The Importance of Compressor/Condenser Operation, Monitoring & Control

Gordon Brothers Industries P/L
for
WEA Conference, Mildura 2007

Aim

- To produce efficient refrigeration systems by specifically looking at:
  1. Suction Pressure (evaporating temperature)
  2. Condensing Pressure (temperature)
  3. Heat Reclaim

What is Refrigeration?

- The transfer of heat from one medium (e.g. wine) to another (e.g. atmosphere)
- Three parameters for heat transfer
  - Temperature difference (ΔT)
  - Area (A)
  - Constant (U)
- Heat Transferred (Q) = U x A x ΔT

Efficient Refrigeration

- High suction pressure (temperature)
- Low condensing pressure (temperature)
- Smaller differences = higher efficiency
- Coefficient of Performance (COP) =

$$\frac{\text{Compressor Capacity}}{\text{Absorbed Power}}$$

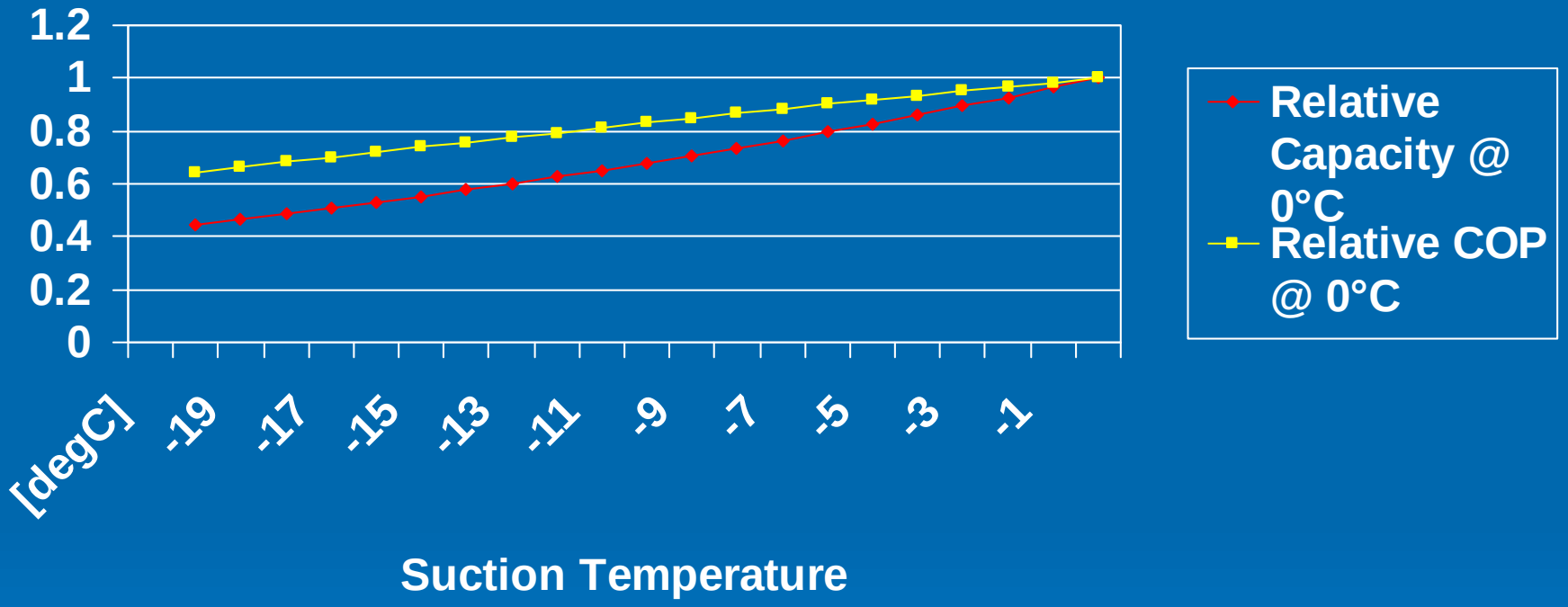
Saturated Refrigerant

- Saturation - for every pressure there is an equivalent temperature
- Can be a saturated liquid or vapour
- Vary the temperature by varying the pressure (e.g. for Ammonia):
  - 0 kPag = –33°C
  - 165 kPag = –12°C
  - 1250 kPag = 35°C

