Welcome

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1ST NACE - JUBAIL INDUSTRIAL FORUM

Water Treatment & Cathodic Protection

"Impact of Deposit on Operation of Package Boiler"

Dr. AVTANDIL KHALIL BAIRAMOV
Consultant
SABIC Technology Center - Jubail
Materials and Corrosion Section

Al - Jubail,
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INTRODUCTION

- Currently SABIC has about 100 package boilers : Few LP; about 90% MP; 8 % HP
- UB rather complex and expensive units fabricated in 7 countries with 13 companies
- Problem dramatically aggravated by fact that there is no idle boiler.
- Generally, investigation into UB failures is a complicated multidisciplinary process with involvement of water treatment, operation, metallurgy, high pressure welding, mechanical integrity, NDE, refractory, fuel quality, cleaning technologies, etc.
- Most of plants commissioned in early 80s have a service life ranging between 1 to 29 years and above.
- Before 1997 there are no records in MCS database of UB failures.

DEPOSIT

Generally, boiler feed water must be sufficiently free of deposit
Actually, deposits result from feed water hardness contamination, and corrosion products moved from condensate and feed water system

4 sources:
water born minerals; used different water treatment chemicals; loose corrosion products moved from preboiler and boiler systems; different contaminants (oxides formed adherent tenacious layer at origination sites are not deposits)

Common components boiler deposits :
phosphates, carbonates, silicates, hydroxides, sulfates, metal oxides, copper, alumina etc.

Deposits act as insulators:
significantly reduce heat transfer; rapid rise in tube metal temperature and may lead to tube-failure by overheating

Large amount of thick deposits throughout boiler can reduce its efficiency

Thermal conductivities ($W/m^2 \cdot °C$) of metals, alloys and deposits

304 SS	Fe-Cr-Ni	22 (500°C)
410 SS	Fe-Cr	28 (400°C)
Carbon steel	Fe	55*
Aluminum	Al	235*
Copper	Cu	420*
Calcium carbonate (Aragonite)	$CaCO_3$	0.14
Calcium phosphate	$Ca_3(PO_4)_2$	0.55
Calcium sulfate (Anhydrite)	$CaSO_4$	0.21
Magnesium oxide	MgO	0.17
Magnesium phosphate	$Mg_3(PO4)_2$	0.33
Serpentine	$3MgO \cdot 2SiO_2 \cdot 2H_2O$	0.16
Aluminum oxide	Al_2O_3	3.6
Quartz	SiO_2	0.24
Ferric oxide (Hematite)	Fe_2O_3	0.09
Magnetite	Fe_3O_4	0.45
Acmite	$Na_2O . Fe_2O_3 . 4SiO_2$	0.01
Analcite	$Na_2O . Al_2O_3 . 4SiO_3\ 2H_2\ O$	0.10
Porous materials		0.01

