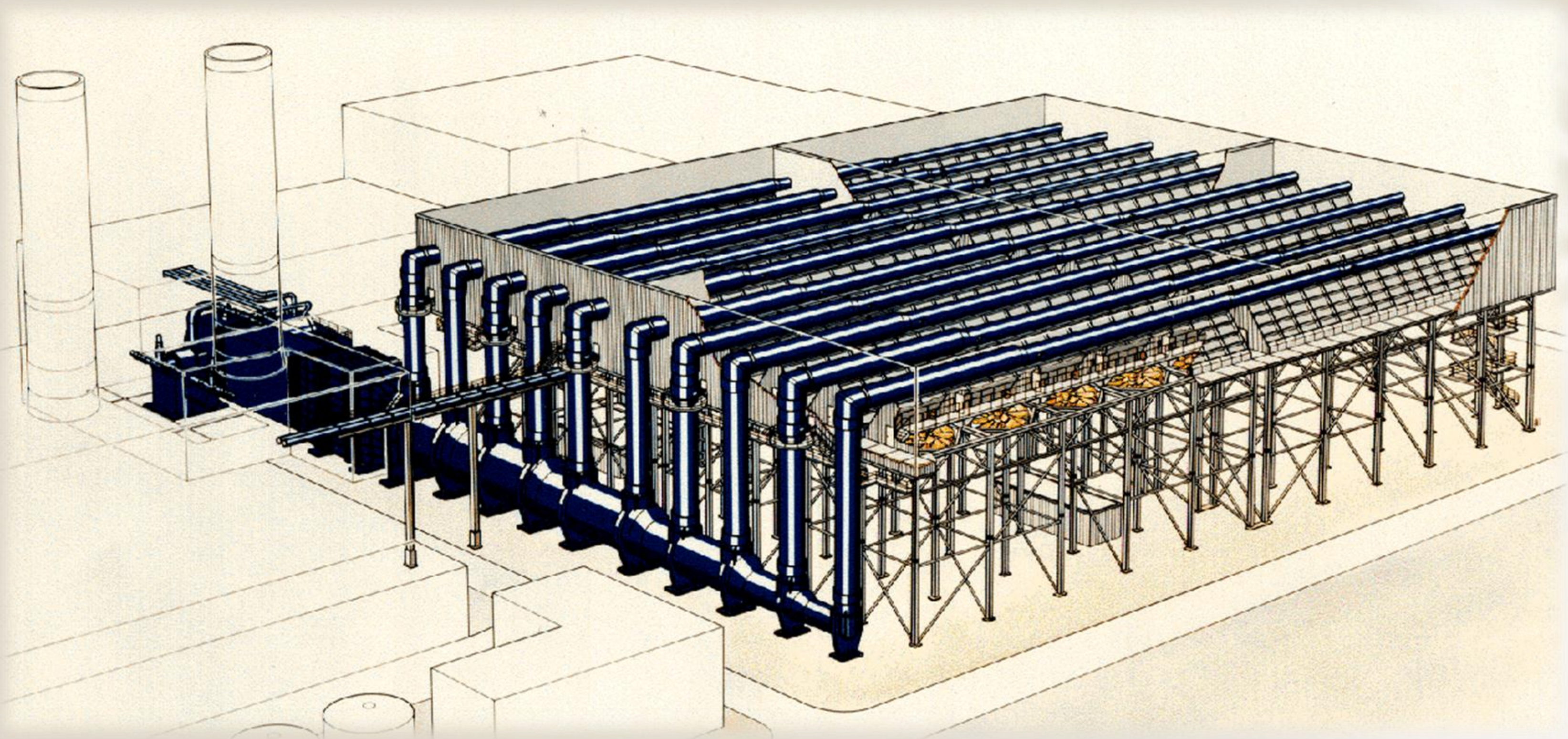
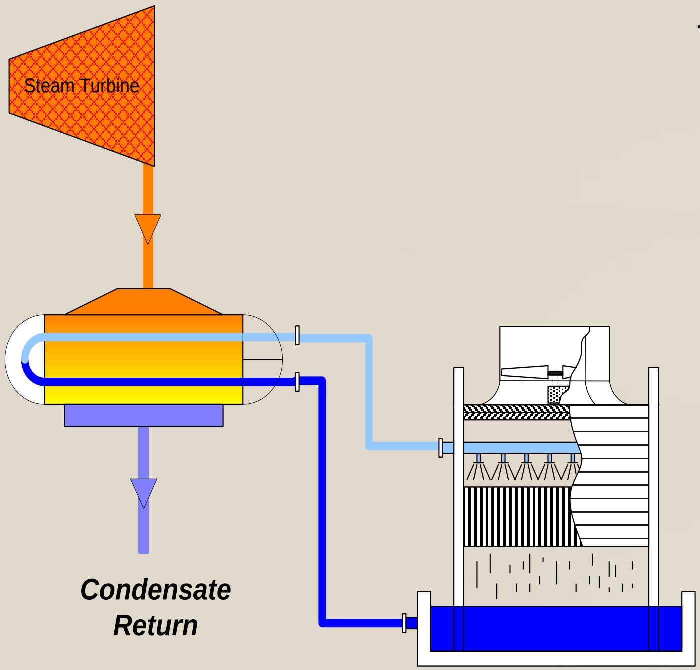
Dry and Parallel Condensing Systems



