




# Condenser Tubes in Thermal Power Plants Issues and Solutions

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# *Tube Problems Recently Erupted*

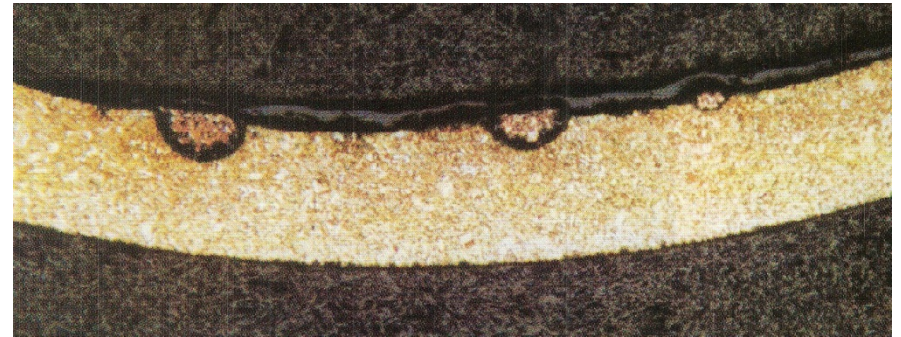
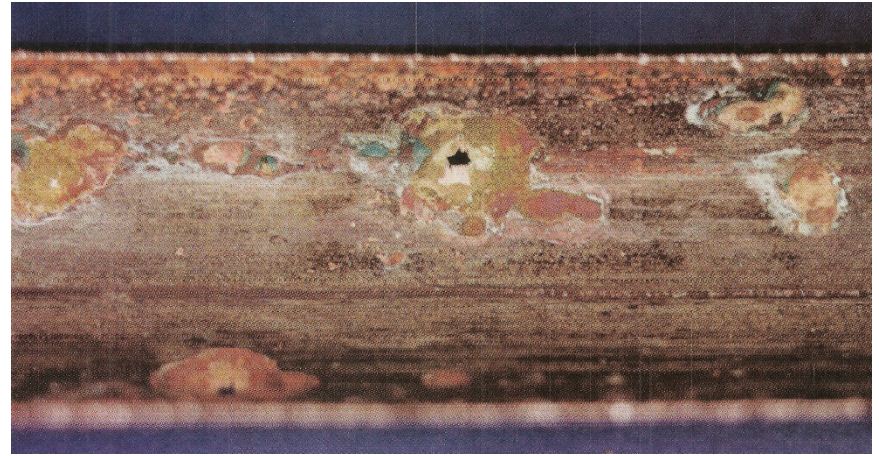
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- Copper failures for several reasons
  - Microbiological influenced corrosion (MIC)
  - Hydrogen embrittlement
  - New titanium fatigue mechanism
  - Cleaning related problems
  - New tubes are not made like they used to be

# 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

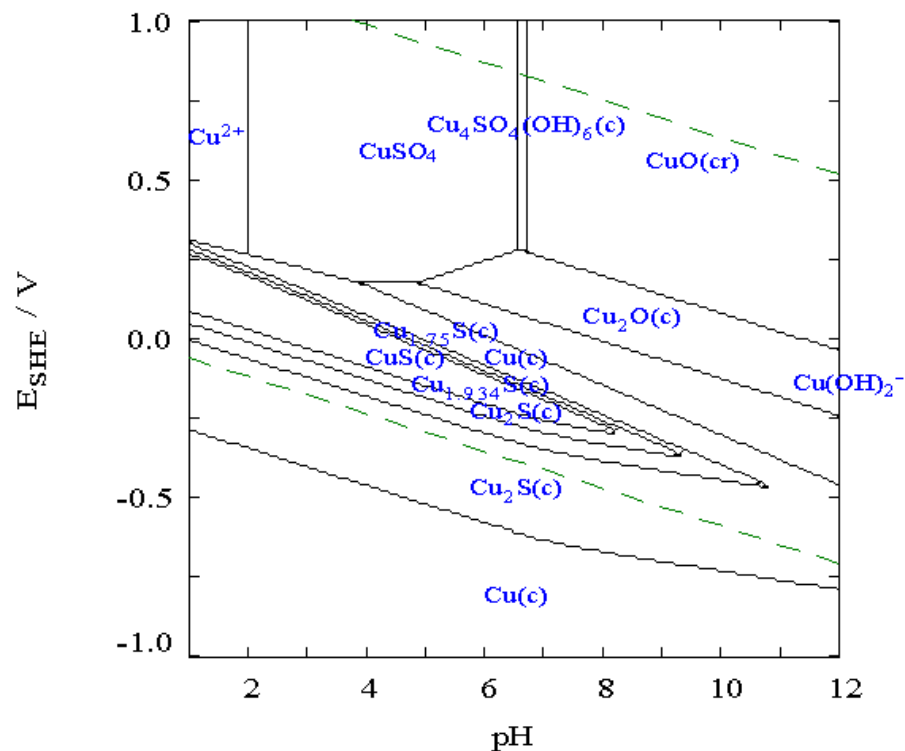
- Pitting and crevice corrosion
- Dealloying
- Ammonia Grooving & SCC



