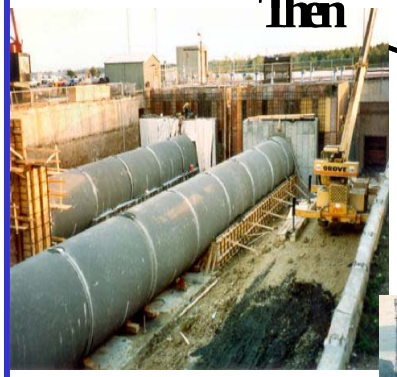
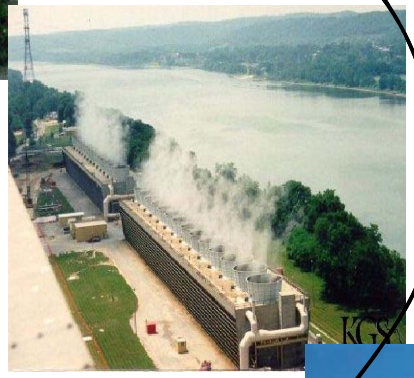
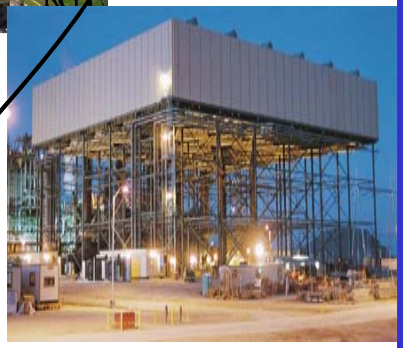
Cooling Systems

--Some things that might work--







Advanced Cooling Workshop

Charlotte, NC

July 8 – 9, 2008

J.S Maulbetsch

maulbets@sbcglobal.net

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?

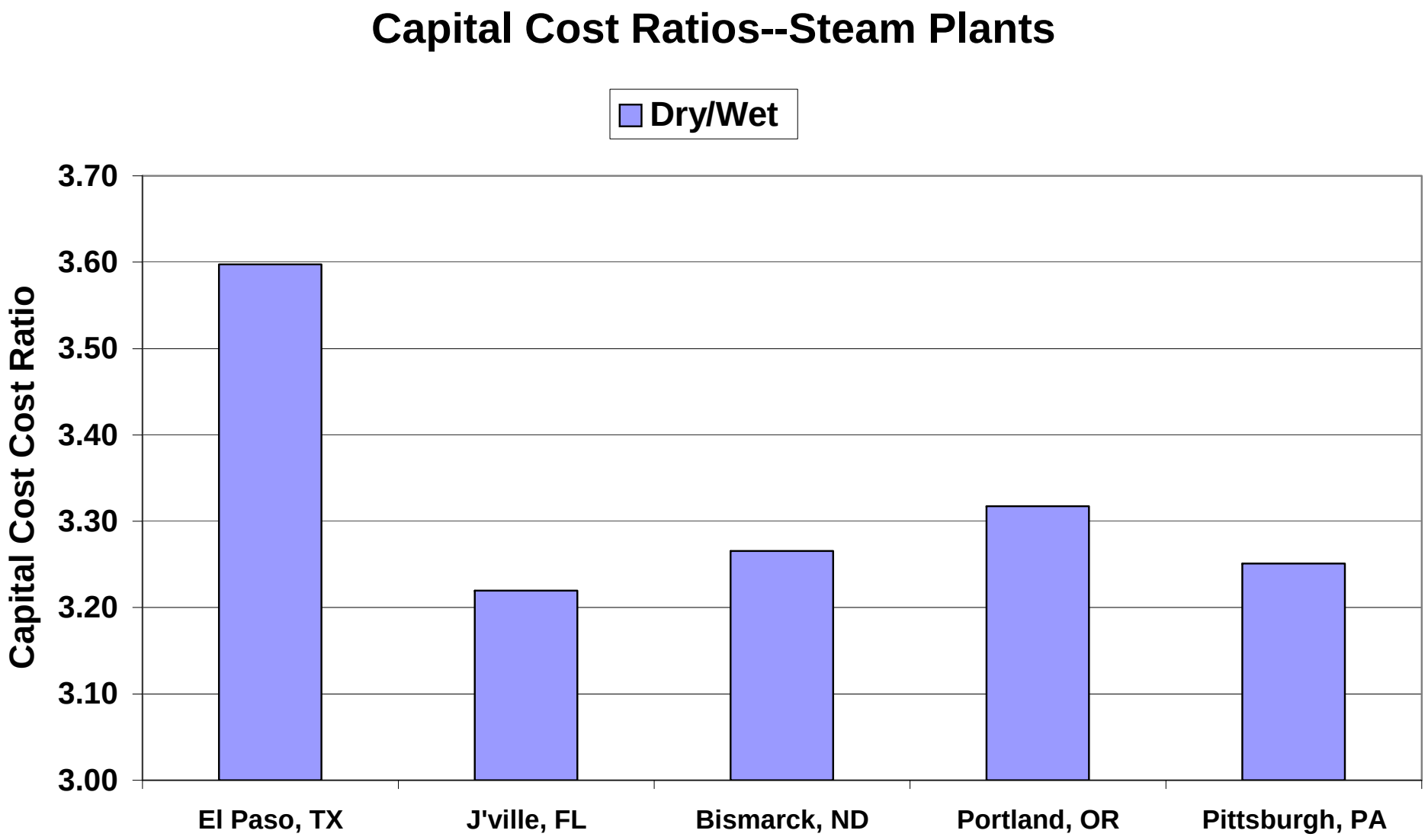
- **Retain once-through cooling at existing plants**
- **Colder water from towers**
- **Reduced fresh water requirements**
- **Cheaper dry cooling**
- **Lower backpressures**

