MISTRAS

One Source for Asset Protection Solutions®

Listening for Corrosion – Using Acoustic Emission to Inspect Storage Tank Floors

Dr Ryan Marks CEng MIMechE

MISTRAS Group

MISTRAS' asset protection solutions support clients with cutting-edge, technology-driven mitigation of risks.

VISION

Be the **integrated-solution partner** to solve civilization's unmet asset protection needs

MISSION

We will deliver value by developing, integrating, and executing asset protection solutions that **maximize uptime and safety**

- Founded in **1978**
- NYSE: **MG**; IPO in 2009
- Global HQ in Princeton, NJ - USA
- **Over 106 Locations Worldwide**
- Over **5,000** Employees

HOW WE HELP

FIELD INSPECTIONS

Individual spot inspections all the way up to evergreen inspection program management and execution

ACCESS

Trained and industry-certified technicians safely access assets in at-height, confined, subsea, and hazardous locations

MAINTENANCE SERVICES

Complementary light mechanical services to clean and repair assets after damages are discovered in inspections

DATA SERVICES

Solutions to manage, analyze, and digitally transform enterprise, site, and asset integrity data

ENGINEERING CONSULTING

Engineering and mechanical integrity consultation services to optimize facility design and operations

EQUIPMENT

Innovative, leading-edge inspection equipment enables our customers to track their assets' conditions

LAB QA/QC SERVICES

In-house testing and quality assurance solutions for newly-fabricated components and materials

SPECIAL EMPHASIS

Proceduralized programs that use our asset protection expertise to target hazardous and costly damages

WHO WE HELP

Backed by decades of experience, our subject matter experts (SMEs) understand the unique problems that our customers face every day, and recommend solutions tailored to particular equipment and facilities.

Certain industries operate in some parts of the world more than others. With locations all over the globe, we have the ability to operate wherever our customers are.

OIL & GAS

AEROSPACE & DEFENSE

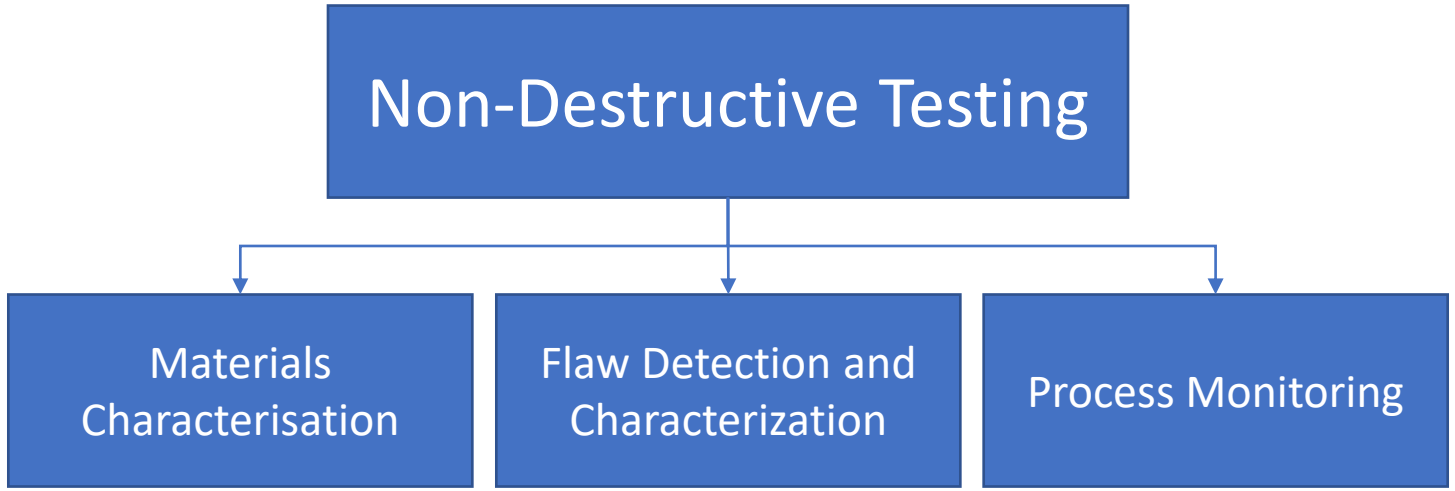
INFRASTRUCTURE

POWER

MANUFACTURING

Acoustic Emission

What is Acoustic Emission (AE)?

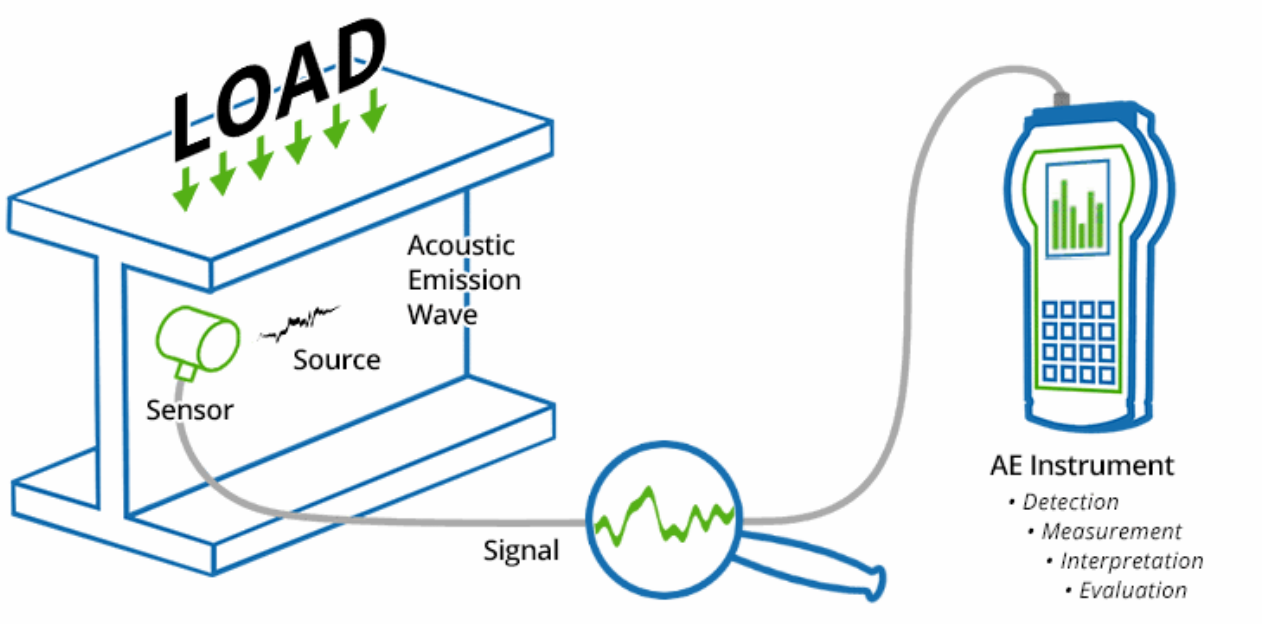


Radiographic Testing (RT)
Magnetic Particle Testing (MT)
Liquid Penetrant Testing (PT)
Ultrasonic Testing (UT)
Electromagnetic Testing (ET)

Acoustic Emission Testing (AE)
Visual Testing (VT)
Infra-Red / Thermal Testing (IR/T)
Vibration Analysis (VA)

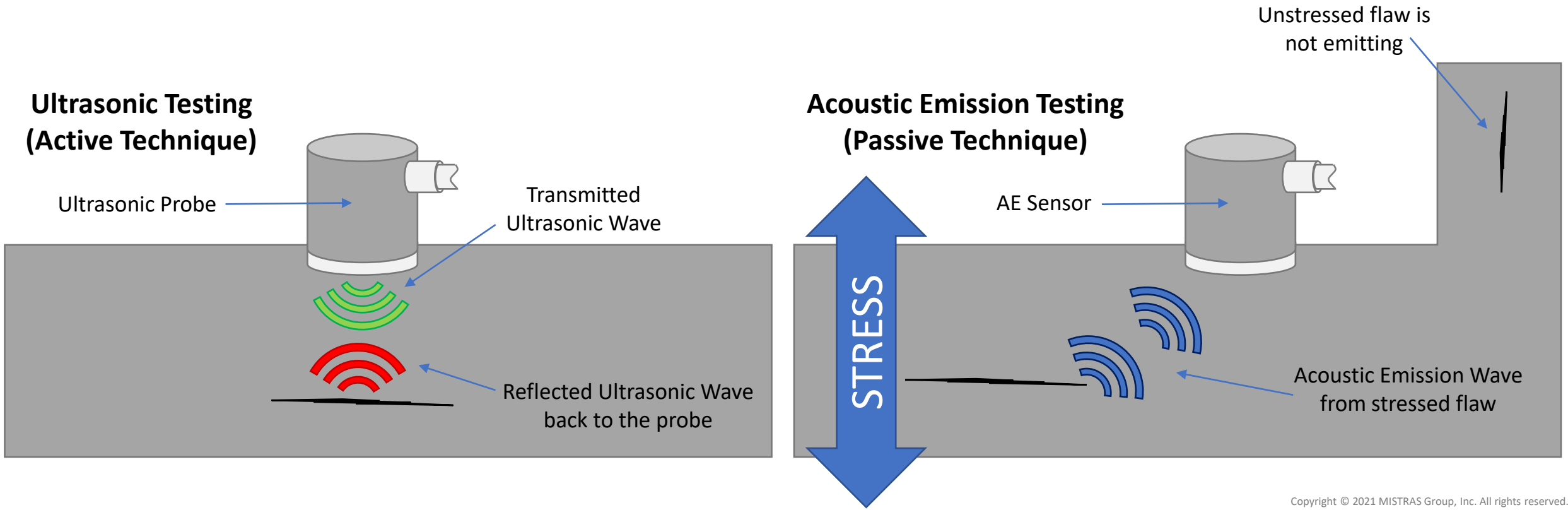
Acoustic Emission is defined as:

- *"Acoustic Emission are transient elastic waves generated by the rapid release of energy from localized sources within a material"* (ASTM E1316)
- AE results from movement within a material
- AE is a non-destructive Testing Technique
- AE is typically in the frequency range above human hearing – 20kHz – 1MHz



Acoustic Emission:

- Is a **passive** NDT method – the energy comes from the flaw/defect. An active technique requires the energy to be put into the material from the instrument.
- Detects **movement** within a material
- Cannot size a flaw
- Cannot detect flaws that are not growing



Acoustic Emission:

- Flaw growth/movement
- Stress-related
- Less intrusive
- Global monitoring
- Anisotropy is good
- Each loading is unique
- Principal restriction: attenuation, noise, dependence on stress history

Most other methods:

- Flaw presence
- Shape-related
- More intrusive
- Local scanning
- Anisotropy is bad
- Inspection is easily repeated
- Principle restrictions: access, local geometry, proximity of flaw to surface

AE provides indications of whether flaws are active, where they are active and how active they are.