Dry Cooling

Cooling System Theory

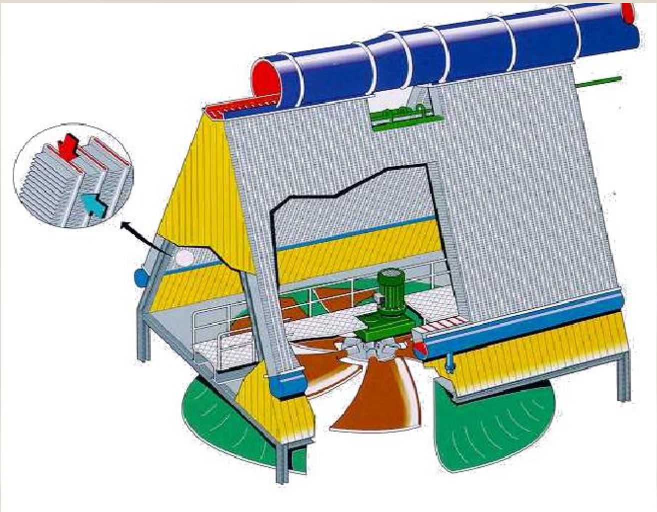
The Condensing Process and Theory of Operation



Traditional Indirect Evaporative Condensing System

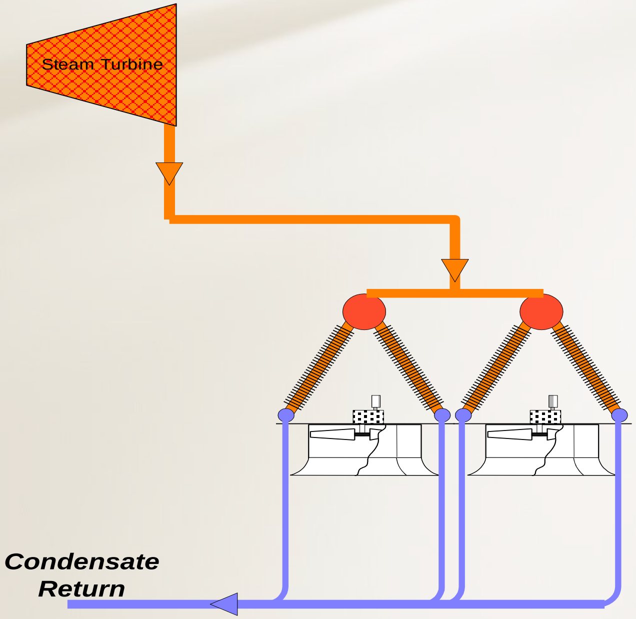
- Vacuum steam and non-condensables from the steam turbine are drawn to the surface condenser
- The steam (shell side) transfers its latent heat to the cooling water (tube side) and condenses. Condensate returns to boiler circuit.
- Cooling water flows through the evaporative cooling tower, rejecting heat, predominately by evaporation, to the air (**heat sink @ Wet Bulb**). Evaporated water is not recovered.
- Non-condensables are continually removed from the surface condenser by air-removal equipment.

