International Association for the Properties of Water and Steam

Steam Purity

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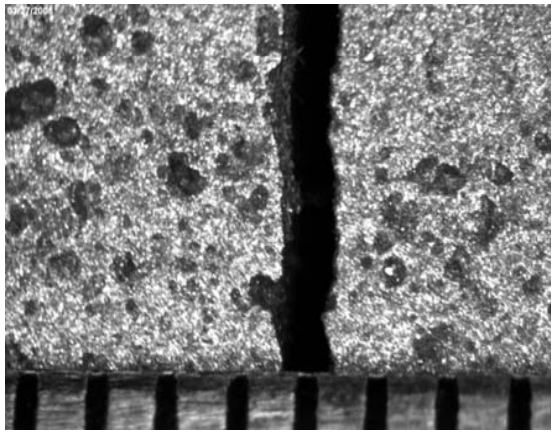
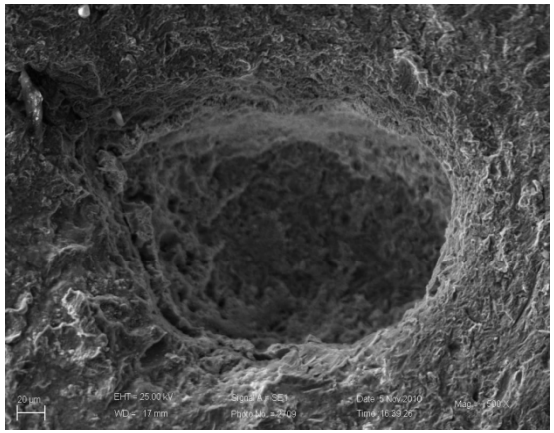
Scientific Background

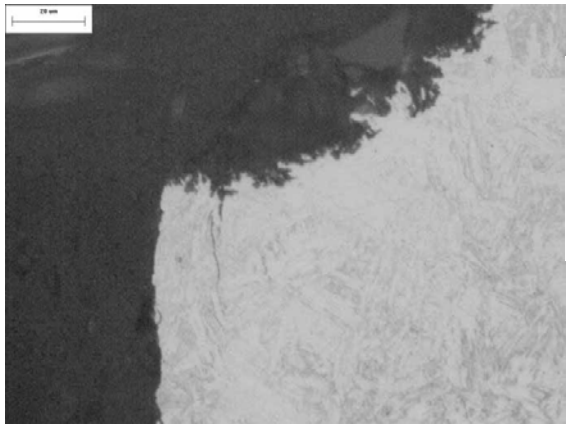
Chemical environment

- **Dynamic environment during operation**
  - local conditions at the PTZ (Phase Transition Zone)
  - deposition of salts

- **Environment produced during shutdown**
  - hygroscopic salt deposits → pitting
  (pitting is always the precursor to other corrosion mechanisms like stress corrosion cracking and corrosion fatigue)