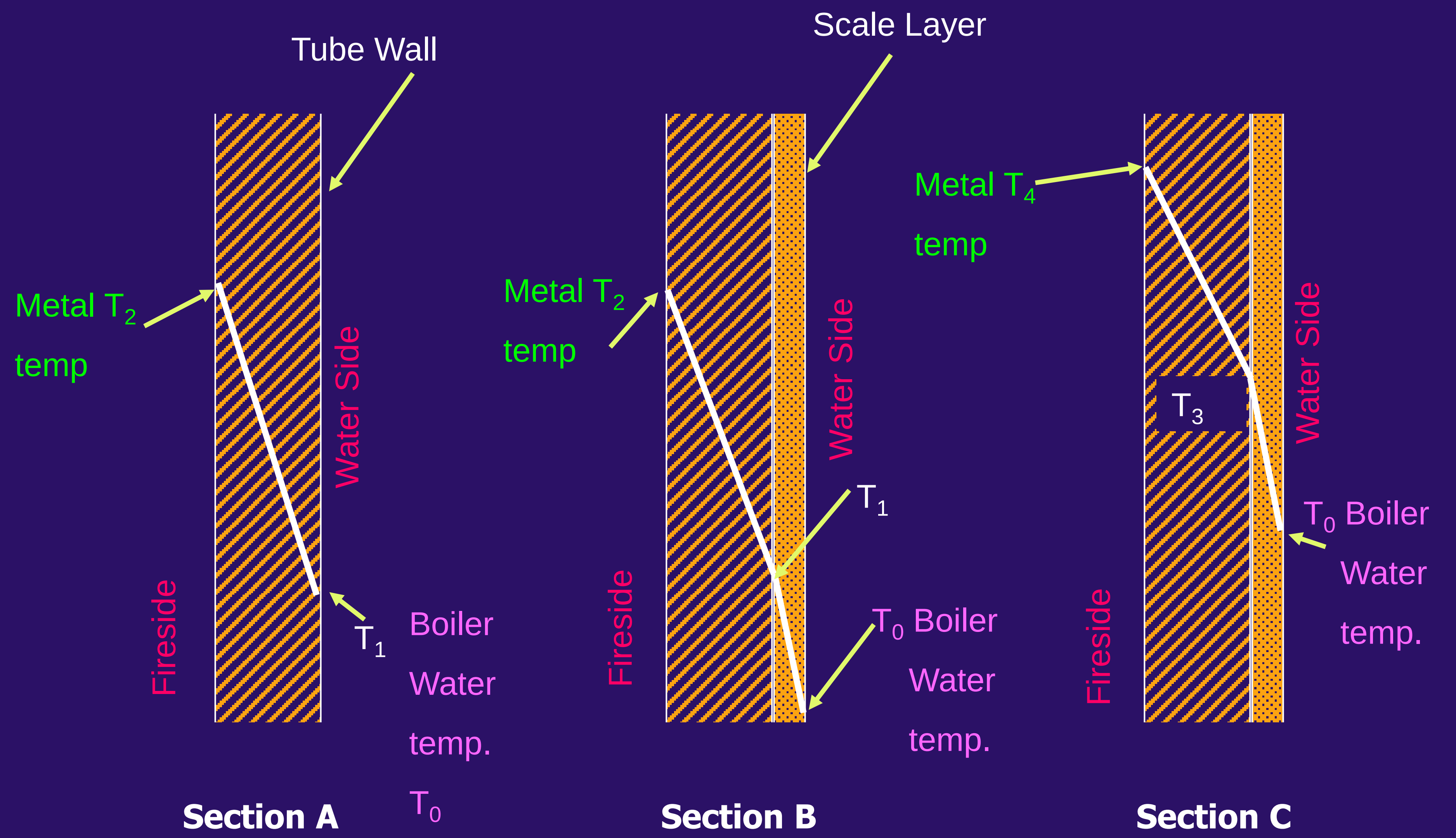


Figure 1: **Temperature profile across clean tube and tube having a water-side deposit.**