Suction Pressure

- Governed by
  - Product temperatures required
  - Size of the ΔT across HX
  - Size (Area, A) & efficiency of heat exchanger
  - Direct or Indirect cooling

Relative Efficiency (@ 0°C) vs Suction Temperature



- Efficiency falls by ~5% for every 2°C lowering of suction temperature

Secondary Cooling

- If the Winemaker wants –6˚C cooling medium, we can use:
  - –6˚C Ammonia directly for Immersion Chillers (spears), or
  - –12˚C Ammonia to 'make' –6˚C secondary brine for jacketed tanks
  - This 6˚C difference results in an efficiency change of 15%

Area vs ΔT

- A bigger transfer area (A) would reduce the temperature difference ΔT
  - More area = higher capital cost but lower operating costs
- Leads to a trade off at design between size and temperature difference

Suction Pressure Summary

- To reduce power consumption & increase efficiency
  - Use high suction pressure/temperature
    - Oversized heat exchangers allow for higher suction temperatures
  - Split product loads with different requirements to separate suction temperatures
    - High temperature for must chilling & red ferments
    - Low temperature for white ferments & cold stabilising

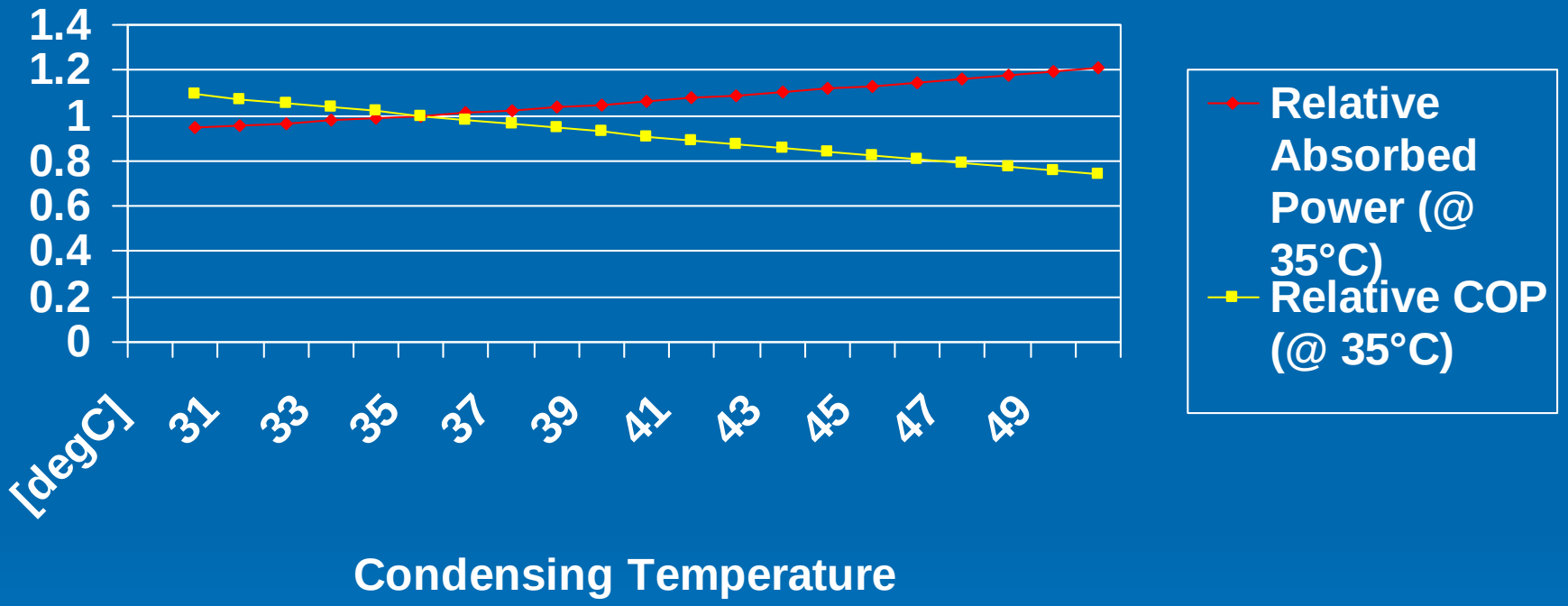
Condensing Pressure

- Governed by
  - Ambient Temperature (wet bulb, dry bulb temperatures)
  - Condenser Type (evaporative, water-cooled, air-cooled)
  - Correct condenser sizing with load
  - Non-condensable gases
  - Correct liquid trapping

