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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

Recirculating Cooling Tower

- 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)

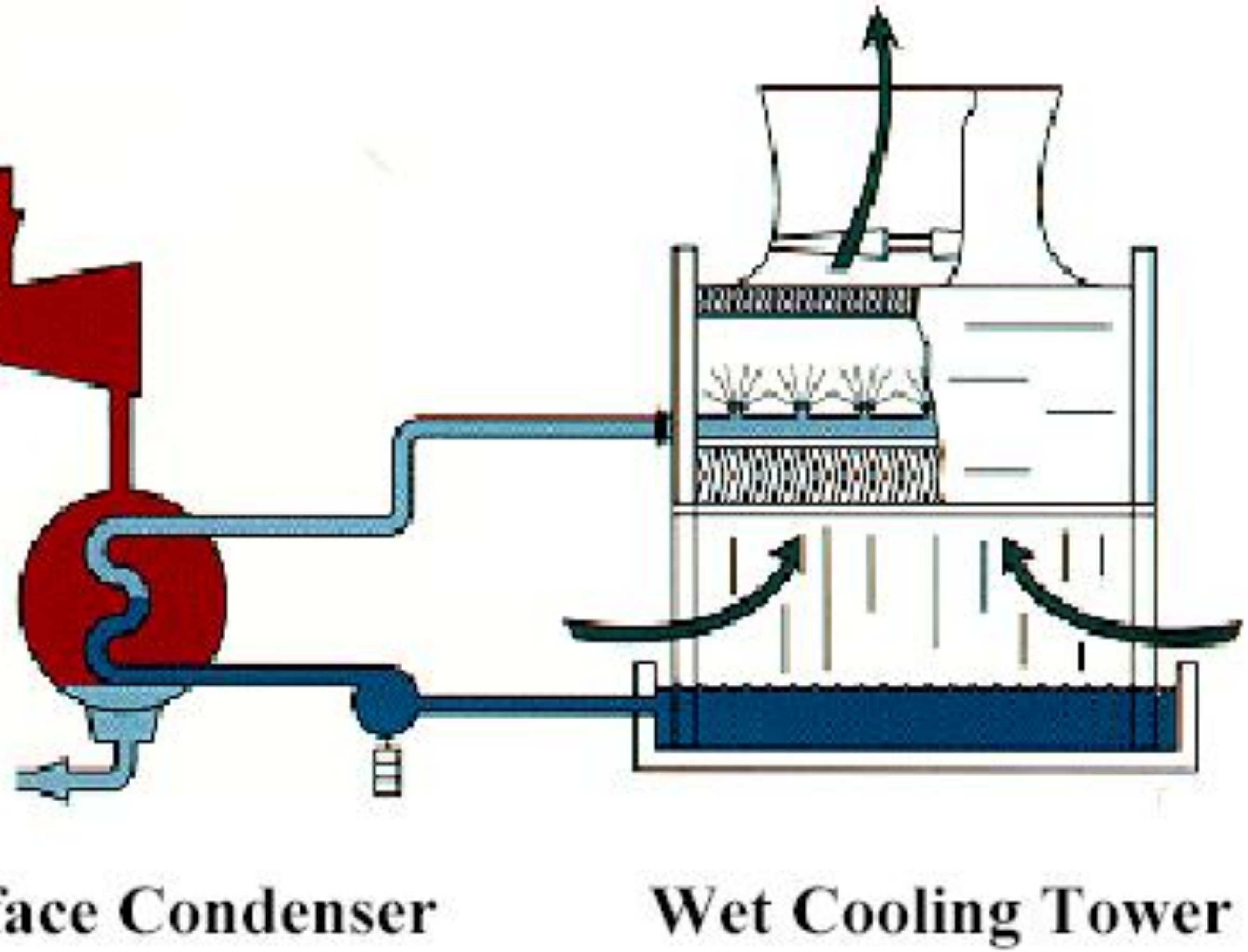
- **similar performance to ACC but closed loop through WCC**
- **lower construction & maintenance costs**
- **use of parabolic natural-draft tower**
- **aluminum components**

Hybrid (Parallel) Cooling
WCC + ACC

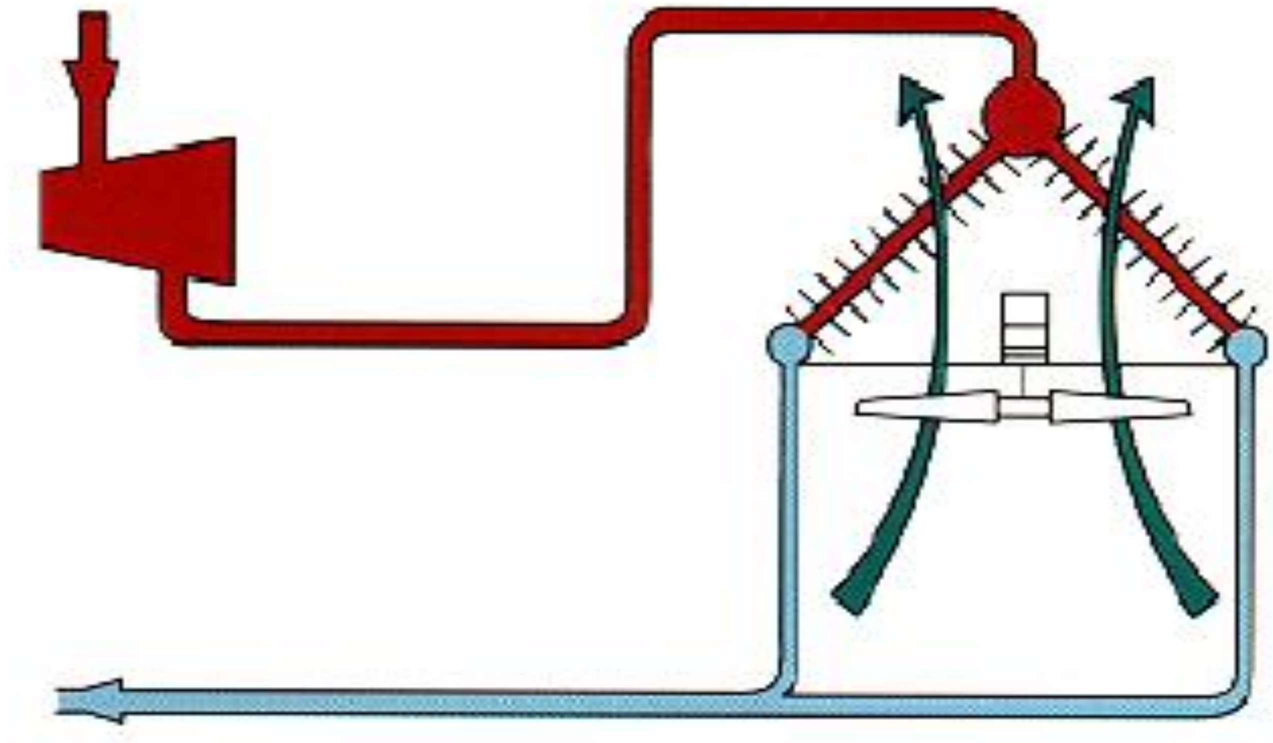
- operation in parallel with no isolation
- lower backpressure depending on water/air cooling ratio
- achieves full load in hot weather
- major contamination risk with WCC tube leak if condensate polisher present

