  (mm) | tmin  (mm) | Inspection Date | tactual  (mm) | CR  (mm/yr) | RL  (yrs) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| {#coil\_thk}{coil\_no} | {cml\_no} | {part} | {tp\_name} | {tp\_desc} | {t\_nom} | {t\_req} | {inspection\_date} | {t\_actual} | {scr} | {rl}{/coil\_thk} |

### Sump thickness

| Sump No | CML  No | Location | TP  Name | TP  Desc | tnom  (mm) | tmin  (mm) | Inspection Date | tactual  (mm) | CR  (mm/yr) | RL  (yrs) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| {#sump\_thk}{sump\_no} | {cml\_no} | {location} | {tp\_name} | {tp\_desc} | {t\_nom} | {t\_req} | {inspection\_date} | {t\_actual} | {scr} | {rl}{/sump\_thk} |

### MFL bottom

| Plate No | tnom  (mm) | %Metal Loss  (Top side) | %Metal Loss  (Bottom side) | Remaining Thk Top Side  (mm) | Remaining Thk Bottom Side  (mm) | X  (mm) | Y  (mm) | Type of Repair | Width  (mm) | Length  (mm) | Thick  (mm) | Radius  (mm) | Repair Status |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| {#mfl\_bottom}{ plate\_no} | {t\_nom} | {metal\_loss\_top} | {metal\_loss\_bottom} | {lowest\_remaining\_thk\_top} | {lowest\_remaining\_thk\_bottom} | {defect\_x} | {defect\_y} | {type\_of\_repair} | {repair\_width} | {repair\_length} | {repair\_thick} | {repair\_radius} | {repair\_status}{/mfl\_bottom} |

### MFL annular

| Plate No | tnom  (mm) | %Metal Loss  (Top side) | %Metal Loss  (Bottom side) | Remaining Thk Top Side  (mm) | Remaining Thk Bottom Side  (mm) | X  (mm) | Y  (mm) | Type of Repair | Width  (mm) | Length  (mm) | Thick  (mm) | Radius  (mm) | Repair Status |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| {#mfl\_annular}{plate\_no } | {t\_nom} | {metal\_loss\_top} | {metal\_loss\_bottom} | {lowest\_remaining\_thk\_top} | {lowest\_remaining\_thk\_bottom} | {defect\_x} | {defect\_y} | {type\_of\_repair} | {repair\_width} | {repair\_length} | {repair\_thick} | {repair\_radius} | {repair\_status}{/mfl\_annular} |

# Evaluation

### Shell settlement

Tank Settlement Survey

- There must be at least 8 settlement points. The maximum spacing of settlement point is 32 ft. (9.7536 m) around the circumference.

- Points shall be equally spaced around the tank shell. There must be at least 4 equally spaced diametrical measurements.

- Measurements can best be taken at (every) vertical weld (with equal distance) of bottom shell coarse.

- Count welds from entry manhole in CW direction.

- If there is no projection plate staff on top first strake.



Datum Point Location

Settlement surveys are in general not carried out on small diameter tanks because, due to less weight of the product, the tanks are less susceptible to developing issues with settlement. Several internationally used specifications specify to carry out settlement surveys only for tanks with a diameter bigger than 9.75 m. If API 653 acceptance criteria are calculated for small diameter tanks the acceptance range will be very tight due to the small arc length between measurement points.

The acceptance criteria as per API 653 for this tank was found to be unacceptable. The results were also compared to the European tank inspection standard EEMUA 159. When the settlement is compared to the European standard the result is found to be within acceptance.

Measured data

| Survey location at the Tank  (Mark on shell map) | Distance between survey location  (mm) | Cumulative  distance around tank  (mm) | Relative Level /  Distance from Datum Point\* (mm) |
| --- | --- | --- | --- |
| {#shell\_settlement\_point}{location} | {maximum\_space} | {cumulative} | {relative\_value}{/shell\_settlement\_point} |

Determination of acceptable differential settlement

| Data Point | Circumferential Distance | Reduced Level | Theta Radians | Theta Degrees | Relative Level | y | Difference (Ui) | Out of Plane Deflection (Si) | Deviation | Difference(2) | Deviation(2) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| {#shell\_settlement\_api}{location} | {cumulative} | {reduced\_level} | {theta\_radians} | {theta\_degrees} | {relative\_value} | {y} | {difference\_value} | {out\_of\_plane} | {deviation\_value} | {difference\_2\_value} | {deviation\_2\_value}{/shell\_settlement\_api} |

The value R calculation

{#shell\_settlement\_api\_sum}

| Sum of (Deviation)²(Syy) | Sum of (Different)²(SSE) | R² = (Syy-SSE)/Syy |
| --- | --- | --- |
| {syy} | {sse} | {r\_2} |

