FAILURE ANALYSIS OF WASTE HEAT BOILER TUBES

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CHEMISTRY THAT MATTERS™

OUTLINE

- Background
- Process Description
- Schematic Diagram of Damage Locations
- Investigation
  - Visual Examination
  - Chemical Analysis
  - Metallography
  - SEM/EDS
- Conclusions

BACKGROUND

A petrochemical plant was shut down due to tubes leaks in a waste heat boiler (WHB).

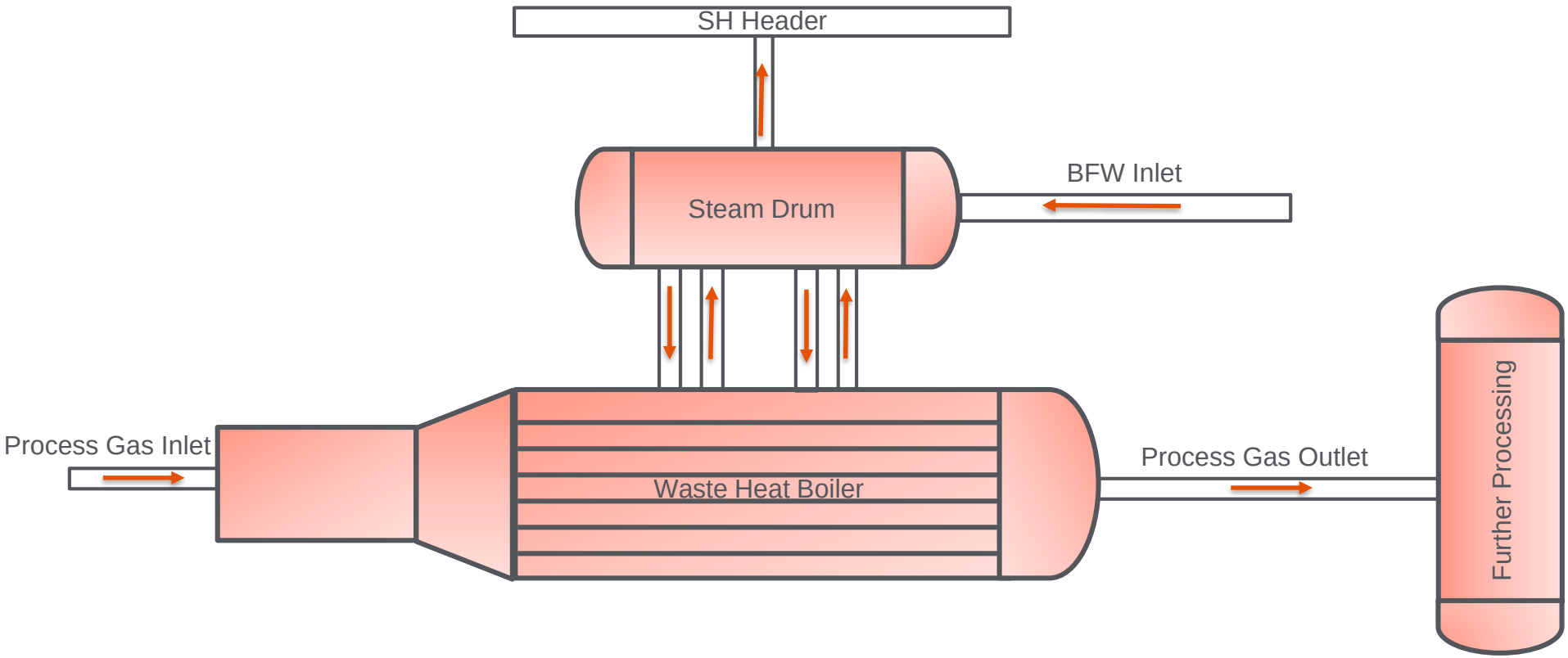
The failed WHB has been in operation for about 20 years, without any previous failure.

Following the incident, inspection activities revealed the following:

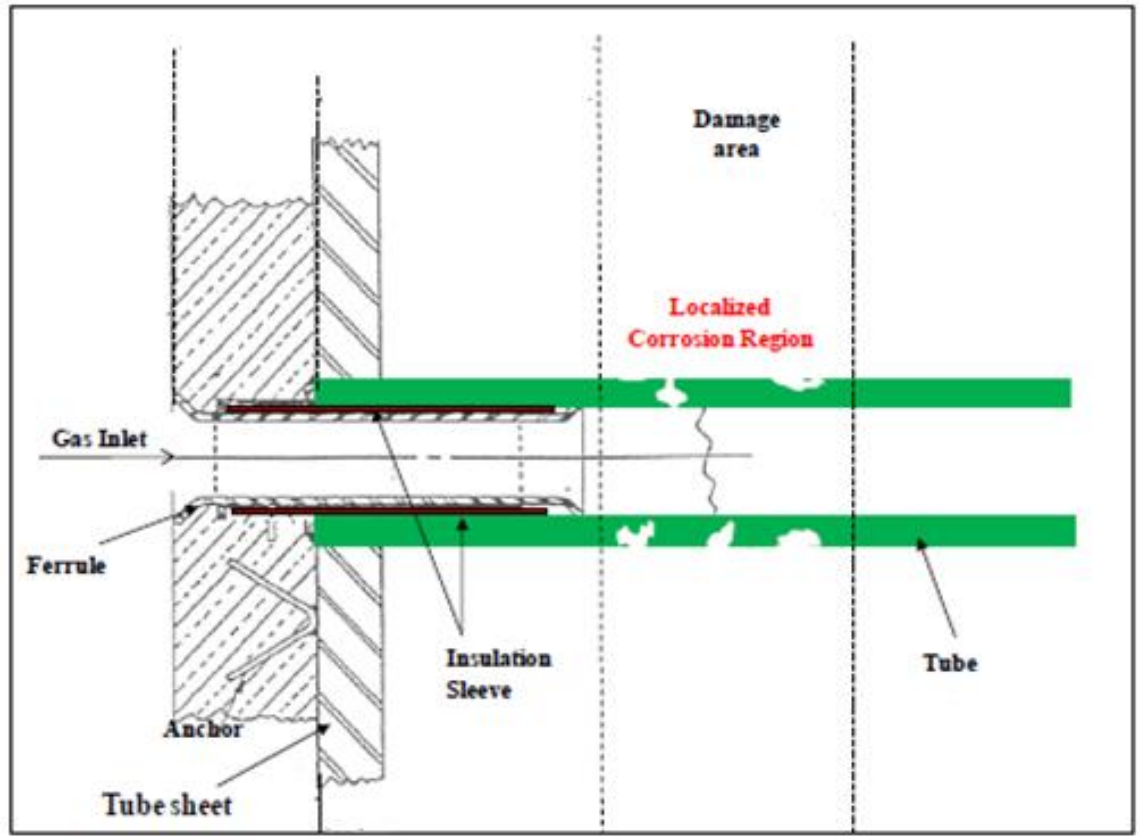
- Leaks were observed at 7 tubes.
- Localized damage was observed on 70% of the ferrules.
- Leakages were always observed after the end of the ferrules.
- Tubes were observed to be externally covered with a deposit.

A leaked tube and another severely thinned tube from the WHB were analyzed to determine the failure mechanism and contributing factors.

