

# The Latest on ACC Corrosion Mechanisms

The Lack of any Further Understanding

ACC Users Group  
Xcel Energy's Comanche Station  
Pueblo, Colorado  
28<sup>th</sup> and 29<sup>th</sup> September 2010

Barry Dooley

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## Corrosion in ACC and The Consequences

- High concentrations of iron around the cycle
  - Boiler/HRSG deposits
  - Boiler Tube Failures
- Need for Iron Removal Processes
  - Condensate Polishing and/or Filters
- Limitations around the cycle
  - Condensate polishing
- Overall an ACC “controls” the unit cycle chemistry
  - Guidelines Worldwide don't consider ACC

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## We all Now Know what the Corrosion Looks Like



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## And what Holes at Tube Entries Look Like



DHACI 5

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**And we have an ACC Corrosion  
Index to Categorize Corrosion  
and Track Improvements**

**DHACI**

**(Dooley, Howell, Air-cooled Condenser,  
Corrosion Index)**



**DHACI for Tube Inlets**

- 1. Tube entries in relatively good shape (maybe some dark deposited areas)**
- 2. Various black/grey deposits on tube entries as well as flash rust areas, but no white bare metal areas**
- 3. Few white bare metal areas on a number of tube entries. Some black areas of deposit**
- 4. Serious white bare metal areas on/at numerous tube entries. Lots of black areas of deposition adjacent to white areas**
- 5. Most serious. Holes in the tubing or welding. Obvious corrosion on many tube entries**



## DHACI for Lower Ducts

- A. Ducting shows no general signs of two-phase damage
- B. Minor white areas on generally grey ducting. Maybe some tiger striping with darker grey/black areas of two-phase damage
- C. Serious white bare metal areas in the hot box and at numerous changes of direction (eg. at intersections of exhaust ducting to vertical riser). White areas are obvious regions of lost metal.

Dooley et al, PPChem 2009

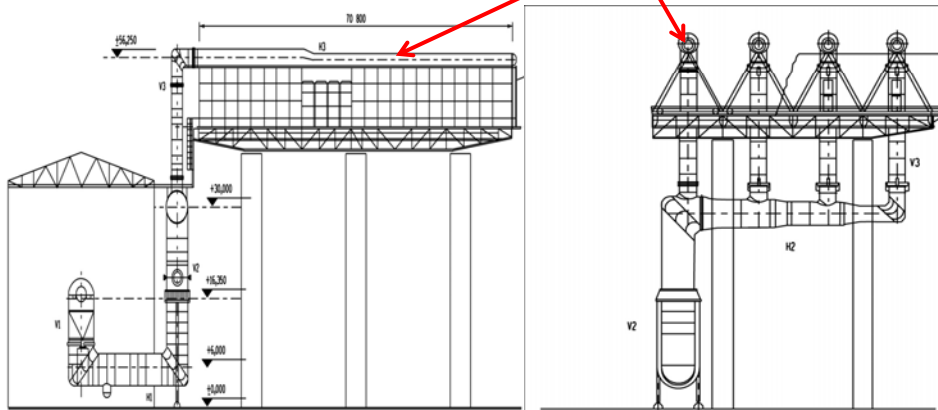
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**But do we Understand the  
Environment and the Corrosion  
Mechanism?**

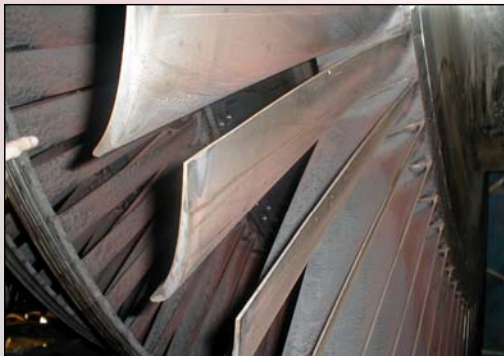
**Solutions are already being  
applied**

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**To Understand the Corrosion Here we need to Understand the Environment in the PTZ**



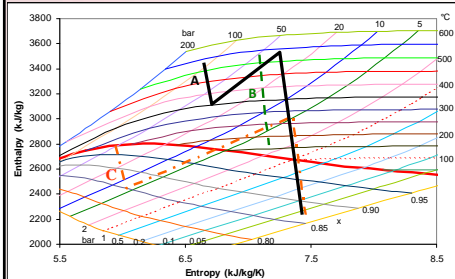
**The PTZ Environment in the LP Steam Turbine**



