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

Air Takeoff to Vacuum System

Secondary Bundle

Parallel Flow

Counter Flow

Primary Bundle

Steam & Non Condensable Flow
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
Dry/Wet Duty Shift for PCS

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

PCS Performance

$Q_{cool} \approx 1,558.6 \text{ MMBtu/h (100%)}$

@MCWBT

DBT / WBT (MC) °F

Duty Split

30% 40% 50% 60% 70%

30/25 35/29 40/32 45/35 50/38 55/41 60/44 65/46 70/49 75/52 80/55 85/57 90/60 95/62 100/63 105/68 110/68 115/69

Dry Duty

Wet Duty
Why Dry or Parallel?

Environmental Constraints
- Visible Plume
- Drift Issues – PM\textsubscript{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

STEAM 3 in.Hg 115 °F
95 °F
ROW 1
63 °F
FREEZING AREA
-14 °F
COOLING AIR

Cold Air
Condensate

△ T row 1 = 49 °F
△ T row 2 = 32 °F
81 °F
**Basic Design Data**

**ACCs**

- \( m \ ( \text{lb/h}) \)   Steam Turbine Exhaust Steam Flow
- \( h \ ( \text{Btu/lb}) \)   Steam Turbine Exhaust Steam Enthalpy
- \( x \ ( \% ) \)   Steam Turbine Exhaust Quality (alternate to enthalpy)
- \( P \ ( \text{in. HgA}) \)   Steam Turbine Exhaust Backpressure
- \( T_{\text{air}} \ ( ^{\circ}\text{F}) \)   Inlet Air Dry Bulb Temperature
- Elevation (ft)   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!