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Coke Drum Workshop and Safety Seminar

Using Acoustic Emission Testing to inspect Coke Drums

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Rio de Janeiro, Brasil

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STRESS ENGINEERING SERVICES INC.

Objectives

Present basic principles and applications of acoustic emission testing (AET) when used to help assess the reliability and structural integrity of coke drums and overhead vapor piping components, while in service, out of service, and during fabrication.

- Acoustic emission testing handbook
- www.asnt.org

Chapter 4 is dedicated to AE testing of Coke Drums.

Why don’t we start with definitions ?

- Reliability….
- Acoustic emission testing….

What is Reliability?

- "*Reliability is defined as the probability of an item to perform a required function under specified conditions for a certain period of time*."

From University of Maryland Web Site

Acoustic Emission (AE) is…

ASTM E 610

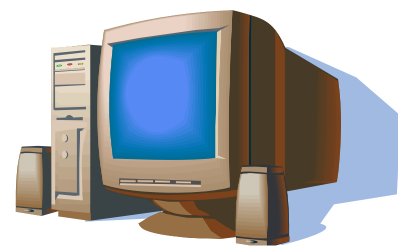
…the class of phenomena whereby transient elastic waves are generated by rapid release of energy from localized sources within a material, or the transient elastic waves so generated.

ASNT

…the elastic energy that is ***spontaneously*** released by materials when they undergo deformation.

How does AET work?

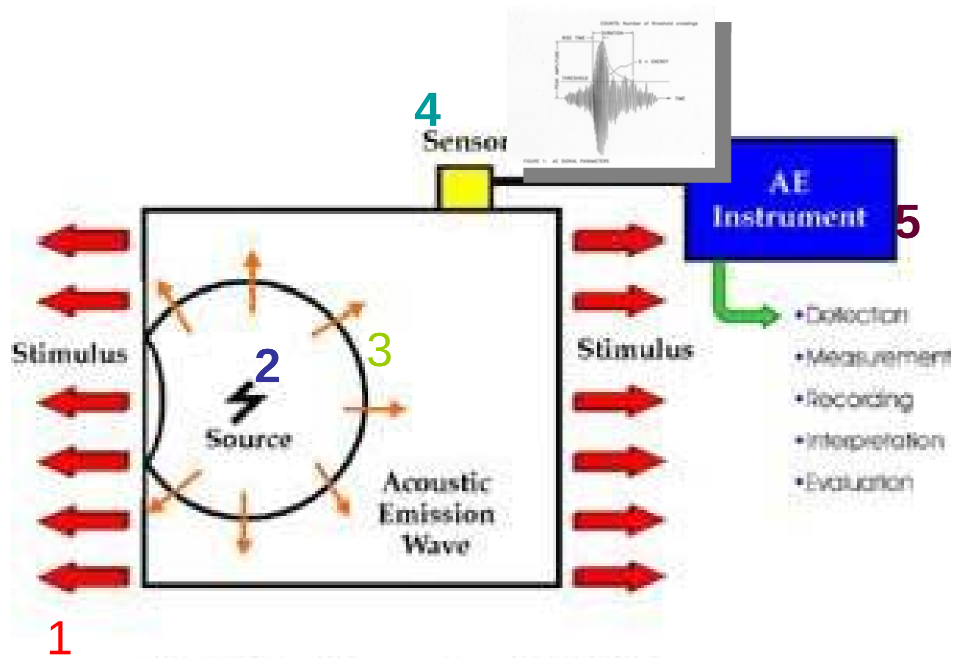
Principles
Description
Instrumentation
Advantages
Limitations
Standards



Measurement Chain

1. **Stimuli** – Global Source of energy, often mechanical load; other examples: thermal gradient, Hoop stress, etc.
2. **AE Source** – localized stress release
3. **Wave Propagation** – dynamic response of structure to AE source
4. **AE Sensor** – conversion of mechanical wave to voltage
5. **Signal Processing** –
   - Preamplifier
   - Main/System Amplifier
   - Amplification and Filtering Functions

Acoustic Emission (AE) Process



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

(Excerpted from ASTM E610-82)

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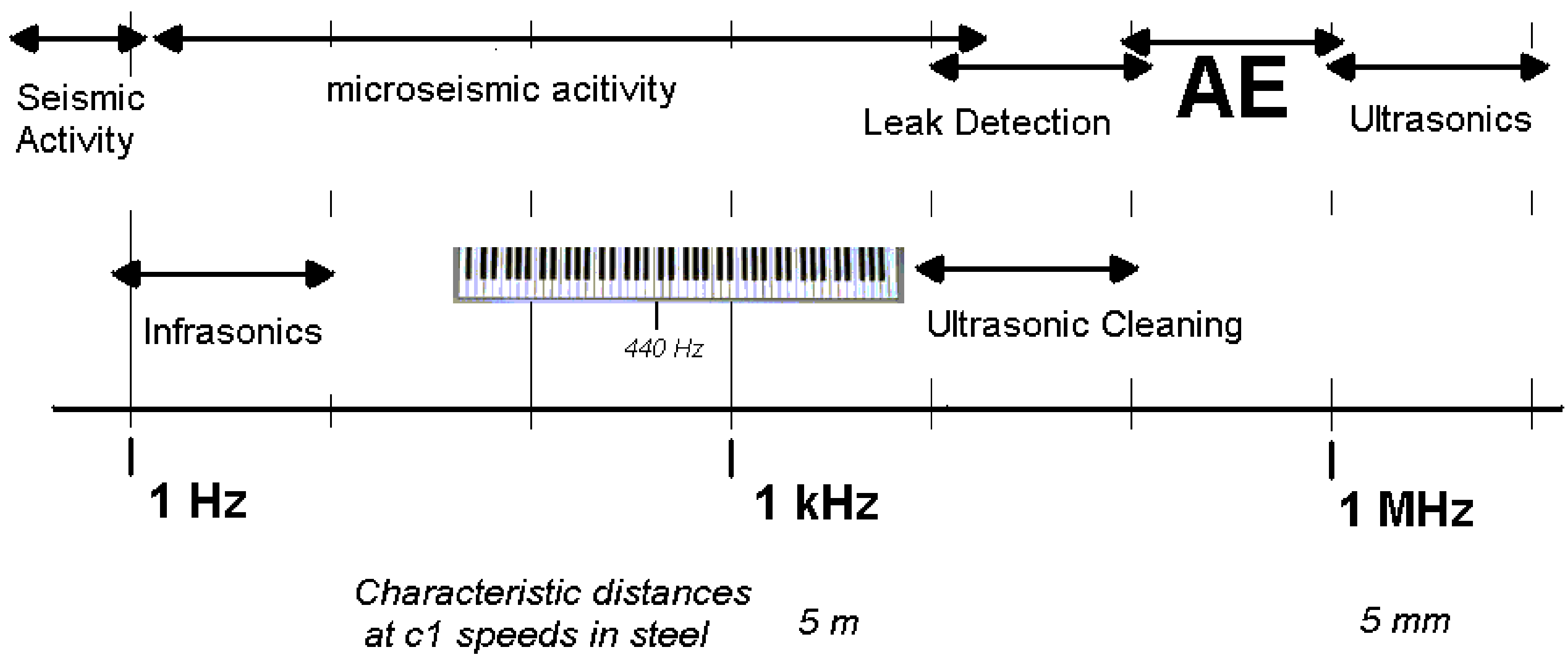
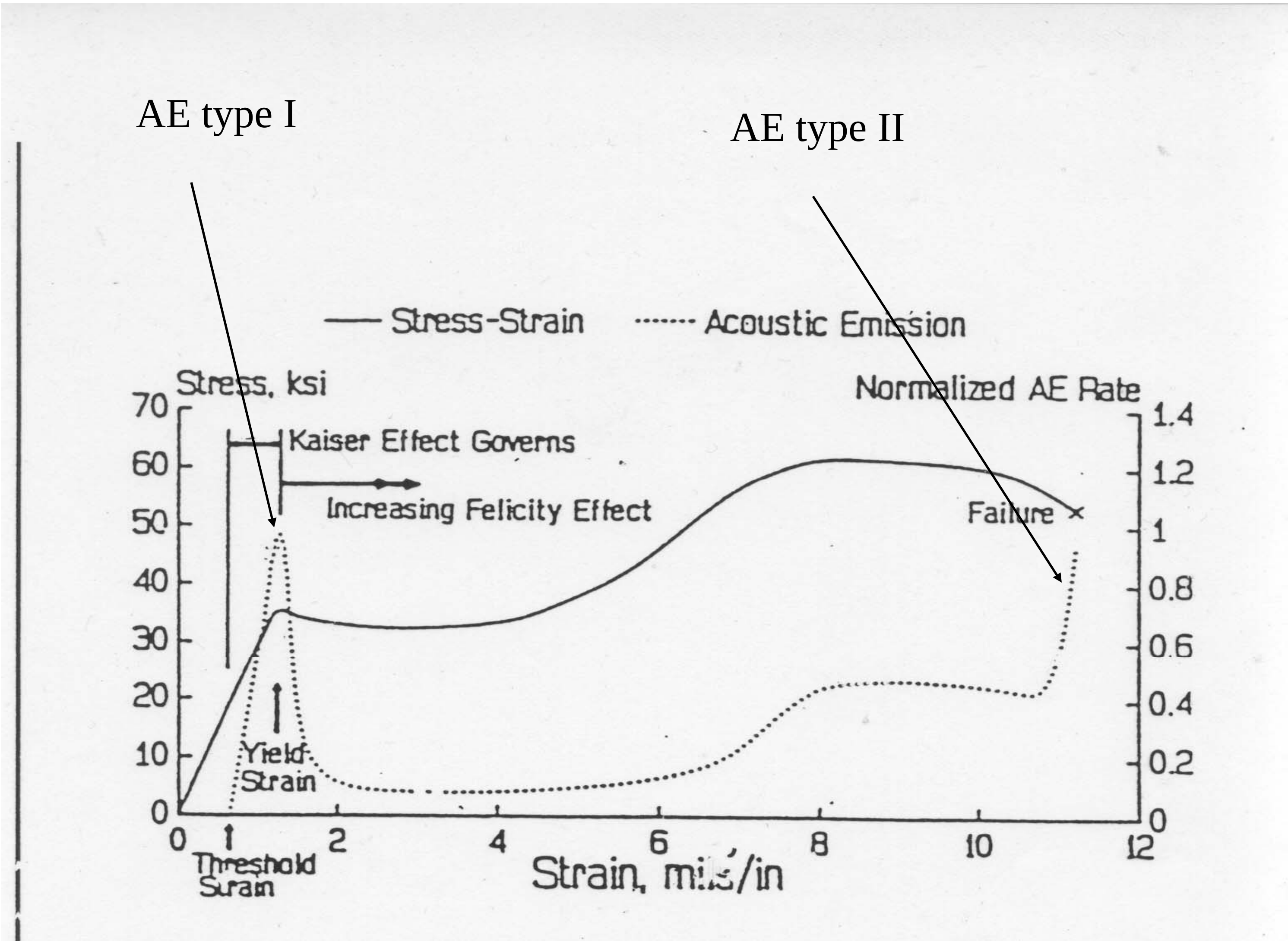
Frequency Regimes