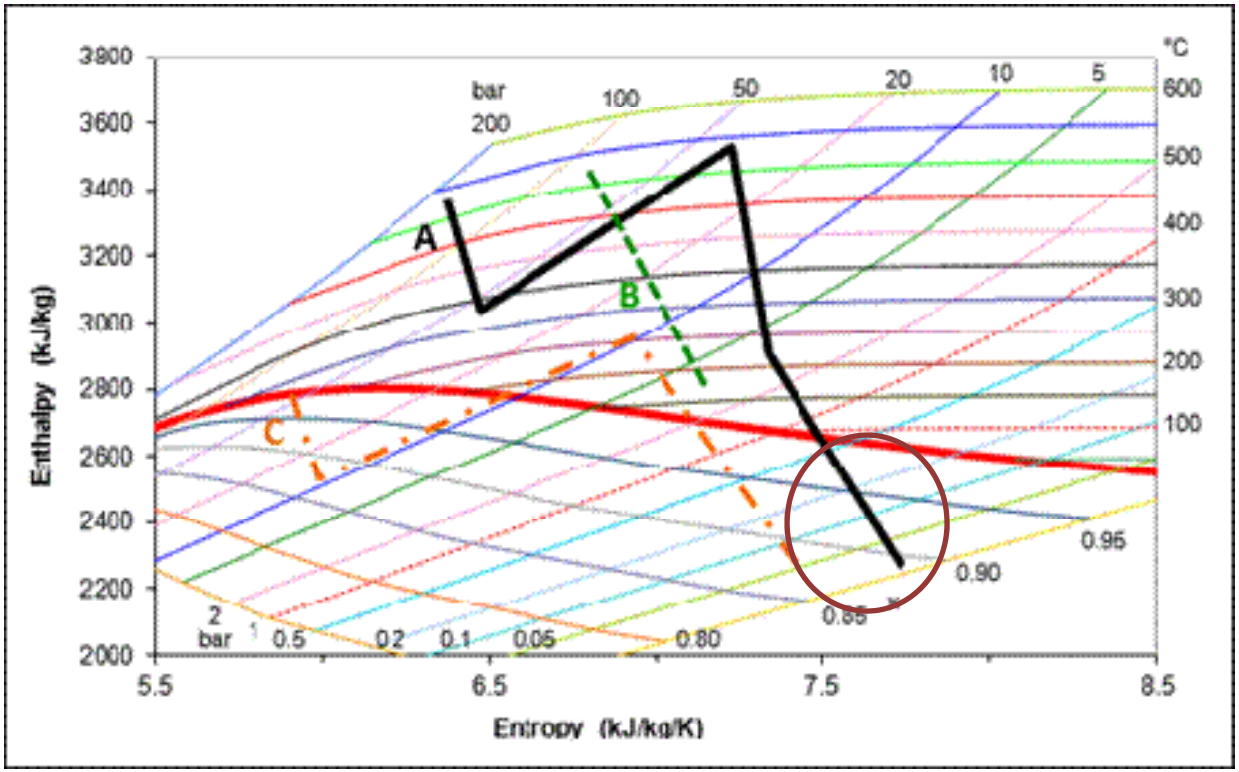






Scientific Background

The phase transition zone (PTZ)