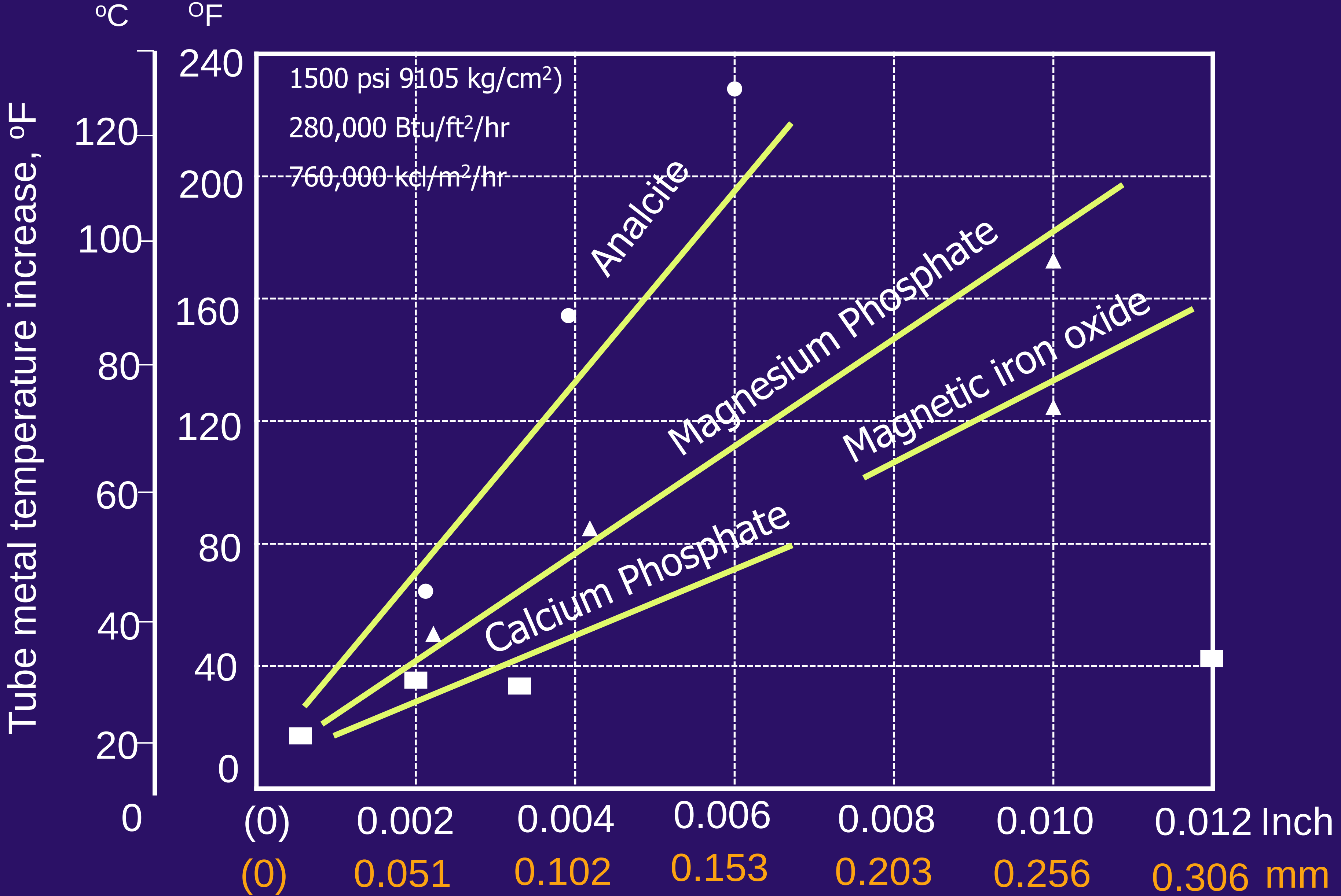


Figure 2: **Effects of differing deposit composition and thickness on temperature increase**

