Using Acoustic Emission to Detect HRSG Tube Cracks

2015 HRSG User's Group Conference
March 09-11 – Orlando-FL

- **Joe Frey**
- **Claudio Allevato**
- **Mauro Araujo**
- **Arilson Silva**

Taking on your toughest technical problems

Araujo
Engenharia e Integridade de Equipamentos

STRESS ENGINEERING SERVICES INC.

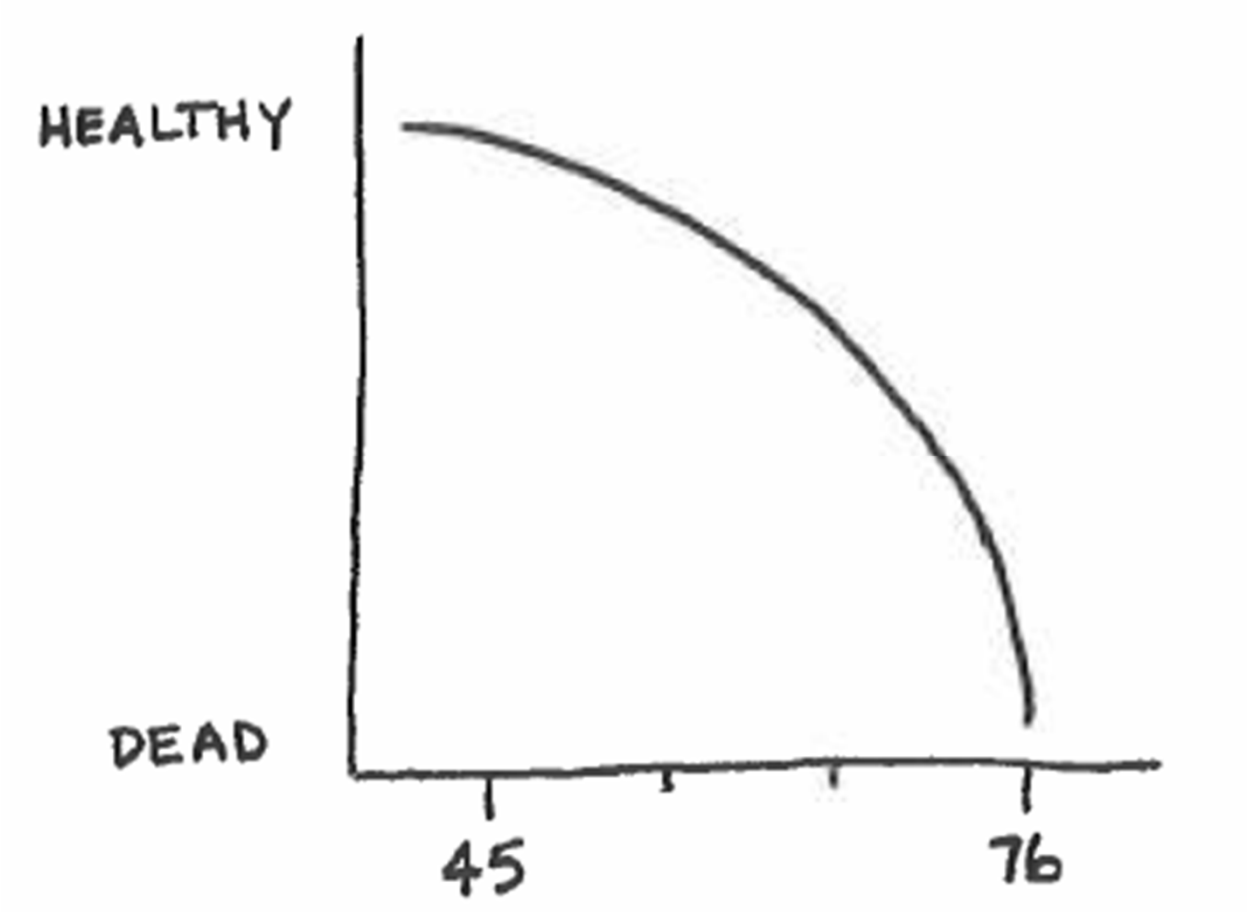
an employee-owned company

Parallels HRSGs / Heart “Piping”

- HRSG
  - Water chemistry
  - Operating regime
- Heart “Piping”
  - Blood chemistry
  - Operating regime (velocity by exercise)

Younger Next Year

Chris Crowley and Dr. Harry Lodge



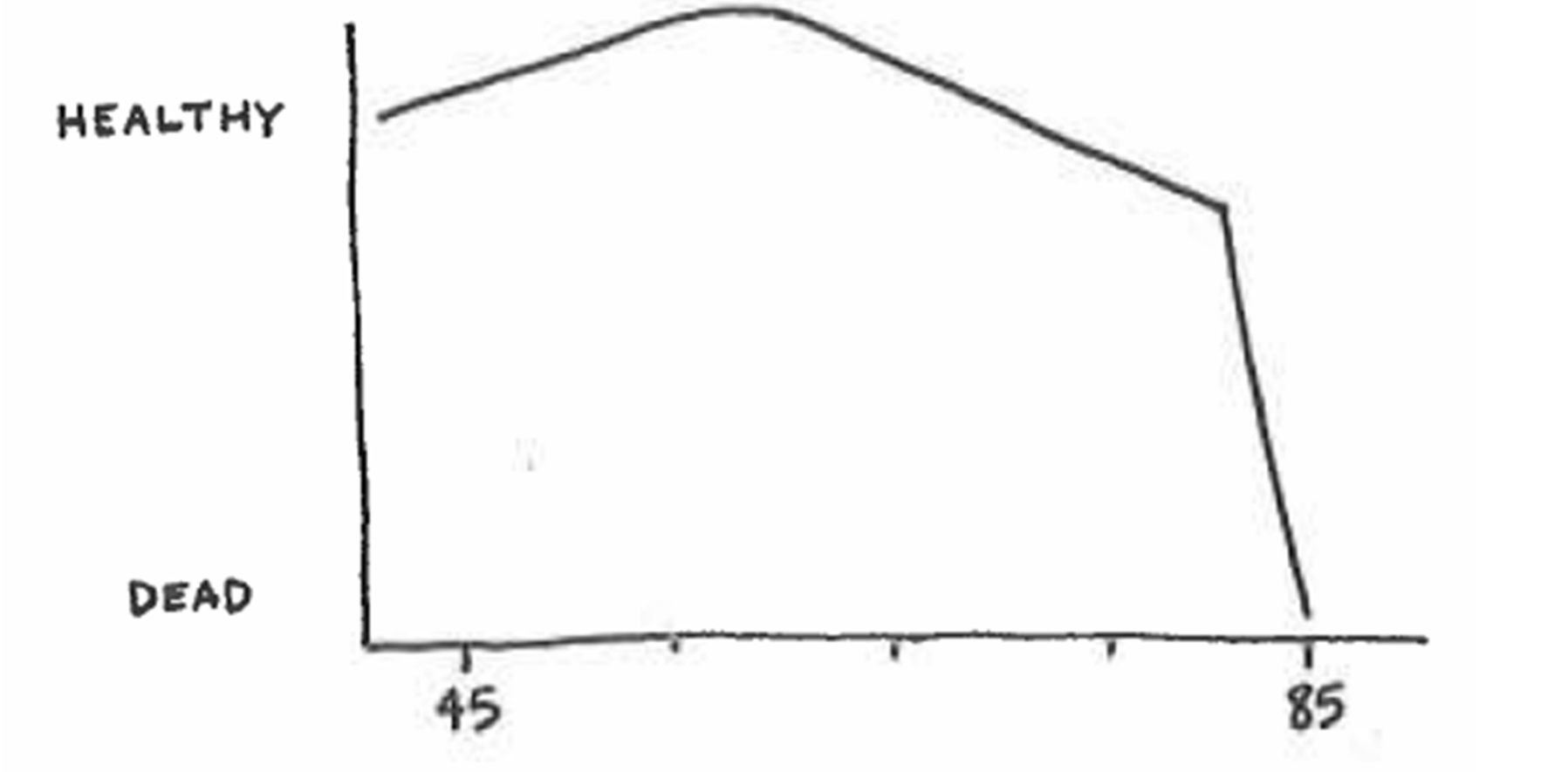
Araujo

STRESS ENGINEERING SERVICES INC.

an employee-owned company

Younger Next Year

Chris Crowley and Dr. Harry Lodge



Araujo

STRESS ENGINEERING SERVICES INC.

an employee-owned company

Superheater and Reheater Outlet Headers

<u>Assessment and Remaining Life Prediction</u>
Typical levels of available information

i) Design data only. *Likely ranking of header risk is possible*.

ii) Design data + Distributed Control System (DCS) data. *Life prediction based on minimum properties and typical header temperature variation.*

iii) Design data + DCS + thermocouple data. *Steady load assessment based on minimum properties is possible. Probabilistic statements to justify inspection intervals may be made.*

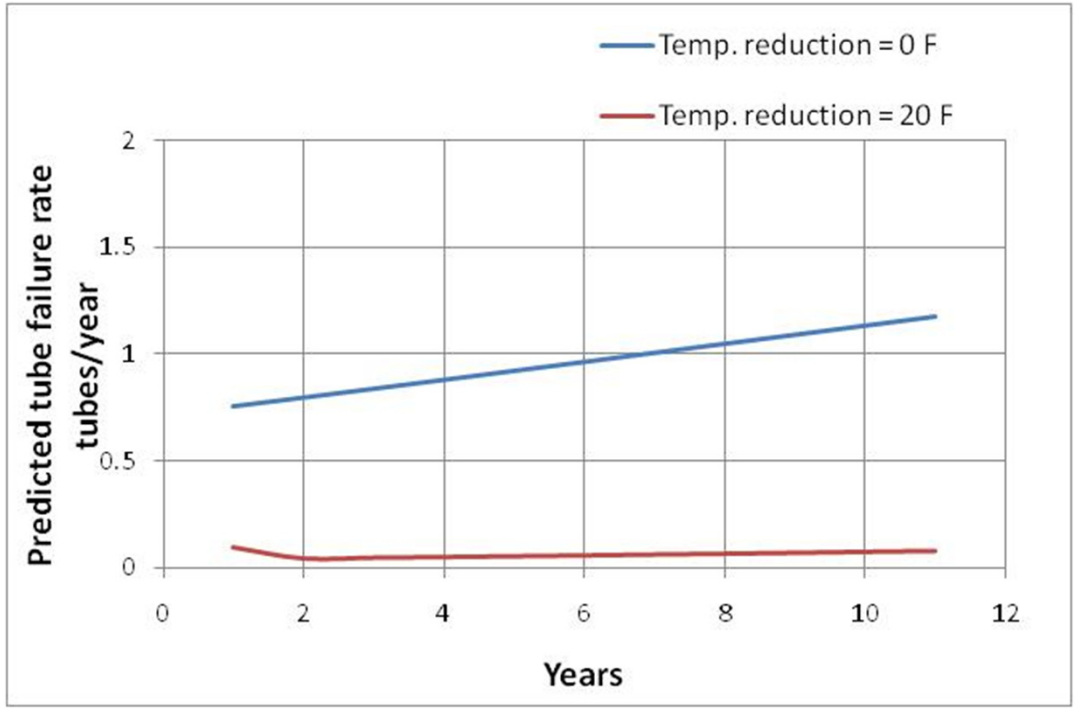
iv) Design data + DCS + thermocouple data (steady and cyclic) + sample material data.
Remaining life estimates can be performed with the most confidence.

Physical measurements
NDT for creep damage and cracking
Accelerated creep testing of samples.