Condensing Pressure

- Wet Bulb
  - Temperature a thermometer would read if the bulb was covered in a wet cloth and exposed to an air stream
- Dry Bulb
  - Temperature that we would normally measure with a ‘dry’ bulb thermometer
- Difference gives a measure of humidity

Relative Efficiency (@ 35°C) vs Condensing Temperature

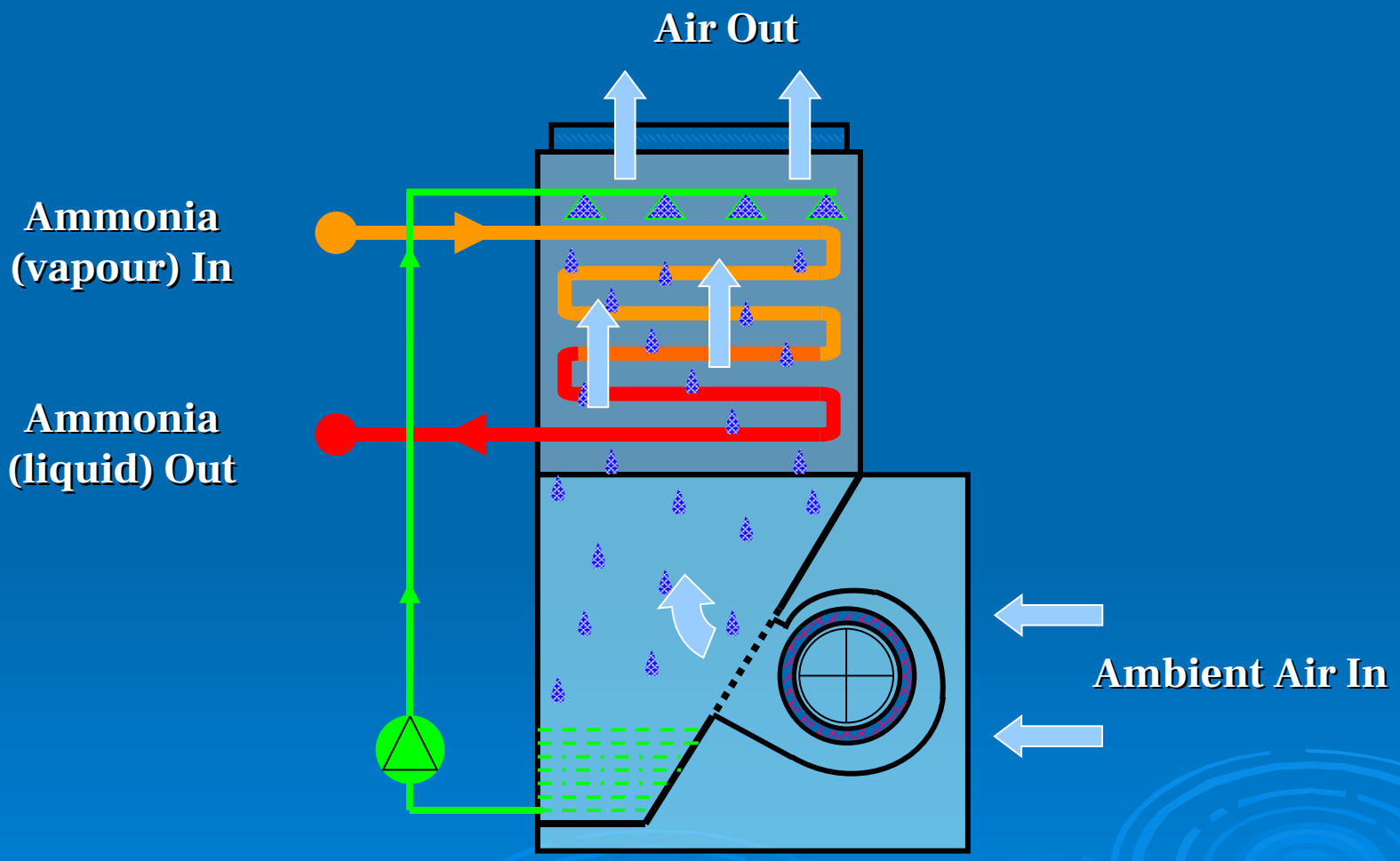


- Efficiency falls by ~5% for every 3°C increase in condensing temperature