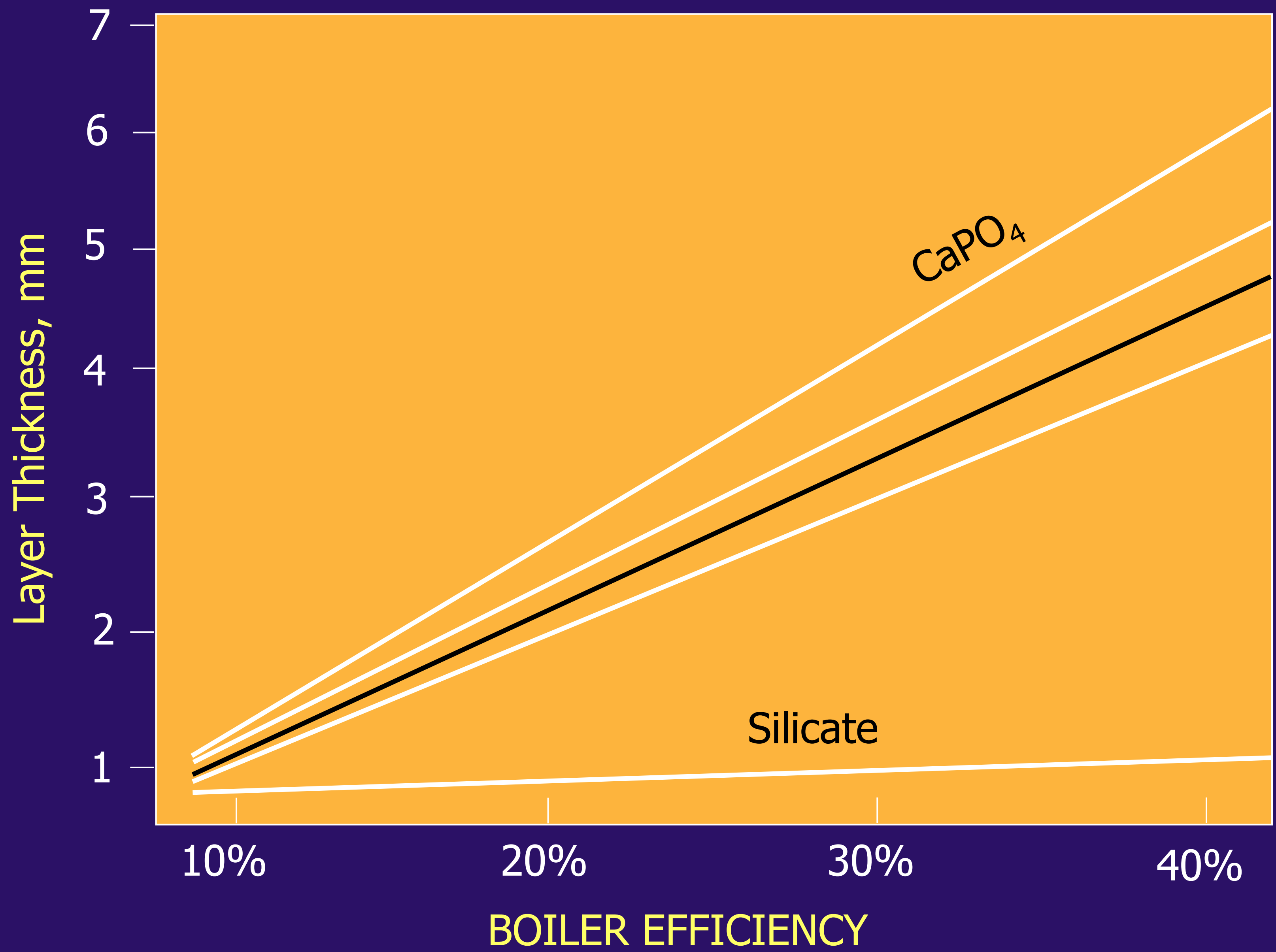


Figure 3: Influence of deposit thickness on boiler efficiency

INFLUENCE OF COPPER

Generally, copper is undesirable element in BFW

Boiler failures caused solely by copper are rare. Can contribute to failure mechanisms

Influence: -

- **weakening integrity of magnetite layer;**
- **decreases protective properties of magnetite layer;**
- **promotes adsorption of chlorides (easier activation of metal, shifting pitting potential to more negative value);**
- **accelerates localization of already initiated corrosion;**
- **galvanic corrosion in specific conditions (oxide free surface, DNB)**
- **copper oxide can "cement" porous iron oxide layer into a hard scale (poor thermal conductivity, localized overheating, failure);**
- **significantly effects on chemical cleaning procedure and solvent formulation. At high amounts separate Cu-removal stage required (layering, plating)**
- **induces liquid metal embrittlement (LME) at temperatures above 871°C (welding of Cu-plated tubes), rare case**

Main sources: corrosion/erosion of Cu-Ni and Cu containing alloys of heat exchangers, coolers, valves, pumps, evaporators & etc.

Limit concentration Cu in BFW - less than 20-30 ppb for LP; 10-15 ppb for MP and less than 5 ppb for HP boilers

Limit concentration of SiO_2 - less than 15-25 ppm for LP; 2.5-5.0 ppm for MP and less than 0.5 ppm for HP boilers

THUS, BUILD-UP DEPOSITS CONSIDERED SERIOUS PROBLEM FOR PLANT

Worldwide experiences shows ***Chemical Cleaning*** – most effective way to extent service life of heavily fouled by waterside deposit package boiler

CHEMICAL CLEANING DECISION

Primary reasons for cleaning boilers to:

prevent tube failures & unscheduled s/d; increase boiler operating efficiency

Chemical cleaning must be planned carefully several months ahead

First step - **deposit density determination – most commonly used primary parameter (mg/cm^2). Practically varied from 20 to 300 mg/sm^2 Deposit thickness (mm), constituent, morphology and adhesion also important.**

Generally accepted values for boilers within 600-1300 psi (41-90 bar):

Less than 25-30 mg/cm^2 - no problems

25-75 ″ - consider cleaning within 15 months maximum

Above 60-100 ″ - immediate cleaning required

Deposit thickness limit - 0.4 mm maximum

At pressures 1700-2500 psi DWD limit - less than 15 mg/cm^2

Second step - solvent selection based upon deposit constitute, thickness and adhesion with metal and compatibility with MOC

Other influencing factors include: safety and environment concerns, time limitation, chemicals availabilities, specific recommendations boiler manufacturer and etc.

Most frequently and widely used solvents:

- Inhibited hydrochloric acid (HCl);
- Citric acid (organic acid, $C_6H_8O_7 . H_2O$);
- Ethylenediaminetetra-acetic acid (EDTA), chelant solution.

CASE STUDIES SABIC PACKAGE BOILERS AND CHEMICAL CLEANING IMPLEMENTATION

CASE I: FAILURE ANALYSIS OF PACKAGE BOILER FIRST SCREEN TUBE & ACID CLEANING

- Mitsui Engineering And Shipbuilding Co. LTD Made, D-Type Package Boiler, Capacity 70T/h
- Carbon steel tubes (SA-192) were 76.2 mm (3.0 in.) In OD with wall thickness of 3.5 mm (0.14 in.)
- Operating temperature 310^{o}C at pressure - 44 barg
- Previously – from commissioning up-to 1997 ammonia+hydrazine and polymer containing program
- Then coordinated orthophosphate BFW treatment program was used.
- Boiler tubes were not chemically cleaned previously.
- Time to failure – 15 years.