Araujo
STRESS ENGINEERING SERVICES INC.
an employee-owned company

Probabilistic Risk Assessment

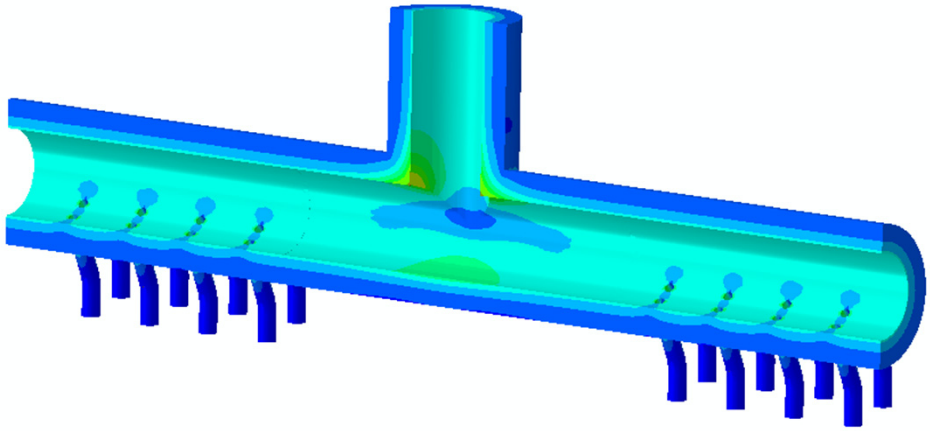
Example: Options for superheat de-rate following results of sample testing indicating increasing risk of failure .



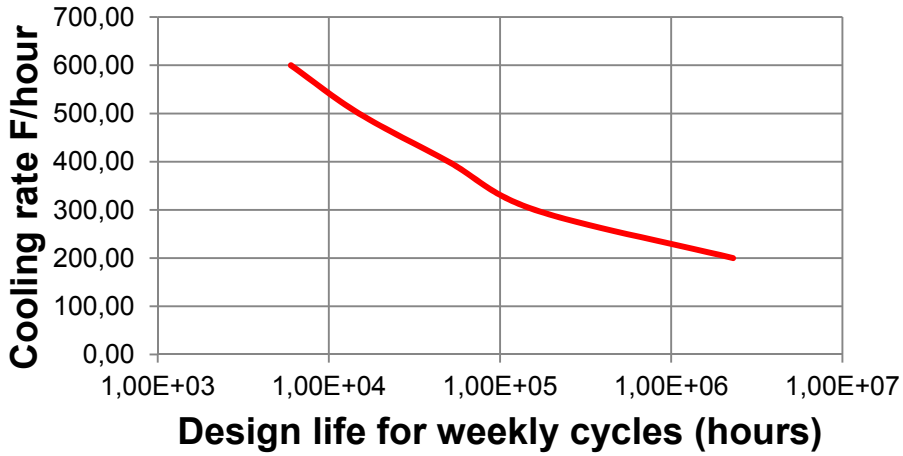
Effects of cyclic loading

Causes of premature cracking and failure:

- Thermal shock due to rapid heating and cooling rates (cracking in thick sections)
- Header distortion due to left to right variation in terminal tube temperatures (circ. cracking at ligaments)
- Individual terminal tube temperature variation due to flow restriction (terminal tube and weld cracking)
- Recommendation: install thermocouples on selected terminal tubes and monitor DCS and T/C temperature data.
- Remediation actions could include re-design of terminal tubes, replacement of blocked tube, etc.



Header Thermal Creep-Fatigue life Calculation



Effects of cyclic loading

Boiler tubes should be a low risk for failures due to cyclic loading.

Possible exceptions

- Terminal tubes (discussed with headers)
- Dissimilar metal welds
- Welded platens
- Welded spacers

Risks may be determined from detailed analysis

9

Most Important Requirement For Each NDE Technique Is A

QUALIFIED INSPECTOR

WHO UNDERSTANDS THE TECHNIQUE, THE STRESSES, THE PROCESS, AND THE DAMAGE MECHANISMS BEING SOUGHT !!

Objective

To present situations where AET could be used to detect cracks in HRSG tubes, piping, drums and headers

Note: Most of the data and images being presented were collected during inspections in HRSG and conventional boilers over the last 10 years in Brazil.

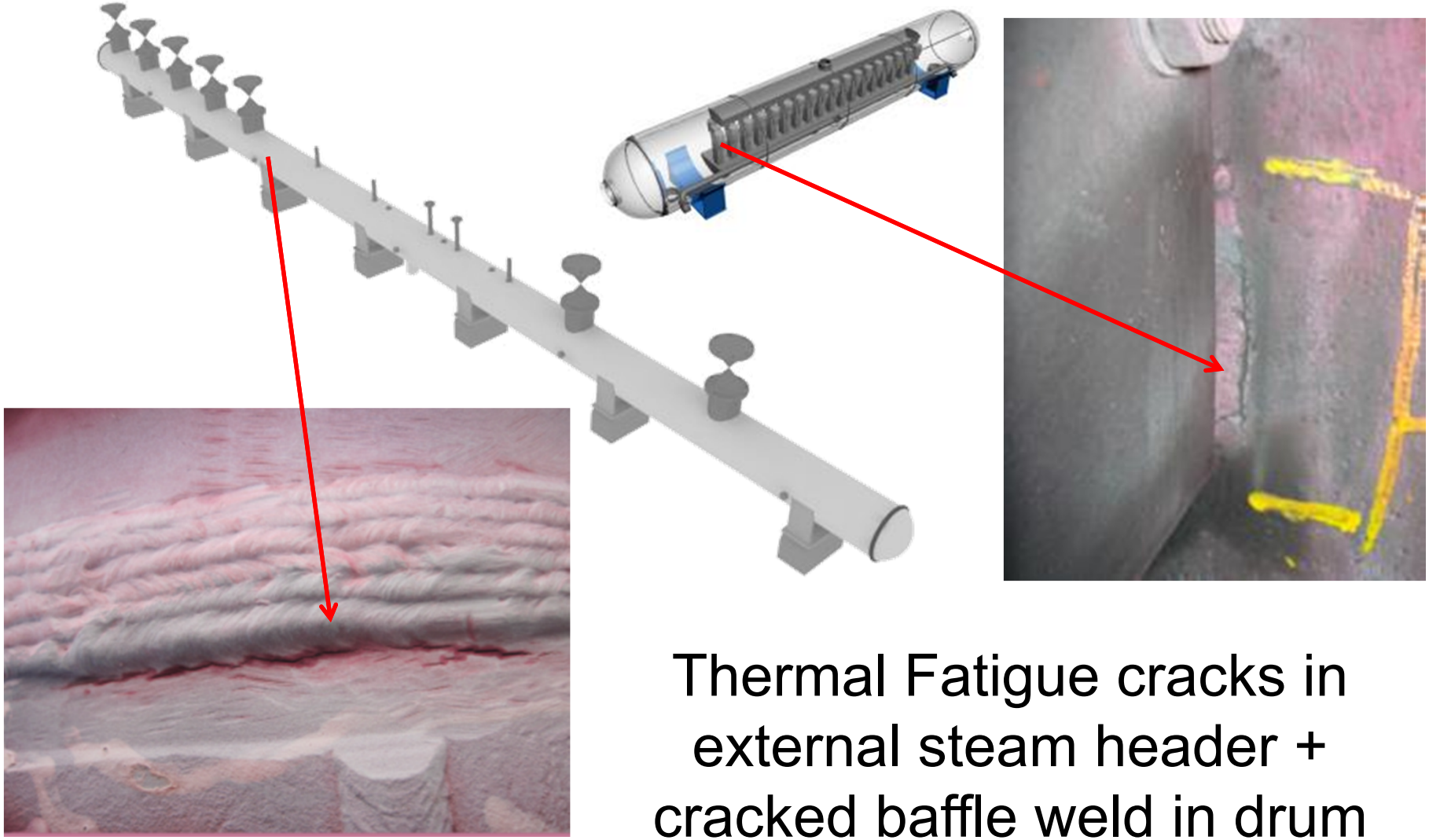
HRSGs are NOT Designed and Built With Inspection In Mind

Difficult access for proper inspection

Scenario

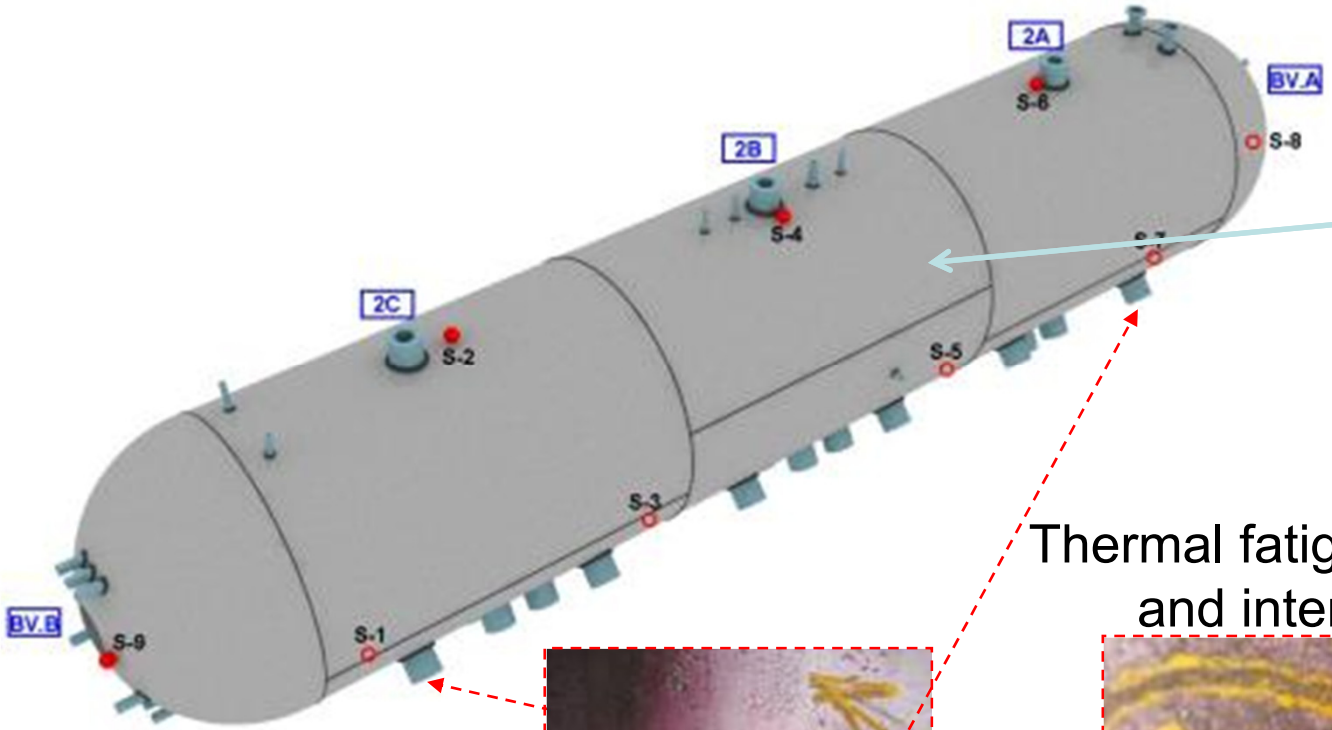
What are we looking for with AET?	**Where** could they be?	**When** are they likely to occur?
Cracks	- Drums - Headers - Piping - Tubes	- Shutdowns - Start ups - Transient Conditions

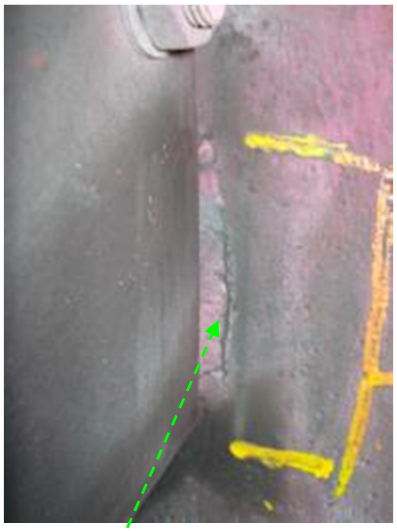
What has AET found?



