Basic Refrigeration Cycle Components
Condensers

Purpose: Converts High Pressure/Temperature Gas to High Pressure/Temperature Liquid and Rejects Heat to the Air or Water

Types

- Water Cooled
- Air Cooled
- Evaporative
Water Cooled Condensers

- Shell and Tube are the Most Common
- Water is in the Tubes, Refrigerant Vapor is in the Shell
- As the Hot Gas comes into Contact with the Cool Outer Surface of the Tube, the Heat is Removed and the Gas Condenses into a Liquid
- Plate and Frame - see Plate and Frame Evaporator. Refrigerant Vapor Condensed instead of Evaporated
Air Cooled Condensers

- Refrigerant Passes through the Coil with Fans Pushing Air Across the Coil, Cooling the Refrigerant, Condensing the Gas to Liquid
- Requires the Refrigerant Temperature to be Higher than Ambient Outside Temperature on the Hottest Day to Function to Design Conditions
Evaporative Condensers

- Makes use of Both Water and Air to Cool Gas
- Water is Sprayed from Above onto the Coil; Air is Pushed from Below the Coil
- As the Water Evaporates from the Coil a Portion of Heat is Removed from the Refrigerant in the Coil Allowing it to Condense
- Ensure Water Treatment to Prevent Scale & Algae Buildup
Hot Saturated Discharge Air

Principle of Operation

Air In → Fan → Refrigerant Vapor In → Refrigerant Liquid Out → Cool Dry Entering Air
Evaporative Condensers Types

- **Forced Draft:** Air is forced into the cabinet, over the condenser tube bundle, through the spray water, and discharge out the top through the drift eliminators.

- **Induced Draft:** Air is drawn in to the cabinet from the bottom, over the tube bundle, through spray water, drift eliminators, then discharge at high velocity through the top mounted fan.

- **Hybrid Condenser:** Induced draft, but is part condenser and part cooling tower. Air is drawn in from the top over the spray water and tube bundle, then over a PVC fill which cools the water further. The air does a 180d turn and is discharge at the top at high velocity through top mounted fans.
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Major Components

- **Sump**: Contains a pump intake screen, pump, float fill valve, overflow connections and drain connections. Sump heater, basin sweeper, and bottom clean outs popular. In cold states, a remote sump is utilized.

- **Fan Plenum**: Forced is at the bottom, Induced at the top. Area for the air velocity to even out before going through the tube bundle/heat exchanger.

- **Drift Eliminators**: Use multiple changes in direction to impinge droplet on the surface and allow them to collect until they are heavy enough to drop back out.

- **Fan Section**: Sometimes double axial fan, some single, some centrifugal. Drive can be direct drive, but most are belt driven.

- **Tube Bundle**: Most important part. Successive tubes coiled in a sloping manner to release heat to the air and water stream. Most are galvanized for ammonia, copper for freon. Can be stainless, but very expensive.

- **Cabinet**: Can be galvanized, stainless, or concrete on large installations.
Tube Bundle/Heat Exchanger
Clean sump of debris 2 to 4 times per year depending on proximity to rural areas or frequency of dust storms.

Lubricate fan and pump motor and shaft bearings per mfr recommendations, twice per year in absence.

Check and clean spray nozzles twice per year. Check monthly.

Pressure wash tube bundle high and low twice per year.

Water treatment should include TDS meter triggered bleed system. biocide, corrosion monitoring, and pH monitoring.