# Add a Bit of H<sub>2</sub>S

[Cu<sup>2+</sup>]<sub>TOT</sub> = 10.00 μM

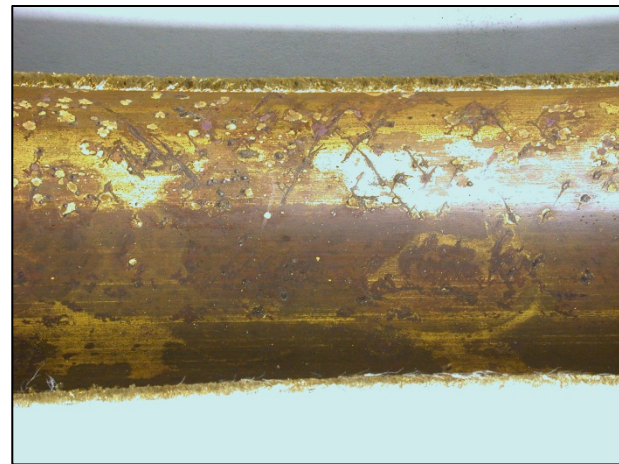
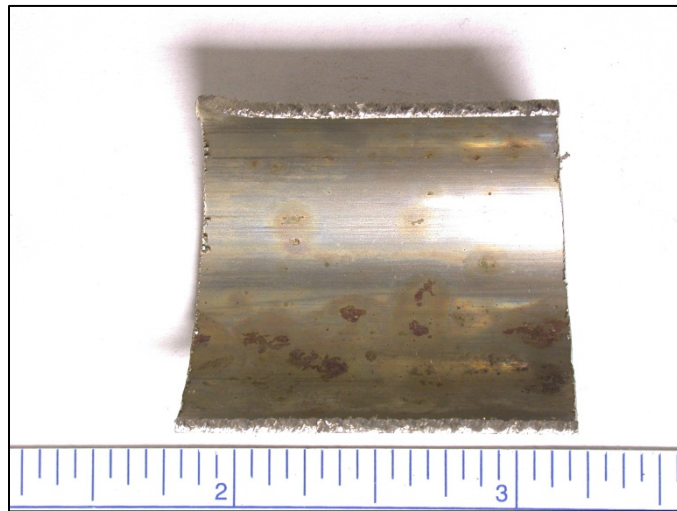
[HS<sup>-</sup>]<sub>TOT</sub> = 10.00 mM