Thermal Fatigue cracks in external steam header + cracked baffle weld in drum

What has AET found?





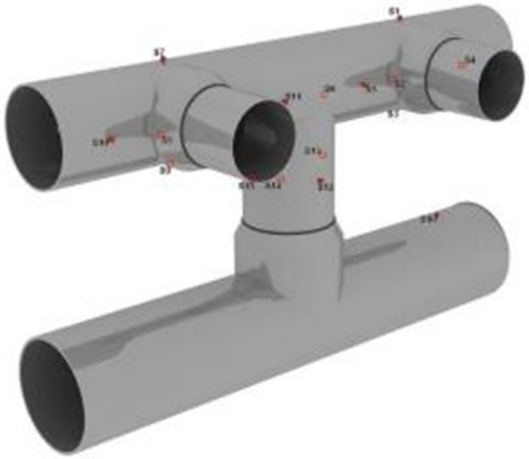
Thermal fatigue cracks in nozzles and internal baffle welds

Araujo Engenharia e Integridade de Equipamentos

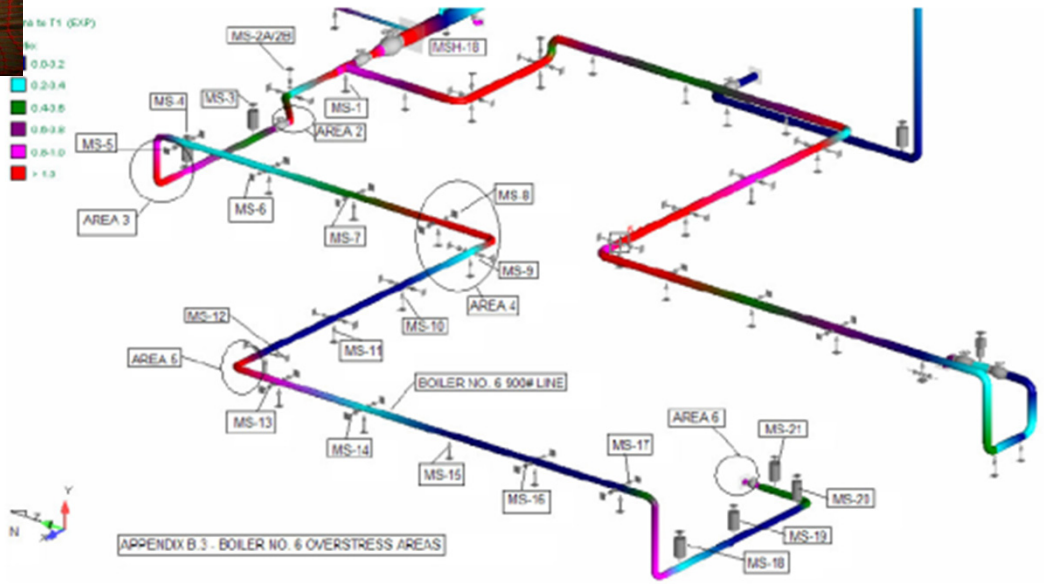
STRESS ENGINEERING SERVICES INC.

an employee-owned company

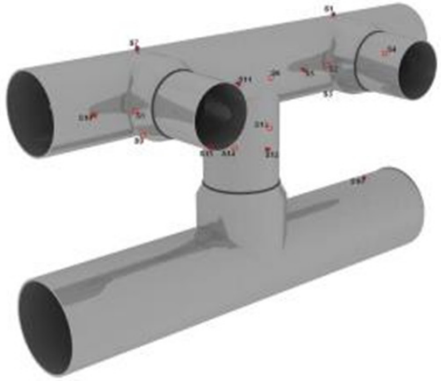
What has AET found?



Creep Fatigue cracks in steam piping



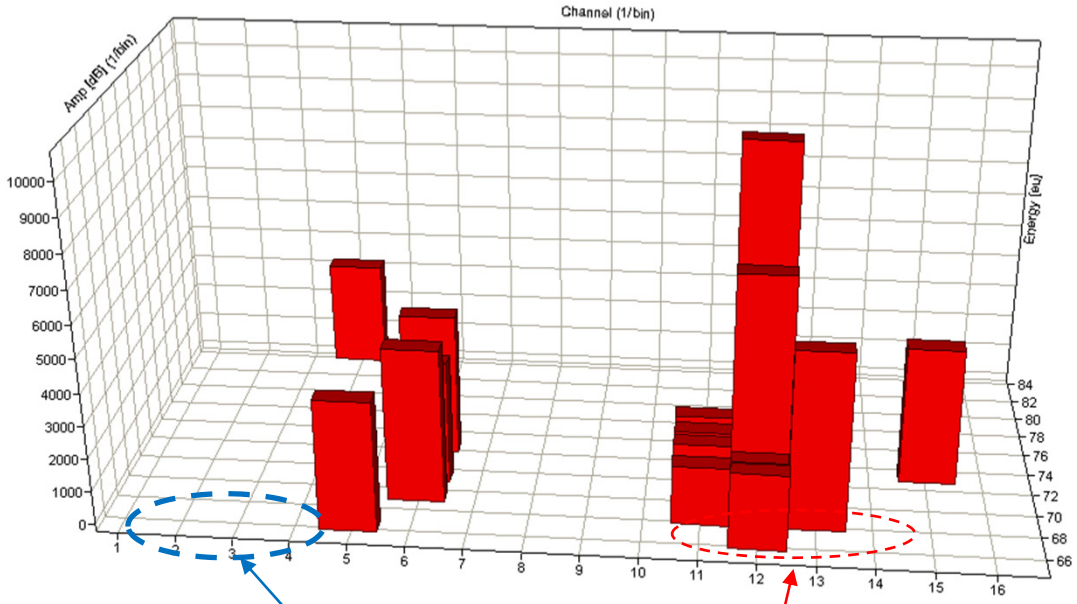
What has AET found?



Creep Fatigue cracks in steam piping

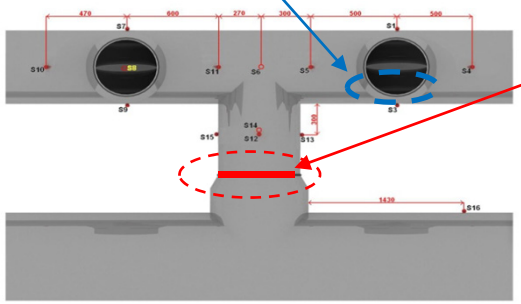
What has AET found?

4 years intermittent AE monit shows active cracking and absence of AE once cracks are removed



Area where cracks were removed

No AET



Area with knew cracks AET flagged

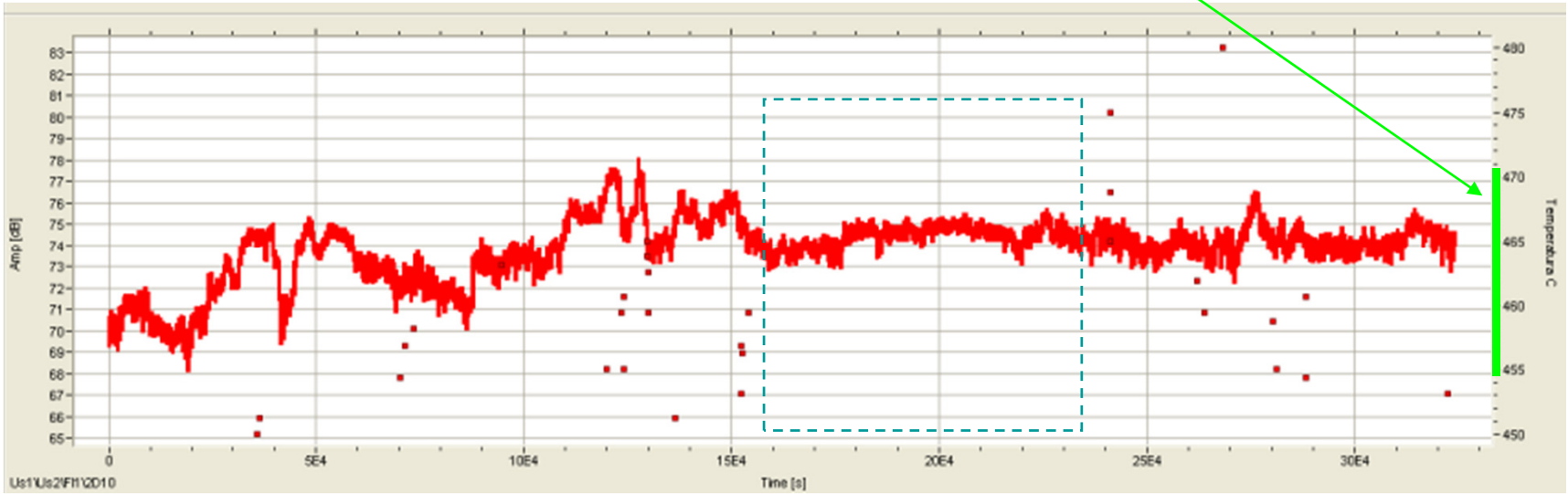
Araujo Engenharia e Integridade de Equipamentos

STRESS ENGINEERING SERVICES INC.

an employee-owned company

What has AET found?

Typical temperature = Termocouple installed in the Weldolet.
Found a variation aproximatly 60º F.

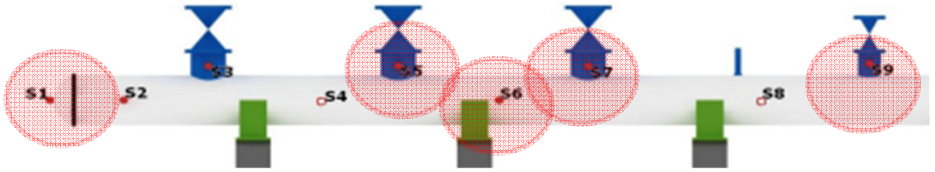


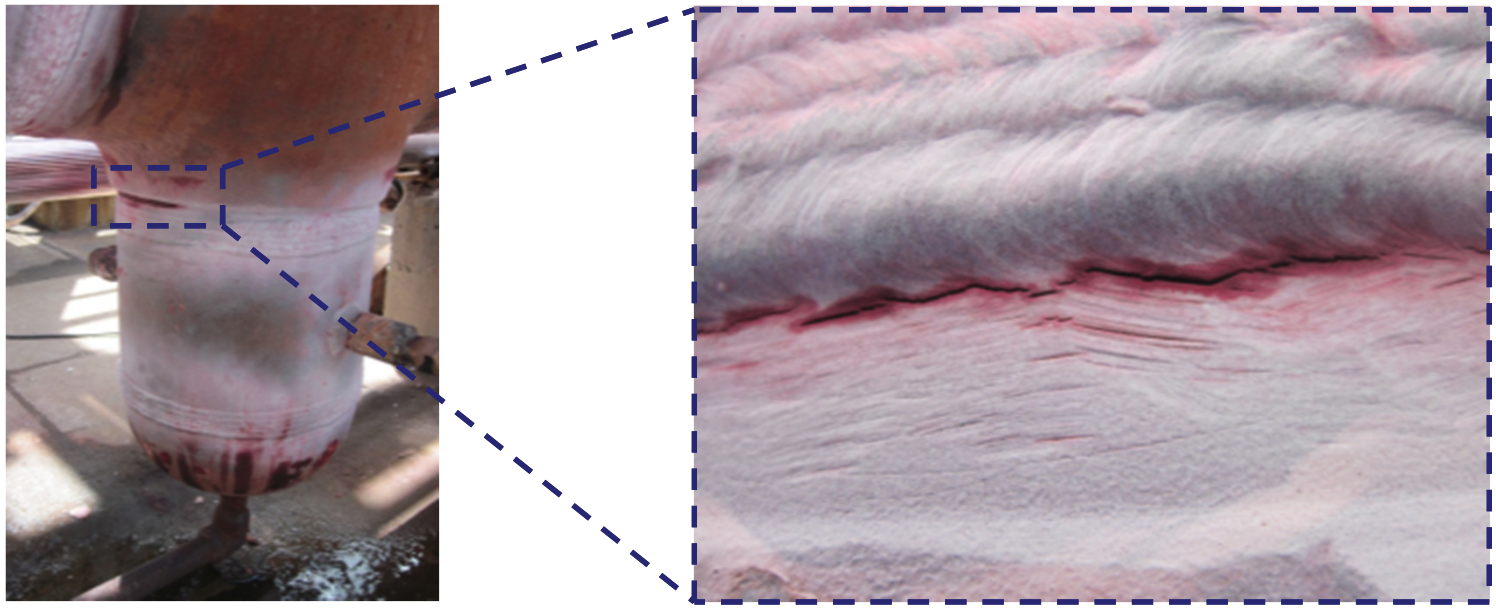
AE activity during the temperature variations

Constant temperature → No AE activity

What has AET found?

