معهد ابتكار تقنيات المياه والأبحاث المتقدمة
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WTIIRA

الهيئة السعودية للمياه
Saudi Water Authority

JUBCOR 2024
CONFERENCE & EXHIBITION
INNOVATIVE SOLUTIONS FOR CORROSION CHALLENGES

Flow-Accelerated Corrosion in Steam Generating Plants

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Introduction

Severe corrosion failures may occur due to elevated temperature conditions in thermal desalination plants.

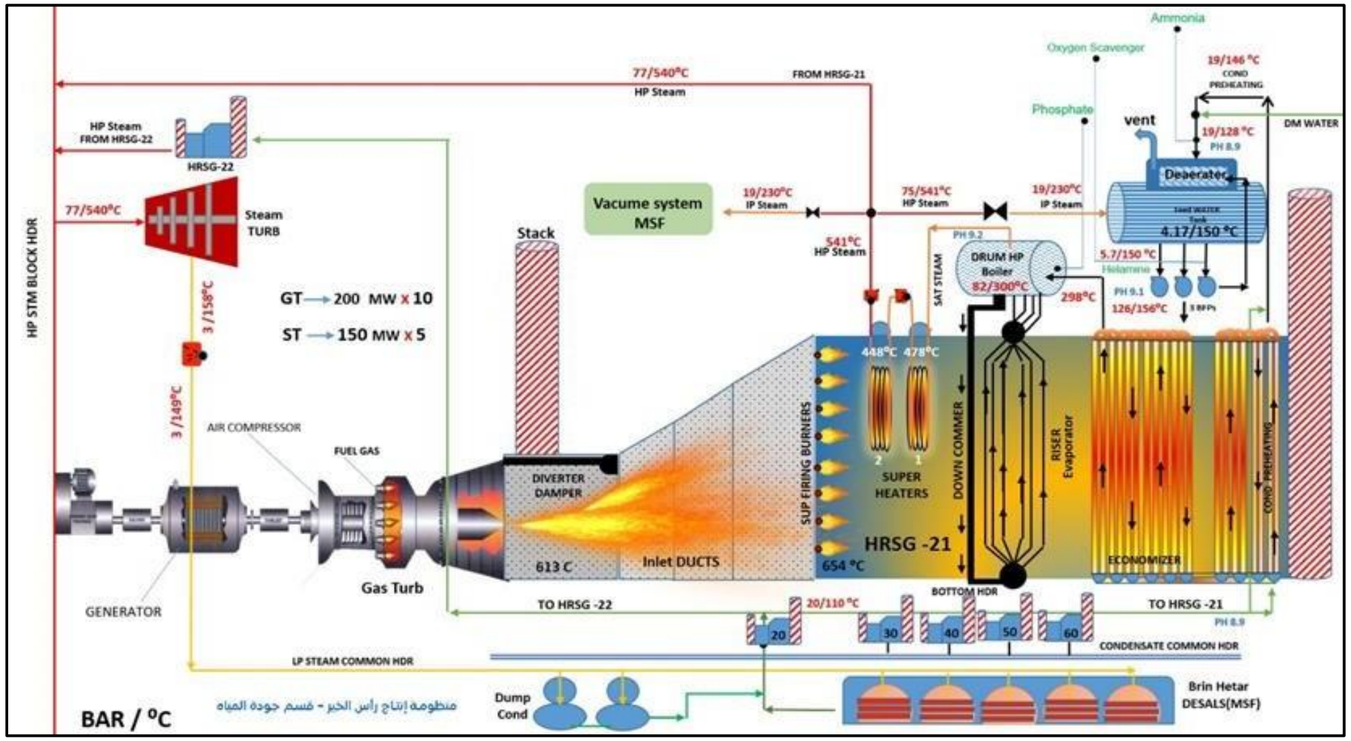
Protective measures such as:

- Chemical treatments,
- Operation conditions control,
- Water chemistry analysis,
- Periodic maintenance,

Are usually followed to avoid material failures.

