



Testing Cryogenic Tank Walls with AE: Double and Single Wall Integrity Tests

Background

In the late 70's and 80's, the use of a method known as acoustic emission (AE) testing was developed for a wide range of applications including the assessment of structural integrity on pressure vessels and storage tanks. The method is written into the ASME boiler and pressure vessel code (section 5 article 12) and is also extensively used to test large gas cylinders (under DOT exemptions) and railcars. The AAR requires 150,000 railcars to be AE tested within the next four (4) years.

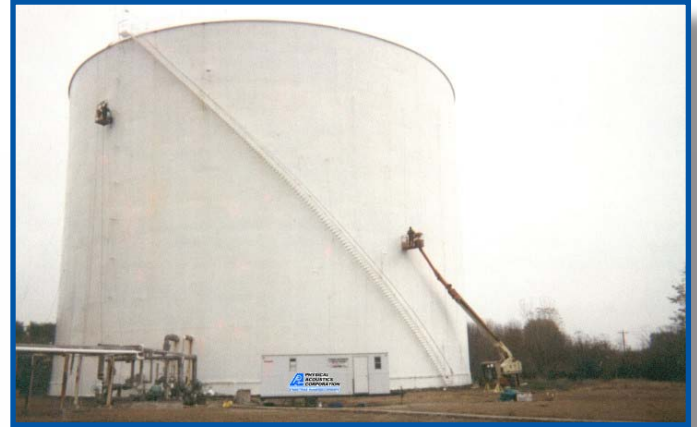
Acoustic emission is the elastic energy released by materials when they undergo deformation. Rapid energy release results in a stress-wave that radiates out from the source of emission and is detected by remote sensors. In metals, emission can be caused by a number of mechanisms including dislocation movement, fracture and inclusion debonding. Its use on storage tanks has so far been mostly on large cryogenic tanks containing high-risk products such as ammonia, butane and propane.

Test Procedures

The most commonly used procedures are those that formed the basis for the ASME code and were developed by the Monsanto Chemical Company from experience with testing thousands of vessels. Monsanto, introduced the method and developed it to be a reliable and routine way of assessing the structural integrity of vessels and tanks. These methods, (known as MONPAC™) are operated under license by a large number of organizations. For storage tanks, the method assesses wall and bottom-knuckle integrity. High frequency AE sensors are attached at typically a 6-meter spacing over the entire test area. Where the vessel is insulated with very thick insulation, the sensors are often mounted permanently underneath the insulation and cabled back to a connection point, so that repeat installation costs are not incurred.

The fluid level in the vessel is then increased while monitoring for acoustic emission. The fluid level has to be preferably below 95% of maximum for the six months prior to the test. It then has to be increased slowly to 100%. Following the test, the AE data is processed to remove any extraneous noise, this is known as interpretation. The severity of emission is then assessed against a database known as evaluation.

This method gives clearly-defined grading system with interpretation and recommendation:



20,000-ton ammonia tank with 95 AE sensors mounted for in-service testing.

Grade	Interpretation	Recommendation
A	Very minor source	None
B	Minor source	Visual external inspection
C	Source further	Evaluation/possibly NDT
D	Active source	Immediate follow-up NDT
E	Intense source	Immediate action

In some cases, it is possible to obtain a more precise indication of the emission source by analyzing arrival times for the stress waves at each sensor in the same way that earthquakes are located. For this to be possible, the stress waves must be energetic enough to reach three sensors. This is most likely in the case where cracking is the source.

Case Histories

- Cryogenic ammonia tank-1:** 96 sensors were placed under the insulation and cabled to a connection box. The vessel was filled and following evaluation of the AE data, a decision was made to remove the vessel from service and carry out detailed local inspection. This resulted in over 2,000 feet of weld being repaired that was defective from the original manufacture.
- Cryogenic ammonia tank-2:** Same test as tank 1 one, but there was no indication of structurally significant defects. The vessel was left in-service and is retested on a periodic basis. The savings compared with decommissioning and internal entry are significant.
- Cryogenic ammonia tank-3:** Again, on-line AE testing kept this tank in-service many years past its normal inspection interval. Eventually, internal inspection was carried out. Fine surface cracks across the weld cap were found in certain areas where the weld hardness was on the high side.

4. **Cryogenic ammonia tank-4:** This tank was monitored with a total of 128 sensors, showing the unusual characteristic of emitting around the knuckle area as the fluid level was reducing at low level. Careful inspection around that area revealed many corroded and cracked hold-down bolts. Many of these tanks, fabricated from higher strength steels, tend to deform into a “sphere” shape at low fluid levels due to vapor pressure (millibars). This puts tensile stresses on the hold-down bolts that are being over stressed for their physical condition, resulting in acoustic emission.

5. **30m Cryogenic propane tank:** This tank was monitored during a water test, following refurbishment. 64 sensors were used and several AE sources were detected and located. X-rays of these areas were reviewed and in all cases, defects were clearly visible. Since the flaws were located in stiffening-ring welds and were not active at higher stresses, the decision was made to leave them.

Thousands of X-rays are generated during manufacture or major repair of these tanks. It is not uncommon to discover defects in these X-rays after reviewing the location of AE sources.

Codes and Standards

Some states in the USA now require visual internal inspection of above ground storage tanks every five (5) years, unless the tank has an inspection and maintenance program that complies with API 653. API 653 states that on-stream, non-destructive methods of inspection shall be considered when establishing inspection frequency. Since the PAC AE method is very widely used to evaluate tank floors, it is an ideal candidate for on-stream nondestructive inspection.

API 653 also states that in no case may the internal inspection interval exceed 20 years. In Europe, the requirements depend upon the country. In the UK, apart from major hazard tanks, it is up to the owner to ensure integrity and to be able to justify his inspection and maintenance plan for any tank.

Conclusions

Acoustic methods of tank inspection can offer considerable financial, safety and environmental benefits by providing information on tank integrity without draining or incurring extensive down time. The tests are non-invasive and pose no threat to the integrity of the tank. When used as part of a predictive maintenance program for tanks, they allow maintenance resources to be targeted to the areas with problems, thereby minimizing costs while focusing on problem tanks.

When ammonia tanks are taken out of service for inspection and repair, oxygen enters the tank and this tends to restart the corrosion process once again.

Benefits of AE Testing

Global Monitoring - Sensors detect AE signals from considerable distances, making this method ideal for global monitoring of large vessels and systems. Identified problem areas can then be inspected using other NDT methods.

Minor Disturbance of Insulation - Only small holes in insulation are required for sensor mounting. On high-temperature applications, waveguides are used to contact the surface. Sensors are then mounted outside the insulation.

On-Line Testing - Opening a tank introduces oxygen into the tank. When the tank is put back into service the corrosion process starts all over again. For most storage vessels, on-line testing is possible either by filling it with product, introducing gas into the vapor space, controlling the temperature or other process parameters.

Cost Reduction - In ammonia applications, it can cost up to \$1,000,000 just for a nitrogen purge. The cost increases further when you add thousands of dollars for scaffolding and the cost of traditional ultrasonic or other traditional inspection, not to mention lost production time. The use of AE can reduce plant maintenance costs considerably, while increasing the information available about plant integrity. Plant downtime for inspection is also minimized.

Rapid Inspection - The actual AE test takes a matter of hours, and in some cases, considerably less. No comparable method can provide 100% volumetric inspection in the same amount of time.

Permanent Record of Test - Data is digitized and stored on disk, providing a permanent record of the test that can be reanalyzed at any time.

For assistance or additional information, please contact our Princeton Junction headquarters.



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