Thermal Fatigue cracks



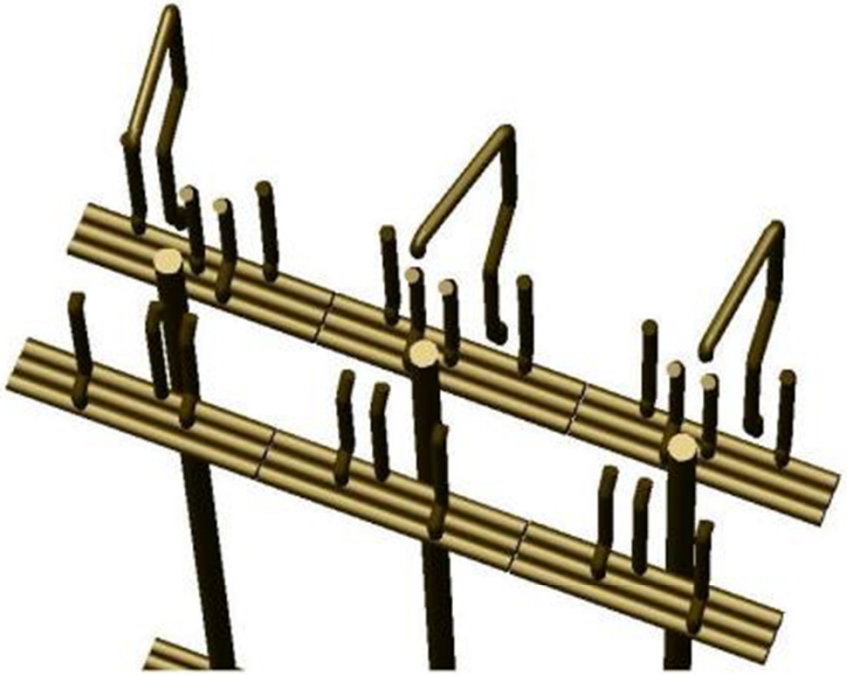


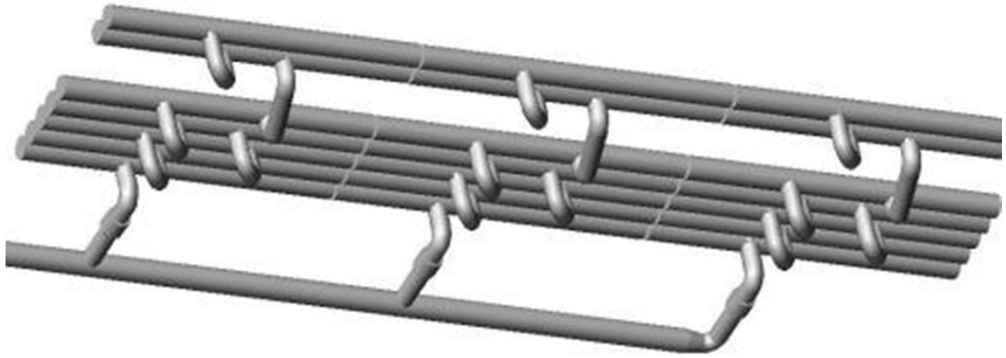
Araujo Engenharia e Integridade de Equipamentos

STRESS ENGINEERING SERVICES INC.

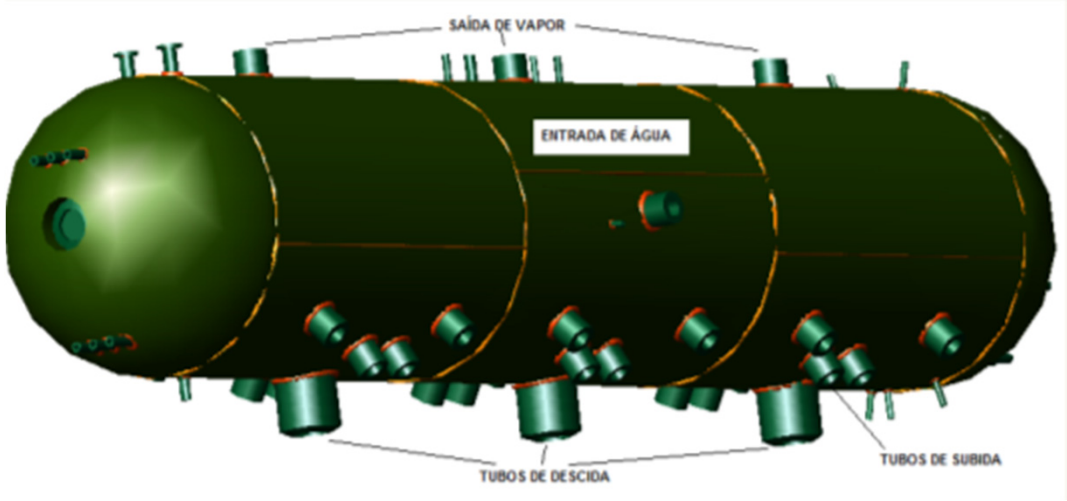
an employee-owned company

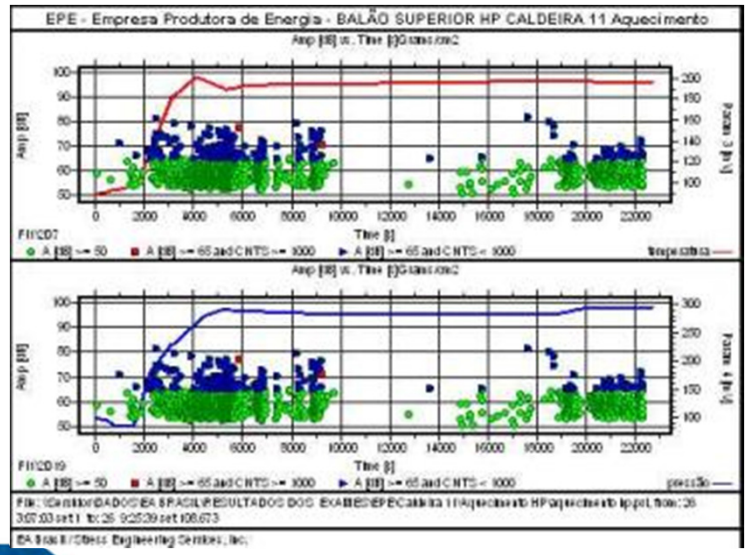
What has AET found?

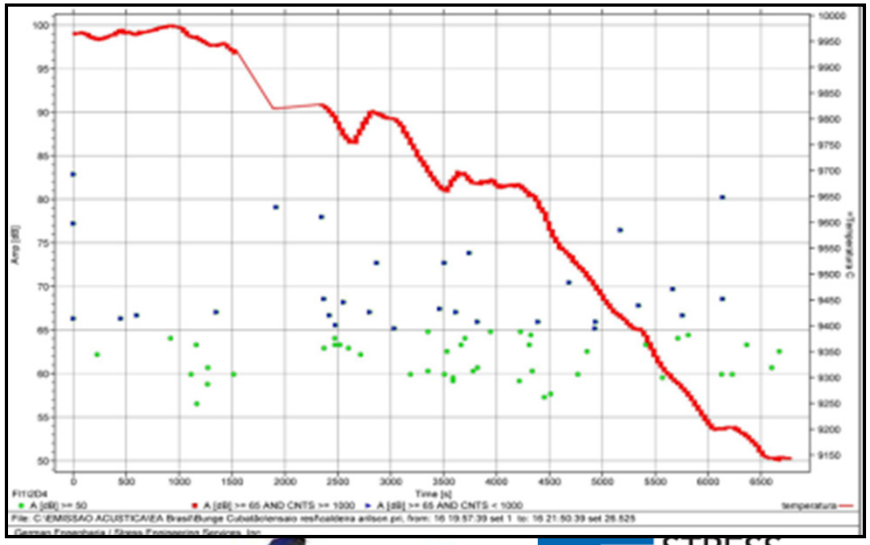




What has AET found?







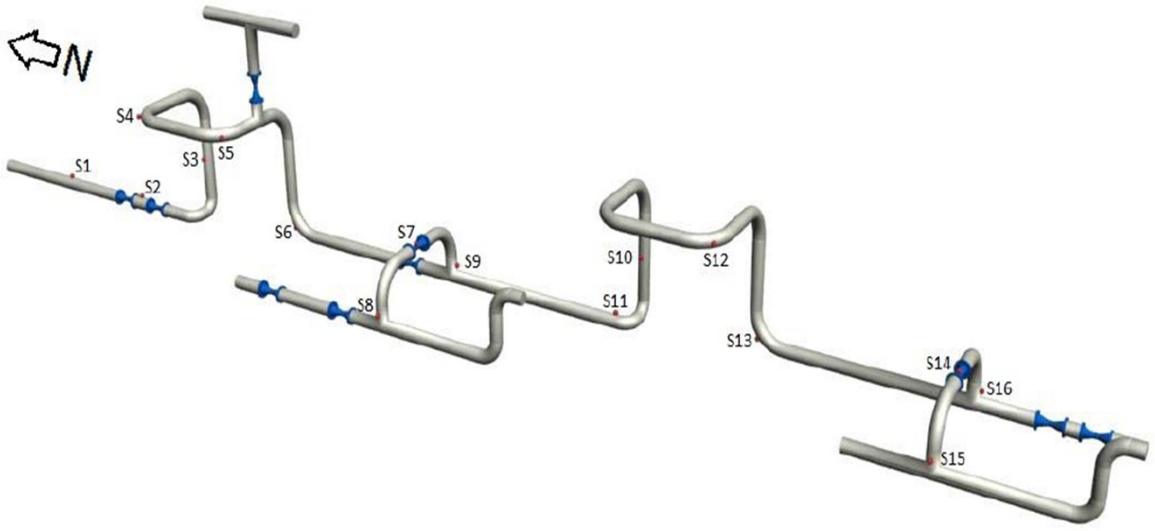
Araujo Engenharia e Integridade de Equipamentos

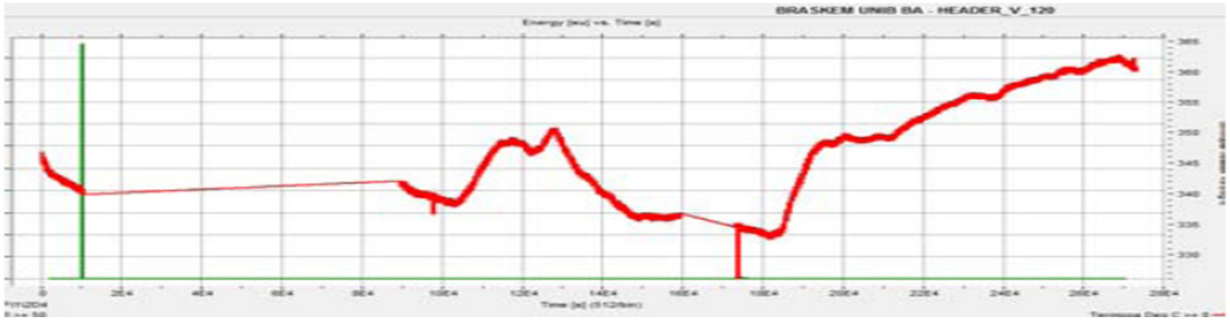
STRESS ENGINEERING SERVICES INC.