{/shell\_settlement\_api\_sum}

Settlement acceptance determination

{#accept}

|  |  |  |  |
| --- | --- | --- | --- |
| API653, Paragraph B.3 – Determination of the permissible Out-of-Plane settlement | | | |
| The optimal cosine curve is valid | | The optimal cosine curve is invalid | |
| ft = (L² x Y x 11) / 2 x E x H | | in = min [K x x (D / H) x (Y / E), 4.0] | |
| L: Arc length between measurement points | {l\_value} ft. | K: API 653 | {k\_value} |
| Y: Yield strength | {yield} lbf/in2 | : Effective settlement arc | {s\_arc} ft. |
| E: Youngs Modulus | {e} lbf/in2 | D: Tank inside diameter | {diameter\_ft} ft. |
| H: Tank Height | {tank\_height\_ft} ft. | H: Tank Height | {tank\_height\_ft} ft. |
| n: Number of measurement points | {points} | Y: Yield strength | {yield} lbf/in2 |
|  | {s\_value} mm | E: Youngs Modulus | {e} lbf/in2 |
|  |  | n: Number of measurement points | {points} |
|  |  |  | {s\_max\_mm} mm |
| API653, Paragraph B.2.2.4 – Determination of predicted Out-of-Plane settlement | | | |
| S or = – (0.5 + 0.5 ) | | | |
|  | | {ui\_max} | |
|  | | {ui\_before\_max} | |
|  | | {ui\_next\_max} | |
| S | | {st\_value} | |
| R² | | {r\_2} | |
| Predicted deflection | | {predicted\_tilt} | |
| at | | {direction\_degrees\_cw\_pi} | |

Acceptance per API 653

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Acceptance Criteria | Cosine Curve | (mm) | S (mm) | Inspection Result |
| - | Valid | {s\_value} | {st\_value} | {insp\_result} |
| Invalid | {s\_max\_mm} | {st\_value} | {insp\_result\_invalid} |

{/accept}

### Shell tilt or plumbness survey

Plumbness Evaluation

The measurements were made 4 directions around the circumference of the tank for tank diameter 1-12 m. and 8 directions for tank diameter > 12 m.

Shape, rectangle, polygon

Description automatically generated

Acceptance criteria per API 653:

1. For FR and EFR, the maximum of out-of-verticality at the tank shell should not exceed 1/100th of the tank height.

2. For IFR, the maximum of out-of-verticality at the tank shell should not exceed 1/200th of the tank height.

Acceptable where St < S

Not acceptable where St > S

| Measurement Location | Bottom of Tank | Top of Tank | Deviation | | S - mm | St - mm | Result |
| --- | --- | --- | --- | --- | --- | --- | --- |
| {#plumbness} {eval\_location} | {bottom\_tank} | {top\_tank} | {deviation} | {in\_out\_ward} | {s\_value} | {st} | {result}{/plumbness} |

### Shell buckling

Radii measured at 1 ft (0.3048 m) above the shell-to-bottom weld and Radius tolerances measured higher than one foot [>1 ft (0.3048m)] above the shell-to-bottom weld shall not exceed the tolerances show in Table.

|  |  |  |
| --- | --- | --- |
| Tank Diameter  m (ft) | Radius Tolerance  Mm (in) (<=0.3048m) | Radius Tolerance  Mm (in) (>0.3048m) |
| < 12 (40) | ±13 (½) | ±39 (3½) |
| From 12 (40) to < 45 (150) | ±19 (¾) | ±57 (3¾) |
| From 45 (150) to < 75 (250) | ±25 (1) | ±75 (3) |
| >= 75 (250) | ±32 (1¼) | ±96 (3¼) |

| Course – Plate No | Measured Height  (m) | Theoretical Shape Diameter  (mm) | Deviation  (mm) | Radius Tolerance  (mm) | Inspection  Result |
| --- | --- | --- | --- | --- | --- |
| {#shell\_buckling} {plate} | {measured\_height\_m} | {shape\_dia\_mm} | {deviation\_mm} | {radious\_tolerance} | {result}{/shell\_buckling} |

### Local deviation

From the theoretical shape (for example, weld discontinuities and flat spots) shall be limited as follows:

a. Deviations (peaking) at vertical weld joints shall not exceed 13 mm (1/2 in.). Peaking at vertical weld joints shall be determined using a horizontal sweep board 900 mm (36 in.) long. The sweep board shall be made to the nominal radius of the tank.

b. Deviations (banding) at horizontal weld joints shall not exceed 13 mm (1/2 in.). Banding at horizontal weld joints shall be determined using a straight edge vertical sweep board 900 mm (36 in.) long.

c. Flat spots measured in the vertical plane shall not exceed 1/200 of the total height.