**Droplet Nucleation and Liquid Films on Blades (Generation of the ACC Environment)**

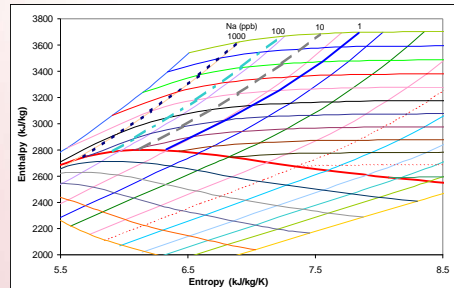


## Mollier Diagrams



**A. Fossil Reheat Turbine**  
**B. Backpressure Turbine**  
**C. Reheat Turbine in a nuclear LWR plant**

**Solubility limits of NaCl at various steam conditions**



Source: IAPWS Technical Guidance Document 2010

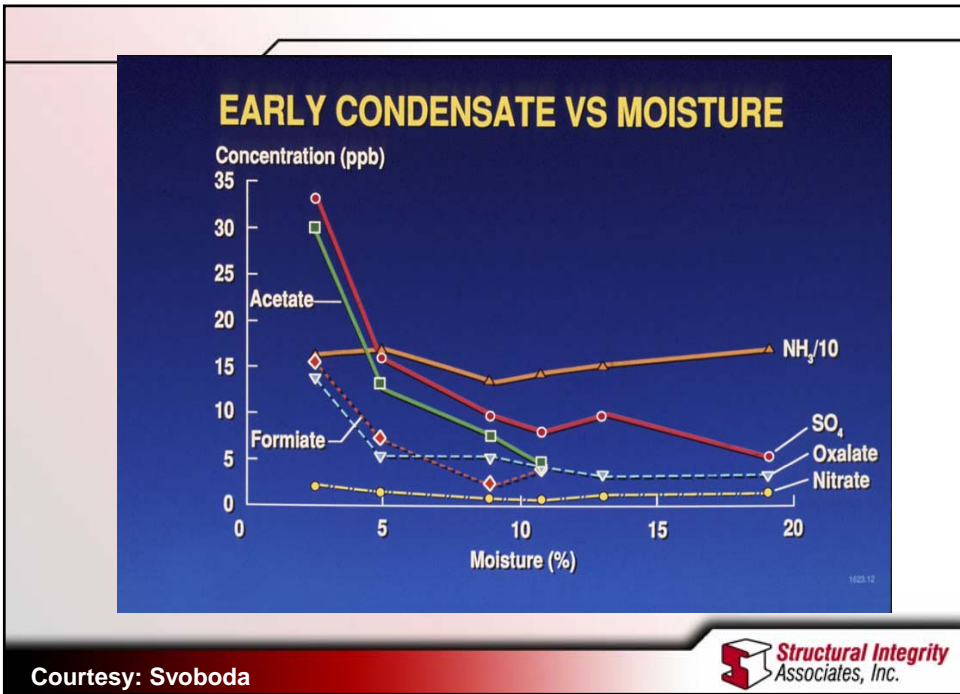
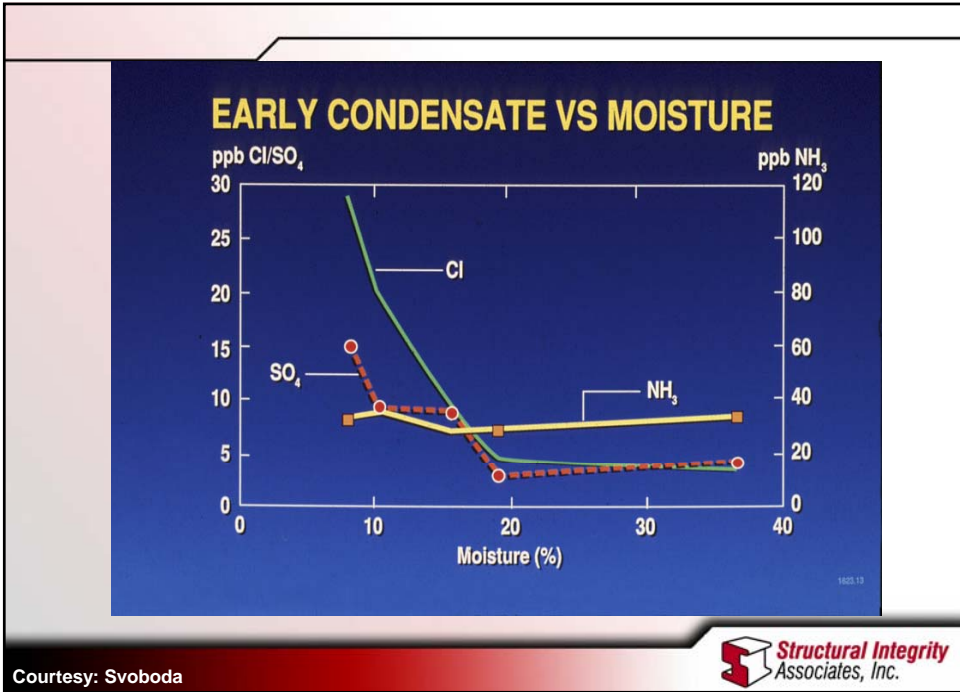
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## Moisture Nucleation/Early Condensate

