Corrosion & degradation of performance was an issue with Absorbers in the past.

Old Absorption technology requires operators to periodically run a vacuum pump to insure operation & to maintain chilled water set point.

Oxygen is the source of corrosion inside an Absorber. If proper vacuum can be maintained for the absorbers life there is no opportunity to have corrosion form inside the Absorber.
“Big 10”, “State”, “Ivy League” and Universities all across North America & Canada are using “Modern Absorption” to lower the cost of proving chilled water on campus.

Absorber Factory Testing is now a “New Normal” and the only way to truly guarantee AHRI 560 performance standards.
Absorption tube material selection is a critical success factor for long life & low life cycle costs.
What should be inside an absorber besides a vacuum?

Lithium Bromide (LiBr) Solution

1) LiBr Boiling point is much higher when compared to water 100°C (212°F) at Atm Pressure
2) Very strong affinity towards water vapor
At high temperature, Copper can react chemically with LiBr solution, leading to electrochemical corrosion.

Challenge = Eliminate the potential for corrosion
Absorbers are made up of multiple shell & tube heat exchangers with *different* application environments

- Single Stage Absorbers have 4 main shell & tube heat exchangers:
  - **Generator** (200°F / 93°C)
  - Condenser
  - Evaporator
  - Absorber
Two Stage Absorbers have 5 or more shell & tube heat exchangers:

- Generator “HTG” (300 F /148 C)  
  “high temperature generator”
- Generator “LTG”  
  “low temperature generator”
- Condenser
- Evaporator
- Absorber
Generator tubes are immersed in Li Br solution at the Highest Temperature

The LiBr solution absorbs heat causing the refrigerant H2O to boil. As the refrigerant is boiled away, or “generated,” the LiBr solution becomes more concentrated.
Condenser tubes theoretically only see H2O inside the absorber. The cooling tower water inside the tubes are often the source of corrosion as it is an “open loop” & local water treatment service can vary greatly.

Heat transfers from the refrigerant vapor to the tower water, inside the tubes the refrigerant H2O condenses on the tube surfaces and collects in the bottom of the condenser.
Evaporator theoretically does not see LiBr solution only R718= H2O

Chilled water through the tubes, liquid refrigerant is sprayed over the tube surfaces. As heat transfers from the chilled water to the cooler liquid refrigerant, the refrigerant boils (vaporizes) change of state.
Absorber tubes are immersed in LiBr solution & typically connected to a open cooling tower.

Refrigerant vapor is absorbed by the LiBr solution. As the refrigerant vapor is absorbed, it condenses from a vapor to a liquid, releasing heat. This heat, is rejected to the cooling tower water.
The Historical Most Common TUBE materials used in Absorbers

• Copper is characterized by high ductility, and electrical and thermal conductivity.

• The softness of copper explains its high thermal conductivity. Pure copper is orange-red and acquires a reddish tarnish when exposed to air. As with other metals, if copper is put in contact with another metal, galvanic corrosion will occur.
Another historical common TUBE materials used in Absorbers such as the generator.

- **Cupronickel** (aka *copper-nickel*) is an alloy of copper that contains nickel and strengthening elements, such as iron and manganese. Despite its high copper content, cupronickel is silver in color.

- Cupronickel is highly resistant to corrosion in seawater. For this reason, it is used for piping, heat exchangers and condensers in seawater systems, marine hardware.
Common Tube materials used in Absorbers and other heat exchangers.

- **Stainless Steel** is a steel alloy with a minimum of 10.5% chromium content by mass.
- Stainless steels are notable for their corrosion resistance, which increases with increasing chromium content. Molybdenum additions increase corrosion resistance in reducing acids and against pitting attack in chloride solutions. Stainless steel differs from carbon steel due to the presence of chromium. Unprotected carbon steel rusts readily when exposed to the combination of air and moisture. In comparison, stainless steels contain sufficient chromium to undergo passivation, spontaneously forming a microscopically thin inert surface film of chromium oxide by reaction with the oxygen in air and even the small amount of dissolved oxygen in water. Stainless steels are used where both the strength of steel and corrosion resistance are required.
Typical Materials in 2018
Stainless Steel economizers – heat exchangers

Plate Heat Exchanger for economizers
316L Plates, Nickel alloy is solder.