Evaporative Condensers

- Governed by the wet bulb temperature
- Evaporation of water on outside condenser coil into air stream
- Condensation of Ammonia inside the coil
- Usually designed for 35˚C condensing temperature
  - Down to 30˚C for low wet bulb locations

Evaporative Condensers



NOTICE
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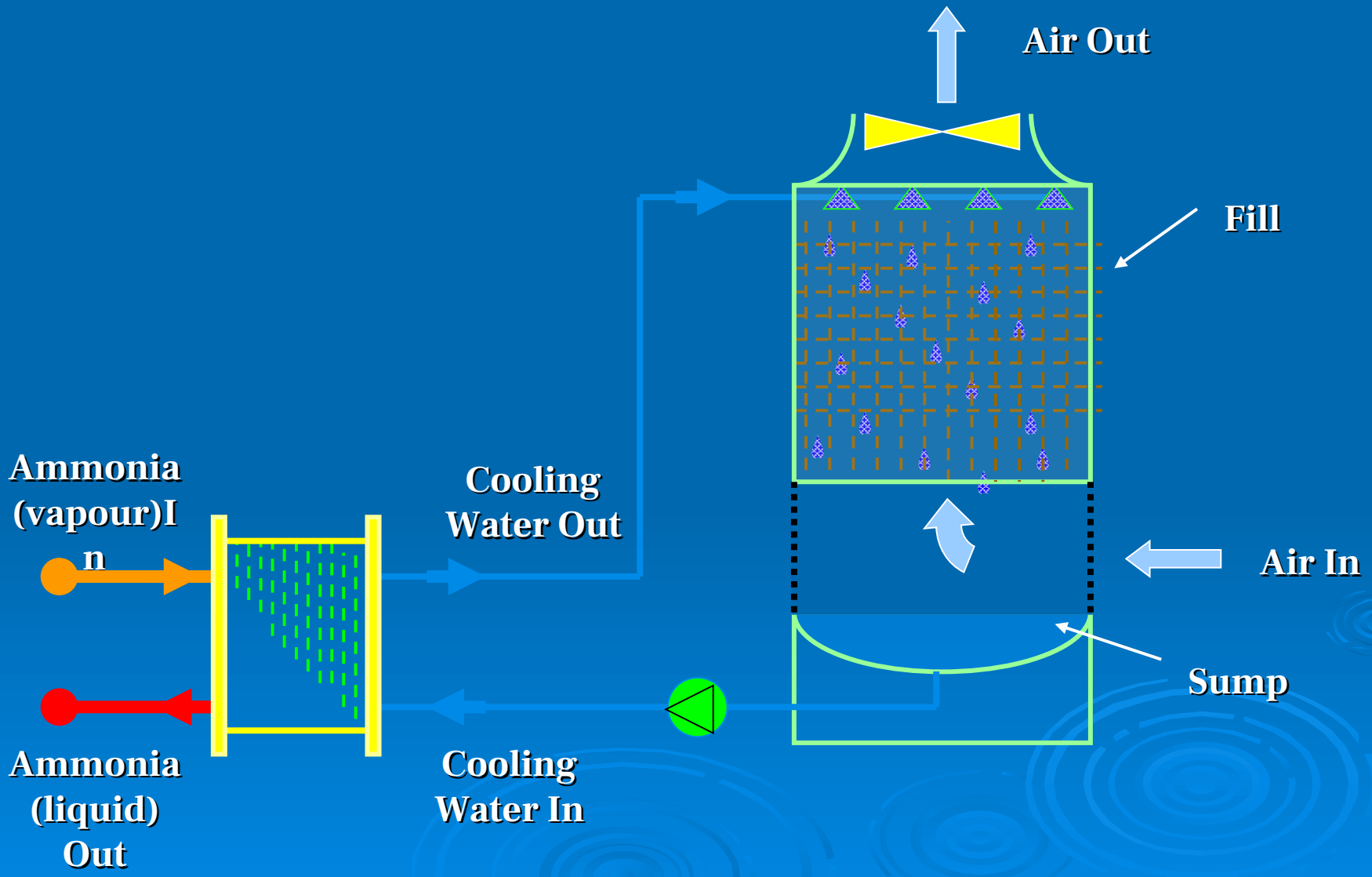
Water-Cooled Condensers