Comanche Station Unit 3

Evaporative (Wet) Cooling Tower

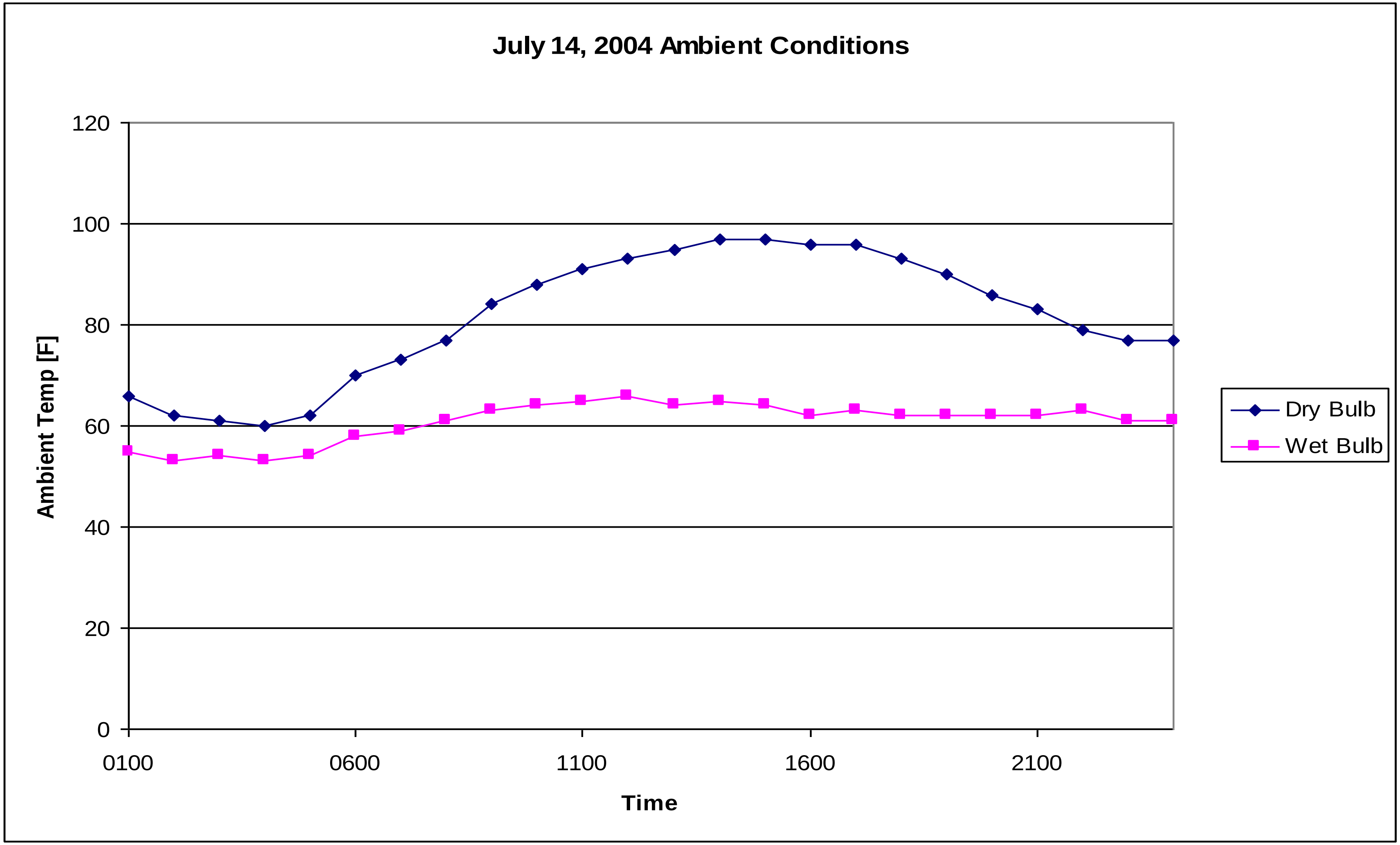


Dry (Air) Cooling

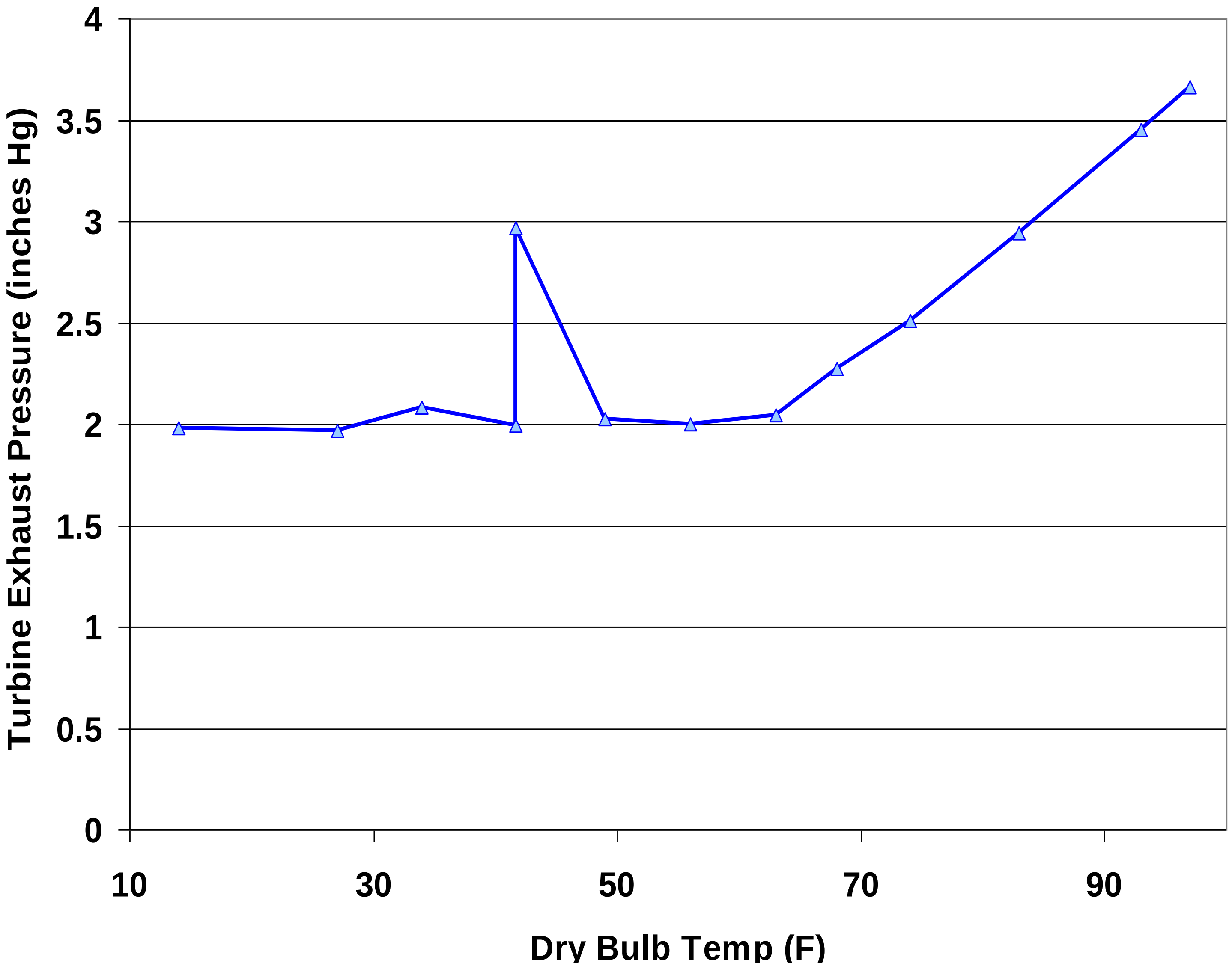


Air Cooled Condenser

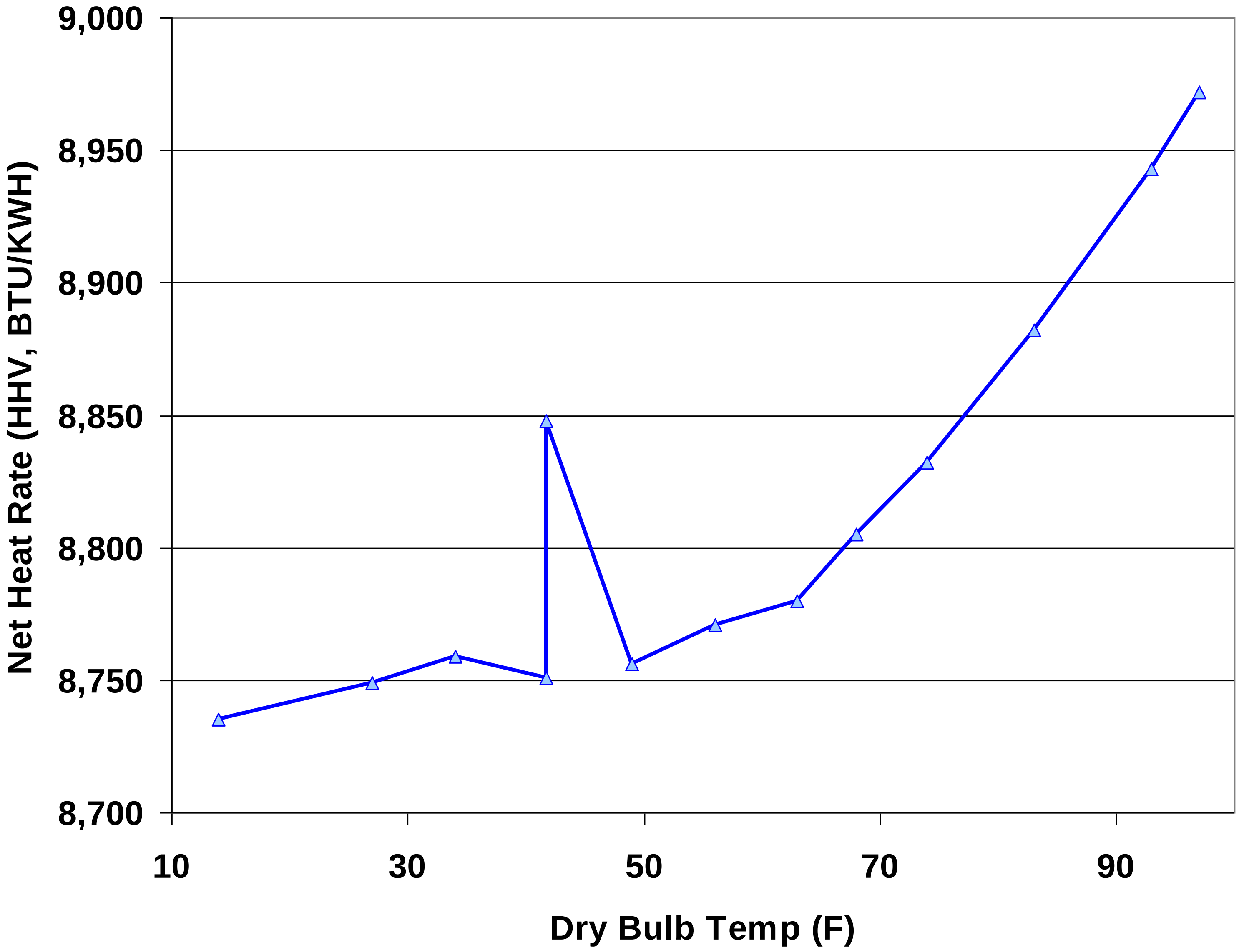