Human Nervous System Analogy

AE Signals in AE sensor network

Sensor Network

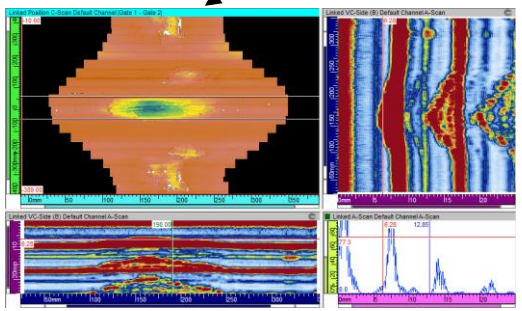
Pain signals in nervous system

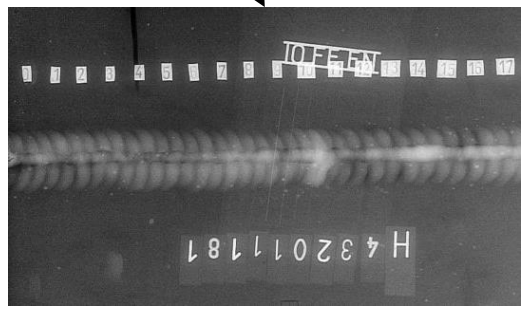
Further inspection

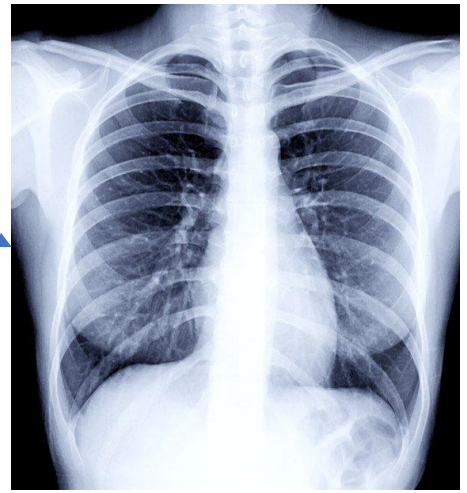
Further inspection

Further Inspection

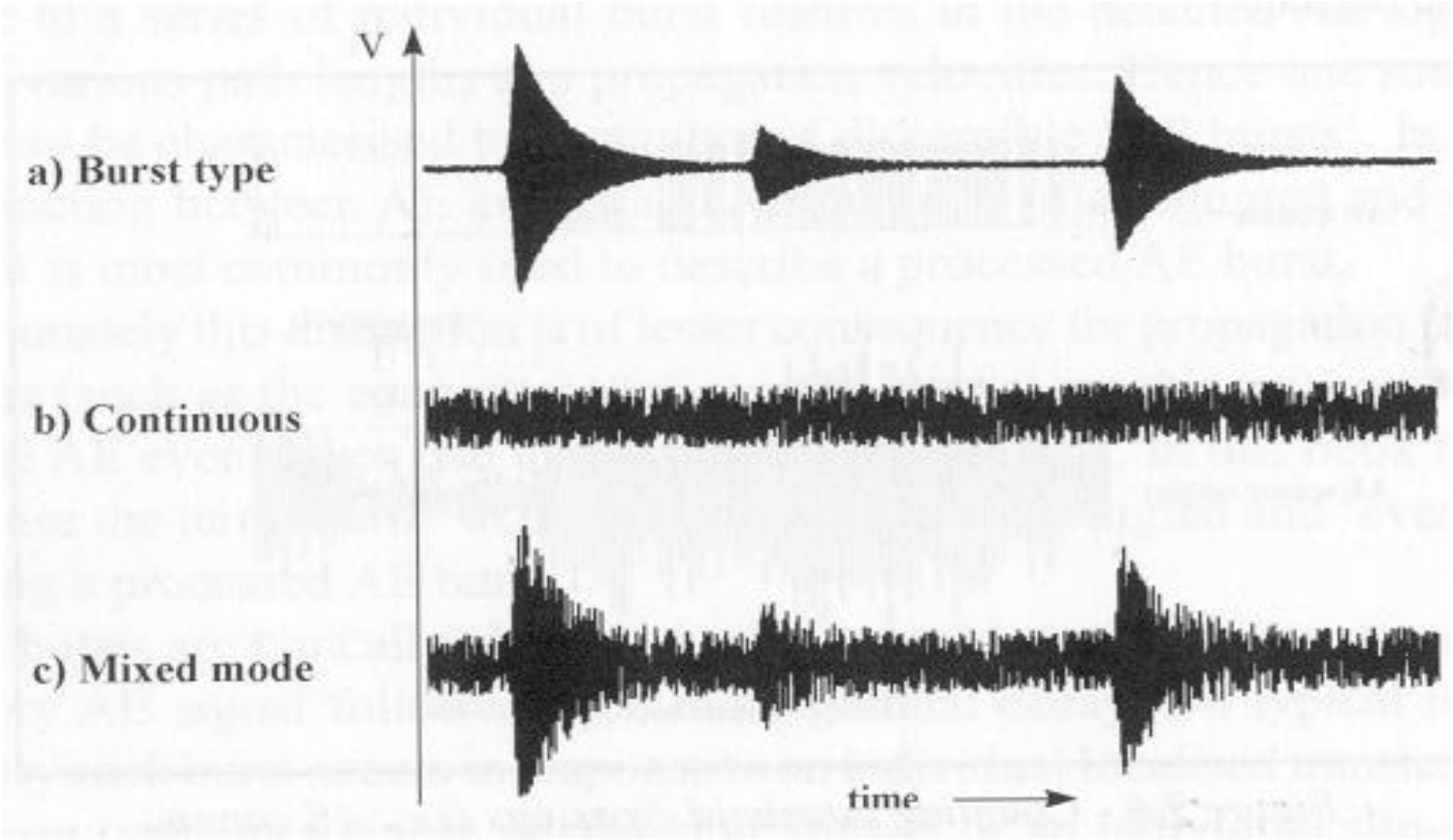
Further inspection







Signal Types

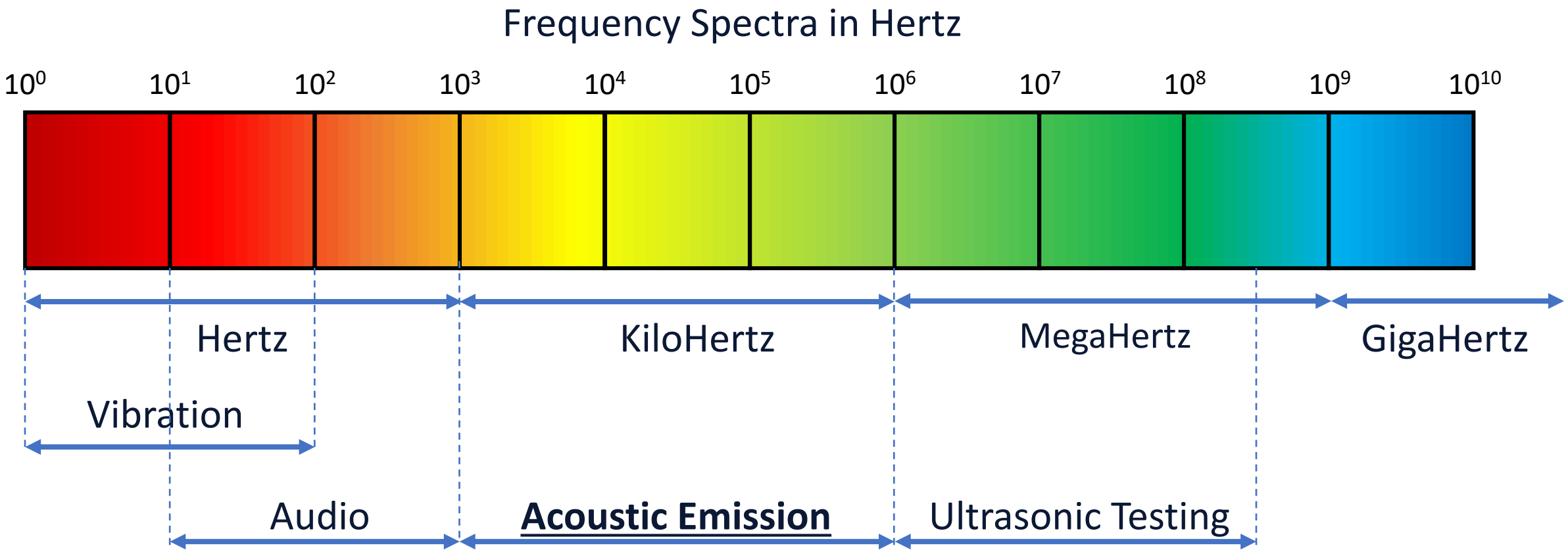


Structural

Corrosion

Bearings

Audio Frequency Spectra



Why use AE?

- Passive (low power)
- Global Method
- Real Time
- Locate sources
- Enables understanding of why something has happened
- Can differentiate different source mechanisms
- Can be more sensitive than other passive methods (i.e. vibration)
- Generally non-invasive
- Can be installed in harsh and hazardous environments (nuclear, subsea, high temperature
- Can be used as an early warning

Why use *NOT* AE?

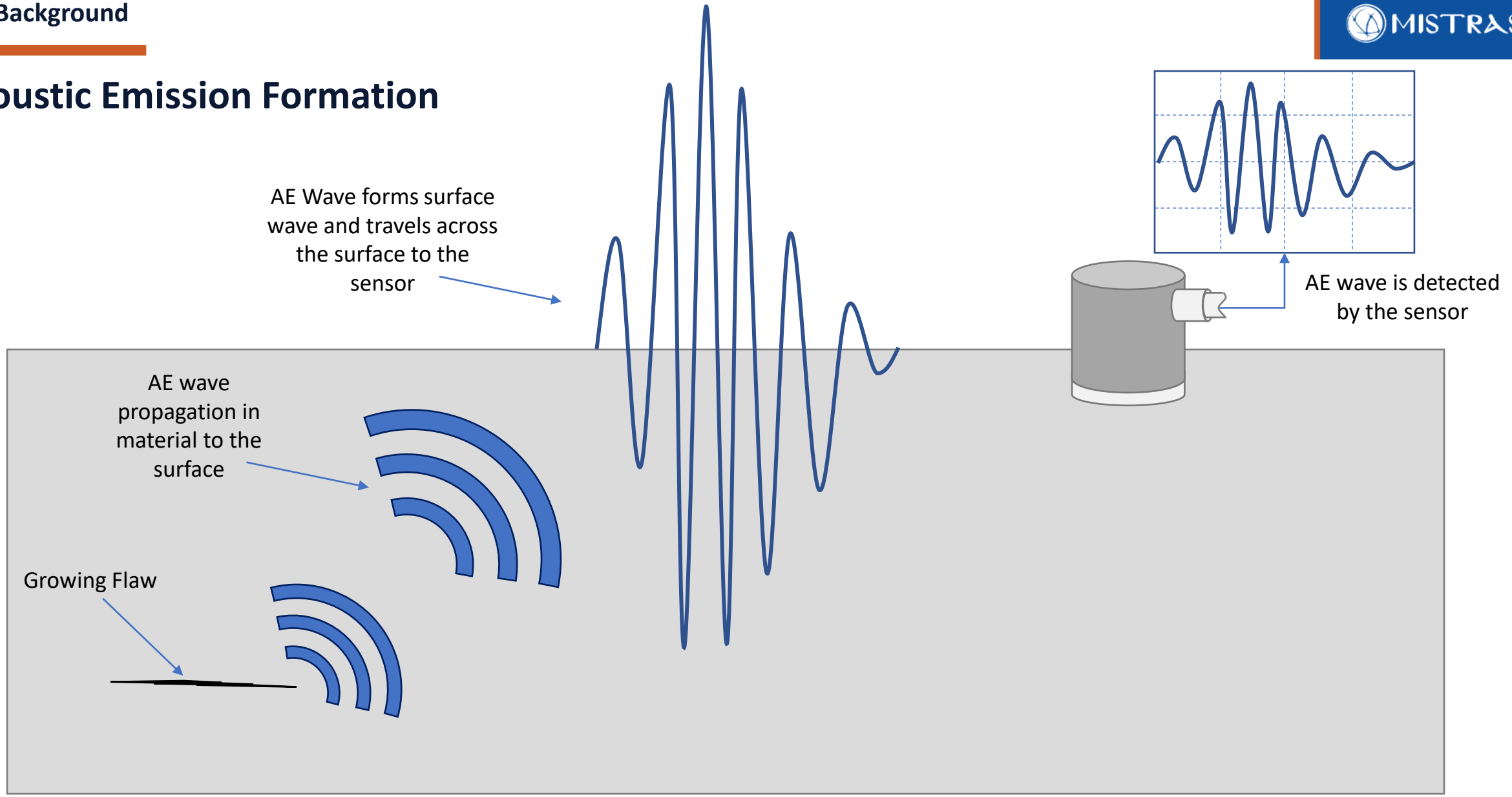
- Cannot size flaws
- Cannot give precise location and geometry of flaws
- Can only detect active, growing flaws – an external stimulus (i.e. Load) is needed
- Requires equipment to be deployed and recovered