- Commonly a Cooling Tower along with Plate Condenser
- Water from cooling tower sump is pumped to the plate condenser
- Ammonia condenses on one side of each plate, with water on the other side
- Usually design for 40˚C condensing temp

Water-Cooled Condensers



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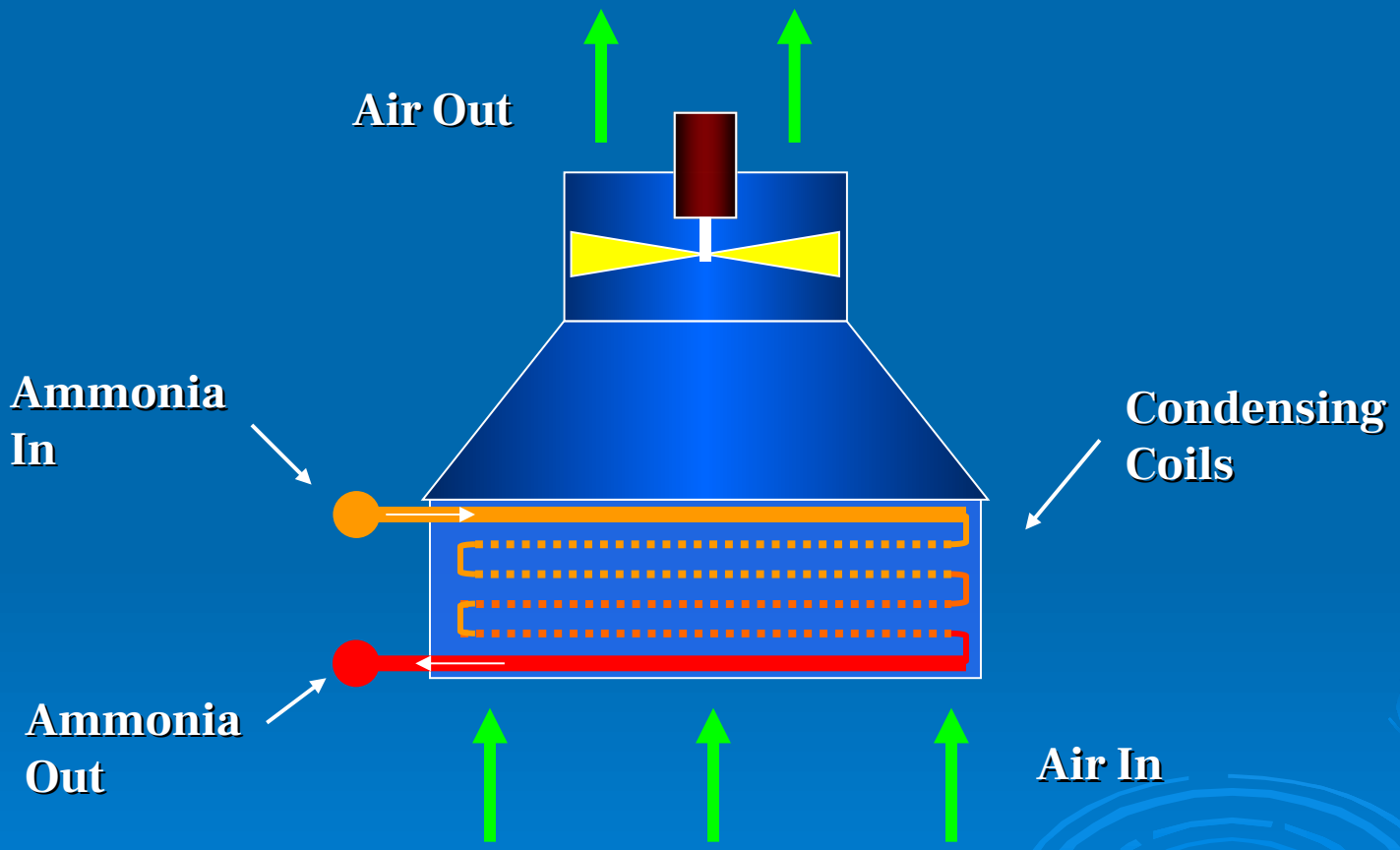
Air-Cooled Condensers