PROCESS DESCRIPTION



SCHEMATIC DIAGRAM OF DAMAGE LOCATIONS

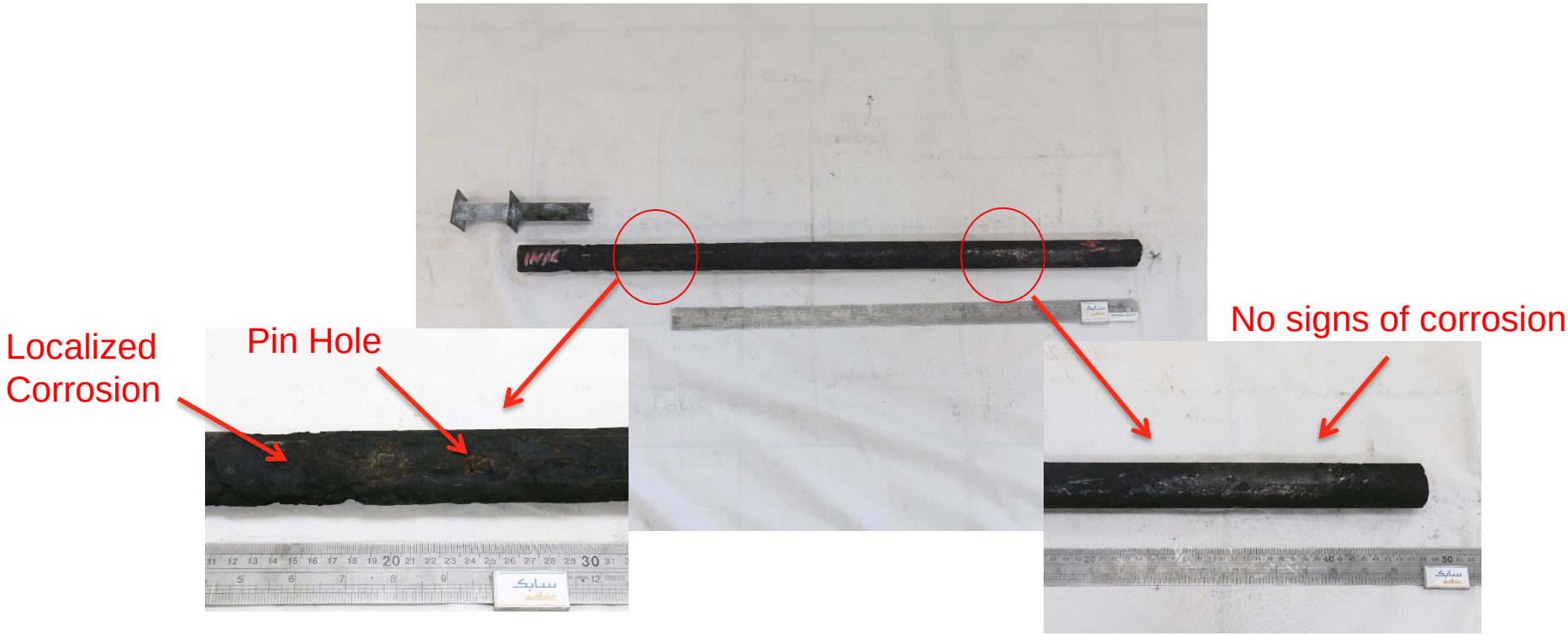


The damage has been observed to be confined to areas after the ferrule's end.

FAILURE ANALYSIS OF WASTE HEAT BOILER TUBES

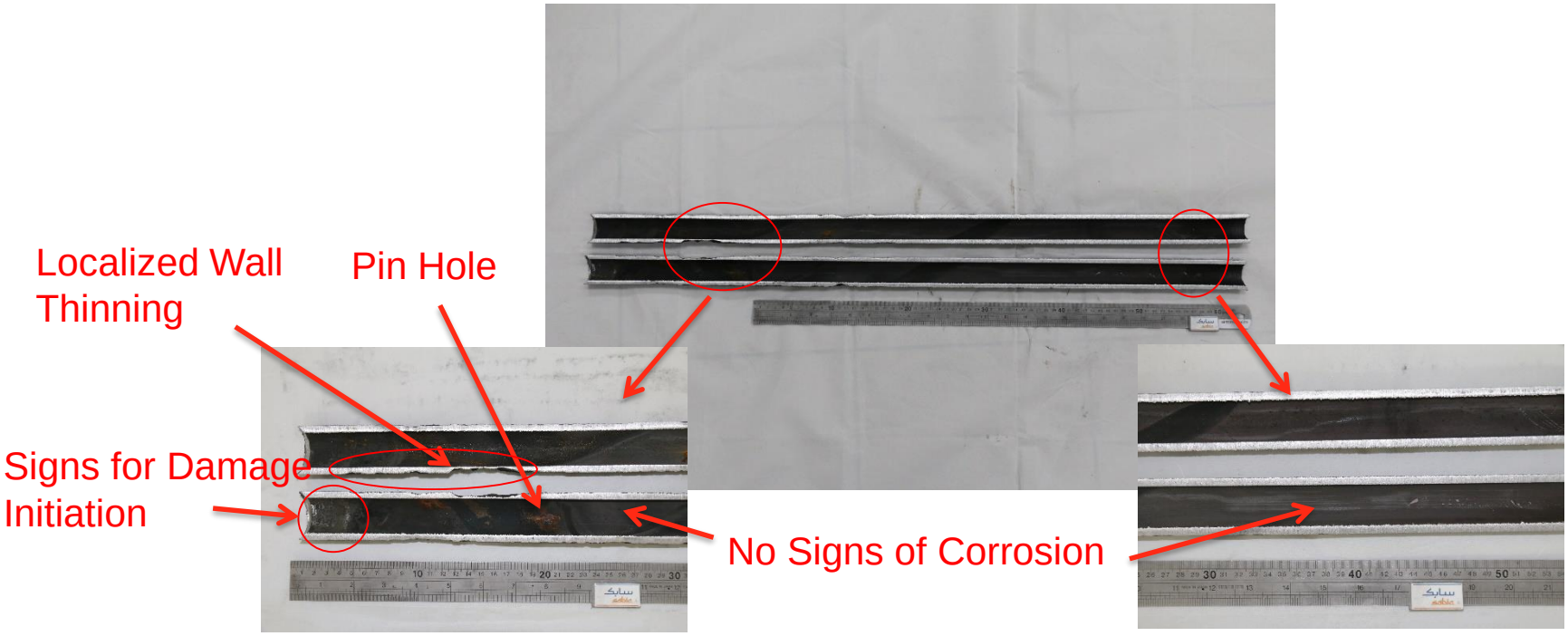
INVESTIGATION

VISUAL EXAMINATION OF THE LEAKED TUBE



The leaked tube sample in as-received condition.