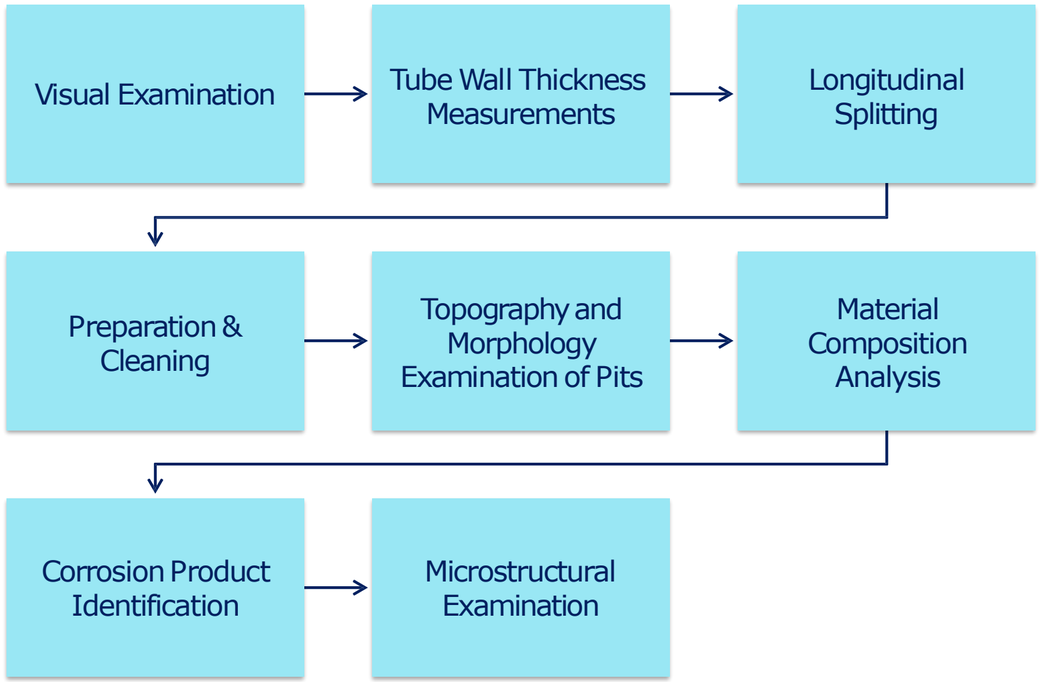
Introduction

- A Heat recovery steam generator (HRSG) is utilized to produce steam that runs the turbine to generate electricity.
- Heat is exchanged between the hot flue gases and the network of water lines through the tube walls.
- Failures due to flow-accelerated corrosion (FAC) were experienced in multiple HRSGs. Consequently, a failure investigation was carried out.



Failure Analysis

- Tube samples, from bend sections of different HRSGs, were received to be investigated.
- Root cause failure analysis was performed as follows:



Failure Analysis

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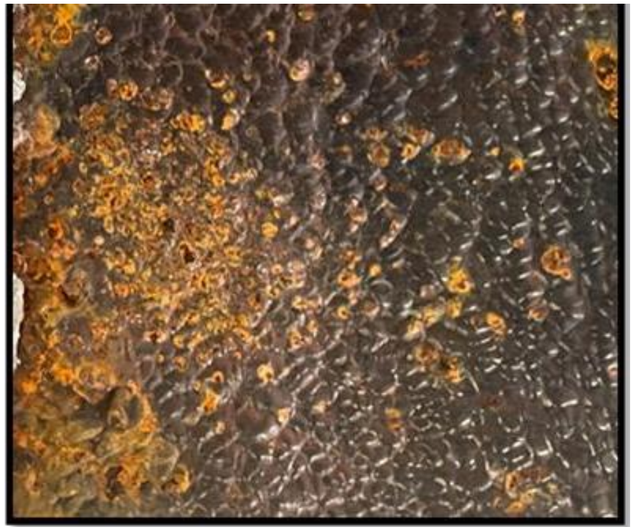
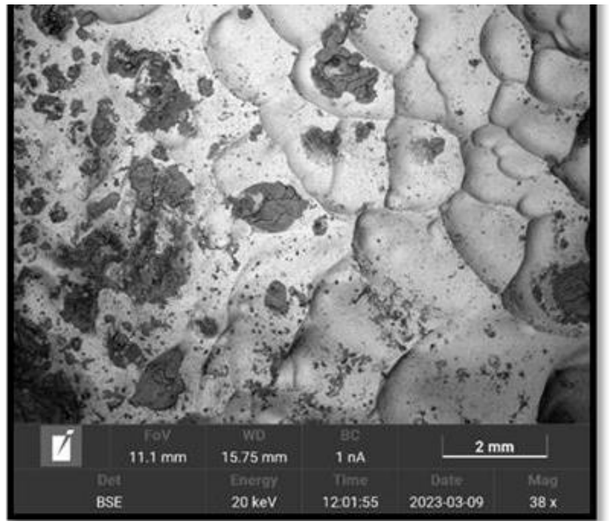
As received economizers tubes