AE principles

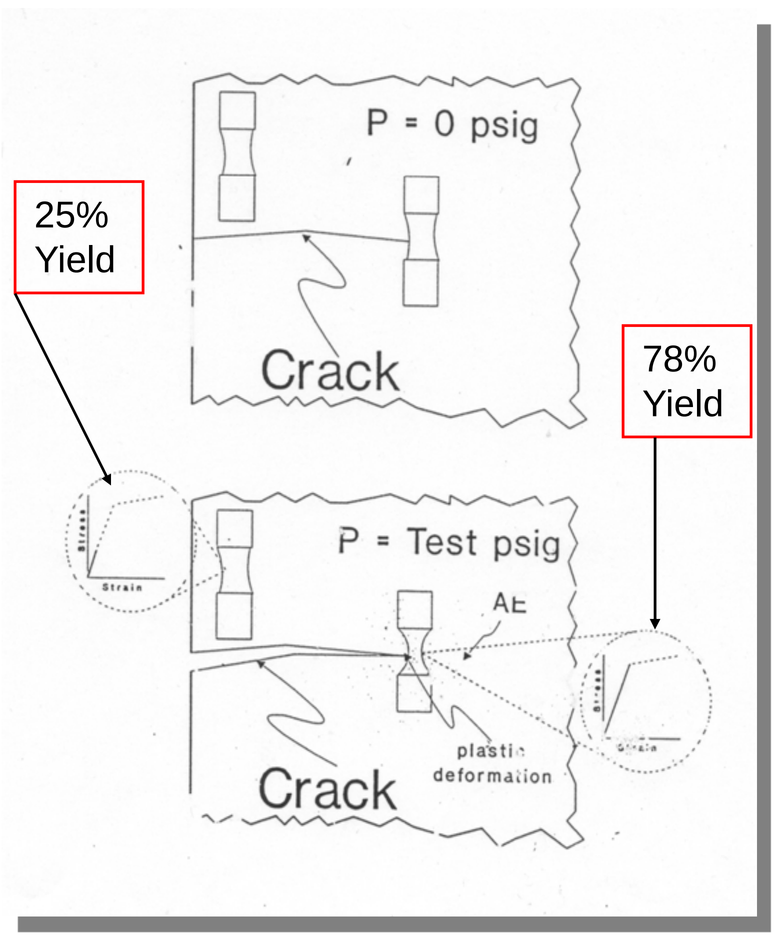
There are primarily 2 types of AE from "flawed" metals:

- AE type I – Associated with plastic deformation (yielding) near stress risers
- AE type II – Associated with actual damage progression/crack propagation


AE type I
AE type II
Stress-Strain
Acoustic Emission
Stress, ksi
Normalized AE Rate
Kaiser Effect Governs
Increasing Felicity Effect
Failure
Yield Strain
Threshold Strain
Strain, mils/in
70
60
50
40
30
20
10
0
2
4
6
8
10
12
1.4
1.2
1
0.8
0.6
0.4
0.2

- Type I AE is used as a global screening of components, using pressure or thermal gradients to find stress risers/cracks by imposing a level of stress slightly above normal stress levels.
- Example: In-service over-pressurization of a column or reactor to 110% of maximum operating pressure over last 12 months.

AE type I comes from elastic deformation/yielding !



No load = No AET signals

Under load + crack free Material = NO AET signals

Under load + cracked Material = AET signals

- Type II AE is used to monitor and/or detect unknown/existing crack-like flaws in components, which cannot be easily overstressed. AE signals come from actual damage progression or crack propagation.
- Example: On-line monitoring of coke drums for thermally induced fatigue cracks.

AE type II…comes from crack propagation !

Thermally induced fatigue crack in circ. weld of a coke drum

Don’t need AE to find that…

…but crack had been growing for a while.

Advantages of AET

- Inspect 100% of the coke drum (global inspection)
- Detect growing cracks, significant to the drum's structural integrity
- Can be applied in-service
- No need to remove insulation
- Wide temperature range (Cryogenic to High temperature)
- Recognized by several standards
- Compliance with local, state & federal regulations
- Significant savings by avoiding vessel entry
- Repeatability / Kaiser Effect

Limitations of AET

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- res
- The mor
- 5 %
- In the , ..
- //!
-
-
-

OK, ...limitations of AET

- Requires experienced and skilled operator
- Qualitative results (can't size defects)
- Fairly complex and expensive hardware/software
- Needs access to circ. Welds via scaffolding or rope
- Requires client/user to be well educated in topic

(that's why I am here....)

- Can't find inactive flaws or old cracks. Only active ones.