Cooling System Theory

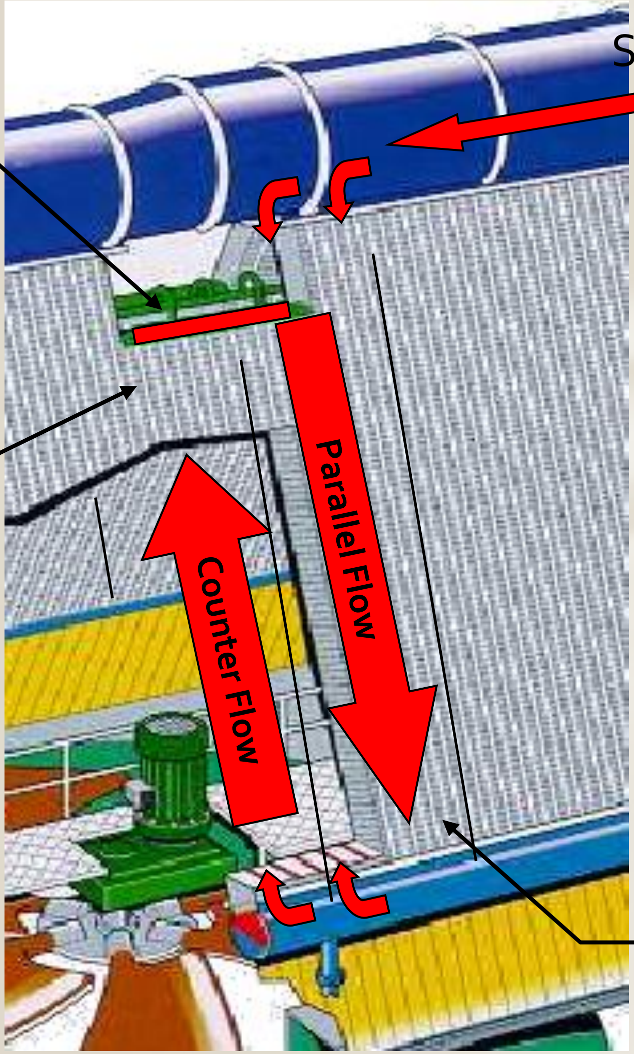


Direct Air Cooled Condenser System

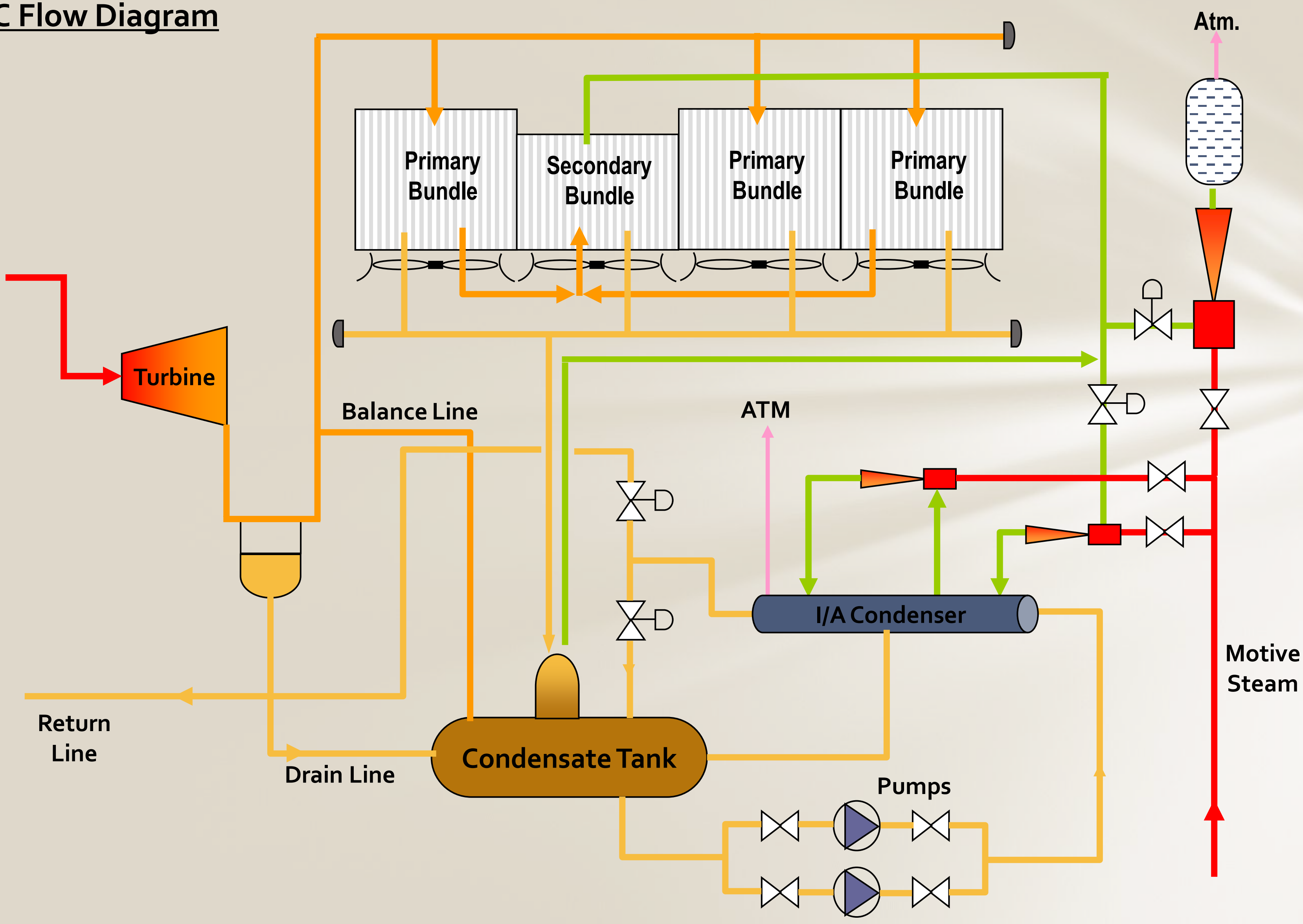
- ACC replaces surface condenser, cooling tower, cooling water pump, piping and water treatment and about 90% of plant water needs
- Vacuum steam and non-condensables from the steam turbine are drawn to the ACC via steam duct
- The steam (tube side) transfers its latent heat to the cooling air (fin side) and condenses. Condensate drains to the condensate tank (hotwell) and returns to boiler circuit.
- Air **(heat sink @ Dry Bulb)** is forced over the ACC fin tube bundles by fans to provide the convective heat transfer mechanism.
- Utilizing a two stage condensing process, non-condensable gas are pushed toward the air removal system and evacuated from the ACC.



