TÜV AUSTRIA GROUP

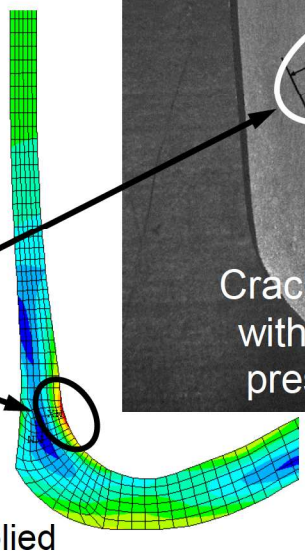
Acoustic Emission innovative techniques for industrial applications

G. Lackner, J. Bohse | EPERC International Conference, Rome, 1-3 April 2019

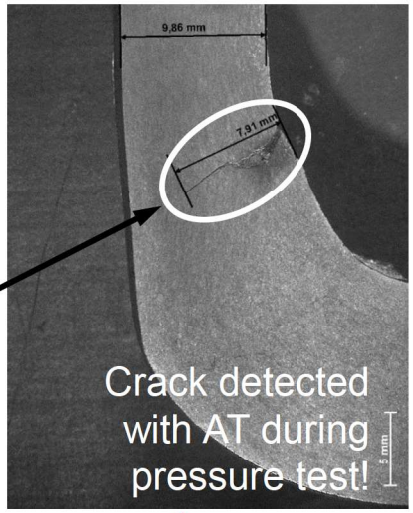
09/04/2019

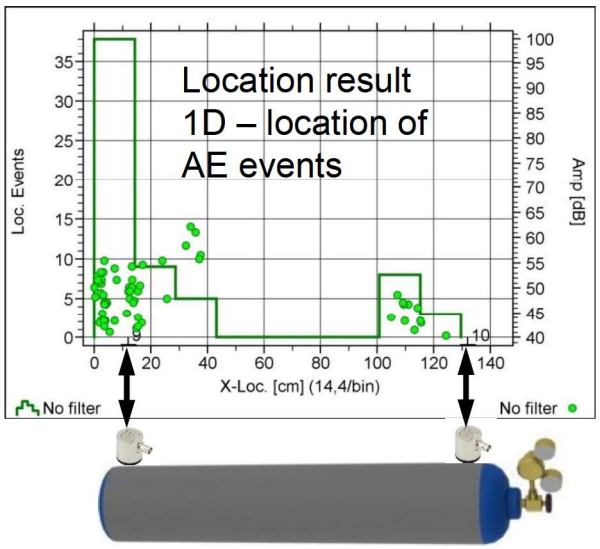
Getting started: crack detection case study summary

Gas cylinders



Finite element method (FEM) applied to given geometry at 200 bar internal pressure





AE indicates local **overstress** at **crack position** while load (stress) is increased. **Evaluation** is done **on-line** as well as offline.

Selection of regular test objects for AT

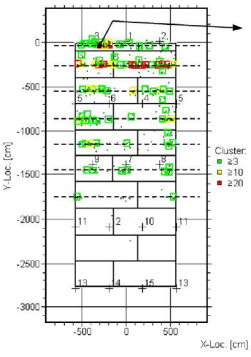
AT usually carried out in the course of **re-qualification**.

AT performed to find:
cracks,
weld defects,
casting defects,
corrosion,
…..
leaks.

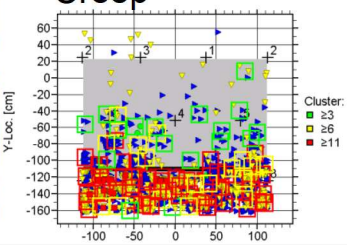
AT to check the **structural integrity** against **degradation**.