AET Instrumentation

304 Stainless Steel waveguide
and 150kHz sensor

Vallen Digital System
TÜF Certified

Four drums
Covered with
56 AET
probes
each

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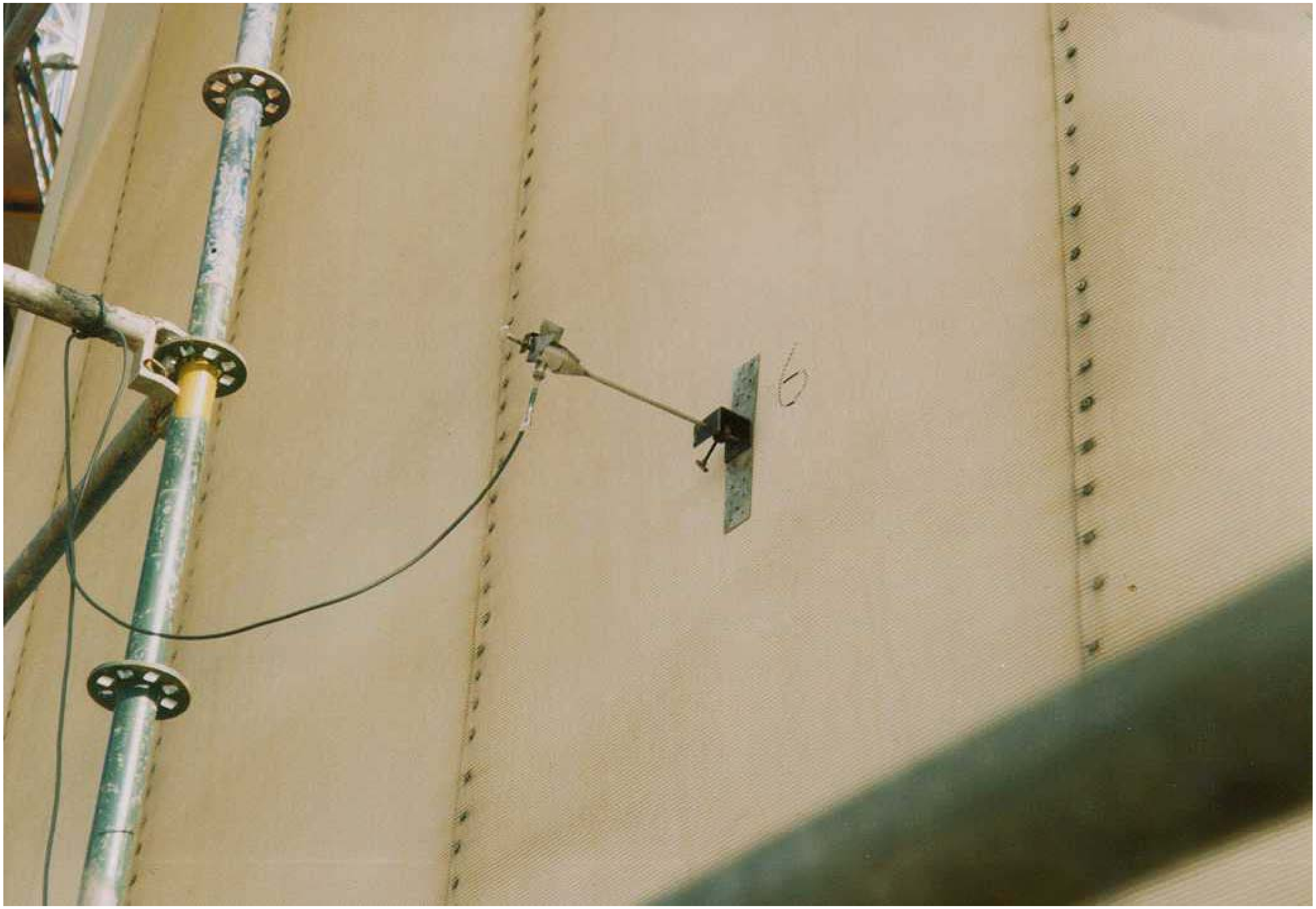
Use of waveguide avoids damaging of transducers.
Loss of 8dB at contact point is known and compensated for



AET applied to coke drums

- **During acceptance code hydrostatic pressurization**
- **During On-line monitoring**

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Section II

Our experience with Acoustic Emission inspection during acceptance hydrotest of new coke drums

- Sumitomo Japan: Four (two 3%Cr) new drums for Citgo Refinery
- JSW Japan: Four 2¼ Cr 1Mo new drums for Citgo Refinery
- Lyondell-Citgo Refinery: Four new CS drums for LCR

Why AET during initial hydrotest?

- To detect fabrication discontinuities, which are acceptable by Code, but are “active” at stress levels above Code Hoop Stresses.
- These are the flaws, which will eventually initiate and grow thermal fatigue cracks.
- This is the best time to repair fabrication discontinuities, and get drum Code Stamped by A.I.

Code AE hydrotest of new coke drums - 1st 3% Cr shell

(Code Max. Press. Modified to reach past 1 ½ Design to find smallest defect possible)

AET results

- From all Japanese built coke drums I have personally inspected via AET during hydro (8)@ 2.5 x design pressure, only one fabrication flaw detected and confirmed (repaired) on 1 drum.

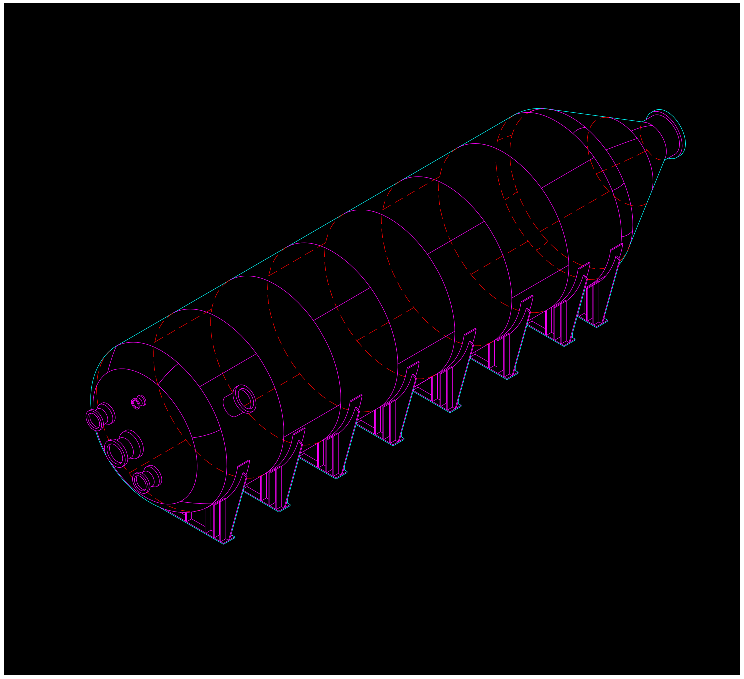
- From all non-Japanese built coke drums I have personally inspected via AET during normal 1.5 design pressure hydro (10), they averaged 23 fabrication flaws detected and confirmed (not all repaired).

AET results

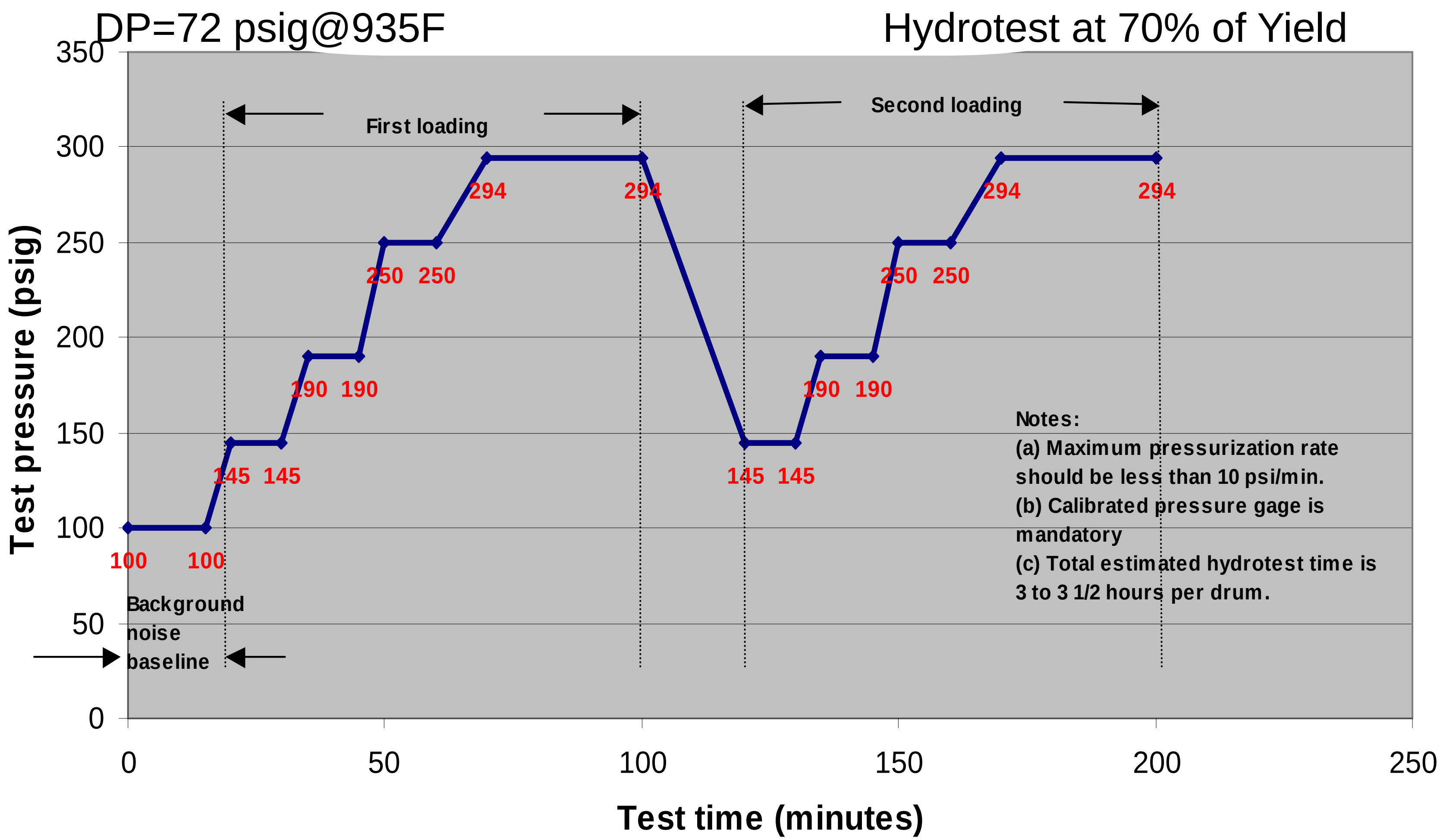
Sumitomo UT inspectors checking AET indication

