Condenser Tubes in Thermal Power Plants
Issues and Solutions

ICCI 2014
April 24, 2014

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Tube Problems Recently Erupted

- Copper failures for several reasons
- Microbiological influenced corrosion (MIC)
- Hydrogen embrittlement
- New titanium fatigue mechanism
- Cleaning related problems
- New tubes are not made like they used to be

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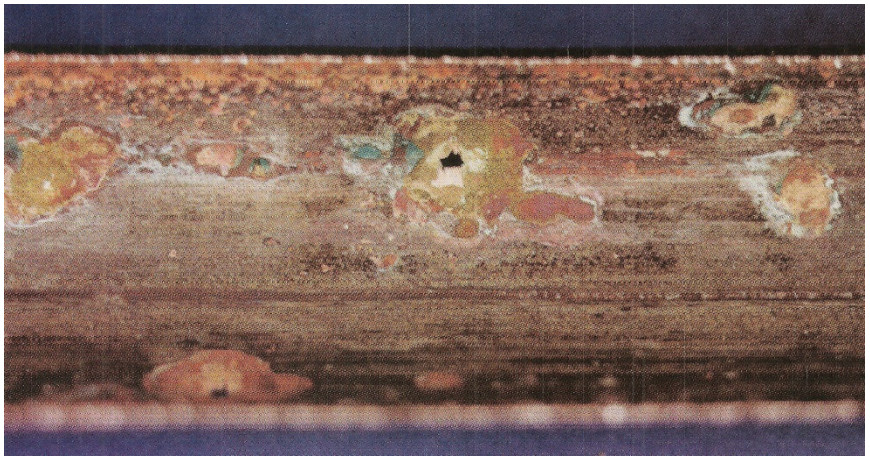
Copper Alloy Failures

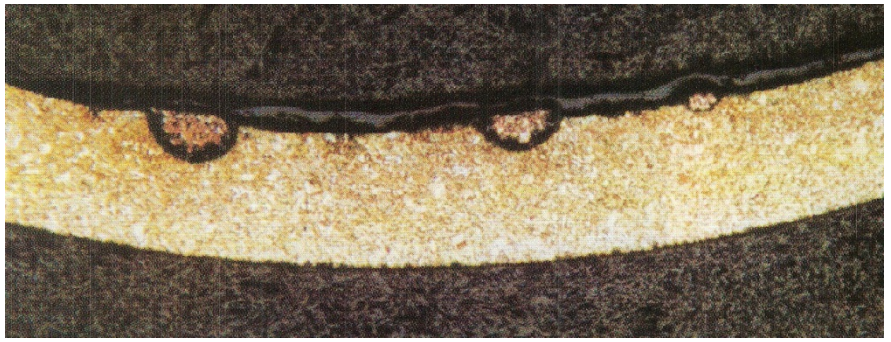
- Pitting and crevice corrosion
- Dealloying
- Ammonia grooving and stress corrosion cracking
- Galvanic corrosion
- MIC
- Many above are combinations
- Erosion-Corrosion (this is actually one that is mechanically based)

