Acoustic Emission Testing

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Presentation Objectives:

(1) To familiarize the ASGE Audience with Acoustic Emission Non-Destruction Testing (AET) methods in general, and

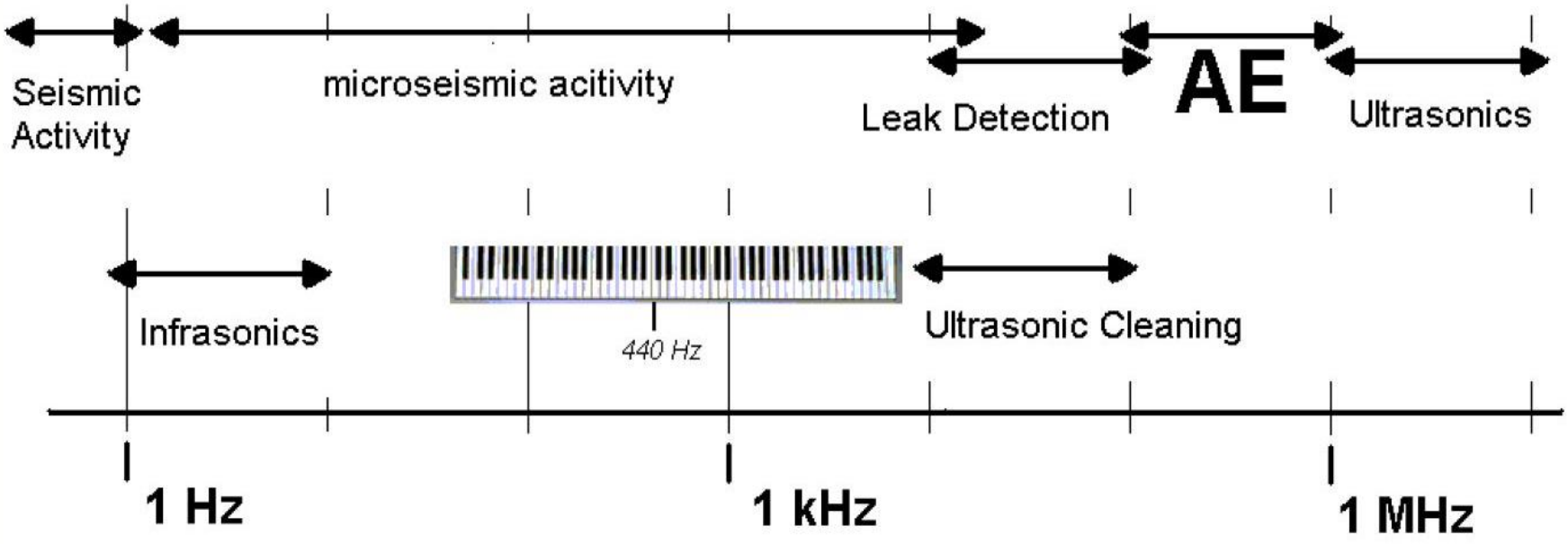
(2) To identify several applications where AET can be used by Gas Engineers.

What is Acoustic Emission (AE)?

- Acoustic Emission (AE) refers to the generation of transient elastic waves produced by a sudden redistribution of stress in a material, as well as when a structure is subjected to an external stimuli or forces such as a change in pressure, load, or temperature. Such generated changes in the stress wave are detected and monitored by judiciously placed acoustic sensors.
- Sources of AE vary from natural events like earthquakes to the initiation and growth of cracks, slip and dislocation movements, melting, twinning, and phase transformations in metals.
- AE's have also been measured and recorded in polymers, wood, and concrete as well as in other materials.

Source: http://www.ndt-ed.org/EducationResources/CommunityCollege/Other%20Methods/AE/AE_Intro.htm

Location of AE in Sound Frequency Regime



Courtesy of Dr. R. Nordstrom – AEWG 2004

Acoustic Emission Testing (AET) vs. Other Forms of Nondestructive Testing (NDT)

- There are two important difference btw. AET and other NDT methods:
  1. With AET, the material structure, once stimulated, generates the signals that are evaluated. AET simply listens for the energy released by the structure under test. AE tests can often be performed on the objects to be tested while they are still in operation, (if adequate loading to propagate defects that will trigger acoustic emissions can be implemented).

Acoustic Emission (AE) vs. Other Forms of Nondestructive Testing (NDT)

2. AET deals with dynamic processes, or changes, in the material structure. Only the active material defect features (e.g. crack growth) are heard, located and monitored.

AET can help discern between developing and stagnant defects. Stagnant defects do not release energy in the structure- and thus they do not generate any AE signals.

It is possible for flaws to go undetected if the loading on the material structure under test is not high enough to cause an acoustic event.

Pros and Cons of AET:

- Pros:

1. AET provides an immediate qualitative indication of the relative strength or of the risk of failure of a component or structure,
2. AET allows for fast and complete volumetric inspection through the use of multiple sensors, or through permanent sensor mounting for process control, and
3. With AET, there is no need to disassemble and clean the specimen under test.

Pros and Cons of AET:

- Cons:

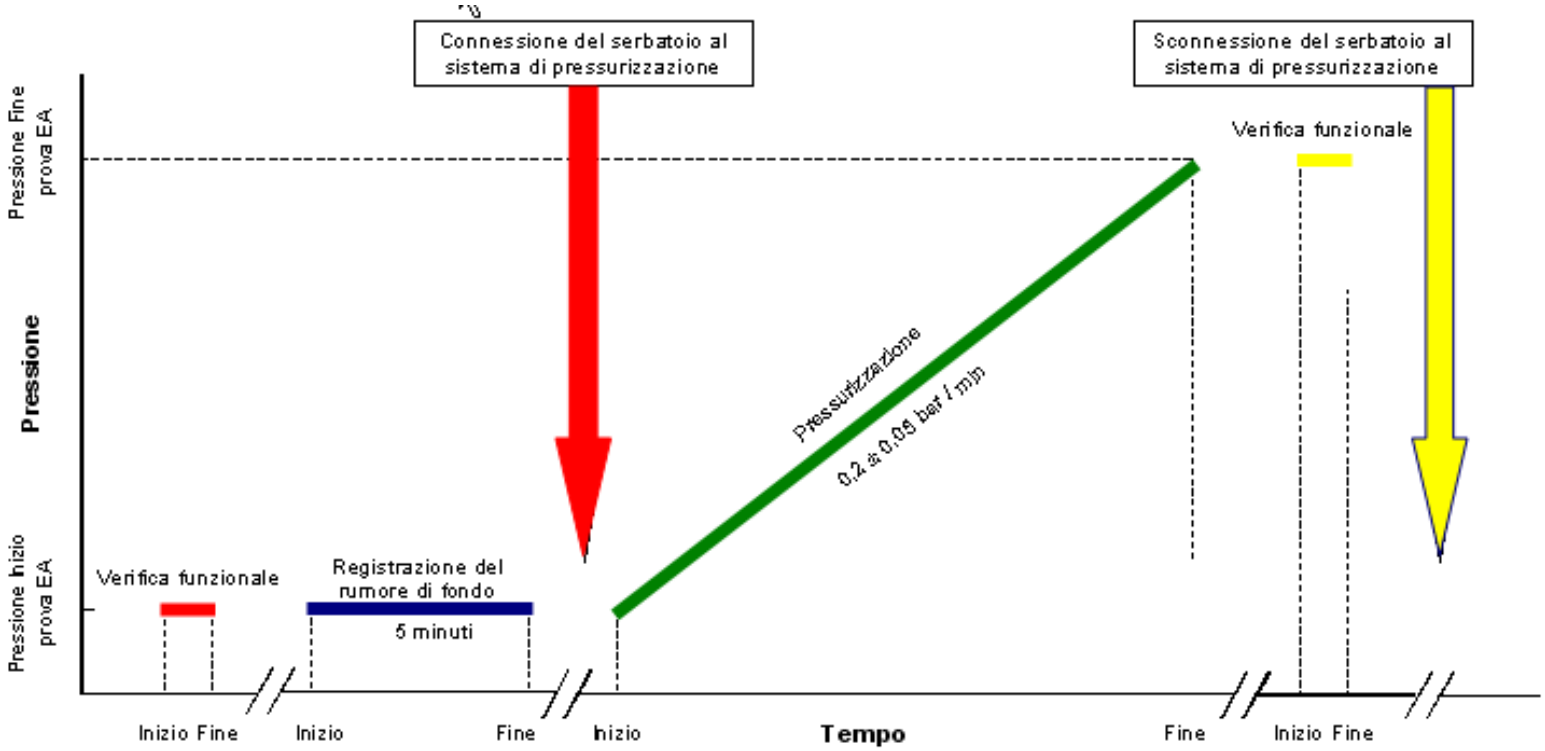
1. AE systems can only qualitatively gauge how much damage is contained in a structure (other NDT methods are necessary if quantification of the damage is to follow)
2. AE systems lose accuracy in loud service environments (due to interference from extraneous noise/s with the AET signals)

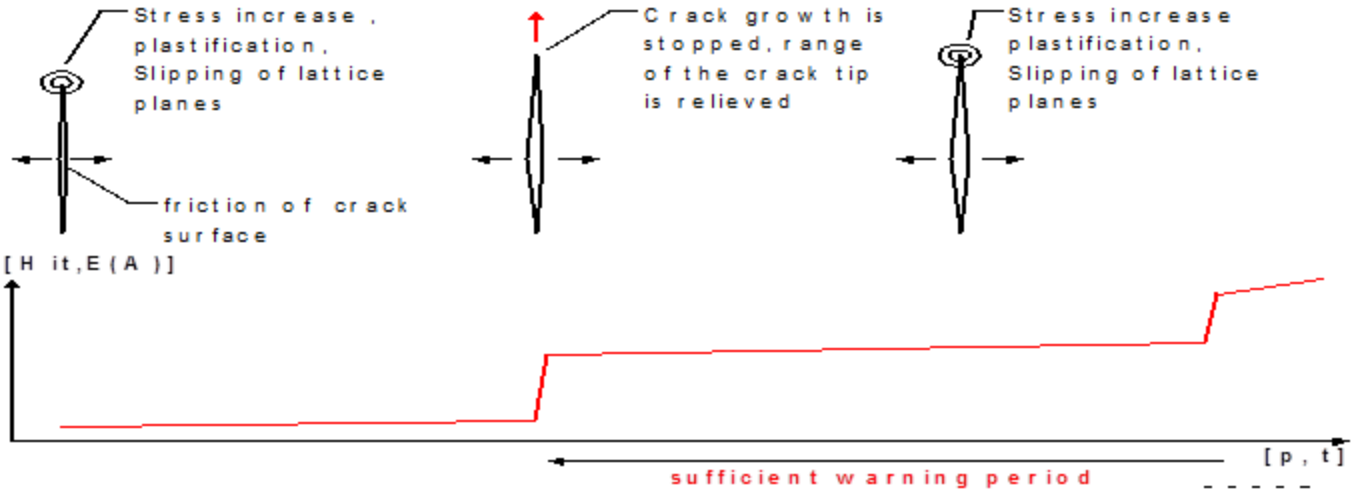
For successful AE applications, signal discrimination and noise reduction are essential.

AET Current Applications in North America:

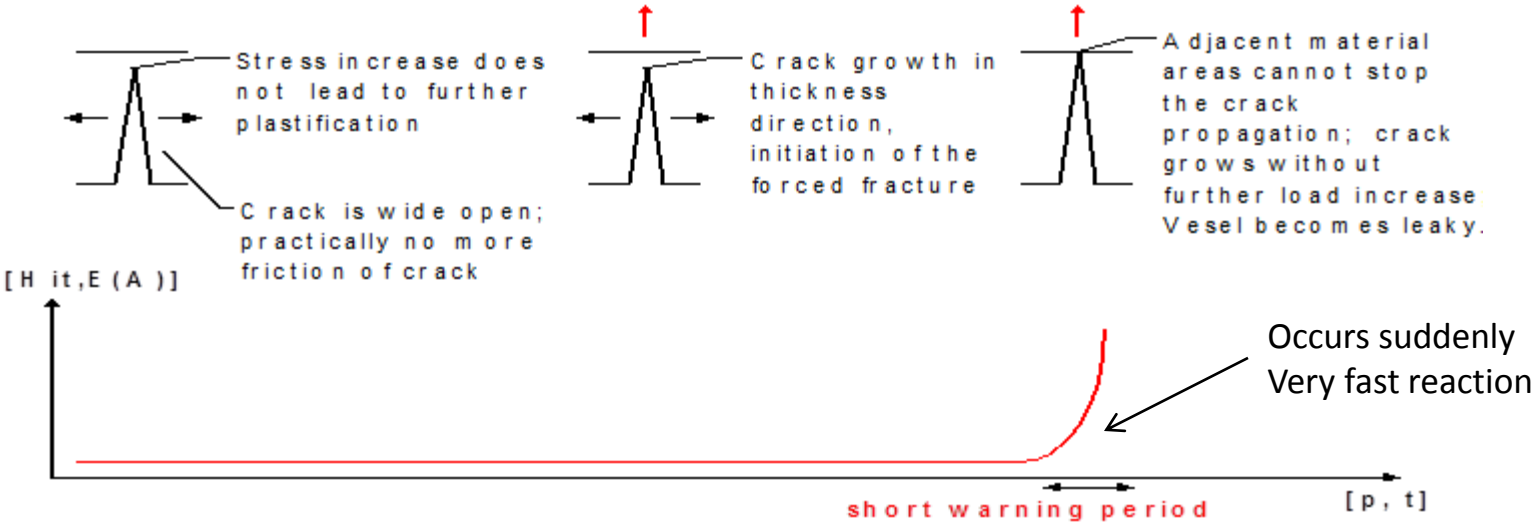
1. Weld Monitoring,
2. Bucket Truck (Cherry Pickers) Integrity Evaluation,
3. Gas Trailer Tubes,
4. Bridges,
5. LP Gas Rail Cars, and
6. Aerospace Structures.