Team from Sumitomo, and Citgo Petroleum

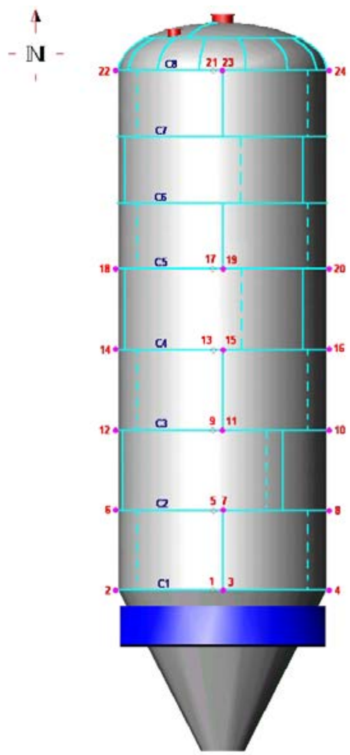
Code AE hydrotest of new coke drums – SES' designed skirt attachment for JSW built drums for Citgo Petroleum



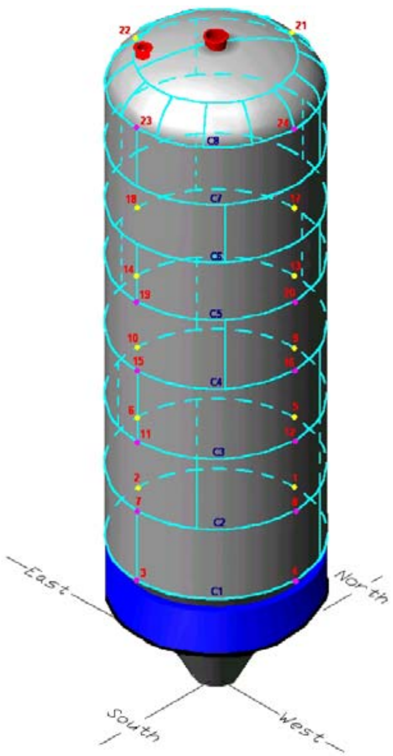
Hydrostatic pressurization sequence for Acoustic Emission monitoring of coke drums 326F201A/B and 326F202A/B at JSW's facilities in Muroran, Japan. Modified from ASME Div.1 code.



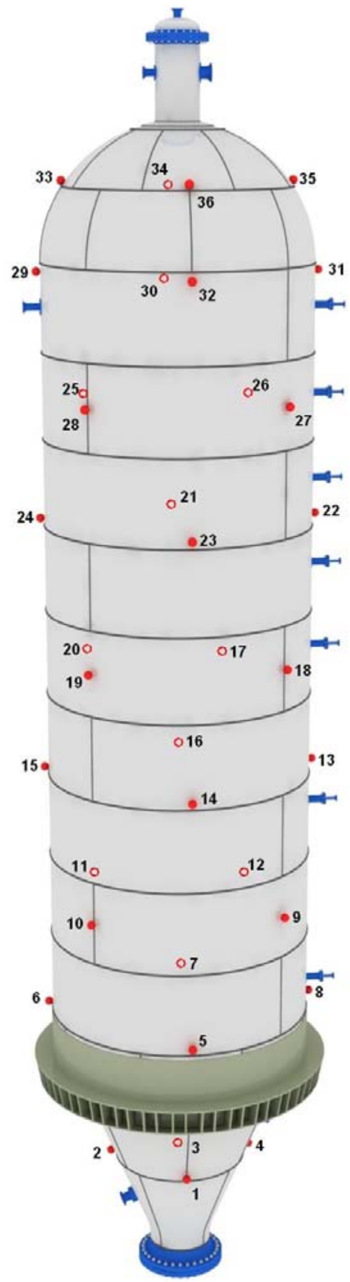
Section III
In-service monitoring of coke drums



Vista Frontal



Vista em Perpectiva



Typical AE transducer distribution

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How do they fail…

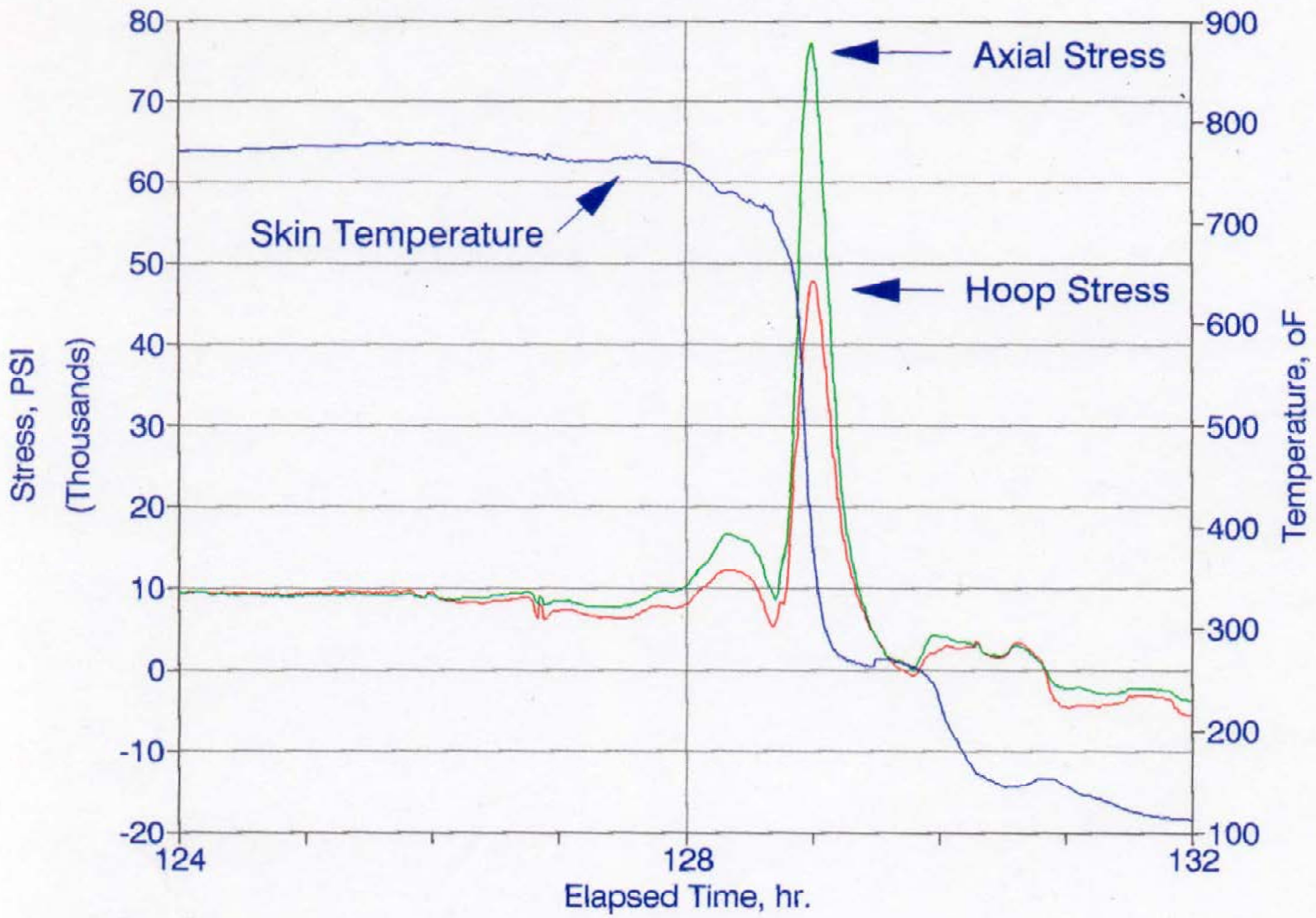
- Thermally induced fatigue mechanism
- Designed as Div.1 vessels, without fatigue considerations
- Costly S/D if through-wall cracks develop
- AE used to map cracks, often with SG's and TC's.

Sample of our experience with Coke Drums

In-Service Acoustic Emission/TC/Inspection

- Petrobras – Brazil, Cubatao, Sao Paulo : 4 drums, 1985
- Petrocanada – Edmonton, Canada: 2 drums, 1988
- Arco Los Angeles: 4 drums, 1990
- Frontier Refinery: 2 drums 1990
- Chevron El Segundo: 6 drums, 1994
- Amoco Whiting: 4 drums, 1994
- Citgo Lake Charles: 4 drums (Coker I), 1990
- Citgo Lake Charles: 4 drums (Coker II), 1995
- Citgo Corpus Christi: 4 drums, 1993
- Lyondell-Citgo Refinery, TX: 4 drums (Coker I), 1995
- Lyondell-Citgo refinery, TX: 4 drums (Coker II), 1996
- Conoco Ponca City: 2 drums 1998
- Conoco Lake Charles: 2 drums 1999
- Chevron El Segundo, CA: 2 drums 2002
- Exxon-Mobil Beaumont, TX: 1 drum 2003
- Valero Refinery, LA: 4 drums 2004
- Suncor, FMM – AB- 4 drums 2005
- PDVSa Venezuela – 4 Coke overhead systems 2006
- ENAP Chile 2 Coke drums 2007
- Petrobrazi – Romania 2 Coke drums 2008

Why drums crack?