Some examples of practical experience

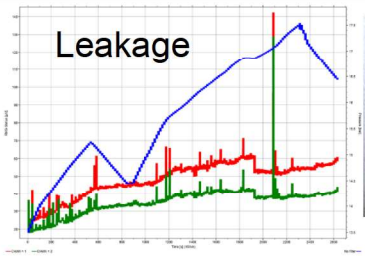
Corrosion



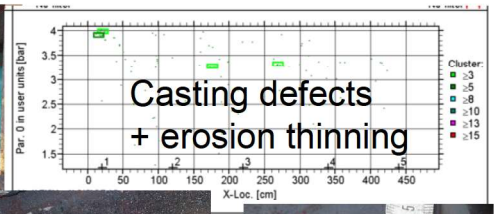
Creep

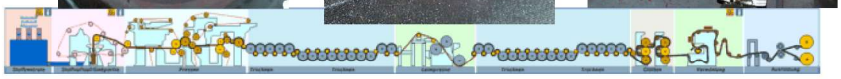


Leakage

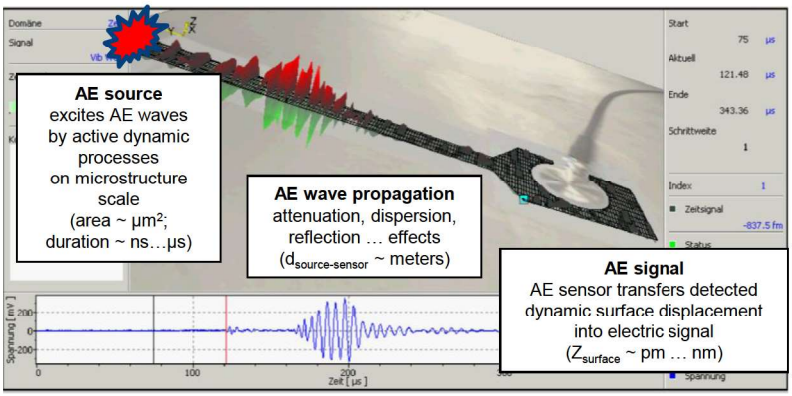


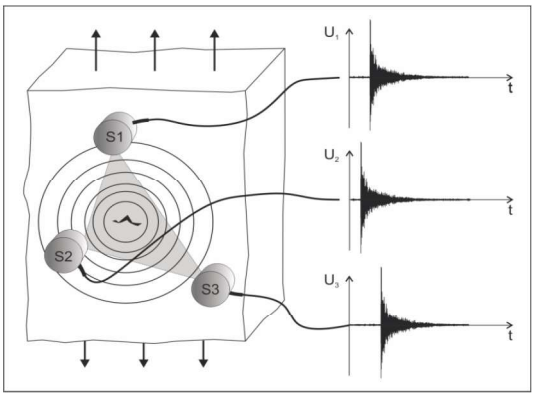
Casting defects
+ erosion thinning



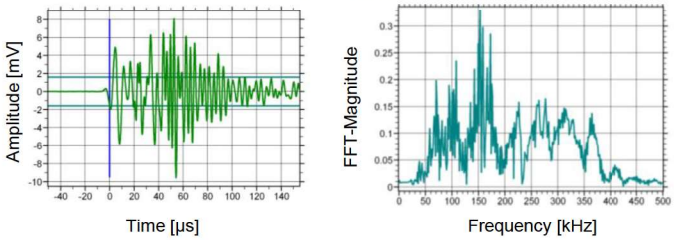


Principle of AE testing

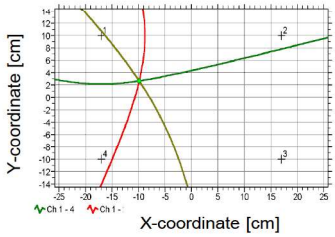




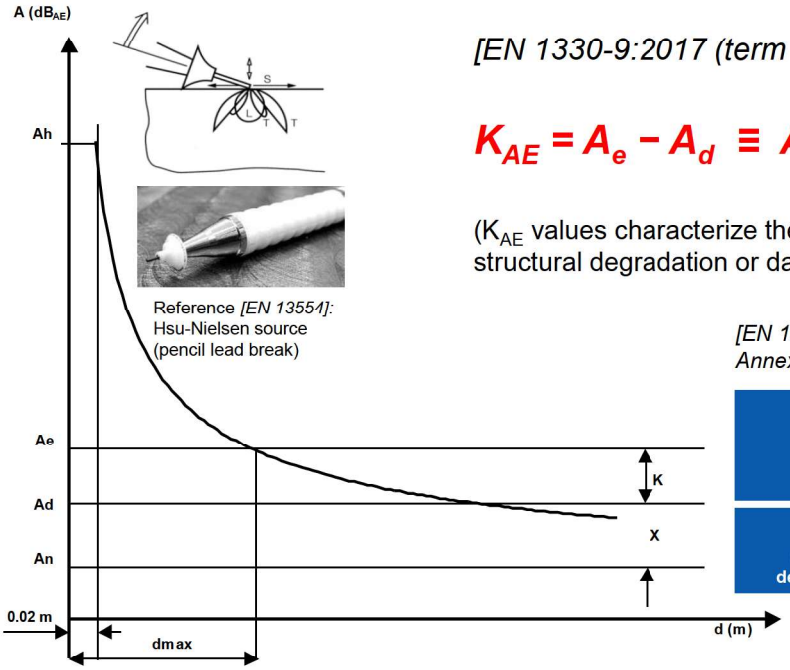
Analysis of AE signals in time & frequency range



Location of AE sources



Detectability parameter K_{AE}



[EN 1330-9:2017 (term 2.5.12)] & [EN 14584]

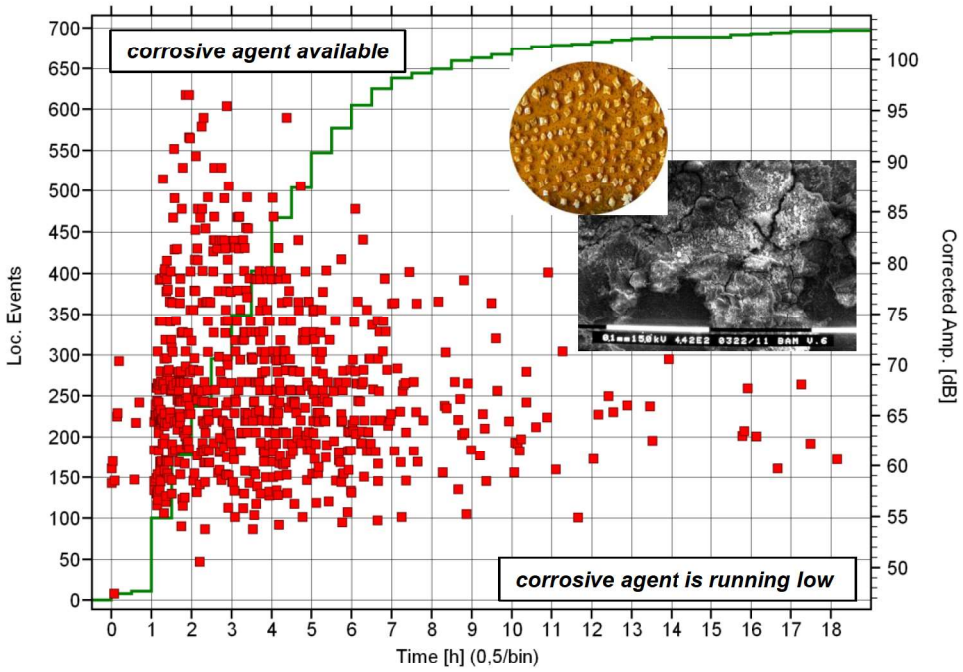
$$K_{AE} = A_e - A_d \equiv A_{h\ (HN;\ 0{,}02m)} - A_{source\ mechanism}$$