THE INTERNAL SURFACE OF THE LEAKED TUBE

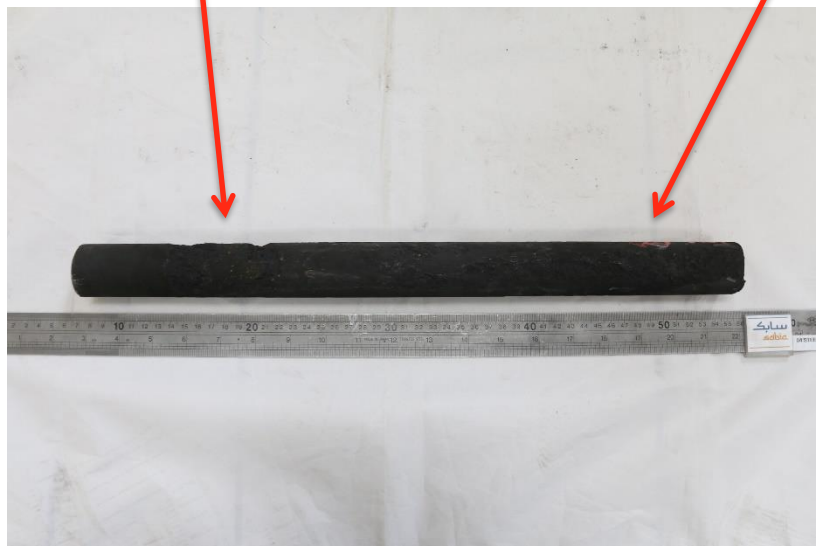


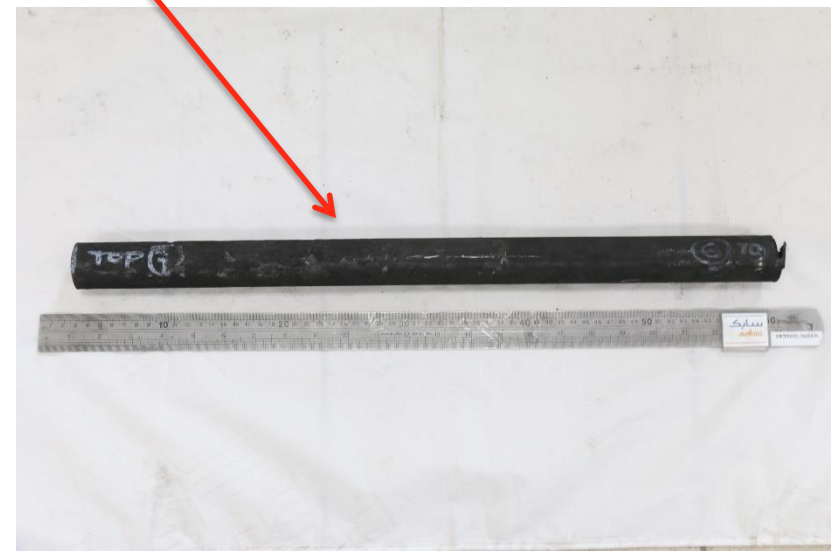
The internal surfaces of the leaked tube.