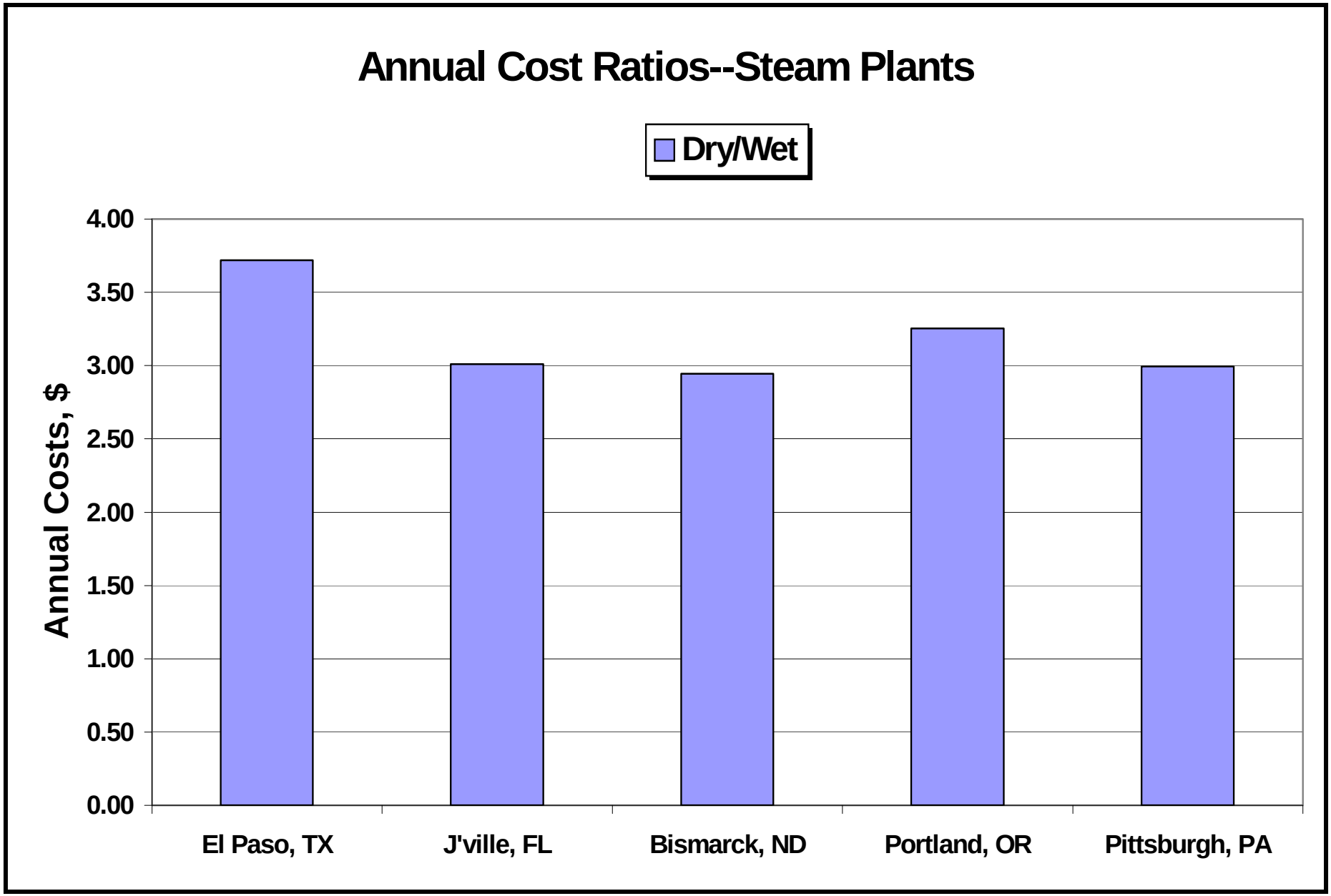
Some things to talk about

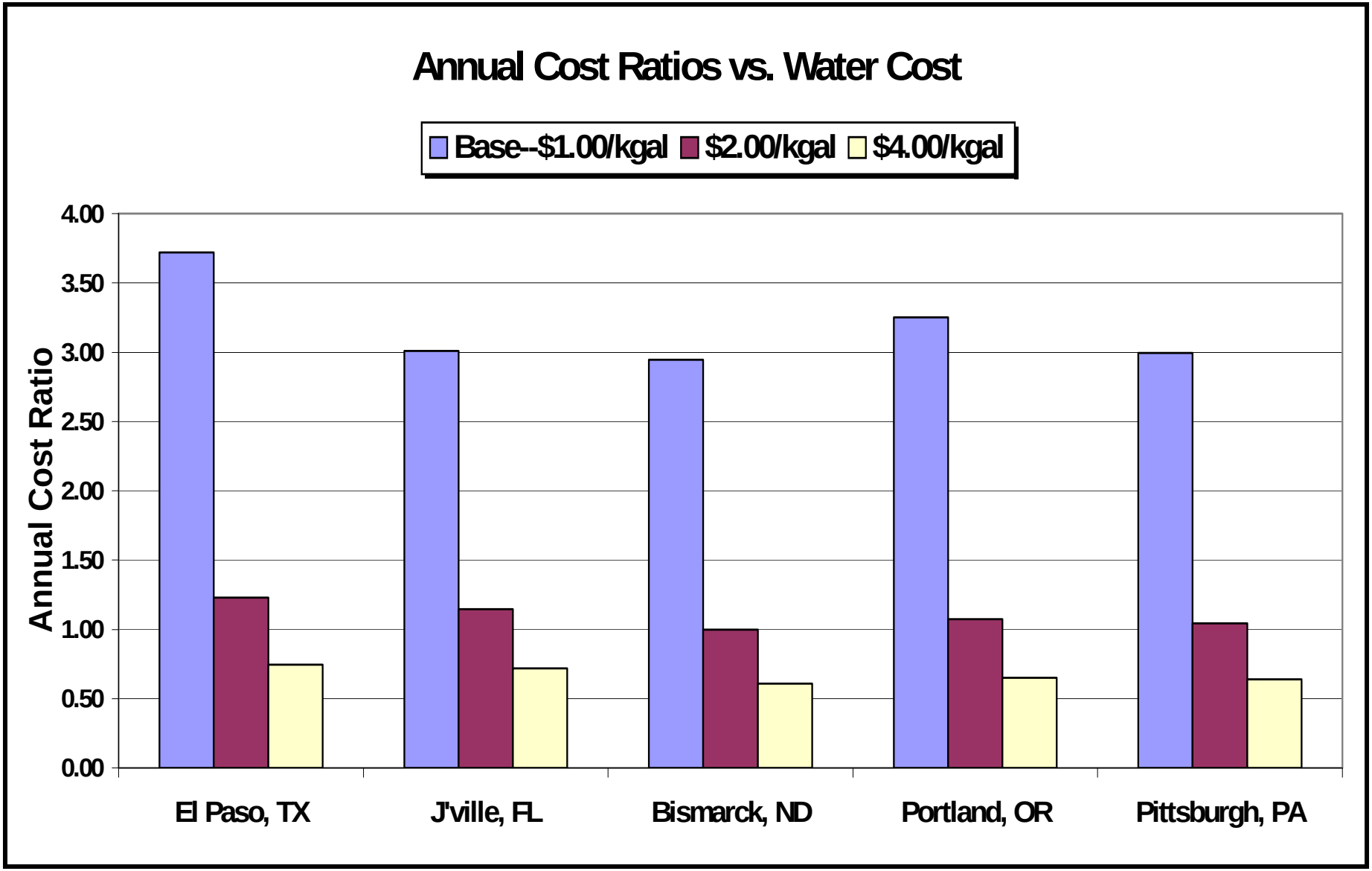
- Costs---what does it really cost?
- Once-through cooling---retrofits
- Wet cooling---evaporate less/cool more
- ACC’s---better fins/more wind resistance
- Indirect dry---eliminate range
- Wet-enhanced dry---spray/store/allocate

