Assessing Corrosion in Air Cooled Condensers at Eskom Medupi Power Station

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Background Information

- Medupi is an Eskom own fossil fuel power plant situated in the Limpopo province, in a small city called Lephalale, in South Africa.
- The station consist of six supercritical once-through units, with each unit having a gross megawatt output of 794 MW.
- All units are fully commissioned and operational, with the first unit (Unit 6) commissioned in February 2015. The last unit, Unit 1 was commissioned in the late in 2019.
- Each unit has an 8 x 8 ACC arrangement, with the ACC surface area of about 72 252 m^2.
- The ACC are manufactured entirely from carbon steel material.
- All Volatile Treatment Oxidising regime, AVT(O) was employed for feedwater treatment during Unit 5 commissioning (September 2016), and later changed to “Alkaline” Oxygenated Treatment, AOT (July 2018).
- Unit 5 ACC internal inspections were conducted during the first major outage (GI), prior to transitioning to AOT, and five months after transitioning to AOT.

Background Information Cont…

Selected Cycle Chemistry Specification

- Eskom experience, and experience elsewhere has proven that “conventional” AVT(O) ($pH_{25} \leq 9.6$) is not adequate to minimise corrosion in the ACC.
- After 5 months of operation, Unit 5 feedwater treatment was converted to AOT regime (only applicable during steady state operation). AOT is a modified OT regime, where, with all things remaining the same, feedwater pH is kept above 9.75 and below 9.85.
- Unit 5 cycle chemistry monitoring and control was and continues to be conducted in accordance with EPRI’s Guideline for New High Reliability Fossil Plants (1012203).

<table>
<tr><th></th><th colspan="3">pH_{25}</th><th colspan="3">$DCACE_{25}$, µS.cm^{-}</th><th colspan="2">Na^{+}, µg.kg^{-}</th></tr>
<tr><th>Sample Stream</th><th>Lower Limit</th><th>Target Value</th><th>Higher Limit</th><th>Lower Limit</th><th>Target Value</th><th>Higher Limit</th><th>Target Value</th><th>Higher Limit</th></tr>
<tr><td>Economiser Inlet</td><td rowspan="2">9.75</td><td rowspan="2">9.80</td><td rowspan="2">9.85</td><td rowspan="2">0.055</td><td rowspan="2">< 0.070</td><td rowspan="2">0.080</td><td rowspan="2">< 0.30</td><td rowspan="2">< 1.0</td></tr>
<tr><td>Main Steam</td></tr>
</table>