Low magnification picture

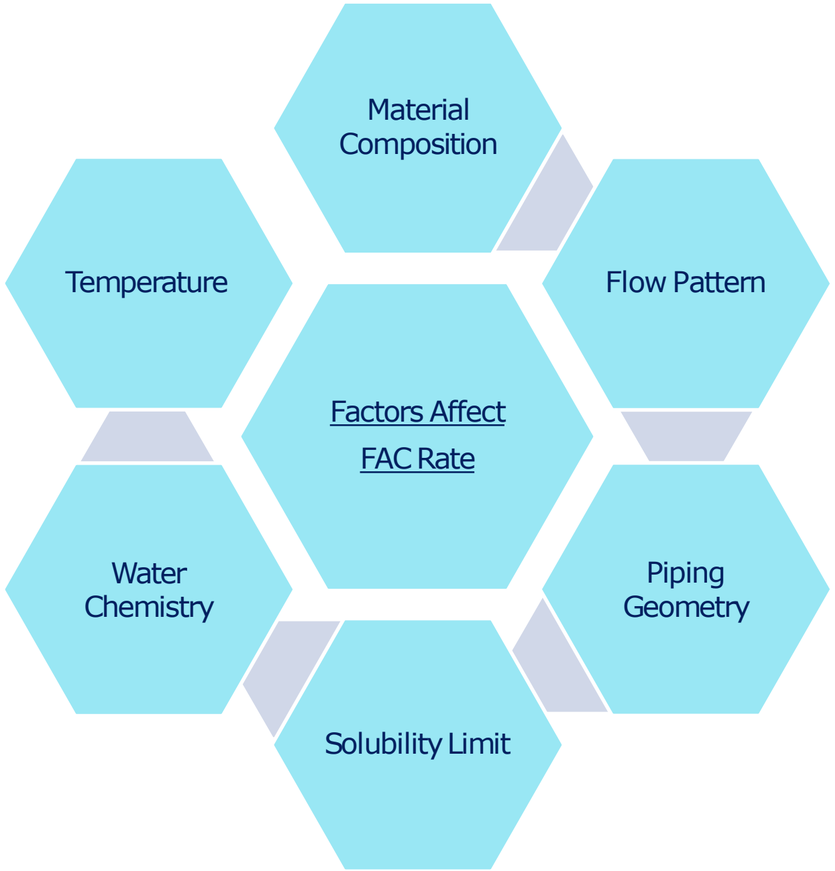


SEM magnified picture

Figure 1. Views of received tubes showing scalloping pits, typical of FAC morphology.

Failure Analysis

- Failure morphology of the tube's internal surfaces was consistent with FAC.
- Partial dissolution of the magnetite layer & exposing the bare metal to the fluid medium are the main reasons for having FAC.



Failure Analysis

- The solubility limit of metallic ions strongly affects the FAC rate.

The flow turbulence and operating conditions influence FAC rate.

- The signature of this type of corrosion appears as micro-pits which are often called horse-shoe pits or scallops.

- This type usually incorporates an increase in the roughness of the inner surface of the tubes.

Analyses Results

Thickness measurements of the tubes verified are undergoing an extremely severe corrosion process, resulting in the thinning of the walls.

Tube	Original Tube	Tube No.1	Tube No.2	Tube No.3
Minimum Thickness Measurement (mm)	2.98	1.45	2.6	1.64
Tube Wall Loss	-	51%	13%	45%

Material chemical composition was tested by OES and CS,
Results complied with the standard composition of low alloy steel.

