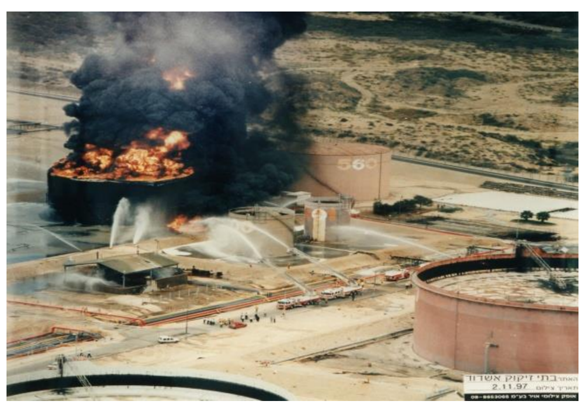
Acoustic Emission Inspection and Monitoring of Petroleum Storage Tanks and Piping

Increased Safety with Excellent Money Saving

Petroleum tanks used to store crude oil, aviation fuel, gasoline, diesel and other products above and below ground. Leaking tanks may create significant environmental damage and jeopardize safety. Soil and water contamination can be tremendous and be undetected for years. A 45-litre gasoline leak contains about 230 grams of benzene, enough to contaminate 46 million litres of water. According to existing statistics in developed countries, up to one third of underground petroleum storage tanks installed prior to the 1990s are leaking or will do so before they are removed.

Different methods have been developed and applied during the recent decades for non-destructive evaluation of metal and fiber-reinforced plastics (FRP) structures. Among these methods, **acoustic emission** technology is unique as it not only detects flaws but also is used for on-line, real time monitoring of structural integrity **without interruption of operation, cleaning or product evacuation.**

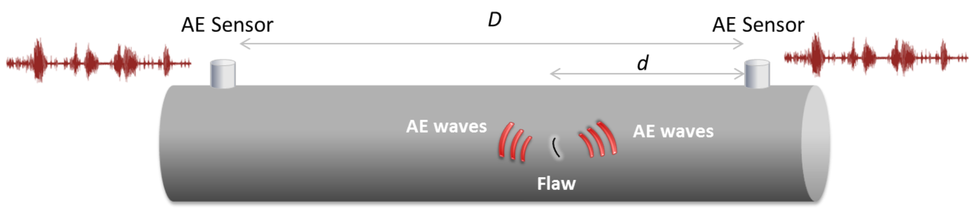


Since 1970s acoustic emission technology is widely applied for inspection of petroleum structures over the world and has a proven experience in assessment of:

- Above ground storage tanks.
- Underground storage tanks made of steel and fiber-reinforced plastics.
- Petroleum piping (above and underground).
- Cisterns for rail and ground transportation of petroleum products.
- Fuel tanks of planes and ships.

What is Acoustic Emission?

Acoustic emission is a phenomenon of sound and ultrasound (stress) wave radiation in materials that undergo deformation or fracture processes.



$$d = \frac{1}{2}\left(D - \Delta T \cdot V\right)$$

d = distance from first hit sensor

D = distance between sensors

V = wave velocity

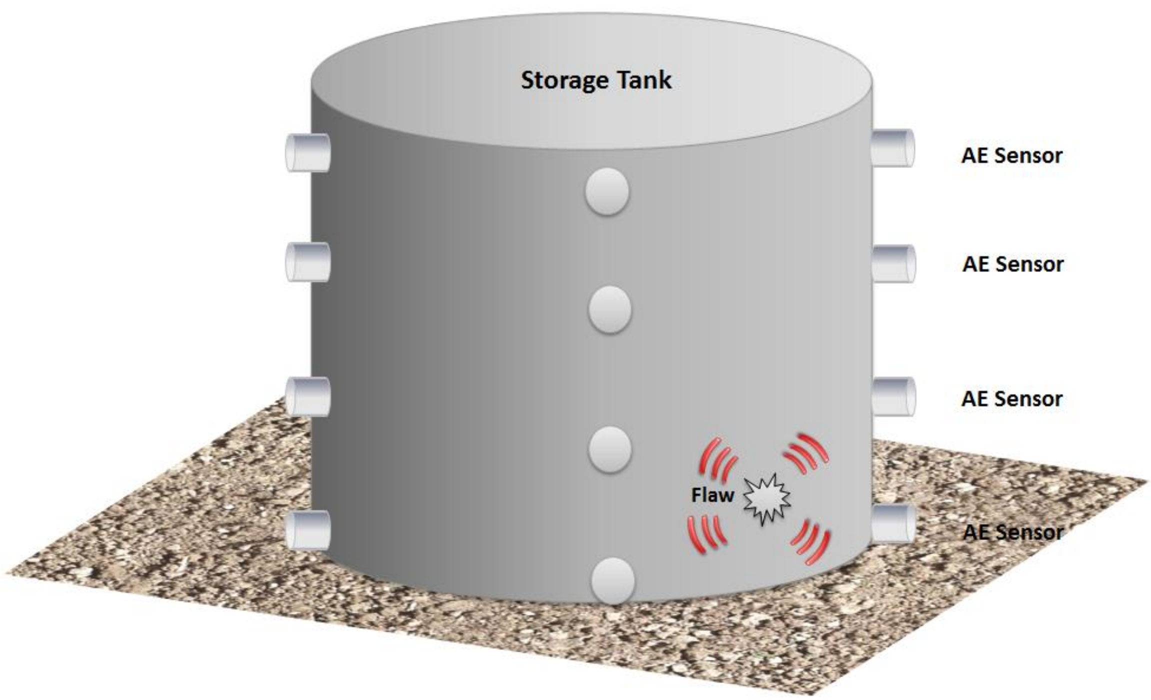
Crack propagation in loaded solid materials such as metal and composites results in a fast release of potential energy in form of stress waves with frequencies typically between 50 kHz and 2 MHz. These waves propagate along the structure for distances of several meters and are detected by piezoelectric sensors. Special analysis of detected AE waves is then performed to locate acoustic emission flaw sources, identify flaw type, evaluate rate of flaw propagation and it sensitivity to load/stress/operational changes.