t = 25°C

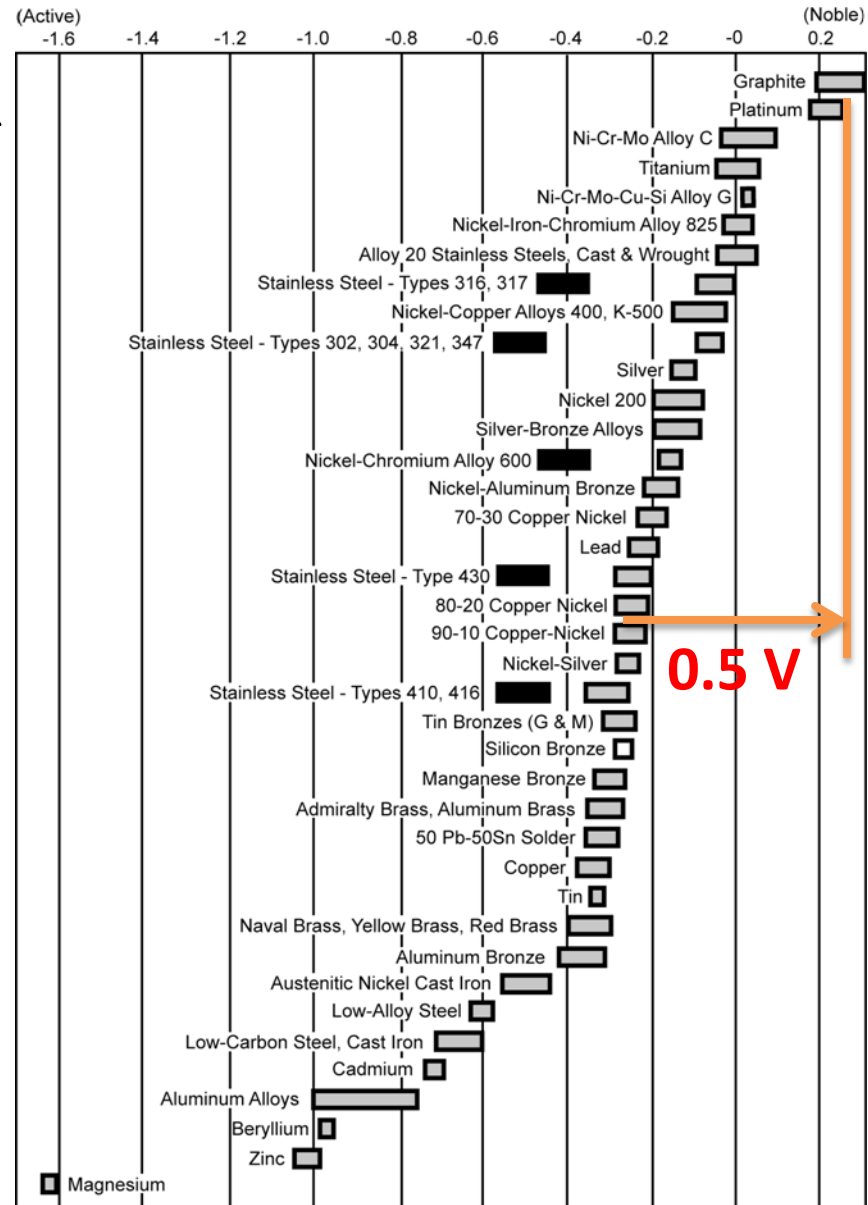
# Copper Failures

- Galvanic Corrosion



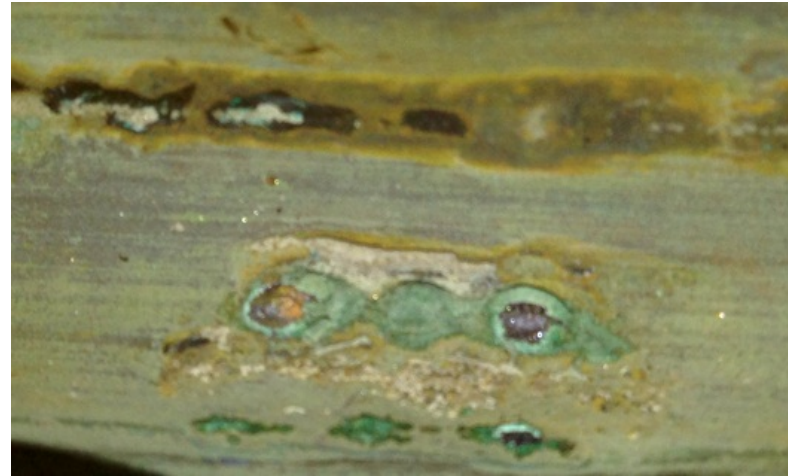
# Galvanic Attack

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

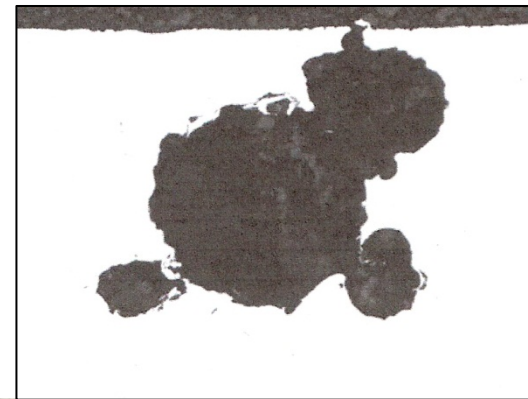


# MIC Attack

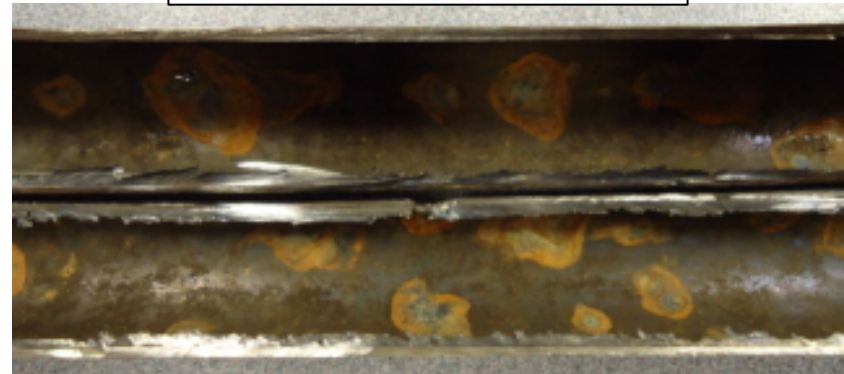
Copper Alloys



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