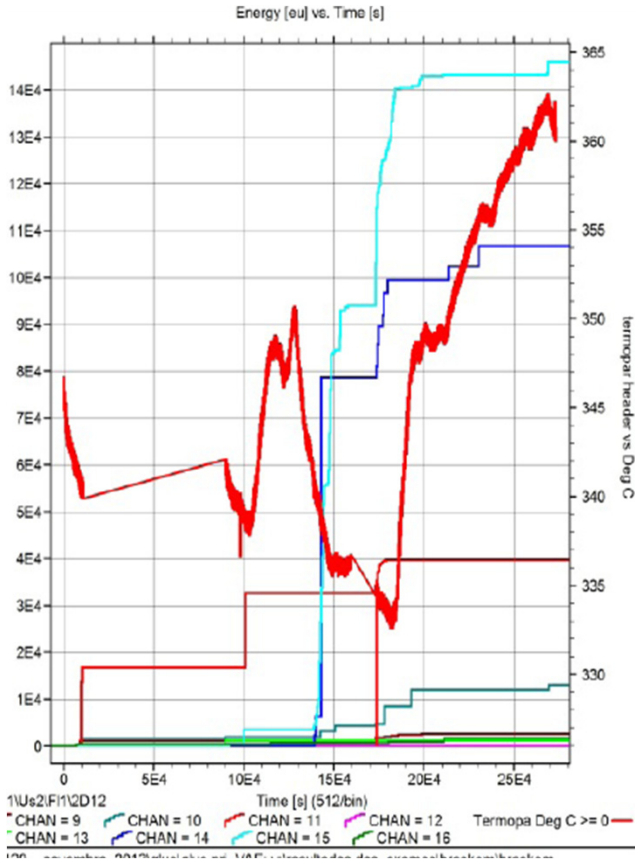
an employee-owned company

What has AET found?

Acoustic Emission related with operational data (pressure, temperature)







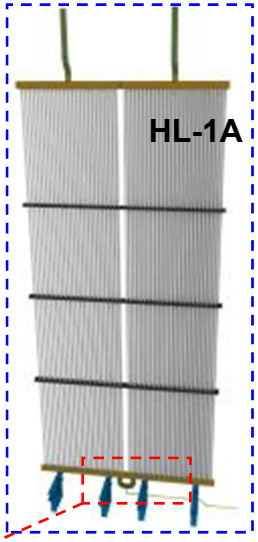
Next section

- So far we have shown a few cases where AET was able to detect damage in HRSG (drums and piping) and conventional units
- Now we will show other types of damage in HRSGs and conv, units we believe AET can be helpful detecting.

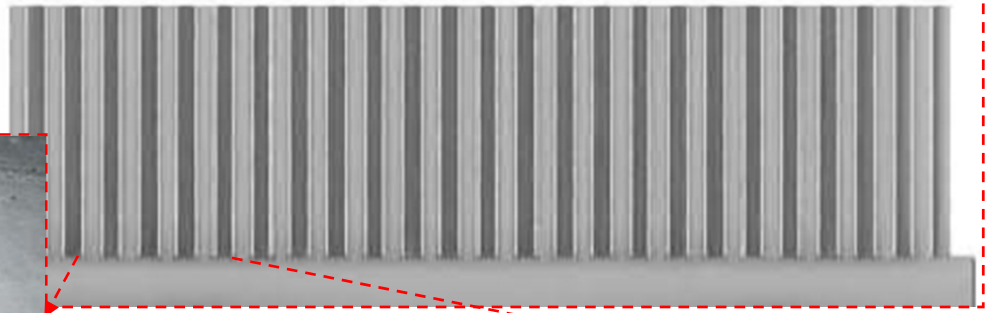
What else could AET be looking for?

Low cycle fatigue cracks

What else could AET be looking for?



Low cycle fatigue cracks

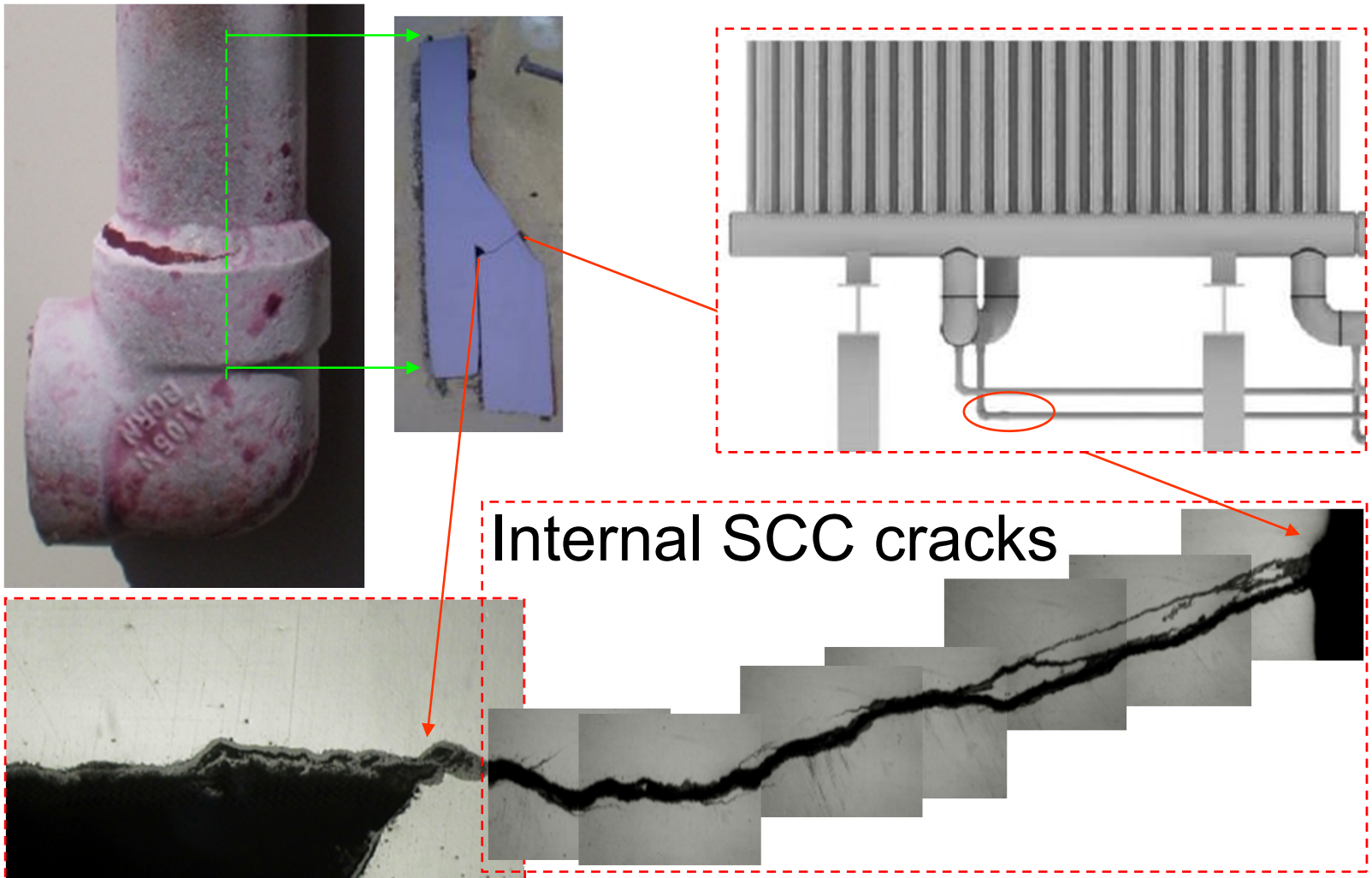


Araujo

STRESS ENGINEERING SERVICES INC.

an employee-owned company

What else could AET be looking for?



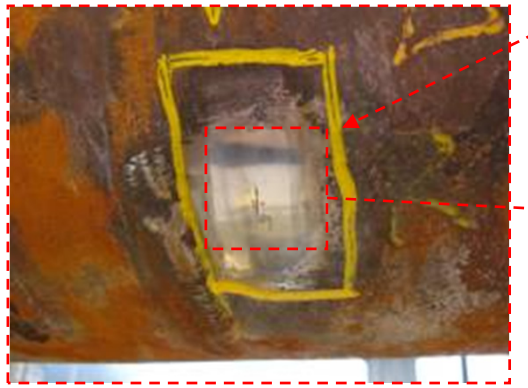
Araujo

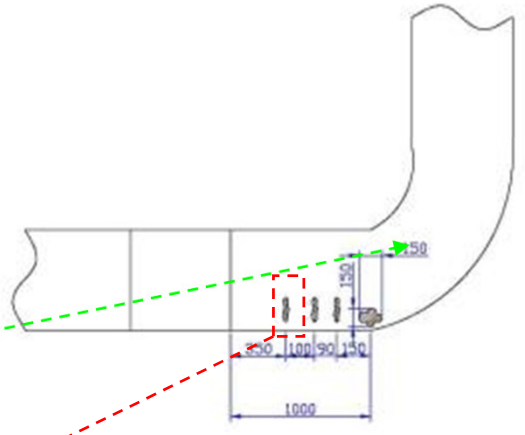
STRESS ENGINEERING SERVICES INC.

an employee-owned company

What else could AET be looking for?

BEND OF THE DESSUPERHEATER





Thermal fatigue cracks in ext piping

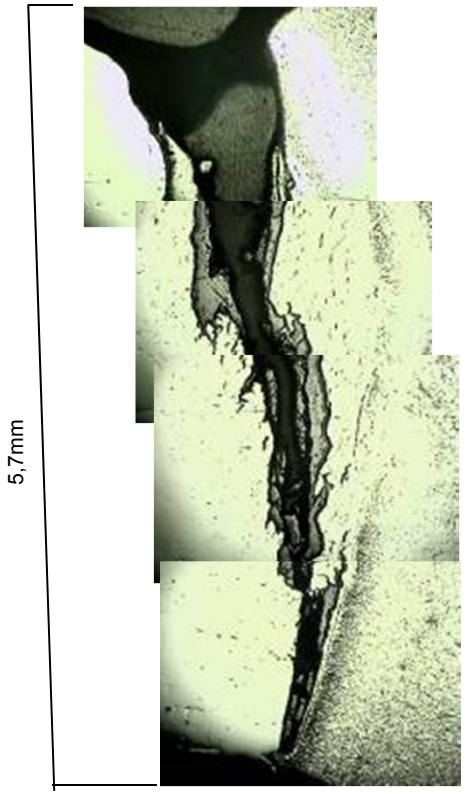
Araujo

STRESS ENGINEERING SERVICES INC.

an employee-owned company

What else could AET be looking for?