(K_{AE} values characterize the detectability of different mechanisms of structural degradation or damage relative to the Hsu-Nielsen source)

[EN 13445: Unfired pressure vessel – Part 5: Inspection and Testing Annex E: Acoustic Emission Testing]

	Yield strength	
	275 – 325 MPa	> 325 MPa
K_{AE} (crack detection)	12 dB	6 dB

Active corrosion processes

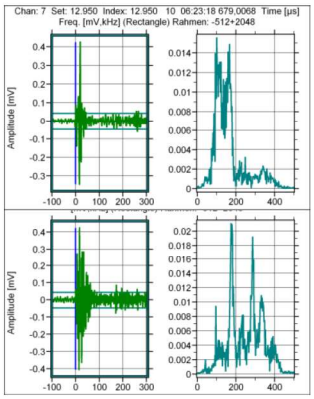


3% salt water corrosion
(pressure vessel steel P 460 NL1):

→ AE only, if corrosion process is active

→ signals from different source mechanisms

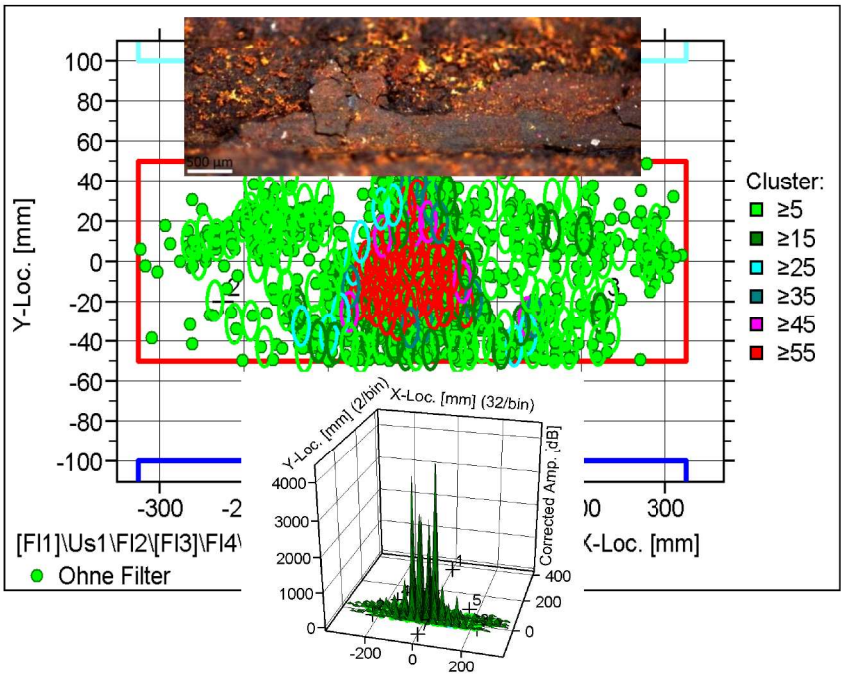
(e.g. stress induced breakage of corrosion products
Fe → FeO· $V_{FeO} \approx 7 \times V_{Fe}$)



→ ***no information about remaining wall thickness!***

[EU project CORFAT, BAM Berlin (2008-2012)]

Passive corroded areas



Pressure loading of locally corroded areas
(pressure vessel steel P 460 NL1):

→ corrosion not active

→ corrosion detection due to secondary effects
(breakage/spalling of hard & brittle rust particles)

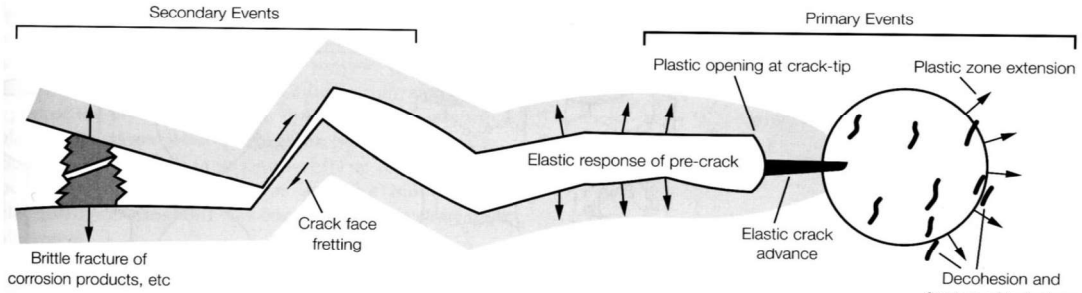
→ AE intensity ↑ with thickness (age) of corrosion layer