VISUAL EXAMINATION OF THE SEVERELY THINNED TUBE

Localized Corrosion

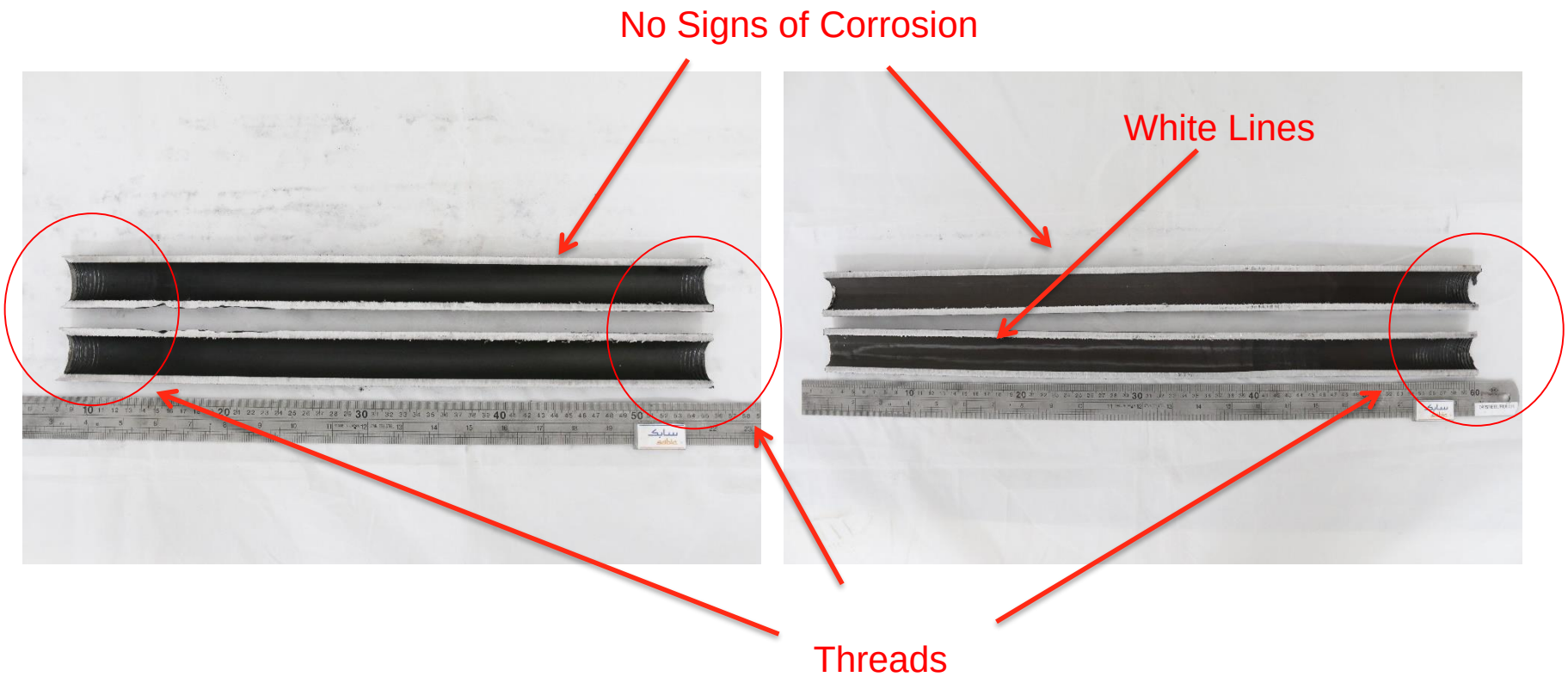
No signs of corrosion





The severely tube sample in as-received condition.

INTERNAL SURFACE OF THE THINNED TUBE



The internal surfaces of the thinned tube.

TUBES MATERIAL CONFIRMATION

XRF & C/S analyses (wt.%).

Element	Sample	ASTM SA213 T12*
C	0.13	0.05–0.15
Mn	0.44	0.30-0.61
Si	0.24	0.50
Cr	0.85	0.80–1.25
Mo	0.44	0.44–0.65
Fe	Balance	Balance
P	0.040	0.025
S	0.012	0.025

*Maximum unless otherwise indicated

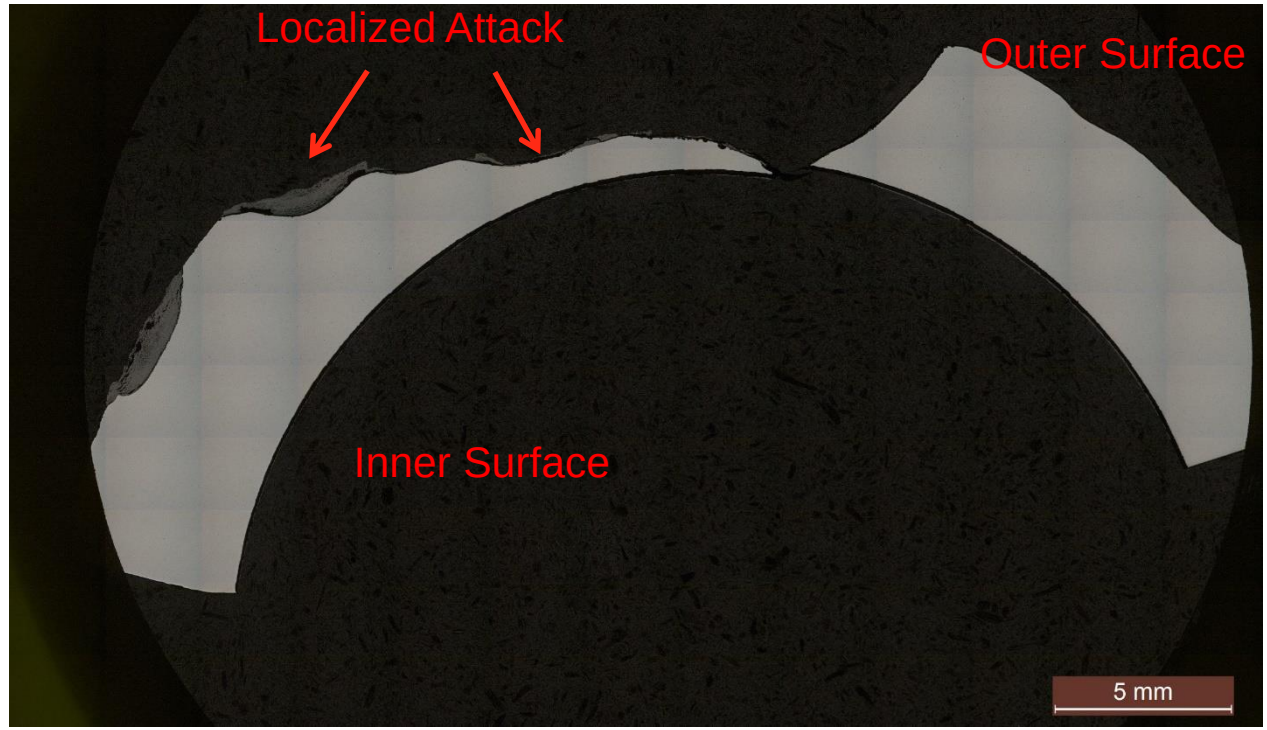
The chemical composition of the materials closely matches the chemical composition of ASTM SA 213 T12.