- **Nucleation around ions and oxides**
  - **Seeds  $10^5 - 10^{13}/\text{kg}$**
- **Concentration ratios up to 100x**
  - **Increases with decreasing moisture**
- **Effect of plant cycle chemistry**
  - **AVT and PT > OT**
  - **<< 5ppb  $\text{O}_2$  in the moisture**
- **Droplets are charged**

Adapted from Dooley and Rieger, 2001

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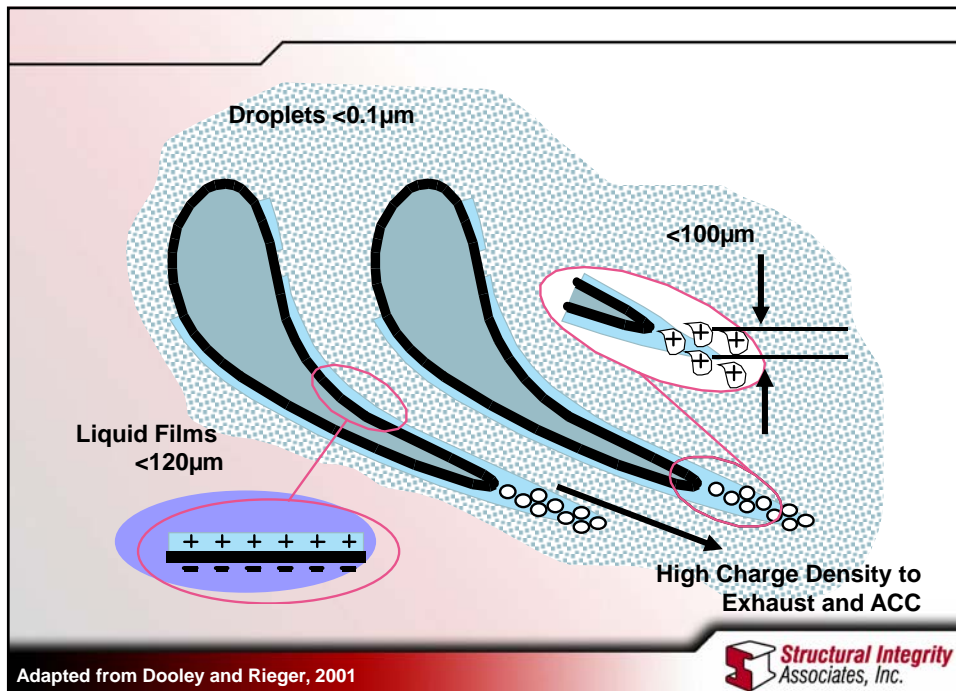


## Liquid Films on Turbine Surfaces

- Range up to 100 - 120  $\mu\text{m}$ 
  - Very variable profile on surfaces
  - Dependent on chemistry
  - OT < AVT and PT
- Concentration factors 10x > Droplets
- < 5ppb  $\text{O}_2$  in LF
- LF are charged

Adapted from Dooley and Rieger, 2001

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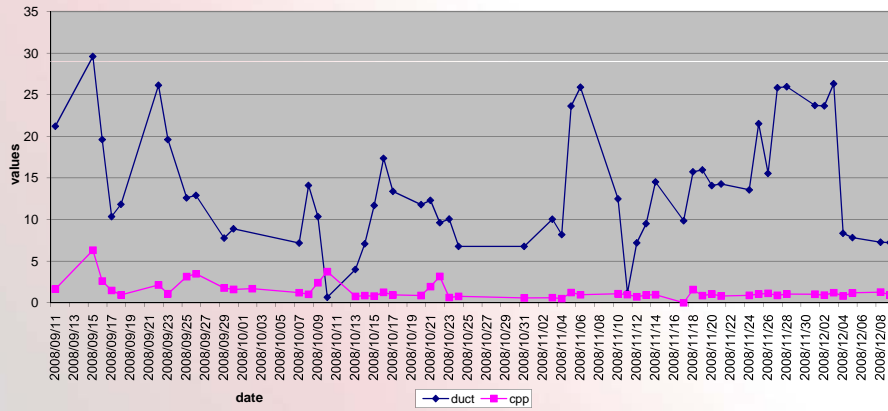
Adapted from Dooley and Rieger, 2001