Design Day: dry bulb vs. wet bulb T



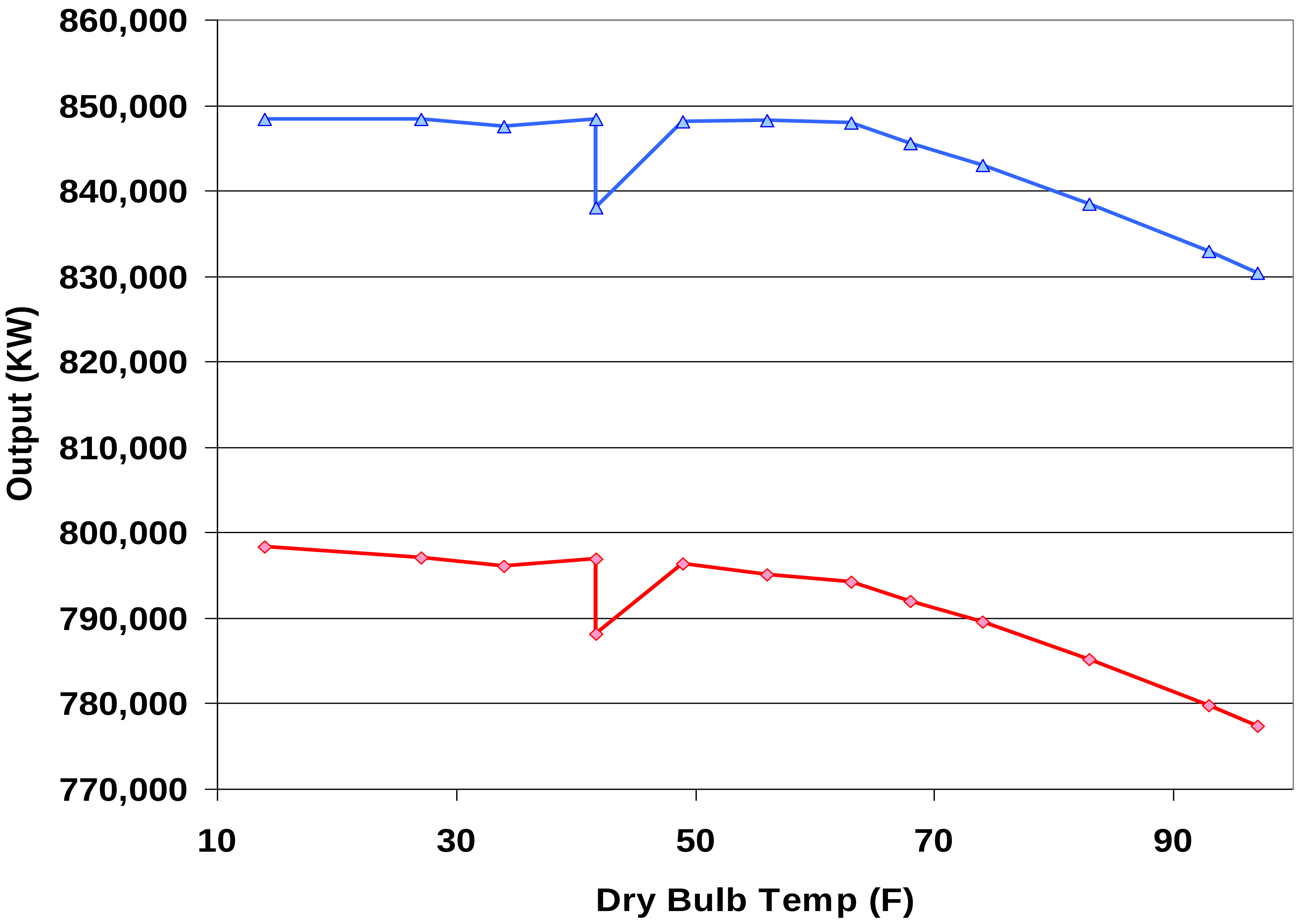
Ambient T vs. Condenser Backpressure



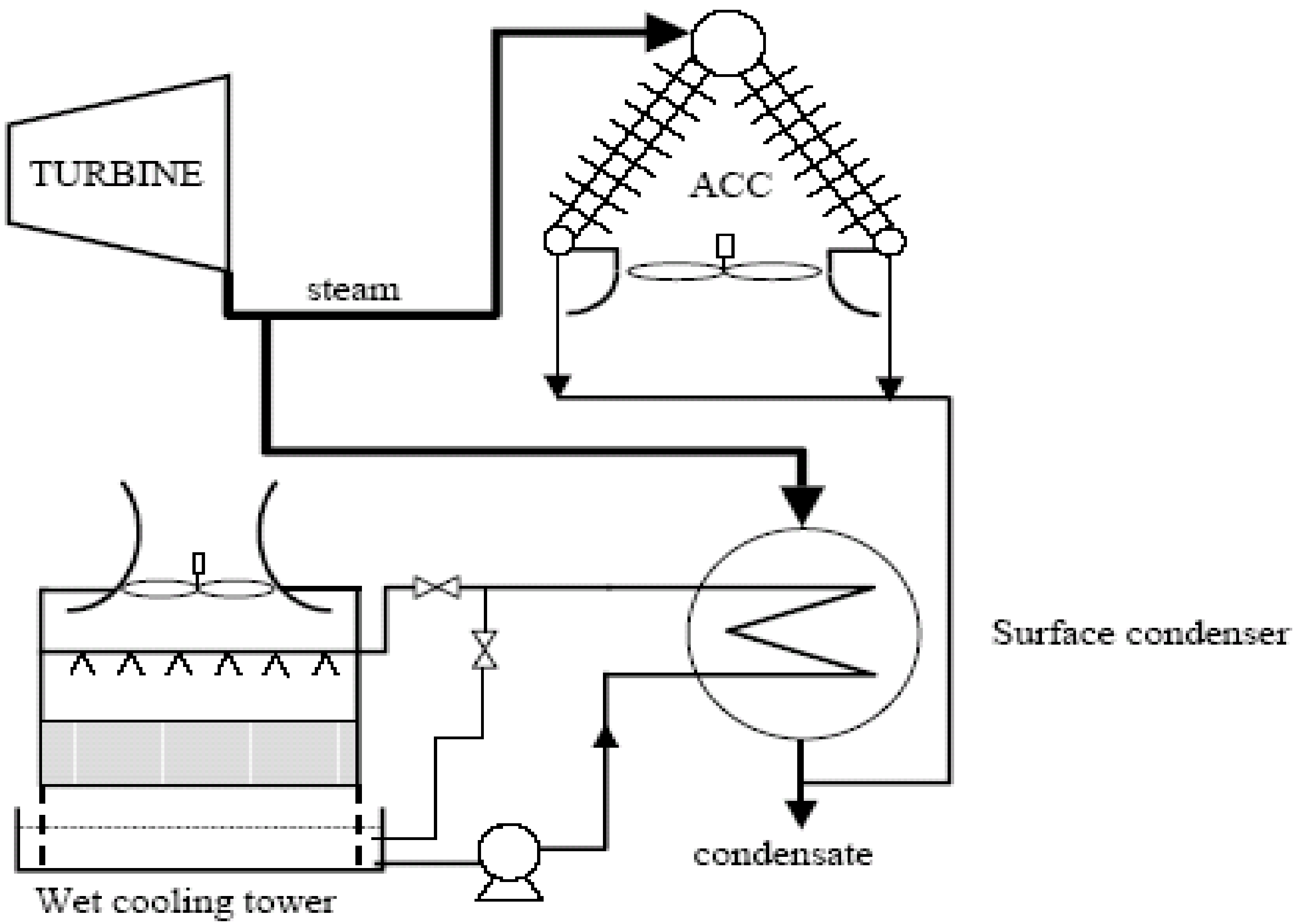
Ambient T vs. Fuel Efficiency



Ambient T vs. Generation Output



