



Common Applications for Acoustic Emission Testing (AET)

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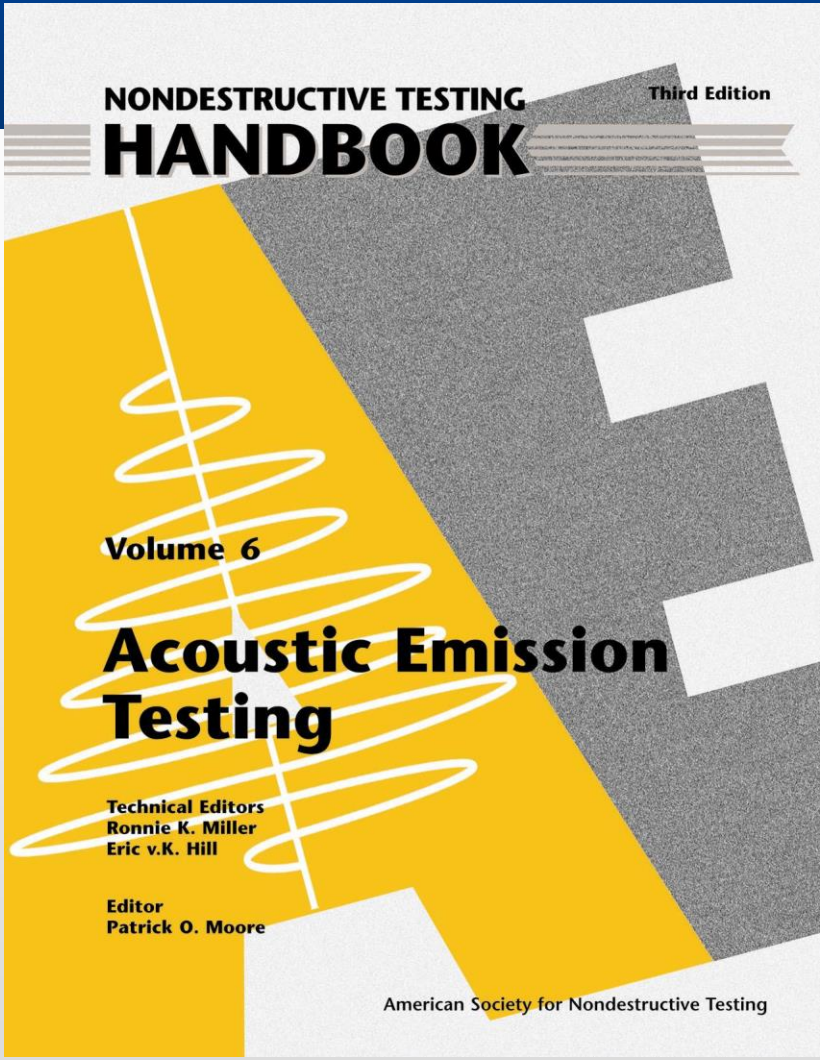
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About the presenter, Steven Garcia

- Started Ameriscan LLC in 2018.
- Performed specialized acoustic emission testing and field data acquisition world-wide for over 24 years.
- Previously Employed with Stress Engineering Services 1996 - 2018
- Graduated from Texas A&M, Mechanical Engineering Technology, B.S.
- ASNT Member

Ameriscan LLC

- Company formed in 2018 to provide acoustic emission testing and 3D laser scanning of coke drums.
- Performed services for several major clients, including Arkema, Chevron, CHS, CNRL, Suncor, Phillips66, PBF Energy, Nayara Energy (India), and others.
- Only company in the world to provide both AE testing and 3D laser scanning for coke drum operators.
- Provide services for global clients.



For more information on AET

Edited by Ron Miller, Ph.D.



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An Overview of the Presentation

- **What is Acoustic emission (AE)?**
- **Common Applications of AE**
- **AE Hardware**
- **AE Basics and Source Discrimination**
- **Location Processor**
- **Advantages of AET vs. other inspection methods**
- **Case Studies**

What is AET?

- An NDE method
- Relies on high frequency emissions from flaws
- Emissions are picked-up and located by PZT probes (Think GPS)
- The part must be properly stressed to generate emissions required to detect damage/defects.
- Tells you if there is a significant flaw, where it is located, and when it is emitting.
- Tells you if a known flaw is growing. (i.e. continuous monitoring)

The role of AET for the Inspection of Pressure Vessels and Piping...

- AET has predominantly been applied to in-service vessels as a “screening” method to detect and locate the presence of active flaws (ID/OD) and to guide inspection/repair efforts during turnarounds.
- AET has also been used to detect and locate fabrication flaws, during initial Code acceptance hydrostatic tests. (Per BPVC Section VIII)
Fabrication flaws are likely to be initiation sites for possible fatigue cracks in a few years.

Test Results

Typical AET results: A drawing showing areas for follow-up. Areas selected will be prioritized according to the intensity of the indications at each location.

More Advanced Results: Correlating damage or cracking vs. operating conditions (ex: Coke Drums, CI SCC), Modal Analysis using waveforms.

Common Applications of AE at Processing Plants

- Crack Detection
 - Online Testing of Pressure Vessels
 - Cooldowns/Start-Ups
 - Hydrostatic Tests (Proof Tests during fabrication or after repair)
- Leak Detection of Above Ground Storage Tanks (AGST)
- Active Corrosion of AGST (NOTE** - Cannot detect inactive corrosion!!)
- Long-Term Monitoring of Existing Flaws for growth
- Composite Testing

Issues affecting AET

- Know the possible damage mechanisms -> How to best stress the component (based on the mechanism)
- Background noise (mechanical, process, electrical)
- Weather issues (Snow, Rain, etc.)
- Pneumatic safety issues
- Planning for AET during a Shutdown
- Interpreting AET results
- Requires localized follow-up NDE at the areas prioritized by the inspection results.

Benefits of AET

- Global inspection method vs. localized
- Saves Money by not having to enter vessels. AE does not require large areas of insulation removal to locate and/or monitor existing defects.
- Saves Money by concentrating inspection budget on specific items
- Shortens Shutdowns by directing inspection resources where it is needed most.
- Monitoring existing “cracks” for growth (24/7 Monitoring)
- Detects leaks
- AE is effective at cryogenic as well as elevated temperatures.
- It is fast!

AE Technology – Hardware

Vallen Digital
System
AMSY-6



AE Technology – Hardware

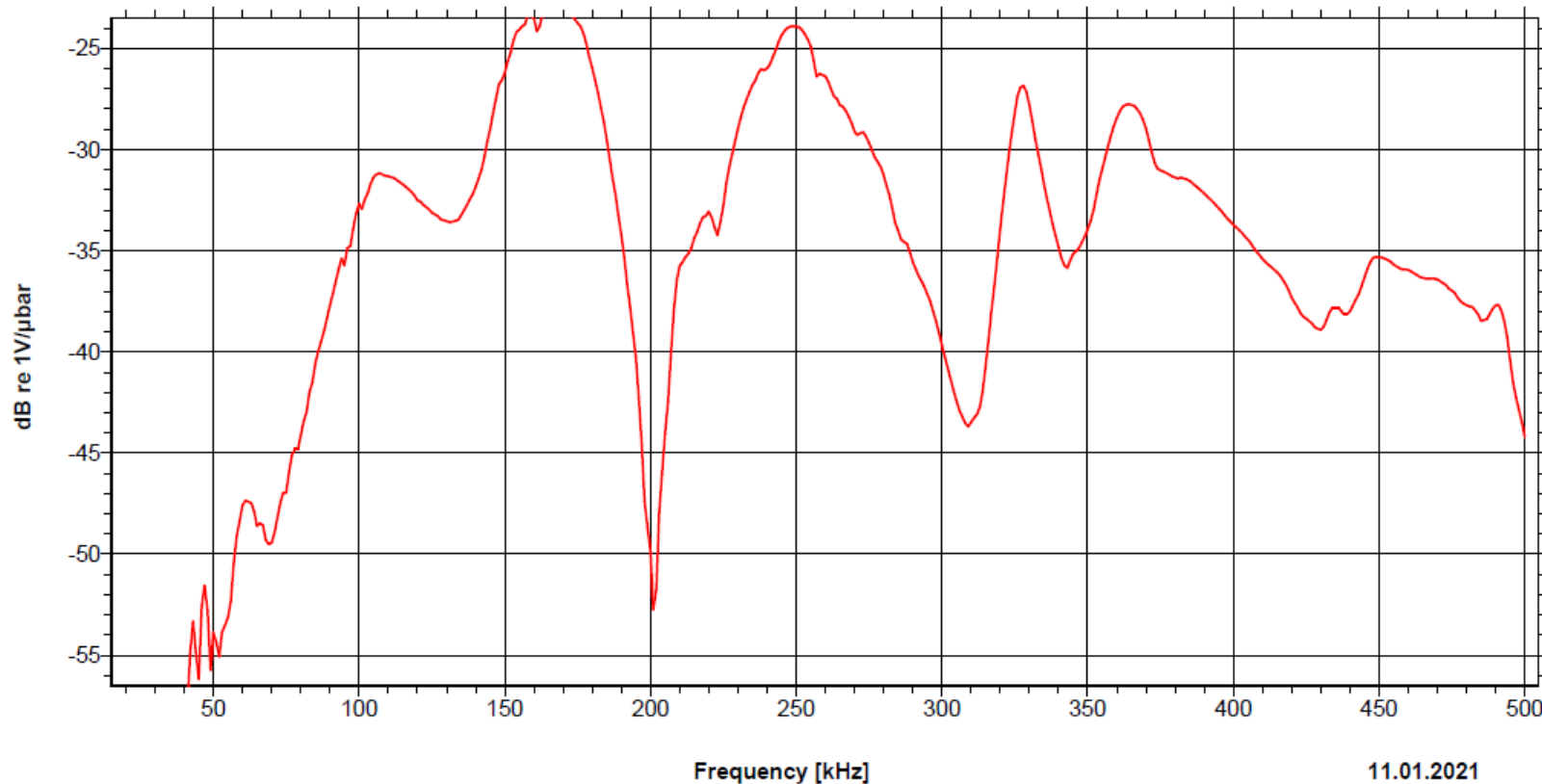
**Arbitrary
Waveform
Generator,
AMSY-6 Chassis,
and Sensor
Verification
Fixture**



Sensor Verification Test Output

Test Certificate

VS150-RIC14654



11.01.2021

This diagram shows the frequency response of the sensor under test in a face-to-face measurement setup. Method based on ASTM standard E976.
Excitation: 0.1 Vrms at V103 (50 Ω), Offset -114 dB,
coupling agent: light machine oil. For sensitivity to ANSI S1.2-1988, subtract 15 dB.