Table 1: Feedwater and Superheated steam chemical quality specification

Unit 5 Feedwater pH_{25}

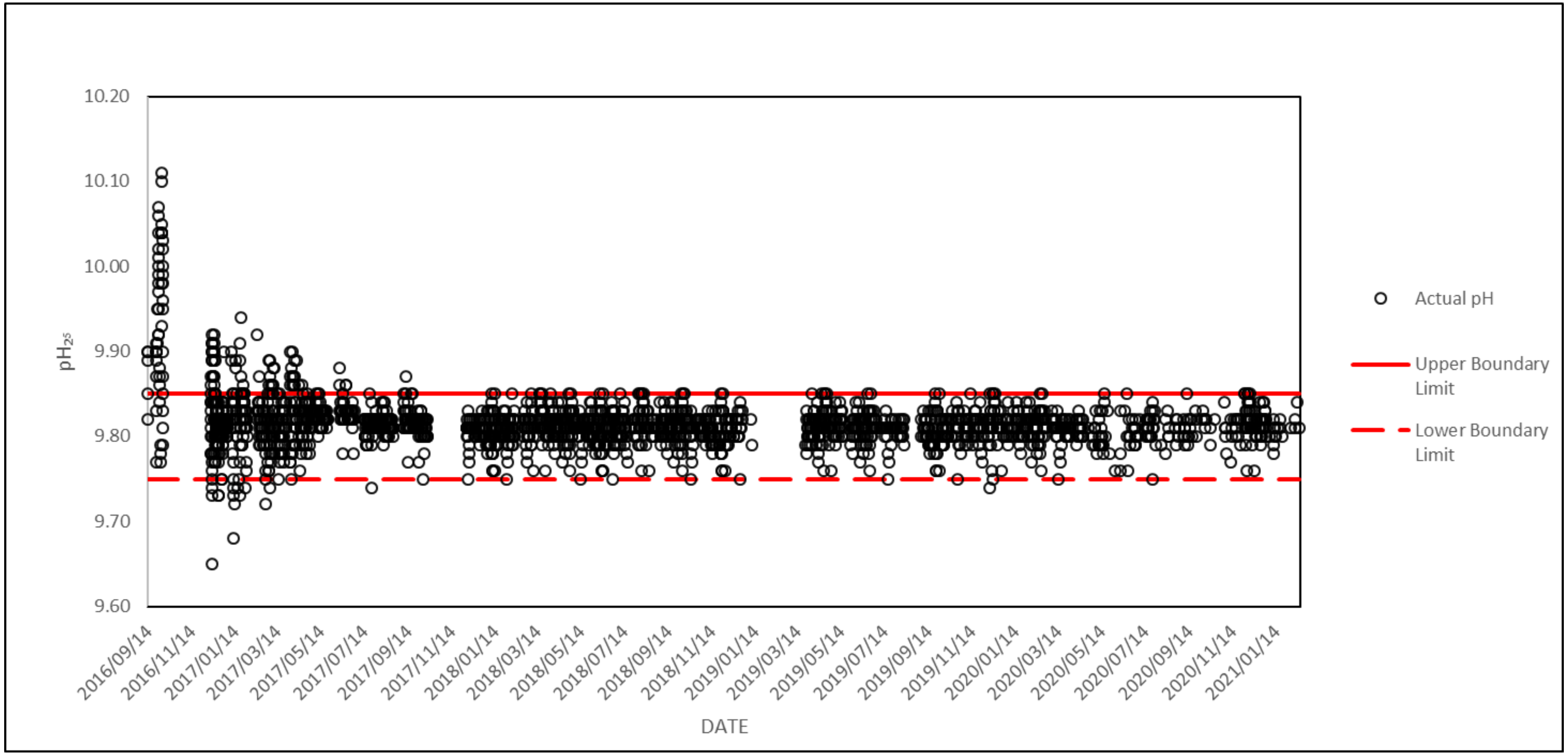


Figure 1: Feedwater pH_{25} as measured at the Economiser inlet

"Early" Condensate Chemistry

- Ammonia is a weak base; it doesn't dissociate completely in water and the equilibrium reaction can be written as follows:

$$NH_{3(g)} + H^{+}{}_{(l)} \rightleftarrows NH_{4}{}^{+}{}_{(aq)} \qquad \text{Eq. 01}$$

- The equilibrium constant is a function of temperature and can be written as follows:

$$K_{(NH_4{}^+)}(\mathrm{t}) = \frac{[NH_4{}^+]}{[NH_3][H^+]} \qquad \text{Eq. 02}$$

At standard conditions (temperature and pressure), water is primarily in the liquid form, with minor dissociation according to the following reaction:

$$\mathrm{H_2O_{(l)} \rightleftarrows H^{+}{}_{(aq)} + OH^{-}{}_{(aq)}} \qquad \text{Eq.03}$$

$$K_W(t) = [H^+].[OH^-] \qquad \text{Eq.04}$$

- Using the isocoulombic approach, $K_w(t)$ can be determined as follows:

$$K_W(t) = a + \frac{b}{T} + \frac{c}{T^2} + \frac{d}{T^3} + \left(e + \frac{f}{T} + \frac{g}{T^2}\right) log p_W \qquad \text{Eq.05}$$

where *a, b, c, d, e, f,* and g are water specific constants, *T* is water temperature, and p_w is water density.

"Early" Condensate Chemistry Cont…

	Reference Conditions				"Early" Condensate conditions											
Treatment Regime	25°C				50°C			60°C			65°C			75°C		
	pH_{25N}	Amm. As NH_3 mg.kg-	pH_{25}	ΔpH	pH_{50N}	pH_{50}	ΔpH	pH_{60N}	pH_{60}	ΔpH	pH_{65N}	pH_{65}	ΔpH	pH_{65N}	pH_{65}	ΔpH
AVT(O)	7.0	4.10	9.75	2.75	6.60	9.0	2.40	6.46	8.74	2.24	6.39	8.61	2.21	6.27	8.37	2.10
		5.10	9.80	2.80		9.05	2.45		8.79	2.29		8.66	2.26		8.43	2.16
		6.30	9.85	2.85		9.10	2.50		8.84	2.34		8.72	2.32		8.48	2.21

Table 2: effect of temperature on condensate pH, at selected ammonia concentration range.

