Common Applications for Acoustic Emission Testing (AET)

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About the presenter, Steven Garcia

- Started Sonus Consulting LLC in early 2022.
- Performed specialized acoustic emission testing and field data acquisition world-wide for over 26 years.
- Previously Employed with Stress Engineering Services 1996 – 2018, Ameriscan 2018-2022.
- Graduated from Texas A&M, Mechanical Engineering Technology, B.S.
- ASNT Member

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. Usually, a 10% overpressure is needed.
- Tells you <u>if</u> there is a significant flaw, where it is located, and when it is emitting.
- Tells you if a **<u>known flaw</u>** is growing. (i.e. continuous monitoring)

What is AET? Continued

- A monitoring tool which can provide early warning of propagating flaws.
- A global, real-time monitoring, nondestructive testing (NDT) method for the assessment of the structural integrity of large-scale structures with an emphasis on metallic and composite pressure vessels.
- A screening tool for surveys and inspection planning. Specifically, in-service AET data technology in the identification of flaws at critical locations to more efficiently target follow-up inspections.
- NDT method to conduct structural condition assessment at critical areas where other NDT methods cannot.
- Can be used as a screening tool for survey planning.

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, Cl SCC), Modal Analysis using waveforms for composite structures.

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 Material Testing - COPVs

Issues affecting AET

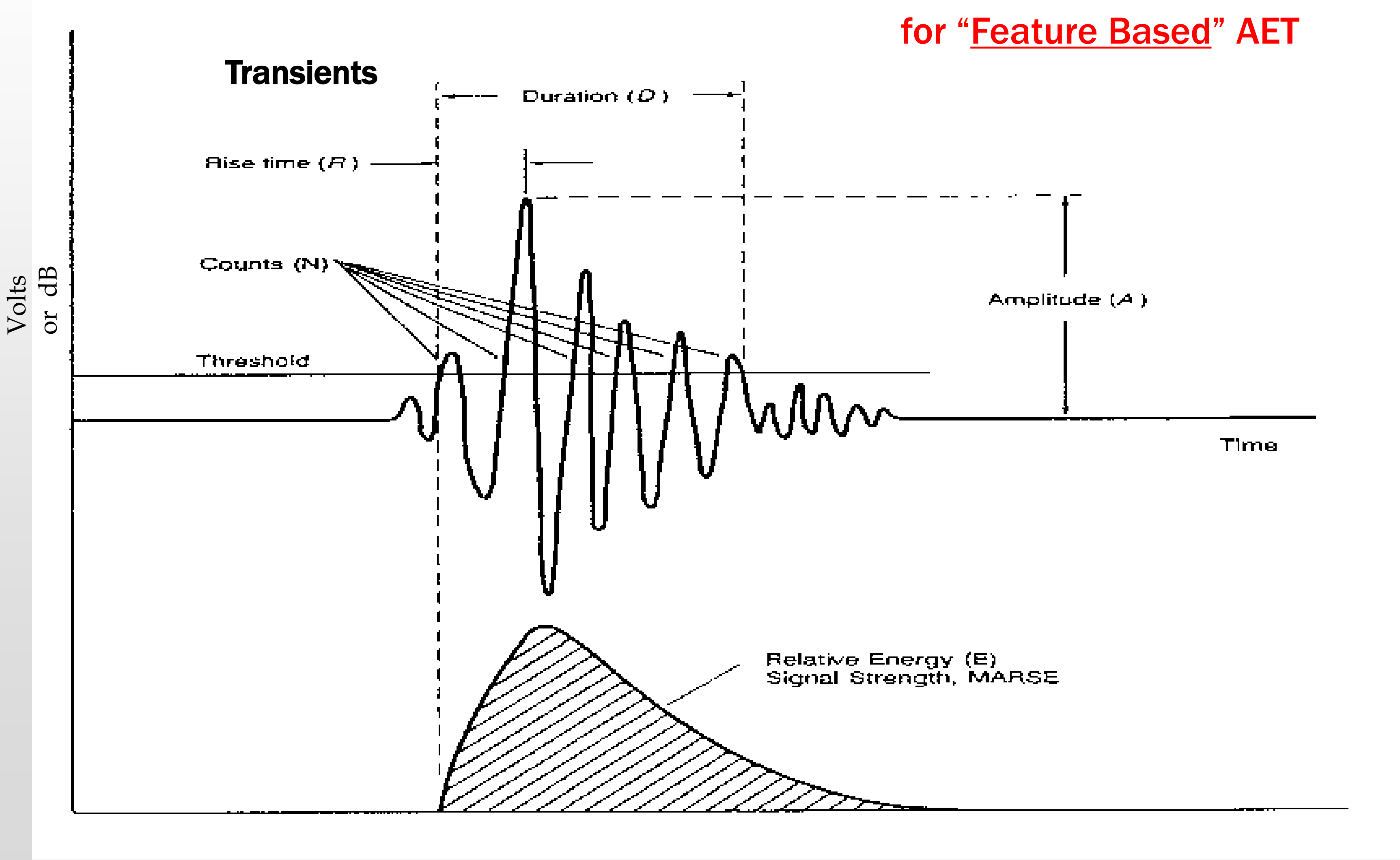
- Know the possible damage mechanisms -> How to best stress the component (based on the mechanism)
- Background noise (mechanical, process, electrical)
- Weather issues (Snow, Rain, etc.)
- Pneumatic safety issues – Hydrostatic tests are preferred!
- Planning for AET during a Shutdown
- Interpreting 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 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.

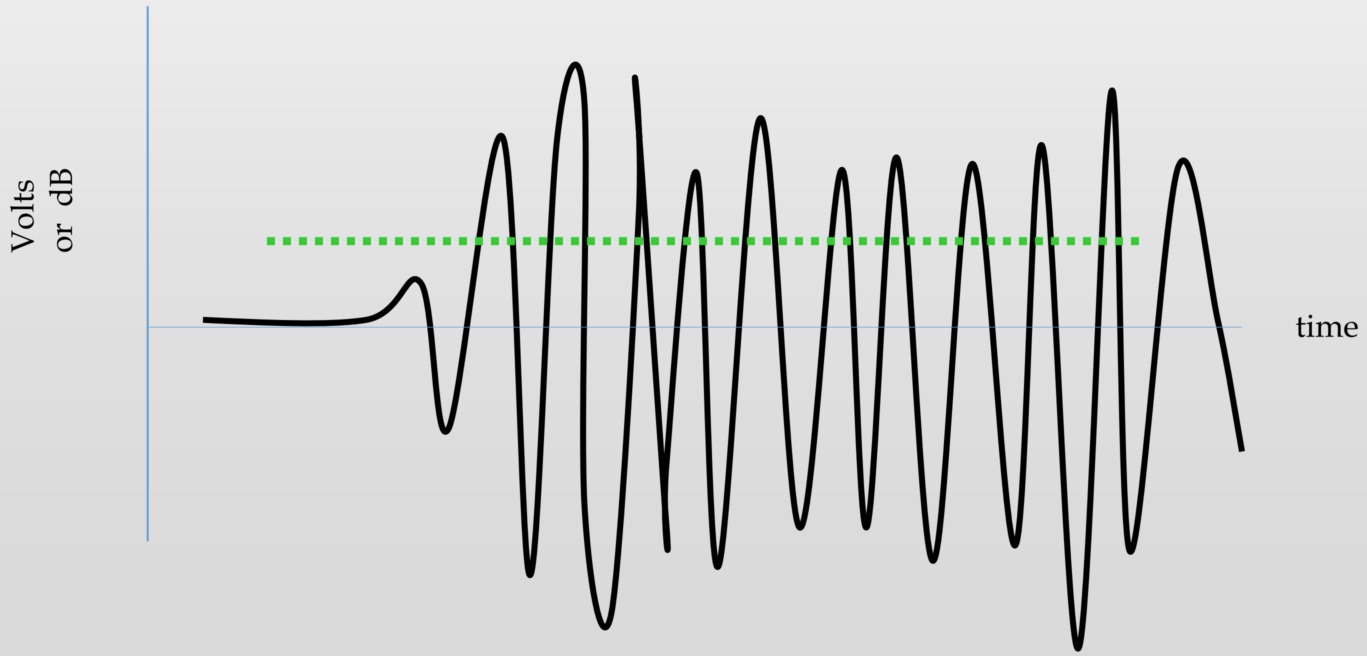
Cracks: high amplitude, short RT, Counts from 100-1000