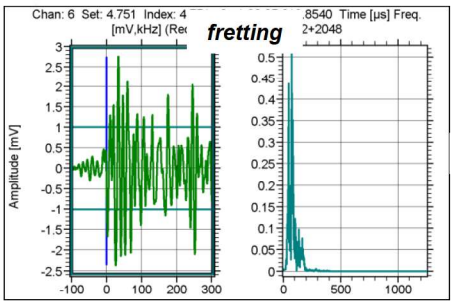
→ ***information about severity of corrosion damage!?***

[EU project CORFAT, BAM Berlin (2008-2012)]

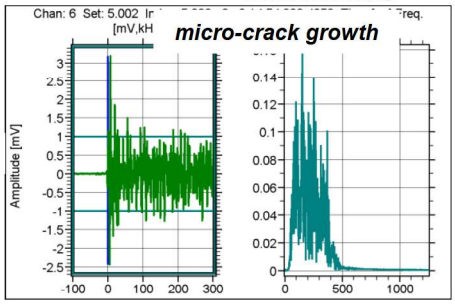
AE detection of cracks

Primary and secondary AE sources from crack areas *[C.B. Scruby: 1986]*



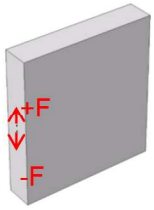


(AE sensor f_R ~ 150 kHz)

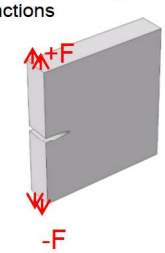


Advanced methods of AE analysis

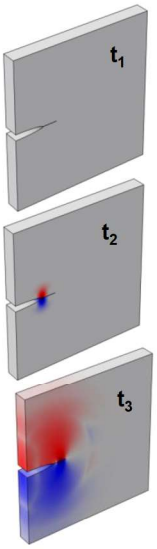
FE modelling of AE signals *[M.G.R. Sause et al.:2012…2016]*

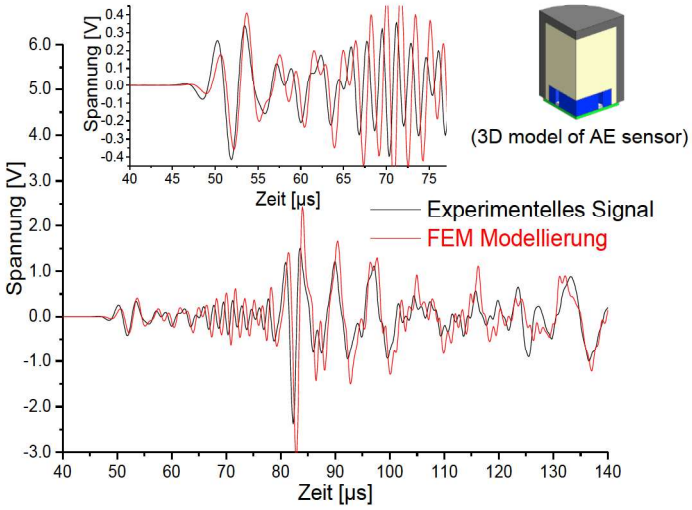


Description using analytical functions



Generation of AE source by fracture mechanics principles

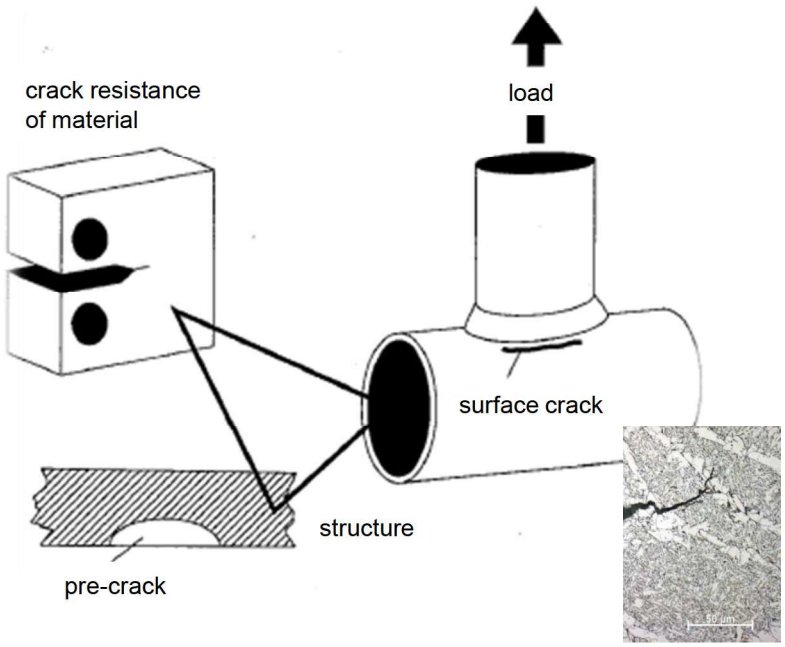




(3D model of AE sensor)

AE source → **Wave propagation** → **AE signal detection**

Fracture mechanics analysis & AT of metal structures



Stress intensity factor (LEFM)

$K = \sigma\sqrt{\pi}\, a \cdot f$

f **(loading, object & crack geometry)**

$K \rightarrow K_C$

→ unstable / brittle macro-crack failure!