Need to use the right tool for the job

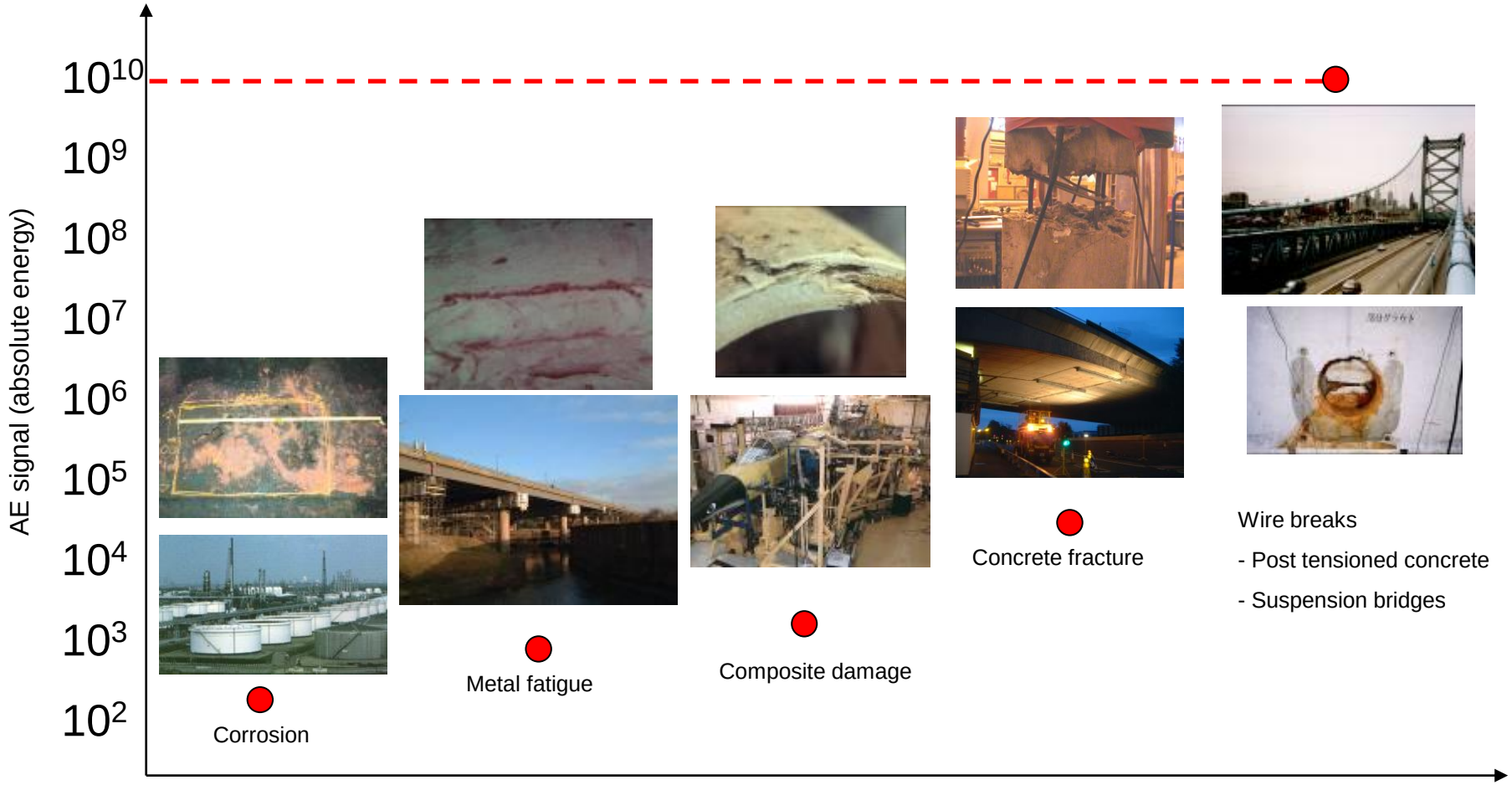
Materials and Processes

Materials	Processes
Fatigue Cracks (Metals, Concrete)	Corrosion
Environmentally assisted cracks (HIC)	Leaks (gas, liquid)
Fretting	Cutting
Crushing	Welding
Delamination	Punching
Fibre fracture (composites, wood)	Chemical (battery charging)
	Particle flow
	Cavitation

Acoustic Emission Formation



AE Damage Mechanisms and Resulting Energy



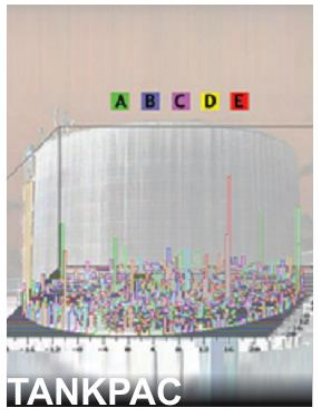
Core AE Applications

Acoustic Emission (AE)

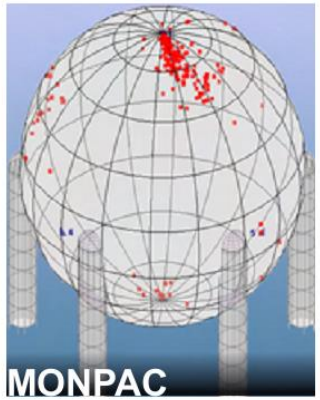
By performing thousands of field tests on pressure vessels, storage tanks, pipelines, valves, nuclear lift rigs, railroad tank cars, bridges, compressed gas cylinders and transformers with Acoustic Emission (AE) inspection, we have developed an extensive database for interpreting the significance of AE signals as they relate to flaws, cracks and leaks.

This extensive experience led to the development of knowledge-based systems such as CORPAC™, VPAC™, MONPAC™, POWERPAC™, and TANKPAC™. Our state-of-the-art AE systems and sensors are manufactured under ISO-9001 Certification and calibrated and maintained by MISTRAS' highly trained staff.

These technology packages are designed and developed by Physical Acoustics Corporation (PAC), a member of MISTRAS Products & Systems division, and have been providing services worldwide since the late 70's.



On-line Acoustic Emission testing of tank floors



Acoustic Emission pressure vessel testing.

Early corrosion detection in alloy materials

Intrinsically safe valve leak detection loss control

Detecting, locating and assessing electrical & thermal faults in power transformers

TANKPAC – Tank Floor Inspection

Above Ground Storage Tanks

- Used in a wide range of industries to hold product
- A range of different designs (fixed, floating roof, insulated)
- Can vary in size (>130m in diameter)
- Can contain electric heaters
- Operate at different temperature
- Integrity is key to operation
- Leakages are a no-go (environment, cost)

Conventional approaches

Strategies used historically:

- Fixed time interval.
- Wait until failure.

Fixed time interval:

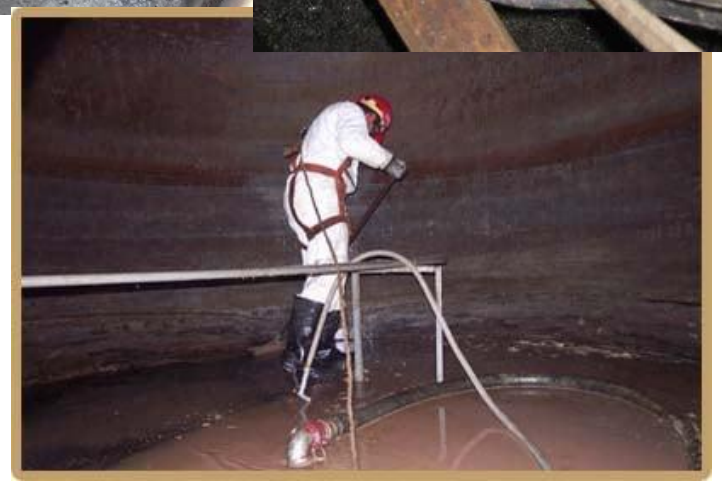
- Some tanks do not need repair so maintenance costs are wasted.
- Some tanks fail between inspections.

or……

- Wait until failure is not environmentally and/or economically acceptable!!

Tank Preparation

- Take tank out of service (can't be used!)
- Remove product
- Clean the tank
  - People inside the tank
  - Confined space
  - Dangerous environment
  - Lots of hazards
- Dump Sludge (where?)
- Make ready for inspection (lots of time out of service!)



Tank Preparation Costs

Approximate cleaning and preparation costs associated with conventional NDT approaches:

>> 100m crude oil tank: ~US$500,000

>> 20m clean product tank: ~US$30,000

THESE COSTS ARE WASTED IF THE TANK DOES NOT NEED REPAIR

WASTE DISPOSAL CAUSES A MAJOR ENVIRONMENTAL PROBLEM

Failure of Time Based Maintenance

Case 1: HOT OIL TANK 140°C

Internally inspected 12 months prior to failure, including UT+MFL. This collapse was due to a narrow band of annular ring corrosion.

MFL could not get close enough to shell. In addition, the corrosion was so narrow, UT procedure could not detect its presence.

When the ring split the very rapid loss of hot liquid pulled a vacuum collapsing the tank shell.

Failure of Time Based Maintenance

Case 2: 50m CRUDE OIL TANK

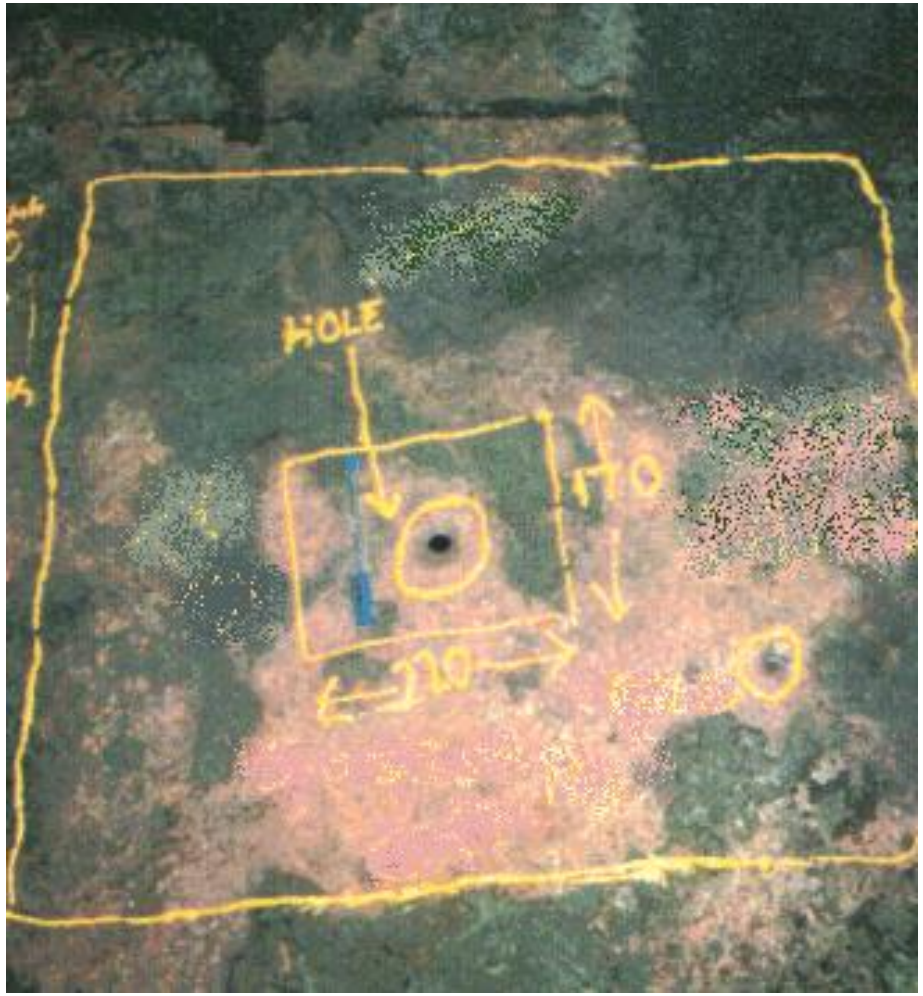
One of 40+ holes in the tank floor, although the tank was not leaking during service, only the sludge and debris were sealing the floor.