Thermal Fatigue cracks at tube/header connections <u>"before they leak"</u>



Araujo Engenharia e Integridade de Equipamentos

STRESS ENGINEERING SERVICES INC.

an employee-owned company

We doubt AET can find this

Dew point
SCC cracks

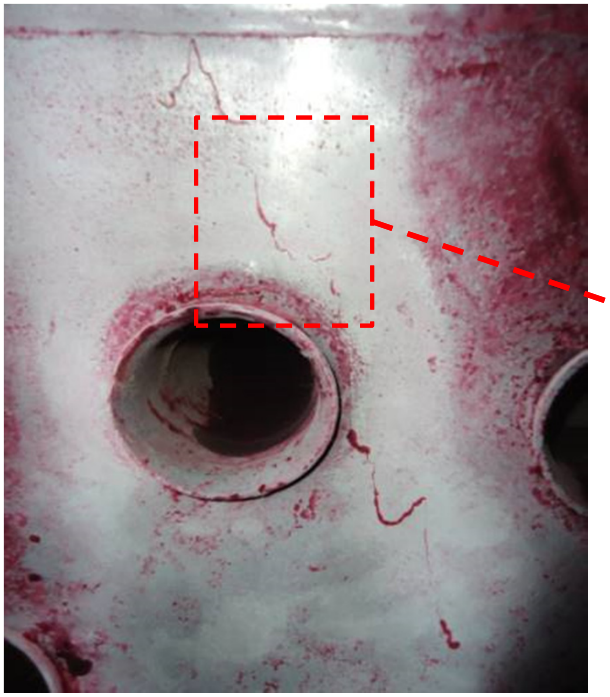
Araujo
Engenharia e Integridade de Equipamentos

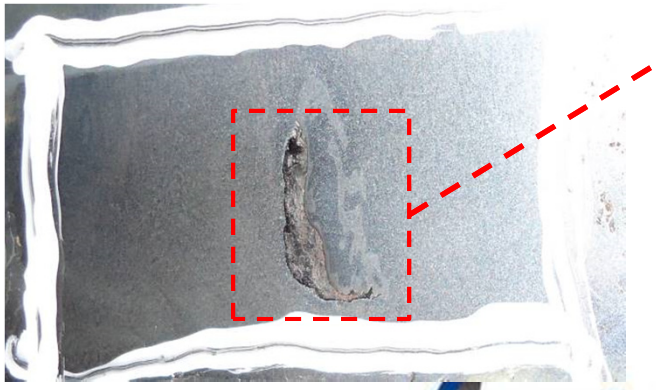
STRESS ENGINEERING SERVICES INC.
an employee-owned company

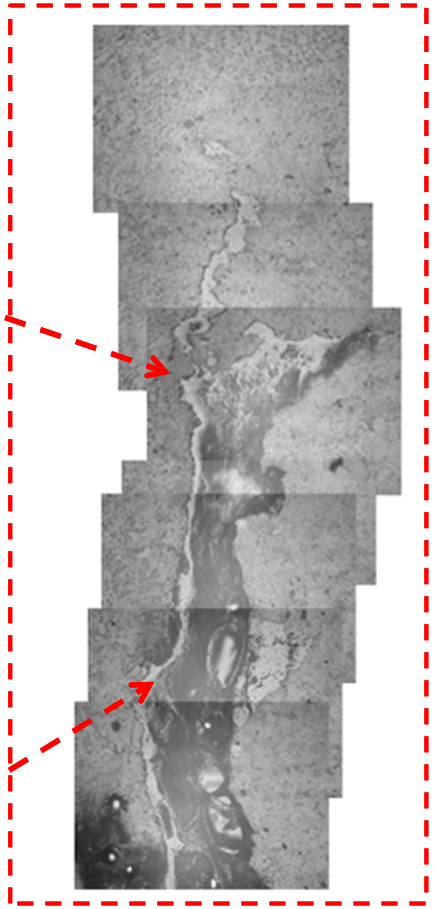
What else could AET be looking for?

Fatigue

What else could AET be looking for?







Fabrication flaw became fatigue crack

Araujo

STRESS ENGINEERING SERVICES INC.

an employee-owned company

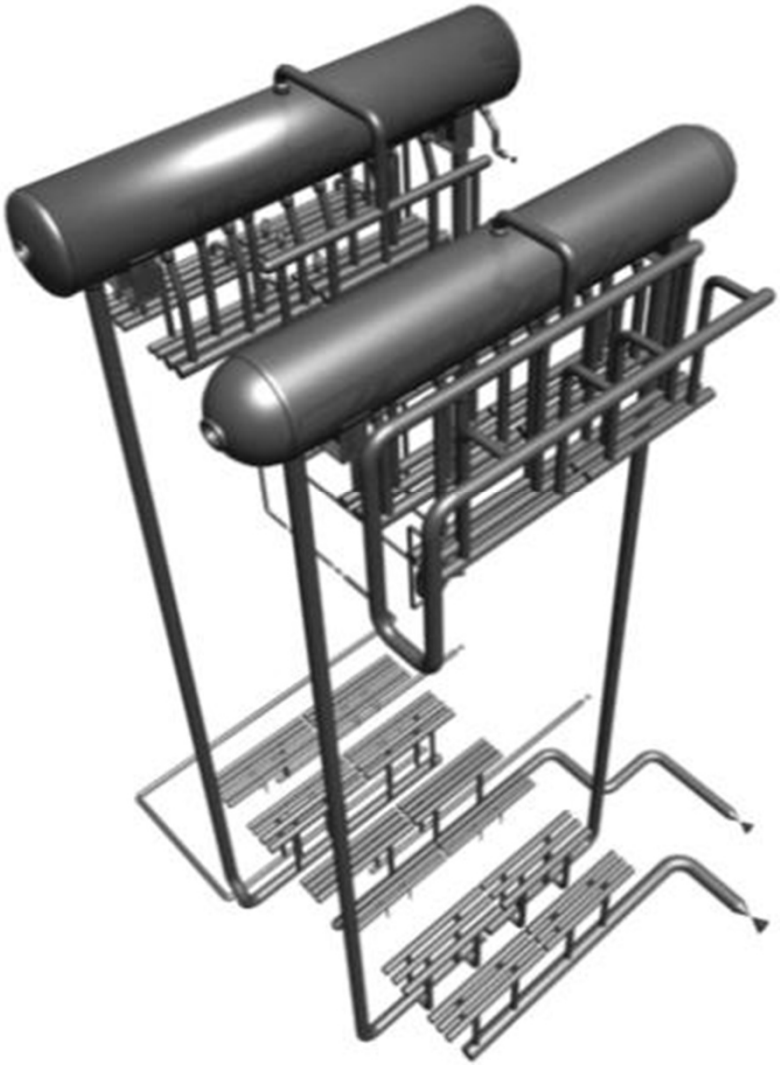
Why should AET be considered?

- Most of these components have no or limited access

- Traditional NDT takes longer and is very expensive, if doable at all

- AET can be done during transient conditions

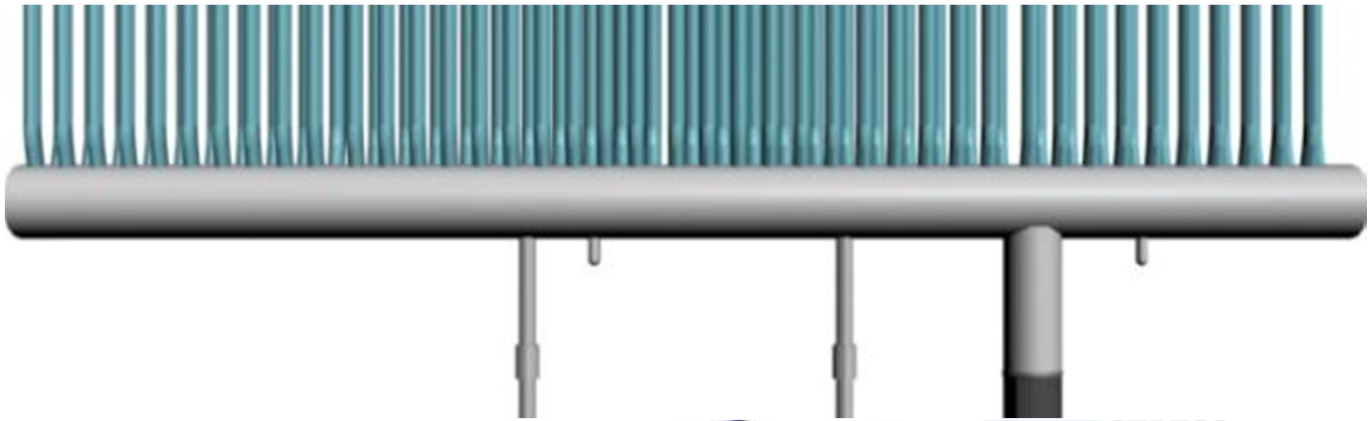
Difficult access - Drums and Headers



Difficult access - Tube x Headers Welds

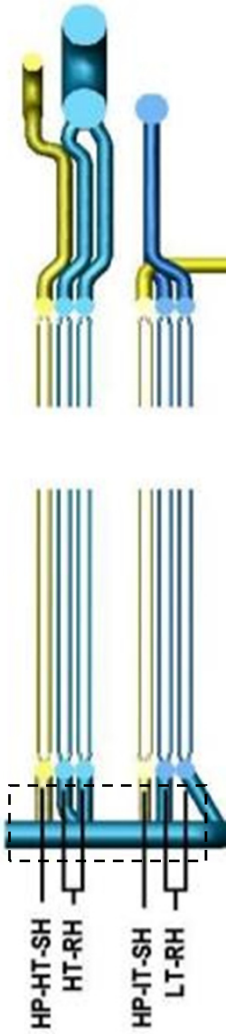
Medium size boiler example:

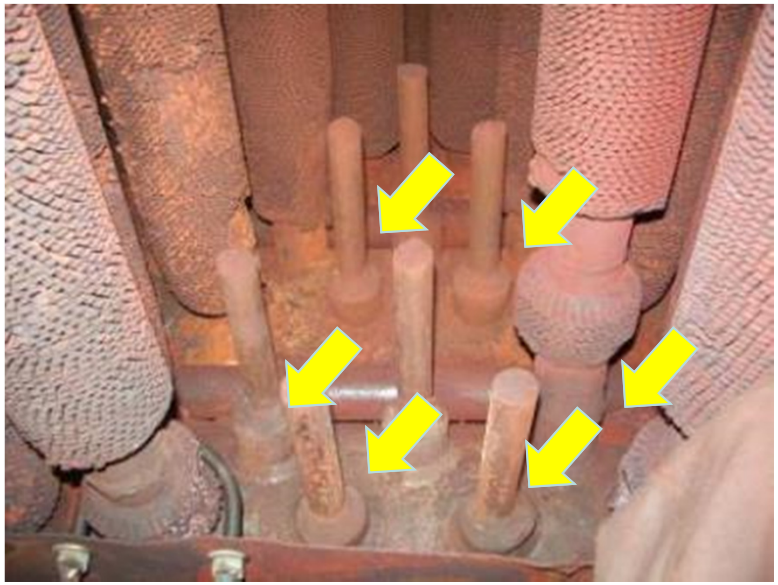
Headers	Number of welds
Each header	50
44 top headers	2200
44 botton headers	2200
Total Header/Tube welds	4400
Acessible Welds	6 headers botton 6 headers top Total = 300 welds



Difficult access - Tube x Headers Welds

ABLE TO INSPECT 300 WELDS (7%)