The pressure increase rate must be held constant at 0.2 $\pm$ 0.05 bar/min until the desired maximum pressure is reached. Note: 1 Bar=14.5 psi





Activity increases with stable crack growth



Activity increases with critical crack growth

Why use AET for Periodic Testing of LP Gas Vessels in Europe?

In Europe, LP Gas underground tanks (UT's) must be inspected every 6 – 12 years. This inspection used to be conducted with a hydrostatic test followed by an internal inspection.
Because these tanks are typically in residential service such testing can cause inconvenience those who live near the tank under test as well as cause air pollution (large VOC release).

AET requires gradual pressurisation of the vessel under test (conducted by heating the LP Gas in the tank) without opening the tank. There is no loss of VOC's to ambient with AET, nor does the tank need to be unearthed.

Blu Solutions operates a fleet of mobile laboratories throughout Italy

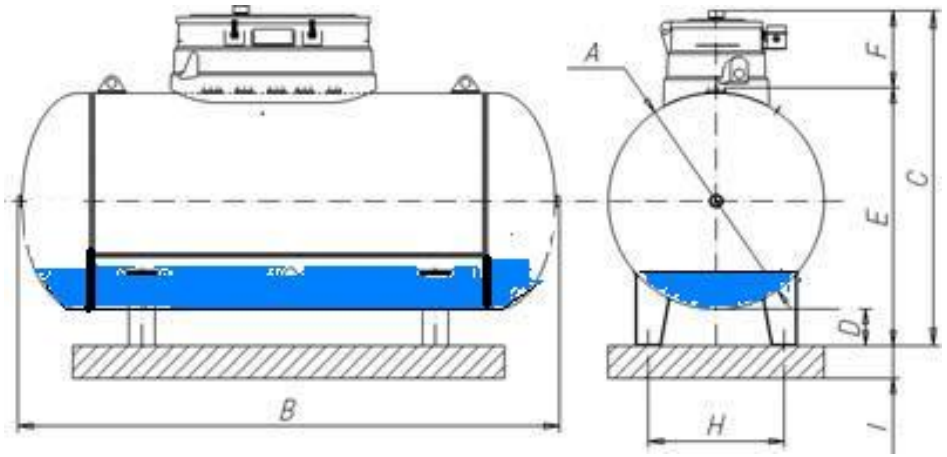
10 of the 12 mobile laboratories

Benefits of Acoustic Emission (AE) Testing for UTs

1. AE testing performs a 100% verification of the vessel.
2. AE can use the LP Gas inside the UT to achieve the target end pressure.
3. No water or methanol are introduced in the UT when conducting an AE test.
4. With AE testing, the UT stays in service. The AE test is conducted on site. Hydraulic testing requires the UT to be out of service. Further, for Ultrasonic and X-Ray testing the vessel must be unearthed.
5. AE testing is a dynamic, real time assessment of all active defects (propagating cracks, corrosion effects, leakage, etc.) Hydrostatic testing yields less and lower value data.
6. Residual risk associated with UT remaining in service can be defined with AE (not so with hydrostatic testing.)
7. A typical AE Test on a common UT requires relatively little time (~90 min)

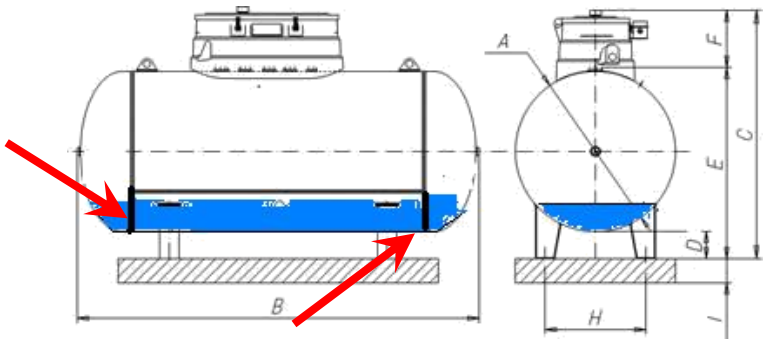
An Example of Conditions Promoting Internal Corrosion

Internal Corrosion can be accelerated when there's a high fuel demand from a tank in which a low level of liquid is typically maintained. A high rate of evaporation occurs when the liquid level in a vessel is at or below ¼ full and when there is an on-going demand for fuel. The on-going demand for fuel causes a significant drop in the remaining liquid temperature which in turn creates low temperature-induced stress on the welds in the lower section of the vessel. Repeated cycles of such conditions aggravate this phenomenon.



This repeated low temperature stress problem is further aggravated by various contaminants found in LP Gas (e.g. mercaptans, excess methanol and water).

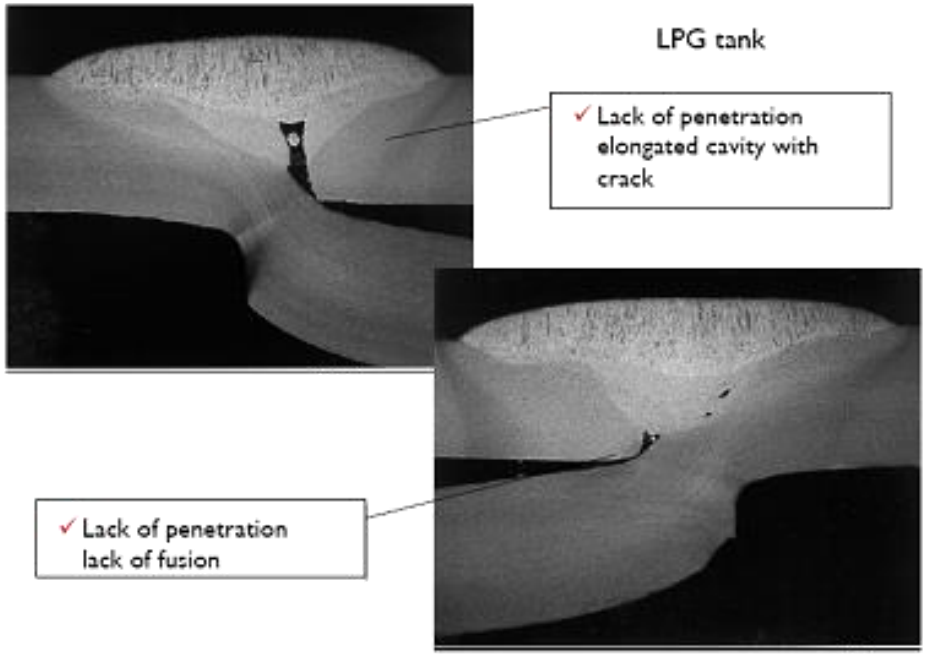
Such internal corrosion on the lower cap welds is shown below.