Attempts to re-suspend the sludge have resulted in major leakage on many occasions.

Failure of Time Based Maintenance

Case 3: NAPTHA TANK

Leaking 100 cubic metres per day through a 1cm hole.
Operations noticed losses after a week, but no visible product, which was disappearing into ground.
When the plates were cut the cavity under the floor was several cubic metres in size.



Failure of Time Based Maintenance

- 1mm diameter pinhole leak in a 25m diesel tank, where epoxy coating failed.
- Collapse of a 25m sulphur tank due to annular-to-shell corrosion.
- 200 cubic metres per day leakage in a 75m crude tank, 100 cu.m/hour in a 97m crude tank...

- Many more examples, however….

- Tanks removed from service, cleaned, sludge dumped, tank inspected……and no repairs required…..
- If time based internal inspection worked……. this would not be happening…….

Summary of Requirements

- To identify tanks that do NOT yet require internal inspection and repair, this prevents the enormous waste of maintenance resources, and protects the environment by reducing waste disposal needs.

- To determine the relative condition of damaged floors so that a correct priority for internal maintenance may be set.

- To do the above with as little disruption to operations as possible. A method for condition assessment of tank floors is required that can be used on-line.

Tank Preparation Costs

Reason.... tank Floors are the only structural part of a tank with no access for inspection during operation.

History of Technology Development

1989 → PAL* approached by customers, discussion on requirements for tank floor condition assessment.

1990 → First AE trials on tank floors, Esso, BP, ICI, KPE

1992 → User group formed, grew from 5 to 20+ Co's.

1996 → User group became part of EEMUA, ~30 Co's (Engineering Equipment Material Users Association) experience now >600 tank floor tests, feedback on internal inspection of >150 tanks, procedure at rev.4.

1997 → Procedure accepted by Saudi Aramco.

1998 → Results of TANKPAC "correlation study" presented at ECNDT by Shell/Dow

1999 → etc. >1000 tests now completed.

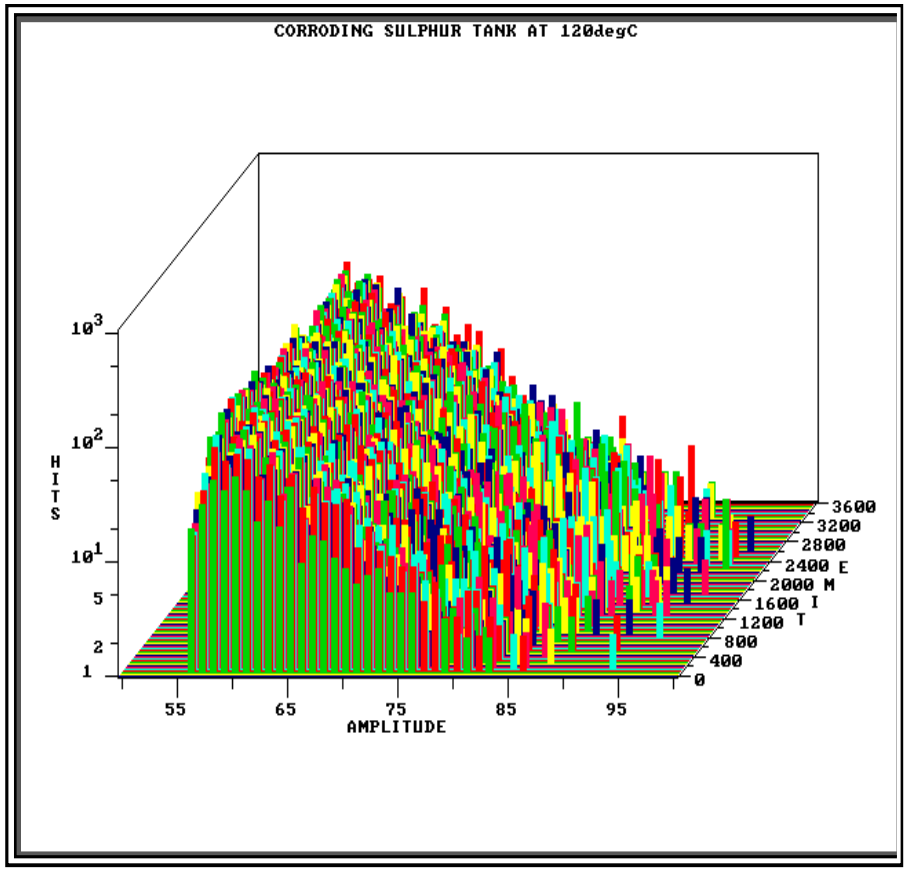
2000 → EEMUA recommendations to members.

2012 → French petroleum Industry announces correlation results. rev.7 method statement and rev.14 analysis procedure, and many 0,000's of tanks tested for all major operators worldwide.

*PAL – Physical Acoustic Limited, former name of MISTRAS Group Limited

Basic Operation

- Corrosion of steel causes Acoustic Emission (Yuyama, Condello etc).
- This is detected by sensors on the outside of the tank.
- Emission reaching three sensors is located.
- Shown right: one hour of emission from a tank with very severe corrosion, characteristics of emission change with scaling

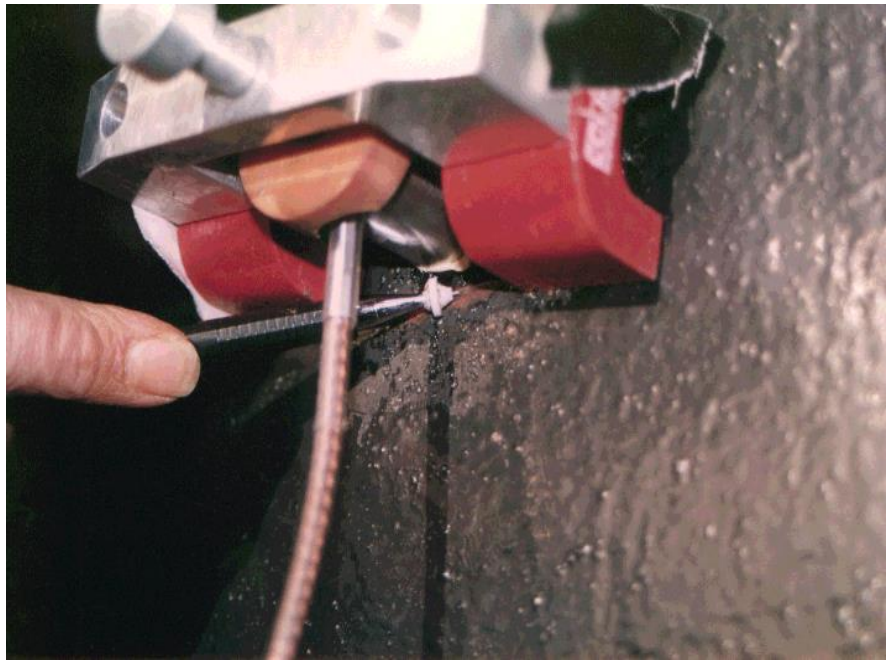


Outline of Procedure

- Sensors are attached to the tank wall around the entire circumference, ~1m above annular. One row, or two rows where condensation or high noise is possible.
- The tank is monitored, duration is ~1-2 hours.
- The data is processed to eliminate unwanted noise.
- Note: effect of noise is conservative >increases grade.
- The result is graded per procedure for the “overall” grade on an “A” (“good”) to “E” (“bad”) scale.
- Location of 3+hit sources by triangulation.
- Location and grading of 3+hit “potential leak” sources*.
- Tank is isolated and allowed to settle.
- Discussion and recommendations.

Sensor Installation and Verification

- Sensors are mounted ~1m above bottom knuckle or above sludge.
- Paint smoothed or removed if not adherent.
- A pencil lead fracture is used for calibration.
- This is detectable at up to 70 metres on large product tanks.
- All sensors are checked after mounting.



Acoustic Sources Detected

- Sources of interest:
  - Spalling of corrosion products.
  - Leak noise: (flow interruption, or turbulence).

- Extraneous noise to be removed:
  - Roof movement noise.
  - Structural movement.
  - External and pipe-borne noise.
  - Condensation.
  - Particle impacts.
  - Valve leakage.
  - Rain!

Inputs to Grade and Recommendations

- "Overall" activity level, "A"-good condition, "E"-bad condition, "B", "C", "D", intermediate conditions:
  - Diameter, product, sludge height.
  - Normalise using: number of sensors, data filtered, threshold.
  - Special procedures for sacrificial anodes, soft rubber lining.
- Locate overall data:
  - The ~5-30% which "hits" >3 sensors, any concentrated sources?
- Separate, locate, and grade "potential leak" data:
  - More severe local damage, "A" to "E" scale.
- Retest recommendation based on above factors.

Recommendations matrix fits with RBI

"PLD GRADE"					
E/5	III	III	IV	IV	IV
D/4	II	III	III	IV	IV
C/3	II	II	III	III	III
B/2	I	I	II	II	n/a
A/1	I	I	II	n/a	n/a
"OVERALL GRADE"	A	B	C	D	E

n/a should not occur at standard threshold

I – No active damage, re-test in 4/5 years.