Parallel Cooling Schematic



Comanche Station Unit 3: design for low water use

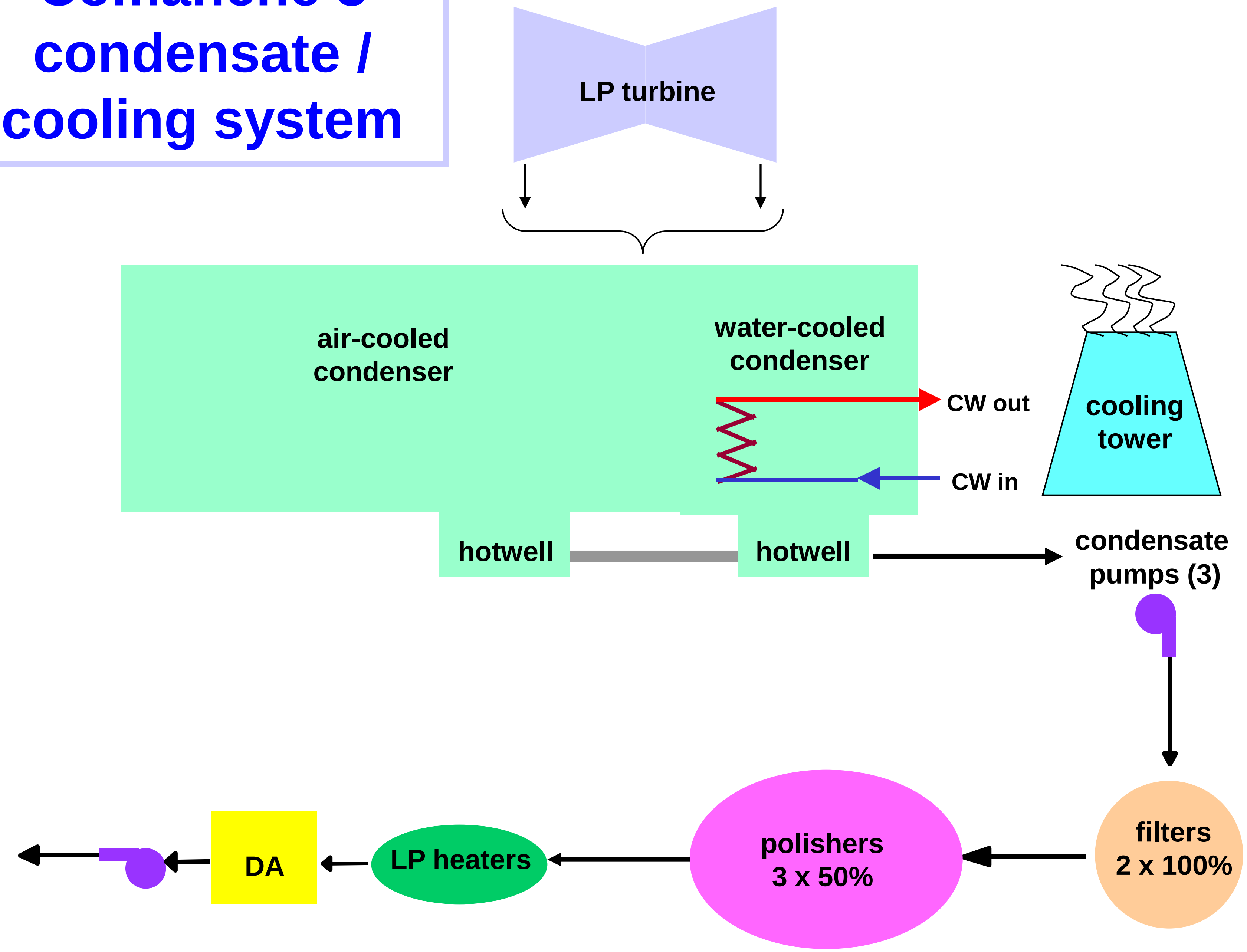
- **low water use technology to optimize unit efficiency and water conservation**
  - **Cooling tower and air cooling systems- designed to operate in parallel**
  - **Below 55ºF (13ºC), ACC alone can handle full heat rejection of plant**
  - **Water-cooling alone cannot provide full load operation without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