Mechanical rubbing: low amplitude, average RT, long duration

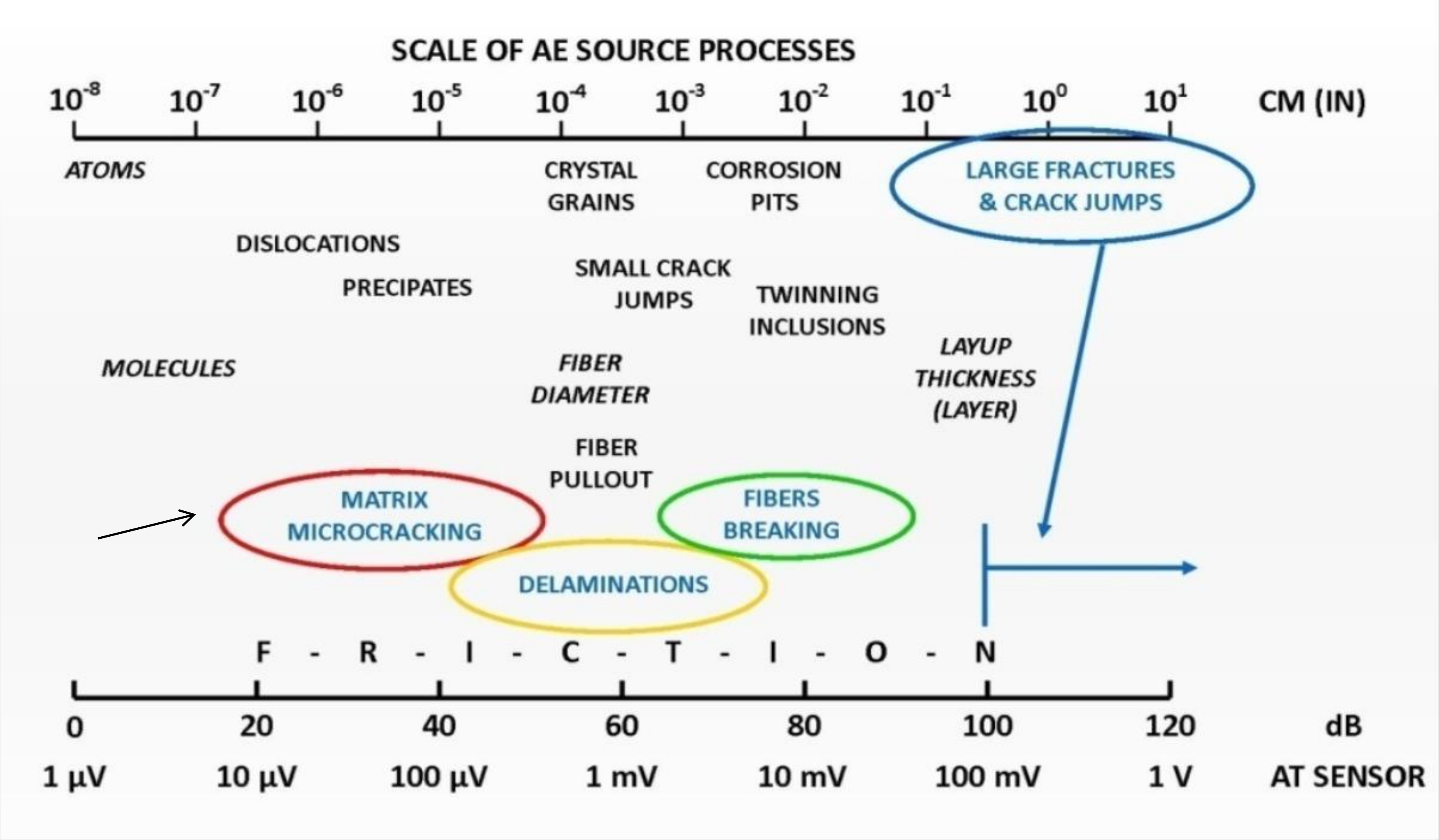
Continuous Emissions

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



Approximate Amplitudes of Various AE Sources

Typical Sensor Mounting Scenarios

Waveguide

Magnet or Epoxy

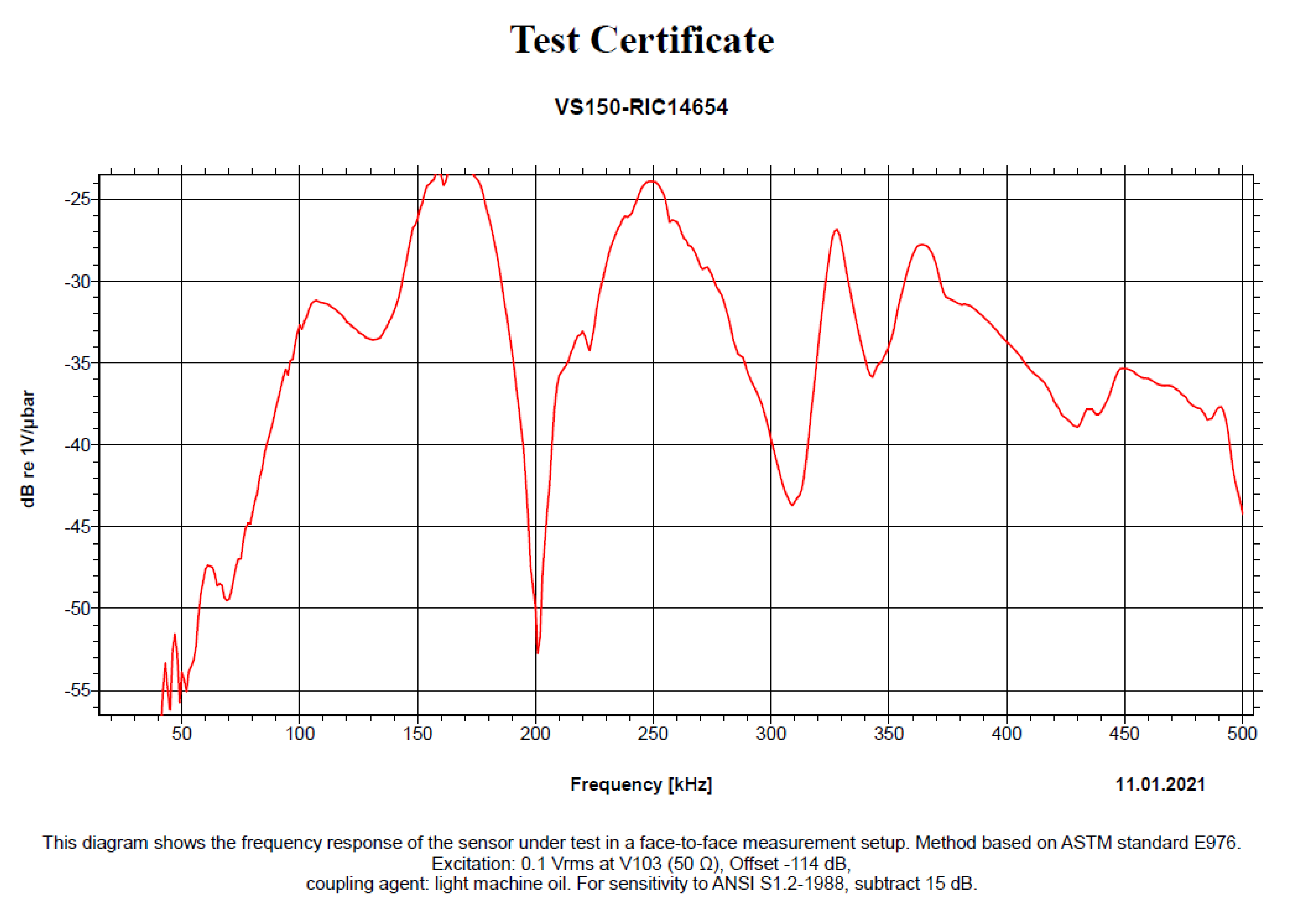
AE Technology – What are Waveguides? Why use them?