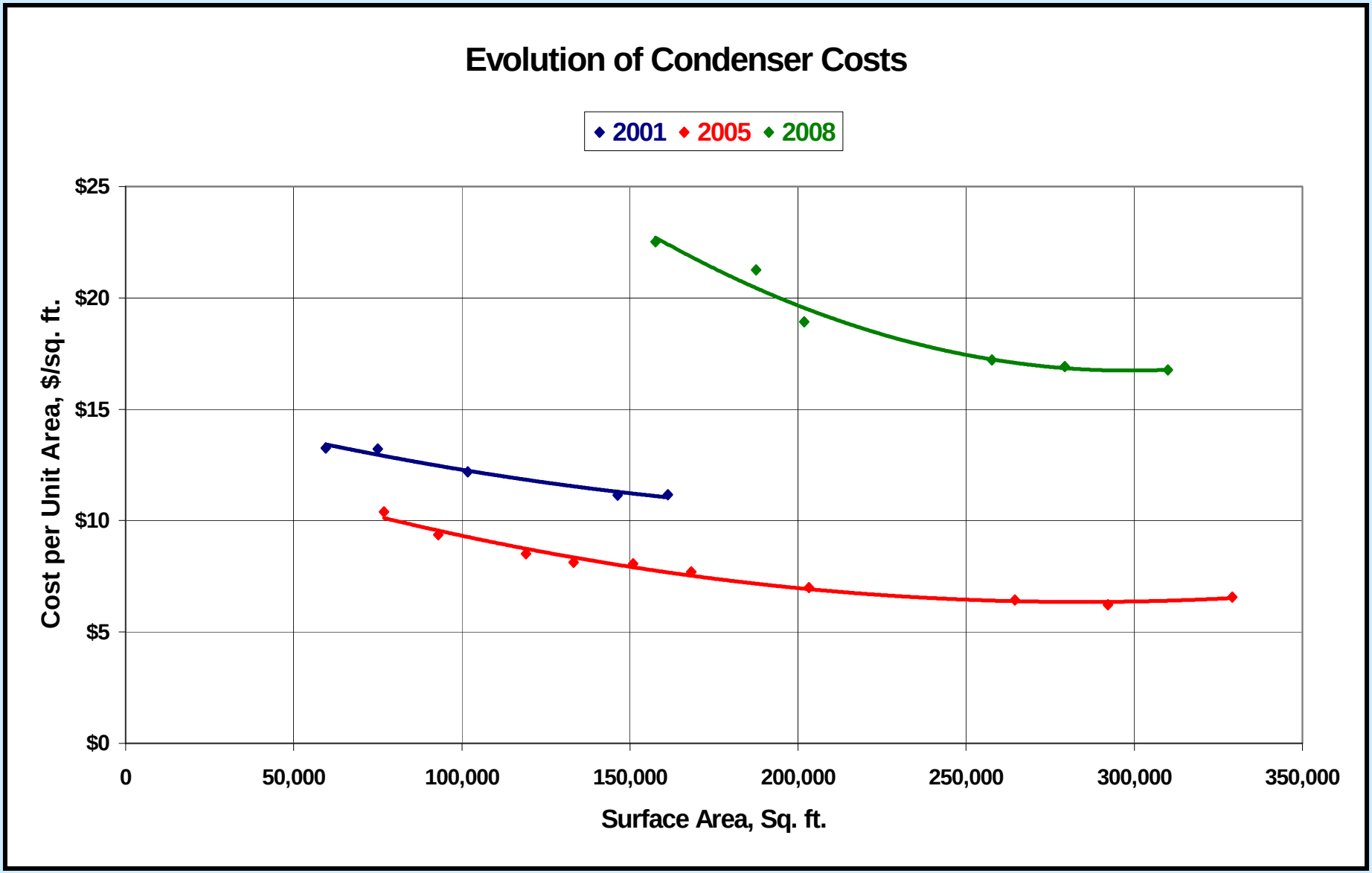
Cost Comparisons

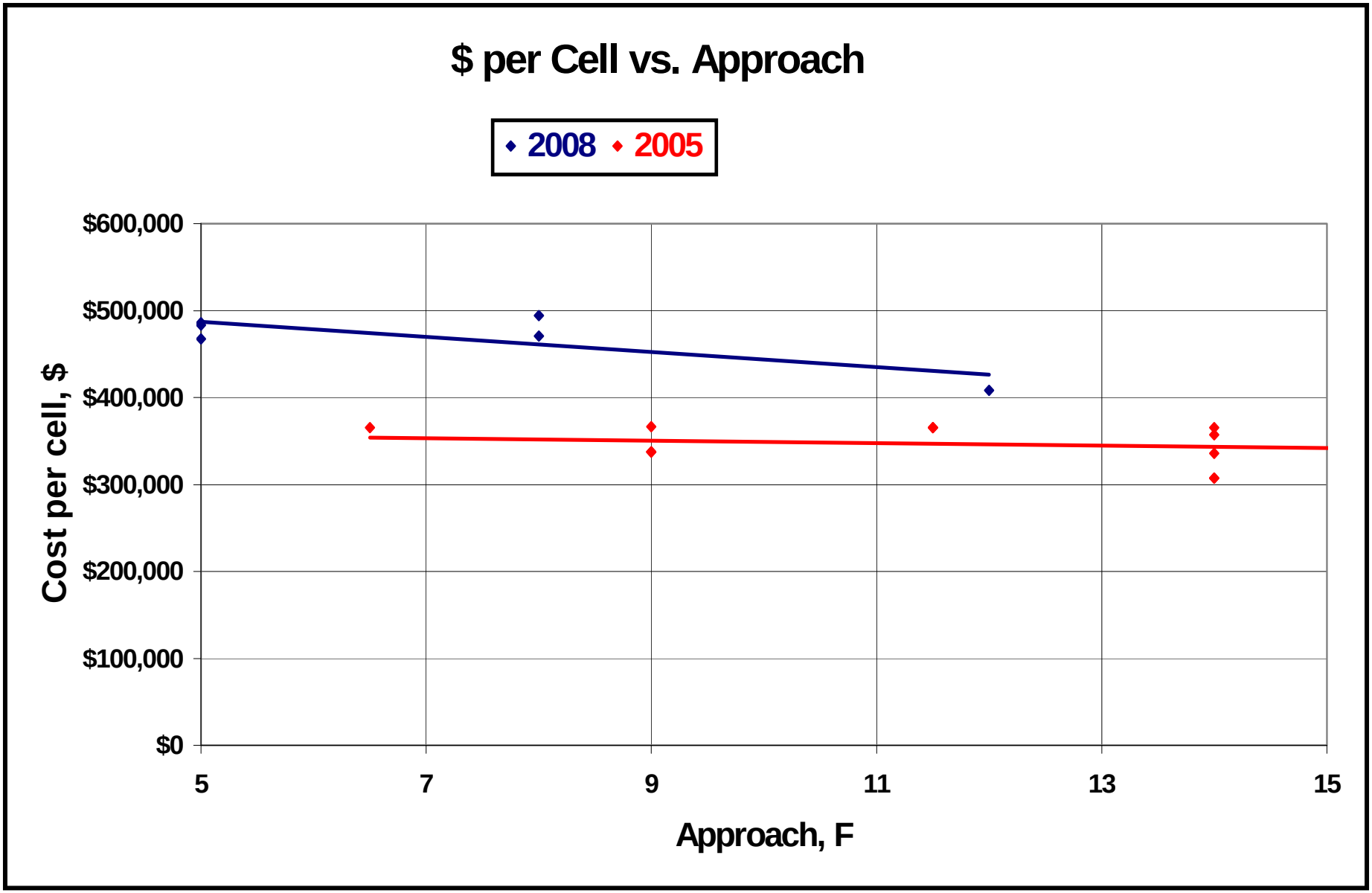
- **Base case is closed-cycle wet cooling**
- **Primary comparison is with direct dry---ACC's; Hybrid is in-between**
- **Absolute costs are elusive; ratios better but tricky**
- **Water costs may get to be important**
- **Differences are big in any case**