| No | Deviation Type | Between Plate | And plate | Deviation  (mm) | Radius Tolerance  (mm) | Inspection  Result |
| --- | --- | --- | --- | --- | --- | --- |
| {#local\_deviation} {no} | {deviation\_type} | {plate\_1} | {plate\_2} | {deviation\_mm} | {tolerance} | {result}{/local\_deviation} |

### Roundness

Radii measured at 1 ft (0.3048 m) above the shell-to-bottom weld and Radius tolerances measured higher than one foot [>1 ft (0.3048m)] above the shell-to-bottom weld shall not exceed the tolerances show in Table.

|  |  |  |
| --- | --- | --- |
| Tank Diameter  m (ft) | Radius Tolerance  Mm (in) (<=0.3048m) | Radius Tolerance  Mm (in) (>0.3048m) |
| < 12 (40) | ±13 (½) | ±39 (3½) |
| From 12 (40) to < 45 (150) | ±19 (¾) | ±57 (3¾) |
| From 45 (150) to < 75 (250) | ±25 (1) | ±75 (3) |
| >= 75 (250) | ±32 (1¼) | ±96 (3¼) |

| Point No | Distance Above Bottom  (m) | Radius Measured Value  (mm) | Relative to nom.  (mm) | Radius Tolerance  (mm) | Inspection  Result |
| --- | --- | --- | --- | --- | --- |
| {#roundness} {point\_no} | {distance\_above\_bottom} | {measure\_value} | {relative\_to\_nom} | {radius\_tolerance} | {result}{/roundness} |

### Grounding connection

The acceptance criteria

1. The distance between grounding connection is between 6 to 30 m.

2. Total resistance from tank to earth not more than 25 ohms (API 575) or 10 ohms (Thai regulation) or Customer.

| Grounding Connection No | The measured resistance to ground (ohms) | Note |
| --- | --- | --- |
| {#grounding} {ground\_no} | {measured} | {note}{/grounding} |

{#grounding\_detail}

| Grounding Connection Detail | |
| --- | --- |
| Total Resistance (ohms) | {total} |
| Acceptance Criteria (ohms) | {acceptance\_criteria} |
| Result | {result} |
| Measurement Summary | {measurement\_summary} |

{/grounding\_detail}

### MRT

{#mrt}

| Bottom Plate | | Annular Plate | |
| --- | --- | --- | --- |
| RTbc | {bt\_RTbc} mm. | RTbc | {an\_RTbc} mm. |
| RTip | {bt\_RTip} mm. | RTip | {an\_RTip} mm. |
| Or | {bt\_Or} years | Or | {an\_Or} years |
| StPr | {bt\_StPr} mm/yr | StPr | {an\_StPr} mm/yr |
| UPr | {bt\_UPr} mm/yr | UPr | {an\_UPr} mm/yr |
| Age of Tank | {bt\_age\_of\_tank} years | Age of Tank | {an\_age\_of\_tank} years |
| MRT | {bt\_MRT} mm. | MRT | {an\_MRT} mm. |
| tmin | {bt\_tmin} mm. | tmin | {an\_tmin} mm. |
| Result | {bt\_result} | Result | {an\_result} |
| Recommendation | {bt\_recommedation} | Recommendation | {an\_recommedation} |

{/mrt}

Minimum Thickness for Tank Bottom plate at the end of interval (For next inspection)

An acceptable method for calculating the minimum acceptable bottom thickness for entire bottom or portion is

MRT = (Minimum of RTbc or Rtip)-(Or\*(StPr+Upr))

Where

**MRT** is the minimum remaining thickness at the end of interval Or, the value must meet the requirements of Table 4.4 and 4.4.5.4 and

4.4.6. If less than in Table 4.4 or 6.4.2.4, the bottom shall be lined, repaired, replaced or the internal inspection shortened.

**Or** is the in-service interval of operation (years to next inspection) not to exceed that allowed by 6.4.2.

**RTbc** is the minimum remaining thickness from bottom side corrosion after repairs.

**RTip** is the minimum remaining thickness from internal corrosion after repairs.

**StPr** is the maximum rate of corrosion not repair on the top side. StPr = 0 for coated areas of the bottom. The expected life of the

coating must equal or exceed Or to use StPr = 0.

**UPr** is the maximum rate of corrosion on the bottom side. To calculate corrosion rate, use the minimum remaining thickness after

repairs. UPr = 0 for areas that have effective cathodic protection.

If the MRT (the minimum bottom thickness, at the end of the in-service period of operation) are caculated to be less than the minimum bottom renewal thickness given in Table 4.4 or thickness providing acceptable risk as determined by ab RBI assessment per 6.4.2.4, the bottom shall be lined, repaired, replaced, or the interval to the next internal inspection shortened.

Summary result

1. MRT Bottom <= or > tmin

2. MRT Annular <= or > tmin

Recommendation

If MRT <= tmin: "Required repair or replace or decrease internal inspection interval."

If MRT > tmin: "Planned internal inspection interval ≤ 15 years"