Startup passivation is critical to long term life. Very complicated.
TABLE 1 - RECOMMENDED WATER CHEMISTRY*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH **</td>
<td>6.5 to 8.0</td>
</tr>
<tr>
<td>Hardness as CaCO3 (ppm)</td>
<td>50 to 300</td>
</tr>
<tr>
<td>Alkalinity as CaCO3 (ppm)</td>
<td>50 to 300</td>
</tr>
<tr>
<td>Total Dissolved Solids (ppm)</td>
<td>&lt; 1,000</td>
</tr>
<tr>
<td>Total Suspended Solids (ppm)</td>
<td>&lt; 25</td>
</tr>
<tr>
<td>Bacteria Count (cfu/ml)</td>
<td>&lt; 10,000</td>
</tr>
<tr>
<td>Chlorides as Cl⁻ (ppm)</td>
<td>200 Galvanized Steel</td>
</tr>
<tr>
<td>Chlorides as Cl⁻ (ppm)</td>
<td>400 Type 304 Stainless</td>
</tr>
<tr>
<td>Chlorides as Cl⁻ (ppm)</td>
<td>4000 Type 316 Stainless</td>
</tr>
</tbody>
</table>

* Based on standard EVAPAK® fill
** Galvanized steel units require routine passivation when operating with a pH of 8.3 or higher in order to prevent “white rust.”
Passivation

Burned Tube Bundle
Passivation
Passivation

- Maintain a pH of 7.0 to 7.8 during passivation process.
- Heavy bleed rate, near 1.5 cycles of concentration.
- Use very dilute acids for pH balance and blend in the sump.
- Going for a protective Zinc Carbonate surface. Hard and protective.
- pH above 8.5 forms Zinc Oxide or White Rust.
- pH above 10 destroys the Zinc Carbonate Layer and starts to destroy the galvanizing.
Design Considerations

- **Specific Efficiency of Condenser:** High horsepower pumps and fan versus larger heat exchangers.

- **Saturated condensing temperature versus wet bulb:** Balance points seem to be between 12 to 17 °F.

- **Low ambient operation:** How are the compressors cooled, how much variation is acceptable.

- **VFD Drives:** Always make sense based on differential above wet bulb temperature. Always have bypass contactors.

- **Forced draft is easier to maintain.** Induced has fewer leaks and high discharge velocity.
Refrigeration system “lift”

Medium temperature systems gain more benefit from floating head pressure.
Condensers – design and selection practice

- Nominal sizes stem from HVAC practice
- Air cooled condensers
  - capacity varies with ambient **Dry Bulb Temp**
  - past practice driven by limiting maximum pressures
  - sizing TD of 10 F (LT) to 15 F (MT) unchanged for years
  - but, big range in motor size
- Evap cooled condensers
  - capacity varies with **Wet Bulb Temp**
  - past industry practice based on first cost (95 F SCT)
  - TD declining over time: 25° >> 16° >> 10°(?)
  - big range in fan power
- Wide range of catalog efficiencies
Variation in efficiency – evap cooled

Examples of evap cooled condenser specific efficiency
Fixed head pressure

- Ambient DBT
- Condensing Temperature
Floating head pressure

- Ambient DBT
- Condensing Temperature
Variable speed fan control – third power relationship

80% speed = 51% power
50% speed = 12% power
Part load condenser performance
variable speed vs. fan cycling

Specific efficiency increased by 300% with variable speed
Condenser/Evaporator Design Trends
400 ton, 6000# NH3
400 ton, 750# NH3
800 ton, 1500# NH3
Primary Advantages

Small Refrigerant Charge

- Up to 75% less
- As low as 1 lb of ammonia per ton
- Reduce or eliminate PSM or RMP requirements

Reduced Liability

- Contain system charge in one location
- Eliminate exposure to people and products
- Reduce liability insurance costs
Primary Advantages

Compact Footprint

- Up to 50% less space for installation
- Smaller equipment room can save $$
- Ease of service (refrigeration system in smaller area)
- Reduced installation cost

Portability

- Entire system a common base
- Transport from one location to another
- Easily re-applied
- Saves time and $$
Primary Advantages

Natural Refrigerant

- It’s Ammonia! Zero ODP & Zero GWP
- More efficient than HFC’s, CFC’s…………
- Ammonia up to 90% less %

Efficiency

- PHE - small approach temperatures
- PHE countercurrent flow technology reduces condensing pressure
- 5:1 turndown variable speed drive technology
Questions?