ACC Process Flow



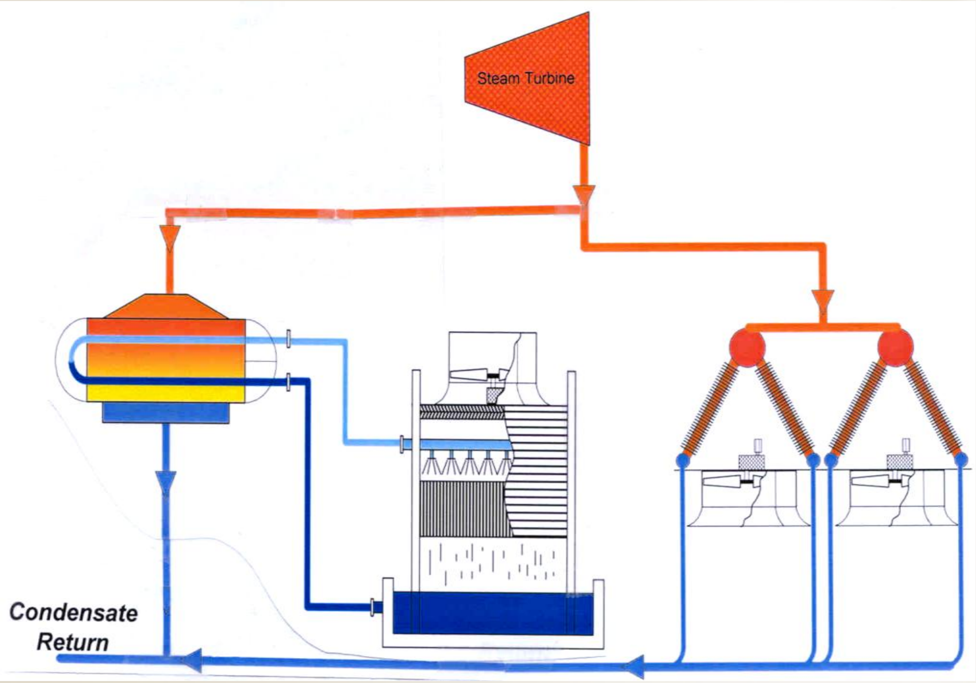
ACC Flow Diagram



Cooling System Theory

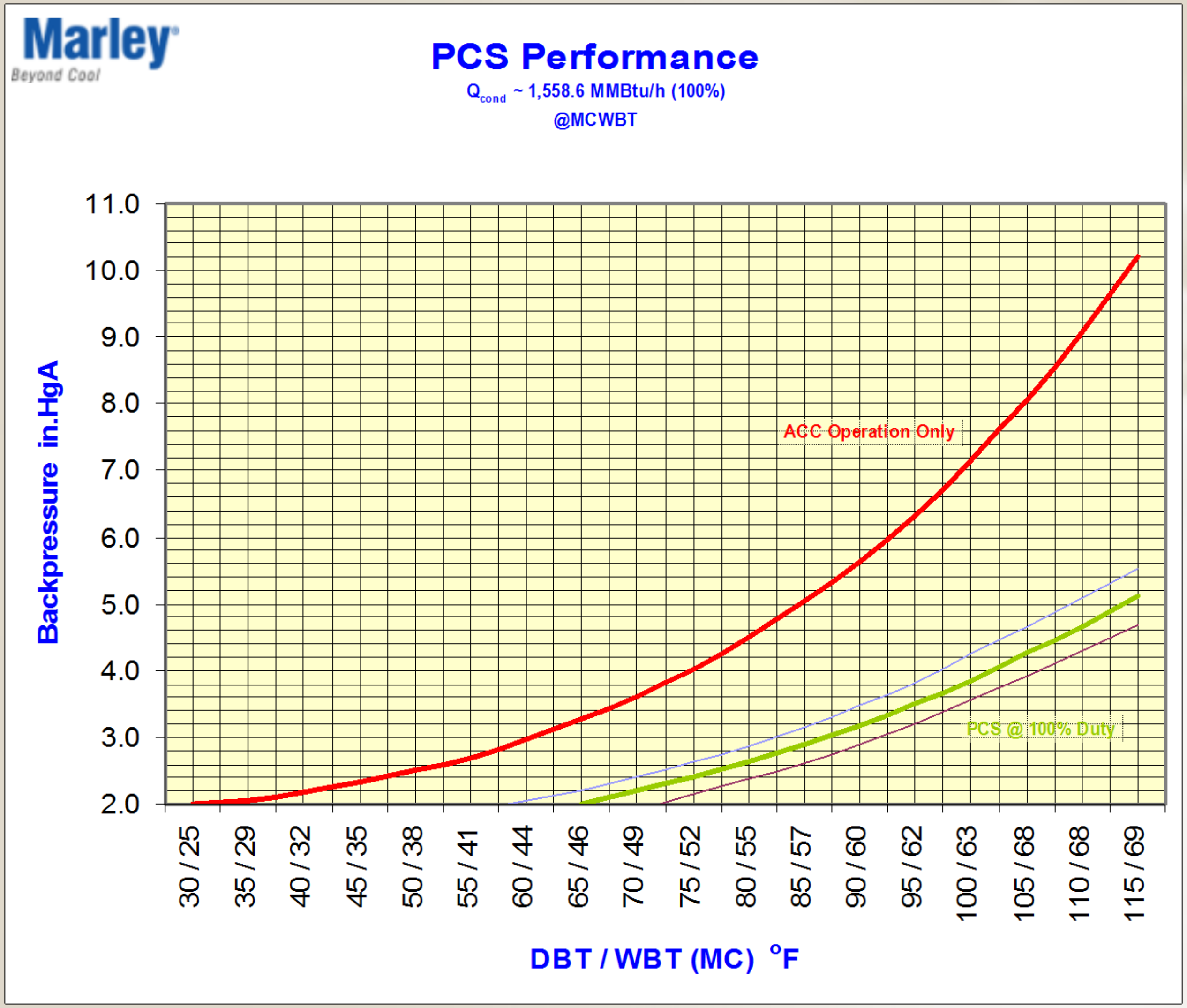
Parallel Direct Air Cooled / Indirect Evaporative Condenser System (PCS)