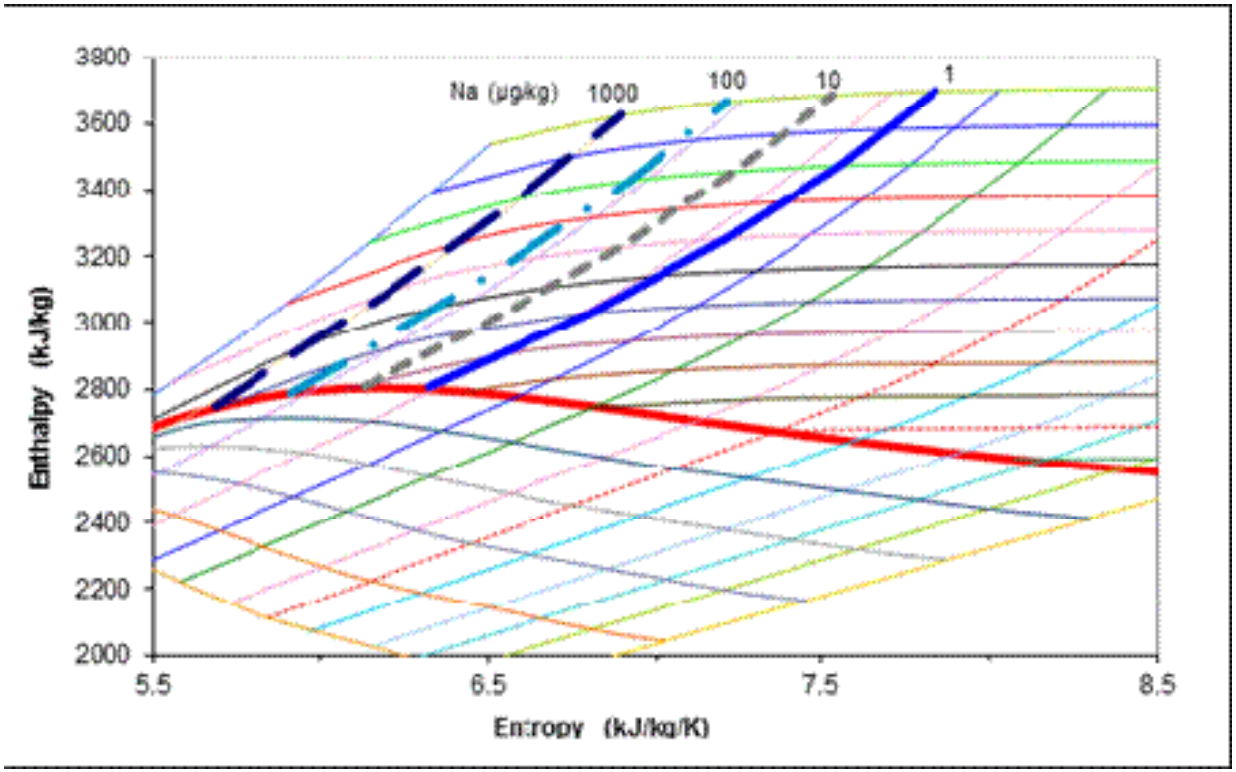


Steam expansion

A fossil reheat
B backpressure
C nuclear PWR

Scientific Background

Deposition of salts



Solubility limits of NaCl at various steam conditions

Source: Harvey and Bellows. 1997

Scientific Background

Most important damage mechanisms

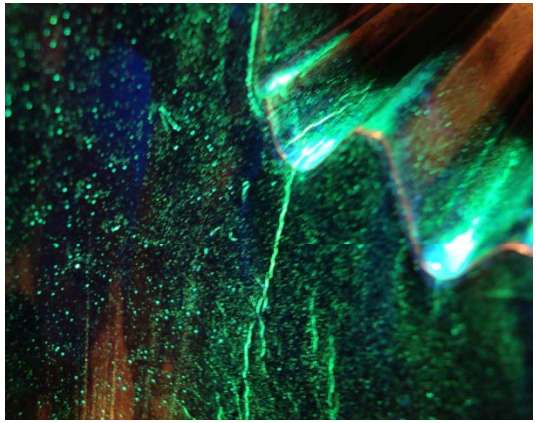
Salt deposits

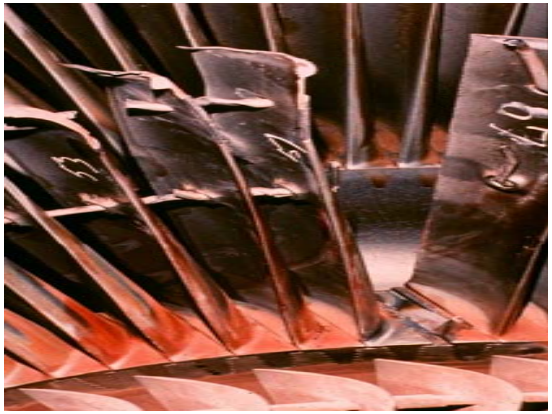
1. Operation: salt deposits
2. Shutdown: pitting in moist air
3. Operation: pits develop into cracks → crack initiation

Corrosive liquid films

4. Corrosive liquid films enhance crack growth

Crack initiation + crack growth → failure





Limiting the Effects of Poor Steam Chemistry

Steam purity parameters

- **Impurities**
  Conductivity, Na, Cl, SO_4, Cu, Fe, Al, organics, O_2
- **Conditioning agents**
  NH_3, volatile reducing agents, amines

Lay up

- **Same importance as steam purity specifications**

Steam Chemistry Limits

Tables of Steam Chemistry Limits for two Standard Cases

Parameter	Unit	Normal / Target Values
Conductivity after cation exchange @ 25 °C	µS/cm	< 0.20
Sodium as Na	µg/kg	< 2
Silica as SiO_2	µg/kg	<10

Steam purity for condensing utility turbines with superheated steam, applicable for steam temperature < 600 °C

Parameter	Unit	Normal / Target Values
Conductivity after cation exchange @ 25 °C	µS/cm	< 0.30

Steam purity for condensing utility turbines with saturated steam without reheat.