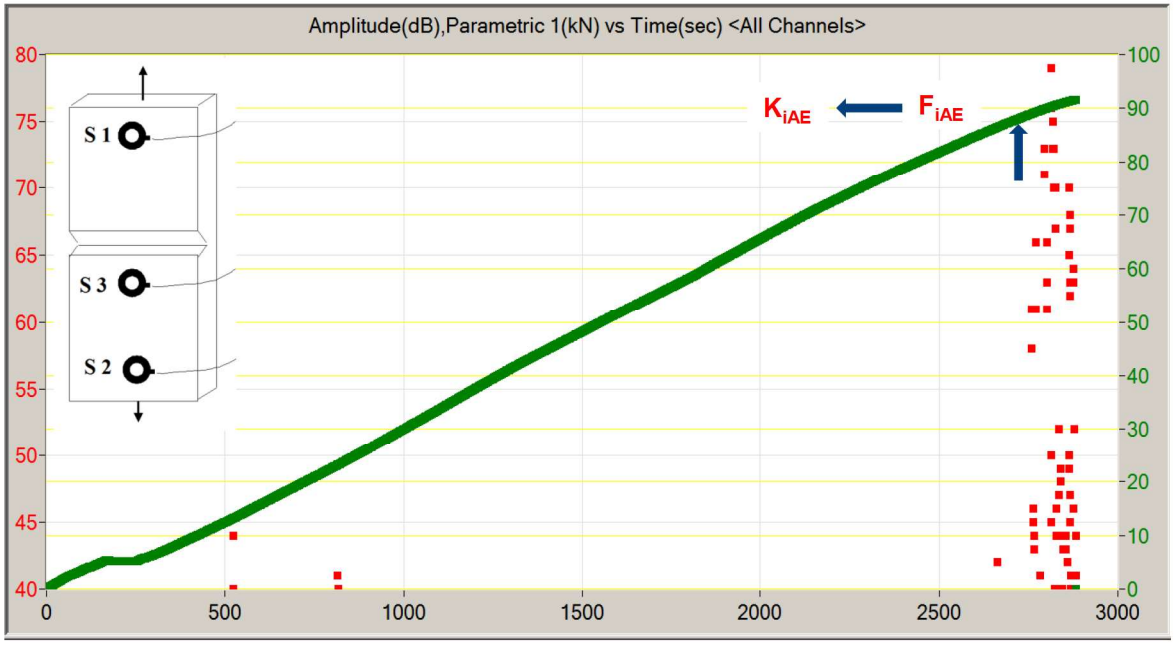
Acoustic emission testing (AT)

$K \geq K_{iAE} < K_C$

→ loading stimulates sub-critical crack growth Δa at the macro-crack tip on crystal structure scale (Δa ~ grain size)

→ AE detection & evaluation of macro-cracks using primary sources from micro-crack growth

Static crack opening (coupons)



Static crack initiation and crack propagation (pressure vessel steel 34CrMo4):

→ AE signals from micro-crack growth events during stable macro-crack propagation of higher strength steel

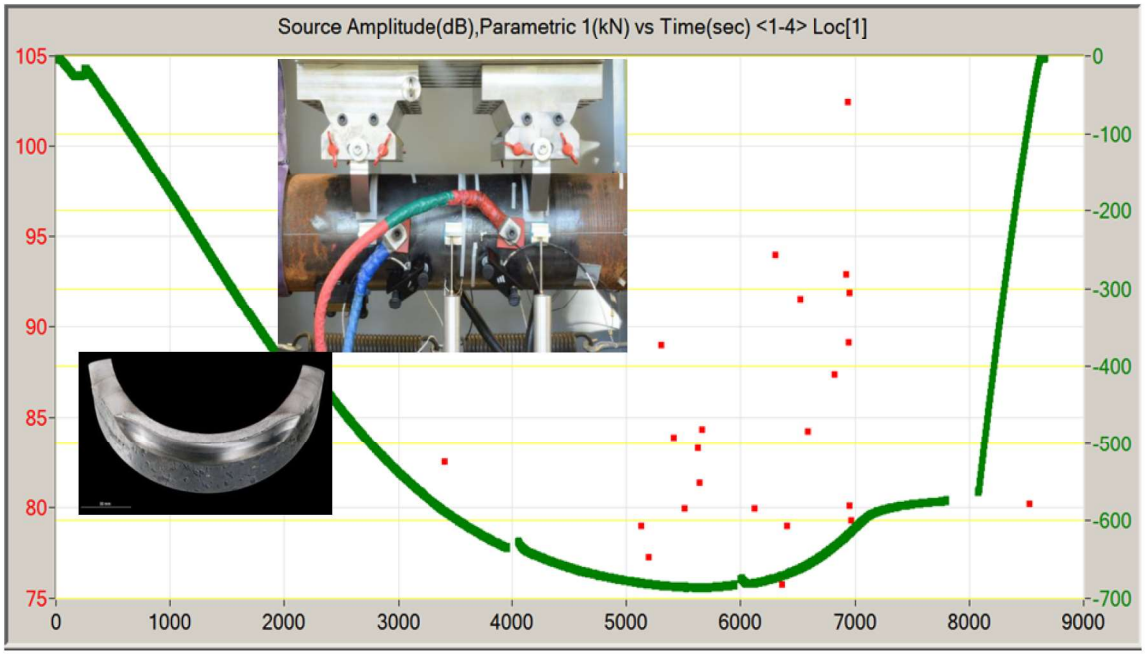
[BMU project Special CNG Technologies, BAM Berlin (2000-2003)]

Static crack opening (structures)