Why Cathodic protection is not enough

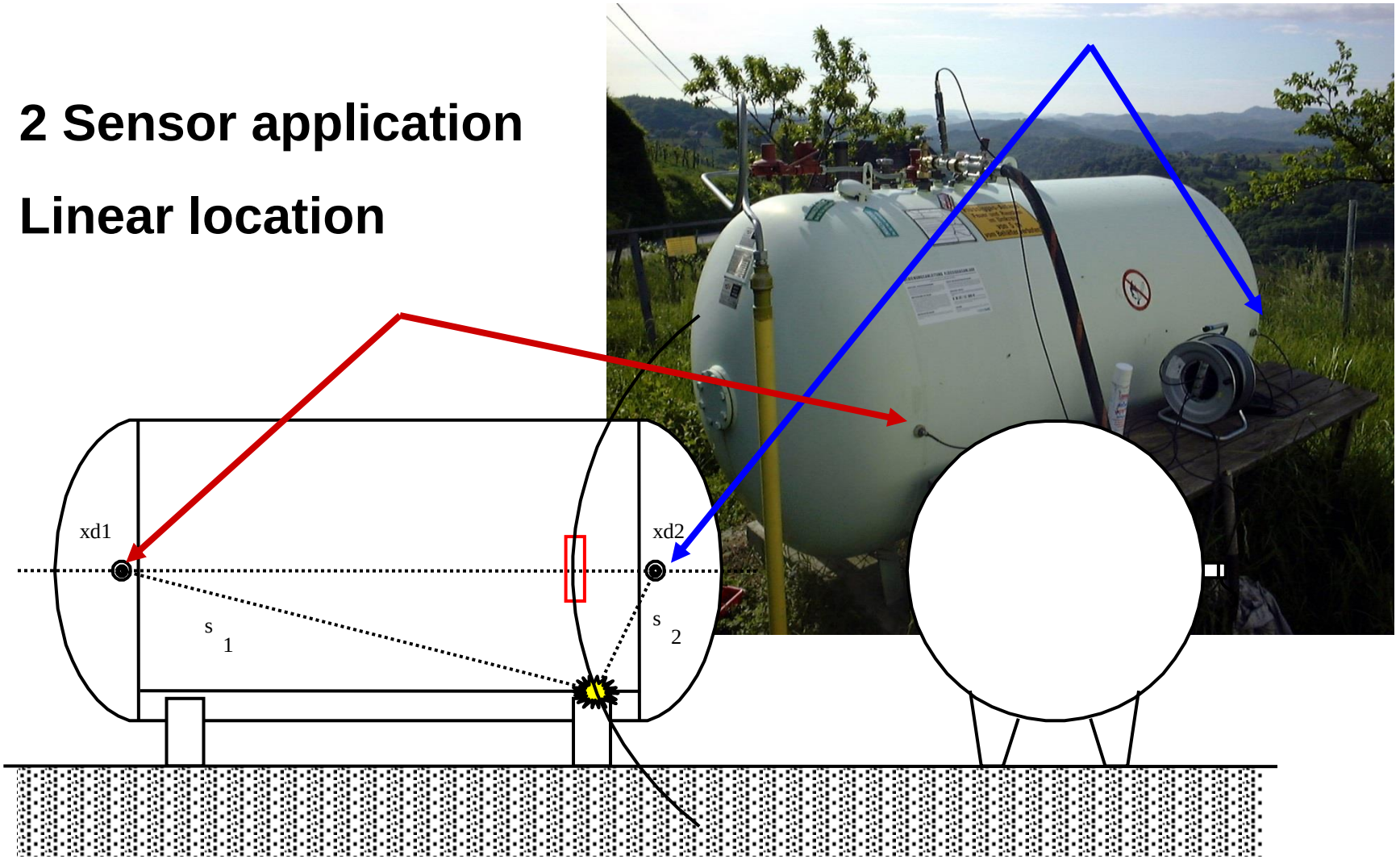
Another problem that can occur over the service life of a UT is related to small and undetected manufacturing defects (i.e. inclusions, voids, lack of fusion or of penetration in the welds, etc.). These can grow during the service life of the tank. Although such defects may have been beyond the initial scope of the prescribed quality control at the time of manufacture, or may have escaped the initial post-manufacturing quality control, AE can and will detect them.

Radiograph images below illustrate such defects.