Temperature > 200 ^{o}F
¼” Hole in lagging
¼” Hole in insulation
Attach to lagging
Adjust collar against spring

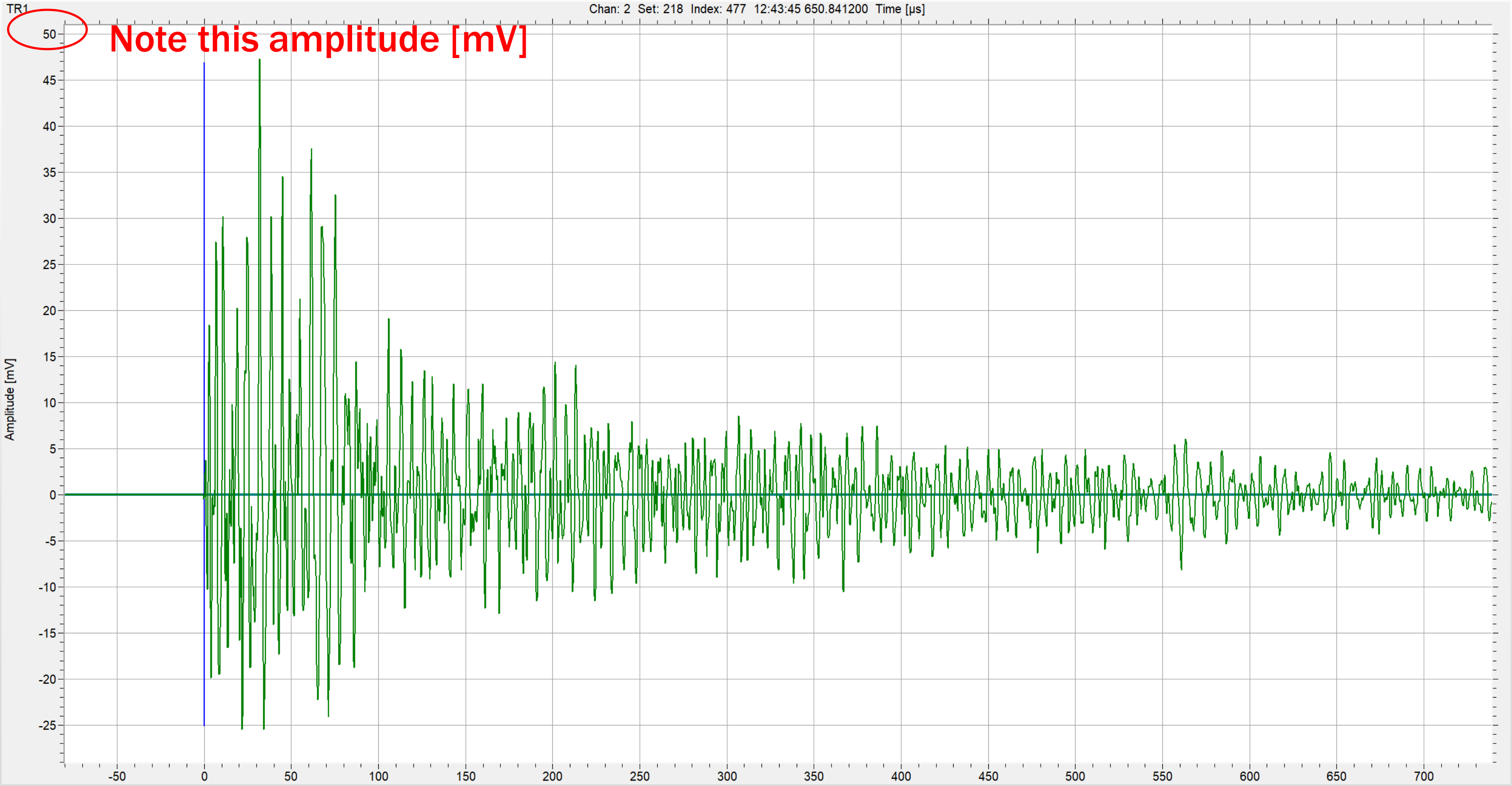
Allow operators to couple the sensors to high or low temperature materials without damaging the sensor