Copper Failures

- Pitting and crevice corrosion

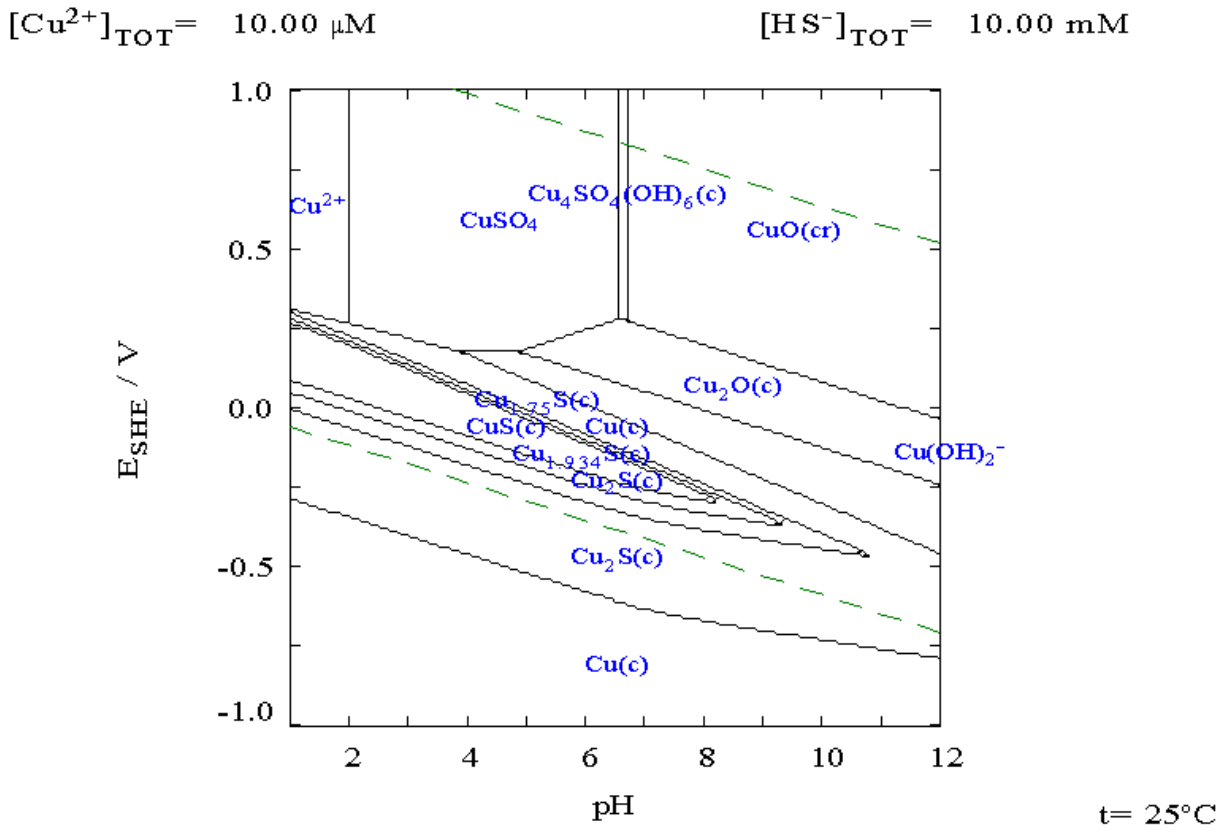


- Dealloying



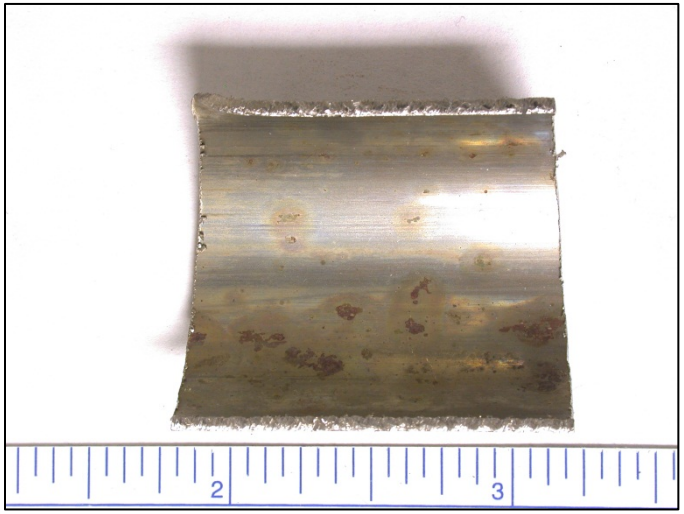
- Ammonia Grooving & SCC

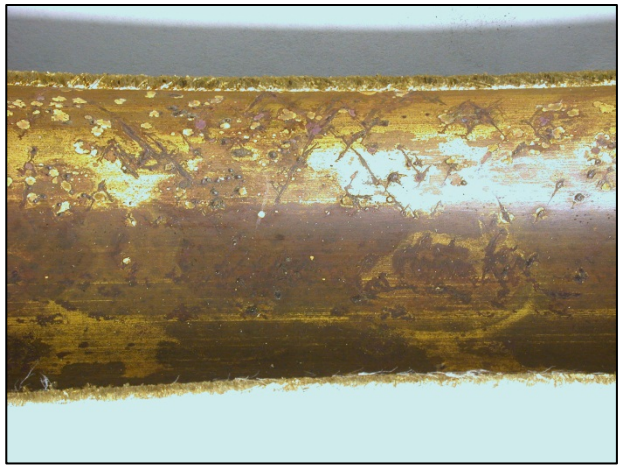
Add a Bit of H_2S



Copper Failures

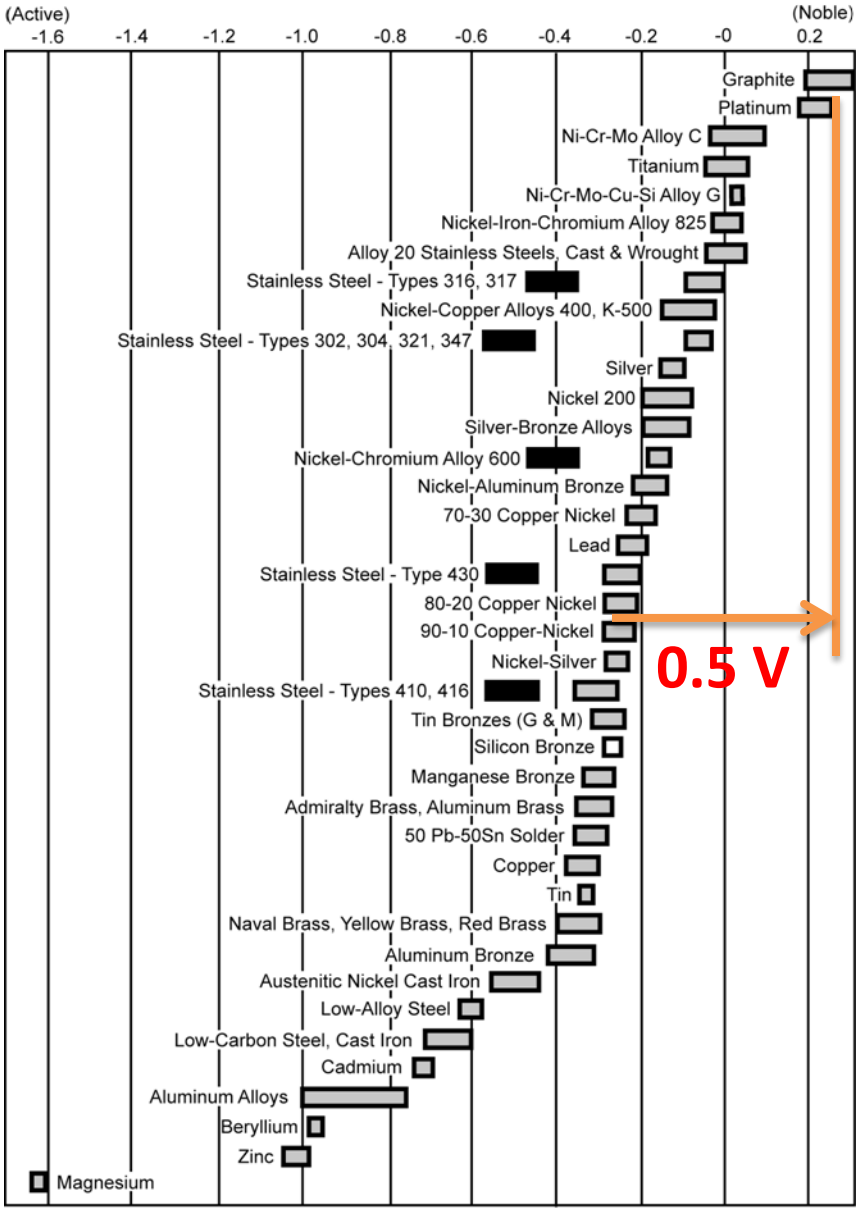
- Galvanic Corrosion





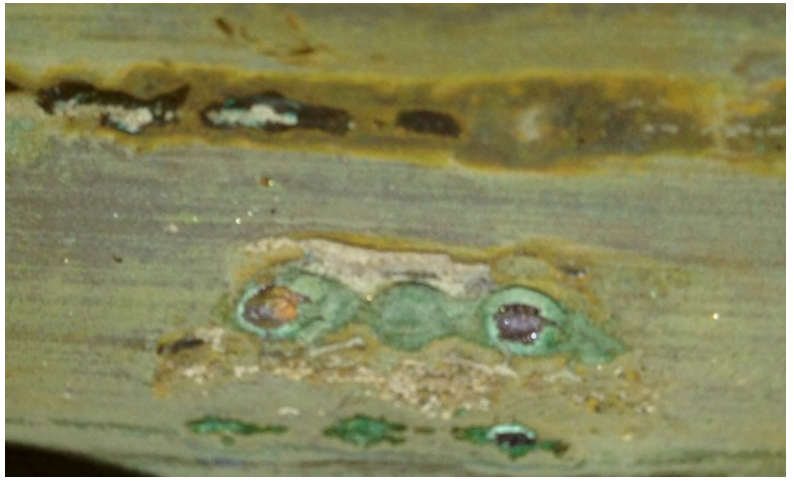
Galvanic Attack

- In area of graphitic char, the Cu/Ni becomes the sacrificial anode!