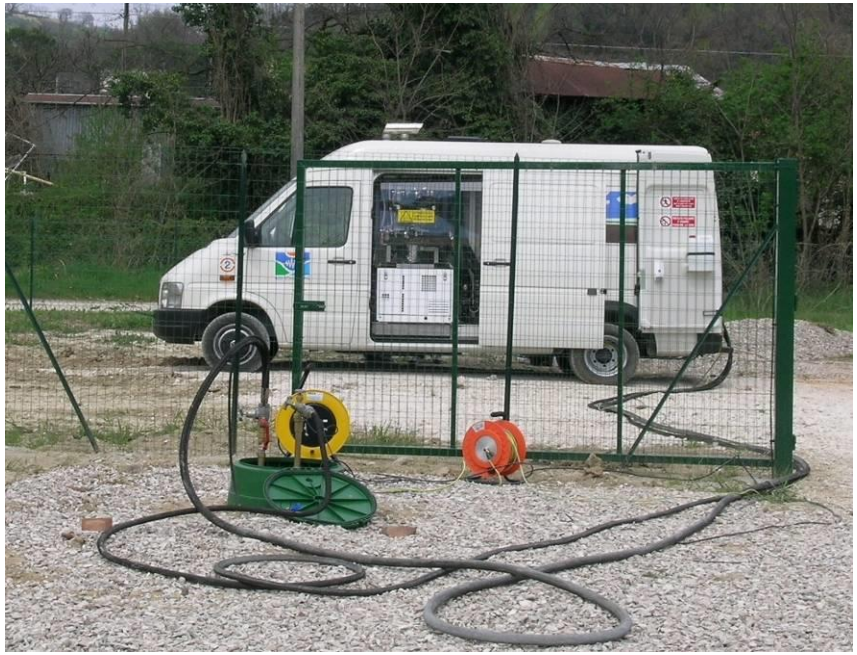


2 Sensor application

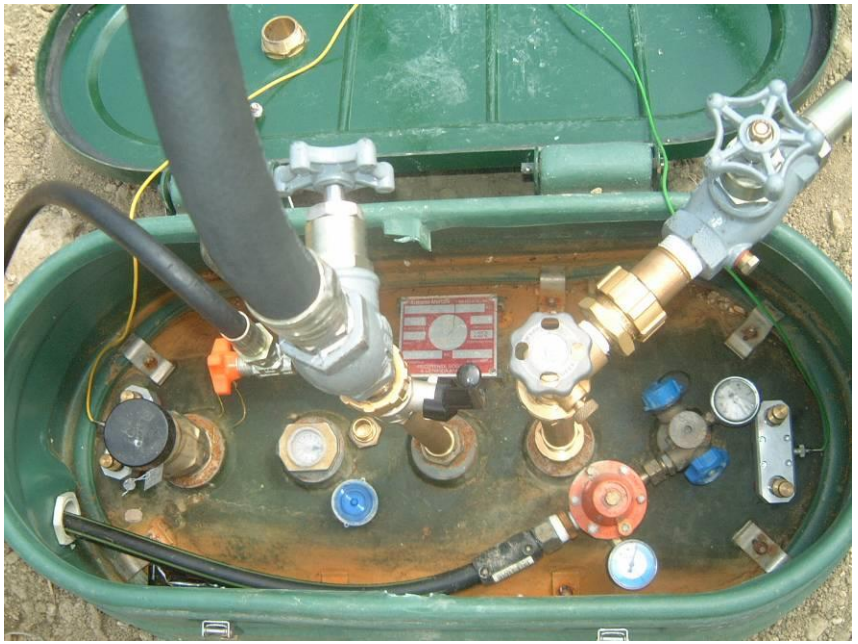
Linear location



AE testing of LP Gas UT's



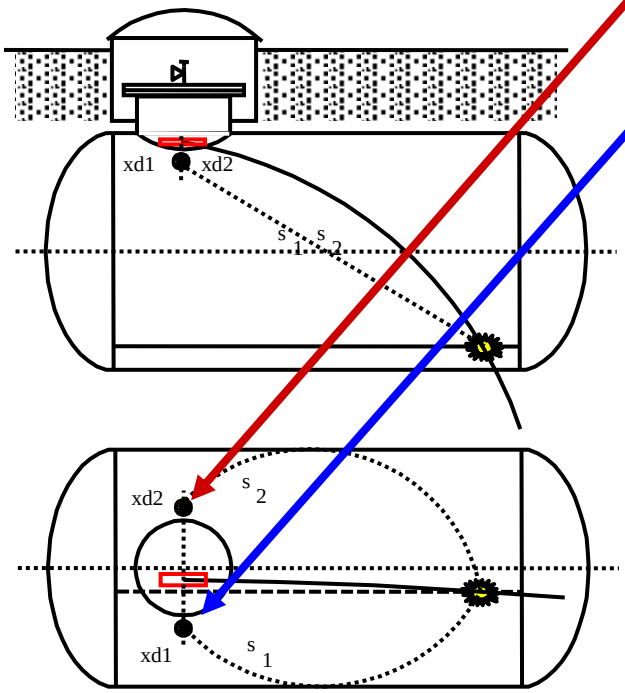
Mobile lab connected to UT

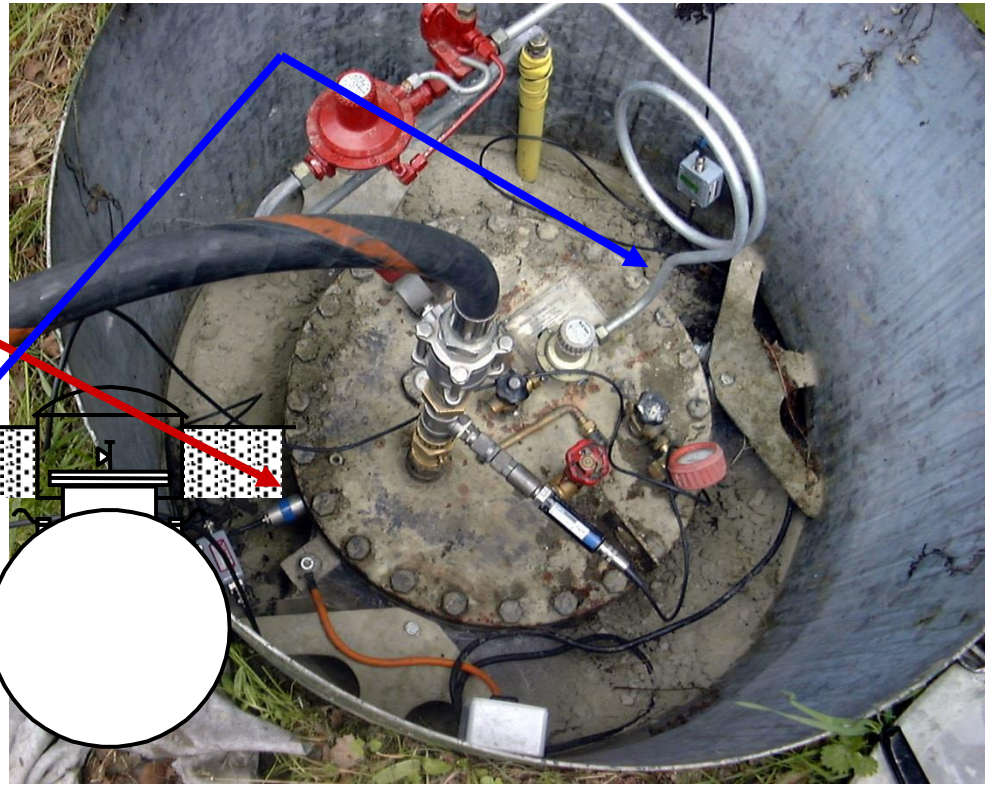


LP Gas circulation connection and two(2) transducers

2 Sensor application

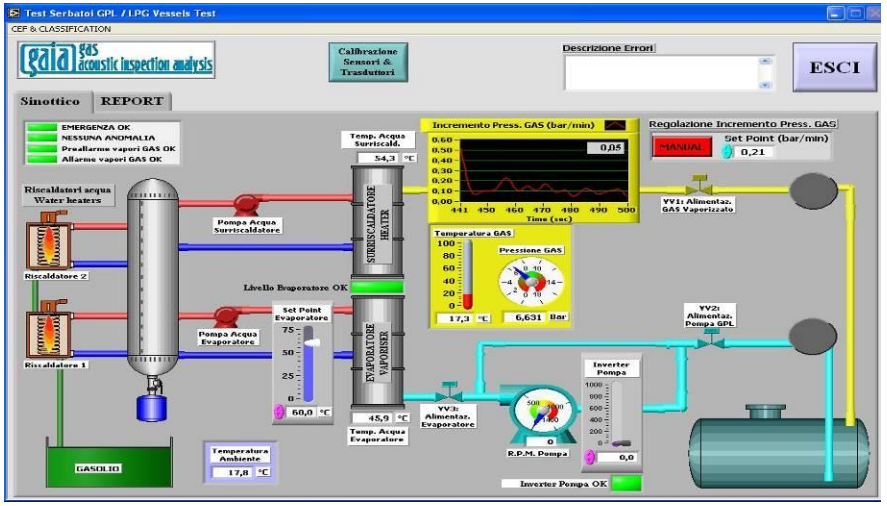
Δt – filter (cluster)