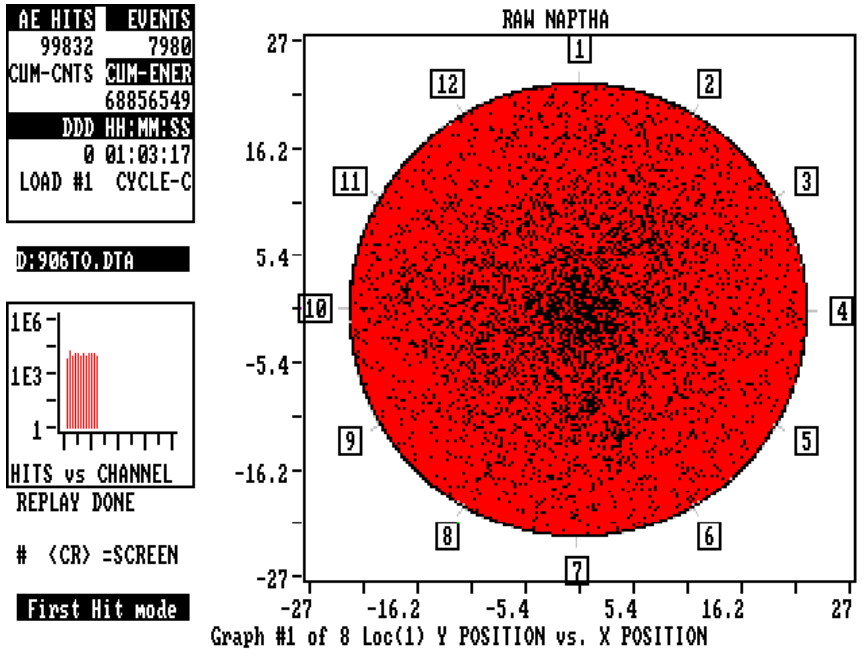
II – Minor active damage, re-test in 2 years.

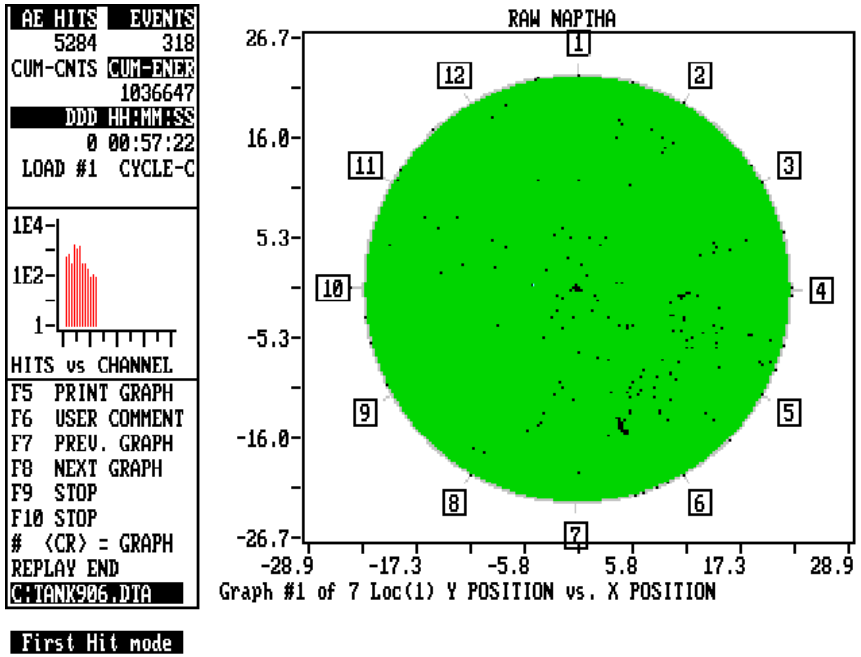
III – Active damage re-test in max.1 year*.

IV– Very active damage. Re-test in 0.5 year*.

* or schedule for internal inspection

Naptha Tank: ‘E’ before repair; ‘A’ after Repair





GRADE A B C D E

" ALL DATA " TANK PLOT

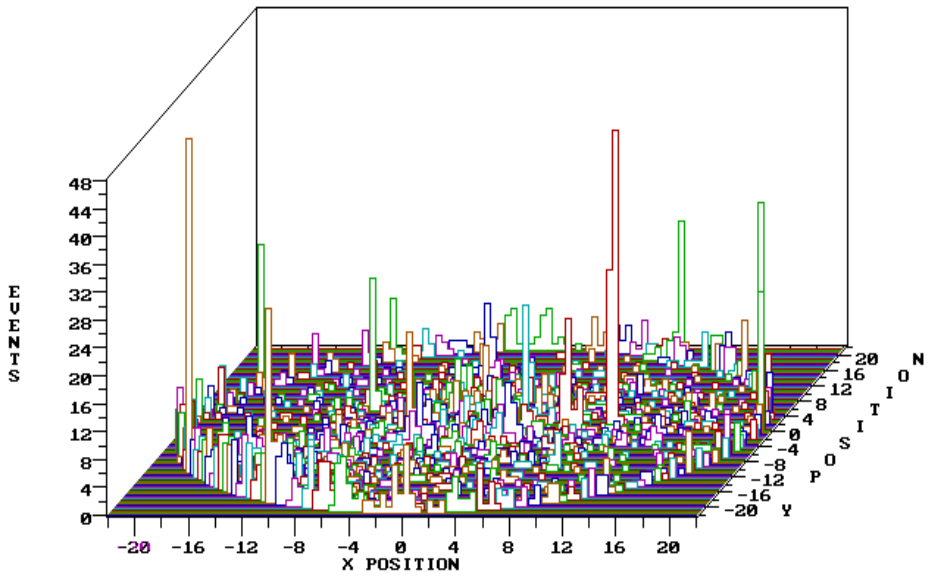
OAL = 24%

GRADE A B C D E

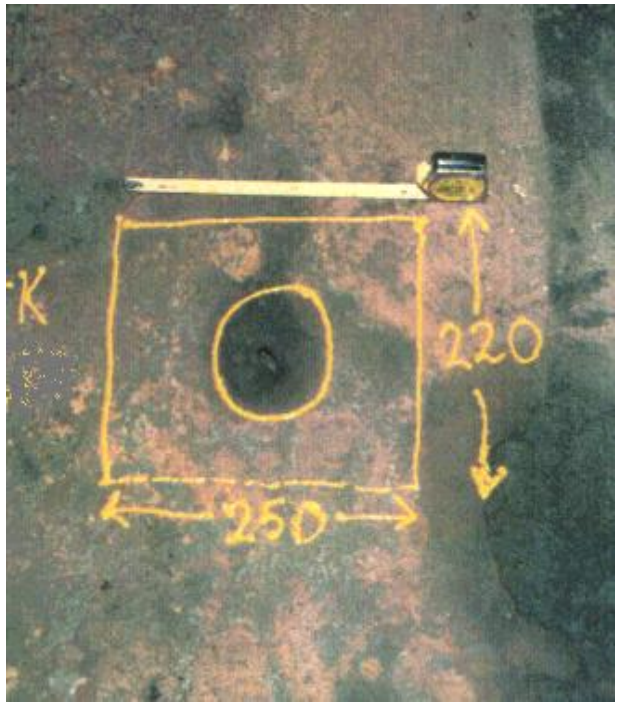
" ALL DATA " TANK PLOT

OAL = 18.1%

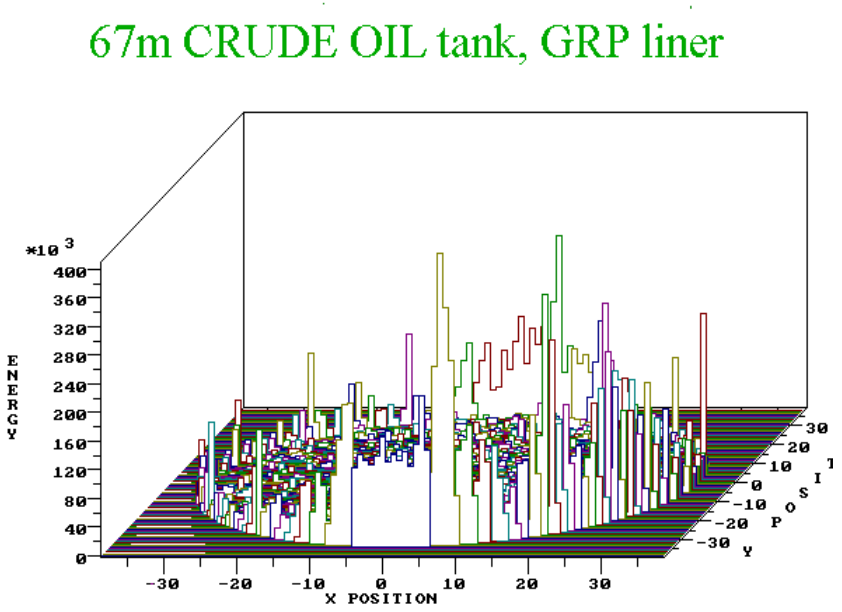
‘E’ Grade 3D View – Damage Found

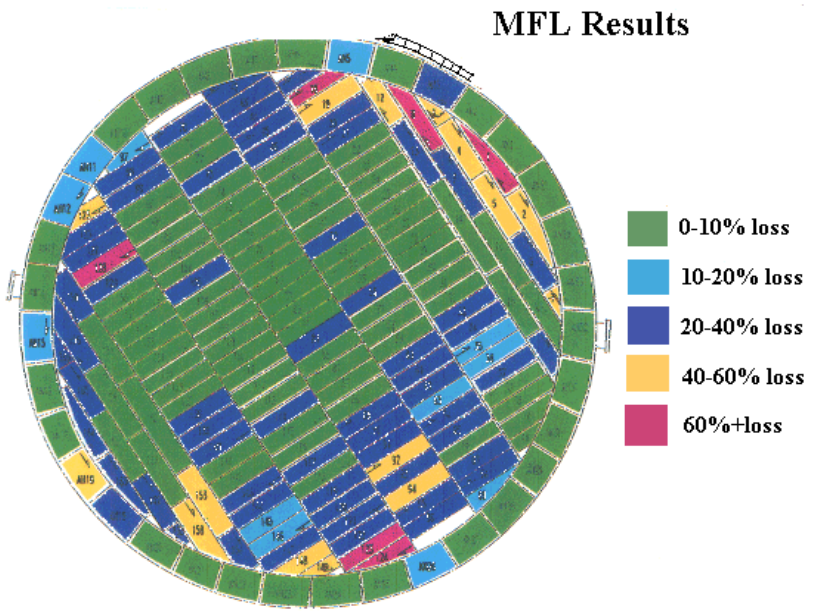


CRUDE OIL



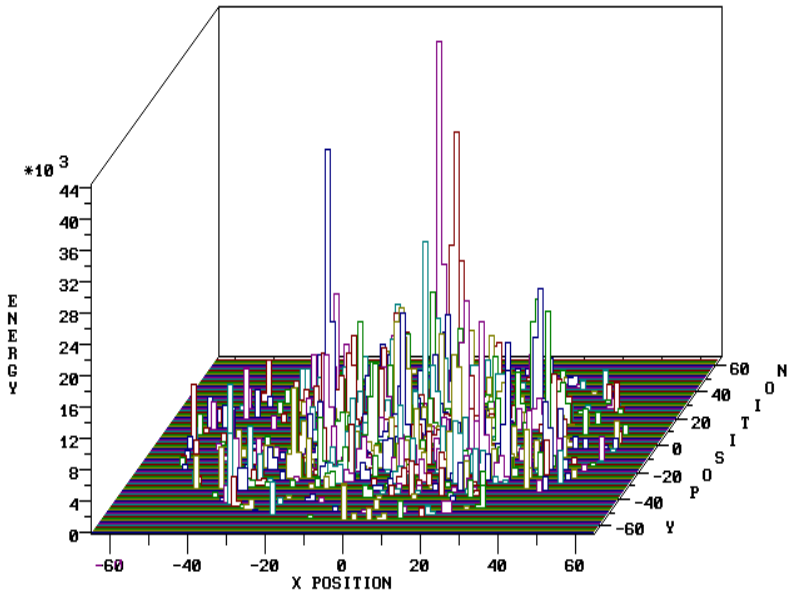
67m Crude tank with GRP Liner – AE vs MFL