- It's crucial to make sure that Cu alloy is clean

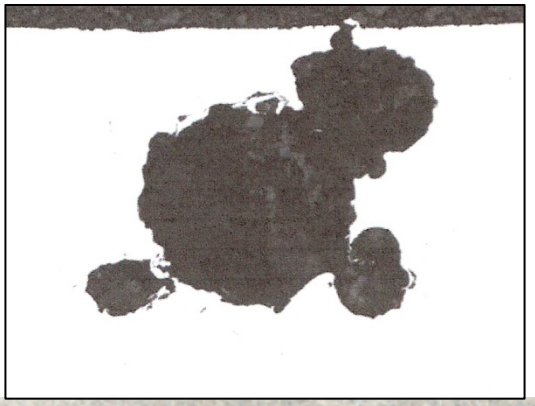


MIC Attack

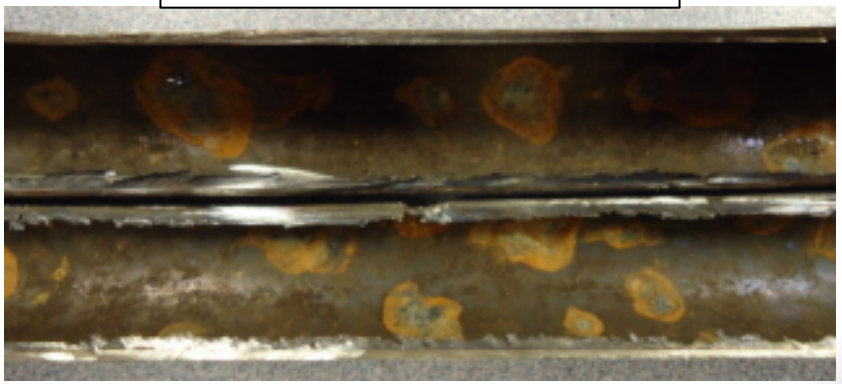
Copper Alloys



300 Series



Type 439



Bacteria Groups

Organism	Action	Problem
Thiobacillus	Sulfate Reducer	Produces H_2SO_4
Desulfovibrio	Sulfate Reducer	Produces H_2S
Gallionella	Mn/Fe Fixer	Precipitates MnO_2, Fe_2O_3
Crenothrix	Mn/Fe Fixer	Precipitates MnO_2, Fe_2O_3
Spaerotilus	Mn/Fe Fixer	Precipitates MnO_2, Fe_2O_3
Nitrobacter	Nitrate Reducer	Produces HNO_3

Bad For Copper Alloys

Bad for 300 Series SS

Bad for Cu & Steel

Hydrogen Embrittlement

- Has become very common on super-ferritic stainless steels and titanium
- Source or hydrogen is often cathodic protection systems
- These high performance alloys are often considered problem-free!