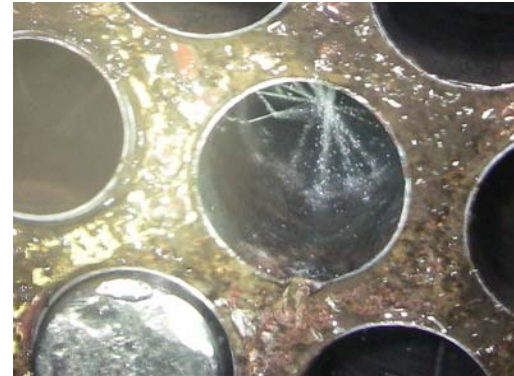
Bad for 300 Series SS

Bad for Cu & Steel

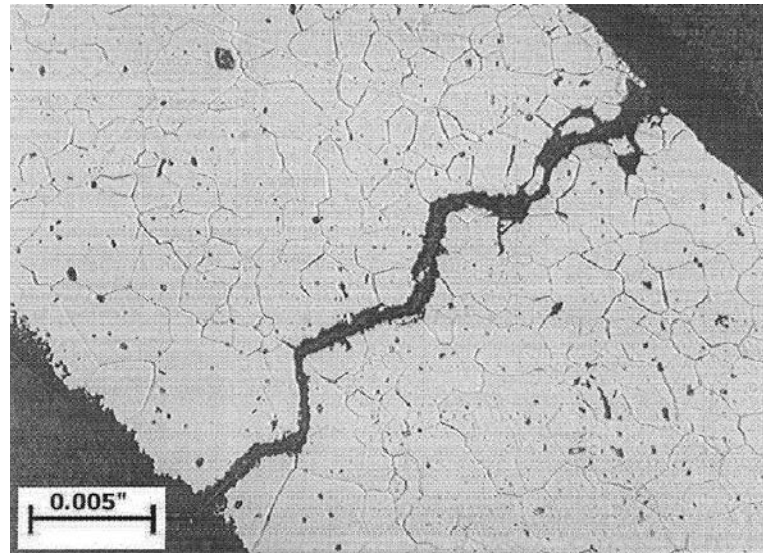
# *Hydrogen Embrittlement*

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

# Hydrogen Embrittlement – Super-Ferritic Stainless

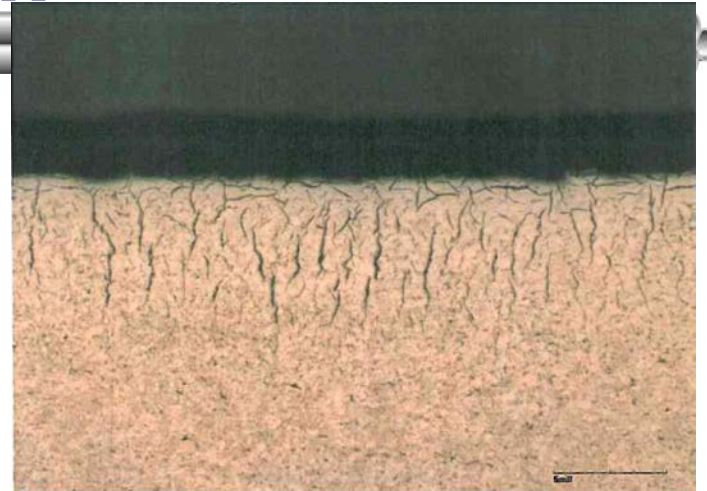


- Can occur quite suddenly under shock condition