AE Technology – What are Waveguides? Why use them?



Allow operators to couple the sensors to high or low temperature materials without damaging the sensor

Waveguides are typically 12-14" long unless the structure is exceptionally hot or covered by thick insulation

Temperature > 200 °F

1/4" Hole in lagging

1/4" Hole in insulation

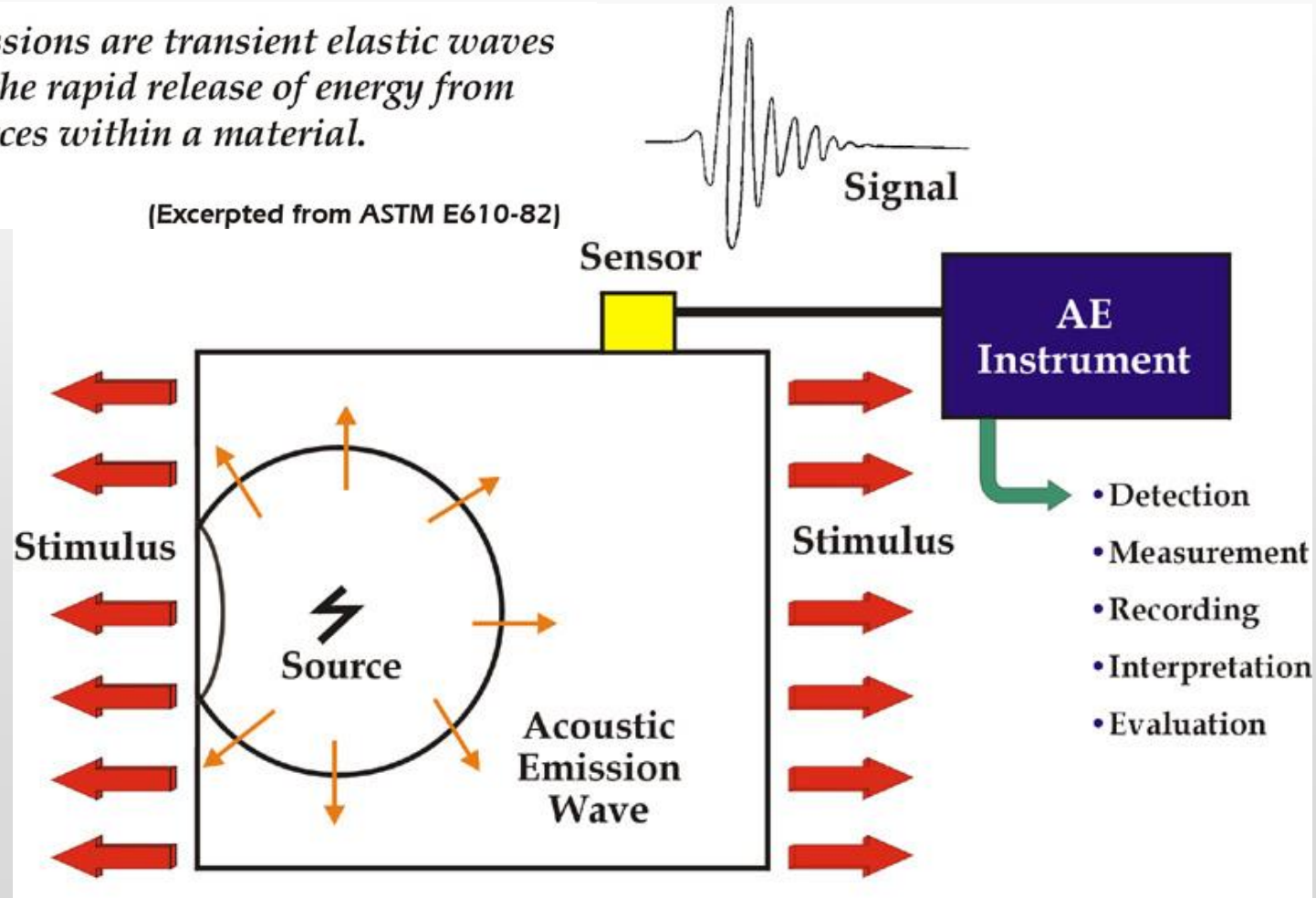
Attach to lagging

Adjust collar against spring

Introduction to AE

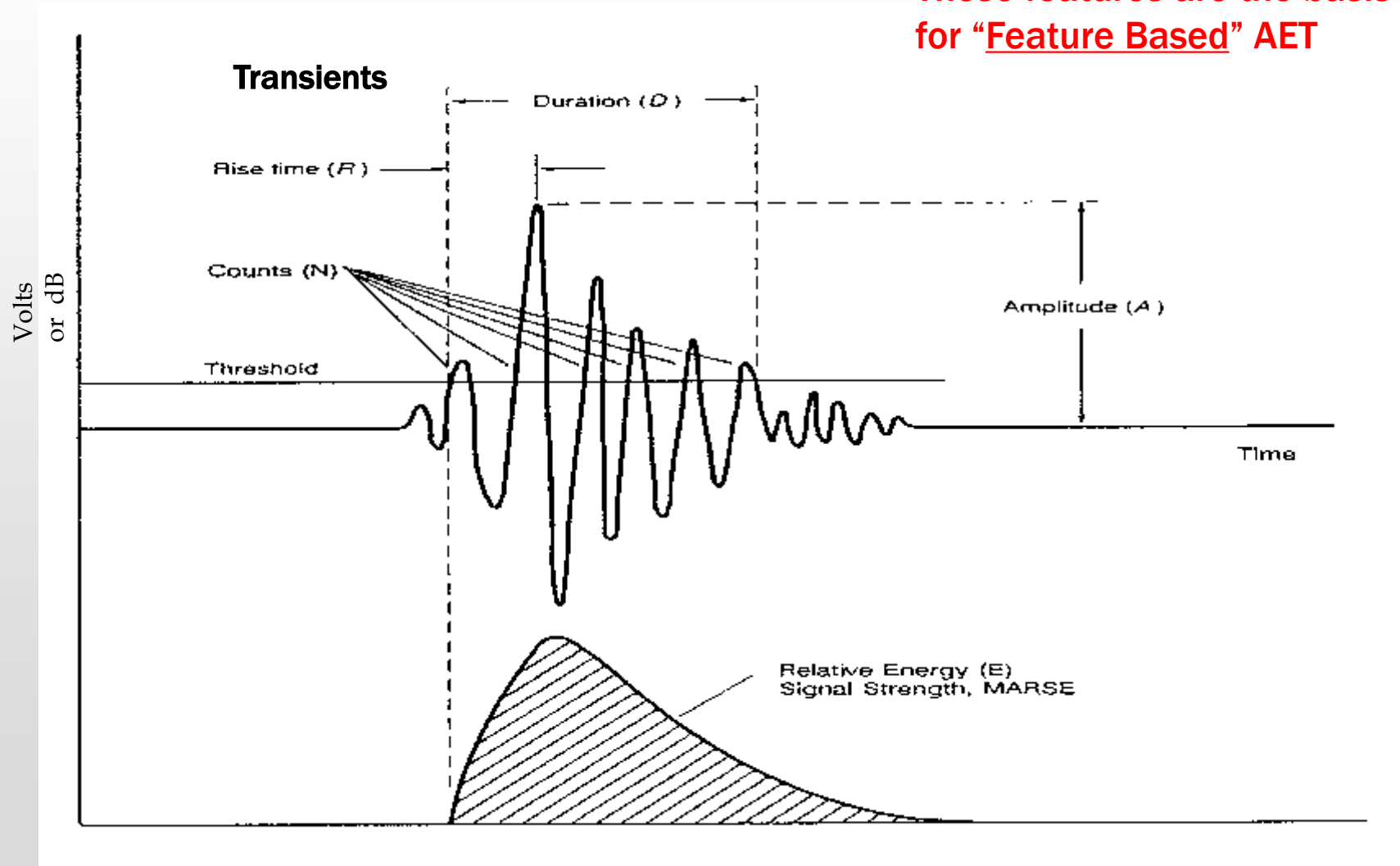
Acoustic Emissions are transient elastic waves generated by the rapid release of energy from localized sources within a material.

[Excerpted from ASTM E610-82]



AE Signals

These features are the basis for "Feature Based" AET



Feature Based Acoustic Emission Analysis

- Signals are analyzed classifying signals based on the various features captured by the system:

Amplitude, Counts, Rise-time, Duration, Energy,
RMS Voltage

- Feature based acoustic emission is a time-proven technique for locating large cracks in a structure.