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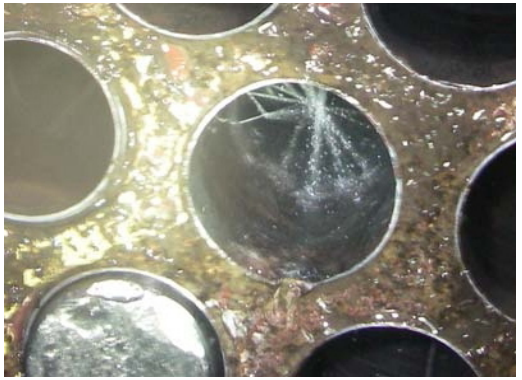
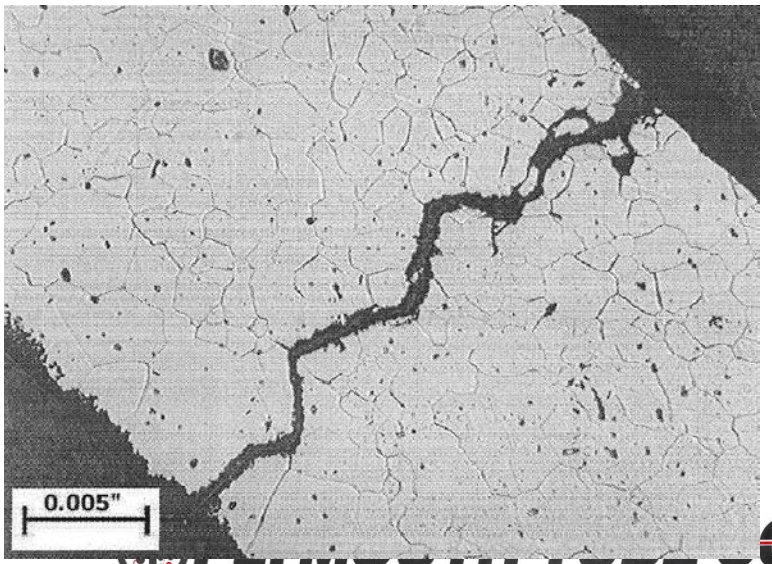
Hydrogen Embrittlement – Super-Ferritic Stainless