Element	C%	Mn%	Si%	P%	S%	Fe%
Failed tube	0.16	0.44	0.2	0.0146	0.0129	Balance
SA210-A1 Standard Composition	0.27 Max.	0.93 Max.	0.1 Min.	0.035 Max.	0.035 Max.	Balance

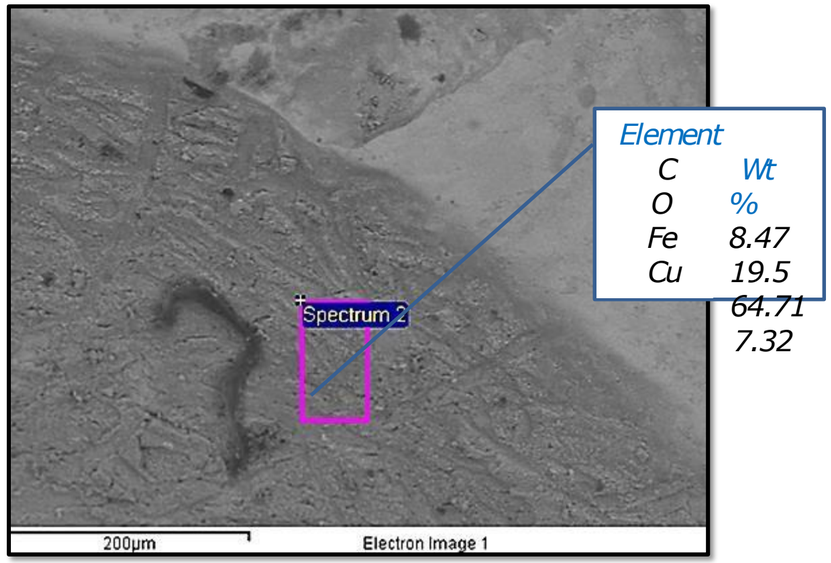
Analyses Results

Elemental analyses showed a lack of magnetite layer (Fe_3O_4) formation on the tube's internal surfaces.

Element	Tube No. 1		Element	Tube No. 2	
	Weight%	Atomic %		Weight%	Atomic %
Fe	71.06	41.63	Fe	49.75	24.49
O	20.16	41.23	O	22.37	38.45
C	5.62	15.32	Al	14.12	14.39
Cu	2.73	1.4	C	7.9	18.08
Si	0.17	0.2	Na	2.78	3.33
Cr ديقم	0.15	0.09	Pt	1.69	0.24
P	0.11	0.12	S	0.62	0.53
			Cl	0.41	0.32
			Mn	0.36	0.18

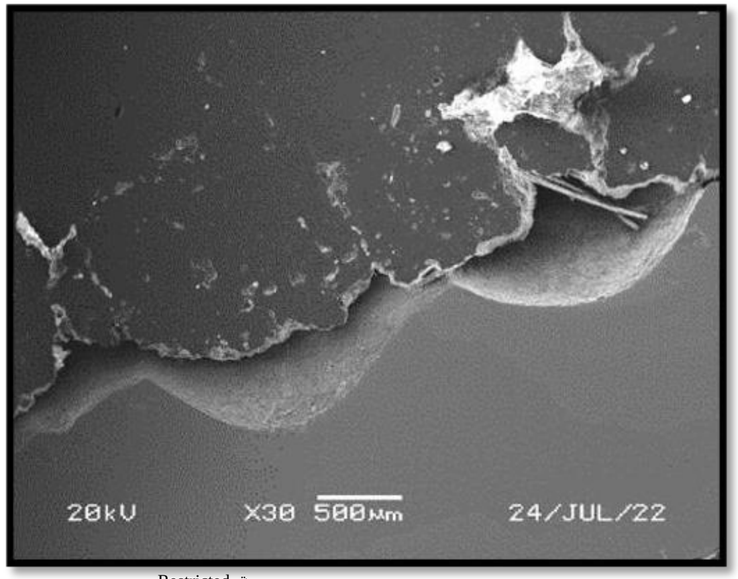
Analyses Results

- All ratios of oxygen to iron (mostly 1:1) indicated the presence of the Wustite layer and the probable presence of the Hematite layer.
- These oxide layers provide weaker protection & less adherence to the metal surface than the Magnetite layer.
- As a result, the economizer tubes were not effectively protected and are more susceptible to localized corrosion attacks.