- PCS combines performance benefits of a surface condenser and evaporative cooling tower system with the water saving benefits of an ACC
- PCS system sized to meet specified / limited cooling water availability
- Maximizes water use (to limit) in order to minimize condensing system costs
- Provides for improved performance vs. 100% ACC system
- Minimizes water use as compared to 100% evaporative system
- Reduced plan area vs. 100% ACC



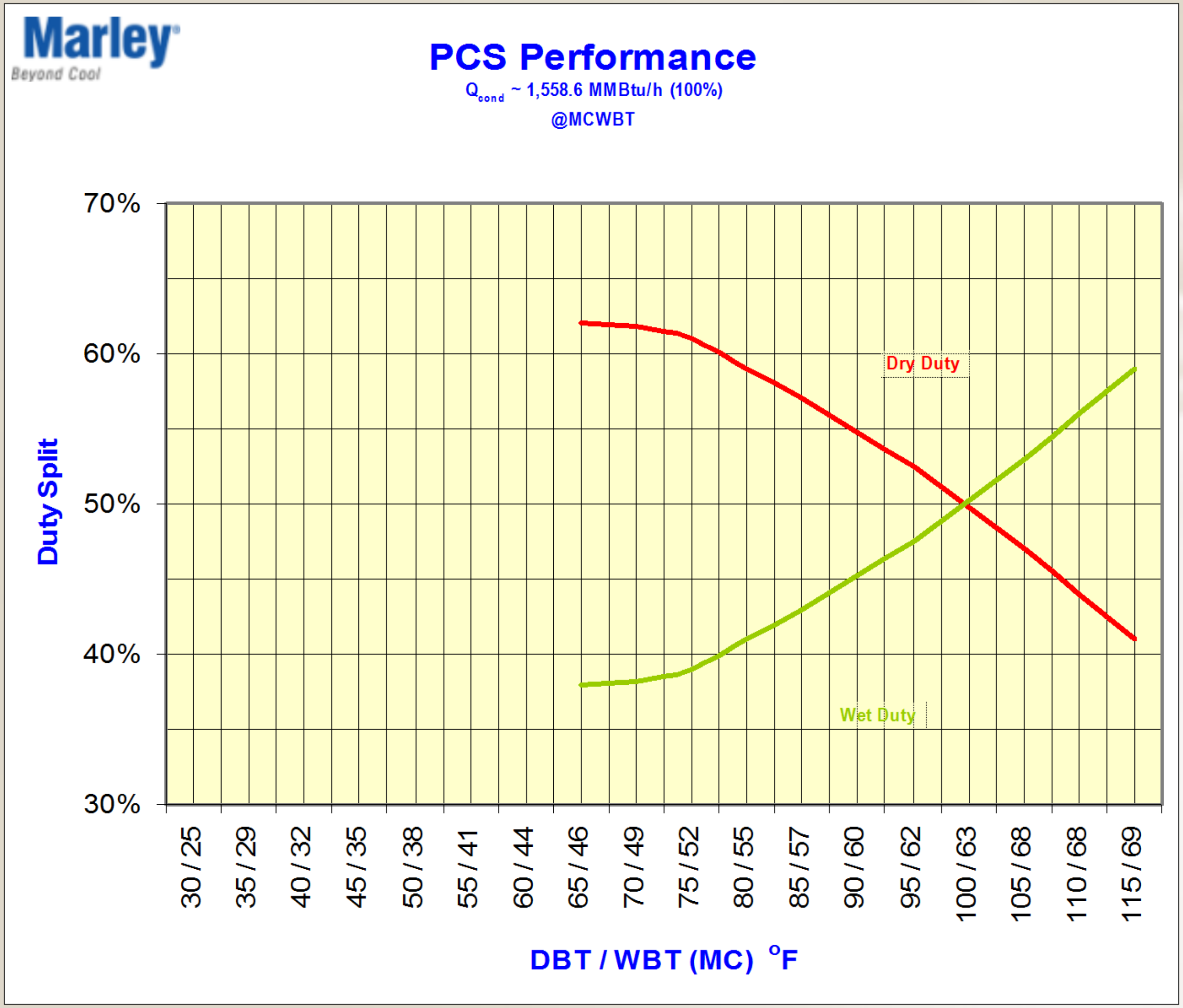
Parallel Direct Air Cooled / Indirect Evaporative Condenser System (PCS)