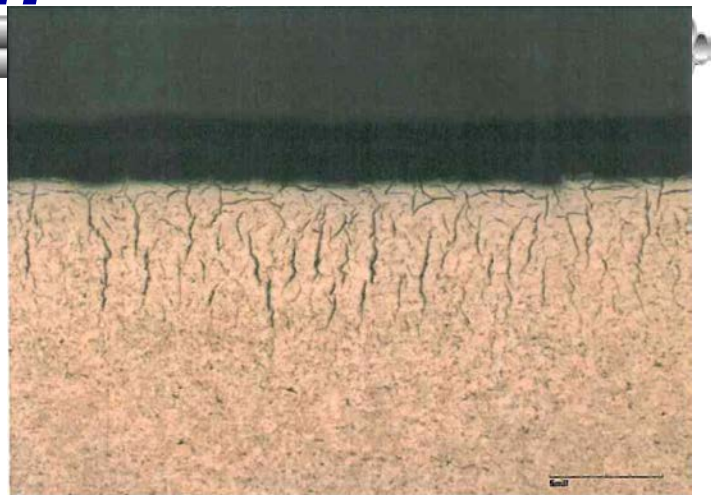


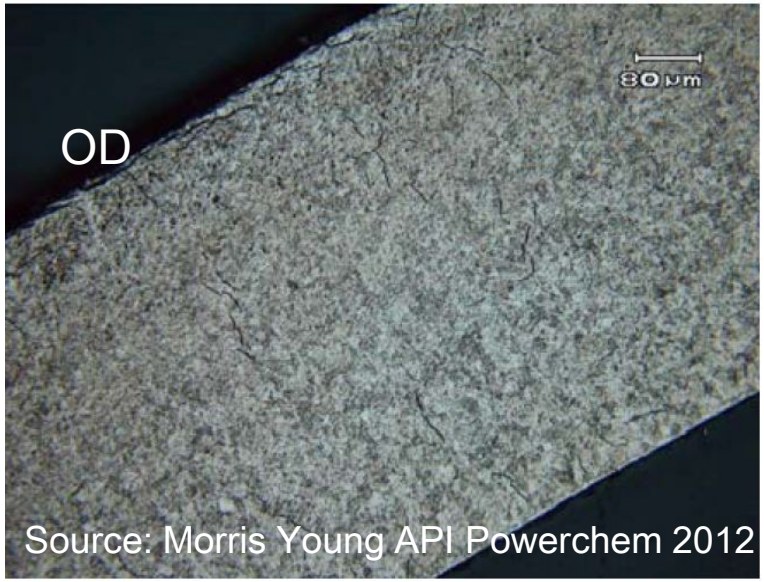
- Can occur quite suddenly under shock condition
- Occurs near H_2 source which is usually at end of tube at rolled transition joint.
- Usually at outer tubesheet edge near anode



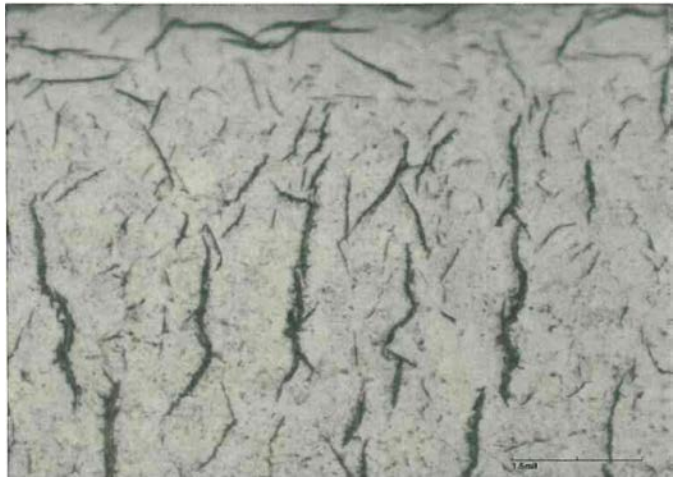
Hydrogen Embrittlement – Titanium

- Growth in Ti is gradual
- Located mostly near source but area is more extended
- If cathodically induced, usually tubesheets are damaged at same time





Source: Morris Young API Powerchem 2012



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Hydrogen Embrittlement

- In most cases – easy to prevent!
  - Keep impressed current system voltage less negative than -750 mv.
  - Don’t use Mg based sacrificial anodes
- Super-ferritic embrittlement is reversible
  - Once discovered, eliminate source and ductility will return
- Ti embrittlement is not reversible
  - 8 entire condensers have been replaced.