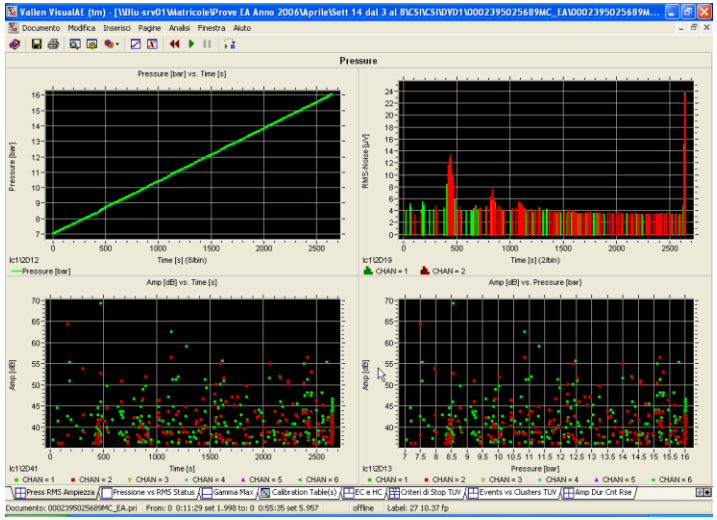


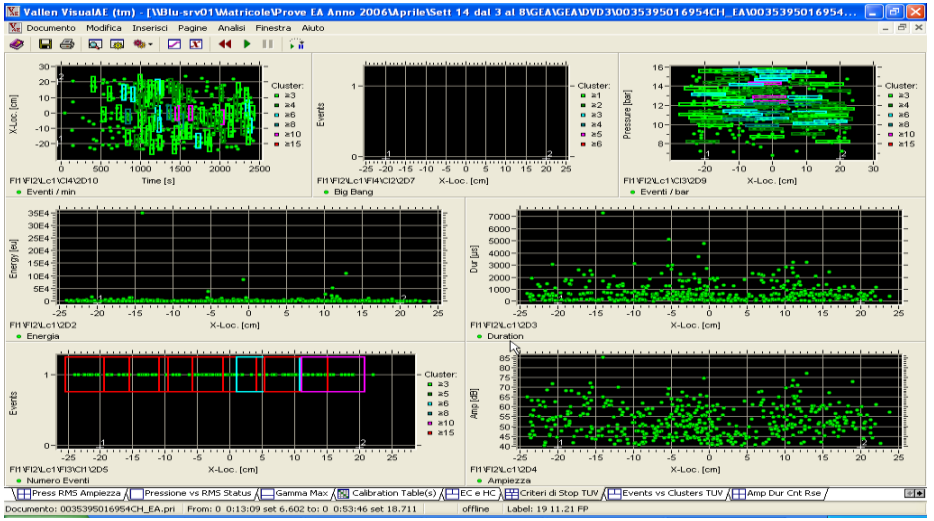


Restricted access within the dome

Mobile Lab Screen Displays of AE Tests of LP Gas UT



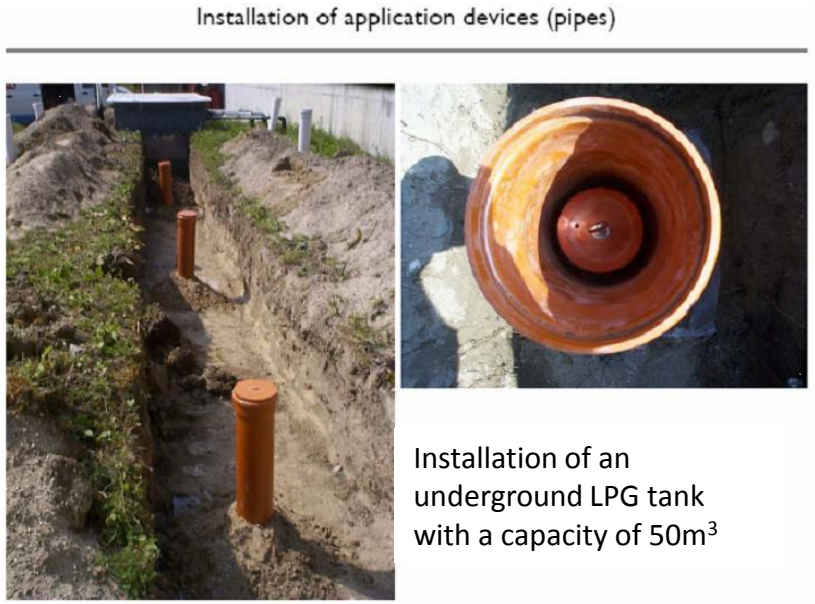




Large LP Gas Storage Vessels

AE testing on bulk UT and on mounded tanks minimizing re-qualification and out-of-service costs.

LPG mounded tank 100m^3 (partly underground)



Installation of an underground LPG tank with a capacity of 50m^3

AE for Production Line QC on New Tanks

AE test methods for QC of new pressure vessels. Allows for better tracking of a vessel's structural integrity over time.

Centro Sviluppo Materiali SpA (CSM)

CSM is a private RTO (Research Technology Organization). It develops and leverages research and technological achievements into industrial applications across the world.

- 50 YEARS HISTORY: 1963-2013

- TURNOVER (2012): 31 M€
- EBITDA (2012): 3.9 M€
- PERSONNEL: ~ 300 employees and collaborators
- POLICENTRIC STRUCTURE:
  Headquarters in Rome
- PATENT PORTFOLIO:
  ~ 200 Italian and International patents

BUSINESS AREAS

OIL & GAS

ADVANCED MATERIALS,
VALIDATION AND FULL SCALE TESTING
(e.g. PIPELINES)

ENERGY & TRANSPORT

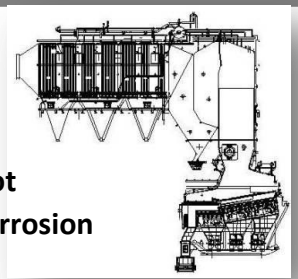
ENERGY & POWER GENERATION MATERIALS ,
COMPONENTS PROTOTYPING AND
ADVANCED COATINGS