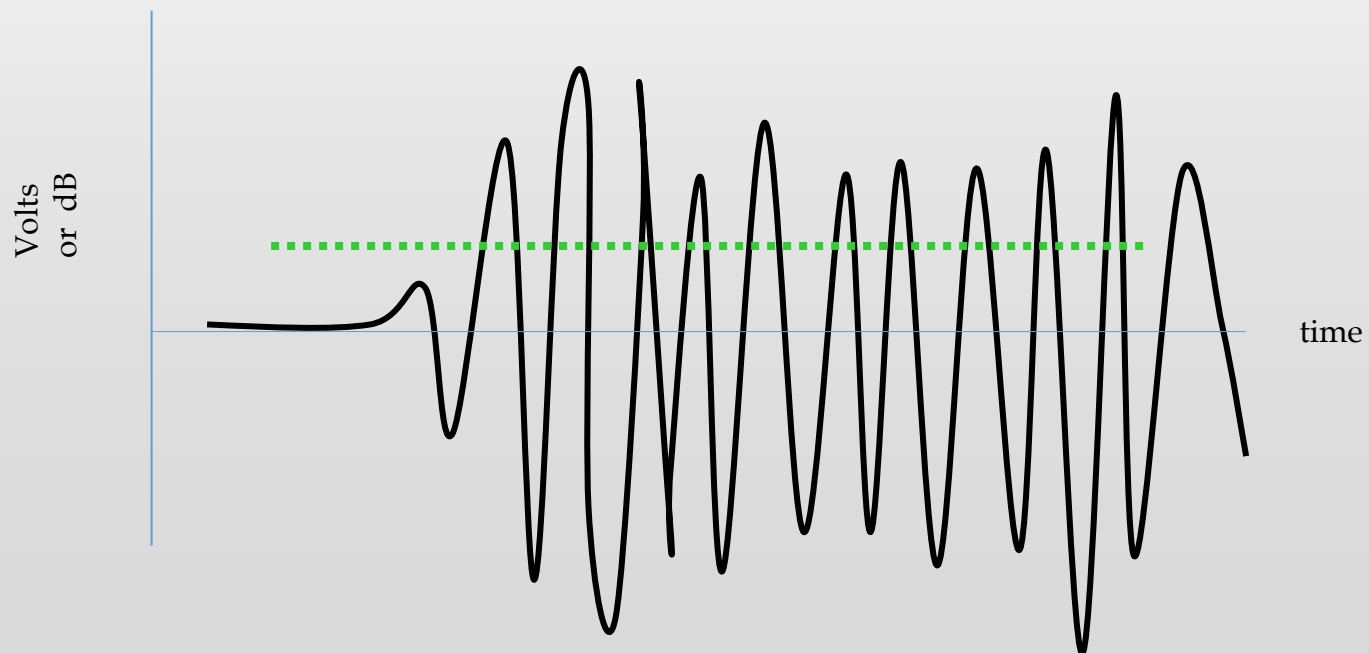
Cracks: high amplitude, short RT, Counts from 100-1000

Mechanical rubbing: low amplitude, average RT, long duration

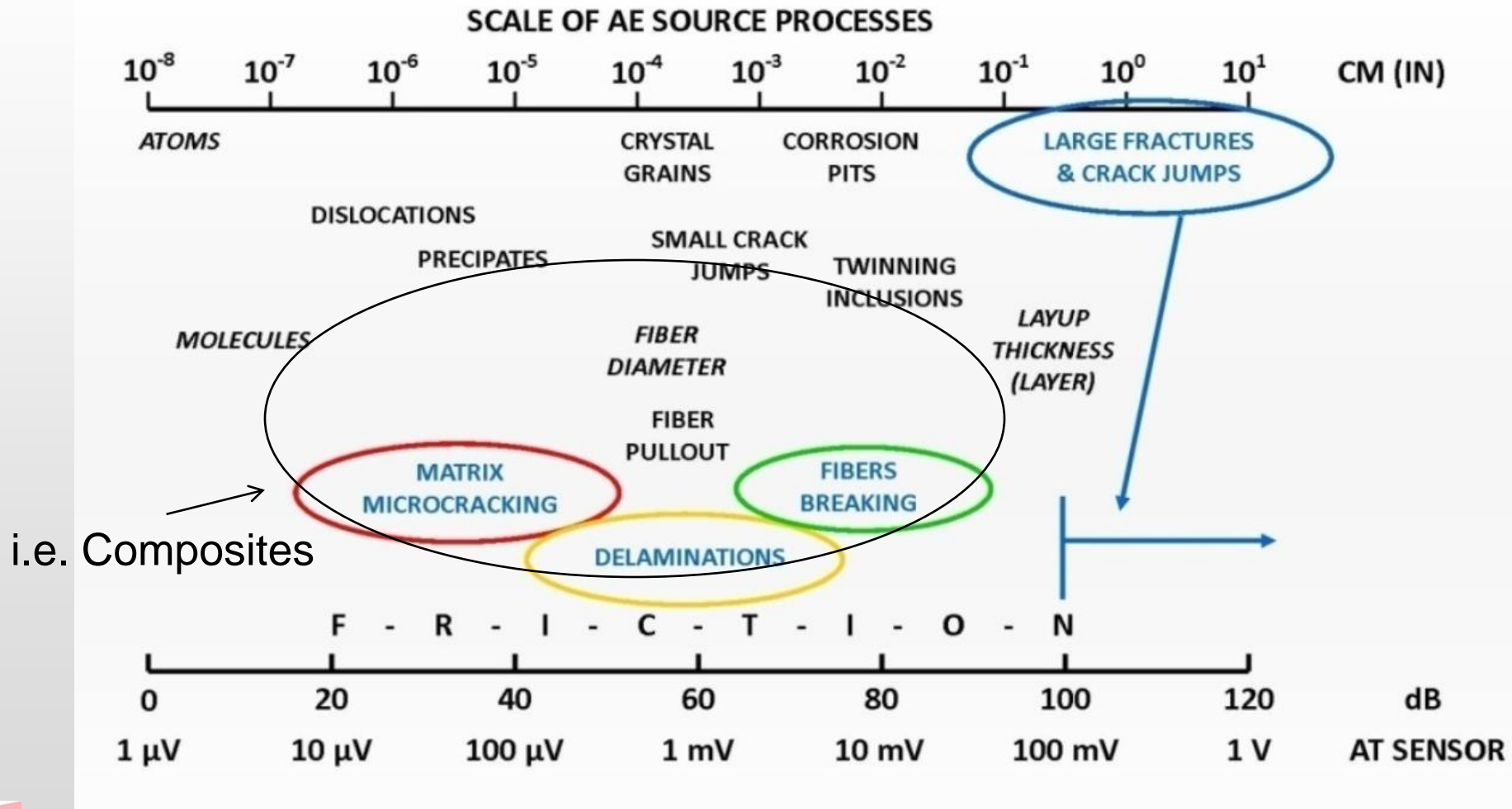
Continuous Emissions

Continuous Emissions – Commonly used for leak testing applications

- Typically measured as RMS (Root Mean Square) Voltage or
- ASL (Average Signal Level) in dB