CHEMICAL COMPOSITION OF DEPOSIT FOUND ON TUBES EXTERNAL SURFACES

XRF & C/S analyses (wt.%).

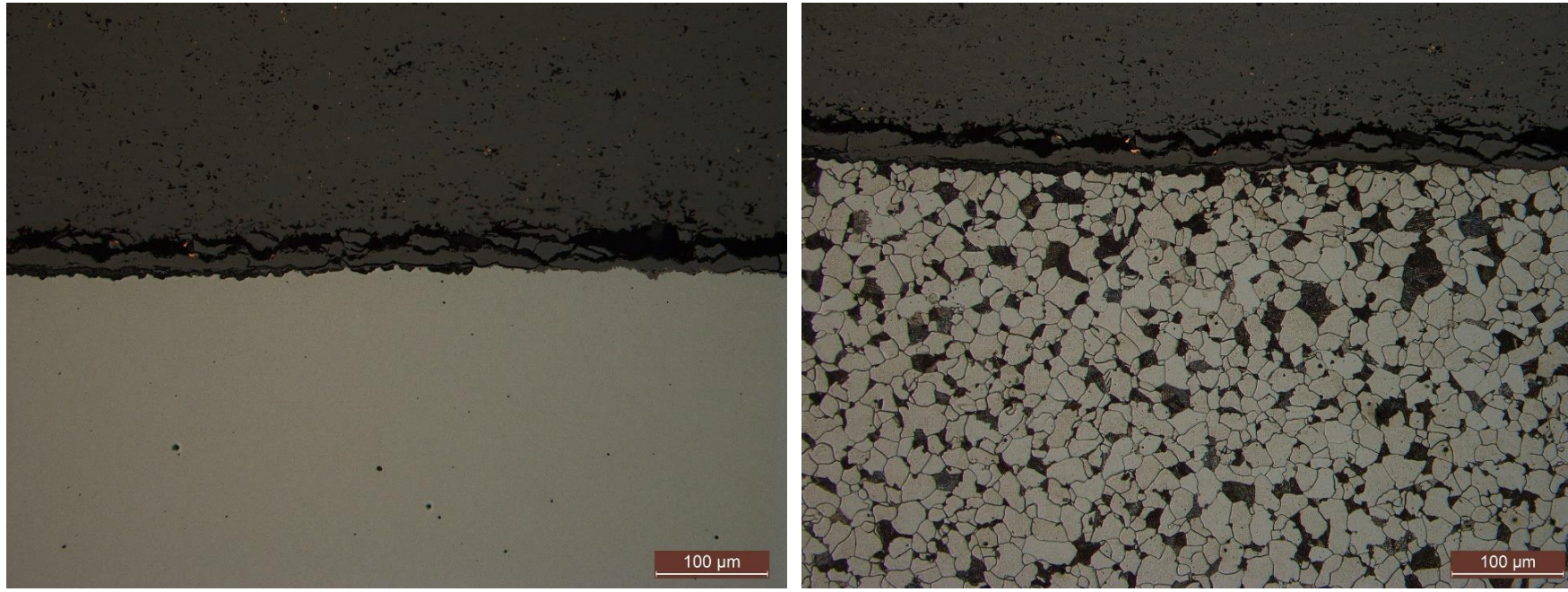
Element	Sample
C	0.04
Mg	0.04
Al	0.08
Si	0.17
P	0.03
S	0.02
Cl	0.02
Ca	0.04
Cr	0.61
Mn	0.34
Fe	Balance
Ni	0.08
Cu	0.10
Mo	0.42