Figure 4

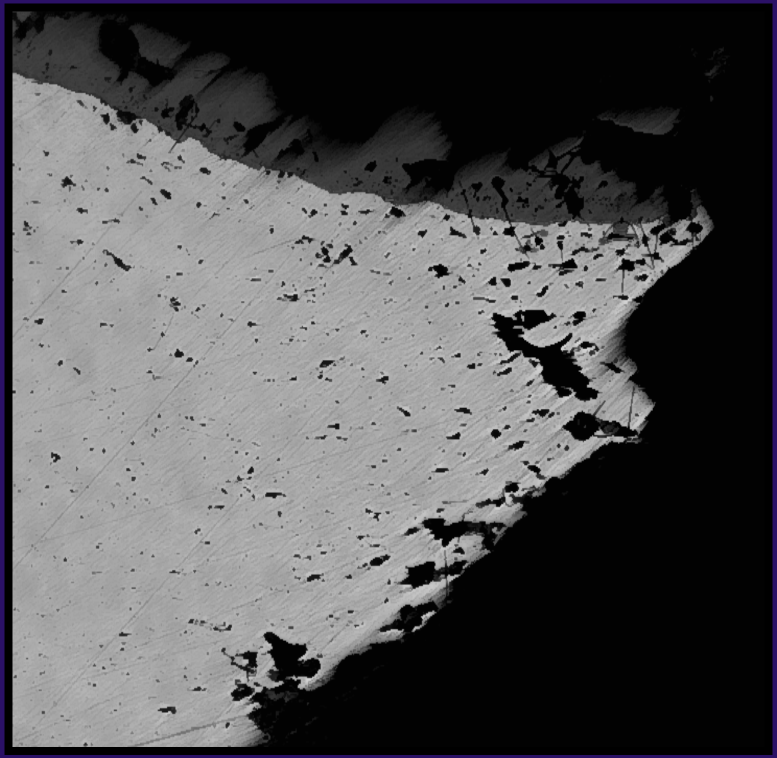


Figure 5

FIGURE 4. Close up photographs of the sample with clearly visible multiple abrupt bulges. Note the presence of spalled layer of the deposit inside the longitudinally split tube.

FIGURE 5. Presence of voids at and near the perforated edge (top of bulge, x400)