In addition to crack propagation, other sources of acoustic emission due to corrosion, stress corrosion cracking and leaks are readily detected and assessed by AE technology.

How Acoustic Emission Technology is Applied?

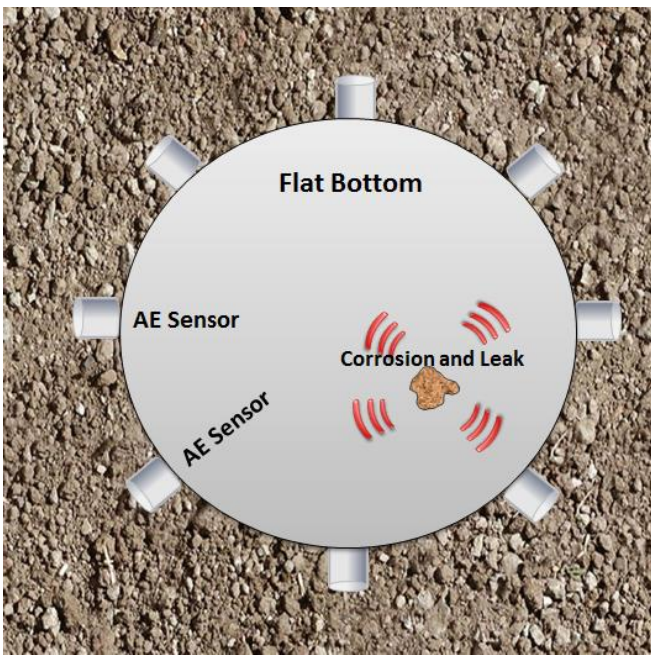
Above ground tanks shell and roof examination:

- Inspections performed to detect and assess flaws in the tank structure including cracks of different nature in welds, corrosion damage and other. Inspections are performed on new and in-service tanks.
- During the examination, a set of acoustic emission sensors sensitive in the range of 100-200 kHz are installed around the tank at several levels with typical distance of several meters.
- After system calibration, AE monitoring is performed under different fill levels for few hours.
- Additional examination of the roof can be performed if pressure is applied above the liquid level.



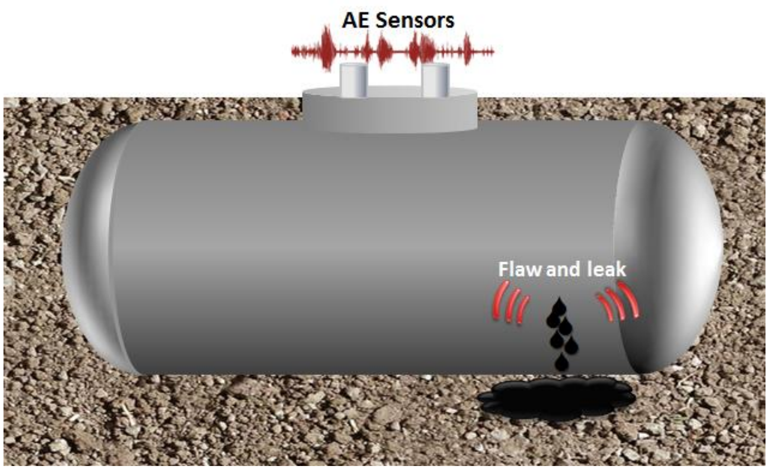
Tank flat bottom examination:

- Flat bottom examination is particularly important for detection of significant corrosion damage and detection of leaks.
- During the examination, a set of AE sensors are installed around bottom part of the tank. As an example, 6 sensors recommended for tanks with 25 meters diameter and 24 sensors for those with up to 100 meter diameter.
- Liquid level should as high as possible but not less than 50%.
- After product setting time of 24 hours for crude oil and 12 hours of petroleum products, AE monitoring begins. Normally, AE monitoring performed for at least 1 hour, however longer monitoring times up to 1 day are desired as specially in condition of environmental noises due to wind, rain, vibration and other.



