APPLICATION OF ACOUSTIC EMISSION FOR QUALITY ASSURANCE IN CAPITAL PROJECTS

7th Middle East NDT Conference and Exhibition
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DEliaVing AsSeT PROTECtiON SOLUtIOnS GlObALLy
Background

- Metallic pressure vessels, e.g. spheres, bullets and reactors, represent a significant capital investment for new projects.

- For obvious reasons, such equipment needs to meet the required level of quality assurance for safe operation throughout its service life.

- Whilst the commercial investment for fibre reinforced composite vessels is generally lower, ensuring safe operation is equally important.

- As part of the quality assurance process, new vessels undergo an initial hydro-test (proof test) prior to commissioning:
  - Demonstrating that the vessel does not leak under pressure;
  - Confirms the safety and design margins are as intended.

- Whilst stress relief is applied during manufacture, e.g. PWHT of thick walled vessels, the hydro-test acts to further mechanically stress relieve the vessel by loading well above the intended service stress.
Inspection requirements for new equipment

• The vessel design codes mandate the level of non-destructive testing (NDT) that is to be carried out new equipment prior to the hydro-test, e.g. MT, PT, UT, RT etc.

• Initial NDT inspections prior to the hydro-test (proof-test) required to:
  – Identify manufacturing defects
  – Provide baseline readings which can be entered into the inspection data management system (IDMS) as part of the facilities mechanical integrity program.

• However, the design codes do not stipulate the requirement for inspection after the hydro-test.

• In the event any large defects propagate during the proof test, the vessel would enter service with them present.
Acoustic Emission (AE) application

- The benefits of applying Acoustic Emission (AE) during the initial hydro-test continues to become more widely understood and accepted by operators.

- Extensive testing of pressure equipment using AE has led to the development of international codes and standards:
  - Articles 11 and 12 of Section Five of the ASME (American Society of Mechanical Engineers) Boiler and Pressure Vessel Code; and

- In addition to the above, the MONPAC™ system has been adopted by ASME Article 12 and is widely accepted as the industry standard for AE testing of pressure equipment.
MONPAC™ grading

- MONPAC™ goes beyond what is outlined in ASME art. 12 and provides a means to quantitatively evaluate the severity of emissions recorded during a new vessel hydro-test.

<table>
<thead>
<tr>
<th>GRADE</th>
<th>INTERPRETATION</th>
<th>RECOMMENDATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Very Minor Source</td>
<td>No action&lt;br&gt;Results recorded for further test</td>
</tr>
<tr>
<td>B</td>
<td>Minor Source</td>
<td>Visual inspection&lt;br&gt;Surface defect such as corrosion, pitting, gouges and cracked attachment welds etc.</td>
</tr>
<tr>
<td>C</td>
<td>Source</td>
<td>Defects requiring immediate or short term follow-up evaluation.&lt;br&gt;Evaluation may be based on further AE data analysis, retest, or complimentary NDE by other NDT methods or AE re-examination.</td>
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<tr>
<td>D</td>
<td>Intensive Source</td>
<td>Significant defects requiring immediate follow-up inspection using complimentary NDE methods.</td>
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<tr>
<td>E</td>
<td>Critical Source</td>
<td>Major defects requiring immediate shut-down and follow-up NDE.</td>
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Acoustic Emission Technology (in brief)
Acoustic Emission (Stress Wave Emission)

• Early references to AE described the technology as “Stress Wave Emission”.

• Stress wave emission removes any misconceptions that AE is the same as audible emission; rather it infers that we are looking to identify the presence of stress waves in a material, i.e. from the release of energy.

• AE monitoring is typically carried out within the frequency range of 100 kHz to 1.2 MHz. Audible range is $<20\text{ kHz}$. 