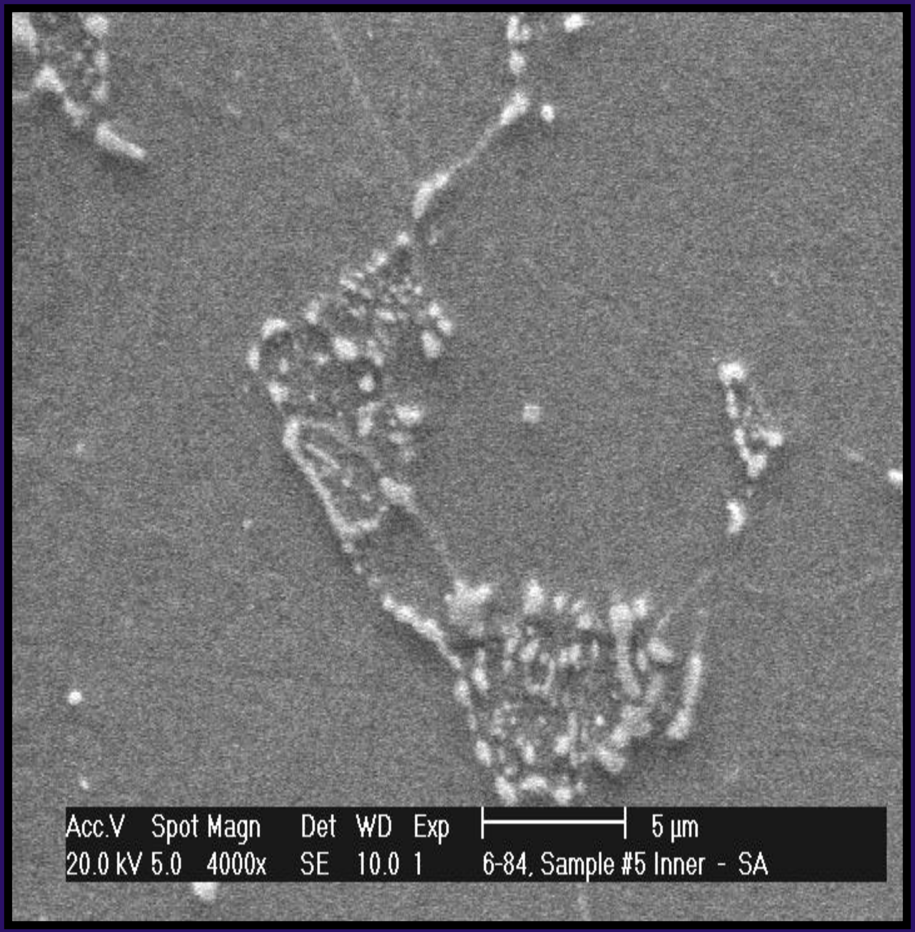


Figure 6 a

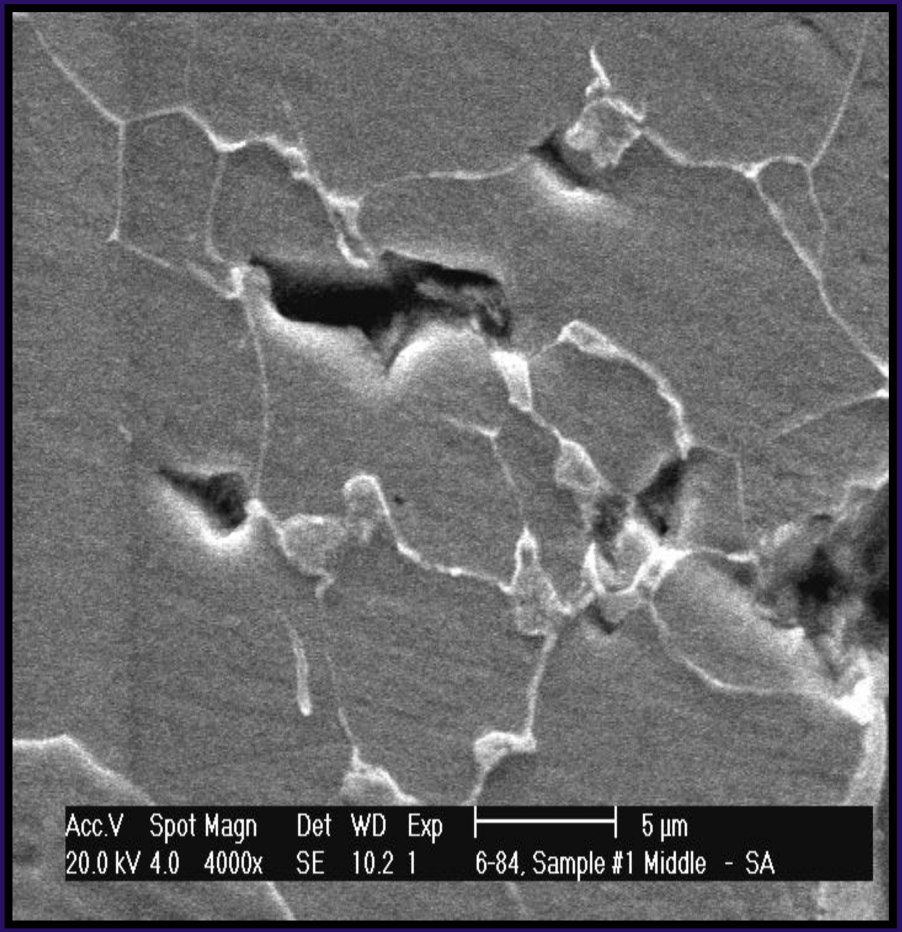


Figure 6 b

FIGURE 6. SEM micrographs showing speroidized morphology in pearlite colonis and the presence of voids (4000X)