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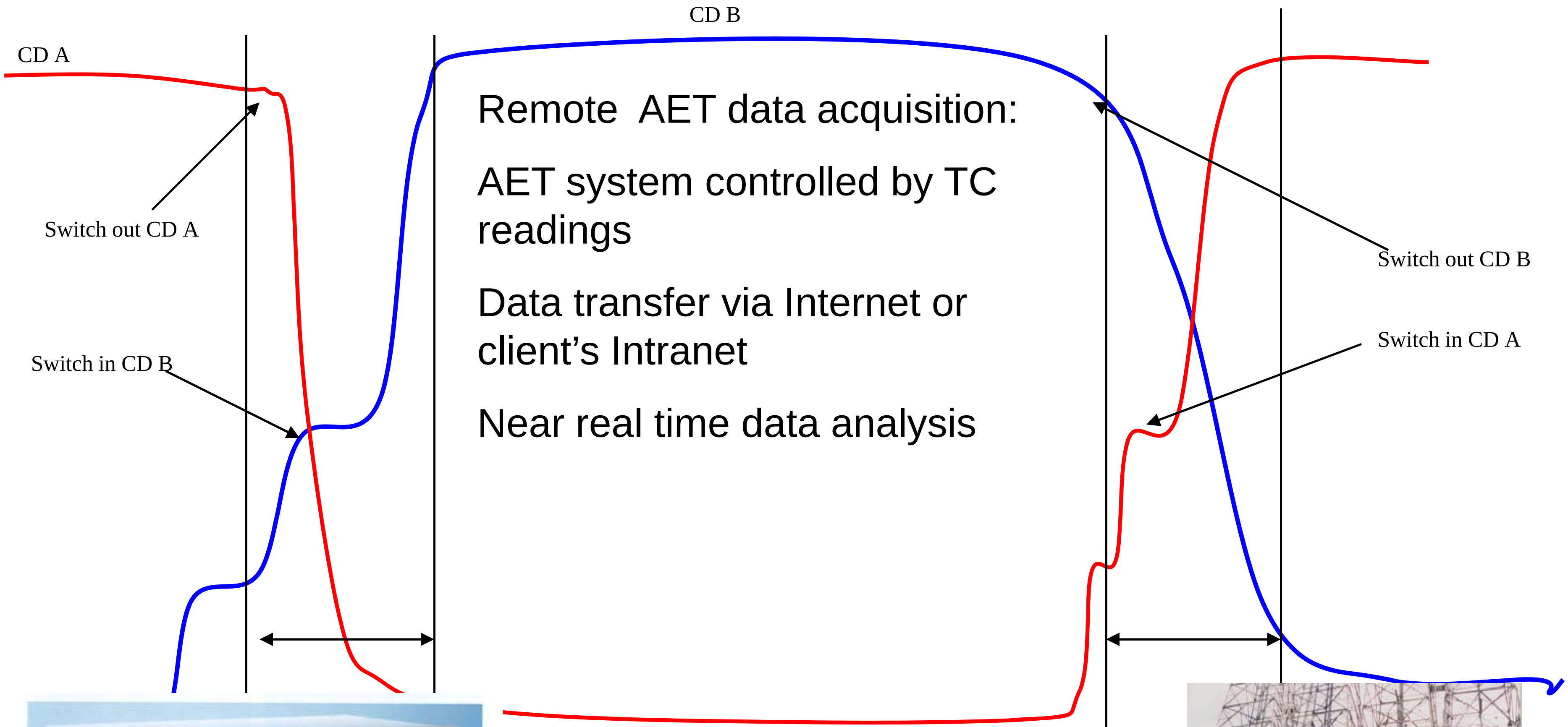
In-service acoustic emission inspection of coke drums

- Performed while in-service during regular operations.
- Uses stresses developing during thermal transients at quench and heat-up
- It relies on detecting <u>actual crack growth</u> due to thermal fatigue.
- Since cycles can be substantially different from each other, 3+ cycles are required to screen the drum.

In-service acoustic emission inspection of coke drums (cont.)

- AET can separate ID from OD connected flaws by means of determining when in the cycle, crack growth occurred
- It provides full coverage of the shell, head and cone, or partial coverage focusing on known problem areas (bulges, skirt, nozzles, etc.)



Remote AET data acquisition:

AET system controlled by TC readings

Data transfer via Internet or client's Intranet

Near real time data analysis

Data acquisition when TC's A and B (both) are above 300 F
Two TC controlling data acquisition (TC-A, TC-B)
Six TC's monitoring skin temperatures for thermal gradients
State-of-the-art Digital AMSY4 Vallen System, remotely operated

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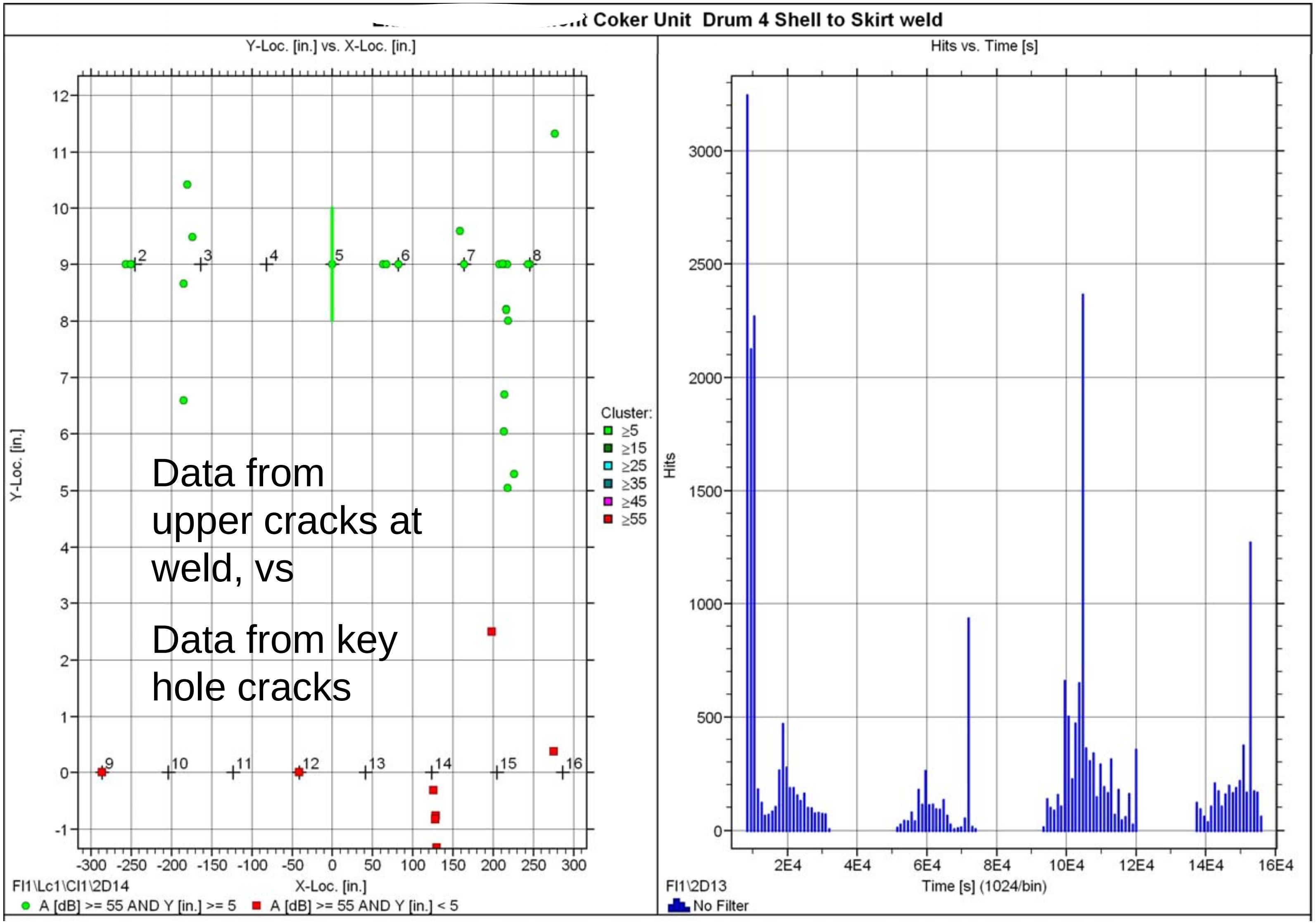
Case history 1

