Cooling Systems

--Some things that might work--

Advanced Cooling Workshop

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Everybody knows

• Water’s a big deal
• Most of it’s used for cooling
• There are things we can do to use less
  but.........
  – they usually cost more
  – they usually use more power
  – they usually hurt plant performance
What would we like?

- Retain once-through cooling at existing plants
- Colder water from towers
- Reduced fresh water requirements
- Cheaper dry cooling
- Lower backpressures
Some things to talk about

- Costs---what does it really cost?
- Once-through cooling---retrofits
- Wet cooling---evaporate less/cool more
- ACC’s---better fins/more wind resistance
- Indirect dry---eliminate range
- Wet-enhanced dry---spray/store/allocate
Cost Comparisons

• Base case is closed-cycle wet cooling
• Primary comparison is with direct dry---ACC’s; Hybrid is in-between
• Absolute costs are elusive; ratios better but tricky
• Water costs may get to be important
• Differences are big in any case
Capital Cost Ratios--Steam Plants

El Paso, TX
J'ville, FL
Bismarck, ND
Portland, OR
Pittsburgh, PA
Annual Cost Ratios--Steam Plants

Dry/Wet

El Paso, TX
J'ville, FL
Bismarck, ND
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Annual Costs, $
Evolution of Condenser Costs

Cost per Unit Area, $/sq. ft.

Surface Area, Sq. ft.

2001

2005

2008
$ per Cell vs. Approach

Cost per cell, $

Approach, F

2008

2005
ACC Cost Evolution

- 2002
- 2005
- 2005 x 1.35
- 2005 x 2.5

Steam flow: $1.08 \times 10^6$ lb/hr

"Condenser cost factor"

"Cooling tower cost factor"
Once-through cooling

- Existing plant issue
- Pressure to reduce intake losses
  - Impingement: 80 to 95%
  - Entrainment: 60 to 90%
- Closed-cycle retrofit cuts flow by > 90%
- Retrofit costs can be very high
- Alternatives have a big window
New plant costs
Wet Cooling Towers

• Currently system of choice for most plants
• Temperature limits on hottest days
• Big consumer of water
• Significant power consumption
• Maintenance issues
• Well studied, mature technology
Wet Cooling Towers

Colder water
- Approach already down to 5 F
- 2 to 3 F recirculation allowance hurts
- Reduce re-entrainment
- Wind/water tunnel modeling
- Modified designs
Wet Cooling Towers

- Evaporate less
  - Recover water
- Alter sensible/latent heat ratio?
- Off-optimum, higher cost, but maybe competitive
Wet Cooling Towers

- Use less power
- Pumps/fans
- Pumping power
  - Rain zone head loss
  - May be recoverable
  - May increase fan power
Counterflow type design

- **Hot water in**
- **Spray nozzles**
- **Distribution system**
- **Warm, moist air out**
- **Fan**
- **Dry air in**
- **Cold water out**
- **Collection basin**
- **Air flow**
- **Water flow**
- **Fill material**
Wet Cooling--Maintenance

- Sometimes bad things happen
Dry Cooling—Air-cooled Condenser

- Not just in the desert
- Large footprint
- High fan power
- Costly heat exchanger
- Subject to wind effects
Dry Cooling---Indirect

- Indirect, natural-draft
  - Maybe the way for nuclear
- High capital cost
- No recent experience with natural drafts in US
- Performance penalties
Dry Cooling—Direct or Indirect

- Three issues
  - High backpressure
  - High fan power
  - High cost
- Address all with improved finned tube bundles.
  - Higher heat transfer
  - Lower pressure drop
Perforated Fin—Interrupted Boundary Layer

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Fin Performance Comparisons

The graph compares the friction and heat transfer for different fin configurations as a function of the Reynolds number. The configurations include:

- Plain--f
- Plain--h
- Perforated--f
- Perforated--h

The graph shows how the friction and heat transfer change with increasing Reynolds number, indicating the performance of each configuration under varying conditions.
ACC’s---Wind Resistance

• Performance falloff with wind
  – Major specification/testing issue
  – Mechanisms
    • Hot plume recirculation
    • Fan performance degradation
  – Possible approaches
    • Walls
    • Screens
    • Lips
    • Louvers
Effect of wind on fans
Extended “lip” at catwalk
Displaced separation zone
Hybrid Systems

- A little bit of water can help a lot
- Different ways to use
  - Parallel wet/dry
  - Series wet/dry—separate
  - Series wet/dry—integrated
  - Inlet spray
  - Deluge
  - Other???
Goldendale, WA---237 MW
Hybrid---integrated/indirect
Inlet spraying

- Finned tubes get wet
- Water gets wasted
- Need better atomization
Hybrid Cooling

• Need to know more about---
  – Optimum system application
  – Optimum water allocation
Recovered Power vs Start Temp vs Spray Period

Eldorado LLP - Steam Flow = 1,067,000#/hr - 2002 Met Data

- Raw Water for Spraying
  - Spray during June, July and August
  - Spray Water Budget = 35,210,000 gallons

- RO Water for Spraying
  - Spray during June, July and August
  - Spray Water Budget = 26,410,000 gallons

10am-8:59pm
- 780 gpm @ Max Recoverable Power
- 752 hours of spraying

10am-6:59pm
- 941 gpm
- 468 hours

10am-6:59pm
- 840 gpm
- 524 hours

Spray Period - 10am to 7:59pm
- 713 gpm
- 617 hours

Spray Water Quantity Assess with Met Data Rev 02
Summing up

If water is top priority.....

• Current technologies work but cost a lot
• Getting to cheaper/better will be evolution and not revolution
• There are some ideas with promise
• Research breeds new ideas

Let us begin.....