CROSS SECTION OF THE LEAKED TUBE



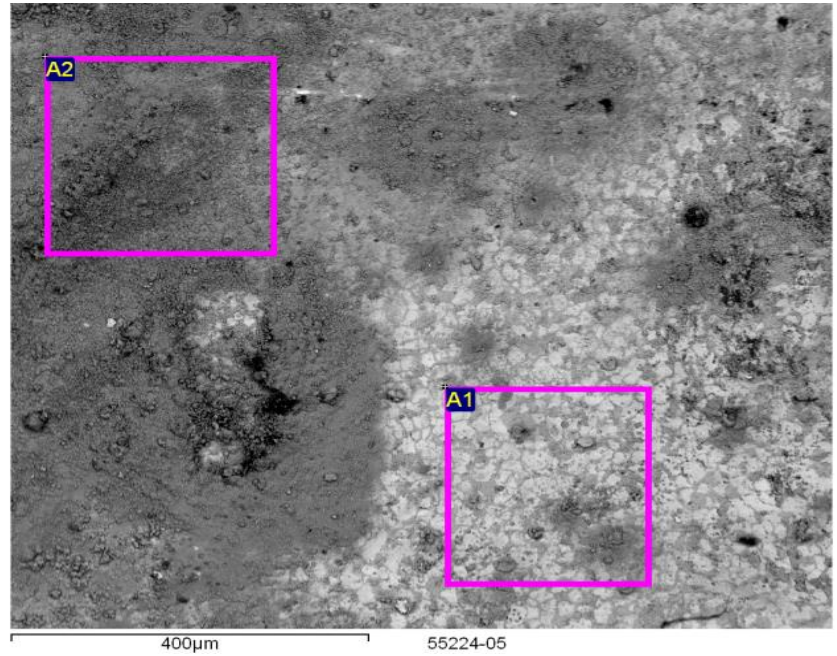
Micrographs showing severe localized corrosion from the outer surface.

MICROSTRUCTURAL ANALYSIS OF TUBES



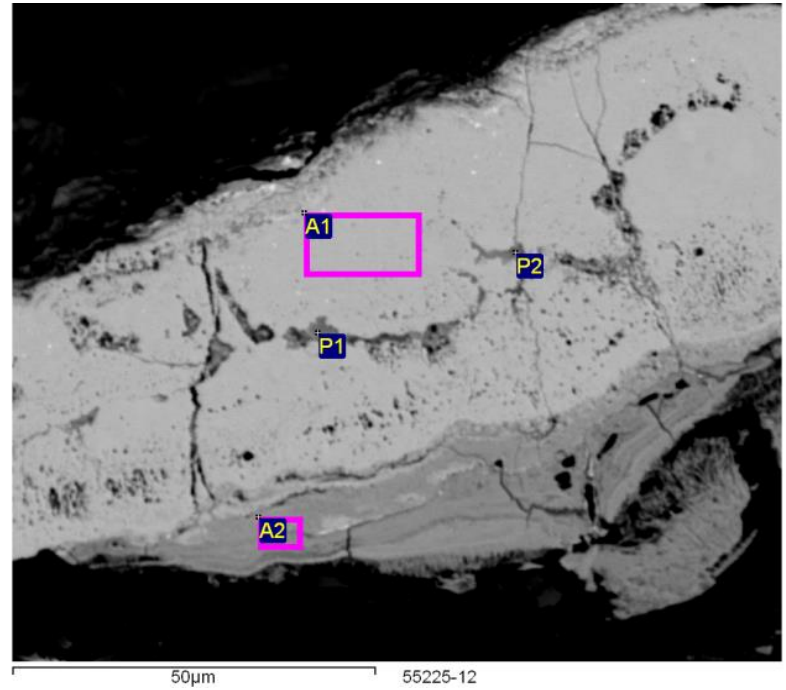
Micrographs of the leaked tube, as polished (left) and etched with 2% Nital (right).

SEM/EDS OF TUBE EXTERNAL SURFACE NEAR PINHOLE



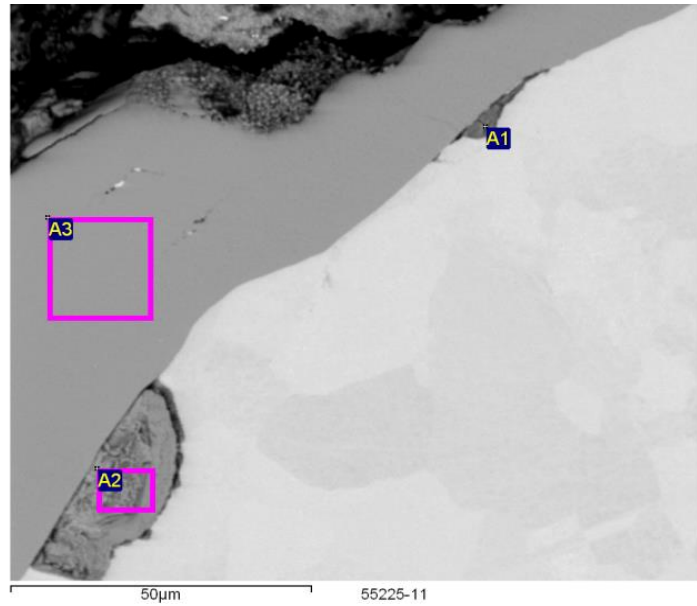
Spectrum	C	O	Na	Si	S	Fe	Cu
A1	2.51	22.79		0.22	0.20	73.53	0.75
A2	2.59	34.73	0.18	0.33		62.17	

