On-line Diagnostic Acoustic Emission Inspection Services of Power Plant Systems and Components

Reliability and safety of power plants is in direct relation with effectiveness of inspection programs. However, a large extent of required inspections, their high costs, significant labor and time consumption make impossible effective reduction of unplanned shutdowns, production loss and personnel casualties.

During the recent decade, **acoustic emission method** has been applied for in-service inspection of power plant systems in several countries of the world and demonstrated it ability to improve production continuity with increased safety and at reduced prices.

Primary applications of acoustic emission technology in power plants are on-line inspection and monitoring of

- **Steam piping**
- **Boiler headers**
- **Deaerators**
- **Turbines**
- **Water walls**
- **Gas piping**
- **Pressure vessels**
- **Petroleum storage tanks and piping**
- **Reinforced concrete and metal structures and foundation**

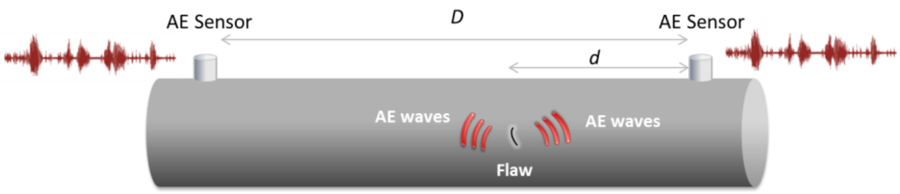
Hundreds of successful acoustic emission inspection projects performed in Power Industry in different countries of the world demonstrated that AE technology is improving operational safety, reducing maintenance costs and downtime. Failures were predicted or avoided while other non-destructive evaluation (NDE) technologies neither could be applied or detect impending danger. Numerous blind and confirmation tests performed by other NDE methods and metallurgical investigations demonstrated high level of detectability of AE method.

AE inspections are performed during normal operation and this grants multiple advantages for this technology over other NDE methods. Unlike other methods, AE performs inspection over 100% of structure during operation, allows quantitative flaw monitoring over long periods of times and can be used to estimate flaw propagation rate. AE is not only used as a non-destructive test method but it also assists to identify risk factors and operational/stress conditions contributing to origination and development of dangerous flaws. Plant operators can use this information to prevent or minimize operational risks.

What is Acoustic Emission?

Acoustic emission technology is based on detection and analysis of *acoustic emission* (stress) waves radiated during elementary crack propagation, local plastic deformation development around stress concentrators such as prefabricated weld defects, system of inclusions or creep cavitation. Once emitted, acoustic emission waves propagate along the inspected structure for distances of meters and then are detected by special acoustic emission sensors that convert mechanical disturbance produced by AE waves into electrical signals.

Special analysis of detected AE signals 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.



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

d = distance from first hit sensor

D = distance between sensors

V = wave velocity

Other mechanical sources of Acoustic Emission (AE) are friction and impacts, detection and analysis of which are used to identify steam leaks, water and steam hummer events, impacts at hangers' location and others.


Multi-channel AE System


AE sensors and preamplifier

Steam Piping and Equipment

AE on-line inspections and monitoring are performed on ***steam piping systems***, ***deaerators***, ***steam headers drums***, ***water walls*** during their normal operation.

AE Capabilities:

AE technology performs:

- Overall, global inspection during operation of hot steam piping and equipment for flaws and faulty conditions.
- Detection and assessment of flaws of different nature at early stages including creep, corrosion-, mechanical-, thermal fatigue and others.
- Detection and assessment of hangers and supports misbalance and other issues.
- Identification of zones subjected to dynamical overstresses.
- Detection of valve leaks, thermal shocks, water hammering and other traumatic events contributing to origination and development of flaws in piping.

AE System Installation and Inspection:

AE system consists of set of AE sensors installed with 3-4 meters characteristic distance. On high temperature components with insulation like steam piping, AE sensors mounted on waveguides welded in a small opening of 20 x 20 cm in the insulation. After installation, the opening is re-insulated and sealed. All steps of installation including welding of waveguides are performed during normal operation.

After installation and calibrations, monitoring is performed for several days under normal and in some cases under variable operational conditions. Based on the results, nature and locations of flaws, their severity and etc., a long term monitoring program or application of other NDE, metallurgical investigations are recommended. Typical re-inspection intervals are 2-3 years while in cases with significant findings, re-inspections can be performed every 3 months or even continuously monitored 24/7.

AE vs. Others NDE Methods:

The main alternative to AE is ultrasonic technology including A-Scan, Focused Phased Array and Time-of-Flight Diffraction methods. Other methods used for examination of steam components are Magnetic Particles for detection of surface defects and nowadays rarely Radiography. Advantages of AE method over the main alternative are summarized in the Table below.