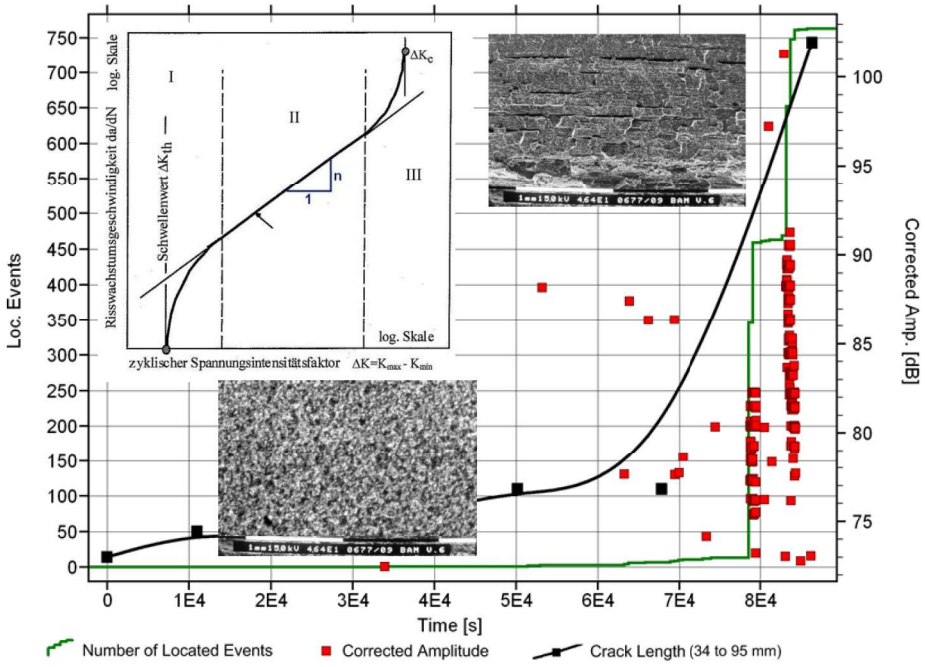
Static crack initiation & propagation (construction steel S 355):

→ only few AE signals from micro-crack growth events during stable macro-crack propagation of moderate strength steel (high A_d = 65 dB_{AE} due to high level of background noise from the testing facility)

[BAM project AGIFAMOR, BAM Berlin (2016-2018)]



Cyclic loading (fatigue crack growth)



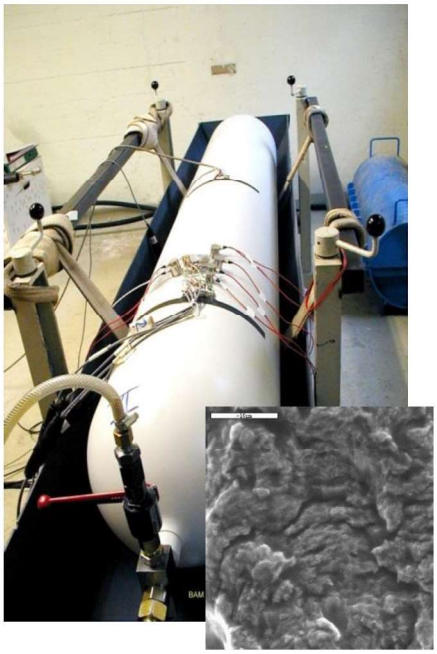
Fatigue crack initiation & stable crack propagation (pressure vessel steel P 460 NL1):

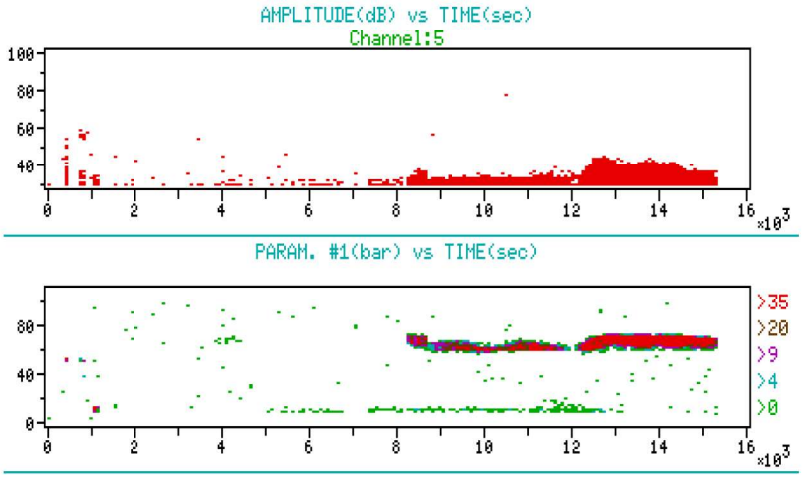
→ very low amplitudes of AE signals from early stages of stable fatigue crack growth

→ amplitudes of AE signals ↑↑ at stages of higher alternating stress intensity ΔK and increasing unstable macro-crack propagation

[EU project CORFAT, BAM Berlin (2008-2012)]

Pressure cycling (notched seamless vessels)





Fatigue crack initiation & stable crack propagation (pressure vessel steel 34CrMo4):

→ very low amplitudes of AE signals (A ≤ 50 dB_{AE}) from early stages of stable fatigue crack growth