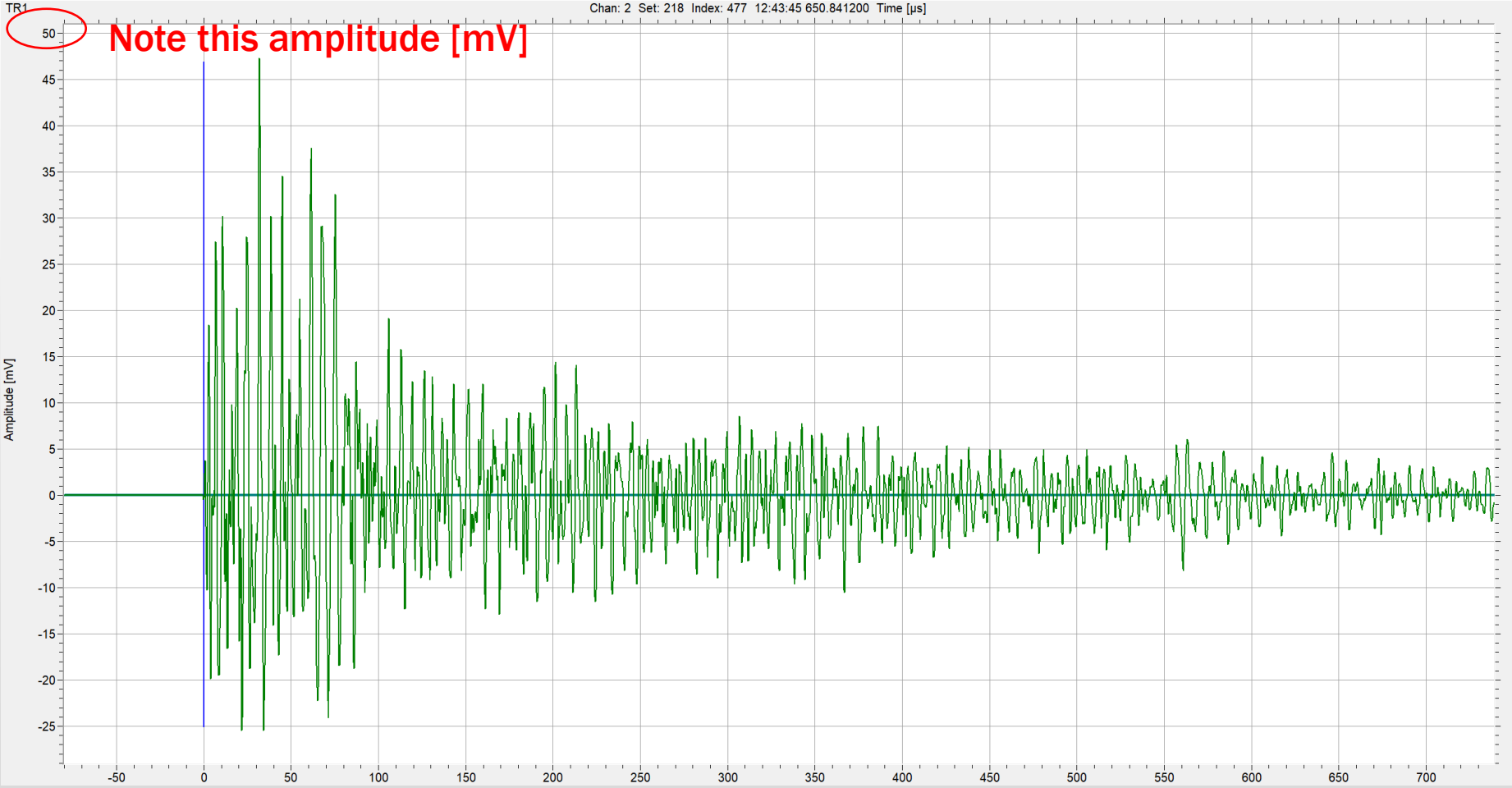
AE SOURCES



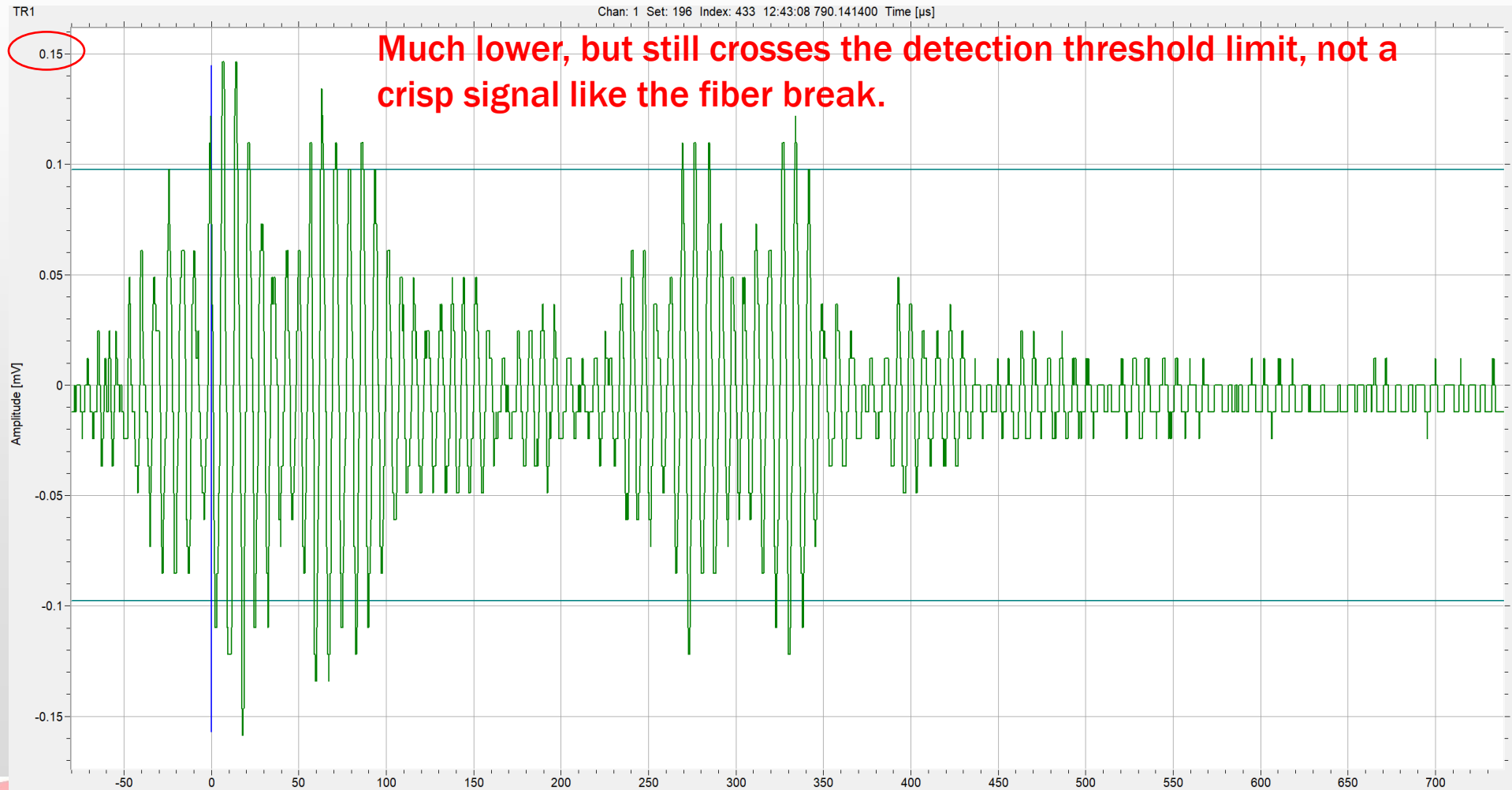
i.e. Composites

Approximate Amplitudes of Various AE Sources

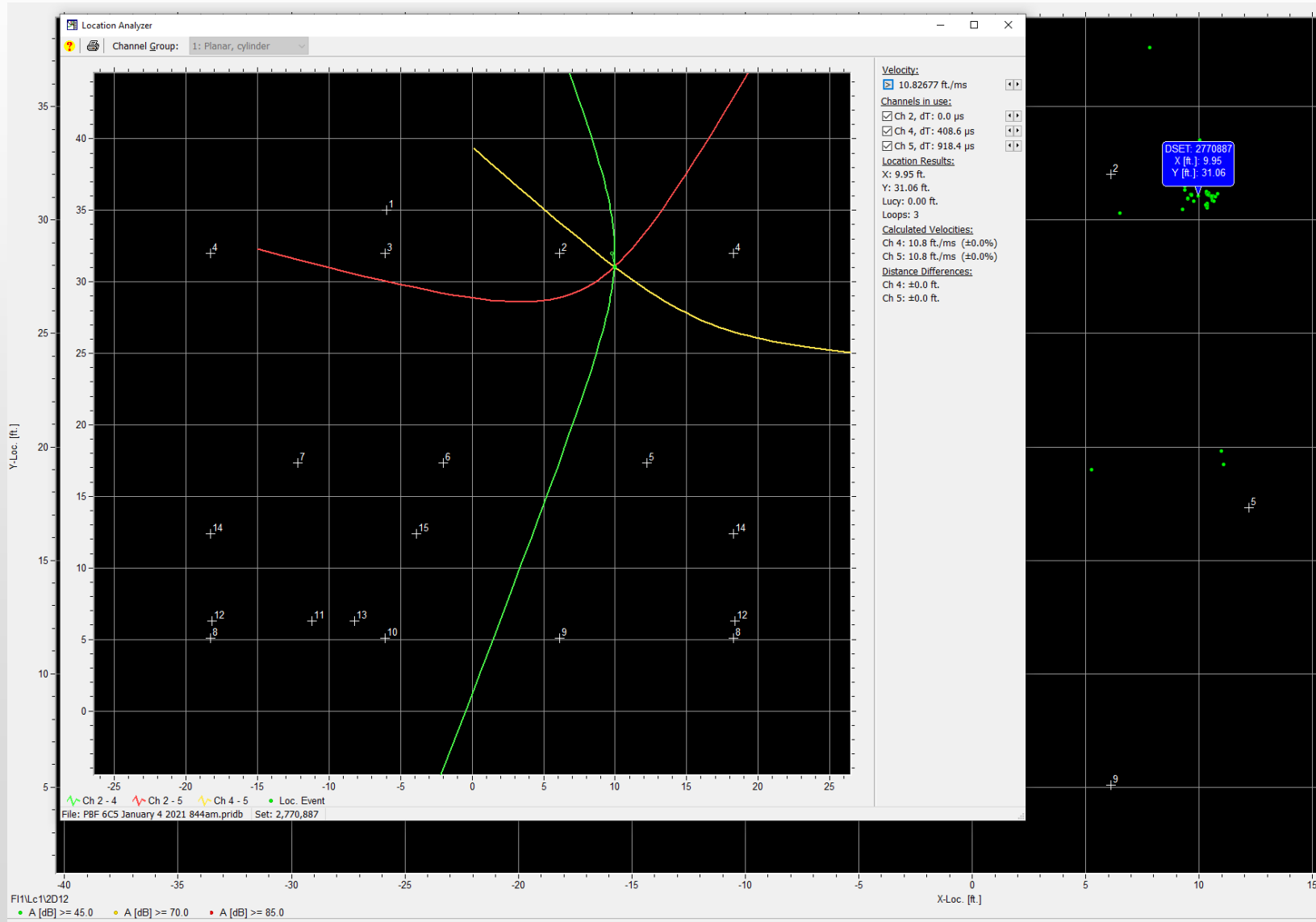
Example of a Fiber Break in a FRP Vessel



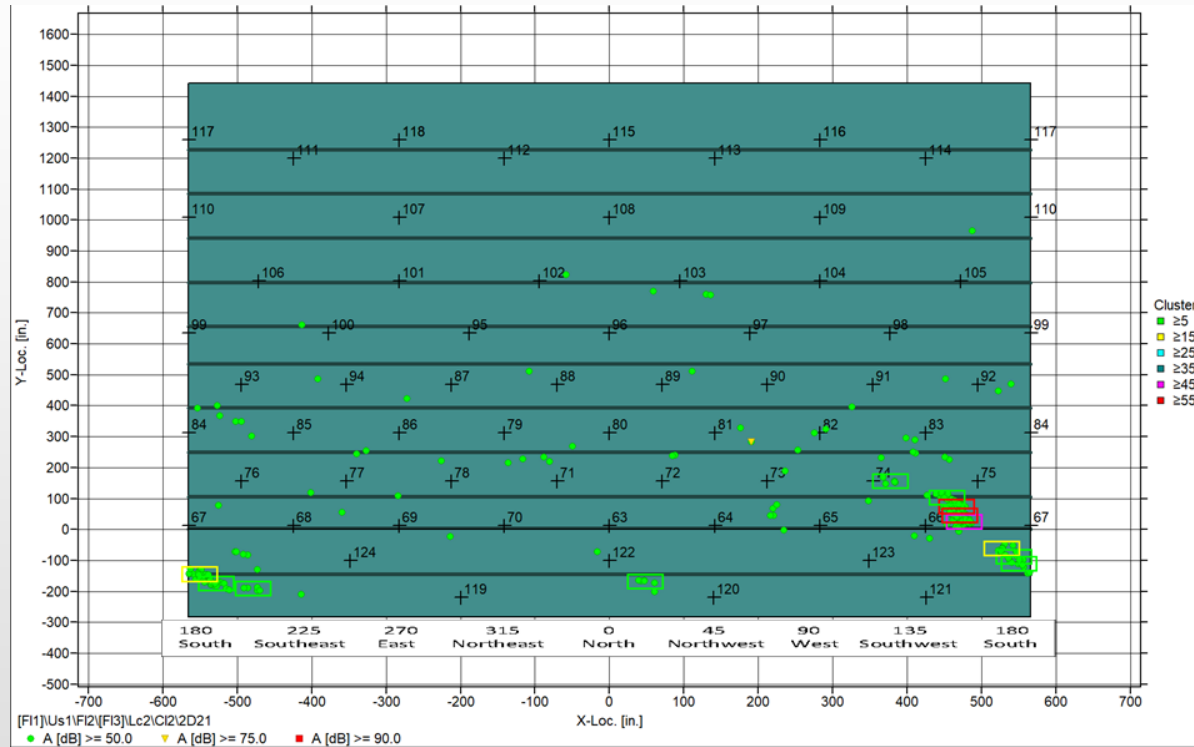
“Noise” i.e. part movement, rubbing, process, etc.