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

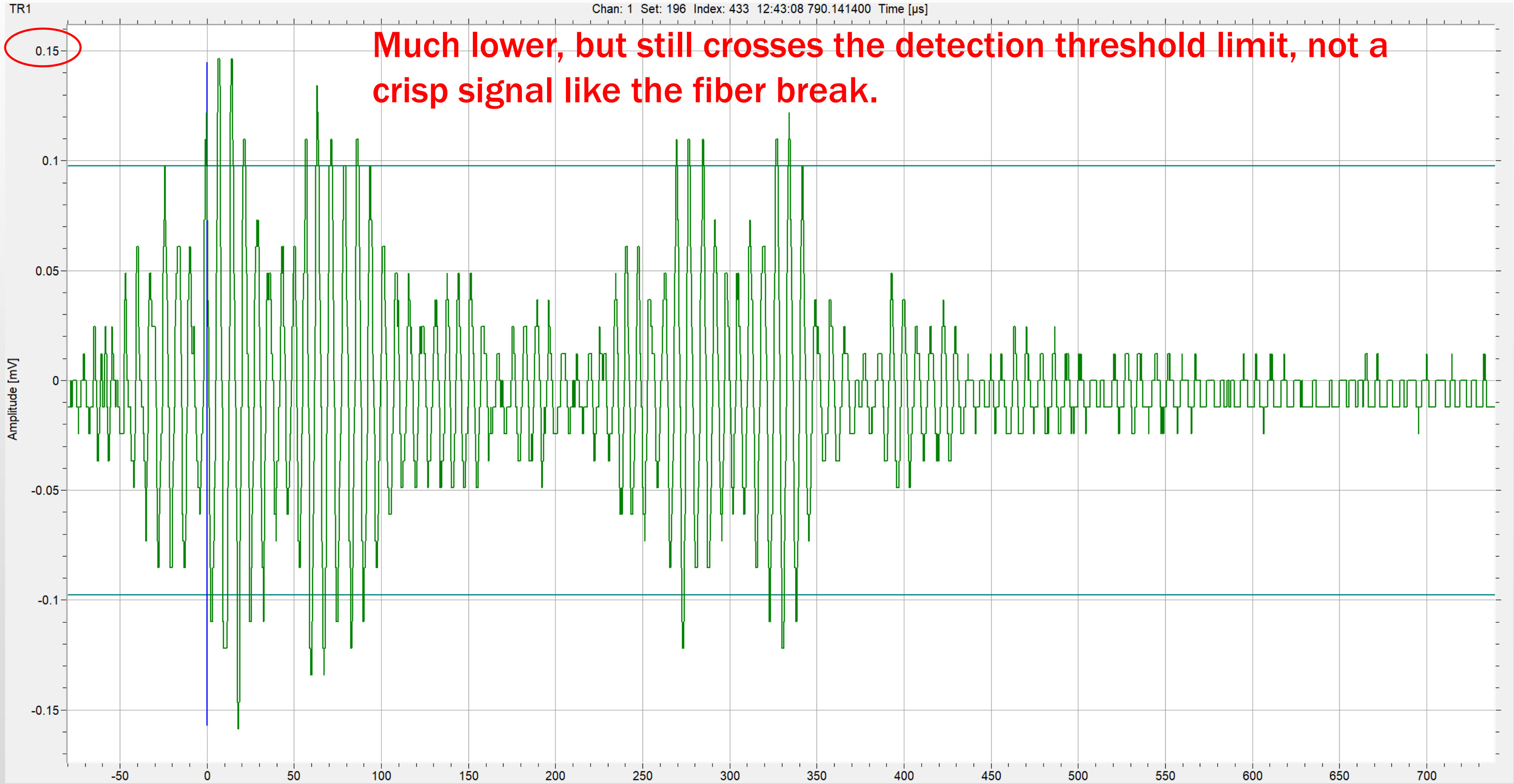
Sensor Verification Test Output



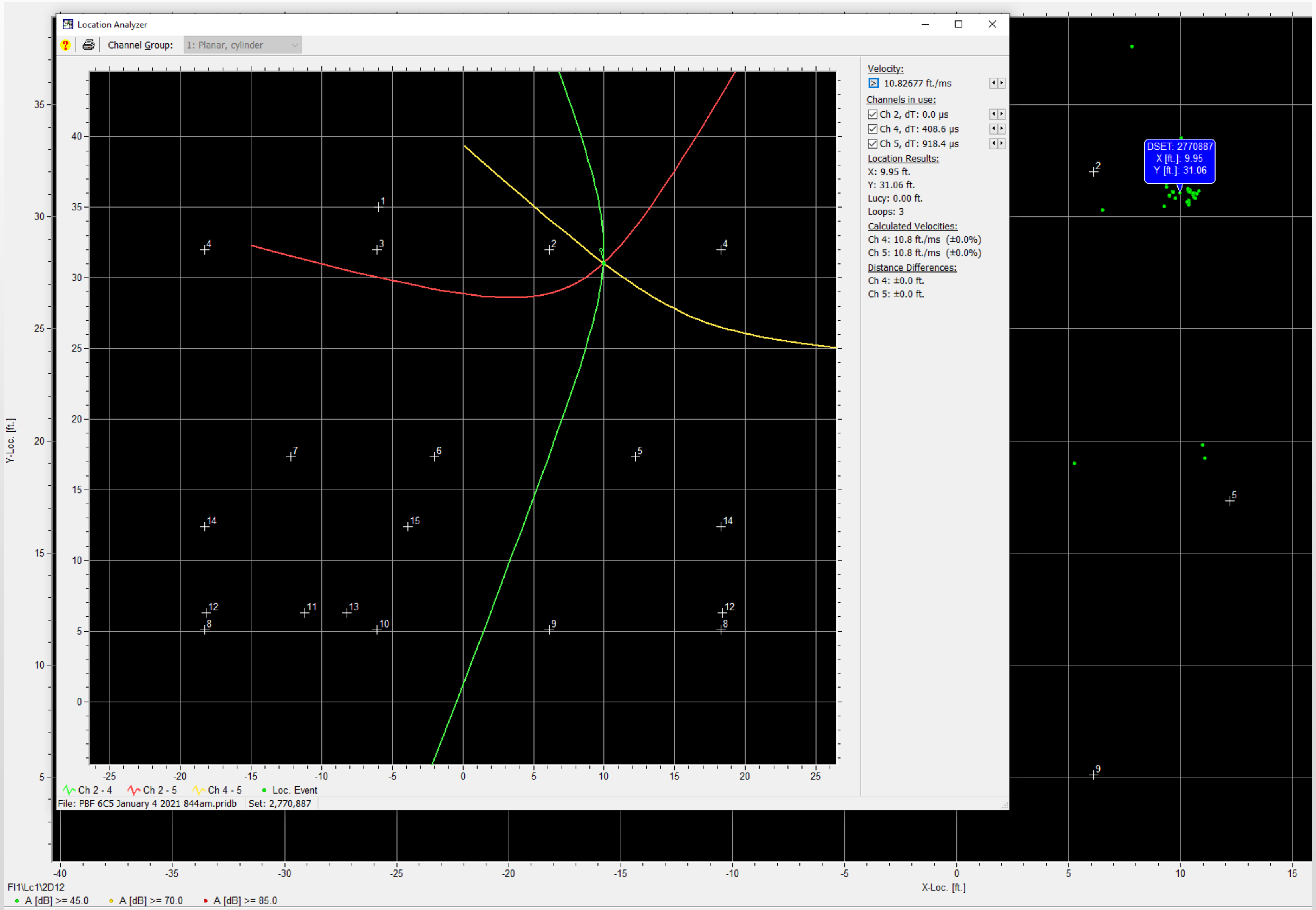
Example of a Fiber Break in a FRP Vessel



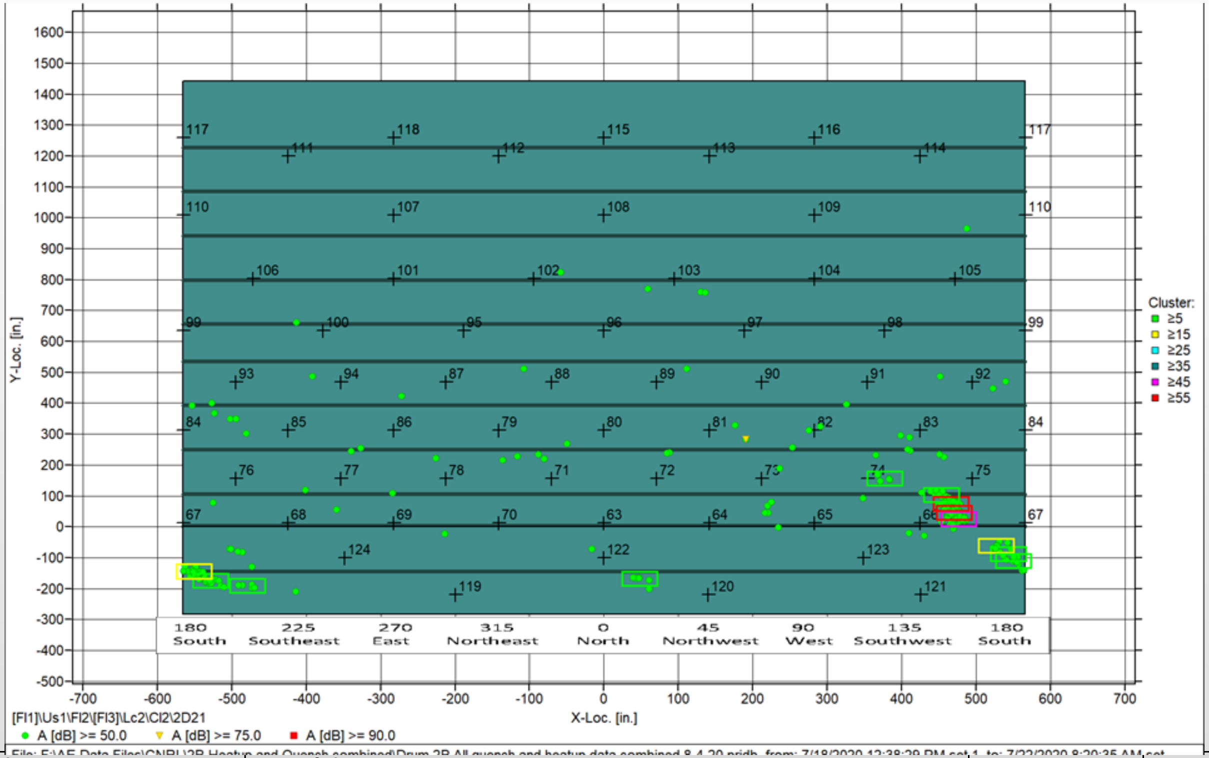
“Noise” i.e. part movement, rubbing, process, etc.