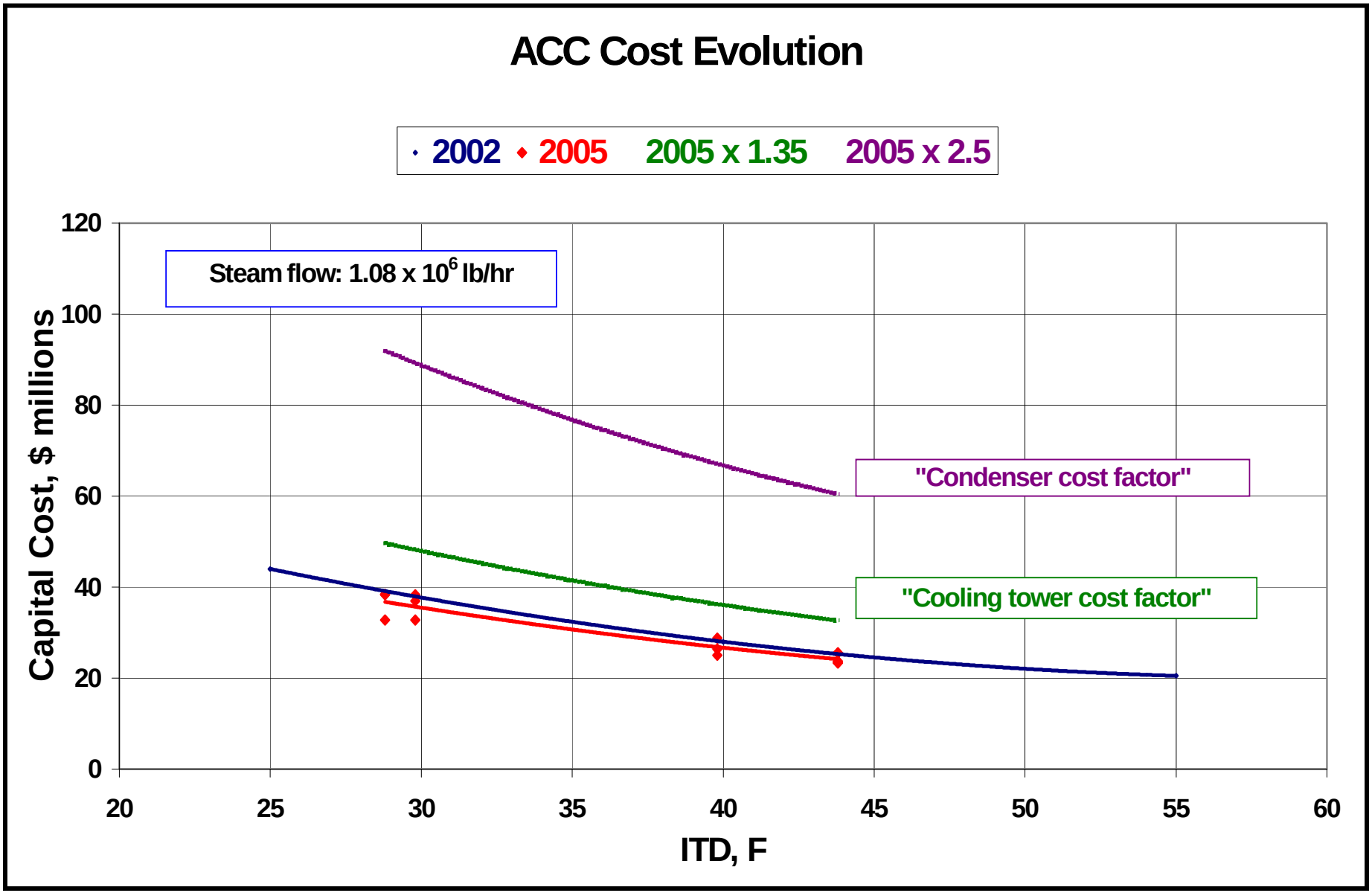

Capital Cost Ratios--Steam Plants
Dry/Wet
Capital Cost Cost Ratio
3.70
3.60
3.50
3.40
3.30
3.20
3.10
3.00
El Paso, TX
J'ville, FL
Bismarck, ND
Portland, OR
Pittsburgh, PA


Annual Cost Ratios--Steam Plants
Dry/Wet
Annual Costs, $
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
El Paso, TX
J'ville, FL
Bismarck, ND
Portland, OR
Pittsburgh, PA


Annual Cost Ratios vs. Water Cost
Base--$1.00/kgal
$2.00/kgal
$4.00/kgal
Annual Cost Ratio
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
El Paso, TX
J'ville, FL
Bismarck, ND
Portland, OR
Pittsburgh, PA