Comanche's Water Supply

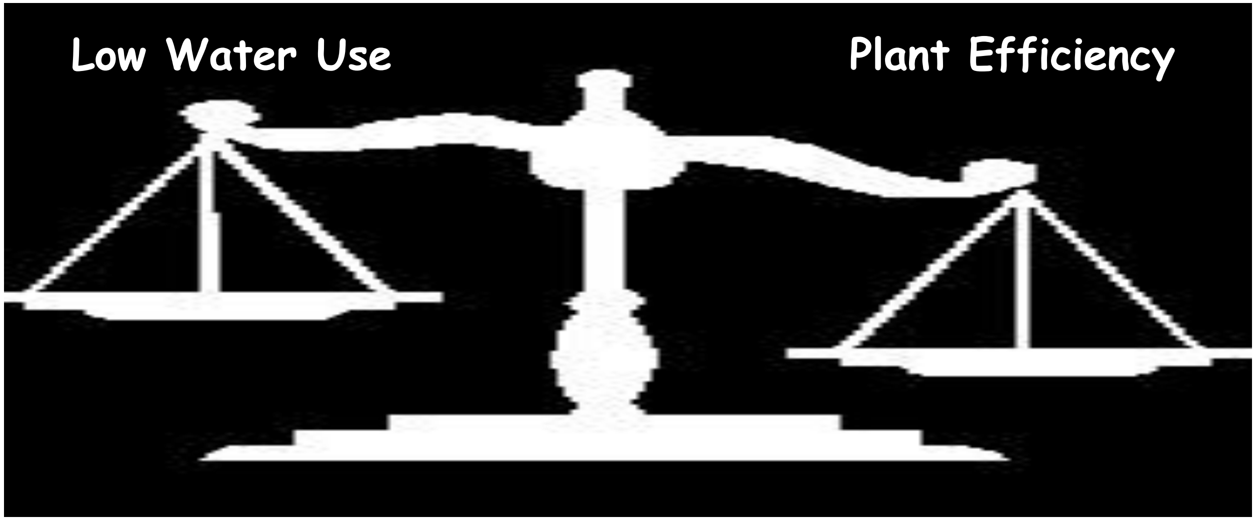
- **8,700 acre-feet/year (2.8 billion gal/year, 10.7 million m^3/year) for existing Units 1, 2 (660 net MW total)**
- **Hybrid (Parallel) cooling utilized for Unit 3 reduced contract amount to 6,000 acre-feet/year (1.9 billion gal/year, 7.4 million m^3/year) (750 net MW)**

Pueblo Board of Water Works
Pueblo Reservoir

Comanche 3 condensate / cooling system



Water Use Optimization



Comanche 3 Air Cooled Condenser

Comanche 3 Air-Cooled Condenser

Steam Turbine

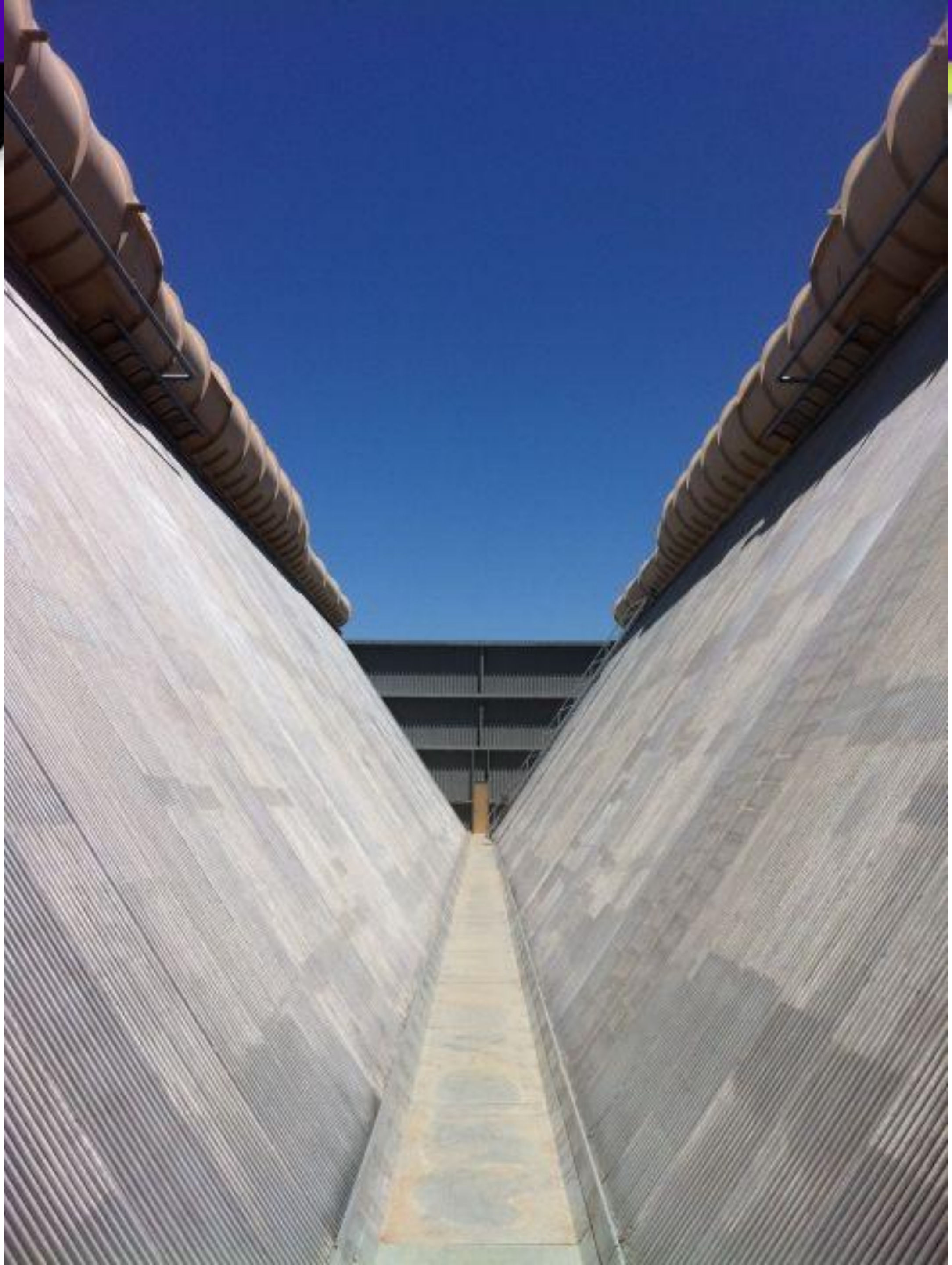
- MHI (Mitsubishi) design
- 829 gross MW capacity
- 4 inch (13.5 kPa) backpressure design
- 7 inch (24 kPa) alarm point
- 10 inch (34 kPa) trip point