New Vibration Failure Mode

- Has been identified in 4 nuclear plants
- Random locations in the bundle
- Always associated with a longitudinal groove such as a scratch or weld depression

Source: T. Mayer EPRI BOP/NDE Conference, August 6-8, 2012

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New Vibration Mode Failure

- Believed to be high cycle fatigue from “whirling” motion
  - Tube may be “ovaling” during whirl
- So far has only occurred to Ti
  - Ti has a low modulus and fatigue limit
  - May be accentuated by anisotropy precaution in ASME Section II Part D para. A454

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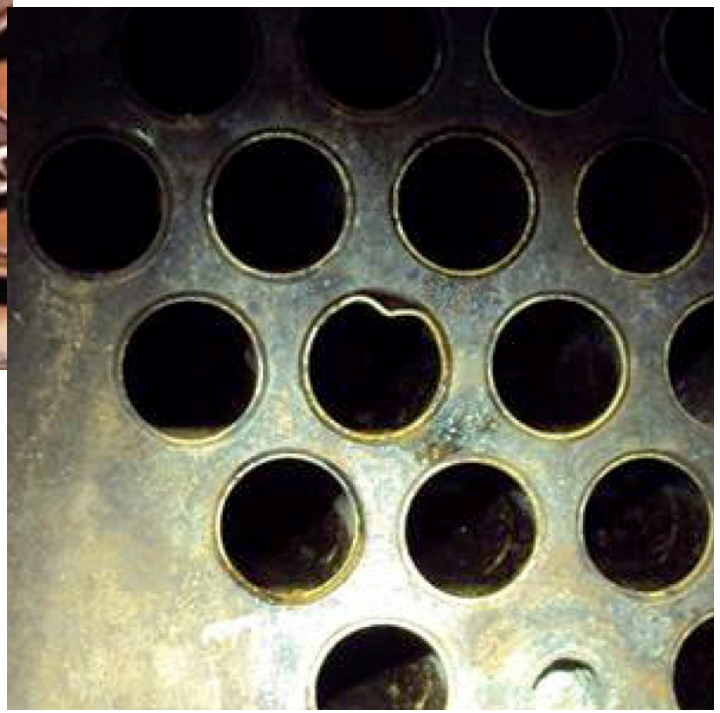
Cleaning Challenges



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Cleaning Challenges

- How to avoid?
  - Turn off wand before exiting and don't turn on until it's into tube!
  - Use other cleaning methods

