Innovative water treatment solutions for seawater open evaporative systems

1st NACE Jubail Industrial Forum
17 – 19 Oct, 2011

Shereif Alsayed
Seawater Salinity Composition

**Sea salts**

- Chloride: 55% (19.25 g)
- Sodium: 30.6% (10.7 g)
- Sulfate: 7.7% (2.7 g)
- Calcium: 1.2% (0.42 g)
- Magnesium: 3.7% (1.3 g)
- Potassium: 1.1% (0.39 g)
- Minor constituents: 0.7% (0.25 g)

**Sea water**

- Water: 96.5% (965 g)
- Salt: 3.5% (35 g)

Quantities in relation to 1 kg or 1 litre of sea water.
Seawater Salinity Distribution

Seawater Properties

Density (Lbs/CuFt) vs Temperature (°F)

- Seawater
- Quadruple
- Triple
- Double
- Normal
- Fresh Water

Temperature

°F

60 61 62 63 64 65 66 67 68 69 70

Density (Lbs/CuFt)

32 60 90 120 150 180
Seawater Properties

Specific heat BTU / LB °F

Temperature °F

- Fresh Water
- 1/4 Normal
- 1/2 Normal
- 3/4 Normal
- Seawater concentration
- Double seawater concentration
Factors affecting physical properties

- Conductivity
- Temp
- Depth
- Desalination plants reject.
- Vicinity of other plants.

PARAMETER

<table>
<thead>
<tr>
<th>Density</th>
<th>Specific Heat</th>
</tr>
</thead>
</table>

- Desalination plants reject.
- Vicinity of other plants.
Seawater Properties

• Effect of lower specific heat

Energy required = heat rejected = Q

\[ Q = \text{specific heat} \times \text{mass} \times DT \]

\[ Q(\text{brackish water}) = \text{specific heat} \times \text{mass} \times DT \]

\[ Q(\text{Seawater}) = \text{specific heat} \times \text{mass} \times DT \]

\[ \frac{Q \text{ brackish water}}{Q \text{ seawater}} = > 1 \]

Brackish cooling system is less efficient

\( Q: \text{Cal} \), \( C_p: \text{Cal/g \degree C} \), \( \text{Mass: g} \), \( DT: \degree C \)

\( Q: \text{BTU} \), \( C_p: \text{Btu/Lb \degree F} \), \( \text{Mass: Lb} \), \( DT: \degree F \)
Seawater Properties

• Effect of higher density

Energy required = heat rejected = Q
Q = specific heat \times mass \times DT
Q(\text{brackish water}) = \text{specific heat} \times \text{mass} \times DT
Q(\text{Seawater}) = \text{specific heat} \times \text{mass} \times DT

\frac{Q \text{ brackish water}}{Q \text{ seawater}} = < 1

Seawater cooling system is less efficient

Q: \text{Cal, } C_p: \text{Cal/g } ^\circ\text{C}, \text{Mass: g, DT: } ^\circ\text{C}
Q: \text{BTU, } C_p: \text{Btu/Lb } ^\circ\text{F}, \text{Mass: Lb, DT: } ^\circ\text{F}
Seawater Properties

Loss in energy can be compensated by:

- Increased tower size.
- Adjusting fan horsepower.
- Increased circulation rate.
Treatment Concerns
Corrosion
“Designed out”

Deposition

Fouling
Scale Formation
Scale Formation

Calcium Carbonate

Scale potential depends on:

- Calcium
- pH control
- Alkalinity
- Temperature
- Ionic strengths
Calcium Sulphate

Scale potential depends on:
- Calcium
- Sulphate
- Ionic strength
Scale Formation

CaSO₄ Solubility

[Graph showing the solubility of CaSO₄ as a function of temperature, with different phases indicated: CaSO₄ · 2H₂O (Gypsum), CaSO₄ · 1/2 H₂O (α-hemihydrate), and CaSO₄ (Anhydrite).]
Factors affecting deposition

- Magnesium
- Silicate
- pH
New Technology
Treatment practices overview

- Typical cycles (1.2 – 1.3).
- No pH control or adjustment.
- Continuous chlorination.
- Material of construction.
  - Sacrificial anode for yellow metallurgy alloys.
"Generally, sea water can be concentrated to approximately 55,000 ppm salinity with no pH adjustment without serious scaling problems in the exchangers. Higher concentrations are possible but pH control by acid additions probably be required. Two of the major users of sea water cooling towers operate to 55,000 ppm salinity as the upper limit and this procedure has been satisfactory."

GE technology reached > 80,000 ppm, free pH
Evaluation of Inhibitors
Operating Conditions

- Coupons: Ti, 70/30 Cu/Ni,
- CRM Probe: 70/30 Cu/Ni
- Heat Exchanger Tubes: Ti, 70/30 Cu/Ni
- Water Temperature: 40 °C
- Estimated Skin Temperature: 52 °C
- Water Velocity: 1.5 m/s
Corrosion Coupons

Titanium Gr2

< 0.1 mpy

< 0.1 mpy

Cu Ni 70 -30

1.7 mpy

1.7 mpy

CRM probe corrosion Cu/ Ni 70-30 : 0.9 mpy
## Heat exchanger tubes

<table>
<thead>
<tr>
<th>Material</th>
<th>Corrosion Rate (mpy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titanium Gr2</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>Cu Ni 70 -30</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>1.7</td>
</tr>
</tbody>
</table>
Technology Guide

- Stiff & Davis Max 1.50 @ 52ºC (skin)
- Up to theoretical LSI of 2.5 @ 52ºC.
- Max 2.4 cycles (depending on chemistry).
- Free pH, pH of 8.4.
- 38.5% saving in make up requirement.
- Reduced energy consumption (make up, blow down pumps)
- Forgiving program, higher tolerance for upsets and excursions.
- Compatible with halogenation practices.
Technology Features & Advantages

- Acid Free Application
- Higher Cycles Tolerance
- Smaller Plants Footprint
- Polymer Based
- Halogen Stable
- Saves Water and Energy
- Safe on Environment