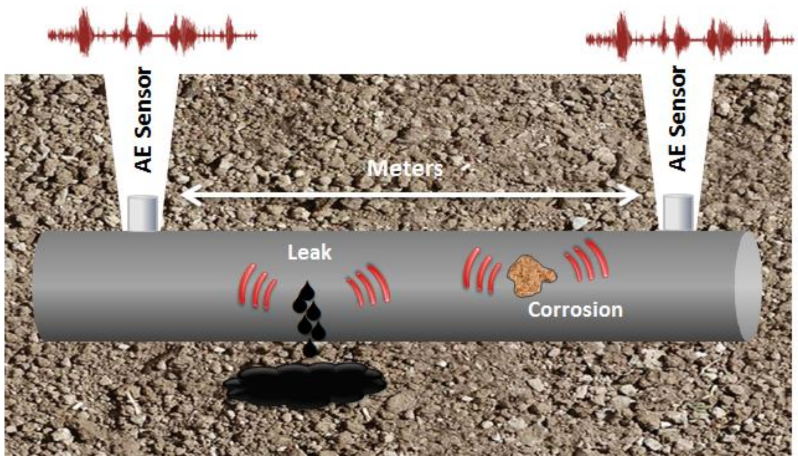
Underground tanks:

- Inspection of underground tanks by the acoustic emission technology is extensively performed for detection of presence of leaks, structural flaws and corrosion damage.
- During examination, two sensors are installed on the underground storage tank opening.
- Whenever possible pressure is applied to intensify leak and/or flaw development.
- AE monitoring is performed for one hour with simultaneous pressure readings.



Underground petroleum piping:

- Acoustic emission technology is used for detection of leaks, cracks of different nature and corrosion damage in underground petroleum piping.
- During examination, small holes are excavated every several meters (several meters for crack and corrosion detection and up to 25 meters for leak detection).
- Piping is monitored for flaw development and leaks for at least one hour.



How Reliable is AE Testing?

A special study conducted in Europe over 150 tanks of Shell, Dow, Exxon, ICI, DSM, Q8, Total companies that were inspected internally after AE examination has showed a very good correlation between severity of AE findings and extend of the following repairs.

In May 2005, a recommended practice for acoustic emission testing for corrosion in the bottom plate of aboveground tanks was issued by the High Pressure Institute of Japan (HPIJ). This procedure was developed by the research project conducted by HPIJ and sponsored by the Japan Oil, Gas and Metals National Corporation. Since introduction of this procedure, more than 160 tanks were inspected. Results of showed a good correlation between acoustic emission and corrosion risk parameters and demonstrated the advantages of acoustic emission for testing of extend of corrosion damage.

Acoustic Emission Standardization

Acoustic Emission one of the standard non-destructive test methods with several dozens of standards, procedures and test methods issued by various international organizations such as ASTM, ASME, EN and others.

Here some of the relevant standards, codes and documents:

1. ASTM E 1930 Standard Practice for Examination of Liquid-Filled Atmospheric and Low-Pressure Metal Storage Tanks Using Acoustic Emission.
2. ASTM E 1211 Standard Practice for Leak Detection and Location Using Surface-Mounted Acoustic Emission Sensors.

3. BS EN 15856 Non-Destructive Testing. Acoustic Emission. General Principles of AE Testing For the Detection of Corrosion within Metallic Surrounding Filled With Liquid.
4. HPIJ, A Recommended Practice for Acoustic Emission Testing For Corrosion in the Bottom Plate of Aboveground Tanks, 2005.
5. BS EN 14584 Non-Destructive Testing. Acoustic Emission. Examination of Metallic Pressure Equipment during Proof Testing. Planar Location of AE Sources.
6. BS EN 15495 2007 Non-Destructive Testing. Acoustic Emission. Examination of Metallic Pressure Equipment during Proof Testing. Zone Location of AE Sources.
7. ASTM E 569 Standard Practice for Acoustic Emission Monitoring Of Structures during Controlled Stimulation.
8. ASTM E 650 Guide for Mounting Piezoelectric Acoustic Emission Sensors.
9. ASTM E 750 Standard Practice for Characterizing AE Instrumentation.
10. ASTM E 976 Guide for Determining the Reproducibility of Acoustic Emission Sensor Response.
11. ASTM E 1316 Terminology for Nondestructive Examinations.
12. ASTM E 2374 Guide for Acoustic Emission System Performance Verification.
13. ASME Standard: Section V, Article 12, Boiler & Pressure Vessel Code, Acoustic Emission Examination of Metallic Vessels during Pressure Testing.
14. ASME Standard: Section V, Article 13, Boiler & Pressure Vessel Code, Continuous Acoustic Emission Monitoring.

AE Unique Advantages – Increased Safety with Excellent Money Saving

- Examination of 100% of structure.
- No need to evacuate product.
- No cleaning.
- No scaffolds.
- Reliable detection flaws and leaks.
- Evaluation of flaw propagation rate.
- Differentiating between developing and non-developing flaws.
- Quantitative long-term monitoring of flaws.
- Prioritization of tanks for maintenance and repair.