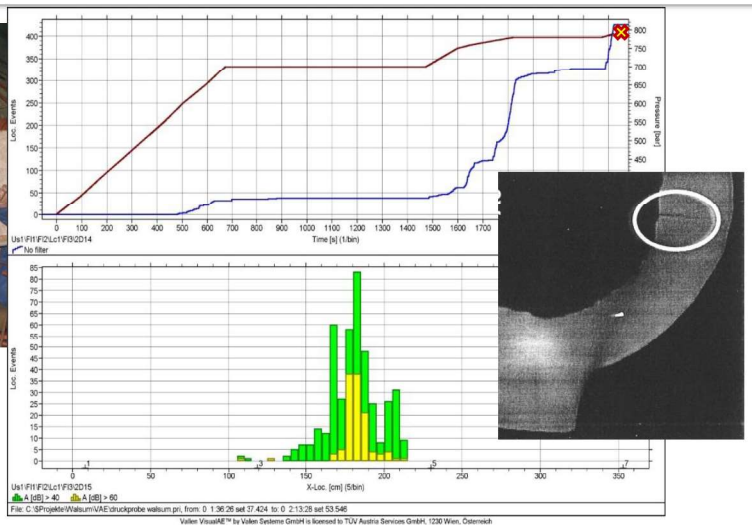
[BMU project Special CNG Technologies, BAM Berlin (2000-2003)]

Experimental (laboratory!) values for parameter K_{AE}

Damage mechanism	Maximum burst signal amplitudes at source location (dB_{AE})	K_{AE} (dB)
Early stages of stable fatigue crack growth (moderate strength steel)	**≤ 50**	**≥ 40**
Stable crack growth at static loading (moderate strength steel)	**≤ 80**	**≥ 18**
Active corrosion processes (salt water)	**≤ 90**	**≥ 12**
Increasing unstable fatigue crack growth (moderate strength steel) or stable crack growth at static loading (higher strength steel)	**≤ 100**	**≥ 6**
Reference = Hsu-Nielsen source: *- lead mine: 0,5 mm / 2H* *- distance: 0,02 m and* *- 150 kHz resonance sensor*	***98***	***0*** ***($A_e = A_d$)***

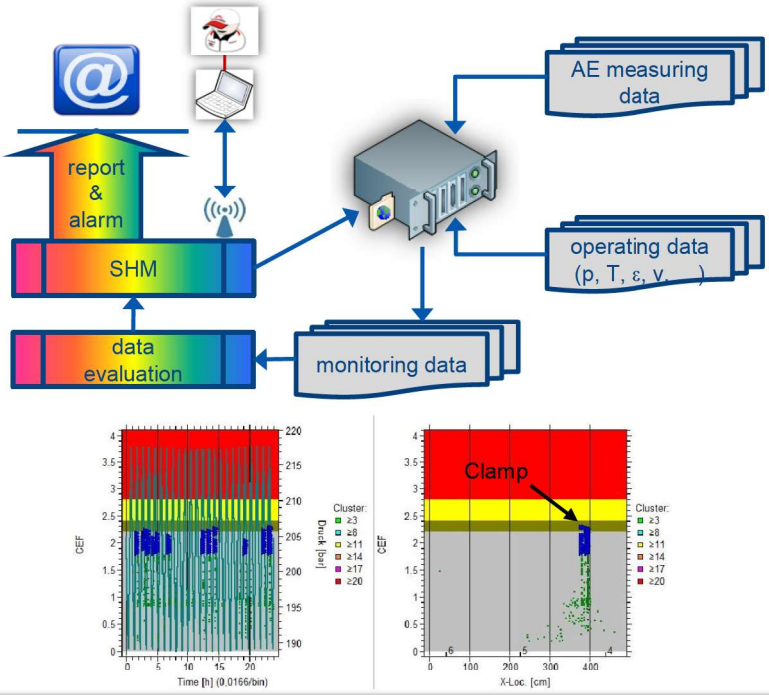
Alternative to AT: In-service AE monitoring

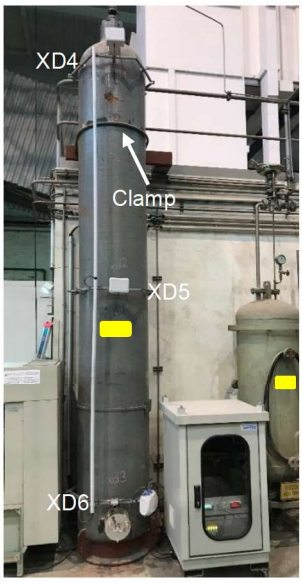
Many cracks detected at steam boiler membrane wall short after final acceptance test when put to service → burst test on several damaged sections of membrane wall monitored with AE.



Burst test result: crack growth detected with AE.
Drawback: high test pressure needed.
In-service AE test not feasible (P_{test} ca. 600 bar)
But in-service AE monitoring is an option!

Monitoring concept and application



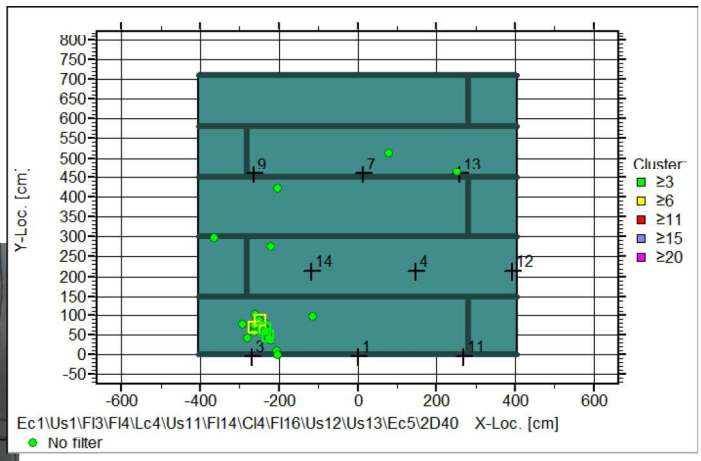


Passivation air cylinder due for re-qualification.