- Neutral condensate pH as well as the calculated "actual" pH, decreases with increasing temperature, therefore pH_{25} (at reference temperature) does not define "early" condensate conditions.
- Understanding early condensate chemistry is very important as relying solely on pH_{25} to control chemistry and mitigate corrosion in the ACC without taking into account the temperature effect would be misleading.
- Previous work done by Ken Galt indicated that a minimum ΔpH (pH_T – pH_N) of 1 pH unit "at temperature" is required in order to elevate the pH in the early condensate, in turn helping minimise FAC.

Main Steam Quality and ACC Corrosion

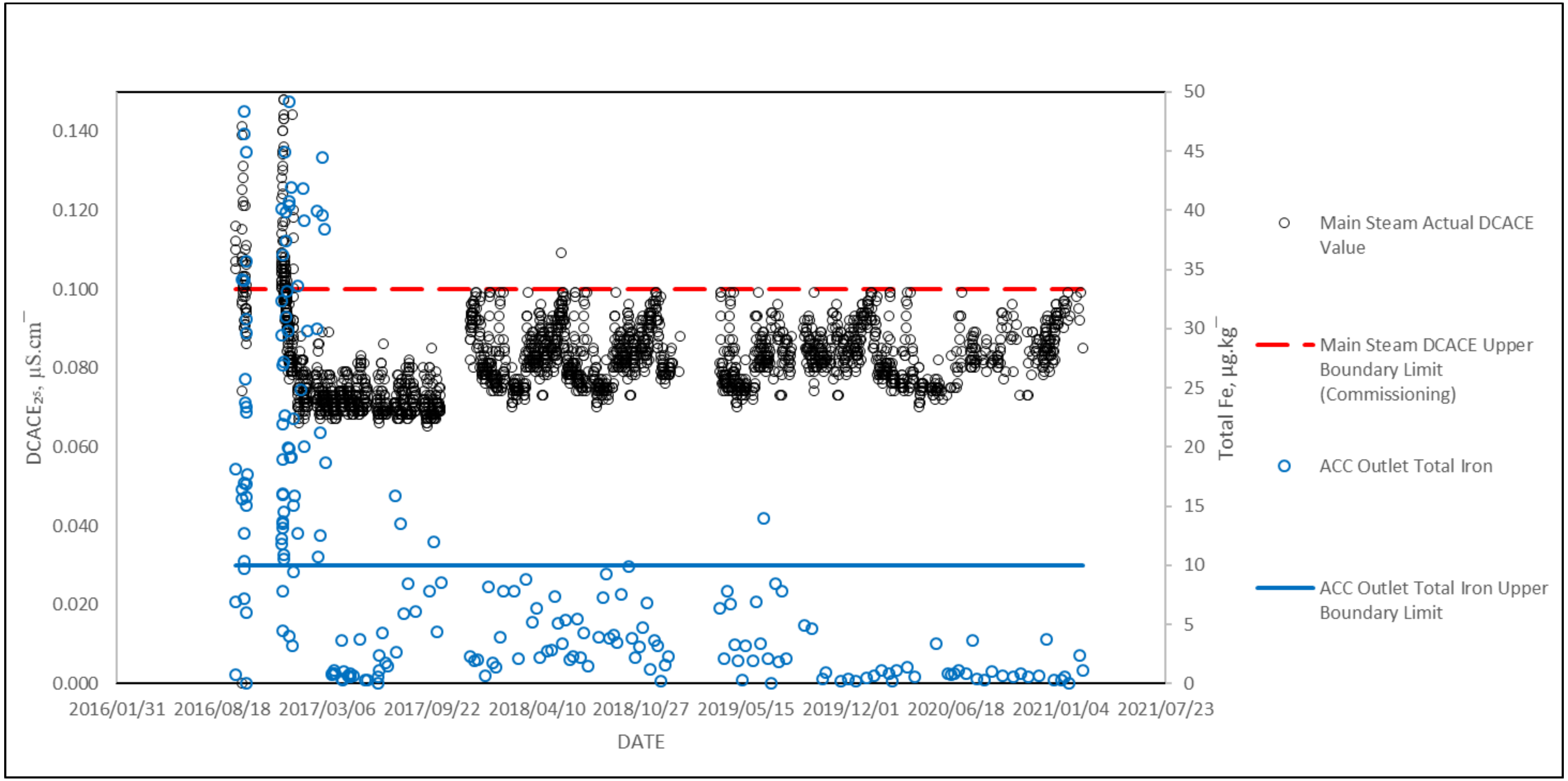


Figure 2 Main steam $DCACE_{25}$ and ACC outlet total iron

ACC Internal Inspection