Comparative Performance



Parallel Direct Air Cooled / Indirect Evaporative Condenser System (PCS)

Dry/Wet
Duty Shift for PCS



Why Dry or Parallel ?

Environmental Constraints

- Visible Plume
- Drift Issues – PM_{10}
- Zero Discharge / Blow-down Restrictions
- 316 Considerations

Practical Issues

- Limited / No Water Available
- Prohibitive Water Cost
- Precedent
- Permitting Time Period
- Great Neighbor / Political

Example Systems

Ryehouse, UK
720 MW CCPP
1,877,900 lb/h, 2.7"HgA, 1993

51 dBa at 400 feet from ACC, including steam turbine exhaust noise

- ACC PWL of 100 dBa
- Steam Turbine Exhaust Duct Silencer
- 100 Ultra Low Noise Fans

Example Systems

Astoria Energy, Queens, NY

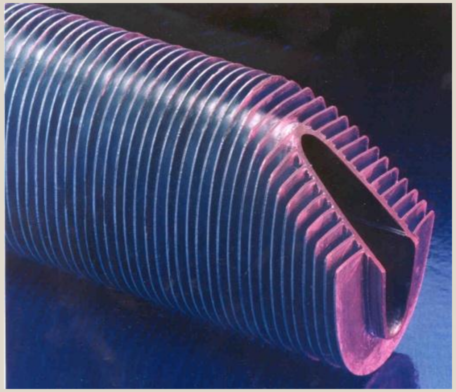
500MW CCPP; 1,125,000 lb/h, 2.00"HgA; 2005 (ACC & ACE)

- 12 x 300 ton Modules; Built off-site and barged in (300 miles)
- Turn-Key MCT Scope

Fin Tubes - ACCs

Single Row – SRC

- Aluminum Clad Carbon Steel Tubes with Corrugated Aluminum Fins



Multi-Row

- Hot-Dip Galvanized, Carbon Steel Tubes and Fin
- Multi-row (3, 4) arrangement; variable fin pitch

Fin Tubes - ACCs

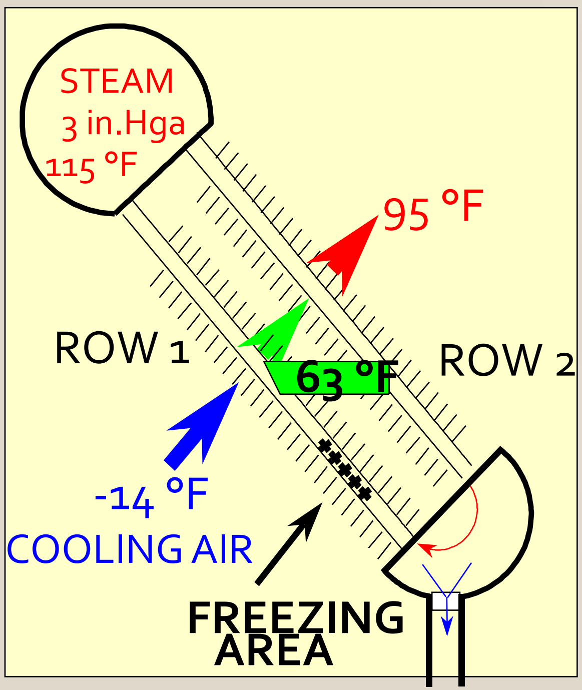
Single Row – SRC

- 16 Years of Installation History – 150+ SRC Installations! (many more MR installations)
- Continuous Tube Development/Improvement – 5th Generation Tube
- Independent Tube Design Provides Inherent Structural/Thermal Flexibility
- In the event (rare) of tube damage (construction), able to Repair/Replace a single tube. Removal of entire bundle not required.
- Design pressure from Full Vacuum to 14.9 psig; 250°F
- Inherent Freeze Protection
- Thoroughly Cleanable