- Cracked skirt attachment weld
- Cracks in “key hole” slots
- Client need to know if and when skirt cracks are growing
- AE needs to separate AET signals from these 2 elevations (9” apart)


Coker Unit Drum 4 Shell to Skirt weld
Y-Loc. [in.] vs. X-Loc. [in.]
Hits vs. Time [s]
Y-Loc. [in.]
X-Loc. [in.]
Fl1\Lc1\Cl1\2D14
A [dB] >= 55 AND Y [in.] >= 5
A [dB] >= 55 AND Y [in.] < 5
Cluster:
≥5
≥15
≥25
≥35
≥45
≥55
Data from upper cracks at weld, vs
Data from key hole cracks
Hits
Time [s] (1024/bin)
Fl1\2D13
No Filter

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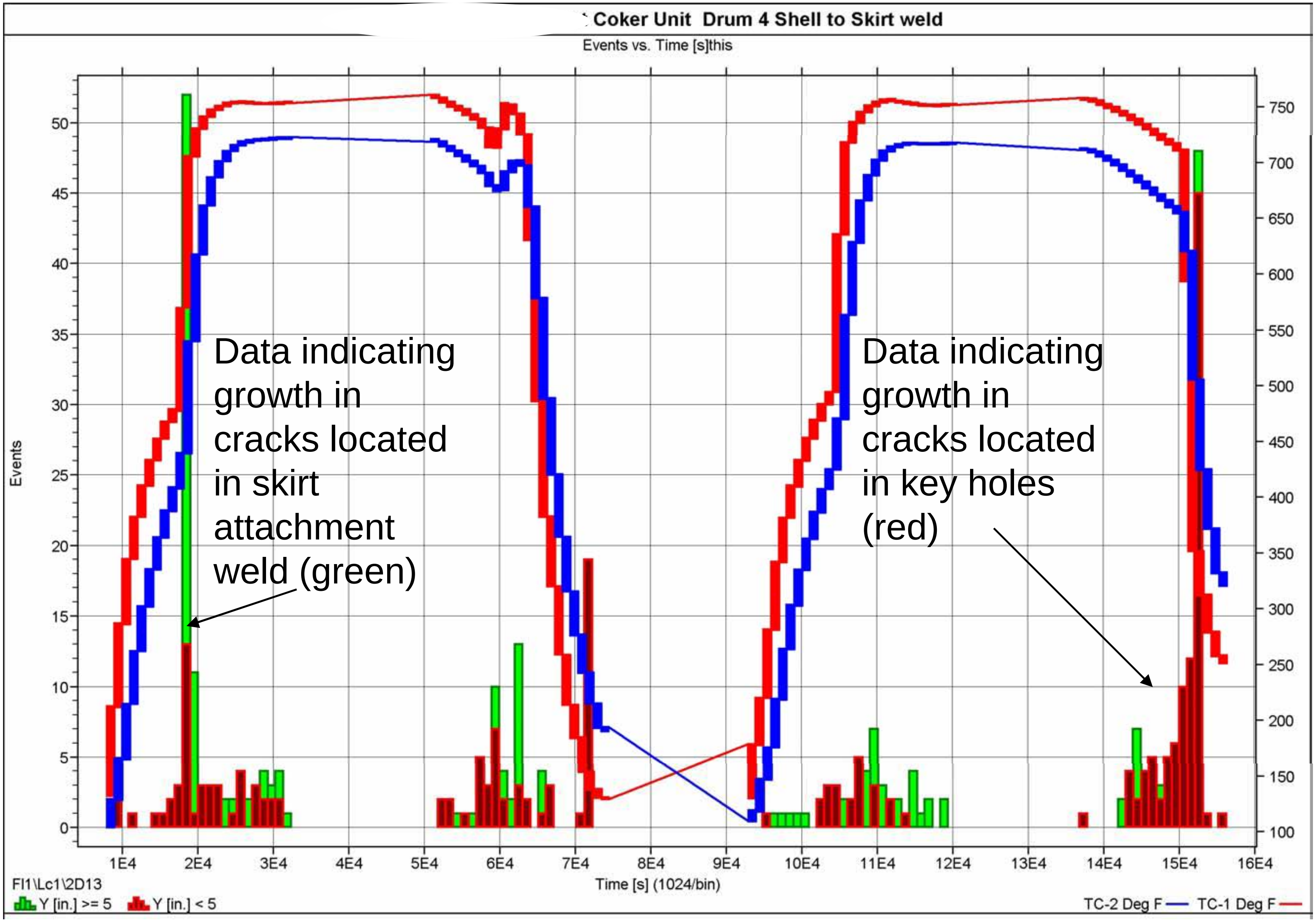
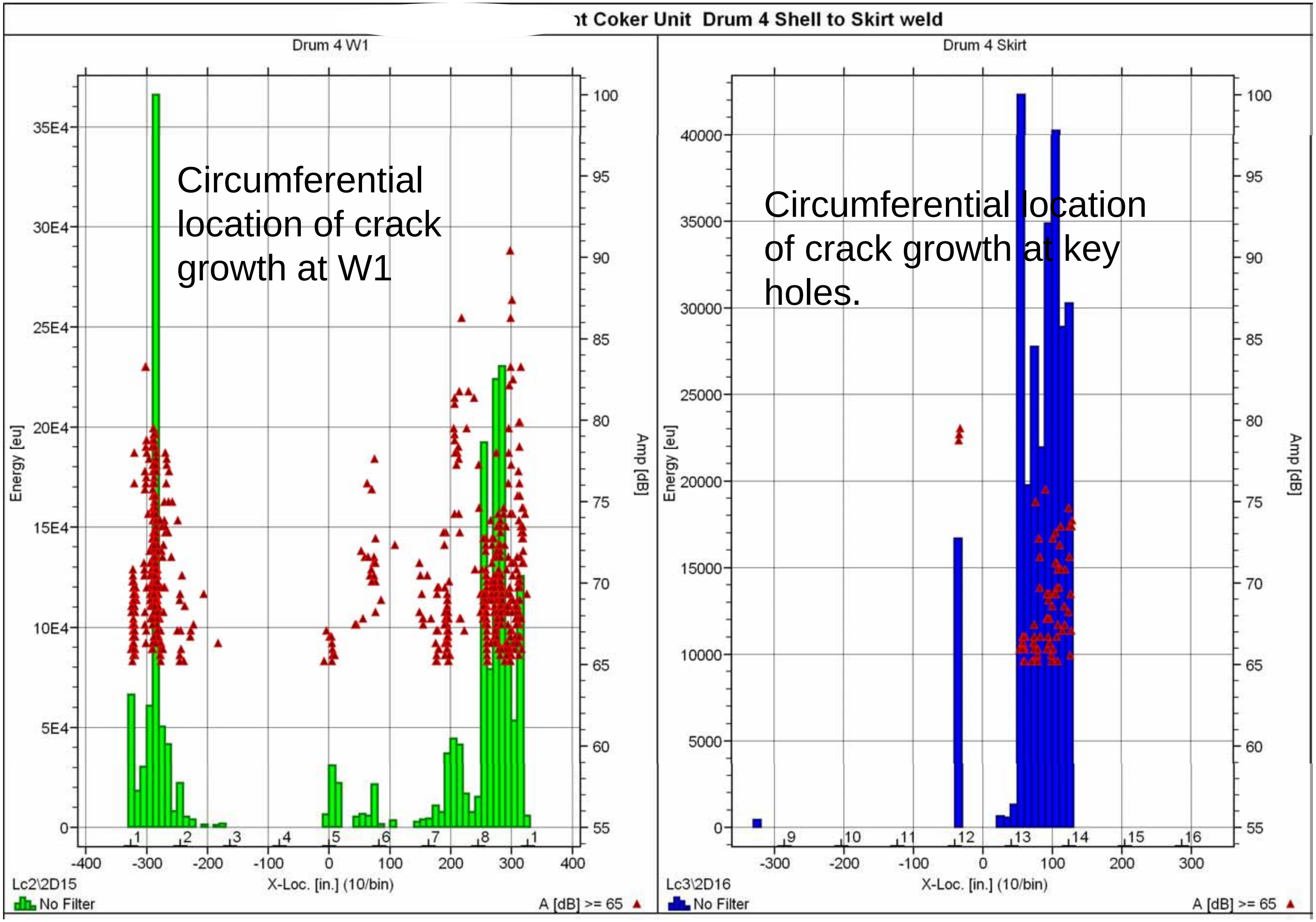

Coker Unit Drum 4 Shell to Skirt weld
Events vs. Time [s]this
Events
Time [s] (1024/bin)
Fl1\Lc1\2D13
Y [in.] >= 5
Y [in.] < 5
TC-2 Deg F
TC-1 Deg F
Data indicating growth in cracks located in skirt attachment weld (green)
Data indicating growth in cracks located in key holes (red)