Extension of service period to next plant shut-down in one year.

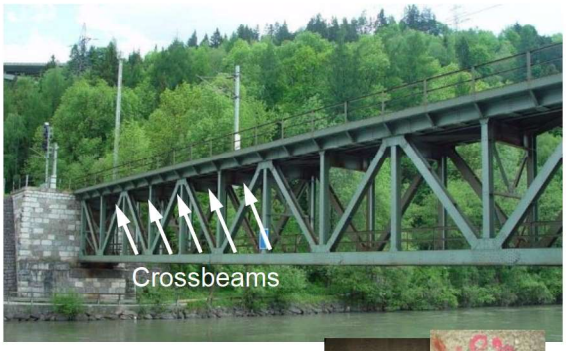
Extension justified by AE monitoring results obtained during several monitoring series.

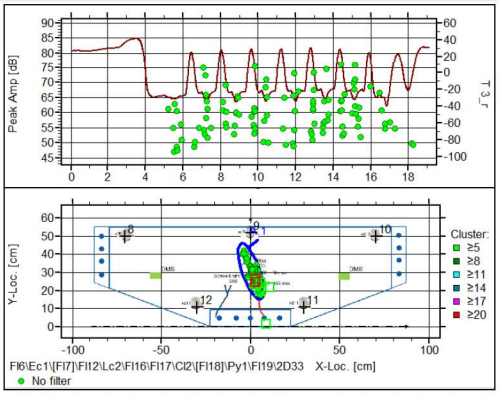
Monitoring of petrochemical reactor

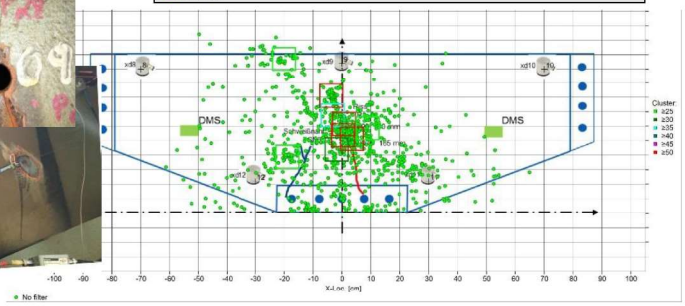


AE in-service monitoring of lower section for indications of further damage evolution. Reactor in operation at about 300 °C requires waveguide application.

Monitoring of infrastructure 1/2







Monitoring of infrastructure 2/2

Bild am Sonntag

Date: 11/04/18 Type of Media: Print Circulation: 981074 Page: 10 Section: Wirtschaft

Pilotprojekt Bilfinger horcht Brücken nach Schäden ab

Nach dem Einsturz einer Autobahnbrücke im italienischen Genua hat Bundesverkehrsminister Andreas Scheuer (CSU) ein verbessertes Kontrollsystem in Deutschland angekündigt. Vorbild für den neuen „Brücken-TÜV" könnte ein Pilotprojekt in Hessen sein. Dabei wird die Talbrücke Thalaubach bei Fulda seit Monaten mit Schallmessungen auf Schäden abgehört. „Jeder Riss, jede kleinste Veränderung im Gefüge eines Bauwerks emittiert Schallemissionen", heißt es in einer Vorlage der Firma Bilfinger Noell für die Verkehrsministerkonferenz. „Diese Spannungsentladungen sind hörbar." Bislang werden Brücken in Deutschland alle drei Jahre gründlich untersucht. Mit der neuen Methode erhalten die zuständigen Behörden permanent Informationen aus dem Inneren der Brücke. Bei kritischen Veränderungen wird automatisch ein Alarmsignal ausgelöst.

Article in German newspaper 'Bild am Sonntag' regarding application of AE monitoring on highway bridge as an inspection tool in response to the collapse of the Morandi bridge in Genoa.

CEN/TC 138/WG 7 acoustic emission testing

Project of WG 7: In-service acoustic emission monitoring (WI 138246)

Scope: This standard describes acoustic emission (AE) monitoring for in service detection, location and grading of AE sources with application to metallic pressure equipment and other structures such as bridges, bridge ropes, cranes, storage tanks, pipelines, wind turbine towers, marine applications, offshore structures etc. The monitoring can be periodic, temporary or continuous, on site or remote controlled, supervised or automated. The objectives of AE monitoring are to define regions which are acoustically active as a result of damage or defect evolution.

Status: First draft is completed and processed for TC enquiry.

DGZfP – TC “Acoustic Emission Test Methods”

DGZfP – TC “AT Methods”

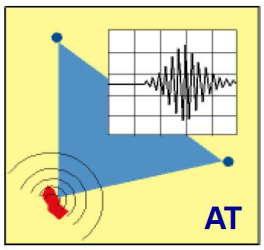
TC members from Germany, Austria & Switzerland (D-A-CH)

SC & working groups:

- Personnel qualification (SC)
- Standardization
- Wireless sensor systems
- Big data
- Structural health monitoring

https://www.dgzfp.de/Fachausschüsse/Schallemissionsprüfverf

DEUTSCHE GESELLSCHAFT FÜR ZERSTORUNGSFREIE PRÜFUNG E.V.



Thanks