Customization for Turbine Types and Chemistries

Steam Turbine Systems and Operations

1. Cycling or Peaking Operation
2. Extended Periods of Shutdown
3. Backpressure Turbines
4. Industry and Process Supply
5. Solar and Biomass Steam Generating Systems
6. Geothermal Steam
7. Nuclear Power Plants
8. Ultrasupercritical Turbines (>600 °C)

Chemistry Parameters

9. Boilers using Phosphate Treatment
10. Elevated Levels of Carbon Dioxide
11. Organic Decomposition Products
12. Elevated Levels of Silica
13. Major Components with Copper or Aluminum

Customization for Turbine Types:
Industry and Process Supply

Example: contaminated return condensate

- ☞ Try to apply "standard case specifications"
- ☞ If required, apply mitigating features:
  - Use an adequate return condensate polishing plant
  - Do not use feedwater for steam attemperation
  - Provide sufficiently low boiler carryover
- ☞ If loosened steam purity limits are applied, check consequences on turbine operation
  - Analysis of steam turbine deposits
  - Test turbine trip and throttle valves at least weekly
  - Wash turbine if necessary
  - Give high importance to proper layup

Customization for Turbine Types and Chemistries

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Customization for Turbine Types:

Boilers using Phosphate Treatment

With drum boilers that use solid alkalizing agents it may be difficult to meet the "standard case" Na limits in steam because of carryover of boiler water.

Tri-sodium phosphate (TSP) is not known to be corrosive to turbine materials. Relaxed Na limit in steam is possible.

Customized Na limit will depend on turbine inspection results indicating which quantities lead to excessive turbine deposits.

Maximum allowance is up to a Na limit of < 5 µg/kg

But no allowance is possible if other products than TSP are used (Phosphate blends, NaOH, proprietary chemicals of undisclosed composition)

Customization for Turbine Types:
Elevated Levels of Carbon Dioxide

Moderate concentrations of carbon dioxide do not significantly influence turbine chemistry in alkalized steam.

A limited allowance to CACE (max 2 µS/cm) can be applied in systems with feedwater pH>8.5, and the absence of corrosive anions like Cl and SO_4 can be reasonably excluded:

- **Use of degassed CACE**
- **Regular ion chromatography analysis**
- **Always use on-line monitoring of Na**

Customization for Turbine Types:

Organic Decomposition Products

Natural organic matter:

Will partly decompose to organic acids

☞ **No allowance to "standard case" CACE limits**

Amines for feedwater treatment:

Will partly decompose to organic acids; depending on temperature, some amine may pass into the steam and neutralize or over-compensate the effect of the acid

☞ **Allowance on CACE is possible, but only under conditions:**

- **The exact composition of the product must be known**
- **The species of decomposition products must be known**
- **The decomposition products will not decrease pH in the liquid films in the turbine**
- **Regular ion chromatography analysis**
- **Always use on-line monitoring of Na**

Key Highlights of the new IAPWS Steam Purity TGD

- For the first time in the world covers all steam turbines
- Provides guidance and limits to protect the turbine
- Some relaxations for boilers on PT (using only TSP)
- Clear indication that the composition of proprietary chemicals must be known
- Guidance on CO_2 and how CACE relaxation can be used
- Proper interpretation of Degassed CACE
- How any relaxation depends on the knowledge of Na

PT	Phosphate Treatment
TSP	Tri Sodium Phosphate
CACE	Conductivity after cation exchange