STEEL

PRODUCTS AND PROCESSES DEVELOPMENT
FOR STEEL INDUSTRY

ENVIRONMENT & SUSTAINABILITY

Plasma torches



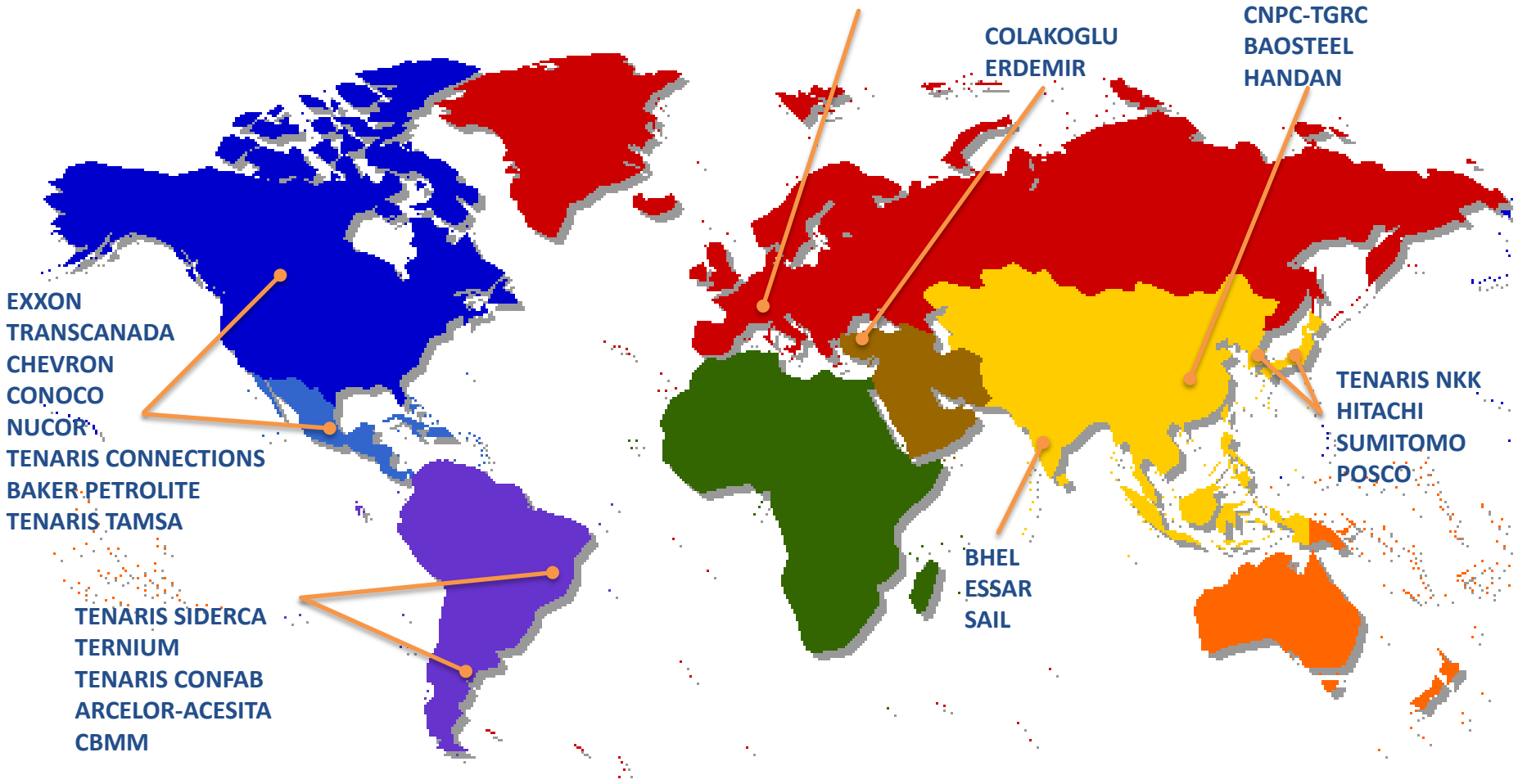
Hot corrosion

Flameless burners

CUSTOMERS

ARCELOR MITTAL, TATA STEEL, SALZGITTER MANNESSMANN, VOESTALPINE, APERAM TUBACEX, DUFERCO, SIEMENS-VAI, BP, STATOIL , TOTAL, HITACHI POWER EUROPE, EPRG, DONG ENERGY,

COGNE ACCIAI SPECIALI, LUCCHINI, ORI MARTIN, VALBRUNA, FERALPI, ASO, DANIELI, MARCEGAGLIA, PAULWURTH, CONAI, ANSALDO ENERGIA, ENI, ENEL, E.ON, ANSALDO NUCLEARE, EMA, AVIO, NUOVO PIGNONE (GE-OIL&GAS), SYNDIAL, ANSALDO BREDA, ARCHIMEDE SOLAR ENERGY, THALES ALENIA SPACE, TETRAPACK, MICROCAST



CSM for Oil&Gas Industry

For the Oil&Gas industry CSM provides support accross the entire production line, from product development to production, design and performance assessment of materials and components for upstream (well, riser, flowline), midstream (underwater and onshore oil&gas transport lines) and downstream (oil and gas industry and/or refineries) applications and World Wide renowned equipment for full scale tests are located in the Rome and Sardinia Test Centres.

CSM follows the whole production chain (from material development to final component qualification), CSM offers its services to both producers (that is steel making companies and pipe producers) as well as to end users (that is both Oil&Gas Companies, Contractors, Utilities).

AET Activities performed by CSM for major Oil&Gas Company (eni) :

1. Investigation of new classes and generations of pipeline steels, according to API grade X5L: standard X65, new generation X80, Future X100, (small scale test)
2. AE Monitoring of Artificial Surface Flaws during the pressurization of single pipe (medium scale test)
3. AE damage monitoring (Dent&Gouge and Cathodic protection) on full scale test buried pipeline section reproducing typical in-service conditions)

Basic knowledge to investigate the relationship between AE signals and the damage sources in PIPELINE STEELS caused by in-service hazards (plastic deformation, cracks initiation, crack propagation, stress corrosion cracking ...)

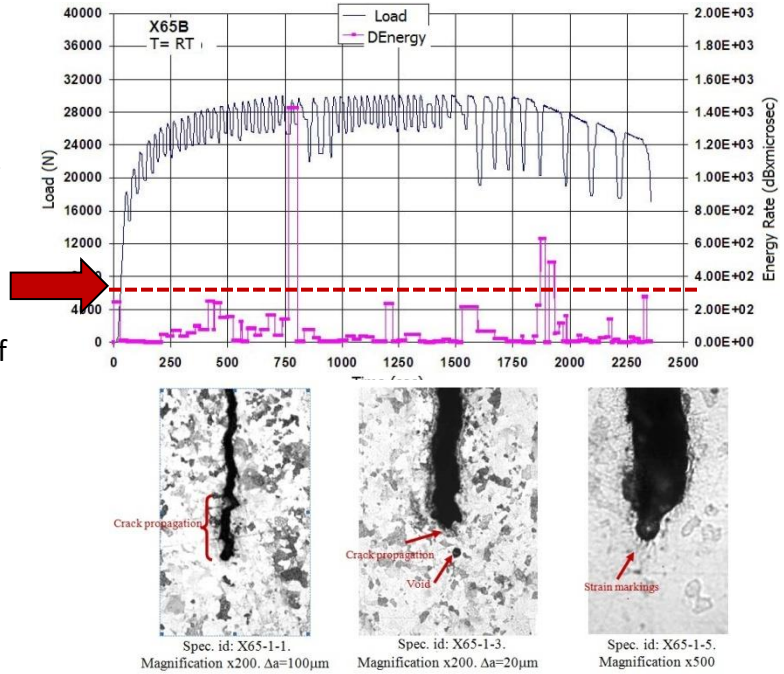
Small Scale Test - Acoustic Emission ENERGY RATE *vs* damage

References:

Budano. S.*, Giunta. G.** Lucci A.* Acoustic Emission Data Analysis to Evaluate Damage Mechanisms in Pipeline Carbon Steels ; nd.net 2011

Budano. S.*, Giunta. G.** Lucci A.*. Damage Mechanism Evaluation in Pipeline Steels using
Acoustic Emission Analysis
53rd Acoustic Emission Working Group Meeting held at the University of Denver, Denver, CO, USA

*Centro Sviluppo Materiali SpA, Rome (Italy)
** eni SpA gas&power division, San Donato Milanese (Italy)



Bending tests shown that AE Energy Rate data parameter can be used to monitor the applicable damage mechanism: plastic deformation, ductile any brittle failure.