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## The Liquid in ACC Upper Ducts

chlorides

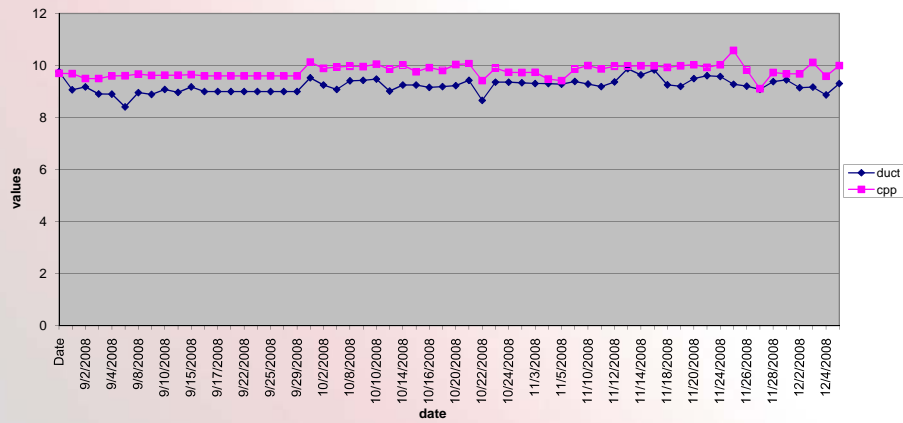


Courtesy Setsweke Phala, Eskom



## The Liquid in ACC Upper Ducts

pH



Courtesy Setsweke Phala, Eskom



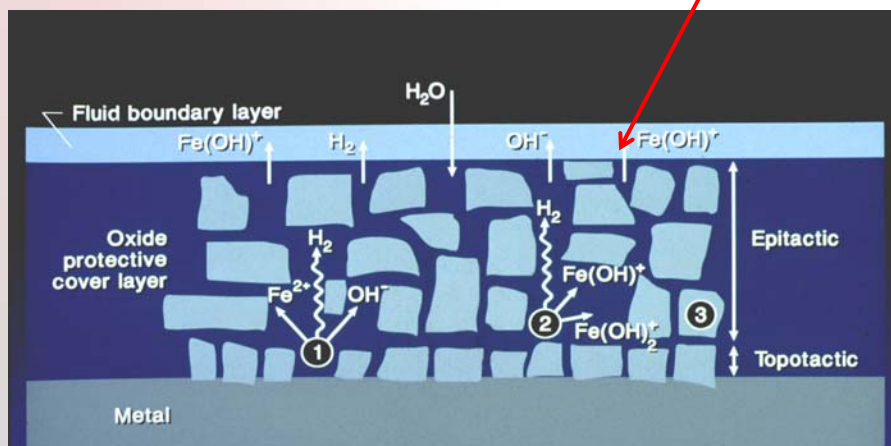
## So is the ACC Corrosion Mechanism Low Temperature FAC?

Dependent on Removing the  
Saturation of  $\text{Fe}_3\text{O}_4$  at the Surface and  
Precipitating it Adjacently

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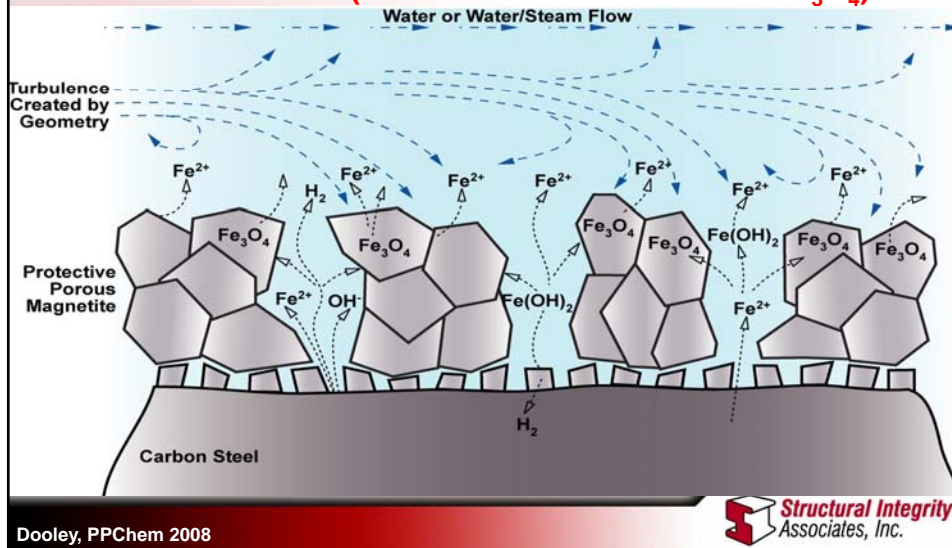
## Growth of Magnetite on ACC Surfaces