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 ft^2 (42,000 m^2)

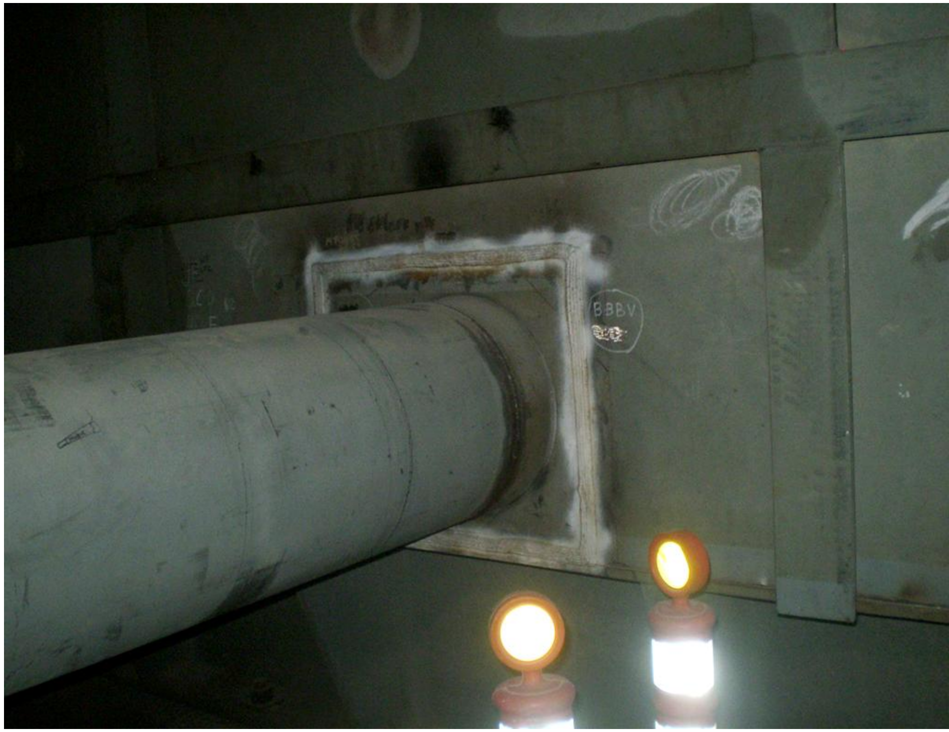
Air-Cooled Condenser

- 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 ft^2 internal (107,000 m^2)
  - 16,514,080 ft^2 external (1,500,000 m^2)



WCC Hotwell

ACC Hotwell



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Estimated / Approximate Water Consumption by Generation Type

Fuel, Plant	Cooling System	Water Consumption (gal/MWh)
Coal, Steam	Wet, recirculating	512
Coal, Steam	Hybrid wet/dry cooling	324
Gas, Combustion Turbine	None	0*
Gas, Combined Cycle	Wet, recirculating	180
Gas, Combined Cycle	Dry Cooling	2*
Nuclear	Wet, recirculating	609

*Limited water use for non-cooling purposes.

Sources:

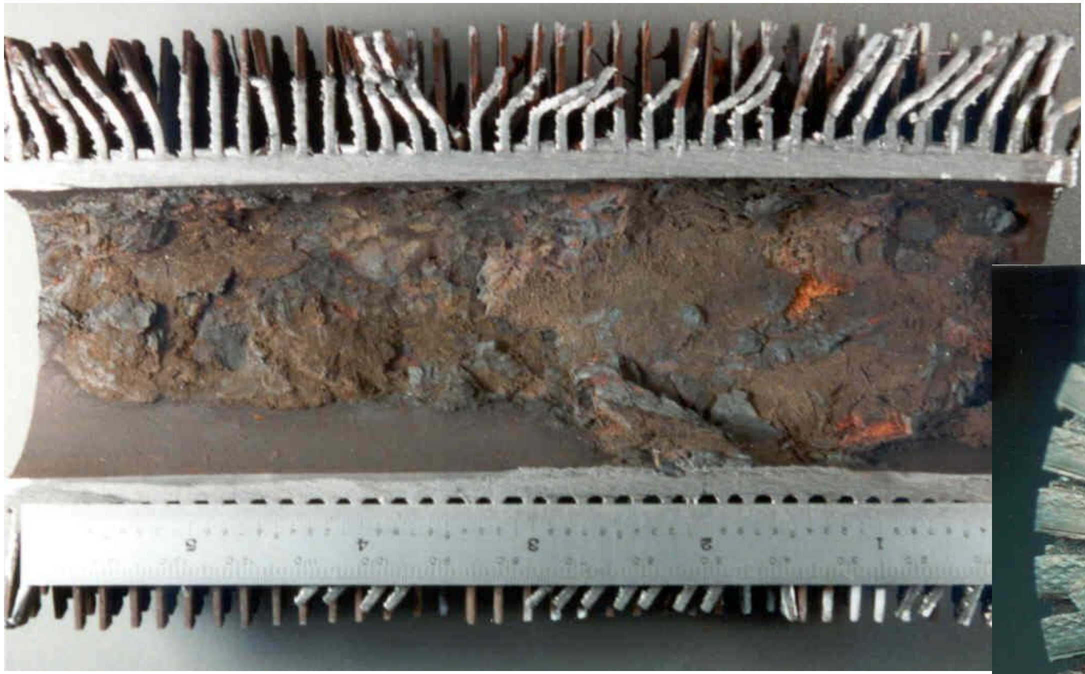
- Protecting the Lifeline of the West, Western Resource Advocates/EDF, 2010 http://www.westernresourceadvocates.org/water/lifeline/lifeline.pdf
- Xcel Energy operating experience