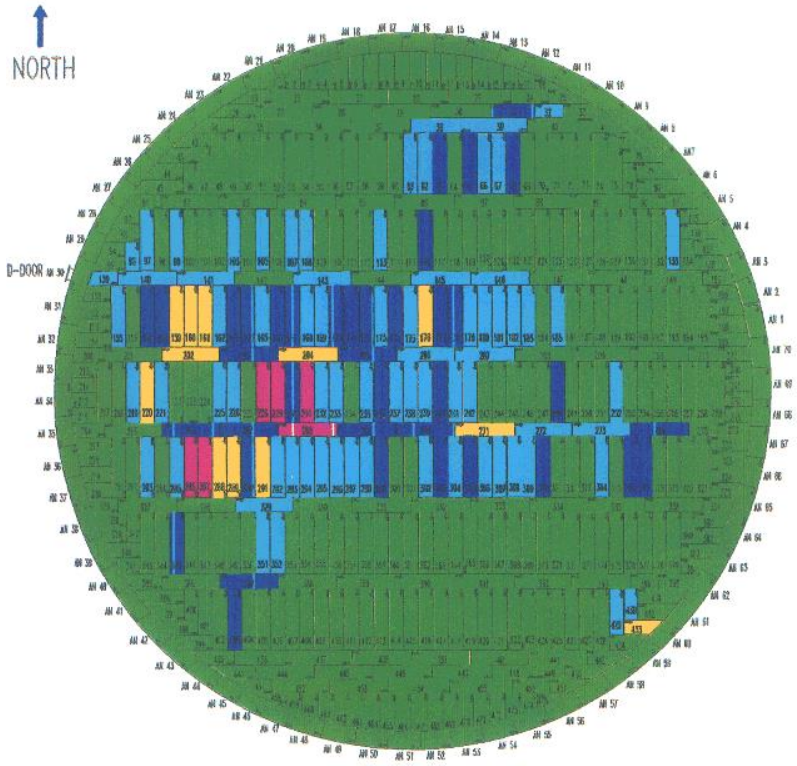




Underside corrosion observed

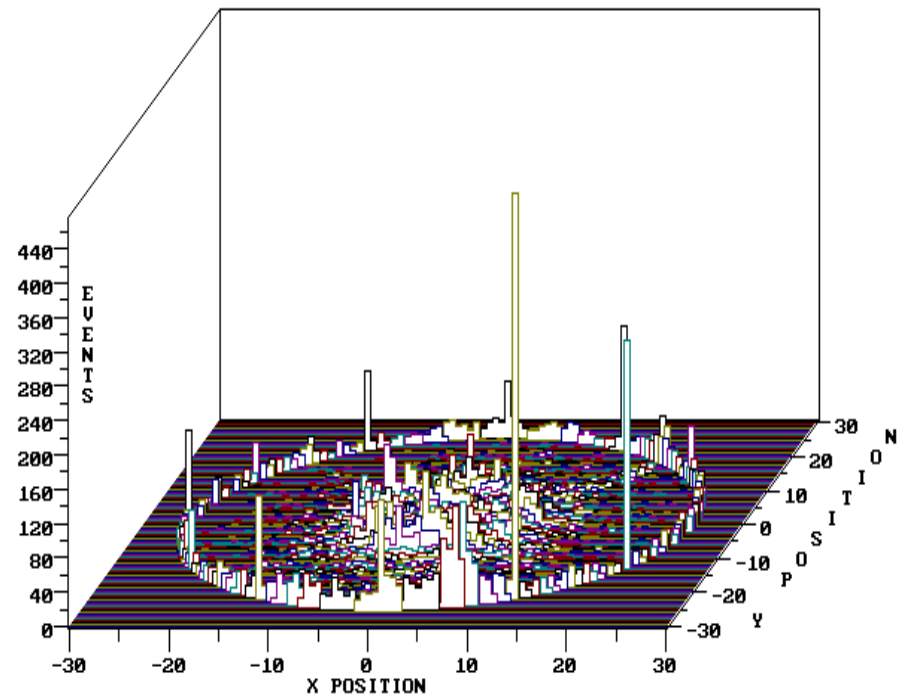
110m Crude Tank – MFL vs AE





50m Hot Fuel Oil Tank

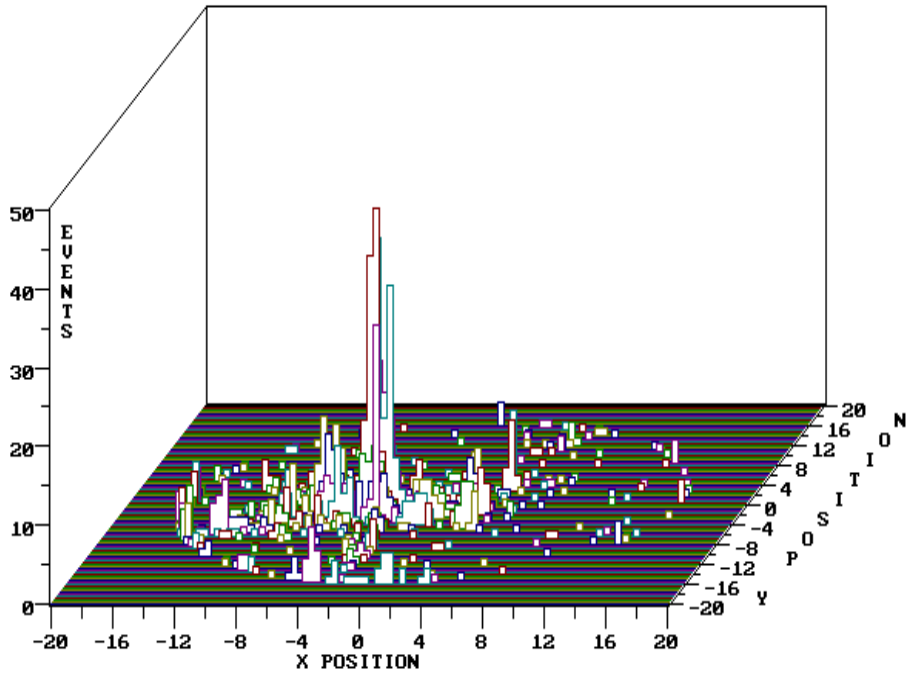
- “E” grade overall.
- Annular ring very active.
- Dug underneath annular ring in most active areas:
- Up to 8mm loss of metal on 15mm annular plates
- Tank shut down immediately, avoiding failure.



3D LOCATION FOR "ALL DATA"

Leaking Naptha Tank

- 100 cu.m/day loss
- No visible indication of a leak
- Faint smell only
- TANKPAC test at 2% sensitivity due to noise-2 mins. only:
- 1cm hole found at location shown



Limitations

- Detects and grades active corrosion only.
- Not suitable for assessing the internal condition of tanks which are cleaned mechanically or chemically as this “resets” the condition, (underside OK). Use history!!
- Small leaks may be masked by active floor corrosion.
- Large leaks will mask overall floor condition.
- Activity from active corrosion under insulation may mask floor condition.
- Location may be unreliable on very active D/E tanks due to simultaneous sources, (the tank needs opening anyway!).
- Not all tanks can be tested, due to noise/condensation etc.
- Complex procedure requires extensive training + control.

Quality Control and Training

- Documentary quality control system under ISO 9001:2008:
  - Trained and certified engineers.
  - Controlled TANKPAC procedures.
  - Controlled TANKPAC Field worksheets.
  - Quality plan for each test.
  - Digital storage of data and full traceability.
- Engineer training and certification:
  - ASNT II general AE
  - TANKPAC procedure class and field training.
  - TANKPAC written and practical examination.
  - TANKPAC minimum experience requirement (~50 tanks).
- Level II/III review of and approval of report.

TankPAC Strategy

- TANKPAC™ is a maintenance planning tool.
- Use TANKPAC™ to help identify the tanks which require inspection and repair, and leave others in-service until their condition indicates action is required.
- Use TANKPAC™ results to set the maintenance priority, and optimise use of maintenance resources.
- TANKPAC™ fits perfectly into an RBI program (risk based inspection), bringing significant cost reductions.

Example Test Locations

- **Europe**
  - UK, Netherlands, Germany, France, Italy, Spain, Ireland, Russia, Greece, Czech Republic, Belgium
- **Middle East**:
  - Saudi Arabia, Kuwait, Oman, UAE, Qatar
- **Africa:**
  - South Africa, Gabon, Ivory Coast, Mozambique
- **South America:**
  - Brazil, Argentina
- **Asia and Far East:**
  - India, Japan, Malaysia, Singapore, Indonesia, Australia, New Zealand
- **North America:**
  - USA

AE Demonstation

Other AE Applications

Valve Leakage

U&D UNDERHÅLL & Driftsäkerhet Nov 97

Shell Refinery AB, Gothenburg

Acoustic measuring a new effective method of valve leak detection

In the fall of 1996, a new acoustic method of valve leak detection was introduced in Sweden, developed by an English company in cooperation with British Petroleum. One company that obtained the instrument that same fall was Shell's refinery in Gothenburg, Sweden. It has been of great use there, saving a lot of money by allowing leaks that once could not be tracked effectively to be discovered and attended to.

By Alf Ohlsson

INDUSTRIAL focus

Kwinana refinery leads way in cutting emissions

by SONIA FACCIN
KIC Community Relations Advisory Committee

EMISSIONS at the BP Kwinana Refinery have been significantly reduced through a campaign focussed on

BP Kwinana Refinery hydrocarbon loss coordinator Brian King.

M48 Severn Bridge

- Continuously monitoring of Severn Suspension bridge main cable for wire break
- 90 sensors, 6 distributed AE systems in deck and base station
- PAL prime contractor working under CDM
- Full system and sensor installation using rope access and MEWP’s for sensor installation
- Automated website reporting
- 5 year maintenance and reporting contract

Concrete Bridge Testing

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Delays on M5 near Exeter due to emergency repairs

23 December 2022

Work on the Exe viaduct means one lane will be closed on the M5

Drivers heading southbound on the M5 near Exeter on Friday have been warned to expect delays due to a lane closure.

The closure - lane one of three - is in place on the southbound motorway between junctions 30 and 31.

National Highways said the lane closure was required for emergency repair work to be carried out on the Exe viaduct, which carries the M5 over the river Exe.

The lane closure is expected to be in place until Saturday morning.

National Highways said Friday was expected to be busy due to traffic heading into Devon and Cornwall for Christmas, so drivers are advised to plan ahead and leave extra time.

Top Stories

Urgent search for baby as couple arrested
41 minutes ago

Trans rapist Isla Bryson jailed for eight years
18 minutes ago

LIVE Deal not about any party, says Sunak, as he visits Northern Ireland
8 hours ago

Features

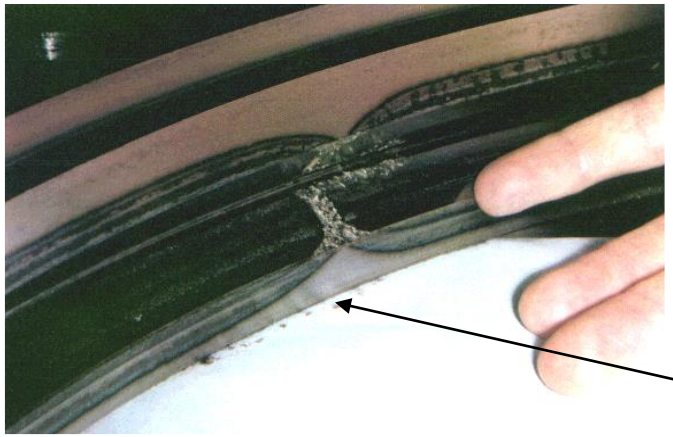
When are teachers striking, and what are they paid?