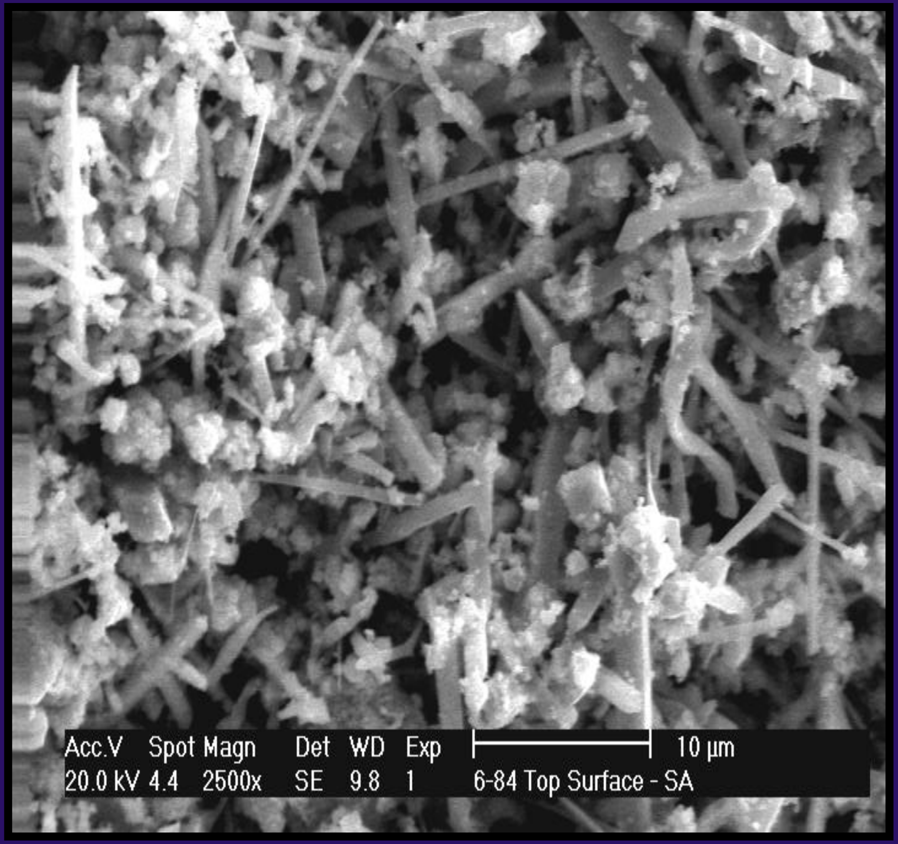


Figure 7 a

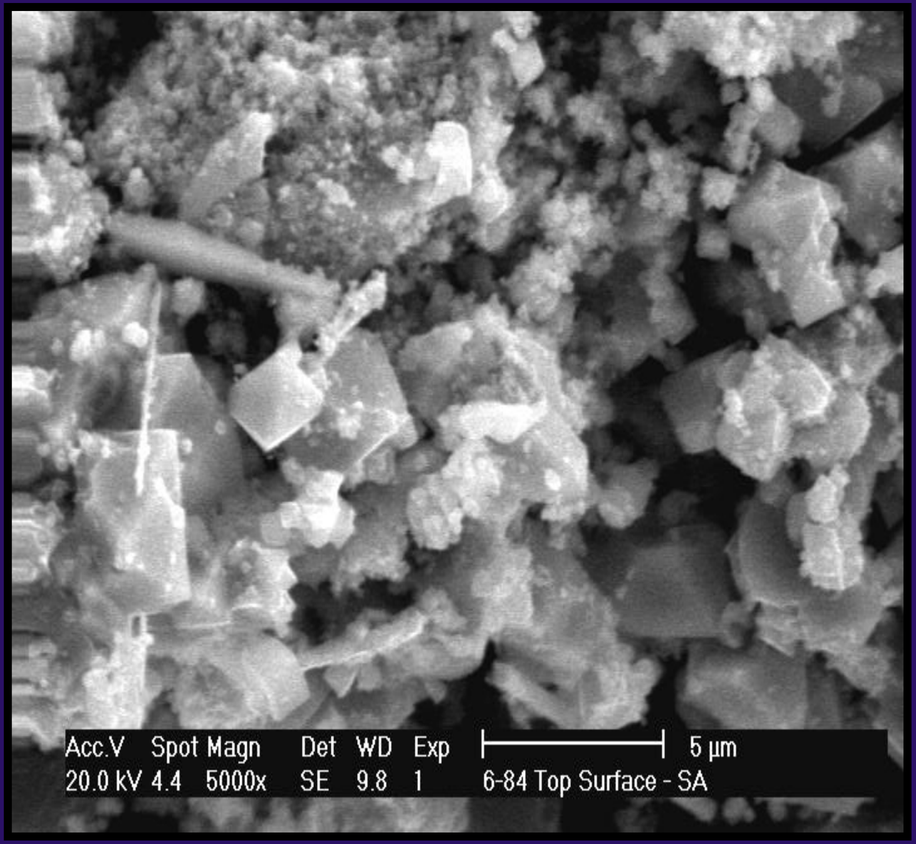


Figure 7 b

FIGURE 7. SEM micrographs of the flakes showing the presence of fine particles, fibers and short rods (a, 2500X) along with the typical crystaline particles (b, 5000X).