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 X-Loc. [in.]	Centroid of Cluster Y-Loc. [in.]	Range of Cluster θ1 - Azimuth Angle [degrees]	Range of Cluster θ2 - Azimuth Angle [degrees]	Range of Cluster Y1 - Elevation on the Drum (Lower Bound) [in.]	Range of Cluster Y2 - Elevation on the Drum (Upper Bound) [in.]	mean(Amp [dB])	sum(Energy [eu])	sum(Counts)
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

Case Study #1
Leaking Pressure Safety Valve (PSV)

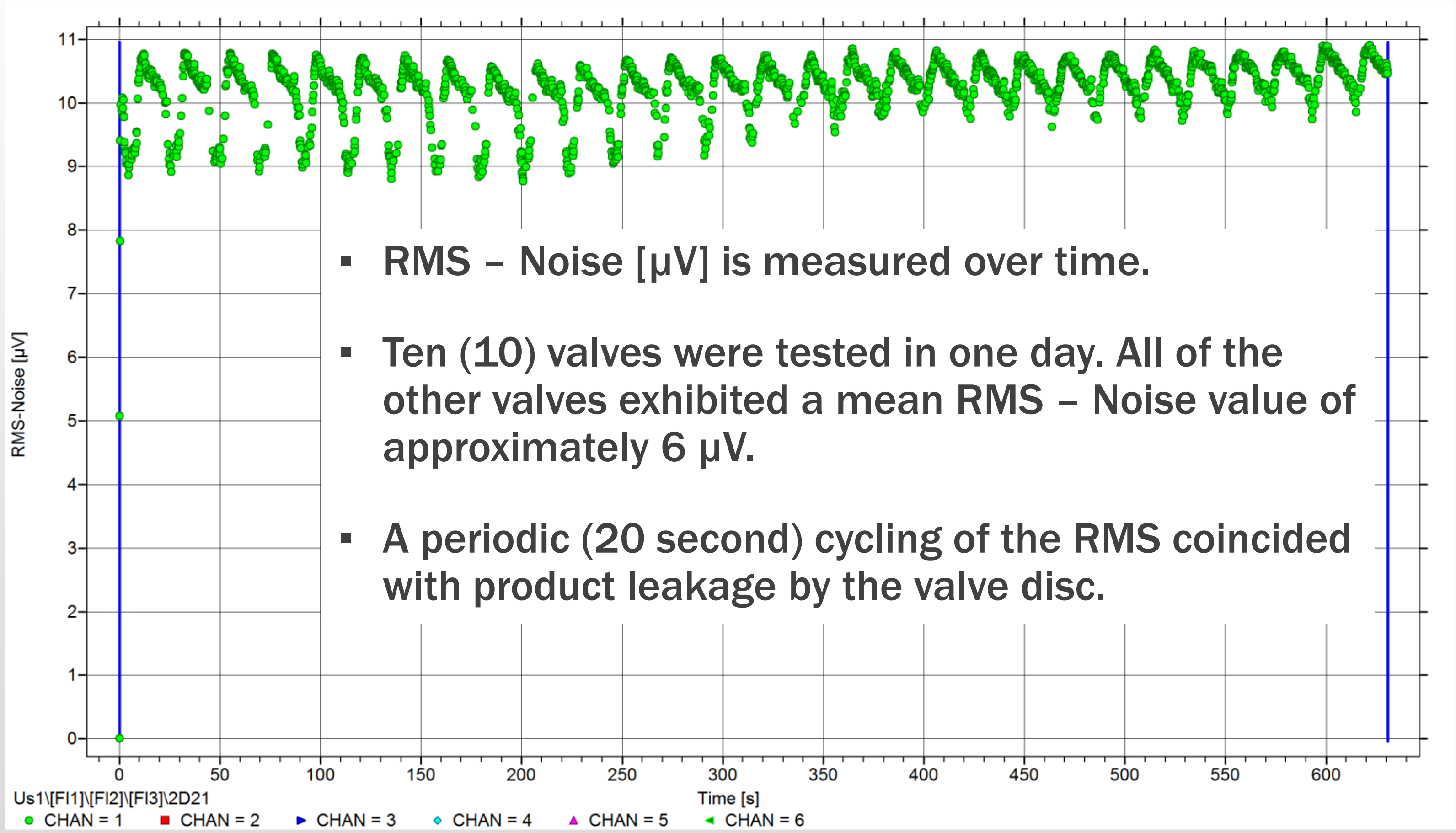
Problem

- The client was detecting excessive H_2S within the flare product flow.
- It was determined that the source of the excessive H_2S 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

Acoustic Emission Data



- RMS – Noise [µV] is measured over time.
- Ten (10) valves were tested in one day. All of the other valves exhibited a mean RMS – Noise value of approximately 6 µV.
- A periodic (20 second) cycling of the RMS coincided with product leakage by the valve disc.

Conclusion

- The client was detecting excessive H_2S 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

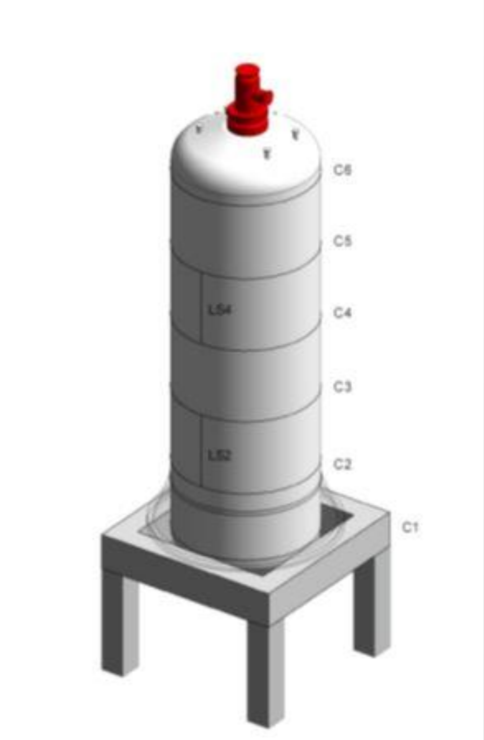
Problem

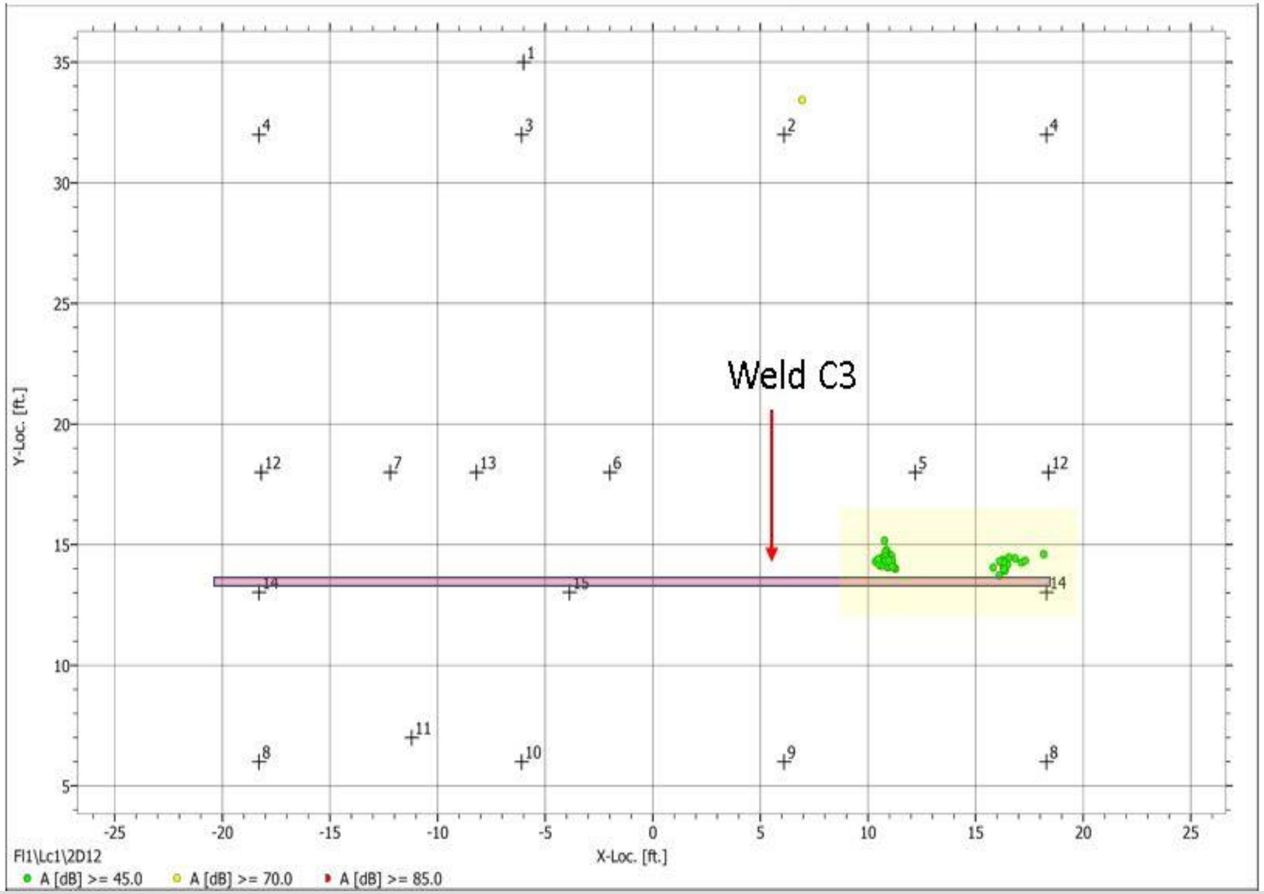
- Pressure vessel survey indicted high-susceptibility to HTHA damage based on material (C-1/2 Mo), time in service, and hydrogen partial pressure.
- Thick-walled reactor - ~4 inches
- Reactor was insulated with skin temp above 700 Deg. F
- High-temp prevented other NDE methods while in service.
- Client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