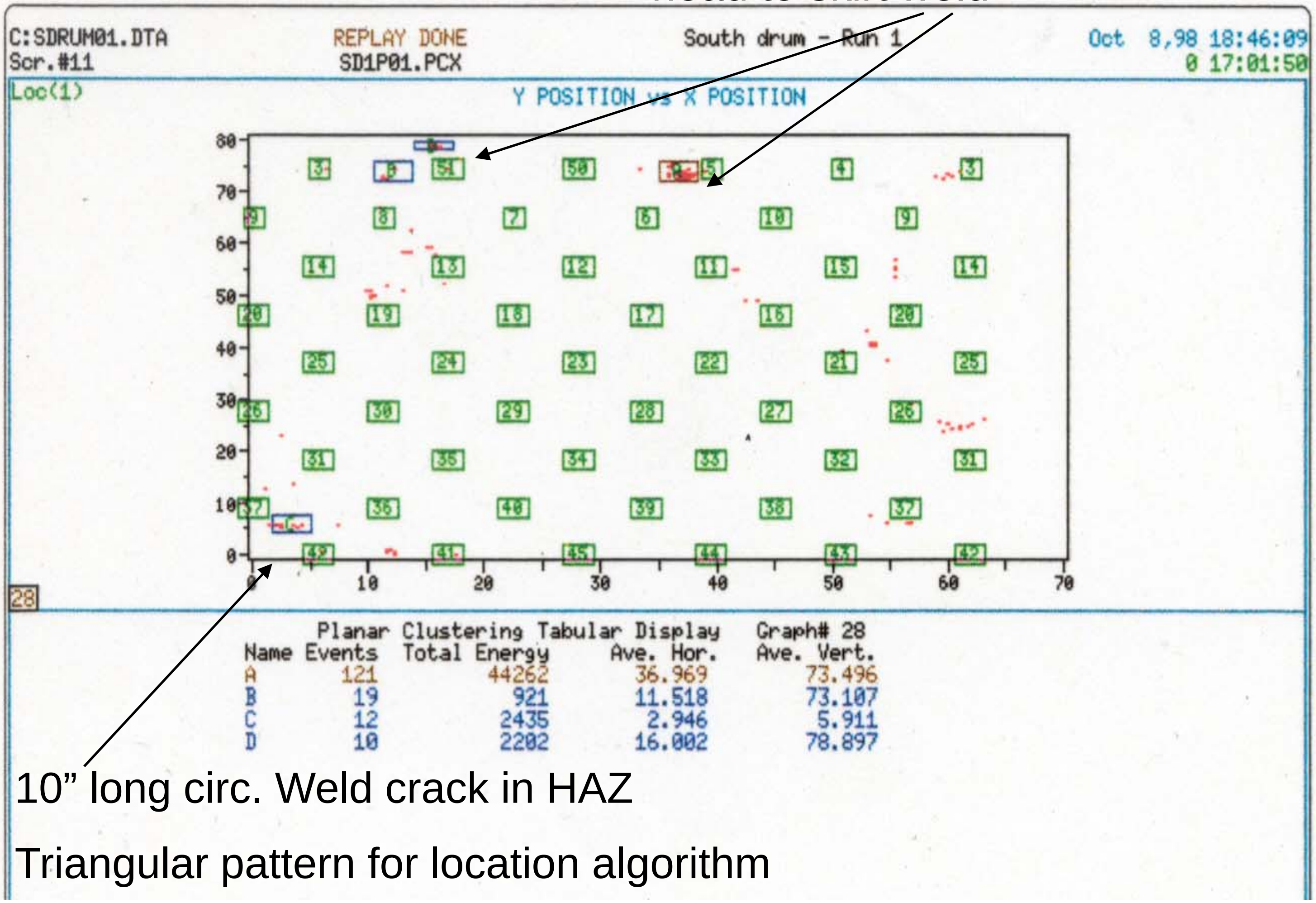
ıt Coker Unit Drum 4 Shell to Skirt weld
Drum 4 W1
Circumferential location of crack growth at W1
Energy [eu]
Amp [dB]
X-Loc. [in.] (10/bin)
Lc2\2D15
No Filter
A [dB] >= 65
Drum 4 Skirt
Circumferential location of crack growth at key holes.
Lc3\2D16

Case history 2

- In-service monitoring of coke drum for 6 cycles.
- Rare design with top derrick supported by top head by means of a cylindrical skirt.
- Significant cracking found at top skirt-to-head attachment welds
- Difficult location to inspect, not planned.

South drum: Location plots for runs 1-3 A123-98

Severe cracks in top head to skirt weld

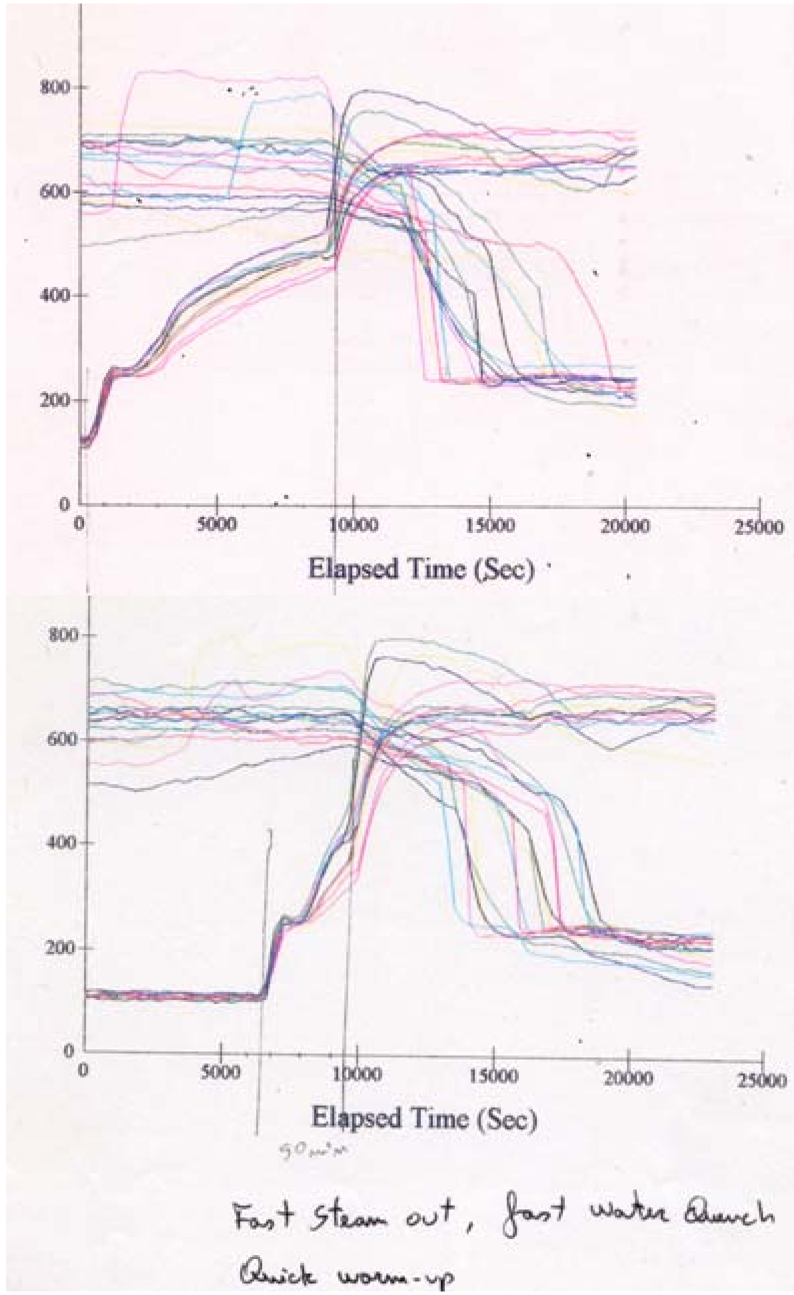


10” long circ. Weld crack in HAZ

Triangular pattern for location algorithm

Case study 3

- Owner wanted to investigate consequences of reducing heat-up time from 3 hr to 45 minutes
- AET and strain gages were used to measure short term (immediate) consequences
- Results indicated no significant changes on AET activity level and strain magnitudes (not a long term assessment)