Capability/Property	Ultrasonics	AE
Principle of the method	Material discontinuities causing reflection and diffraction of artificially generated ultrasonic waves	Material discontinuities, when they propagate, naturally release potential energy in form of stress waves
Method of application	Applied locally, in statistically selected potentially high risk zones	Global inspection, 100% of structure
Evaluation criteria	Criteria based on flaw position, orientation and size	Criteria based on energy and kinetic characteristics of flaws related to the released AE
Detects crack like flaws	✓	✓
Detects prefabricated weld defects	✓	✓ (when it develop a local plastic deformation)
Detects creep micro-cracking	✓	✓
Detects creep cavitation	-	✓ (when a large enough volume of material involved into creep)
Distinguish developing and non-developing flaws	-	✓
Used to monitor flaws	-	✓
Used to evaluates flaw propagation rate	-	✓
Identify operational and stress conditions contributing to flaw origination and propagation	-	✓
Outage independent	-	✓

AE methodologies and standard procedures:

AE procedures for inspection of power plant systems and components comply with the following standards and guides:

- ASTM E569: Standard Practice for Acoustic Emission Monitoring of Structures during Controlled Stimulation.
- ASTM E1139: Standard Practice for Continuous Monitoring of Acoustic Emission from Metal Pressure Boundaries.
- ASTM E1211: Standard Practice for Leak Detection and Location Using Surface-Mounted Acoustic Emission Sensors.
- ASTM E2374: Standard Guide for Acoustic Emission System Performance Verification.
- ASTM E750: Standard Practice for Characterizing Acoustic Emission Instrumentation.
- ASTM E650: Standard Guide for Mounting Piezoelectric Acoustic Emission Sensors.
- EPRI Guidelines for Acoustic Emission Examination of Seam-welded Piping.
- ASME and ISO codes for inspection of pressure vessels.

Gas Supply Pipelines

Gas supply pipelines are considered critical systems at elevated risk of catastrophic failure with casualties and high economic damage. Also, number of pipelines and their capacity constantly increasing which makes routine inspection of such pipelines for flaws and leaks extremely important.

AE Capabilities:

AE is used to inspect and monitor 100% of gas line length and:

- Detect flaws such as general electrochemical corrosion, pitting, cracks of different nature including stress corrosion cracking and others.
- Reliably detect and quantify gas leaks out of valves or connections.
- Monitor leaks through improperly closed valves.

AE vs. Others NDE Methods:

Overall inspection of gas pipelines by traditional methods such as different ultrasonic methods can be limited due to large number of welds to be examined, insulation, limited access in case of underground lines and other reasons. Even when a flaw is detected, traditional methods in many cases cannot distinguish developing or non-developing flaws or effectively monitor their propagation. All these limitations can be overcome with AE technology.

AE methodologies and standard procedures:

AE examination of gas lines comply with the following ASTM and ASME standards:

- ASTM E1139: Standard Practice for Continuous Monitoring of Acoustic Emission from Metal Pressure Boundaries.
- ASTM E1211: Standard Practice for Leak Detection and Location Using Surface-Mounted Acoustic Emission Sensors.
- ASME, Boiler and Pressure Vessel Code, Section V, Article 13: Continuous Acoustic Emission Monitoring.

Gas Pressure Vessels and Storage Tanks

AE is used widely for inspection of ***pressure vessels*** and ***storage tanks*** of different types. The inspections performed according to ASTM, ASME and ISO codes. However, not every pressure vessel or storage tank can be inspected "by the book". There are cases when a specially developed approach and solution are necessary for reliable diagnostics. Examples are ammonia and other vessels subjected to stress corrosion cracking.

AE System Installation and Inspection. AE vs. Others NDE Methods:

Ultrasonic, radiography, magnetic particles and other methods are used for evaluation of pressure vessels and storage tanks. However, these inspection normally do not cover 100% of structure, requires expensive shutdown of operation, cleaning, and scaffolding. All these are avoided using AE. System installation and inspection is performed during normal work of vessels, without scaffolding by climbers while entire vessel is simultaneously inspected and monitored. In case of insulated vessels small openings in insulation are made to mount AE sensors which later are re-insulated and sealed. Whenever significant indications revealed, other NDE methods can be applied to confirm AE findings. These capabilities of AE technology increase operational safety of vessels and significantly reduce inspection time and costs.

AE standard procedures:

- ASTM E1139-07: Standard Practice for Continuous Monitoring of Acoustic Emission from Metal Pressure Boundaries.
- ASME, Boiler and Pressure Vessel Code, Section V, Article 12: Acoustic Emission Examination of Metallic Vessels During Pressure Testing.