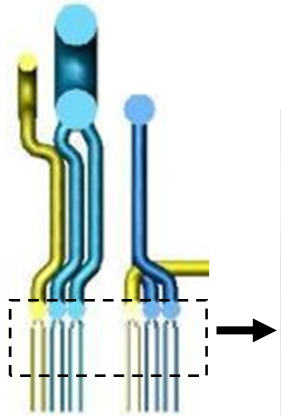
Araujo

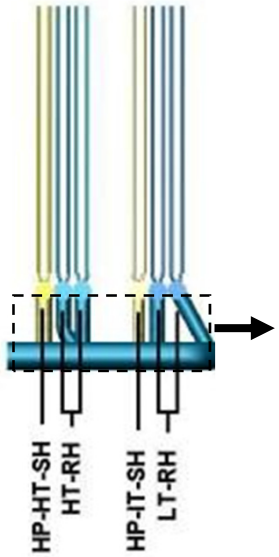
STRESS ENGINEERING SERVICES INC.

an employee-owned company

Difficult Access - Headers

ABLE TO INSPECT 100 to 200 HEADERS (50%)



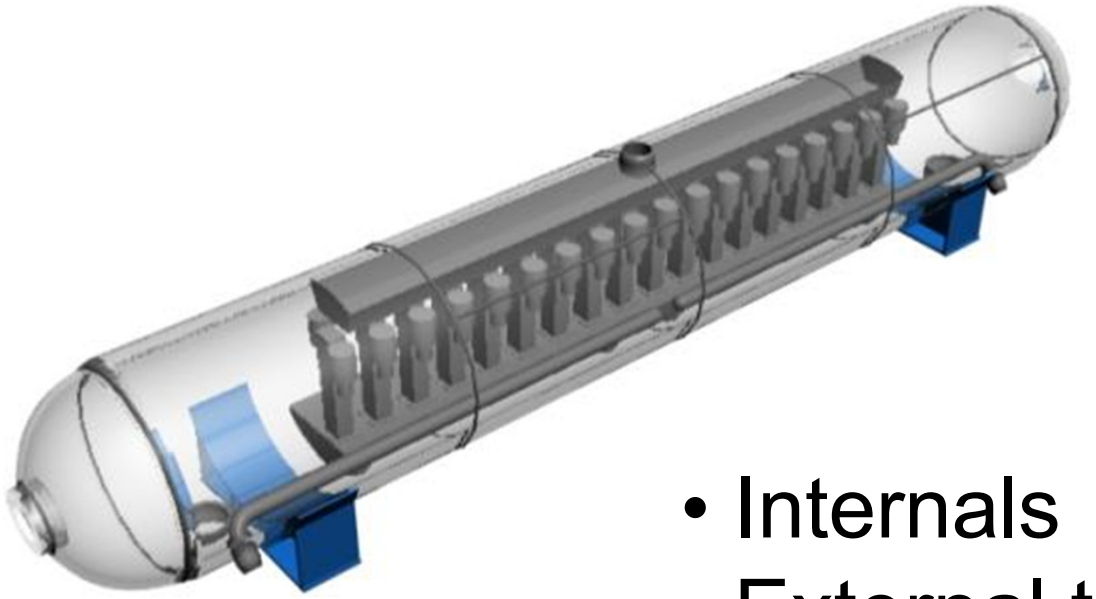


Araujo

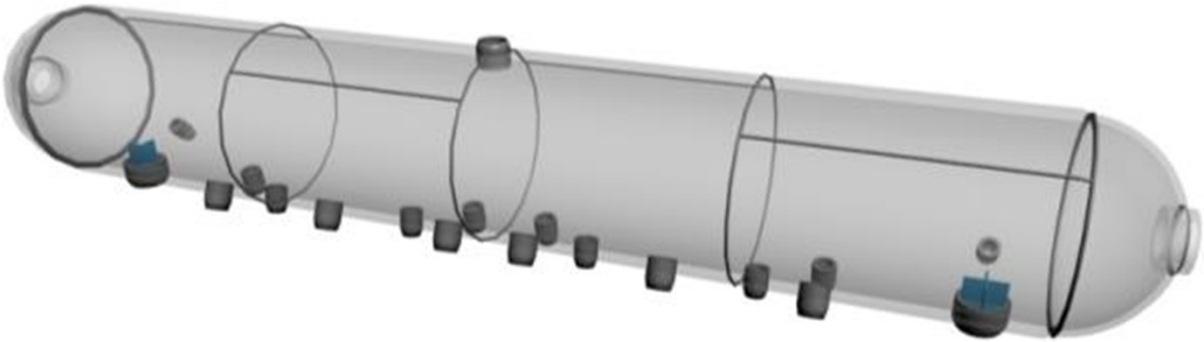
STRESS ENGINEERING SERVICES INC.

an employee-owned company

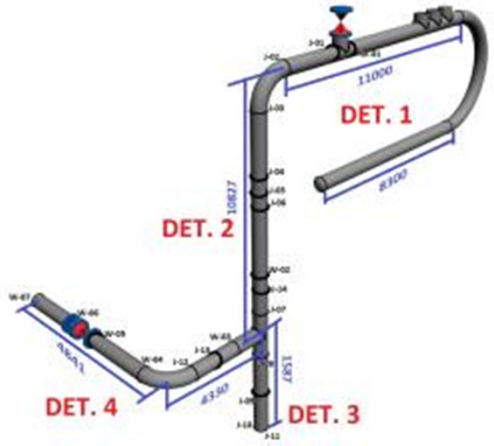
Difficult access for conventional NDT - Drums



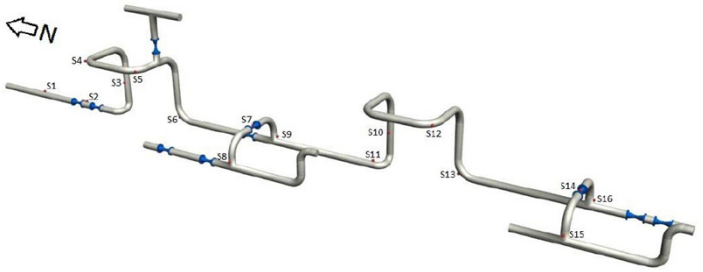
- Internals
- External thermal insulation



Difficult access for conventional NDT - Piping



- **External thermal insulation**
- **No access (scaffold needed)**



Araujo

STRESS ENGINEERING SERVICES INC.

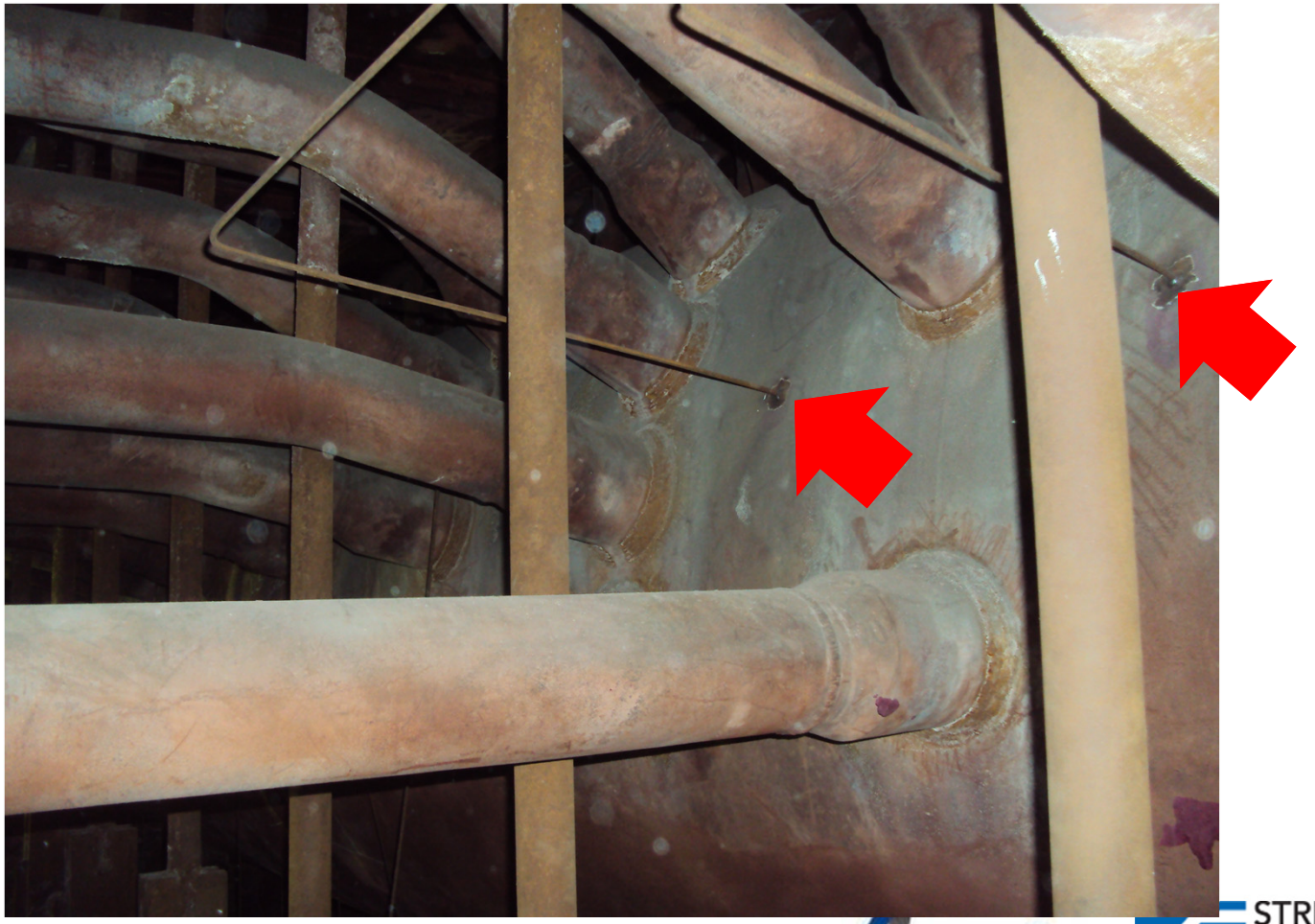
an employee-owned company

How to/when to apply AET as alternate NDT

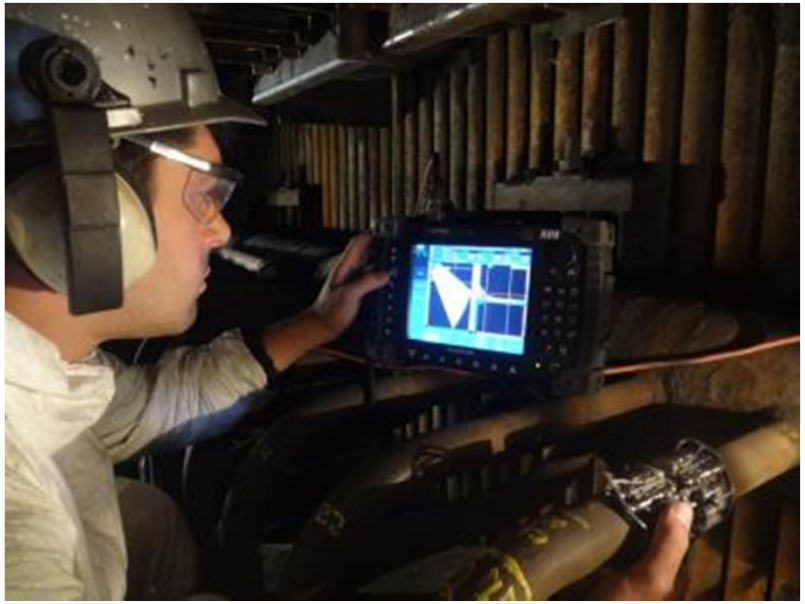
Execute NDT during...	Method
During normal operating conditions/themal swings/start-ups/cooldowns	- Acoustic Emission - Skin Temperature monitoring - Stress monitoring
During outages on areas flagged by AET	- Eddy Current - Advanced Ultrasonics - FMR/PT