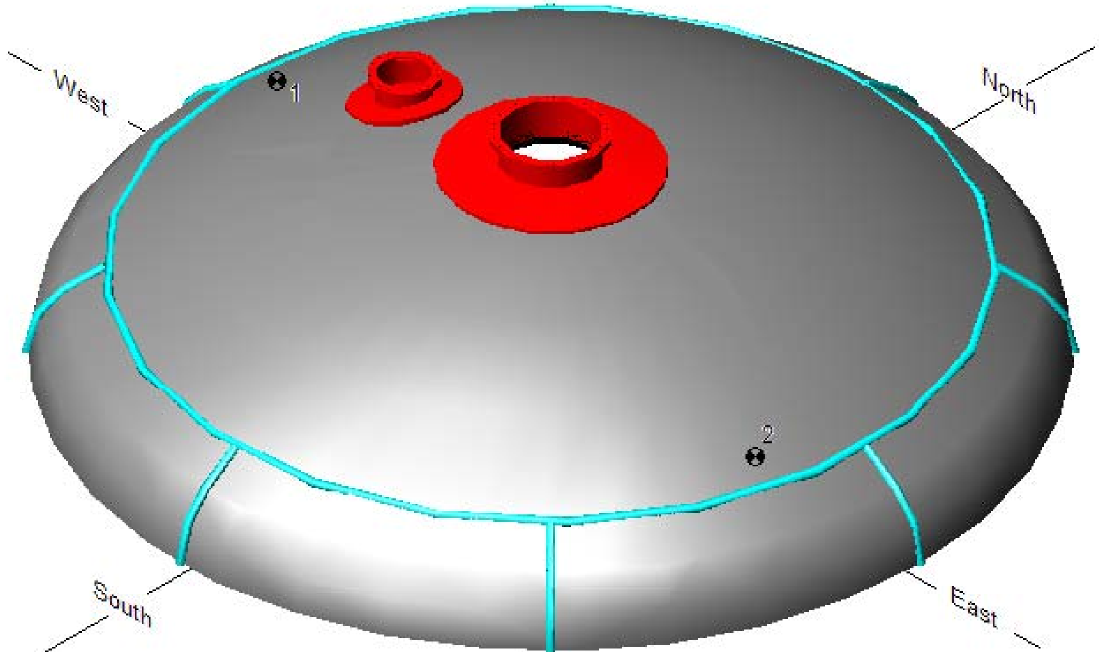


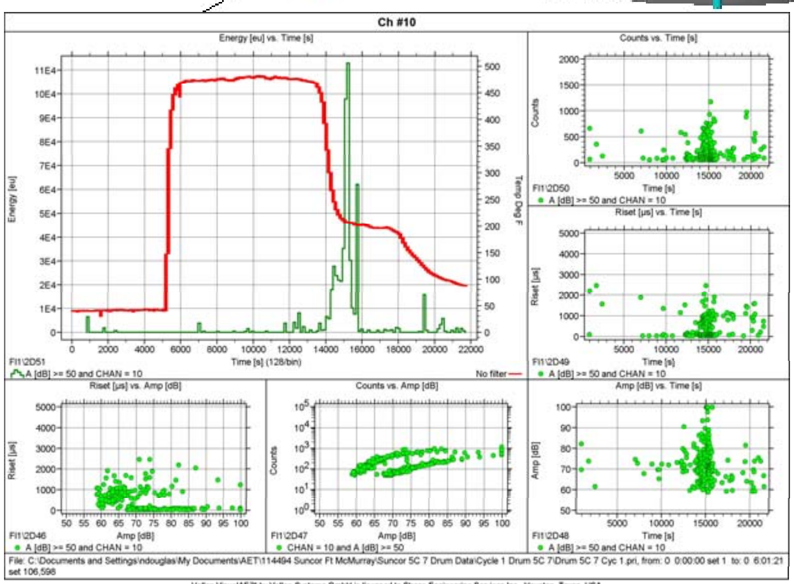
US West Coast refinery
Wanted to know what would
Happen if "heat-up" times
Were shortened by 2 hrs.
AET and SG indicated
No significant damage being
Caused by operational
change

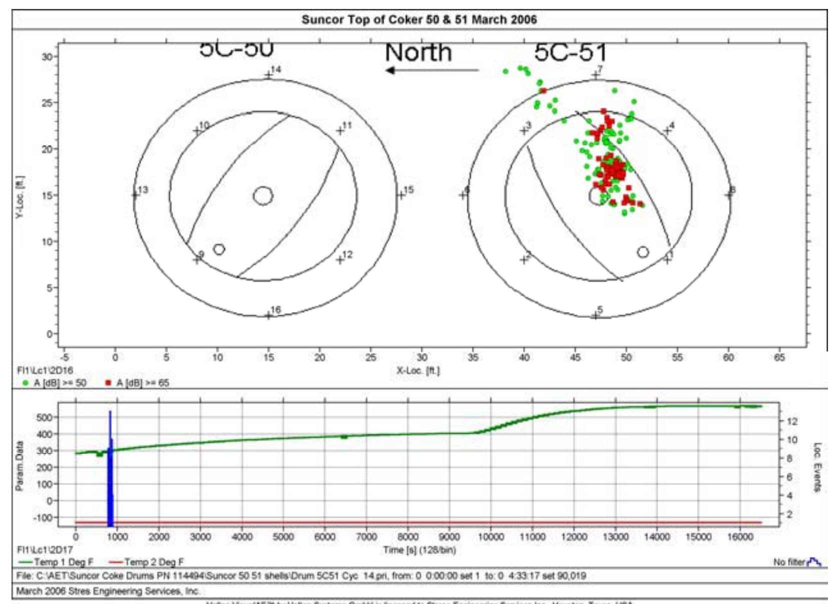
Shell thermocouples only

Case Study 4

- AET on-line monitoring of top head after drill stem dropped.
- Crack located by AET, and monitored for further growth for 3 weeks, until outage allowed repairs


West
North
South
East
1
2


Ch #10
Energy [eu] vs. Time [s]
Counts vs. Time [s]
Riset [µs] vs. Time [s]
Riset [µs] vs. Amp [dB]
Counts vs. Amp [dB]
Amp [dB] vs. Time [s]
Time [s] (128/bin)
No filter


Suncor Top of Coker 50 & 51 March 2006
5C-50
North
5C-51
X-Loc. [ft.]
Y-Loc. [ft.]
Time [s] (128/bin)
Temp 1 Deg F
Temp 2 Deg F
March 2006 Stres Engineering Services, Inc.

Case study 5

- New coker unit with severe vibration issues causing mechanically induced fatigue cracks on overhead vapor lines and nozzles, and foam injection piping.
- Three through-wall failures prior to AET monitoring activation on August 2006.
- AET continuous monitoring have warned of other cracks, which were promptly repaired between cycles. No other failure as of today.
- SES is currently installing mechanical remediation to reduce vibration.

Four coker unit

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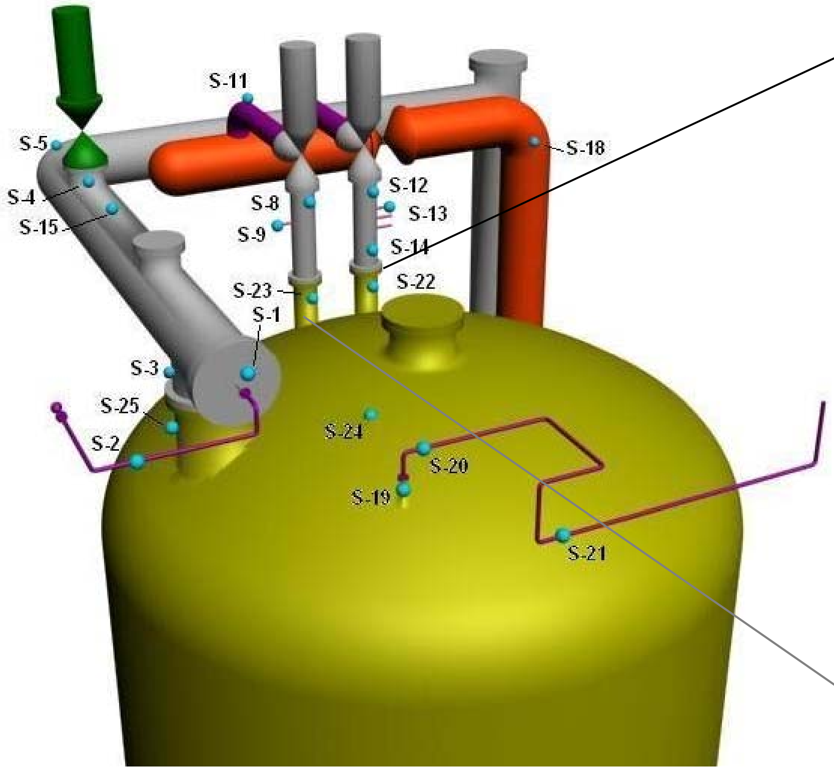
Overhead piping system in Coker Unit subjected to vibration induced fatigue cracking



Conclusions

- Acoustic emission inspection can screen existing or new coke drums to detect and locate existing crack-like or significant flaws
- It can have a positive impact on T/A planning and budget by reducing and optimizing NDT efforts
- It can predict failure locations, therefore avoid costly shutdowns

Conclusions (cont.)

- Plants need to maintain critical units operational, despite presence of significant flaws.
- There is a wide array of NDE methods available to plant owners/operators to help achieve that objective.
- On some cases AET can provide the necessary information and data to allow for safe continued operation until other actions can be implemented.

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