- No copper in plate heat exchanger, no corrosion.
TUBE materials used in Absorbers

• Titanium: **Titanium** is a chemical element with a silver color, low density, light weight and high strength. Titanium is resistant to corrosion in sea water, aqua regia, acids and chlorine.
Comparison on Material Corrosion Resistance and Velocity

<table>
<thead>
<tr>
<th></th>
<th>Pure Copper</th>
<th>Copper-Nickel</th>
<th>Stainless Steel</th>
<th>Titanium</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clorine</strong></td>
<td>Resist corrosion under low temp &amp; low concentration</td>
<td>Resist corrosion under low and medium temperature</td>
<td>Resist corrosion differs by types of stainless steel</td>
<td>No corrosion</td>
</tr>
<tr>
<td><strong>salt water (speed)</strong></td>
<td>1.2 m/s  3.9 Ft/sec</td>
<td>3.6 m/s  11.7 ft/s</td>
<td>5-7m/s  16.2 -22.7 ft/s</td>
<td>No limitation</td>
</tr>
<tr>
<td><strong>Ammonia</strong></td>
<td>Serious corrosion</td>
<td>Corrosion</td>
<td>No corrosion</td>
<td>No corrosion</td>
</tr>
<tr>
<td><strong>Polluted air &amp; water</strong></td>
<td>Corrosion</td>
<td>Slight corrosion</td>
<td>No corrosion</td>
<td>No corrosion</td>
</tr>
</tbody>
</table>
### Comparison on Material Strength

<table>
<thead>
<tr>
<th></th>
<th>Pure copper</th>
<th>Copper Nickel</th>
<th>Stainless Steel</th>
<th>Titanium</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tensile Strength</strong></td>
<td>250-270</td>
<td>320-380</td>
<td>480-520</td>
<td>420-480</td>
</tr>
<tr>
<td><strong>PSI</strong></td>
<td>36250 39150</td>
<td>46400-55100</td>
<td>69600-75400</td>
<td>60900-69600</td>
</tr>
<tr>
<td><strong>Yield Strength</strong></td>
<td>150-160</td>
<td>190-230</td>
<td>290-320</td>
<td>320-380</td>
</tr>
<tr>
<td><strong>PSI</strong></td>
<td>21750-23200</td>
<td>27550-33350</td>
<td>42050-46400</td>
<td>46400-55100</td>
</tr>
</tbody>
</table>

The importance of Tube Material Strength in sections that see large temperature swings frequently (thermal stresses) such as generator(s) room temperature to well above 300F / 148 C is often a large design consideration.
Typical Materials in 2018 by location

Evaporator Tube Bundles

Condenser Absorber Generator Tube Bundles
Economics & life cycle factors tube material selection has an impact.
In Conclusion

• Tube selection can be a significant factor to and Absorbers life cycle & should be a considered with each application for use based on project goals and specifics.

• As tubes become stronger and less resistant to deterioration wall thickness can be reduced to gain or overcome thermal efficiency differences between material choices.

• Less weight can reduce installation costs.

• Materials that are stronger and resistant to corrosion will reduce life cycle cost

• Economics of materials and tubes technology changes such as enhancements, cross hatching-rifleling allow for numerous choices for tube selection to improve life cycle costs and the efficiency of the chiller.
Condensing Direct Fired Absorption?

Condensing Heat Recovery:

Condensing heat recovery chiller:
- Natural Gas 18289MBH
- Natural Gas 3262MBH
- Total (21551MBH)

Heating Capacity: 7060MBH
- COP: 0.91
- Rate: 1.7
- Sub-cooling: 996 RT

17060MBH: production processing

Cooling Capacity: 367 RT
- COP: 1.36

1365 RT Building cooling

Normal direct-fired chiller:
- Natural Gas 18289MBH
- Natural Gas 12045MBH
- Total (30334MBH)

Heating Capacity: 7060MBH
- COP: 0.91

17060MBH: production processing

Cooling Capacity: 367 RT
- COP: 1.36

1365 RT Building cooling

Condensing heat recovery chiller utilizes only 71% energy of normal direct-fired chiller
High density magnetic field filters trap and hold ferrous fines, fragments, and small metal objects.
Maintains LiBr solution purity
Maintains COP
Maintain low operating cost
Titanium Tubes the “New Normal of Modern Absorption Units”

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