The Evolution of Titanium Powerplant Surface Condenser Tubing…..
Forty Years & 600,000,000 Feet later

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Because it is not possible to anticipate specific uses and operating conditions, Valtimet urges you to consult with technical service personnel on your particular application.

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Martin Heinrich Klaproth named titanium after the first sons of Titan in Greek Myth.

Oceanus
Hyperion
Coeus
Cronus
Crius
Lapetus
Titanium
commercial - consumer - architecture

Boeing 777 - 787 + series
Airbus 300+ series
Golf clubs

consumer products
medical prosthetics
Bilbao Guggenheim museum
Titanium
military, armor, etc.

- F22 Raptor
- Stryker vehicle
- Submarine
- F35 JSF
- DDG 72
- M 113
- CVN 21
- Automotive
world metallic (*) titanium usage projections

- commercial aero: 38%
- industrial: 35%
- military: 12%
- consumer/Emerging: 9%
- other: 6%

(90% of all mined Ti = pigments)
## Chemical Requirements Gr. 2... cp
(Composition, Weight Percent)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Carbon Max</th>
<th>Oxygen Max</th>
<th>Nitrogen Max</th>
<th>Hydrogen Max</th>
<th>Iron Max</th>
<th>Others Max</th>
<th>Others Max Total</th>
<th>Titanium</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.08</td>
<td>0.25</td>
<td>0.03</td>
<td>0.015</td>
<td>0.3</td>
<td>0.1</td>
<td>0.4</td>
<td>Remainder</td>
</tr>
</tbody>
</table>
40 years & 600 million ft later..
primary equipment applications for titanium tubing

shell & tube heat exchanger

powerplant surface condenser
Protect Assets

Corrosion ID & Abatement Drives Mat’l Selection
Miscellaneous Cooling Water Sources

Sea Water, Brackish Water, River Water, Cooling Lakes, etc.

Cooling Tower and/or Cooling Tower Blowdown

Produced Water

Gray Water, Plant Effluent or Municipal Wastewater

FGD or Other Plant Wastewater

Holy Water

Waste Streams – Demin, HRSG, RO

Steam/Condensate/Feedwater

Scotch & Water
corrosion

“Dirty Dozen”

activities that put equipment in harms way

conventional

- Chlorides
- Steam Droplet Erosion (Nuclear)
- Inlet Erosion/Corrosion
- Ammonia
- Suspended Solids Erosion (I.E. Sand)
- Calcium Carbonate
- MIC
- Manganese
- Gray Water (Effluent)
- Hydrogen Embrittlement
- Biocidal Growth Fouling

\( \text{FUTURE CIRH} \text{_0 SOURCES ???} \)
MIC
(MICROBIOLOGICAL INFLUENCED CORROSION)

or bacteria in a biofilm……..

- CAUSED BY SULPHURIC/SULPHUROUS PRODUCING BACTERIA COLONIES
- THE CHLORINE/HYPOCHLOROUS REACTS WITH MANGANESE PRODUCING HYDROCHLORIC ACID
- RESULT----------> REDUCTION OF THE CREVICE/PITTING & CORROSION RESISTANCE
### “TYPICAL” GRAY, IMPAIRED OR TREATED EFFLUENT WATER ANALYSIS

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>EFFLUENT (mg/l)</th>
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<tbody>
<tr>
<td>Fecal Coliform</td>
<td>13</td>
</tr>
<tr>
<td>BOD (Biochemical Oxygen Demand)</td>
<td>5.5</td>
</tr>
<tr>
<td>TSS (Total Suspended Solids)</td>
<td>5</td>
</tr>
<tr>
<td>COD (Chemical Oxygen Demand)</td>
<td>47.3</td>
</tr>
<tr>
<td>Nitrate+ite</td>
<td>21</td>
</tr>
<tr>
<td>Ammonia</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>TKN (Total Kjeldahl Nitrogen)</td>
<td>2.66</td>
</tr>
<tr>
<td>T Phosphorus</td>
<td>2.23</td>
</tr>
<tr>
<td>Potassium</td>
<td>10.8</td>
</tr>
</tbody>
</table>

Beware of sinkers & floaters!