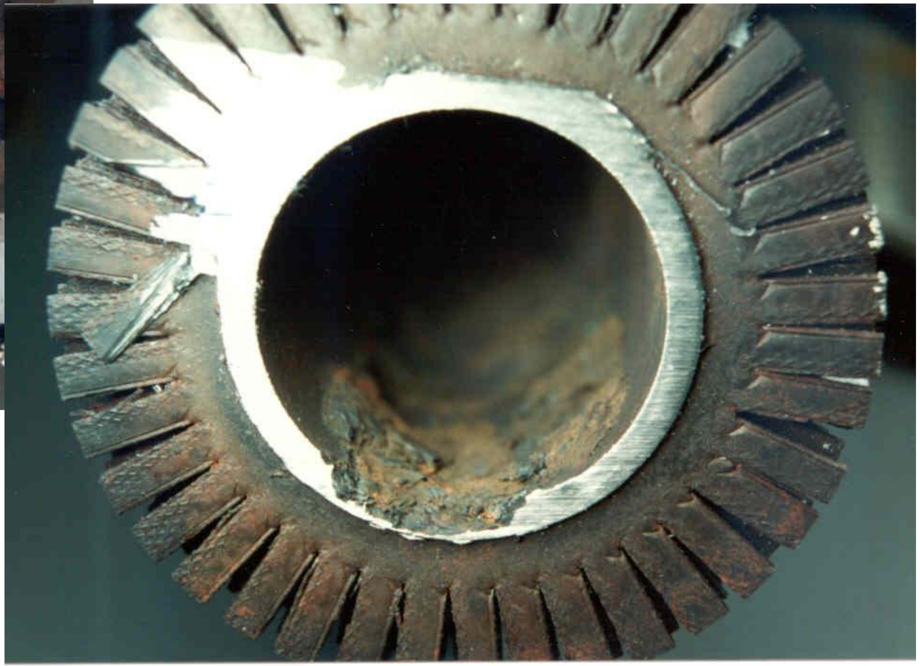
Units with Air-Cooled Condensers:

- 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





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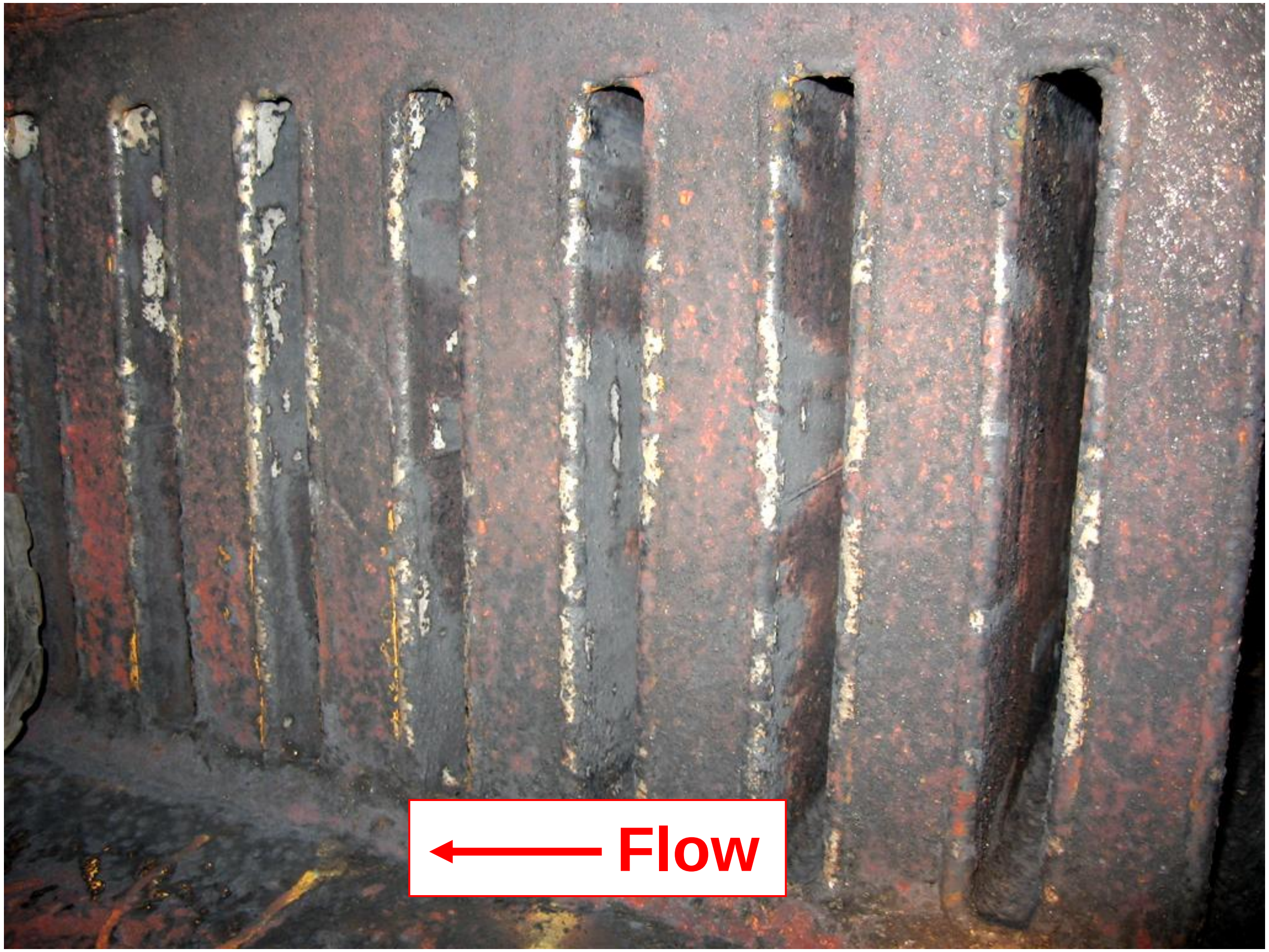
Potential Consequences of Corrosion in the ACC



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?