Steam Cooling Systems and Hybrid Cooling

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Steam Cooling Systems

• Once-through
• Recirculating Cooling Tower
• Direct Dry Cooling (air-cooled condenser)
• Indirect Dry Cooling (Heller)
• Hybrid or Parallel Cooling (wet + dry)
Once-through Cooling

- large volume of water required (river, ocean)
- temperature increase at discharge
- minimal actual water consumption
- inlet fouling / condenser tube biofouling
- section 316(b), CWA: fish entrainment if > 50M gpd
• relatively low water supply volume required
• dissolved constituents concentrate
  – chemical treatment required
• consumption: ~ 75% of water evaporated
• cooling tower maintenance
• blowdown handling
  – discharge monitoring / limitations
  – elimination of discharge - ZLD
Direct Dry Cooling (air cooled condenser)

- no water required
- high capital cost
- significant maintenance – gearbox, fans, finned tube cleaning
- increased fuel cost (high backpressure)
- fan energy consumption
- ~15% energy loss in hot weather
- minimal system contamination with tube leaks
- iron transport can be major issue
Indirect Dry Cooling (Heller)

• similar performance to ACC but closed loop through WCC
• lower construction & maintenance costs
• use of parabolic natural-draft tower
• aluminum components
Hybrid (Parallel) Cooling

**WCC + ACC**

- operation in parallel with no isolation
- lower backpressure depending on water/air cooling ratio
- achieves full load in hot weather
- major contamination risk with WCC tube leak if condensate polisher present
Evaporative (Wet) Cooling Tower
Dry (Air) Cooling

Air Cooled Condenser
Design Day: dry bulb vs. wet bulb T
Ambient T vs. Condenser Backpressure

Turbine Exhaust Pressure (inches Hg)

Dry Bulb Temp (F)
Ambient T vs. Generation Output

Dry Bulb Temp (F) vs. Output (KW)

- Blue triangles: Ambient T
- Red diamonds: Generation Output
Parallel Cooling Schematic

- TURBINE
- ACC
- Surface condenser
- Wet cooling tower
- Condensate
Comanche Station Unit 3: design for low water use

- low water use technology to optimize unit efficiency and water conservation
  - Cooling tower and air cooling systems-designed to operate in parallel
  - Below 55ºF (13ºC), ACC alone can handle full heat rejection of plant
  - Water-cooling alone cannot provide full load operation without ACC
Comanche’s Water Supply

- **8,700** acre-feet/year (2.8 billion gal/year, 10.7 million m³/year) for existing Units 1, 2 (660 net MW total)

- Hybrid (Parallel) cooling utilized for Unit 3 reduced contract amount to **6,000** acre-feet/year (1.9 billion gal/year, 7.4 million m³/year) (750 net MW)
Comanche 3 condensate / cooling system

LP turbine

air-cooled condenser

hotwell

water-cooled condenser

CW in

CW out

cooling tower

condensate pumps (3)

DA

LP heaters

polishers 3 x 50%

filters 2 x 100%
Water Use Optimization

Low Water Use

Plant Efficiency

Air Cooled Condenser

Cooling Tower
Comanche 3 Air-Cooled Condenser
Steam Turbine

- MHI (Mitsubishi) design
- 829 gross MW capacity
- 4 inch (13.5 kPa) backpressure design
- 7 inch (24 kPa) alarm point
- 10 inch (34 kPa) trip point
Water-Cooled Condenser

- 2-pass, upper / lower waterboxes
- 31,520 UNS S44660 alloy tubes (SeaCure)
  - 44 foot (13.4 m) length
  - 1.25 inch (3.2 cm) outside diameter
  - 0.022 inch (0.56 mm) wall thickness
- Condensing surface area 453,000 ft² (42,000 m²)
Air-Cooled Condenser

- 45 fans, drawing ~8 MW combined
- 9 ‘streets’ or bays, 20,358 tubes total
- tubes:
  - single-row
  - 35.3 feet (10.8 m) length
  - 8.2 by 0.75 inch (21 by 2 cm) cross-section
  - carbon steel with aluminum exterior fins
  - 0.059 inch (1.5 mm) wall thickness
  - 1,158,902 ft² internal (107,000 m²)
  - 16,514,080 ft² external (1,500,000 m²)
## Estimated / Approximate Water Consumption by Generation Type

<table>
<thead>
<tr>
<th>Fuel, Plant</th>
<th>Cooling System</th>
<th>Water Consumption (gal/MWh)</th>
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<tbody>
<tr>
<td>Coal, Steam</td>
<td>Wet, recirculating</td>
<td>512</td>
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<tr>
<td>Coal, Steam</td>
<td>Hybrid wet/dry cooling</td>
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<tr>
<td>Gas, Combustion Turbine</td>
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<td>Gas, Combined Cycle</td>
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<td>Gas, Combined Cycle</td>
<td>Dry Cooling</td>
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<tr>
<td>Nuclear</td>
<td>Wet, recirculating</td>
<td>609</td>
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</tbody>
</table>

*Limited water use for non-cooling purposes.

Sources:
- Protecting the Lifeline of the West, Western Resource Advocates/EDF, 2010
- Xcel Energy operating experience
Units with Air-Cooled Condensers:

- Must address corrosion product release from large internal carbon steel surface area (1,158,902 square feet for Comanche 3)

- Must be concerned with through-wall corrosion of tubes and consequent air inleakage.
Potential Consequences of Iron Transport from ACC
Potential Consequences of Corrosion in the ACC
Management of Iron Corrosion & Transport

- Condensate particulate filter
- Elevation of steam cycle pH to 9.6 – 10.0
Conclusions

• Parallel wet-dry cooling achieves water savings while permitting improved fuel efficiency (vs. dry cooling) and full load operation with high ambient temperatures.

• Operation of a hybrid cooling system on units with condensate polishing forces compromise between corrosion minimization and polisher optimization.
Questions?