Location Processor – Lightly Filtered Data



Example Data from a Pressure Vessel



The recorded data is filtered to eliminate erroneous emissions and a cluster analysis is performed.

Events	Centroid of Cluster		Range of Cluster		Y1 - Elevation on the Drum (Lower Bound)	Y2 - Elevation on the Drum (Upper Bound)	mean(Amp [dB])	sum(Energy [eu])	sum(Counts)
	X-Loc. [in.]	Y-Loc. [in.]	θ1 - Azimuth Angle [degrees]	θ2 - Azimuth Angle [degrees]					
78	466.70	73.53	140.91	156.19	49.53	97.53	69.88	6,275,982	88,871
62	470.47	43.91	142.11	157.39	19.91	67.91	69.67	5,600,586	74,899
47	476.42	24.26	144.01	159.28	0.26	48.26	70.49	5,109,110	60,605
23	-549.79	-145.44	177.36	192.64	-169.44	-121.44	59.55	273,983	15,723
16	527.27	-62.48	160.19	175.47	-86.48	-38.48	61.74	326,590	14,299
14	-528.16	-175.68	184.25	199.52	-199.68	-151.68	63.15	286,551	12,229
12	453.64	102.21	136.76	152.03	78.21	126.21	71.36	1,223,632	14,838
11	48.25	-169.42	7.72	23.00	-193.42	-145.42	56.43	101,334	4,289
10	-478.49	-191.50	200.06	215.33	-215.50	-167.50	58.31	124,237	5,710
7	543.29	-89.48	165.29	180.57	-113.48	-65.48	60.56	112,728	5,200
5	549.89	-111.51	167.39	182.67	-135.51	-87.51	59.39	53,943	3,021
5	377.26	156.01	112.44	127.72	132.01	180.01	62.05	237,898	3,958

MONPAC Method for Classifying Indications – Intensity Analysis

Developed as a joint venture between MISTRAS and Monsanto and released in 1989 as a means for evaluating fixed equipment. At the time, MISTRAS was known as Physical Acoustics (PAC). This is where the name MONPAC was derived from.

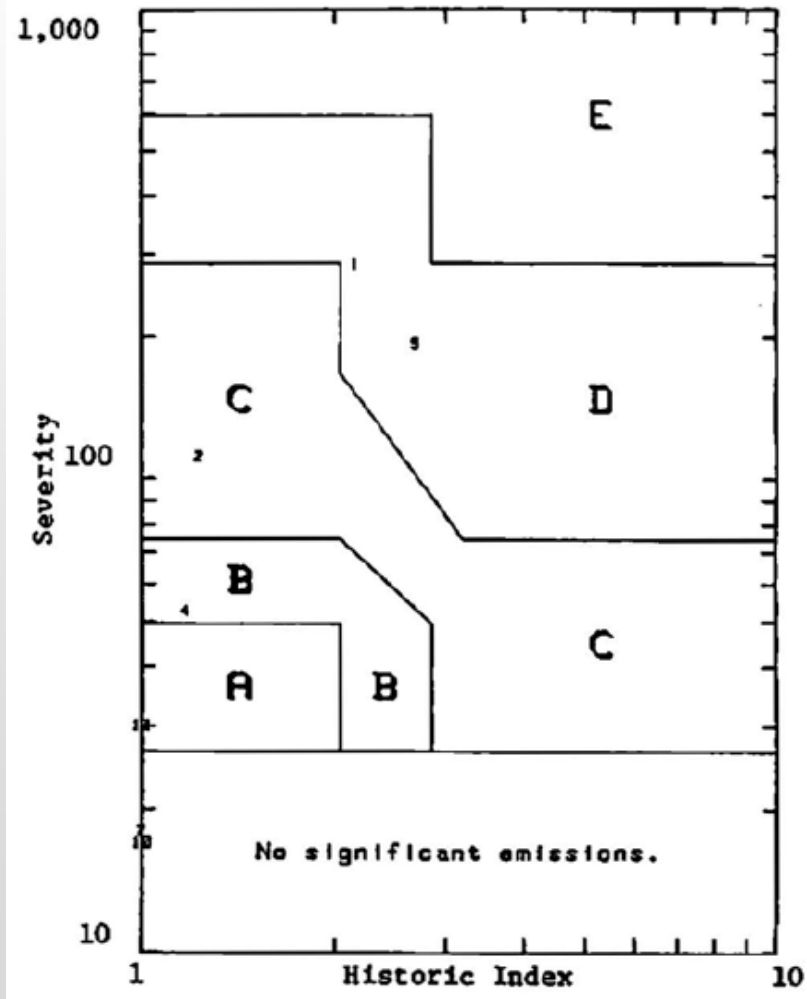
The method analyzes data on a per-channel basis (zonal) instead of a multichannel approach. Technology back in 1989 was a limitation when considering a multichannel approach. Today, at Ameriscan, we prefer to use a combination of per channel data and multichannel source location. MONPAC has proven to be an over-simplified approach when inspecting in-service pressure vessels with significant background AE activity.

MONPAC Method for Classifying Indications – Intensity Analysis (MISTRAS' Method)

Historic Index – Compares the average signal strength of the last 20% or 200, whichever is less, events to the average signal strength of all events. It is used for determining the changes of the slope in the cumulative signal strength vs. hit curve. A sharp rise at the “knee” of the curve (a large historic index) represents the onset of damage.

Severity - The average signal strength for the ten events having the largest numerical value of signal strength. Will also increase sharply at the knee of the curve.

Example of a Zonal Intensity Plot (ZIP) Used for Intensity Analysis



Zone Intensity	Recommended Action
A	Minor defect, note for reference in future tests.
B	Note for reference in future tests and check for surface defects such as corrosion, pitting, gouges and cracked attachment welds.
C	Defects requiring immediate follow-up inspection. Evaluation may be based on further data analysis, retest, or complimentary nondestructive examination.
D	Significant defects requiring immediate follow-up inspection using complimentary nondestructive examination methods.
E	Major defect requiring immediate shutdown and follow-up nondestructive examination.

Case Study #1

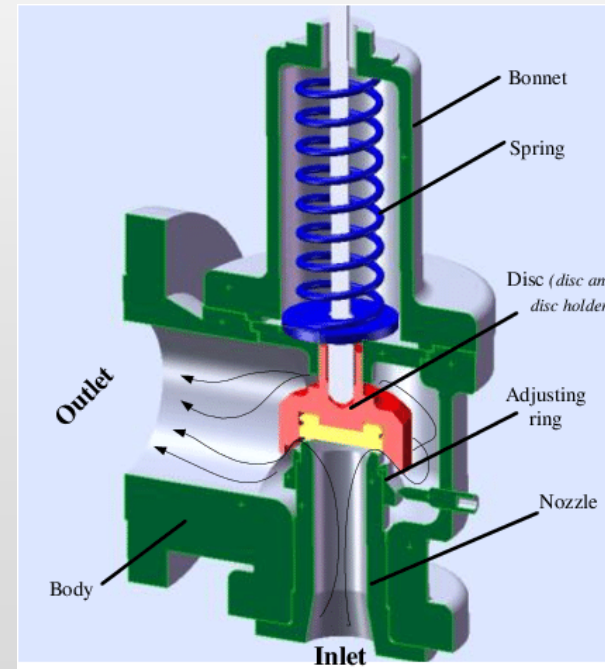
Leaking Pressure Safety Valve (PSV)

Problem

- The client was detecting excessive H₂S within the flare product flow.
- It was determined that the source of the excessive H₂S was due to a faulty pressure safety valve (PSV) within one of their process units, but they could not narrow down which valve was faulty.
- Shutting down the unit would lead to approximately one week of unscheduled downtime. This unit had been previously shut down to make repairs to the PSVs, but the necessary repairs were not made to eliminate the leak in the faulty PSV.