- Occurs near H<sub>2</sub> source which is usually at end of tube at rolled transition joint.
- Usually at outer tubesheet edge near anode



# 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



# *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

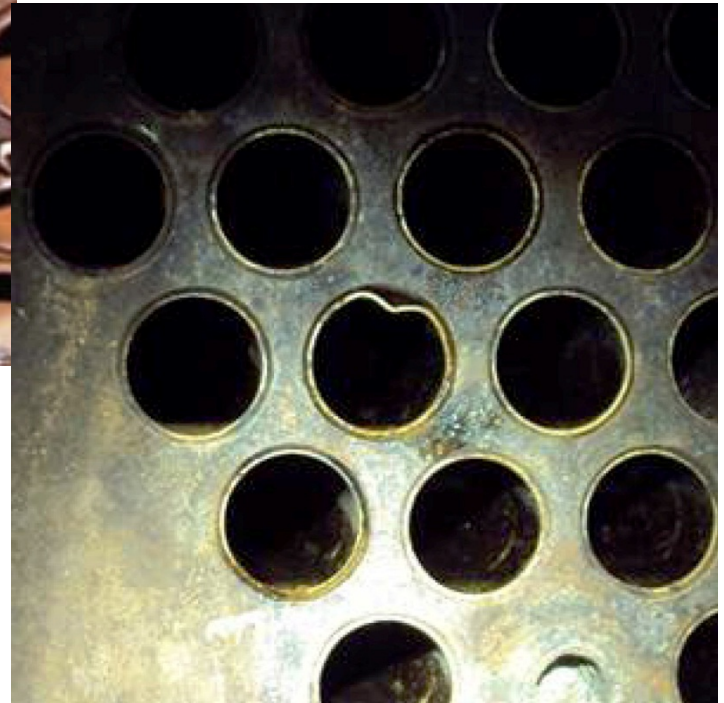
Source: T. Mayer EPRI BOP/NDE Conference,  
August 6-8, 2012