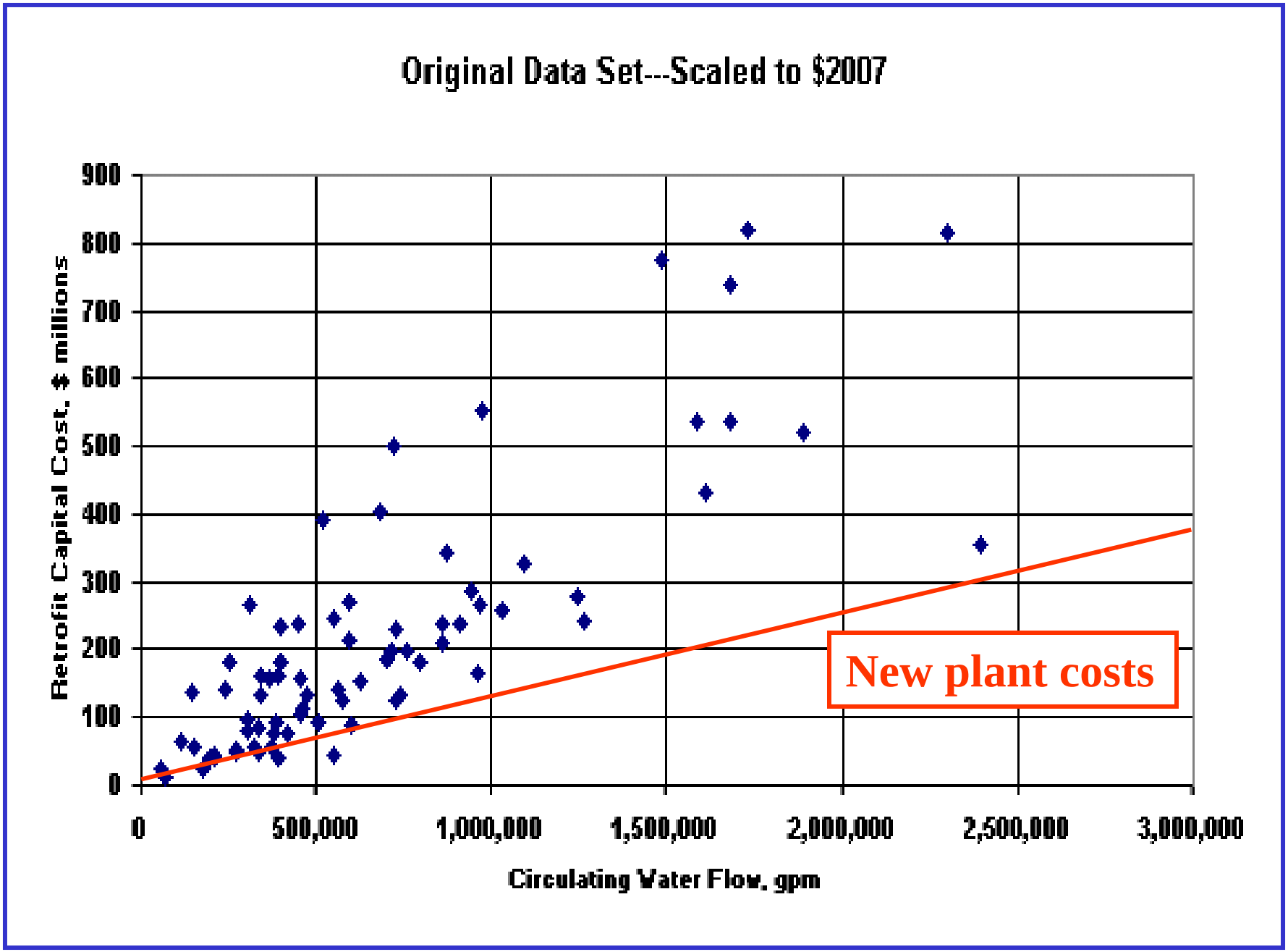

Evolution of Condenser Costs
2001
2005
2008
$25
$20
$15
$10
$5
$0
Cost per Unit Area, $/sq. ft.
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
Surface Area, Sq. ft.


$ per Cell vs. Approach
2008
2005
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$0
Cost per cell, $
5
7
9
11
13
15
Approach, F


ACC Cost Evolution
2002
2005
2005 x 1.35
2005 x 2.5
Steam flow: 1.08 x 10^6 lb/hr
"Condenser cost factor"
"Cooling tower cost factor"
Capital Cost, $ millions
ITD, F
0
20
40
60
80
100
120
20
25
30
35
40
45
50
55
60

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 <u>very</u> high**
- **Alternatives have a big window**


Original Data Set---Scaled to $2007
Retrofit Capital Cost, $ millions
900
800
700
600
500
400
300
200
100
0
0
500,000
1,000,000
1,500,000
2,000,000
2,500,000
3,000,000
Circulating Water Flow, gpm
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

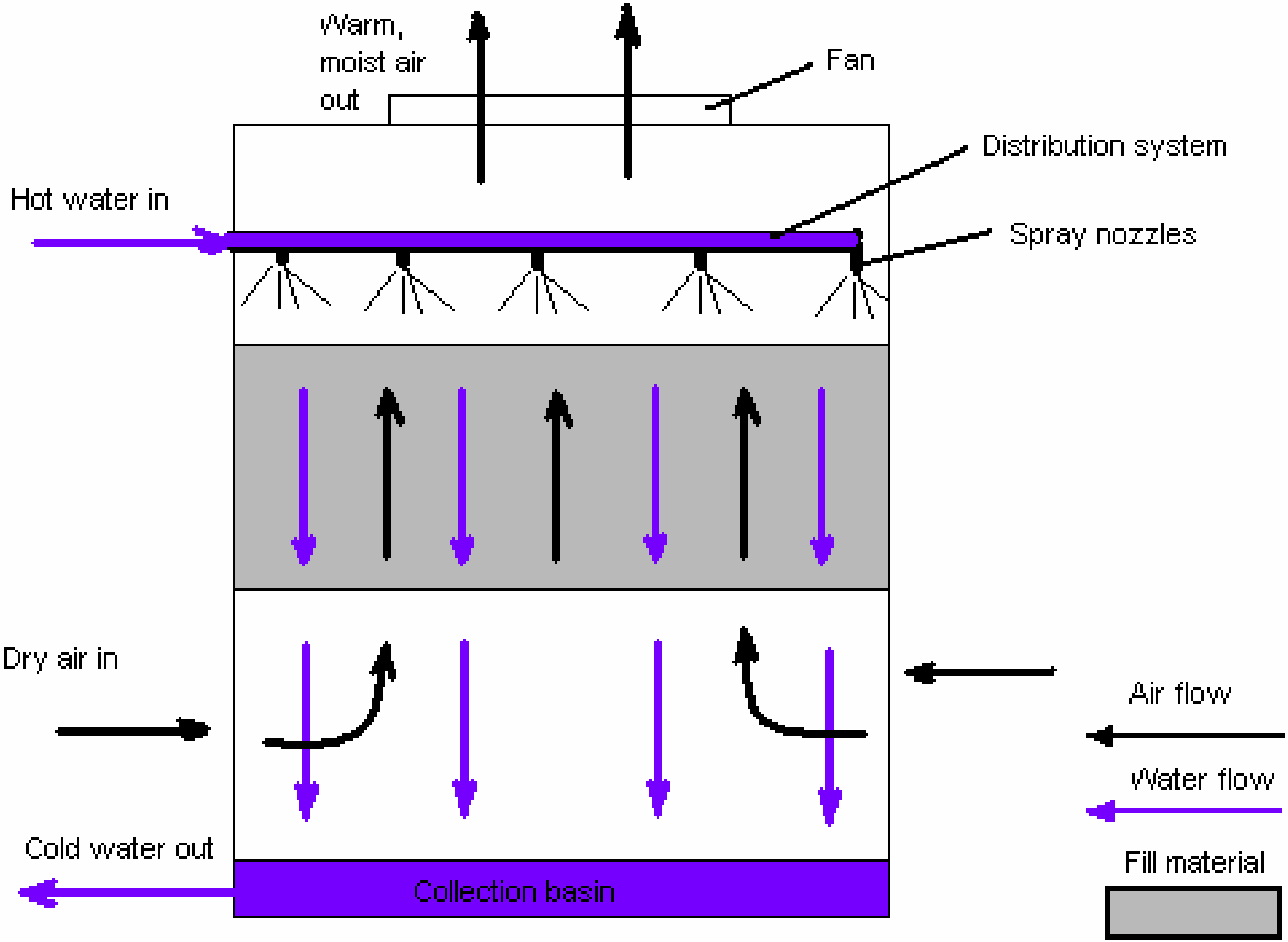
- **Approach already down to 5 F**
- **2 to 3 F recirculation allowance hurts**
- **Reduce re-entrainment**
- **Wind/water tunnel modeling**
- **Modified designs**