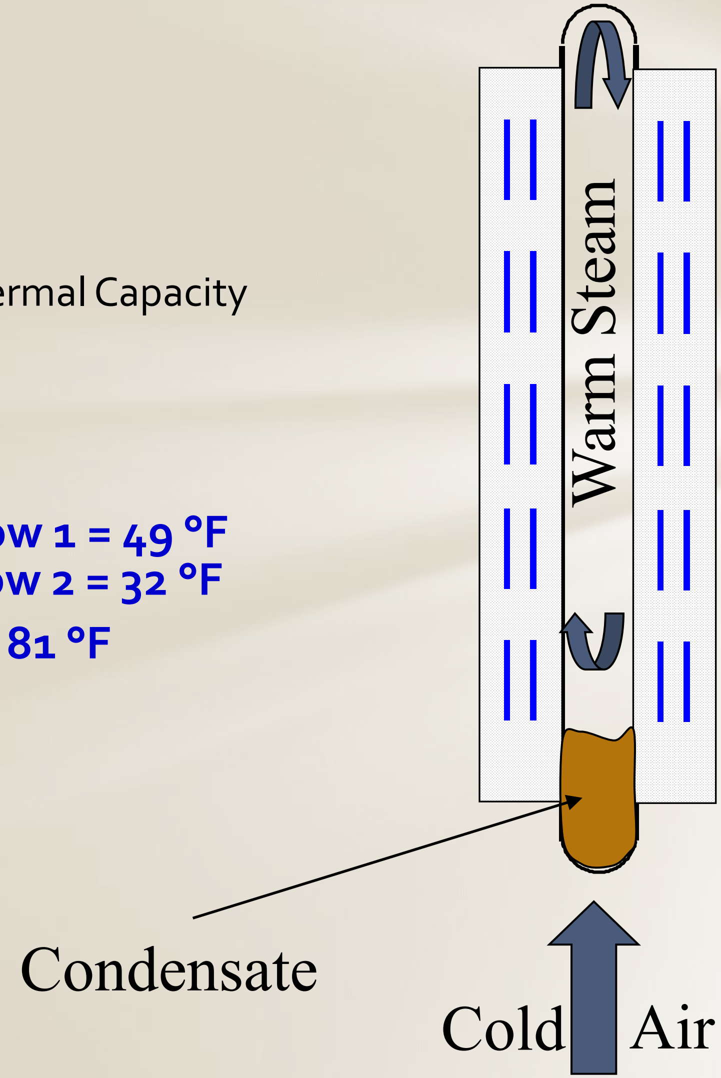
Freeze Resistance / Protection

Single Row – SRC

- Reduced Freezing Risk
- Reduced Flooding Risk
- No Row-Wise/Tube-Wise Differential Thermal Capacity



△ T row 1 = 49 °F
△ T row 2 = 32 °F
81 °F



Basic Design Data

ACCs

- m (lb / h) — Steam Turbine Exhaust Steam Flow
- h (Btu / lb) — Steam Turbine Exhaust Steam Enthalpy
- x (%) — Steam Turbine Exhaust Quality (alternate to enthalpy)
- P (in. HgA) — Steam Turbine Exhaust Backpressure
- T_{air} (°F) — Inlet Air Dry Bulb Temperature
- Elevation (f t) — Site Location Elevation

Other Design Data (if Available)

ACC

• Noise Limitations	(X dBa (SPL) at Y ft from ACC/ACE)
• Site Limitations	(Plot Area, Height, etc.)
• Equipment / Plant Arrangement	-
• Ambient Conditions	(T_{max}, T_{min}, Other)
• Seismic Conditions	-
• Capitalized Auxiliary Power Cost	($ / kW)
• Anything Else You Can Get / Share	

Some Approximate Values

ACC

- Spacing between tube is 57.2 mm (2.25”)
- Heat Transfer Coefficient on the air side is 40 to 50 W/m2/K
- Overall Uo is about 30-35 W/m2/K
- Re is in the order of 4000 to 6000 with a D of 19~20 mm
- Air Side Static Pressure Drop is typically 80 to 105 Pa

Thank You!