APS
Palo Verde Units 1, 2 & 3
Make-up = 100% Treated Sewage Effluent
• Oxidizing Neutral & Inhibited Conditions
• Chlorides
• Inlet Erosion/Corrosion
• Pitting Crevice Corrosion (Temp limited)
• Cavitation
• Fatigue-Related Corrosion
• Flow-Assisted Corrosion (FAC)
• SCC
• Galvanic Attack
• MIC
• Manganese
• Gray Water
Titanium = \textit{corrosion immunity in the condenser system}

Ref: IMI (Imperial Metals) Peacock, et’ al’
new shop fabricated units
field rehab existing units
field rehab existing units

Mechanical Tube Expansion
## 2010 Tube Pull-Out Load Tests update

<table>
<thead>
<tr>
<th>Test Project</th>
<th>Tube Mat'l</th>
<th>Tube OD</th>
<th>Tube Wall (AVW)</th>
<th>TS Mat'l</th>
<th>Pull-Out Load Range (lbs)</th>
<th>Serrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santee Cooper/Winyah</td>
<td>Ti Gr 2</td>
<td>1.0”</td>
<td>0.028”</td>
<td>Mtz</td>
<td>1750</td>
<td>No</td>
</tr>
<tr>
<td>Santee Cooper/Winyah</td>
<td>Ti Gr 2</td>
<td>1.0”</td>
<td>0.028”</td>
<td>Mtz</td>
<td>2350 – 2500</td>
<td>Yes</td>
</tr>
<tr>
<td>Santee Cooper/Winyah</td>
<td>Ti Gr 2</td>
<td>1.0”</td>
<td>0.035”</td>
<td>Mtz</td>
<td>2050 – 2250</td>
<td>No</td>
</tr>
<tr>
<td>Santee Cooper/Winyah</td>
<td>Ti Gr 2</td>
<td>1.0”</td>
<td>0.035”</td>
<td>Mtz</td>
<td>3900 - 3950</td>
<td>Yes</td>
</tr>
<tr>
<td>SCS Yates</td>
<td>Ti Gr 2</td>
<td>0.875”</td>
<td>0.022”</td>
<td>Mtz</td>
<td>1200 – 1300</td>
<td>No</td>
</tr>
<tr>
<td>SCS Yates</td>
<td>Ti Gr 2</td>
<td>0.875”</td>
<td>0.022”</td>
<td>Mtz</td>
<td>2700</td>
<td>Yes</td>
</tr>
<tr>
<td>SCS Yates</td>
<td>Ti Gr 2</td>
<td>0.875”</td>
<td>0.035”</td>
<td>Mtz</td>
<td>1400 - 1550</td>
<td>No</td>
</tr>
<tr>
<td>SCS Yates</td>
<td>Ti Gr 2</td>
<td>0.875”</td>
<td>0.035”</td>
<td>Mtz</td>
<td>3400 - 3700</td>
<td>Yes</td>
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</tbody>
</table>
Titanium condenser “thinning” tube gauge history
The Wrap Up….

A case for future optimism in titanium PowerGen
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- Fossil Plant Upgrades

40 years & 600 million ft later.....
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- New Nukes & Power Uprates

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- Increasingly poor H2O Quality

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- World Capacity Additions
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- Ti pricing vs. competing material
The Wrap Up....

A case for future optimism in titanium PowerGen

- Fossil Plant Upgrades
- New Nukes & Power Uprates
- Increasingly poor H2O Quality
- World Capacity Additions
- Ti pricing vs. competing material
- Raw material availability

40 years & 600 million ft later.....
POWERFUL TUBING SOLUTIONS
FOR CORROSIVE ENVIRONMENTS

Always ask questions
Thank you for your attention