- Optimal cycle chemistry programme should include periodical inspection of corrosion susceptible systems.
- The internal inspection was conducted in accordance with the Guidelines for Internal Inspection of Air Cooled Condensers (ACC.01).
- Corrosion is quantitatively defined using the corrosion index; DHACI (Dooley Howell ACC Corrosion Index).
- The index separately describes corrosion in the lower and upper sections of the ACC.
  - Lower duct: (best) A – B – C (worst)
  - Upper duct: (best) 1 – 2 – 3 – 4 – 5 (worst)

ACC Internal Inspection: Lower Ducts

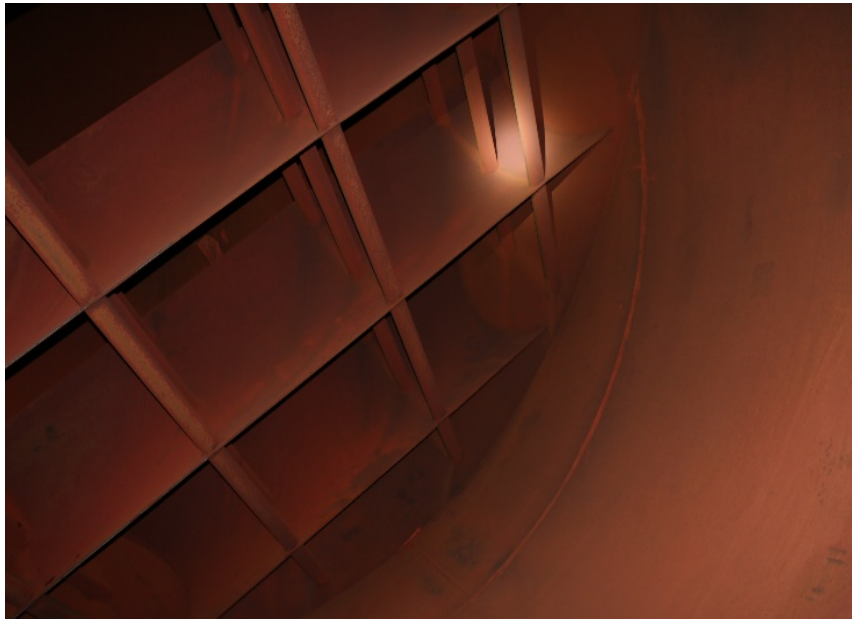
LPT 1 exhaust duct
Feedwater treatment regime: AVT(O)
DHACI rating = A

LPT 2 exhaust duct
Feedwater treatment regime: AVT(O)
DHACI rating =A

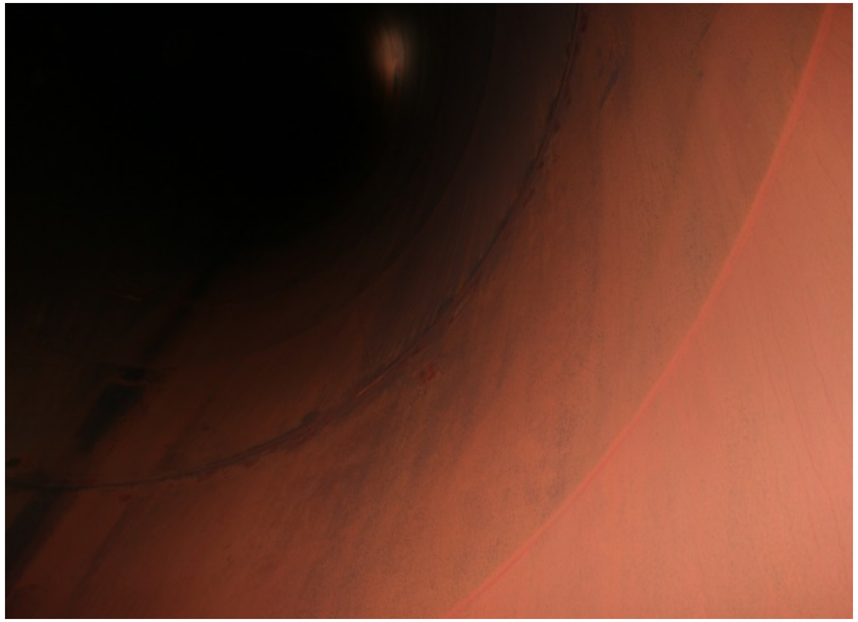
LPT 1 exhaust duct
Feedwater treatment regime: AVT(O)
DHACI rating = A