- Use ambient air to condense Ammonia
- Condensing temperature governed by the dry bulb temperature of the air
- Australia regularly reaches 40˚C ambient temperature in summer
- Usually design for 45 – 50˚C condensing temperature

Air-Cooled Condensers



Area vs ΔT

- A bigger transfer area (A) would reduce the temperature difference (ΔT)
  - More area = higher capital cost but provides lower condensing pressures and therefore operating costs
- Leads to a trade off between size and temperature difference

Condenser Type Summary

- Evaporative
  - Designed for 30-35˚C condensing temperature
- Water-Cooled
  - Designed for 35-40˚C condensing temperature
- Air-Cooled
  - Designed for 45-50˚C condensing temperature

Why Not Evaporative?

- Why not choose evaporative or water cooled?
  - Water treatment hassles
  - Chemical dosing equipment
  - Legionella bacteria
  - Lack of (or poor quality) water supply
  - Cheap energy / expensive water

Hybrid Condensers

- Combination of air-cooled and evaporative condenser
- Separate ‘wet’ & ‘dry’ coils in a single unit, or
- Dry condenser with evaporative pre-cooler pads
- Can be run in ‘wet’ or ‘dry’ modes

Hybrid Condensers

- Mode selected based on ambient wet & dry bulb temperatures and condenser load
- Have the benefits of both condenser types
  - Minimises water usage by running ‘dry’
  - Minimises energy by running ‘wet’
- Avoid water treatment concerns by regularly dumping the ‘wet’ section

Smart Condensers

- Add VSD on condenser fans
- Control the condenser fan speed, using
  - Air temperature & humidity and discharge pressure inputs to controller
- Achieves condenser performance at lowest absorbed power

Condenser Summary

- Condenser type & location varies the condensing pressures available
- Increases in condensing pressures increases absorbed power
- Oversized condensers can lead to lower condensing pressures
- Can add Heat Reclaim to reduce load on condensers

Heat Reclaim

- Predominantly two types
  - Desuperheating
  - Oil cooling
- Typically used for producing hot water for
  - Fermentation initiation assistance in cold climates
  - Wash-down water
  - Boiler feed water

Desuperheater

- Extra heat exchanger in discharge line
  - Either welded plate or shell & tube
- Removes superheat from compressor discharge line
  - Equates to a reduction in condenser load
  - Which leads to a reduction in condensing pressure
  - Leads to an increase in refrigeration capacity

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Oil Cooling

- An additional oil cooler heat exchanger added upstream of the ‘normal’ oil cooler
- Removes oil cooling heat load from condenser system
  - Equates to a reduction in water consumption
- No pressure drop implications
- Use clever control to avoid over-cooling the oil
  - 3-way valve, bypass line, etc

Heat Reclaim

- Water Savings
  - For every 1 kW of oil cooling removed from condenser, equates to 38 litres per day
- For example, screw compressor with 35 kW of oil heat load
  - Water saving up to 500,000 litres per year

Summary

- Efficient Refrigeration
  - Keep suction pressure/temperature high
    - Loads should be ‘handled’ at highest possible temperature – separate loads if necessary
  - Condensing pressure / temperature as low as possible
    - Add VSD to condenser fans to maximise efficiency
  - Heat reclaim can reduce both power and water consumption, while providing ‘free heat’

Any Questions?

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