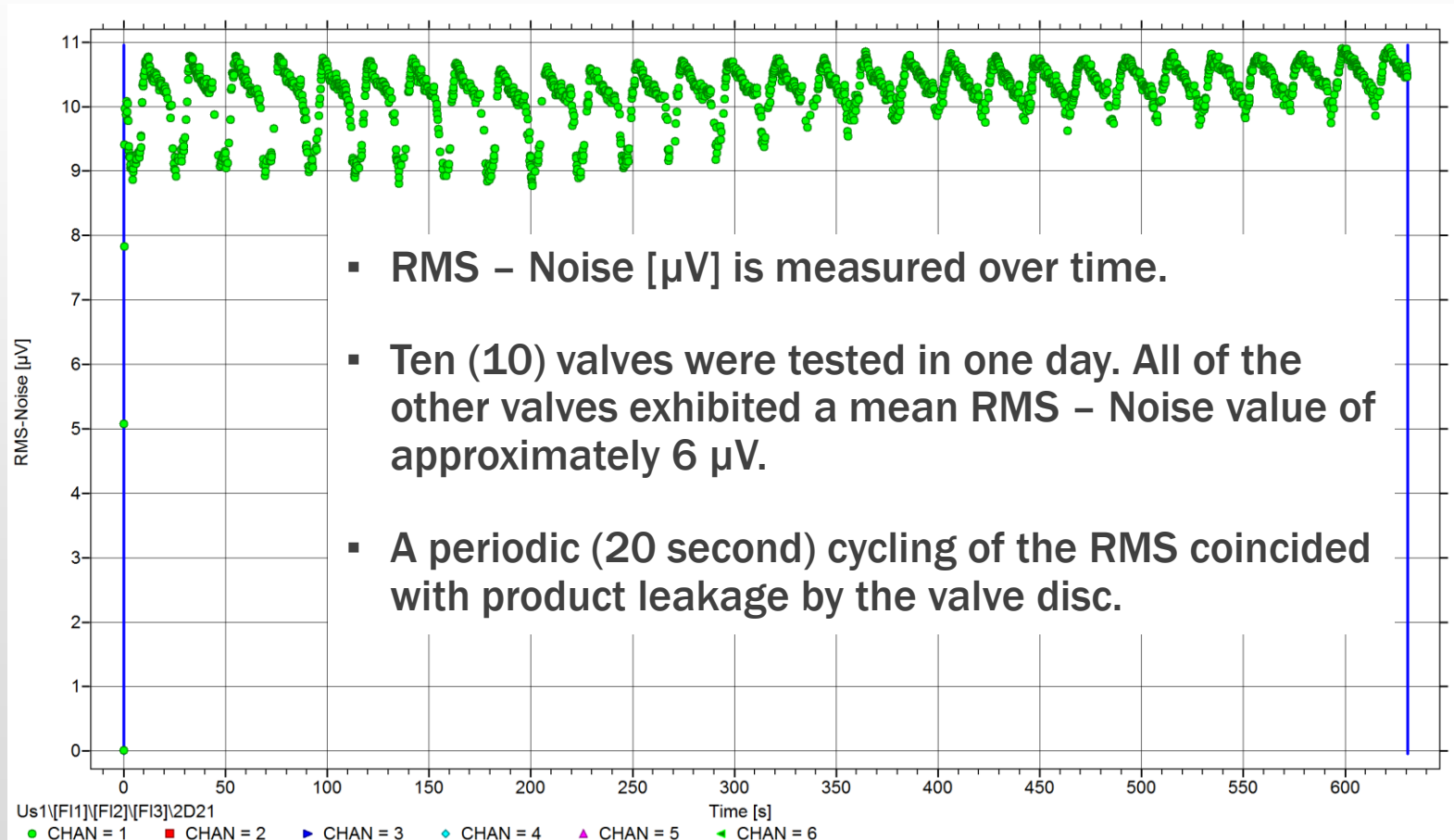
Utilizing AE to Detect the Leak

- Acoustic Emissions has a long history related to valve leak detection applications. The instrumentation detects the ultrasonic “whistling” noise related to the turbulent flow of product through the valve.
- A single sensor (400KHz or broadband) is mounted to the valve body via a magnetic hold-down, tape, etc.
- The acoustic emissions were monitored for approximately 10 minutes per valve



From Researchgate.net

Acoustic Emission Data



Conclusion

- The client was detecting excessive H₂S within the flare product flow.
- Acoustic Emission was utilized to test ten (10) valves in the unit to investigate the source of the product leakage.
- Leakage was detected on one of the PSVs. This provided the operators with the information required to order the parts to make the repairs at the next shutdown.
- Acoustic Emission was a rapid, reliable, and cost effective means to locate the product leakage through the PSV.

Case Study #2

Potential HTHA Damage of a Catalytic Reactor

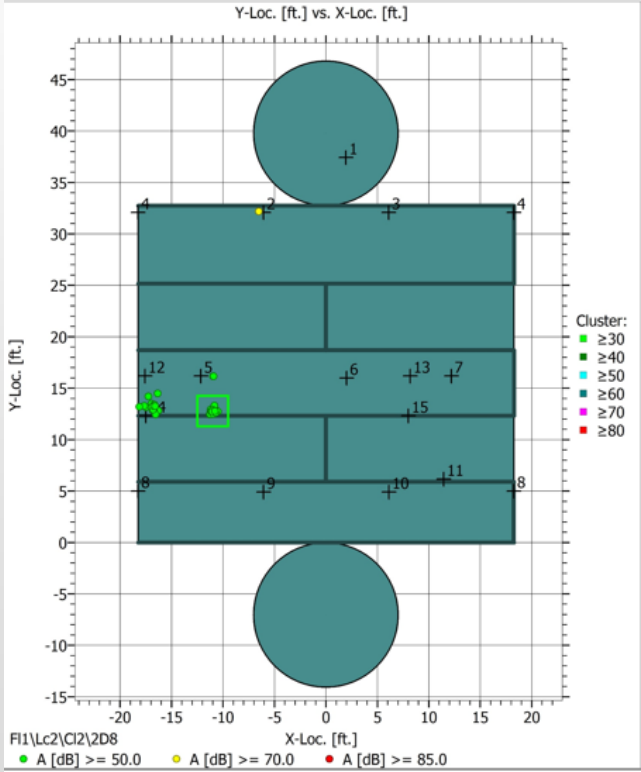
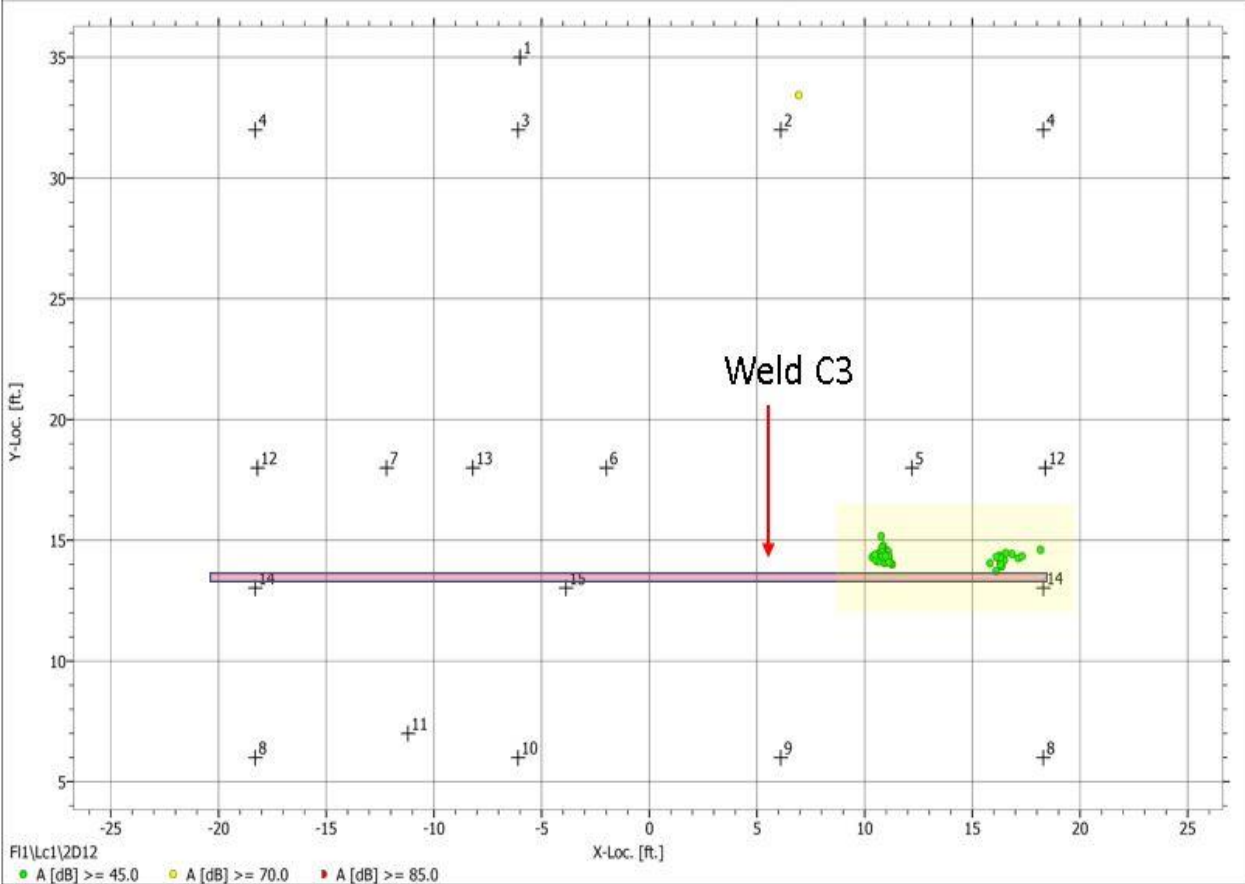
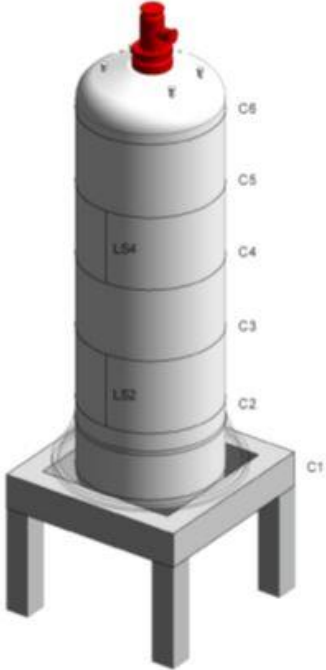
Problem

- Pressure vessel survey indicted high-susceptibility to HTHA damage based on material (C-1/2 Mo), time in service, and hydrogen partial pressure.
- Thick-walled reactor - ~4 inches
- Reactor was insulated with skin temp above 700 Deg. F
- High-temp prevented other NDE methods while in service.
- Client could not shut down operating unit for internal inspection.
- Client needed information quickly to plan for future.