LPT 1 exhaust duct
Feedwater treatment regime: AOT
DHACI rating = A

ACC Internal Inspection: Lower Ducts Cont…



LPT 1 exhaust duct louver (inlet to the vertical rider)
Feedwater treatment regime: AOT
DHACI rating = A

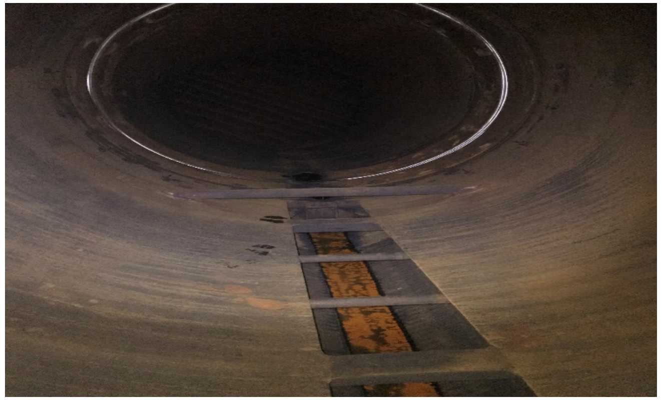


LPT 1 exhaust duct main vertical rsier
Feedwater treatment regime: AOT
DHACI rating = A

ACC Internal Inspection: Upper Ducts

Steam distribution duct 1 inlet louver
Feedwater treatment regime: AVT(O)
DHACI rating = 1

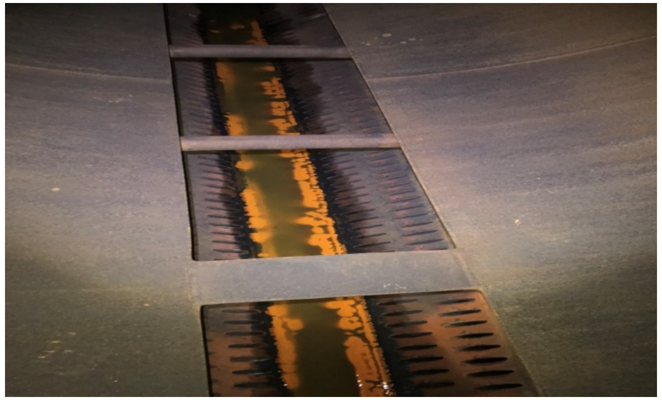
Steam distribution duct 1 inlet louver
Feedwater treatment regime: AOT
DHACI rating = 1



Steam distribution duct 3
Feedwater treatment regime: AVT(O)
DHACI rating = 1

Steam distribution duct 3
Feedwater treatment regime: AOT
DHACI rating = 1

ACC Internal Inspection: Upper Ducts Cont..



Upper steam distribution duct 5
Feedwater treatment regime: AVT(O)
DHACI rating = 1

Upper steam distribution duct 5
Feedwater treatment regime: AVT(O)
DHACI rating = 4

Upper steam distribution duct 5
Feedwater treatment regime: AVT(O)
DHACI rating = 1

Upper steam distribution duct 5
Feedwater treatment regime: AOT
DHACI rating = 1

Conclusion

Eskom

- Selected cycle chemistry data showed that Unit 5 cycle chemistry control programme was effective for ACC corrosion control.
- The choice of applying elevated pH_{25} AVT(O) regime over conventional AVT(O) during commissioning proved to be beneficial.
- Generally, the entire ducts were actively passivated, with minor active corrosion on the walls and steel supports.
- There were a selected number of tubes that showed severe corrosion immediately below the seal weld at the tube entry.
- Significant corrosion was observed on structures which are on the steam path (stiffeners).
- AOT provided adequate oxidizing power to promote the formation of hematite in the ACCs.
- More inspections will be conducted in future to further enhance our understanding of ACC corrosion control.
- Other corrosion monitoring techniques such as the use of target plates in strategic areas may be considered.
- Work on possible use of alternative amines to further optimise the two-phase pH will also be considered.