Wet Cooling Towers

- **<u>Evaporate less</u>**
  - **Recover water**
- **Alter sensible/latent heat ratio?**
- **Off-optimum, higher cost, but maybe competitive**

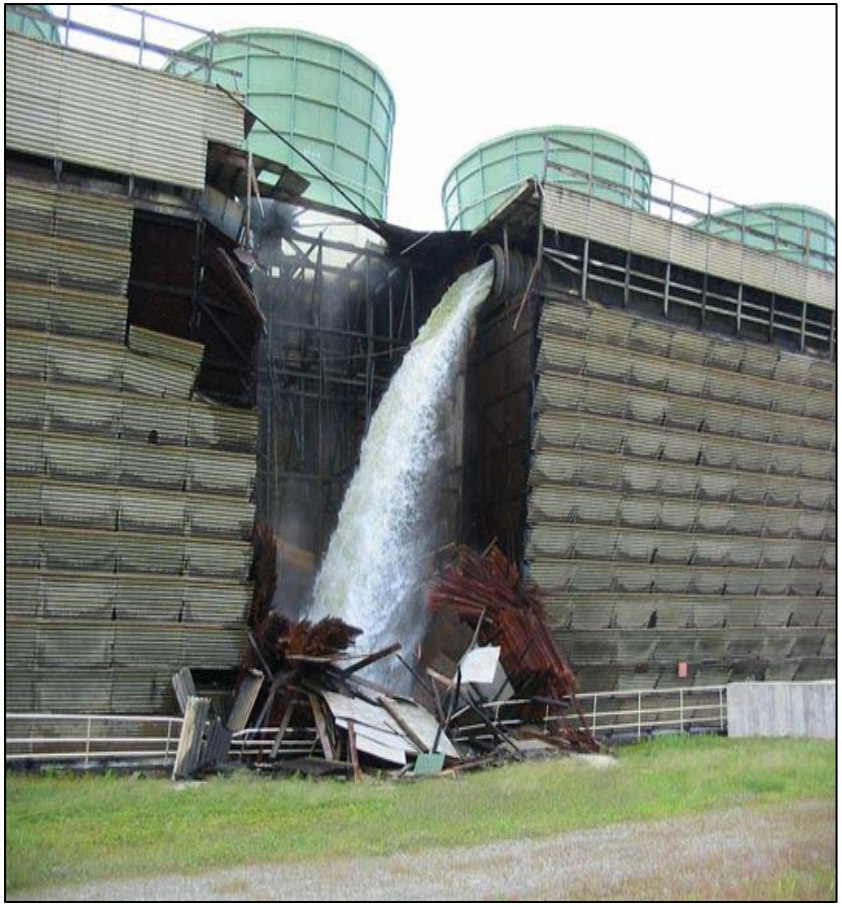
Wet Cooling Towers

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



Counterflow type design

Wet Cooling--Maintenance



- **Sometimes bad things happen**

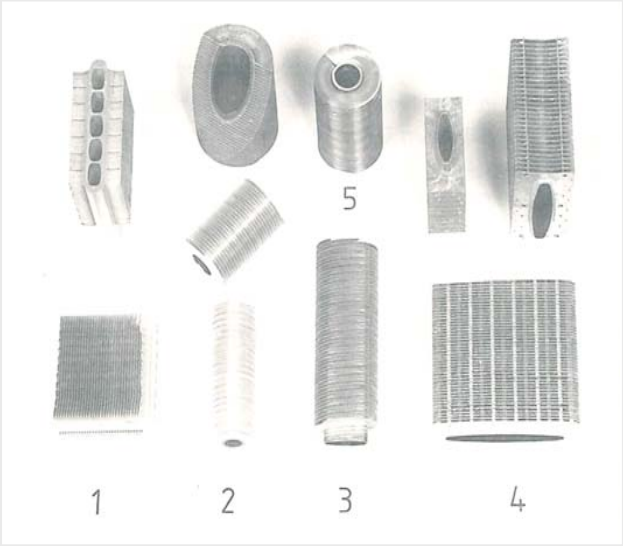
Dry Cooling—Air-cooled Condenser

- 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



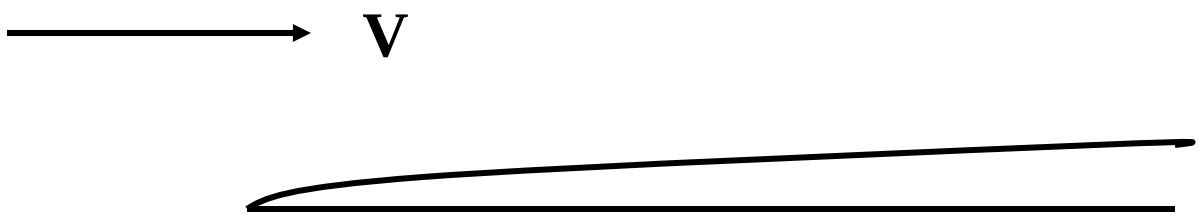
- **Three issues**
  - **High backpressure**
  - **High fan power**
  - **High cost**
- **Address all with improved finned tube bundles.**
  - **Higher heat transfer**
  - **Lower pressure drop**