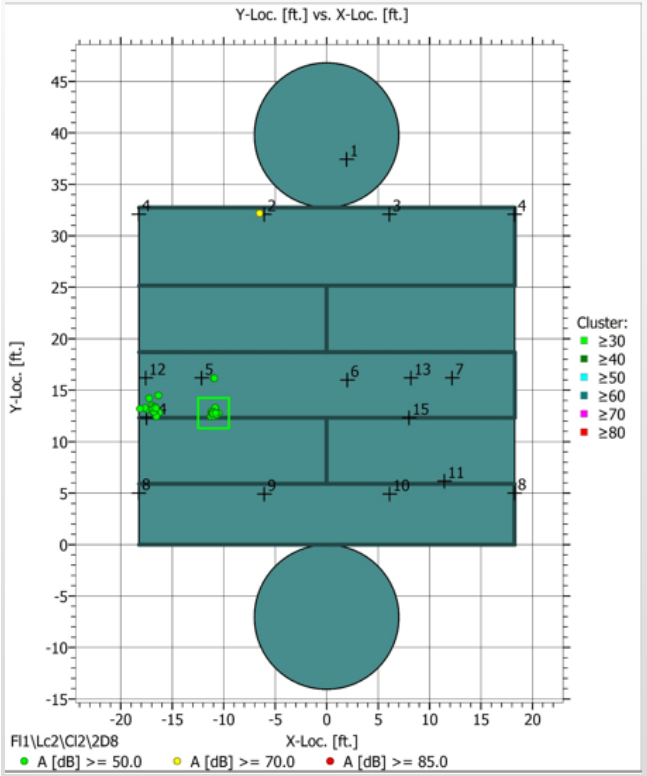
Utilizing AE to Determine Potential HTHA Damage

- 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 ares 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 had been in place for over 3-1/2 years.
- Managed remotely via cellular connection.

Case Study #3
Coke Drums

Problem

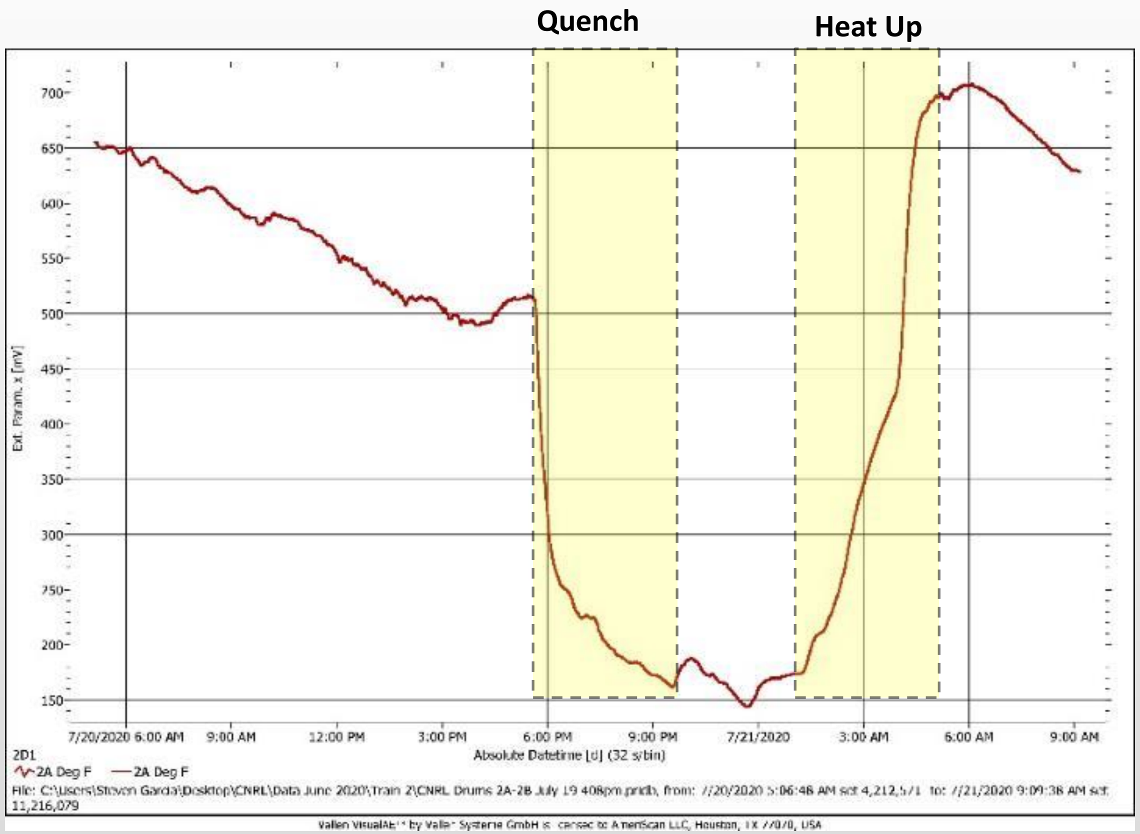
- Recent laser scan showed severely bulged areas on 2 drums.
- Engineering analysis showed problematic area with bulge at a circumferential weld seam.
- Client wanted inspection with minimal disturbance to normal coking cycles and insulation.
- Scaffolding entire structure was cost-prohibitive.
- AE 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.

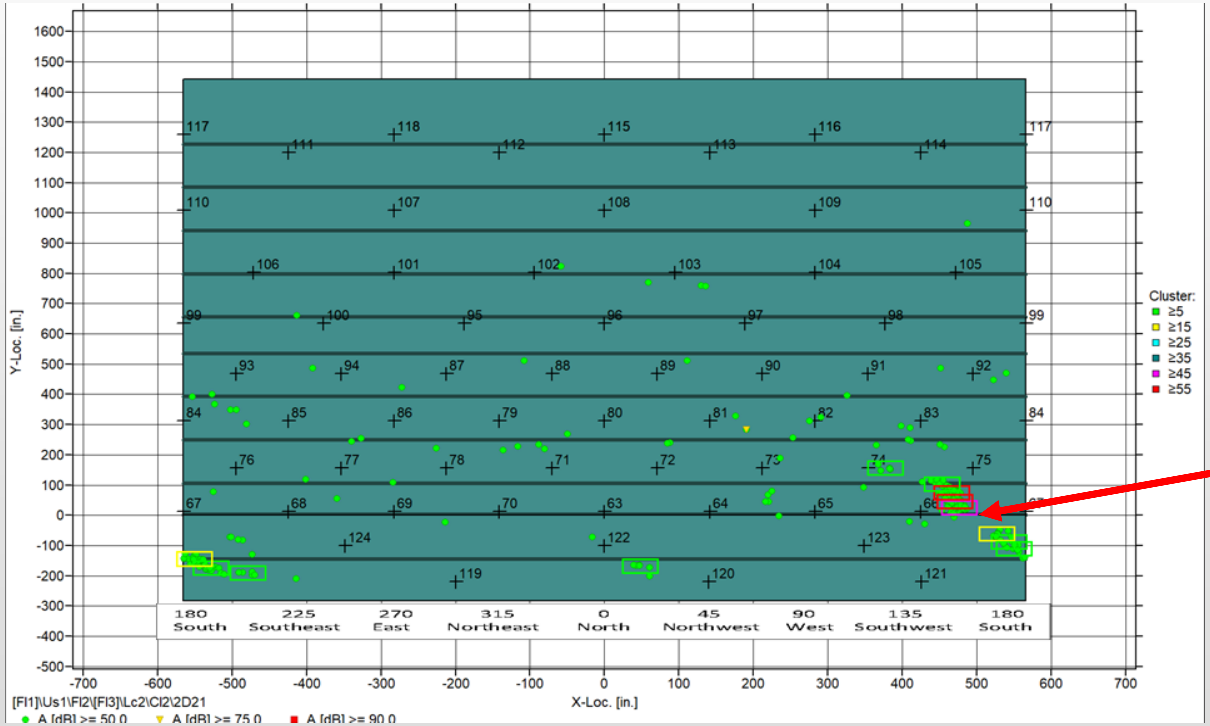
- Waveguides used to minimize insulation disturbance and protect sensor from surface temp.
- Data collection equipment mounted on skirt deck to minimize cable lengths.