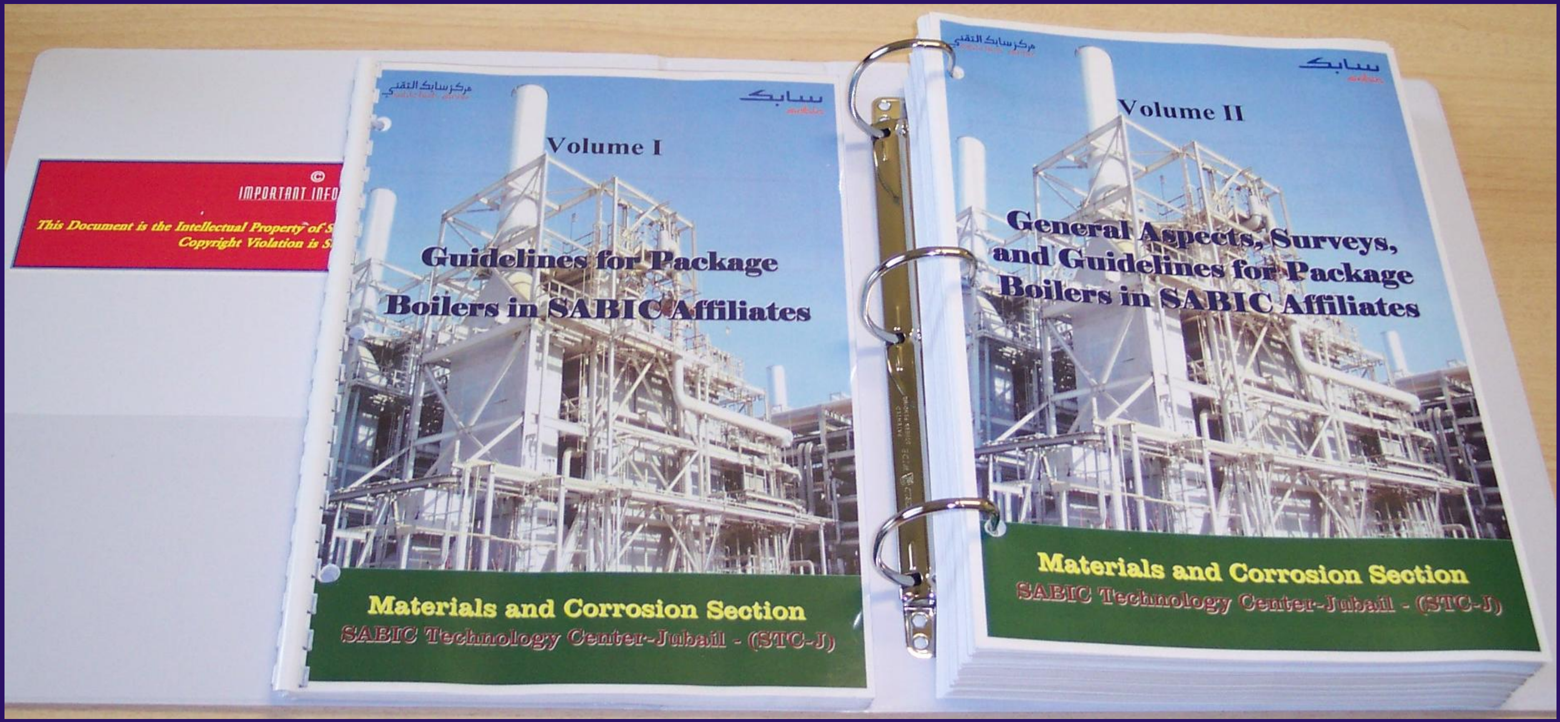
CONCLUSIONS

- Screen tube failed due to creep rupture as result of local overheating caused by presence of excessive dense deposit layer inside tubes.
- Calculated density of internal deposit was more than 200 mg/cm^2 at average thickness of 1.2 to 1.5 mm.
- Determined cleanliness of tubes is considered as “very dirty”.

RECOMMENDATION

- Acidic chemical cleaning was recommended and had been implemented.

Since then, the boiler operates normally more than 9 years.



[Package Boilers (http://ss-jhq-web-1.sabiccorp.sabic.com/STC_J/Boilers/index.aspx)](http://ss-jhq-web-1.sabiccorp.sabic.com/STC_J/Boilers/index.aspx)

Deliverables

- Mechanism and location of Corrosion damages in boiler Components
- Summary of Failures of Utility Boilers Components in SABIC Affiliates
- Guidelines on BWT
- Guidelines on condition and Remaining Life Assessment of UTB components
- Guidelines on UTB Chemical Cleaning.

Thank You