• Detectability (size) of the AE wave depends on two main factors:
  – the incremental crack area
  – the crack velocity during this incremental growth
Important test considerations

Examples of key considerations for running an AE test during the hydro-test include:

- Controlled pressurisation and appropriate apparatus for pressurisation
- Hardware setup to control data rates (experience!!)
- Numbers of sensors installed and their locations
- Attenuation considerations

Influence P.O.D
Vessel hydrotest – AE monitoring principle

- First loading: Regions of high residual stress in the vessel can be relieved, which by nature, is a high energy event.
- Natural phenomena will result in significant AE being recorded, which will occur in addition to data from growing defects. Care should be exercised when during data evaluation to avoid misinterpretation of activity.
- A series of pass/fail evaluation criteria are applied to the data recorded from the first loading; in the event that the vessel fails any part of this criteria, the ASME code section stipulates a second pressurisation up to test pressure.
- Data from the second loading is subject to the same grading criteria.
- If the second cycle is “quiet” then any defects present are considered stable and the vessel “passes” the test.
Pressurisation sequence example

![Graph showing pressurisation sequence example](image-url)
Case Study 1

Spherical pressure vessel

- Expected service: Propane
- Material: Carbon steel
- Dimensions: 13.5m dia.
- Operating pressure: 17.5 Barg
- Hydro-test pressure: 24.7 Barg
- AE sensor no.: 34 sensors
Initial & repeat pressurisation CS#1

First pressurisation

Repeat pressurisation
Repeat pressurisation findings CS#1

- Plot shows MONPAC™ intensity grading for the test data.
- Low intensity and low severity indications are representative of vessel stress relief. Grouping to the lower left hand region of the plot.
- Second pressurisation produced insufficient data to grade.
- Therefore, this vessel passed the AE testing allowing the vessel to enter service.
Case study 2

Cylindrical pressure vessel

- Expected service: Ethane refrigerant
- Material: Stainless 304L
- Dimensions: 5m x 21m
- Operating pressure: 27.5 Barg
- Hydro-test pressure: 39.2 Barg
- AE sensor no.: 42 sensors
Initial pressurisation CS#2
Repeat pressurisation findings CS#2

- Whilst the number of located events during the second pressurisation reduced significantly to 31 events, a small cluster still presented itself close to channel 10 near the saddle support; the activity was recorded with low severity.
Case Study 3

Cylindrical pressure vessel

- Expected service: Hydrogen
- Material: A516-70
- Dimensions: 2.74m x 13.9m (tested horizontally)
- Design pressure: 25.2 Barg at 94°C
- Hydro-test pressure: 38.75 Barg at ambient, ~10°C
- AE sensor no.: 17 sensors
- Special features: Catalyst loading man-way in top head, ~half diameter of vessel.
Initial pressurisation CS#3

- Significant activity during initial pressurisation.
- Activity focused close to sensor 13 (almost twice the amount of activity to the nearest sensor).
- Sensor 13 located close to the catalyst loading man-way.
Second pressurisation findings CS#3

• Minimal emission was recorded during the second pressurisation until approximately 70% of the previous maximum pressure.

• The source of the same AE location found during initial pressurisation continued to emit until the end of the second loading.

• MONPAC™ analysis of the first pressurisation produced grade “E” indications for the sensors around the man-way;

• Activity reduced to grade “C” on the repeat pressurisation resulting in a recommendation for further evaluation and possible follow-up NDT.
Summary

- AE monitoring during the initial hydro-test of pressure equipment is an extremely useful tool for assessing the integrity of the equipment.
- Careful application of the technique should be adopted to avoid misinterpretation of data.
- AE resulting from crack growth during the first pressurisation can be difficult to identify within emission from expected stress relief.
- Quantitative analysis using approaches such as MONPAC™ can differentiate the higher levels of activity.
- Where it is practical/cost effective to use planar location, this can be very beneficial to identify areas of concern.
- Second pressurisation is more straightforward to interpret; in general terms, no emission means (1) no propagating defects or (2) no continuing stress relief under the test pressures.
• Consideration should be given to AE activity from secondary welds which may pose a problem in service, e.g. defects that act as stress raisers for flaws which may grow in service.

• Unusually high levels of AE from stress relief may be the result of inadequate weld pre-heat or other manufacturing material problems that leave high residual stresses in the welds.

• High emission levels do not necessarily mean the presence of growing defects that can be found by conventional NDT.

• Where significant emission sources are found during the hydro-test, follow up inspection along with sound engineering judgment.

• The above minimises the chances of placing a vessel in service with defects that have the potential to grow.