'I'd send 50 messages a day to try to convert people'

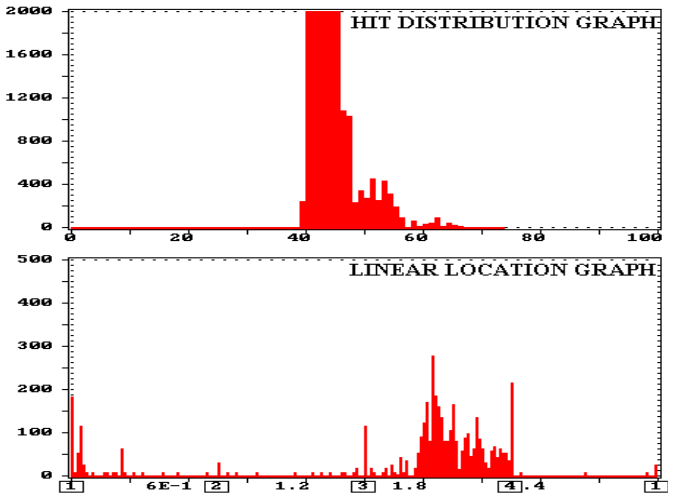
Low Speed Bearings

- Vibration signature difficult to identify due to due to low speed and high background noise.
- AE identifies:
  - Crushing of corrosion/debris.
  - Cracking and Fretting.
  - Lack of lubrication.

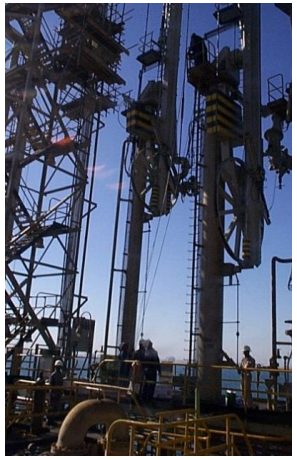
- Method:
  - Periodic AEM during normal oper
  - AE classification cf database.
  - Multiple sensors gives location.
  - Time series analysis gives fault diagnosis.



Location of damage around a 60 rpm radar bearing (3 sensors).



Low Speed Bearings



Usage:

- Radar aerial bearings
- Steel industry
- Jetty cranes and loading arms
- Bridges
- Ship Propulsion

Bearing grading based on:

Location
AE activity
Peak Signal Amplitudes
Energy release rate
Average signal level