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

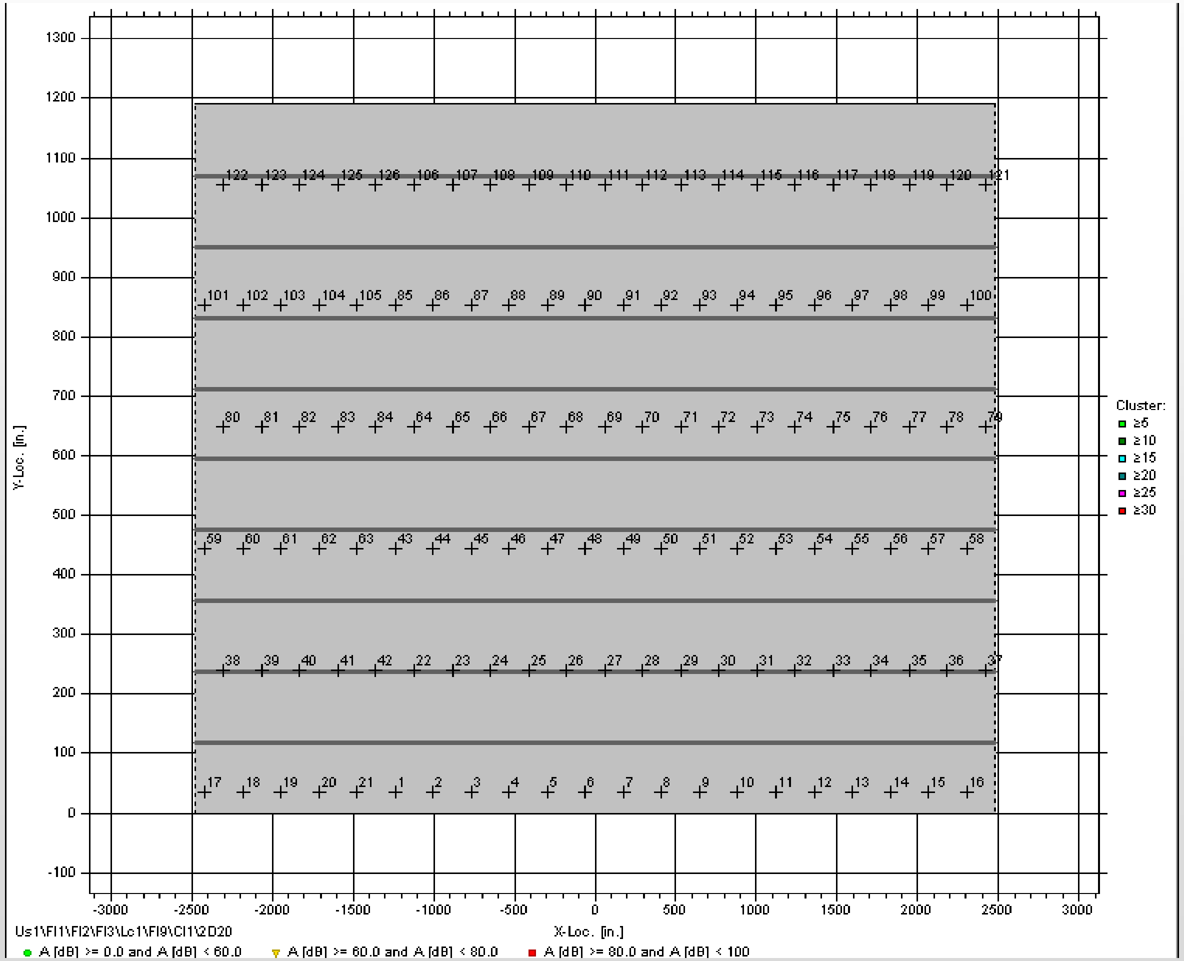
Problem

- 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



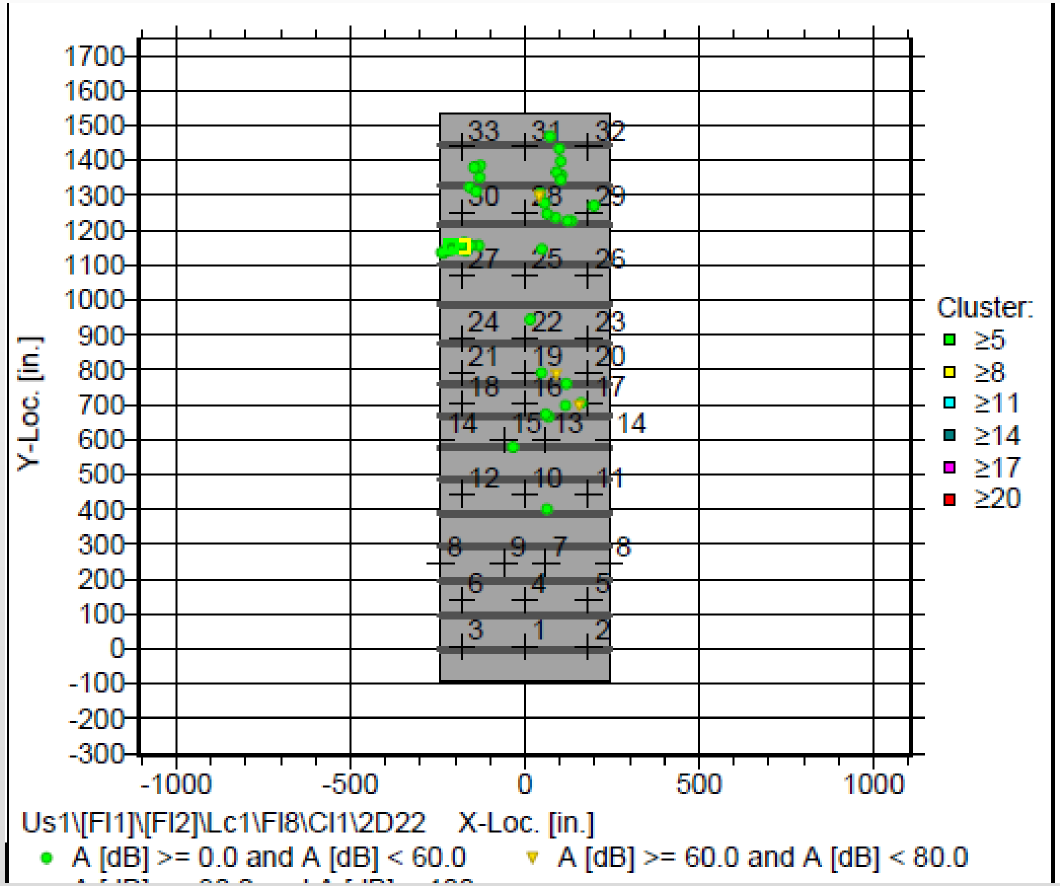
- No locatable AE data from propagating flaws due to ammonia SCC were observed during the fill test.
- Client resumed tank operation until next inspection interval.