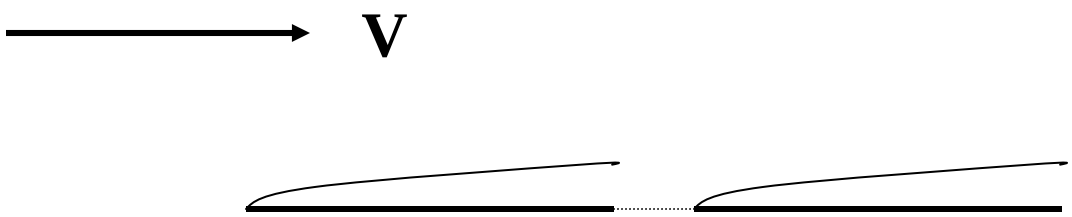
COMPACT HEAT EXCHANGERS

THIRD EDITION

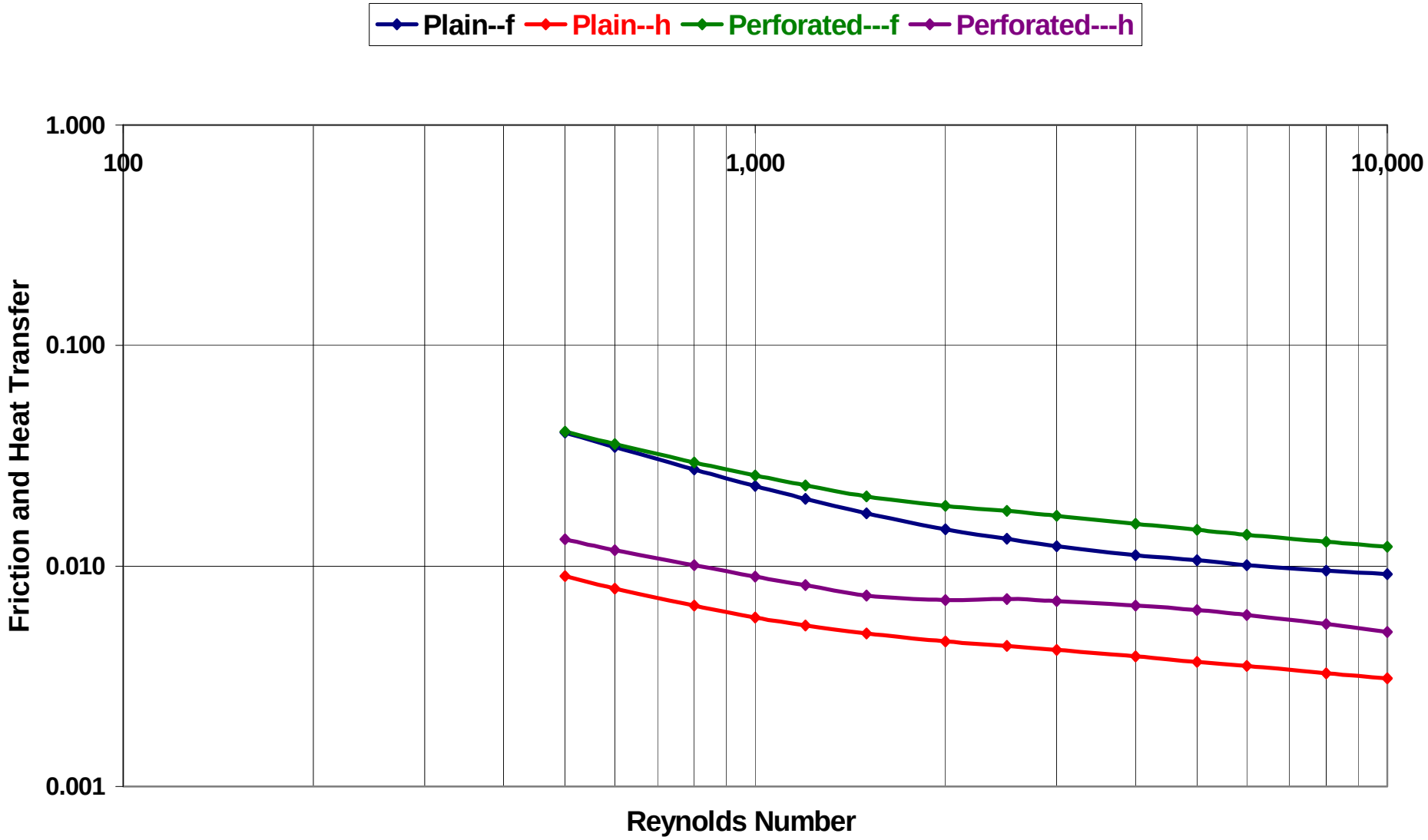
W. M. Kays and A. L. London

Perforated Fin—Interrupted Boundary Layer





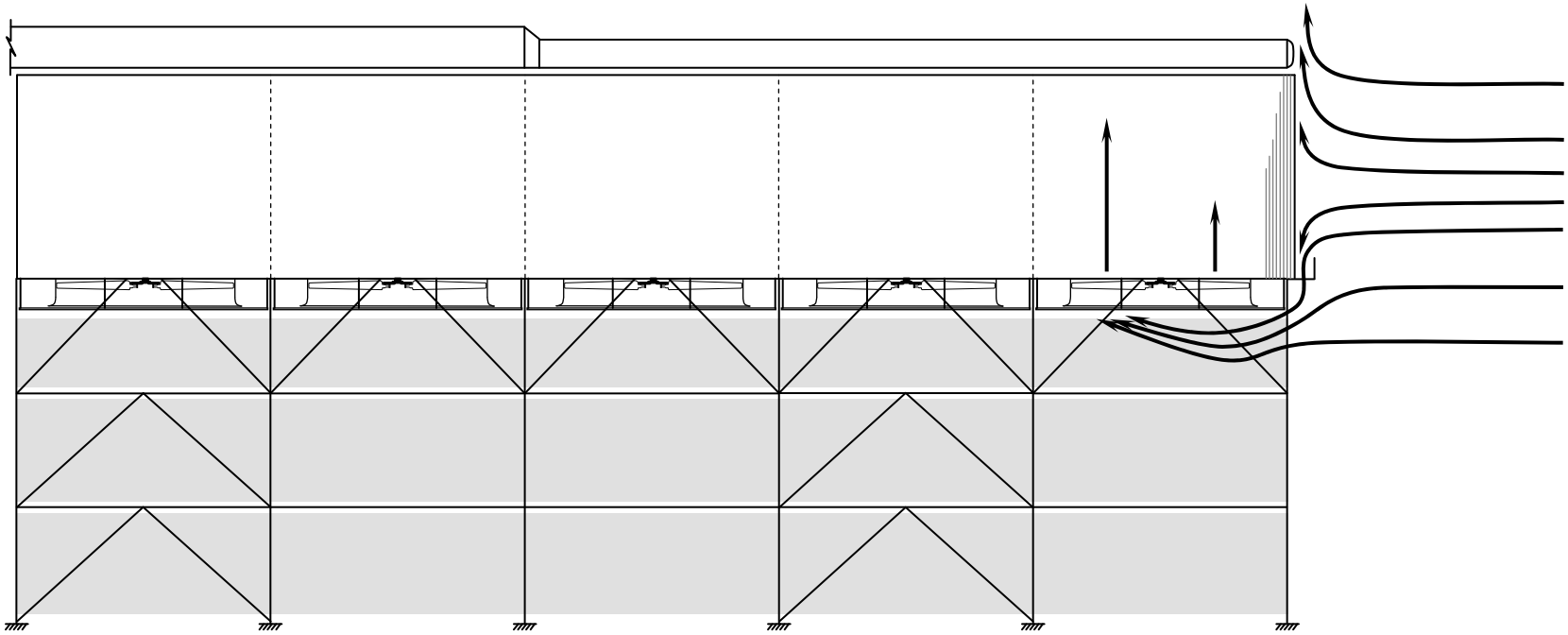
Fin Performance Comparisons



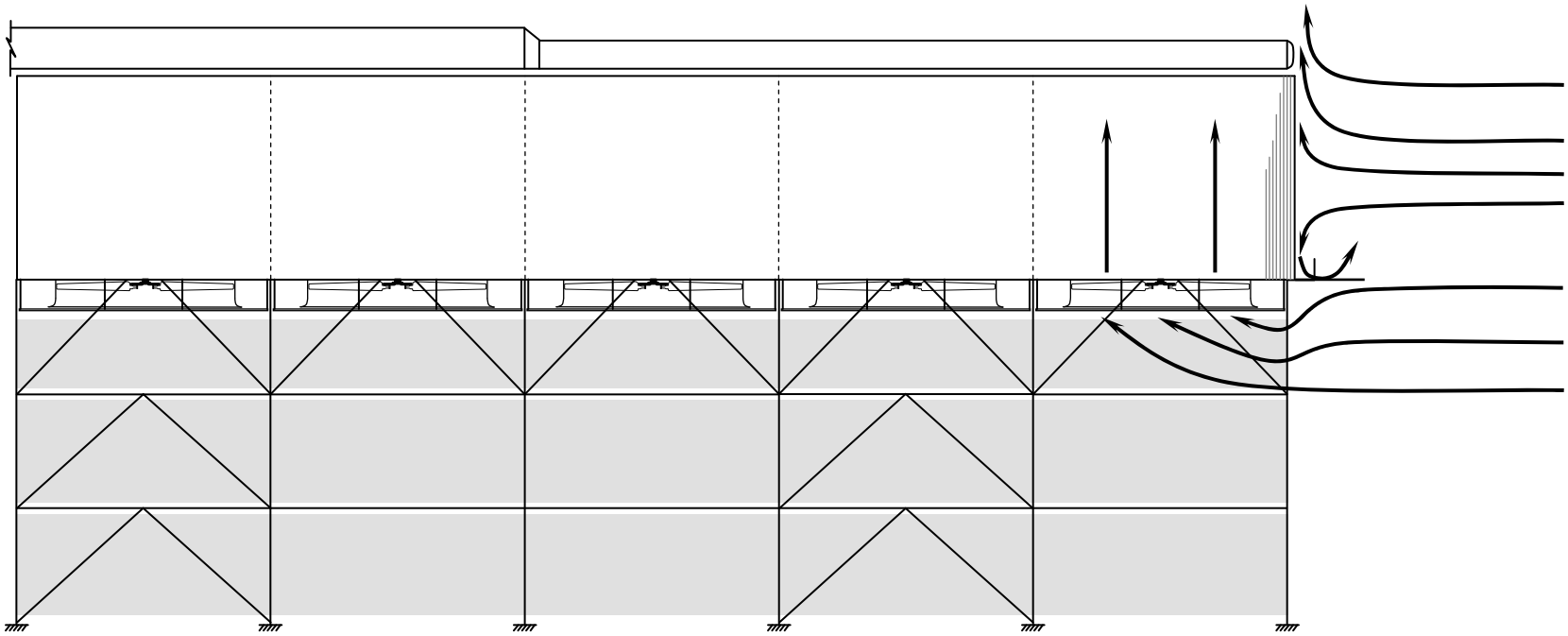