# ***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 anisotropyprecaution in ASME Section II Part D para. A454

# *Cleaning Challenges*





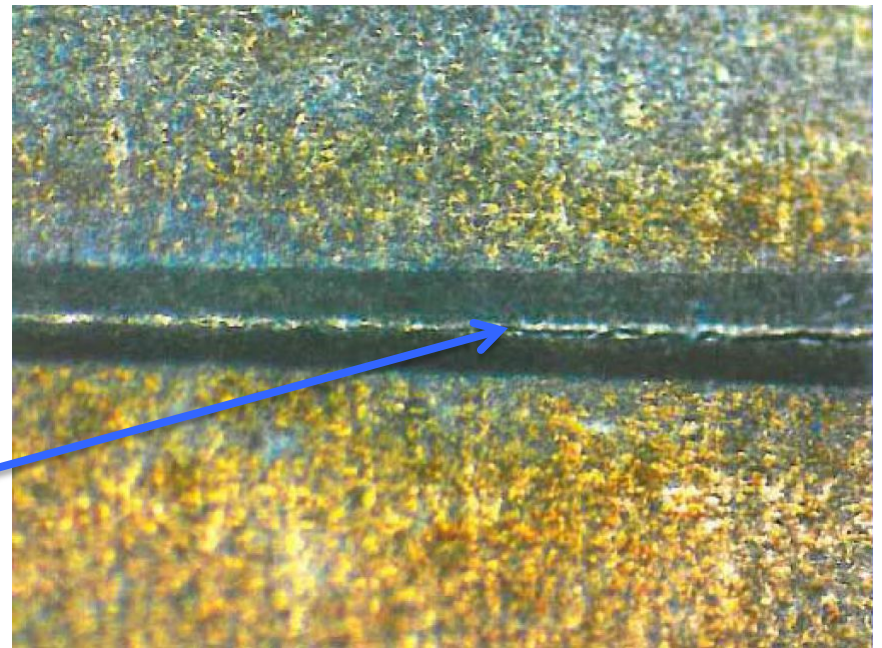
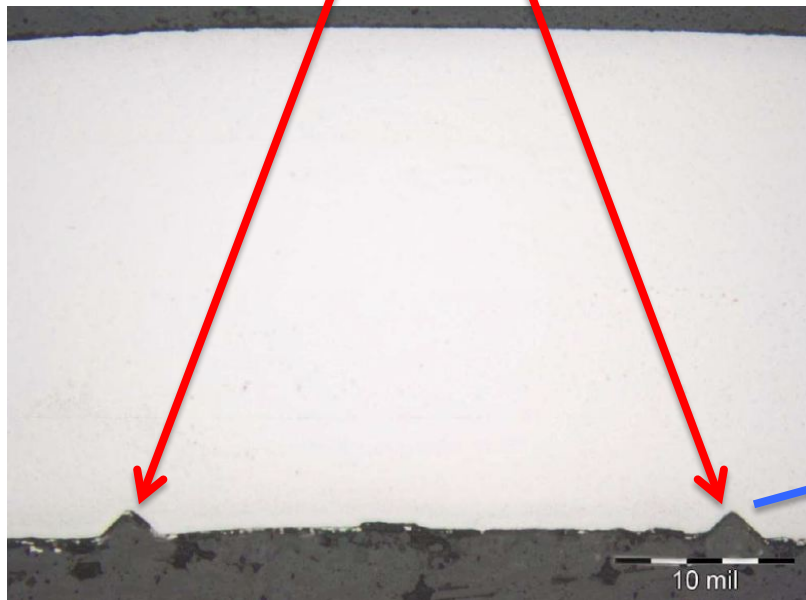
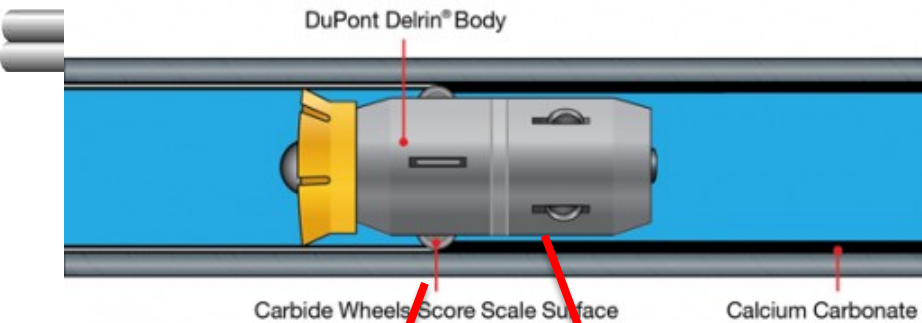
# *Cleaning Challenges*

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



# Cleaning Challenges

- Two Ti tubed plants  
now having failures  
from ID grooves



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

# ***“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

# *Failures Happen Quicker!*

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- 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.



# *Questions*

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