Medium Scale Test - Acoustic Emission ENERGY RATE *vs* damage

References:

Giunta. G.**, Prandi L.** , Budano S.*, Lucci A.* “Fracture Mechanisms Evaluation in Gas Transportation Pipes by Acoustic Emission Analysis” ASNT- Fall Conference and Quality Testing Show, Palm Springs Convention Center, Palm Springs, California, 24–28 Oct. 2011

Budano S.*, Piancaldini R.*, Lucci A.*, Giunta G.*, “Gas pipeline full scale burst test monitoring by AE technique”. 54th Acoustic Emission Working Group Meeting Acoustic Emission PRINCETON, NJ – USA - MAY 21 & 22, 2012

Giunta G.**, Budano S.*, Lucci A.*, Prandi L.**. “Pipeline Health Integrity Monitoring (PHIM) Based on Acoustic Emission Technique”. Proceedings of the ASME 2012 Pressure Vessels & Piping Division Conference PVP2012-78545 July 15-19, 2012, Toronto, Ontario, CANADA.

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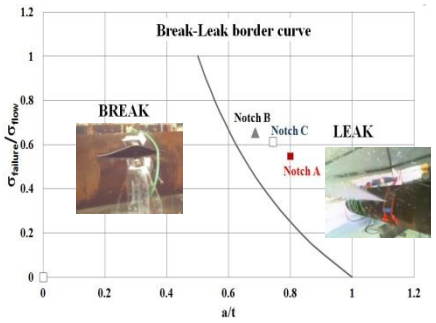
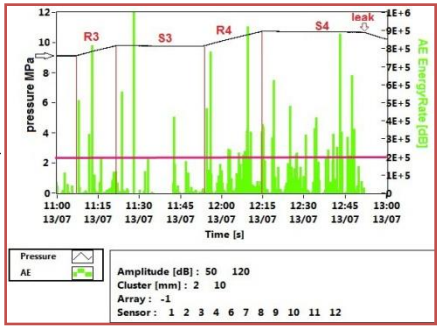
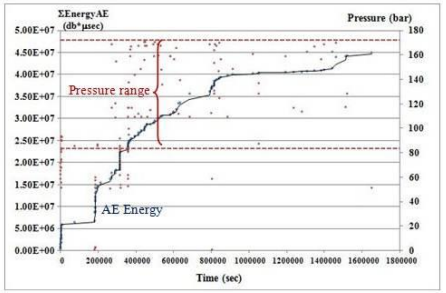




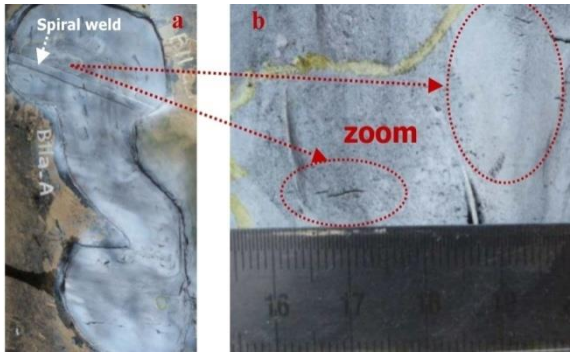
Medium scale tests confirmed that Acoustic Emission Testing (AET) is a useable NDT method to detect incipient damage. The failure mode is identified through observed variation in the Energy Rate AE parameter.

Full Scale Test - Acoustic Emission ENERGY RATE *vs* damage

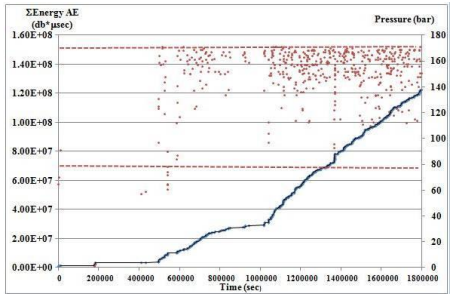


Crack initiation

Defects



Full scale test confirmed that AET is suitable to detect with high sensitivity the both crack initiation and crack propagation in buried pipeline in service facing typical stresses and service environment.



Crack propagation

References

Budano S.*, Piancaldini R*. Giunta G.**, “Damages Monitoring for Oil&Gas Pipeline Using AE Technique”. 30th European Conference on Acoustic Emission / 7th International Conference on Acoustic Emission GRANADA (SPAIN) 12-15 SEPTEMBER 2012.

Giunta G.**, Budano S.*, Lucci A.*, Piancaldini R.*, Prandi L.**, Improvement of Reliability Assessment of Gas Pipeline Using Acoustic Emission Technique. ASME PVP2013, next July 14-18, Paris France.

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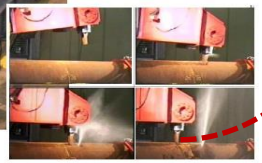
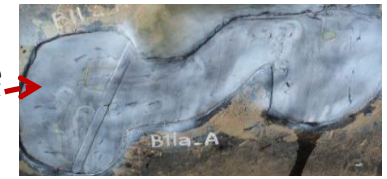
** eni SpA gas&power division, San Donato Milanese (Italy)

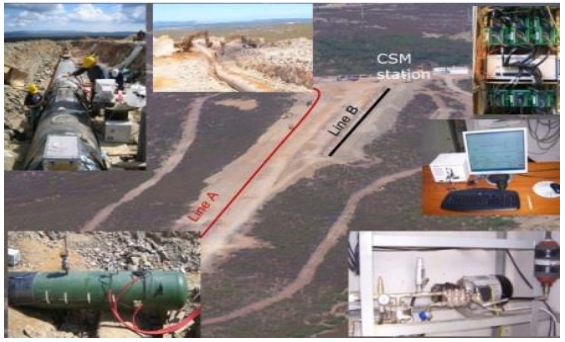
Full Scale Testing at CSM's Facilities

Dent & Gouge (D&G) Test stand for full scale test





Acoustic Emission Testing revealed higher sensitivity to detect the early stage of damage onset vs. standard NDT methods.



Full scale test lab

Pipeline with length of up to 500m (1600ft) is damaged with measured D&G defects and buried. Both cathodic protection and internal pressure variations can be applied faithfully to reproduce in-service conditions .

The damage evolution can be monitored by Acoustic Emission Testing Techniques using Vallen AMSY-6 system as well as strain gauges. Periodically, the pipeline is unburied and the D&G damage is measured using NDT standard methods.

Q & A