Examples in next slides

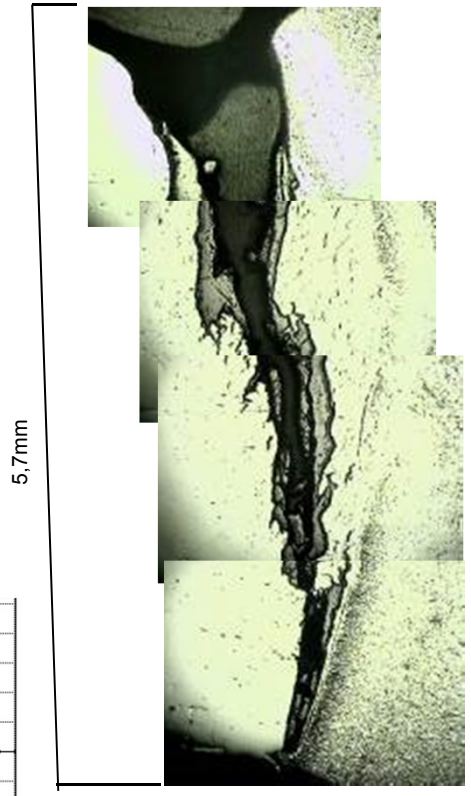
Welded waveguides onto a steam drum



PA/ET applied to “AE flagged” area during outage



Phased Array



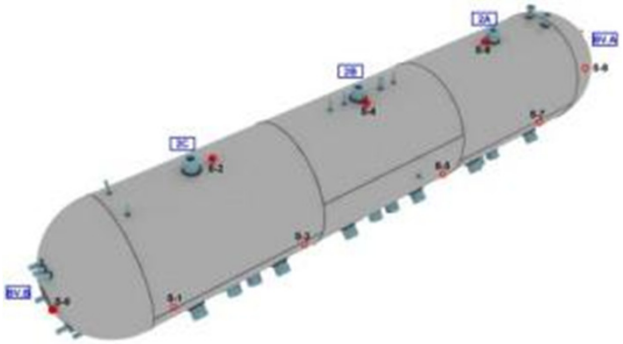
Eddy Current

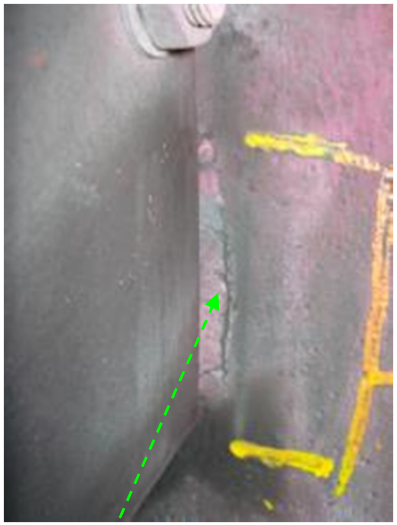
Araujo Engenharia e Integridade de Equipamentos

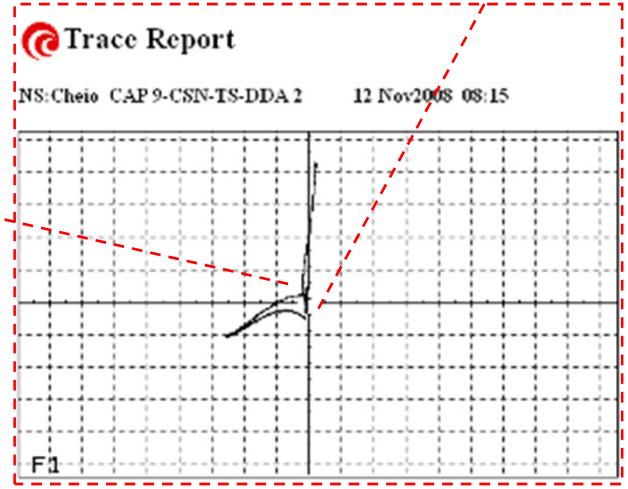
STRESS ENGINEERING SERVICES INC.

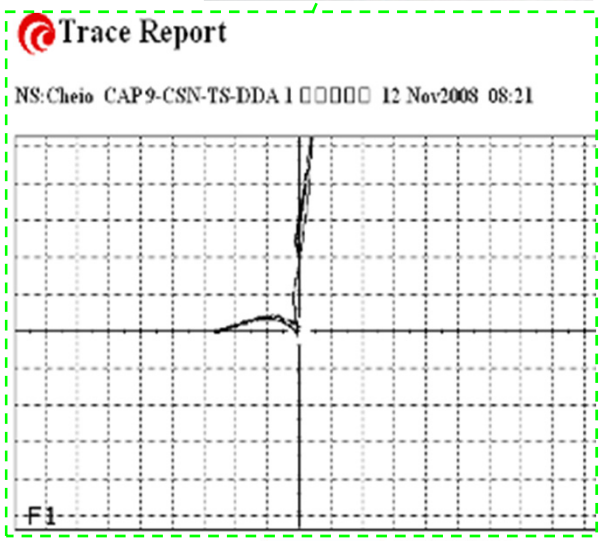
an employee-owned company

ET applied to “AE flagged” area during outage









Araujo

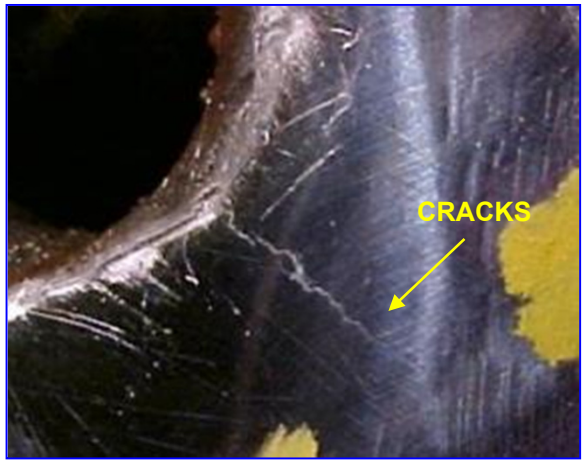
STRESS ENGINEERING SERVICES INC.

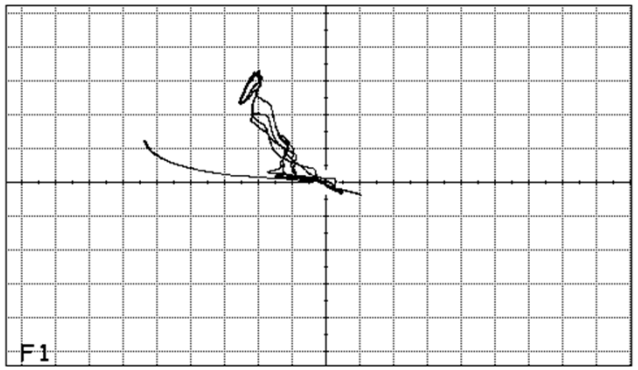
an employee-owned company

PA/ET applied to “AE flagged” area during outage

Phased Array

Eddy Current





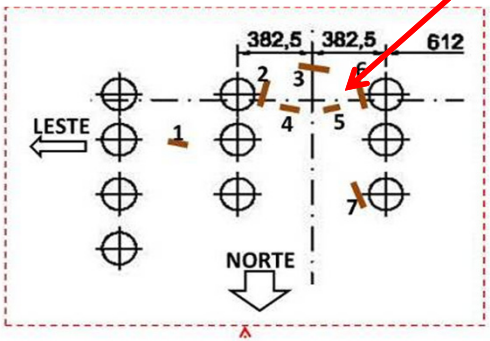
Araujo

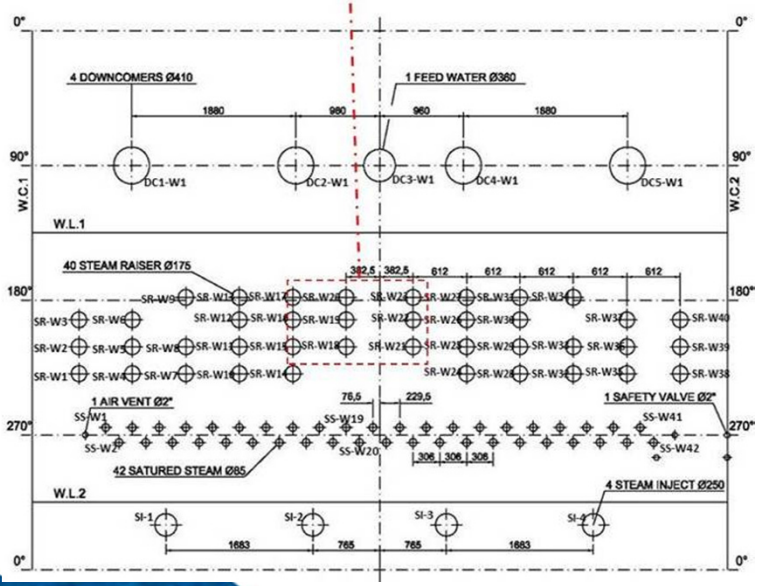
STRESS ENGINEERING SERVICES INC.

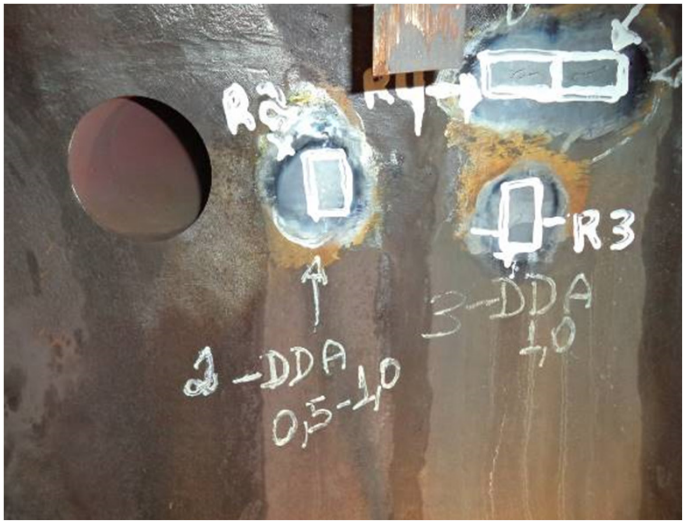
an employee-owned company

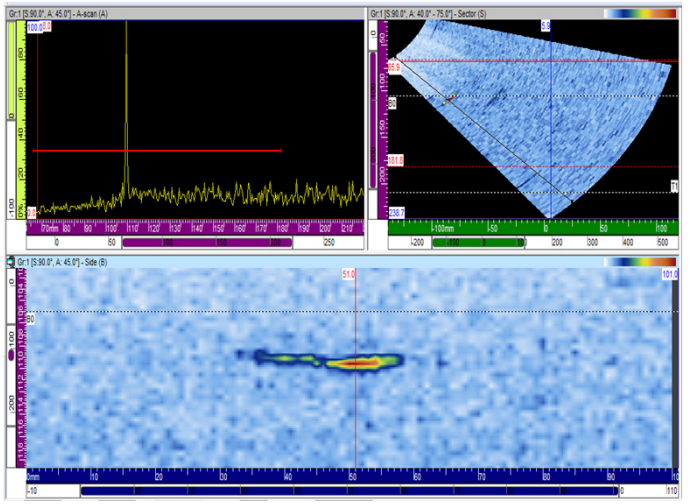
PA/ET applied to “AE flagged” area during outage

Drum









STRESS ENGINEERING SERVICES INC.

an employee-owned company

Conclusions

HRSG Inspections should be based on combining knowledge of process conditions, stress analysis, materials and possible damage mechanisms, and proper on stream AE monitoring, with selective NDT during outages

AET has been used as a powerfull on stream monitoring technique aiming at flagging areas with “crack-like” indications for follow-up during outages.

Thank you to our affiliate Araujo Engineering in Brazil for sharing their experiences.

Questions?