Utilizing AE to Determine Potential HTHA Damage

- Initial online AE test revealed activity near a circumferential weld seam/heat-affected zone. High concern for potential HTHA damage due to age/process/material.
- Reactor skin temp made it difficult for other NDE methods.
- Long-term AE monitoring was suggested in lieu of shutdown.
- Process upsets during monitoring caused rapid thermal gradients, which caused high-amplitude AE activity in areas of concern.

Acoustic Emission Data



Conclusion

- Plant Management requested maintaining online AE for extended period until replacement reactor was available.
- New reactor was designed with 2-1/4 chrome material and ordered for fabrication.
- Process controls put in place to maintain temp below 600 F to prevent damaging excursions.
- Client able to maintain critical operations uninterrupted.
- Continuous AE monitoring has been in place for over 3 years.
- Managed remotely via cellular connection.

Case Study #3

Coke Drums

Problem

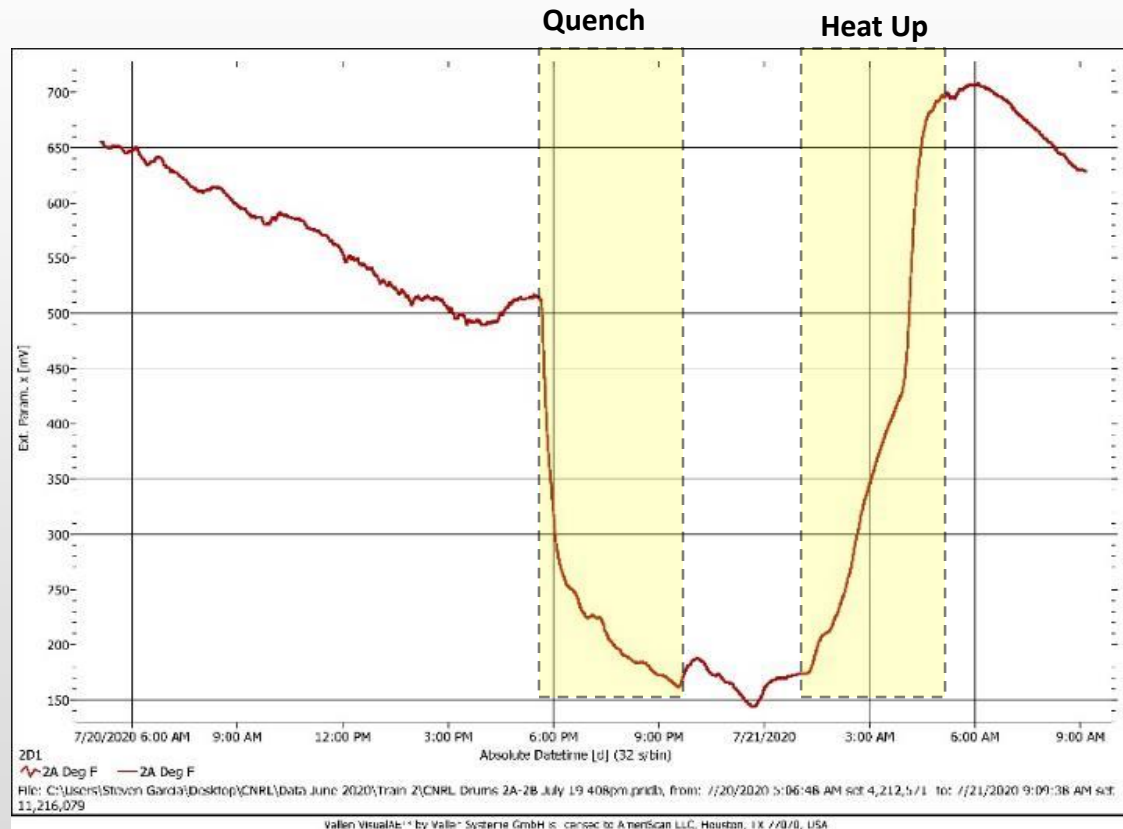
- Recent laser scan showed severely bulged areas on 2 drums.
- Engineering analysis showed problematic area with bulge at a circumferential weld seam.
- Client wanted inspection with minimal disturbance to normal coking cycles and insulation.
- Scaffolding entire structure was cost-prohibitive.
- AE testing had never been performed.

AE Used to Detect Problem Areas for Follow-up

- Multiple AE sensors installed by a rope access crew for all 6 drums.
- Monitoring took place during normal coking cycles.
- Waveguides used to minimize insulation disturbance and protect sensor from surface temp.
- Data collection equipment mounted on skirt deck to minimize cable lengths.

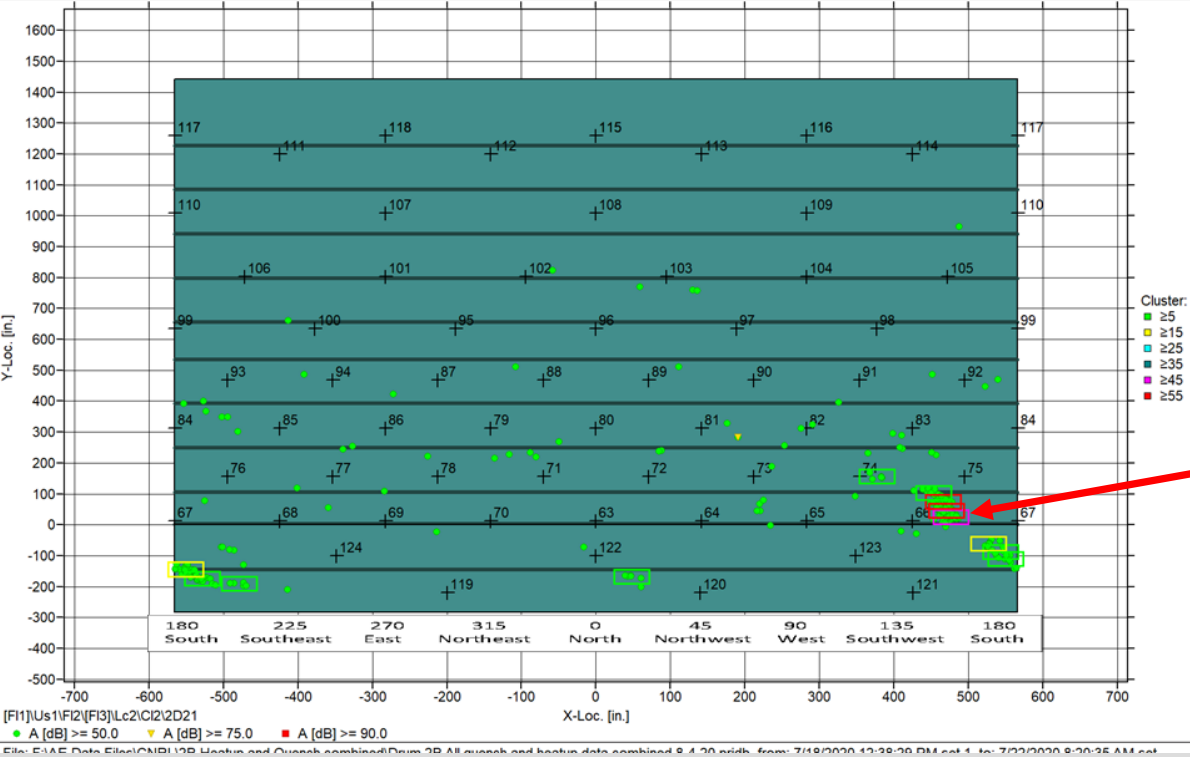


Acoustic Emission Data



- Only data during the quench and heat-up portions of the cycle were used for data analysis.
- Thermal gradients during these periods are most damaging and cause the most cumulative damage.

Acoustic Emission Data Cont.



- Several areas identified, but most severe area highlighted based on repeated AE activity during multiple cycles at same location.



Conclusion

- Multiple AE sensors were installed to cover entire drum
- All drums tested with no incidents and within time-frame requested by client.
- No scaffolding required, saved client significant money.
- Most problematic area of bulge near weld seam identified with confirmed crack after PAUT.
- AE data correlated well with laser scans and engineering assessment.