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



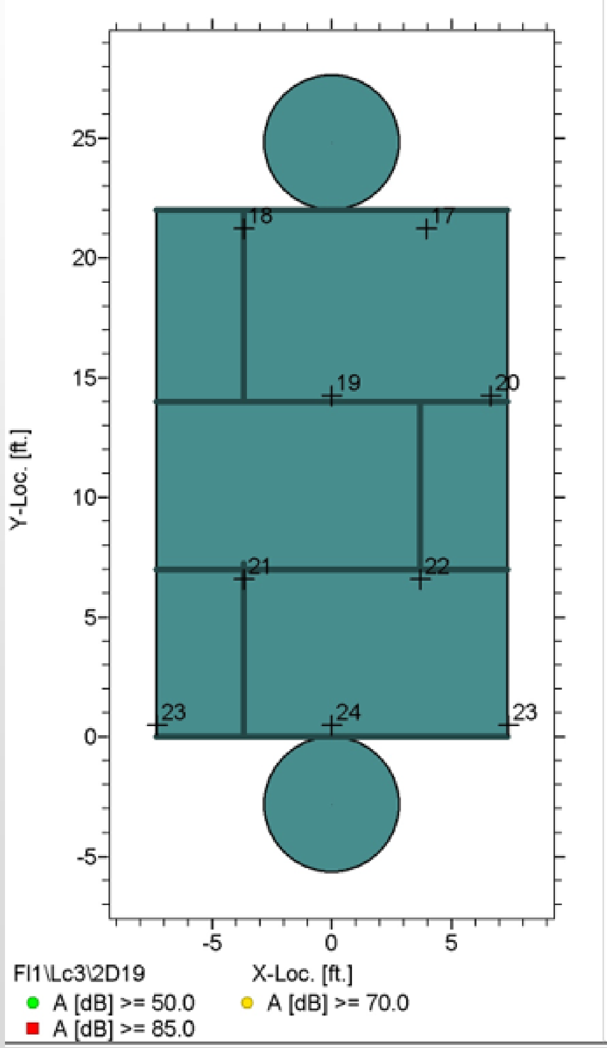
- Multiple AE sensors installed for complete coverage.
- AE testing took place during pneumatic over-pressure test.
- Locatable AE data was observed during the pneumatic test and reported.
- Recommended to the client to follow-up in the specific areas noted using conventional NDT.

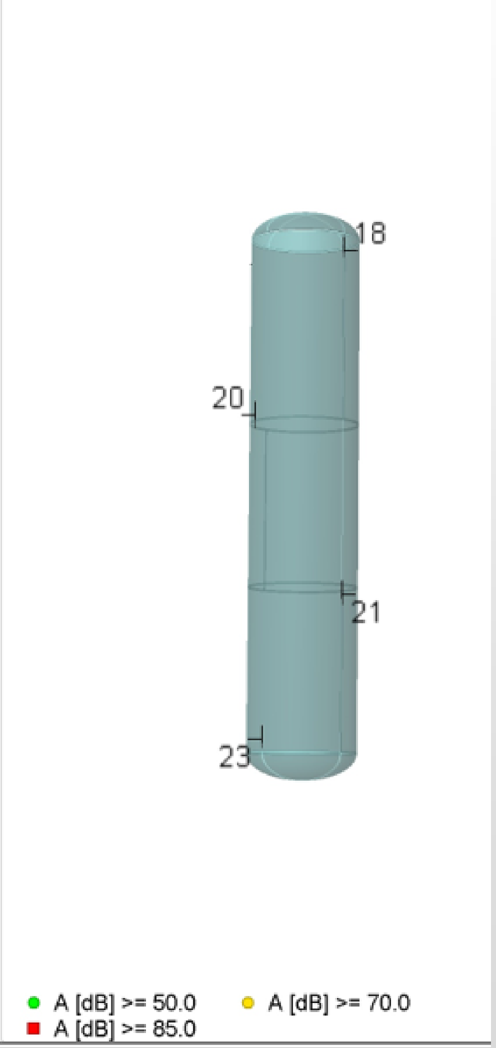
Case Study #6
H2S Driers

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





- 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.
- Real-Time alarms used to alert for power failures and important data activity.

Conclusion

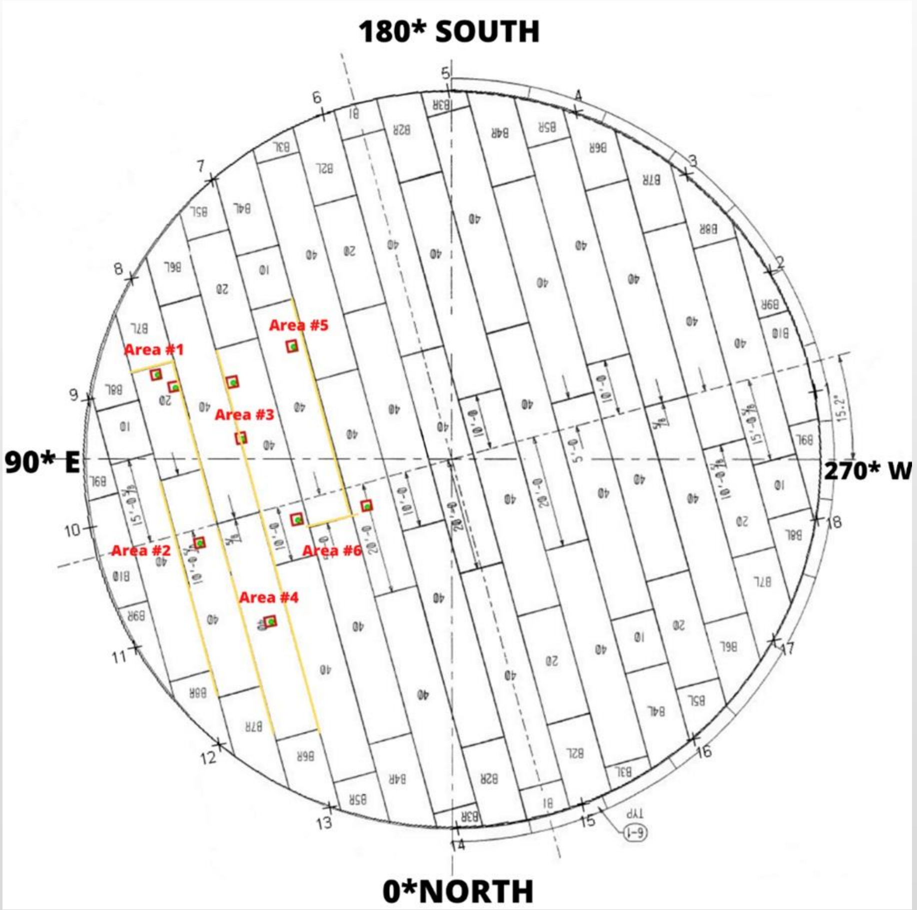
- Multiple AE sensors were installed on each vessel to provide 100% coverage.
- Remote monitoring system installed with wireless access to AE monitoring system and data.
- Alerts for any AE activity sent via text messages.
- Managed 24/7 from Houston office with no personnel in the unit.
- Client continued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

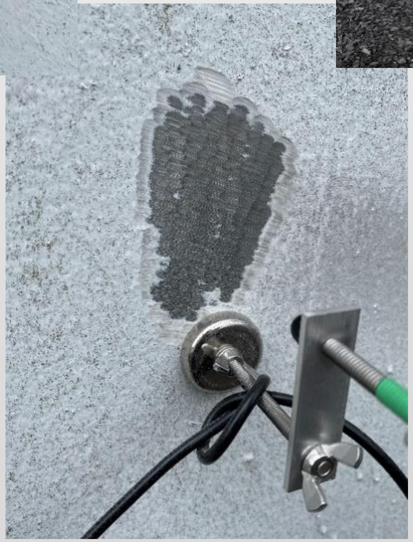
Case Study #7
Leaking Above Ground Storage Tank

Problem

- Large above ground storage tank suspected of small leak during service.
- Tank was internally inspected less than 2 years prior, with no previous issues.
- Small amount of product detected during soil sample analysis.
- Tank could not be taken out of service until next T/A.
- Client needed immediate confirmation of suspected leak.
- AE testing had never been performed on this tank.

Acoustic Emission Setup





Conclusion

- Multiple AE sensors were installed to provide 100% coverage for the bottom floor monitoring.
- 36 Hours of continuous AE monitoring was performed.
- Several locations were identified with very small leaks. Leaks seem to correlate with tank level.
- Report with identified leak locations given to the client for further inspection during next internal inspection.

Conclusion

- **Questions ?**