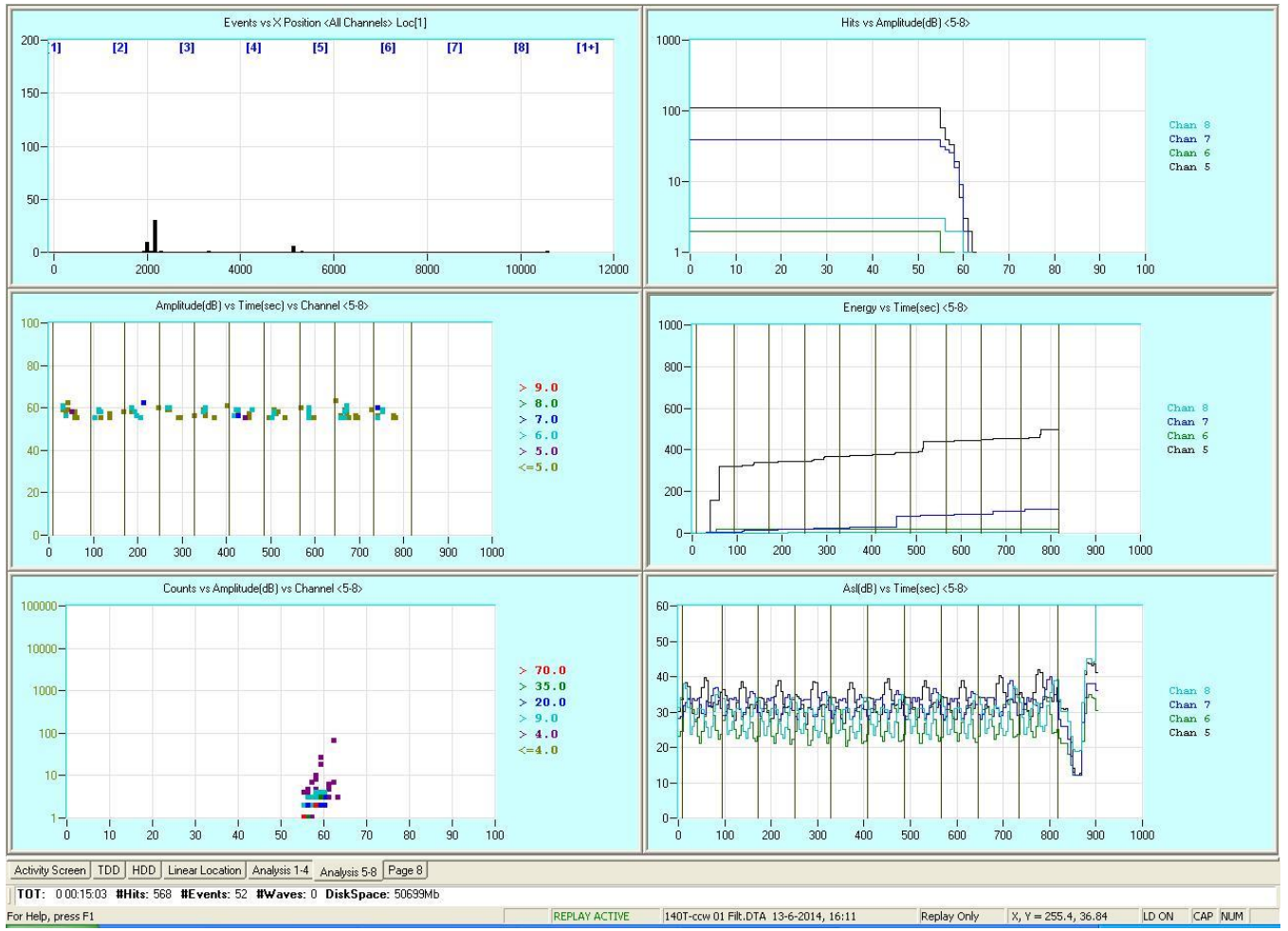
A – No activity

B – Minor activity

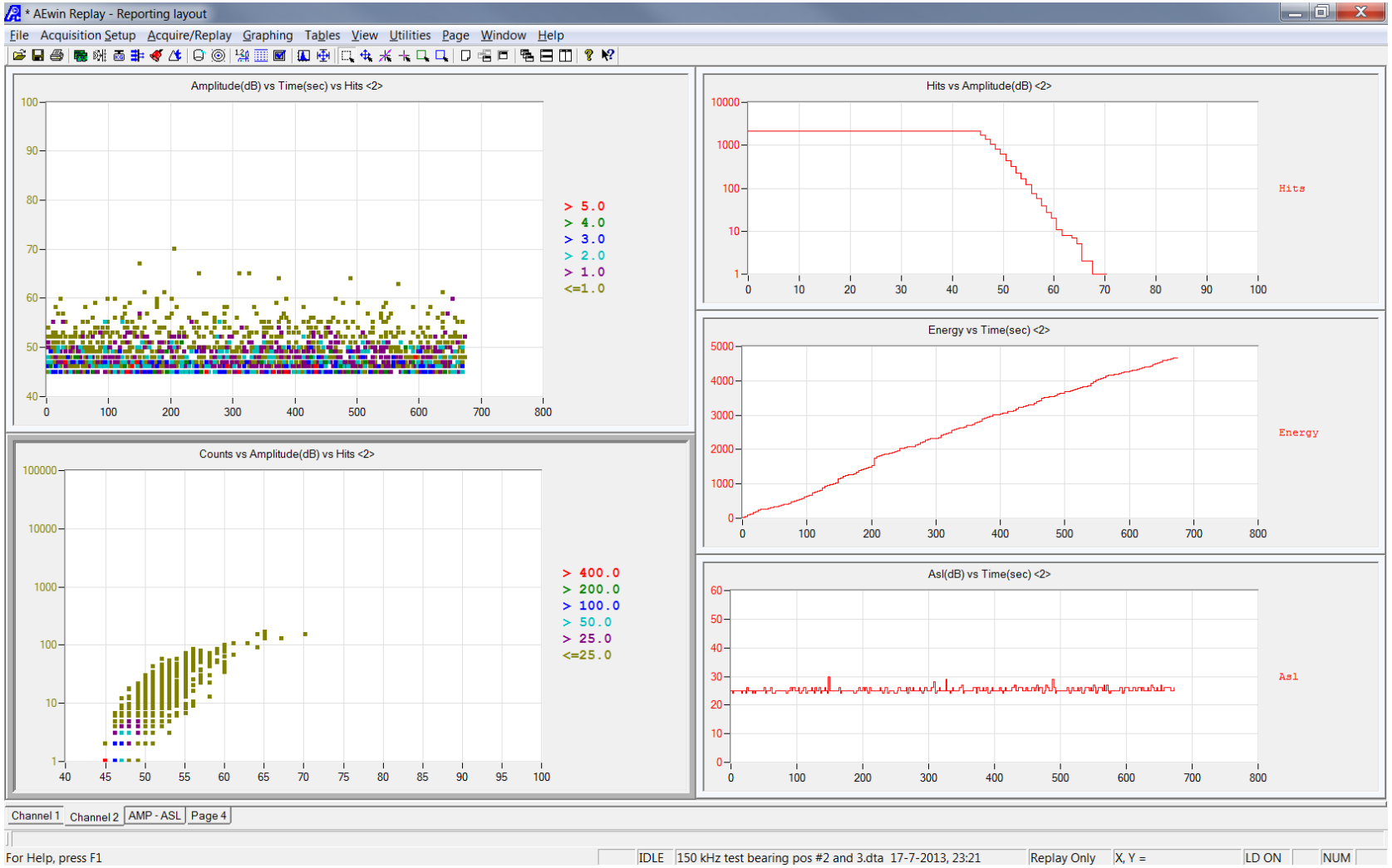
C – Intermediate activity

D – High activity

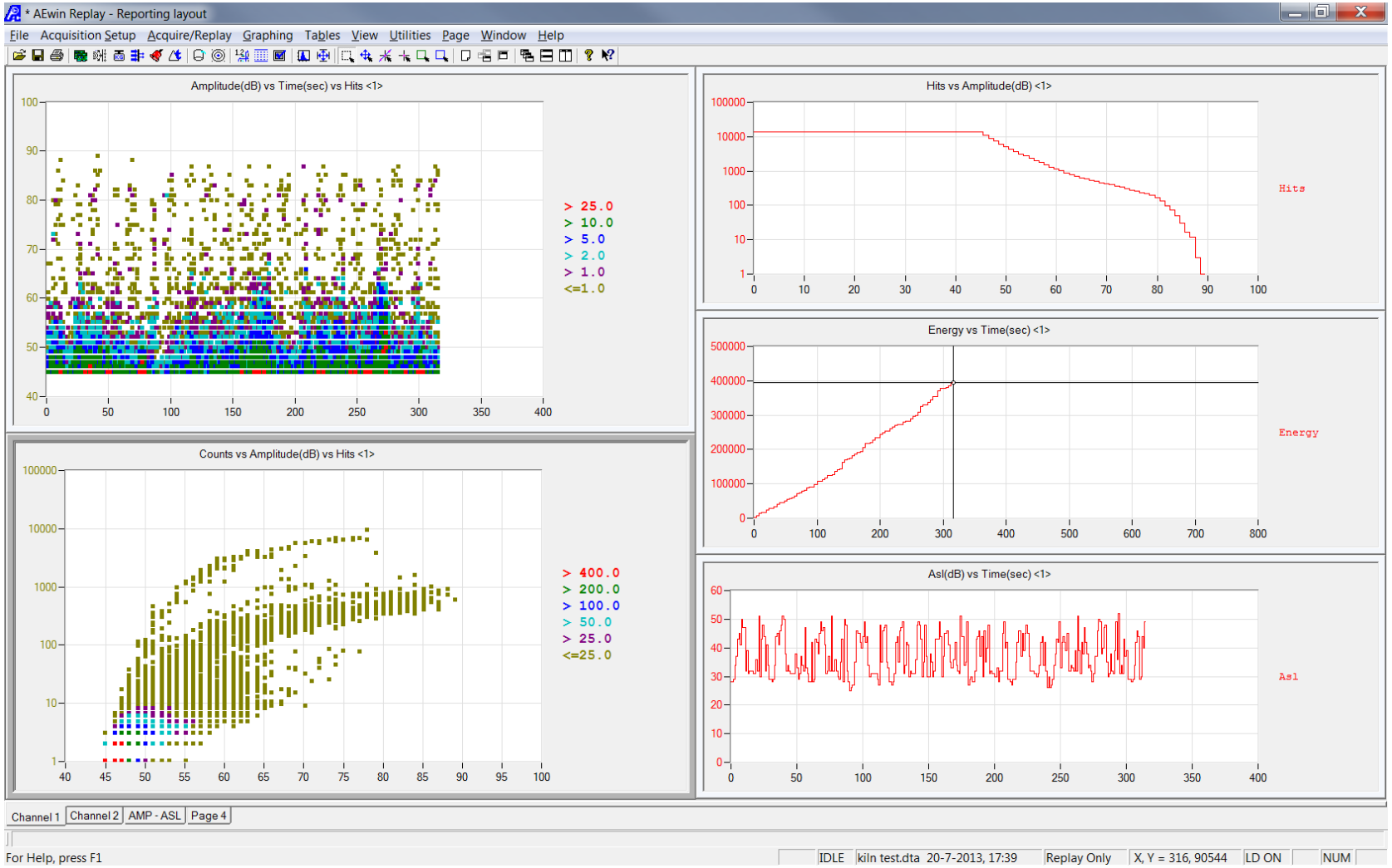
E – Intense activity



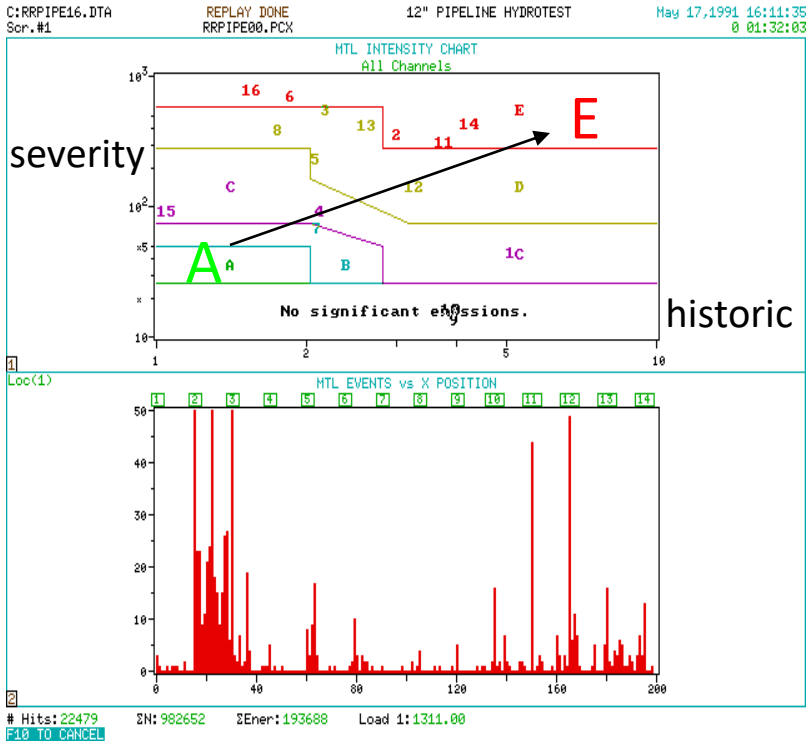
Bearing A – 2 RPM, C Grade



Bearing B – 2 RPM, E Grade



- Code: MONPAC (proprietary)
  - ASME VIII, Sect. 5, art. 12
- Acceptance: worldwide IPSG
  - Oil/chemical industry.
- Usage: Since ~ 1983
- Method:
  - AE on-line or static.
  - A-E evaluation.
  - Used in RBI programs.



- MONPAC acoustic emission test on-line indicated major structural defects, sphere removed from service.
- Follow-up ultrasonics found serious cracks: one 54” long, one 25” long, plus numerous other indications.
- Vessel “passed” hydro-test requirements with these defects present!!!! Hydro-test alone is not sufficient for re-qualification…….

Blast Furnace Monitoring

- Acoustic Emission monitoring carried out
- Three furnaces graded as follows;

C – Source found requiring further evaluation

D - Active sources requiring follow-up local inspection

E - Intense sources immediate action required

Blast Furnace Monitoring

Acoustic Emission result on May 2001
Grade D, C and E as below

Condition on March 2002

News in Brazilian paper: Accident shut down the furnace

folha online | dinheiro online

Notícias
Brasil
Mundo
Dinheiro
Cotidiano
Esporte
Ilustrada
Informática
Ciência
Educação
Em cima da hora
Galeria de imagens
Serviços
Manchetes do dia

25/03/2002 - 17h20

Acidente pára alto-forno da Açominas e causa prejuízos

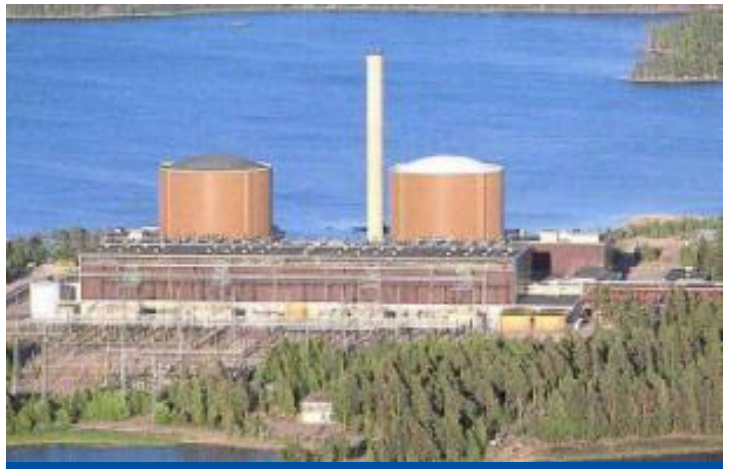
da **Folha Online**

A unidade da Açominas registrou um acidente no último sábado na usina em Ouro Branco (MG), afetando um dos três regeneradores do alto-forno, informou há pouco a Gerdau, controladora.

"O episódio nao envolveu pessoas restringindo-se apenas a danos materiais. Com base em uma avaliação preliminar dos danos causados e o impacto na operacão, estima-se que a retomada do funcionamento do alto-forno, mesmo que parcial, ocorra nos próximos dias", diz a Gerdau.

Continuous Monitoring

Methanol Converter, continuous monitoring since 1998



Nuclear power plant eight primary exchangers-since 2005

Fourteen Heat Exchangers

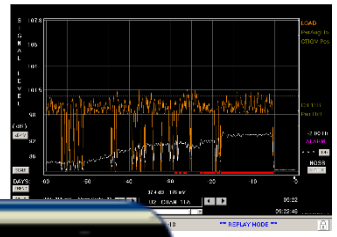
FPSO, eight critical areas, AE, strain, monitored since January 2001

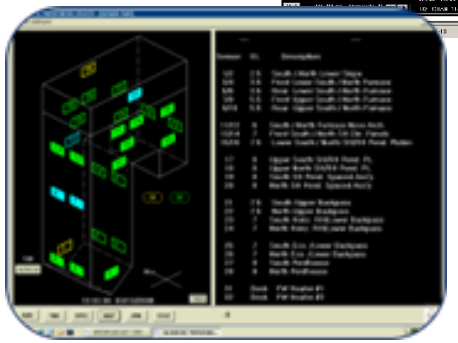
Platformer, shutdown monitoring and on-line for 12 months

Valve and airborne leak detection

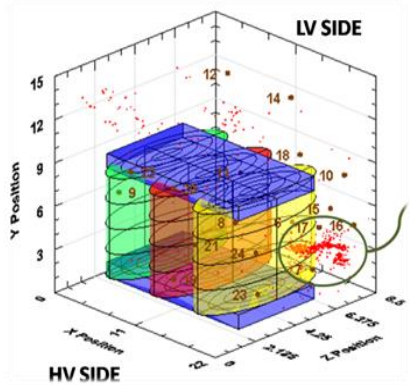
Online Monitoring (OLM)

Boiler Tube Monitoring

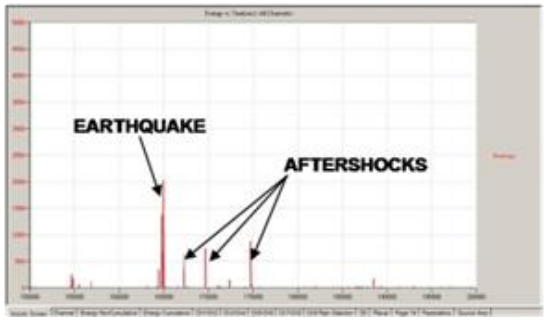




Transformer Monitoring



Bridge Monitoring



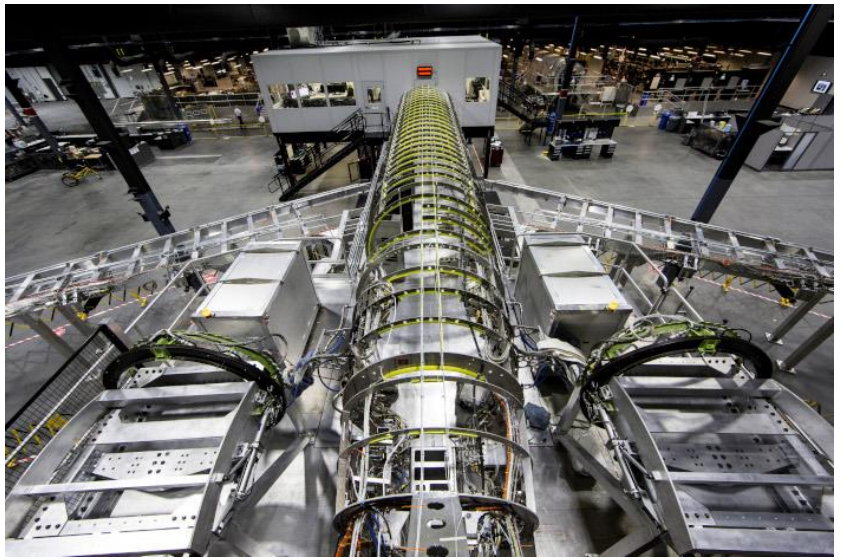
Online web-based monitoring during an earthquake

Pressure Vessel Monitoring

Other Applications

“Be Not Afeared; the isle is full of Noises,”

-William Shakespeare, The Tempest



Dr Ryan Marks CEng MIMechE

Ryan.Marks@mistrasgroup.com

mistrasgroup.com