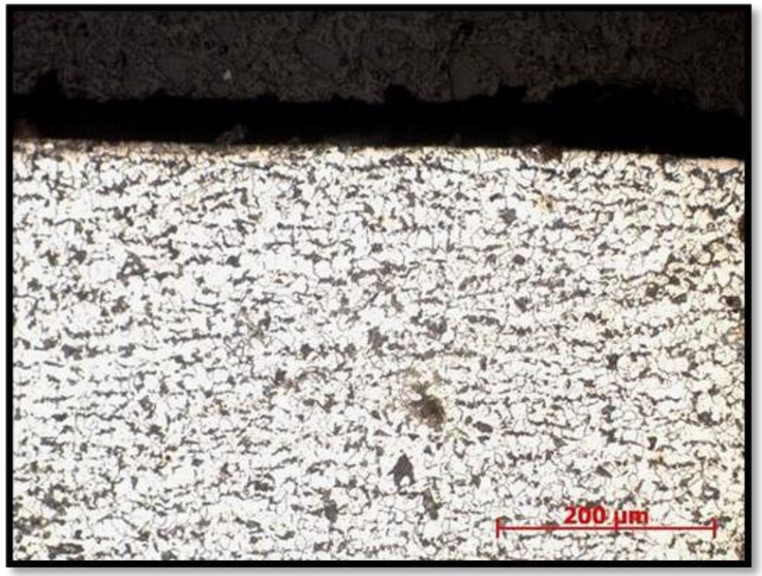


A high content of copper (7.3 weight%) was identified on the internal surface of one of the tubes.
This may enhance the corrosion rate due to the higher cathodic potential of cu than Fe.

Analyses Results



The scalloping pattern of pit morphology was observed in different samples, Confirming FAC mechanism.



Tube microstructure showed pearlite structures, ruling out possibilities of overheating of the tubes.

Conclusions

- HRSG operates at elevated temperatures subjecting the metallic tubes to corrosion attack if not protected by the formation of Magnetite layer on the internal surfaces of the tubes.
- Flow pattern and piping geometry have a considerable impact on fac initiation & progression. Turbulence may be experienced in bend areas.
- Turbulent fluid dynamics and deficiency of magnetite layer formation results in the removal of loosely held oxide scales locally & cause pitting problems.

- Based on the analysis results, it was found that material loss and pitting of HRSG tubes were due to FAC and not due to erosion corrosion, or overheating of tubes.
- Poor corrosion protection (insufficient magnetite formation) provided by the chemical treatment of the BFW seems the root cause of this failure.
- After changing the BFW chemical treatment & maintaining pH (9.2-9.6), dissolved oxygen (<10 ppb) & iron content (<20 ppb), FAC in HRSGs was significantly eliminated.

Remedial Measures

- The Economizer tubes should be inspected regularly per the instruction of the boiler manufacturer. Damaged tubes should be replaced with new tubes containing 1%-2% Cr.
- The Oxidation-reduction potential (ORP) measurement system should be used to monitor the passivation potential of the tube material (Magnetite formation).
- The Concentration of solid Iron particles should be monitored to be below 5 ppb.
- These measures help to make necessary changes in the chemical treatments before failure.
- Maintain the pH of the BFW between 9.5 - 10.0 by ammonia (<1 ppm).

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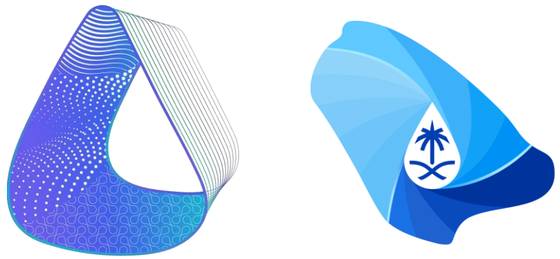

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