ACC's---Wind Resistance

- **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

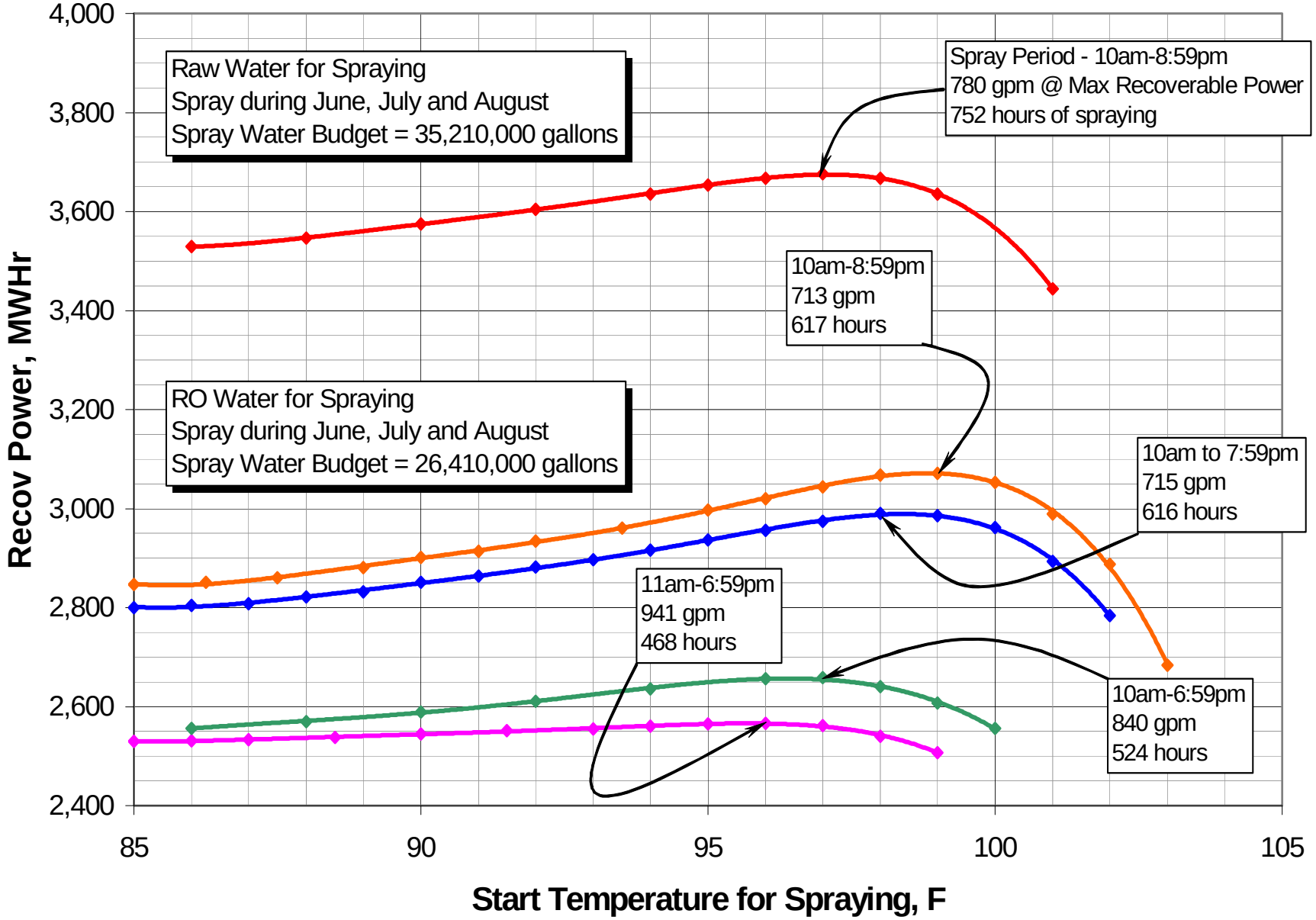
- **Finned tubes get wet**
- **Water gets wasted**
- **Need better atomization**

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



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…..