Case Study #4

Anhydrous Ammonia Tank

Problem

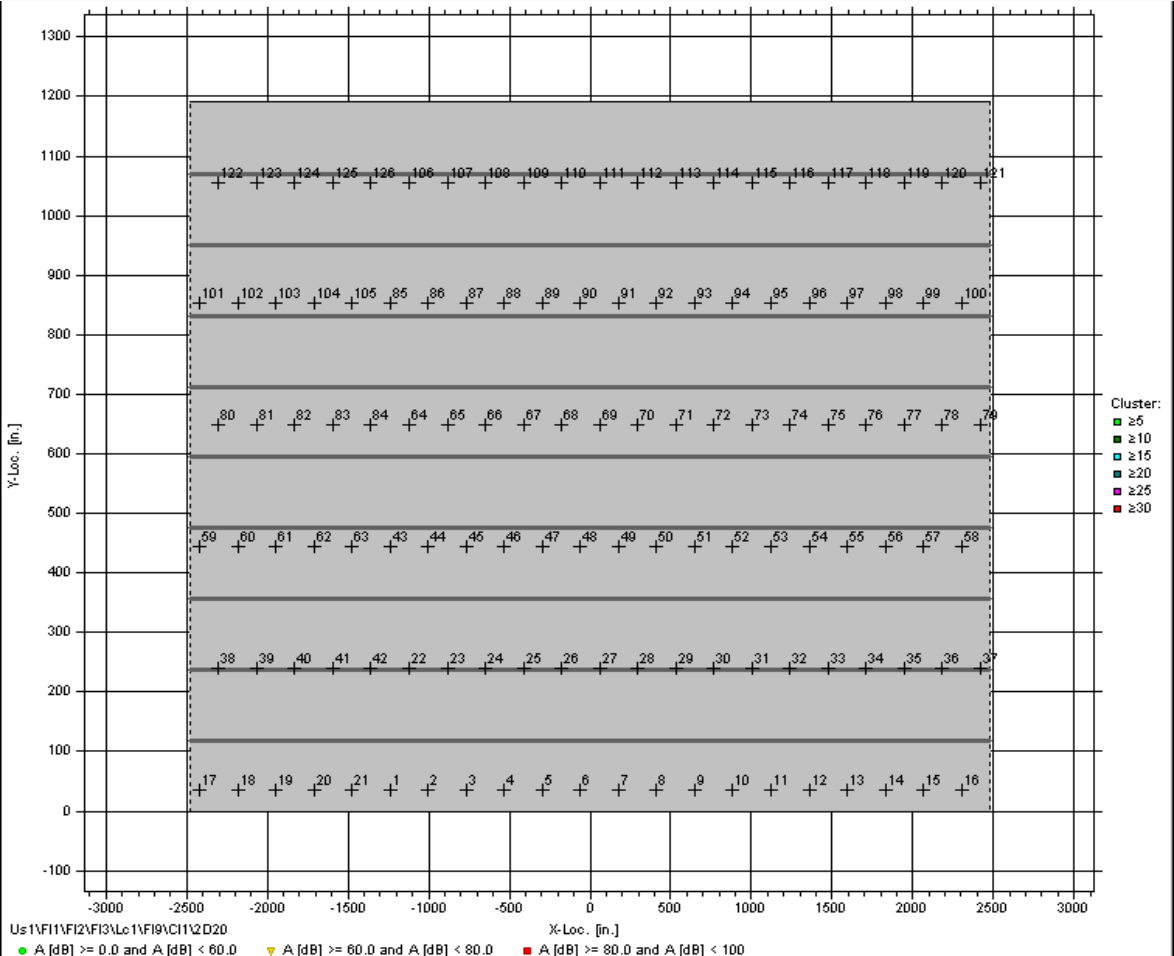
- Large atmospheric anhydrous ammonia tank needed periodic inspection for mechanical integrity.
- Opening tank for internal inspection not an option due to concerns with oxygen exposure exacerbating ammonia SCC potential.
- Cold temperatures caused ice to form on external walls when exposed to air.
- UT survey needed to be done simultaneously as AE inspection.
- Client unhappy with previous inspection report.

Ammonia Tank AE setup

- **126 AE sensors installed by AE crew using JLG manlifts. UT Survey performed at same time as sensor installation.**
- **Monitoring took place during filling operation from barges at dock.**
- **Utilized existing inspection ports used for UT measurements to minimize insulation disturbance.**
- **Methanol/Alcohol used to mitigate ice formation during sensor installation.**



Acoustic Emission Data



- No locatable AE data from propagating flaws due to ammonia SCC were observed during the fill test.
- Client resumed tank operation until next inspection interval.



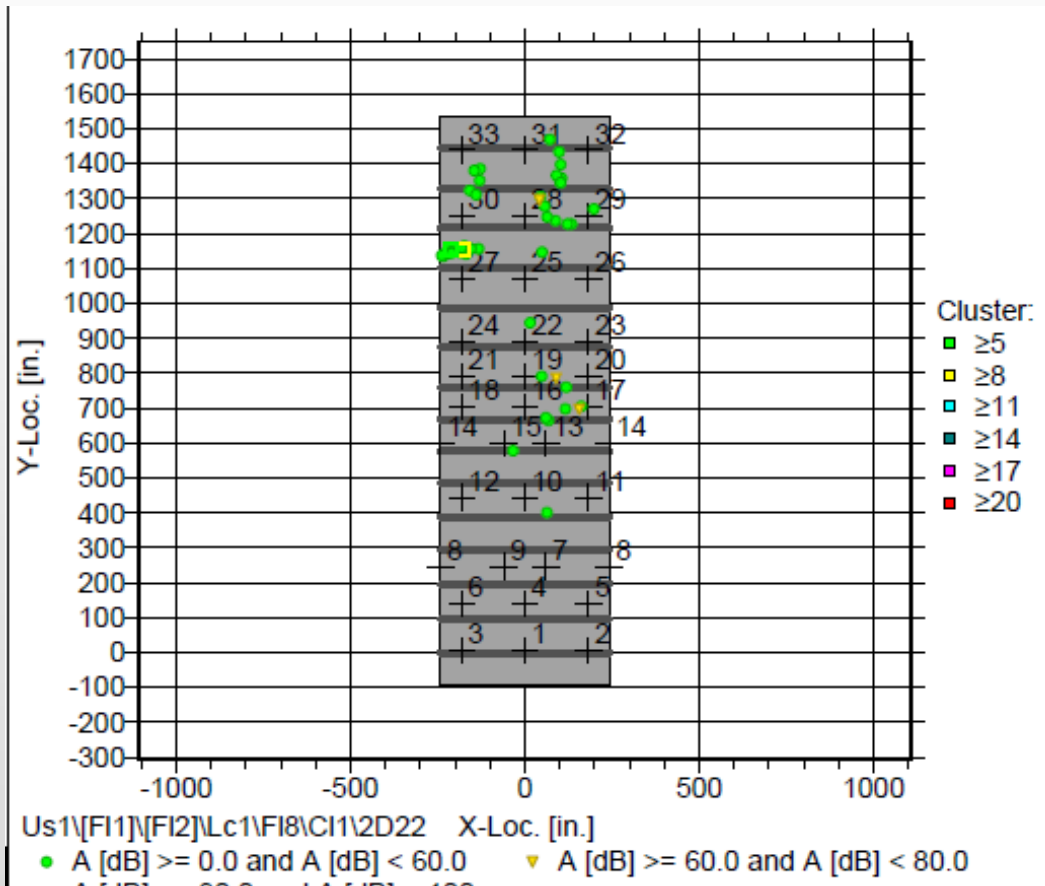
Case Study #5

Process Column Through-wall failure

Problem

- Chemical company developed through-wall failure in a process absorber tower causing immediate unit shutdown.
- Failed area removed for metallurgical analysis and new section plate welded in to repair.
- Concern about other areas of column due to unknown failure mechanism.
- Limited time to perform the inspection and give results.

Acoustic Emission Data



- Multiple AE sensors installed for complete coverage.
- AE testing took place during pneumatic over-pressure test.
- Locatable AE data was observed during the pneumatic test and reported.
- Recommended to the client to follow-up in the specific areas noted using conventional NDT.

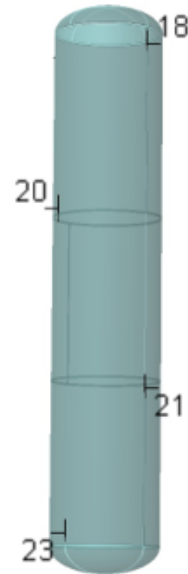
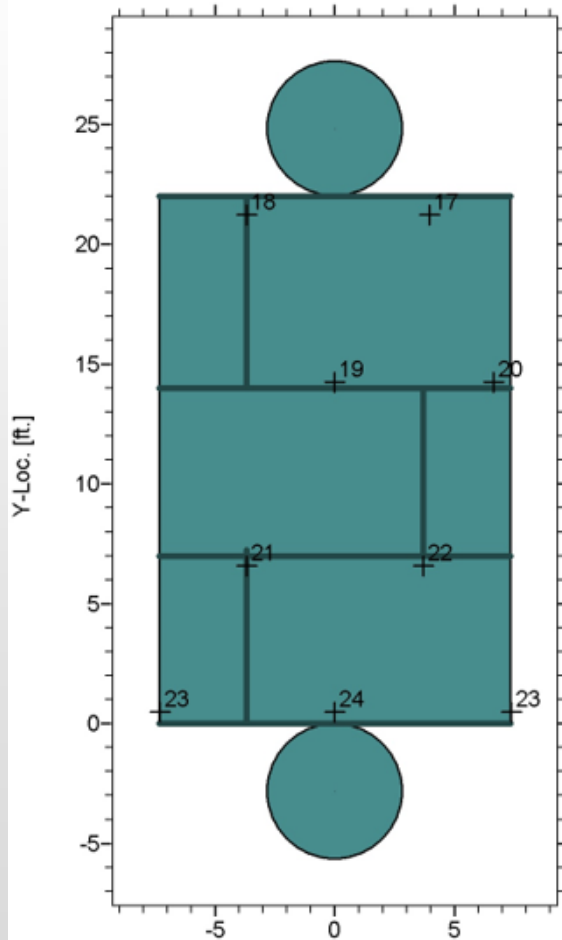
Case Study #6

H₂S Driers

Problem

- 2 of 4 H₂S Dryers developed through-wall failures during service within months of each other.
- Vessels were less than 6 years in-service, all built at same time by same fabricator.
- Material specs were reviewed and were correct for the service conditions.
- H₂S being released during failures.
- Client wanted long-term inspection until vessel replacement with minimal disturbance to insulation and process.
- Needed immediate notification of potential failures.
- AE testing had never been performed at this facility – client unsure of technique.

Acoustic Emission Setup



F11\Lc3\2D19

● A [dB] >= 50.0
■ A [dB] >= 85.0

X-Loc. [ft.]

● A [dB] >= 70.0

● A [dB] >= 50.0
■ A [dB] >= 85.0

● A [dB] >= 70.0

- Multiple sensors installed per vessel to obtain 100% coverage.
- Waveguides used to minimize insulation disturbance and protect sensor from surface temp.
- Wireless connection for 24/7 monitoring.
- Data alarms used to alert power failures and data activity.

Conclusion

- **Multiple AE sensors were installed on each vessel to provide 100% coverage.**
- **Remote monitoring system installed with wireless access to AE monitoring system and data.**
- **Alerts for any AE activity sent via text messages.**
- **Managed 24/7 from Houston office with no personnel in the unit.**
- **Client continued normal operations for 11 months with no incidents of failure while new vessels were fabricated for replacement.**

Conclusion

- Questions ?