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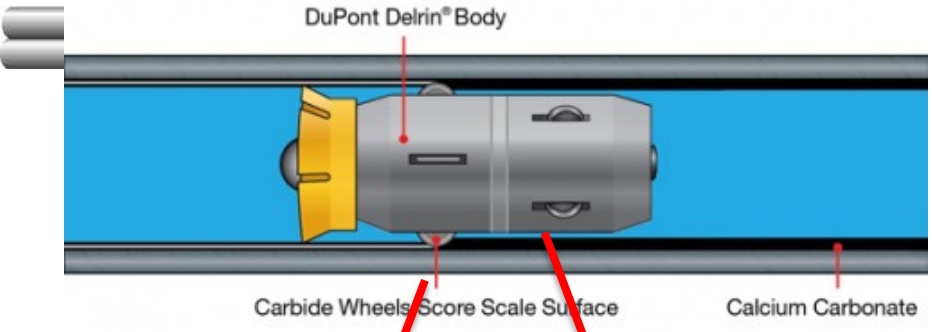
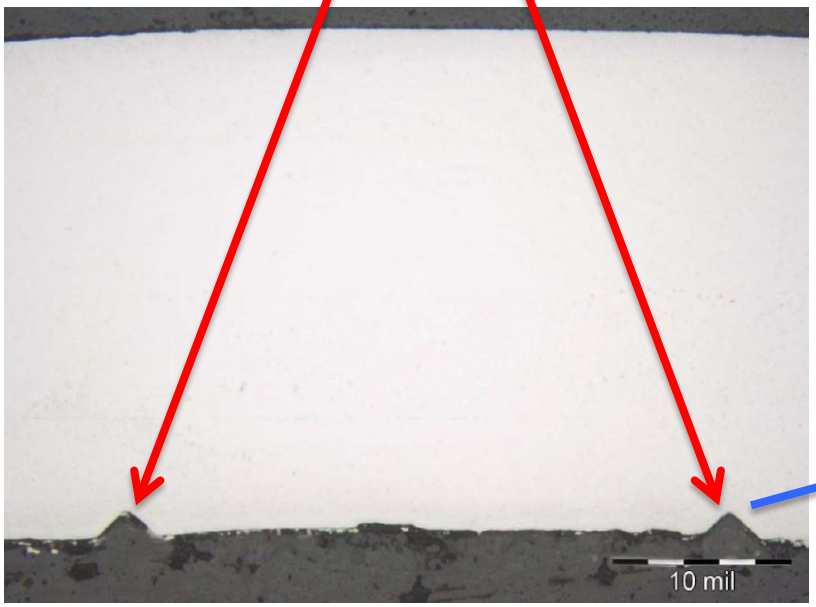
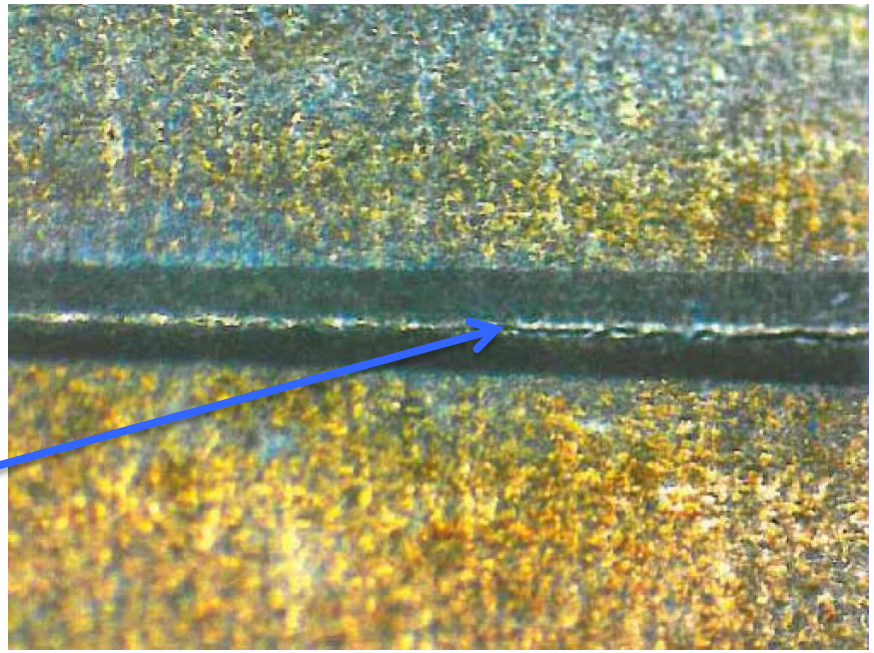
Cleaning Challenges



- Two Ti tubed plants now having failures from ID grooves





Source: W. Wiltsey EPRI BOP/NDE Conf; Aug 6-8, 2012

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"Tubes Are Not Made Like They Use To Be"
Summary of 300 Series Critical Pitting Potential

Source	Ident	Anneal	Corr mV	Alloy	Comment
PTWM	D	Good furnace bright anneal	>1200	304L	
A	A		783	316L	
PTWM	L	Tinted furnace bright anneal	519	304L	
PTWM	E	Poor furnace bright anneal	472	304L	Less shiny
Trent	G	Good in-line anneal	453	316L	
B	B		432	316L	
Trent	F	In-line too low of temp	423	316L	Spec min
Trent	H	In-line with poor purge	364	316L	No tint
B	K		253	316L	Looks OK
C	C		248	316L	Dull

E. Blessman; EPRI Condenser Conf, Chicago 2011

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Failures Happen Quicker!

- Copper Alloys
  - Years ago Arsenic was standard addition
  - Today's manufacturing is focused on price
- 300 Series Stainless
  - Today alloy shaving has alloys at bottom of ASTM specification
  - Furnace annealing almost non-existent today
- Specifications rarely require corrosion resistance test

Summary

- No alloy is immune to everything! Even the expensive ones…
- The old “proven” alloys are no longer proven.
- Almost every failure is avoidable provided homework and planning is done.

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Questions

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