SEM/EDS OF TUBE INTERNAL SURFACE AT PINHOLE



Spectrum	C	O	Na	Al	Si	P	Ca	Mn	Fe	Mo
A1	1.17	32.02	0.46		0.38				65.13	0.83
P1	2.45	33.54	0.66	0.15	0.90	5.87	0.31	7.30	48.82	
P2	2.13	33.27	1.02	0.35	0.31				61.54	1.38
A2	2.55	35.51	0.18	0.28	0.12				61.37	

SEM/EDS OF TUBE EXTERNAL SURFACE AT PINHOLE

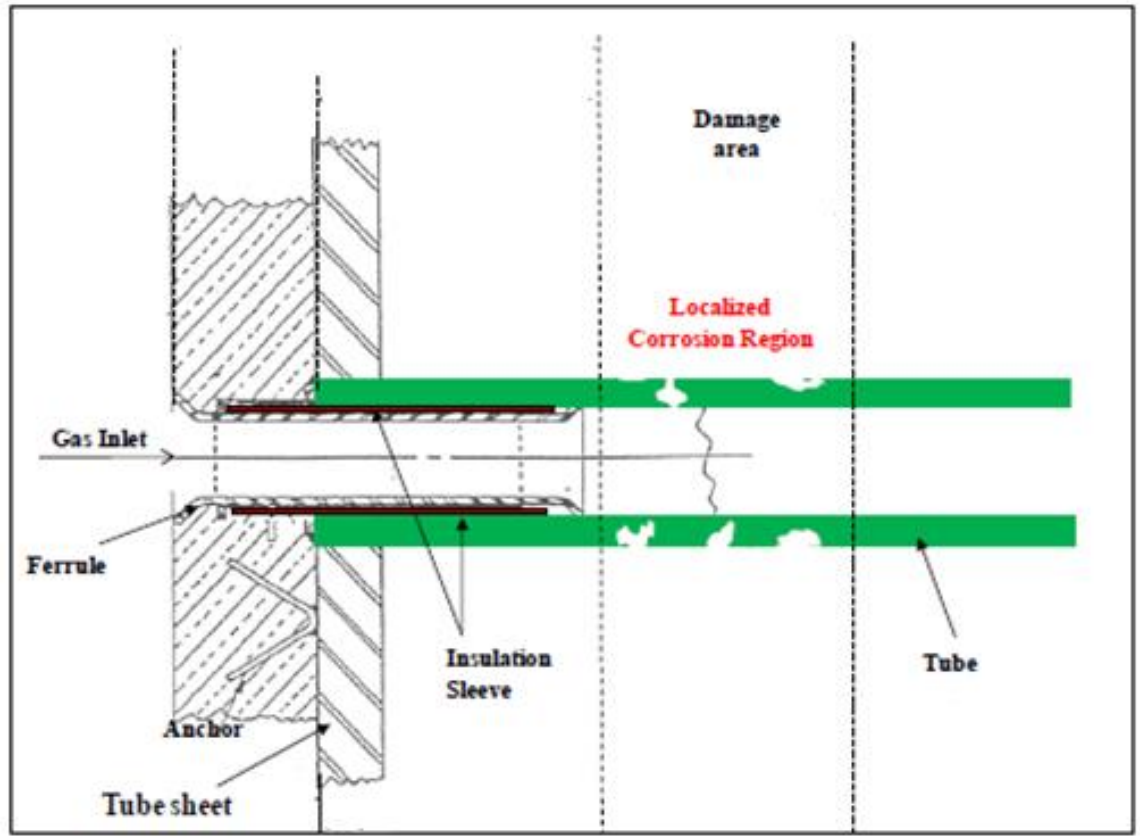


Spectrum	C	O	Si	S	Cl	Fe	Cu	Mo
A1	1.76	35.54	0.65		0.42	60.99	0.64	
A2	3.86	32.57	0.64	0.68		62.26		
A3	1.30	31.87	0.31			65.72		0.80

FAILURE ANALYSIS OF WASTE HEAT BOILER

CONCLUSIONS

FAILURE MECHANISM



The experimental observations suggest that the tubes failed by caustic gauging.

CONCLUSIONS

- The experimental observations suggest that the tubes failed by caustic gauging.
- The damage is confined to a small portion of the tubes where deposit formation has been observed.
- Deposition resulted mostly due to the quality of BFW.
- Reduction of temperature gradient at the entrance of the boiler could help in reducing deposition.

THANK YOU!