$\text{Fe}_3\text{O}_4$  is semi-protective because of saturation here



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## Two-phase FAC in Flowing Turbulent Flow at ACC Tube Entries (Removes the Saturation of $\text{Fe}_3\text{O}_4$ )

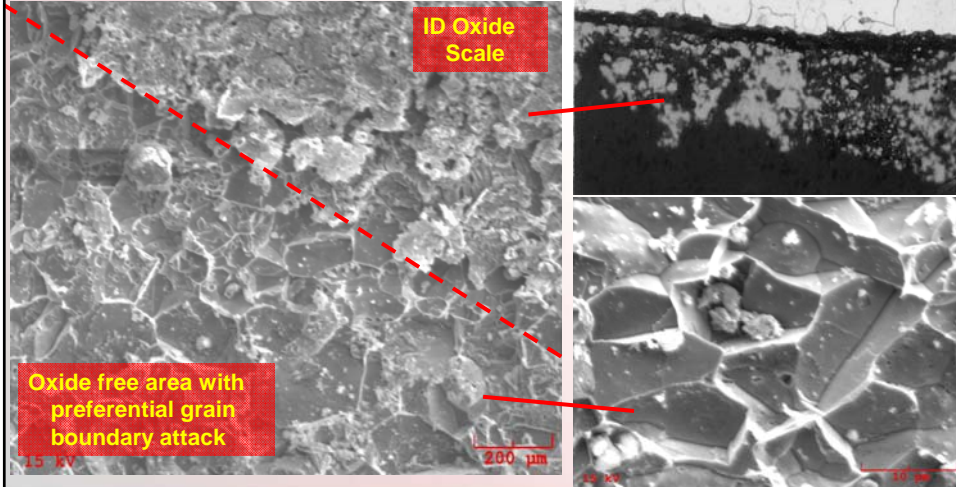


## Inside diameter surface of an A-Frame ACC Tube

The black areas are where the  $\text{Fe}_3\text{O}_4$  is Precipitated Locally



## Corroded (FAC?) ID Surface of ACC Tube



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6 inch section of ACC tube and detail of the surface showing black deposits and white "bare" metal areas

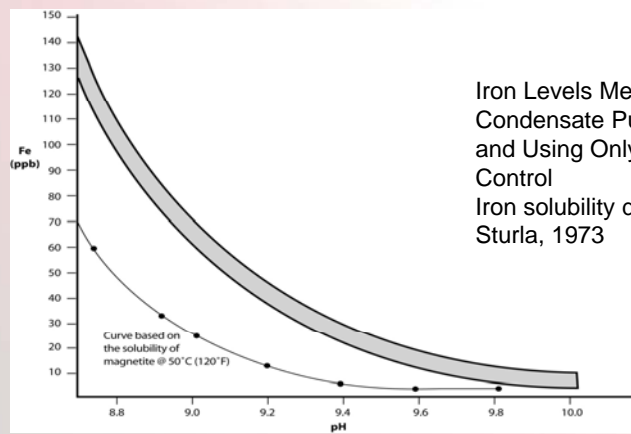
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## Or is the ACC Corrosion Mechanism Something Other than FAC?

and  
Why does the Dooley/Aspden  
Relationship Work ?

## Dooley/Aspden pH Versus Iron Relationship



Iron Levels Measured at  
Condensate Pump Discharge  
and Using Only Ammonia for pH  
Control  
Iron solubility data extracted from  
Sturla, 1973

## In Summary

- **Some aspects relate to Low Temperature FAC**
  - Adjacent black and white areas
  - Increasing pH reduces damage
- **Environment is only loosely known**
  - Two-phase mixture formed in PTZ
  - Concentrating liquids
  - Higher in chloride/sulphate, organics etc.
  - Lower in pH
- **Clearly more tubes need to be analyzed**
- **Clearly we need to understand environment better**
- **Clearly we need these to help provide solutions**

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