EPRI Workshop on Advanced Cooling Technologies: Preparing for a Water Constrained Future

HYBRID COOLING SYSTEMS AND AIR COOLED CONDENSERS

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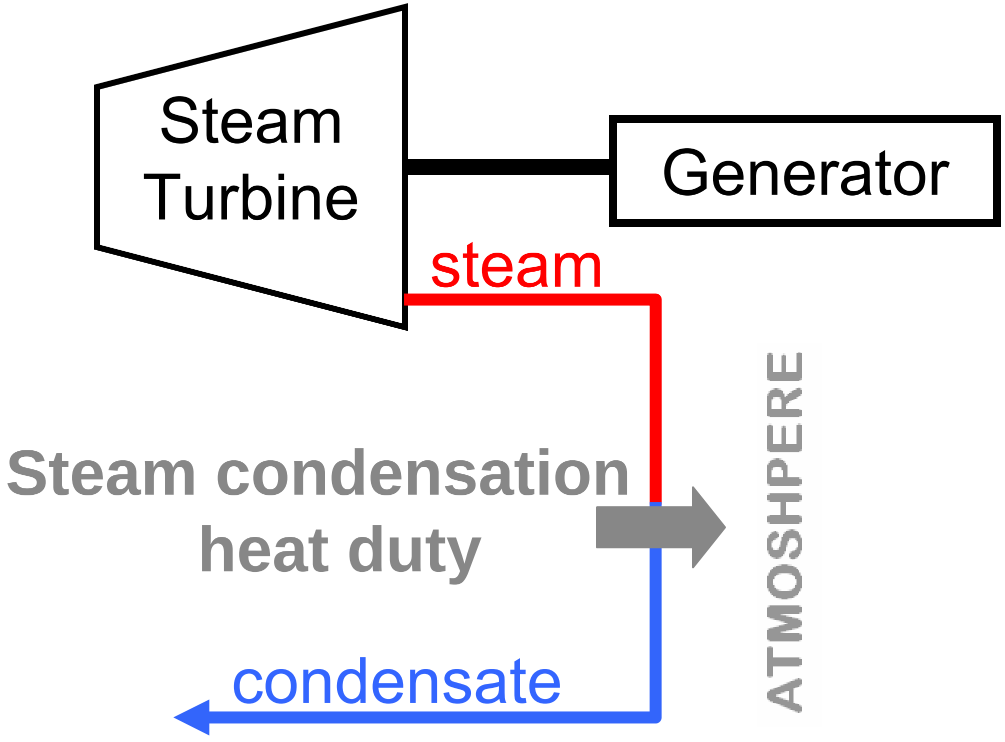
Introduction

Major purpose of cooling system = reject heat duty (from steam condensation) to the atmosphere



Important note:

Steam turbine output is directly related to the capacity of the cooling system which is a function of the ambient temperature (DBT for dry cooling; WBT for wet cooling) → remember for later.

Cooling system performance & ambient conditions

1. **Wet Cooling Systems**:

   If WBT □ than CWT □ which results in BP □ and output □

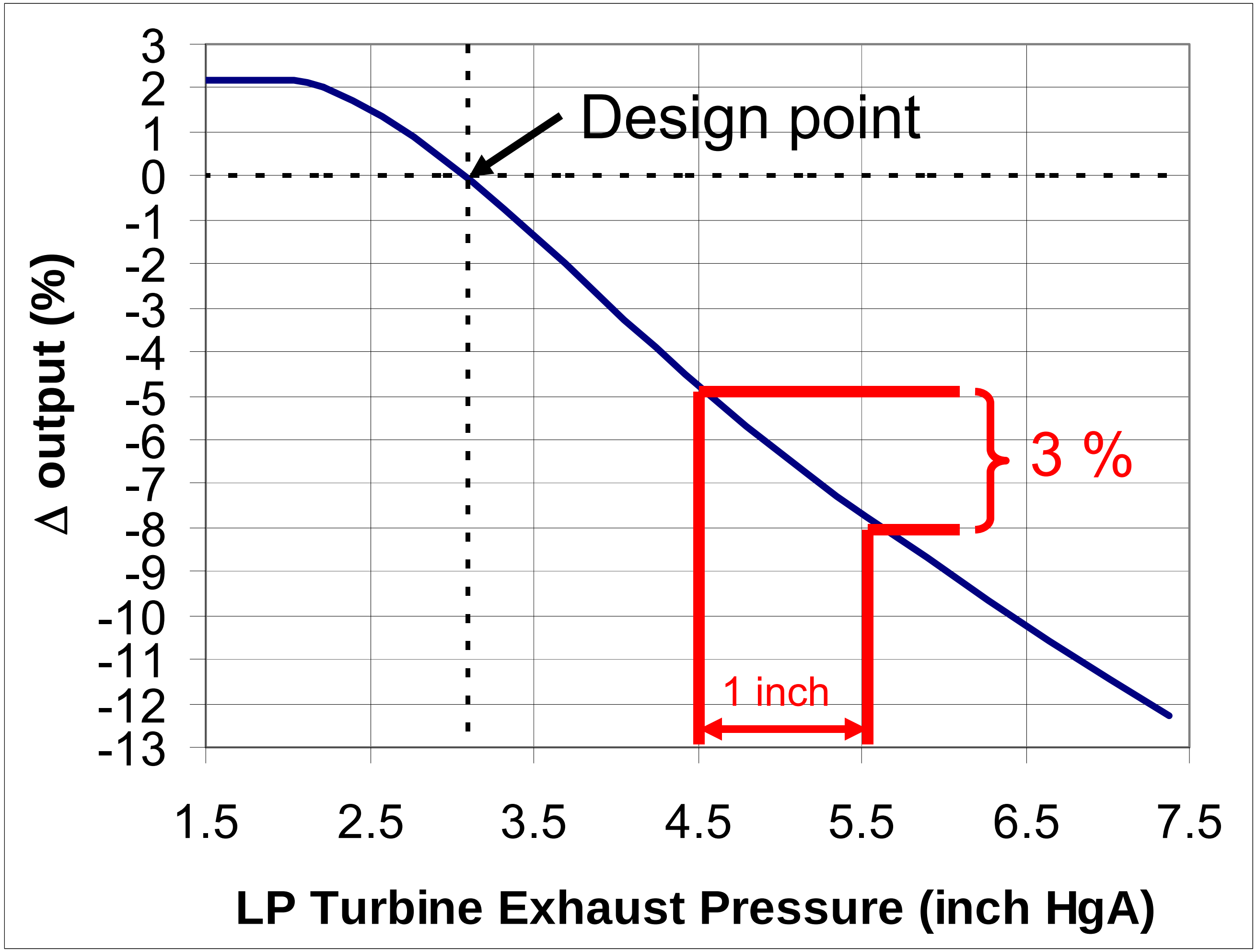
2. **Dry Cooling Systems**:

   If DBT □ than BP □ and output □

Since performance wet cooling depends on WBT while performance dry cooling depends on DBT, the steam generator output is larger for wet systems since WBT ≤ DBT

3. **Hybrid Cooling Systems**: intermediate performance

Steam tubine back pressure and generator output



BP ↗ ⇒ kW ↘

Design: 3.1 in Hg
→ 100 % output

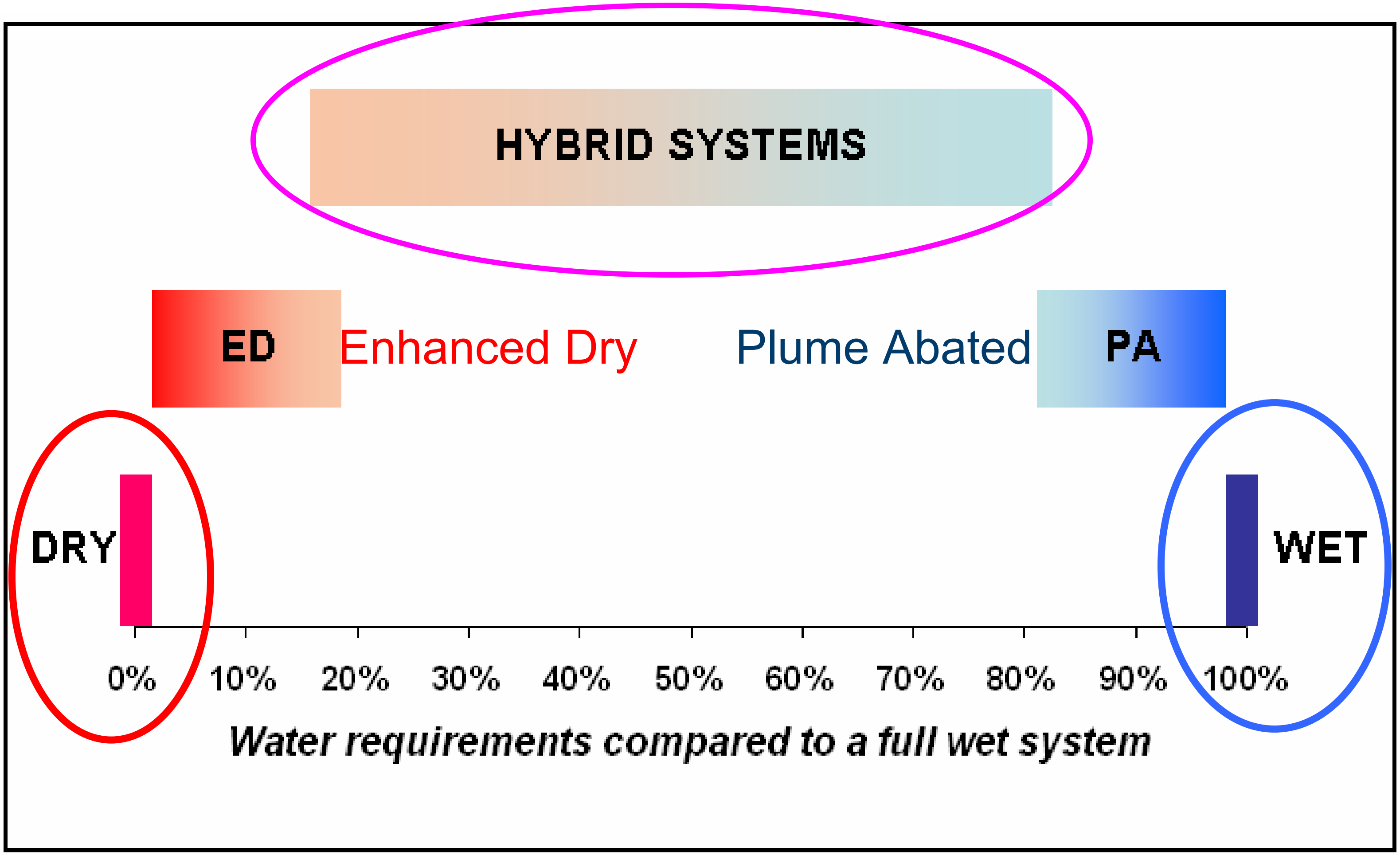
Δ BP = 1 inch

⇩

Δ output = - 3%

Wet cooling systems can reach lower BP than dry cooling systems

Classification of Cooling Systems

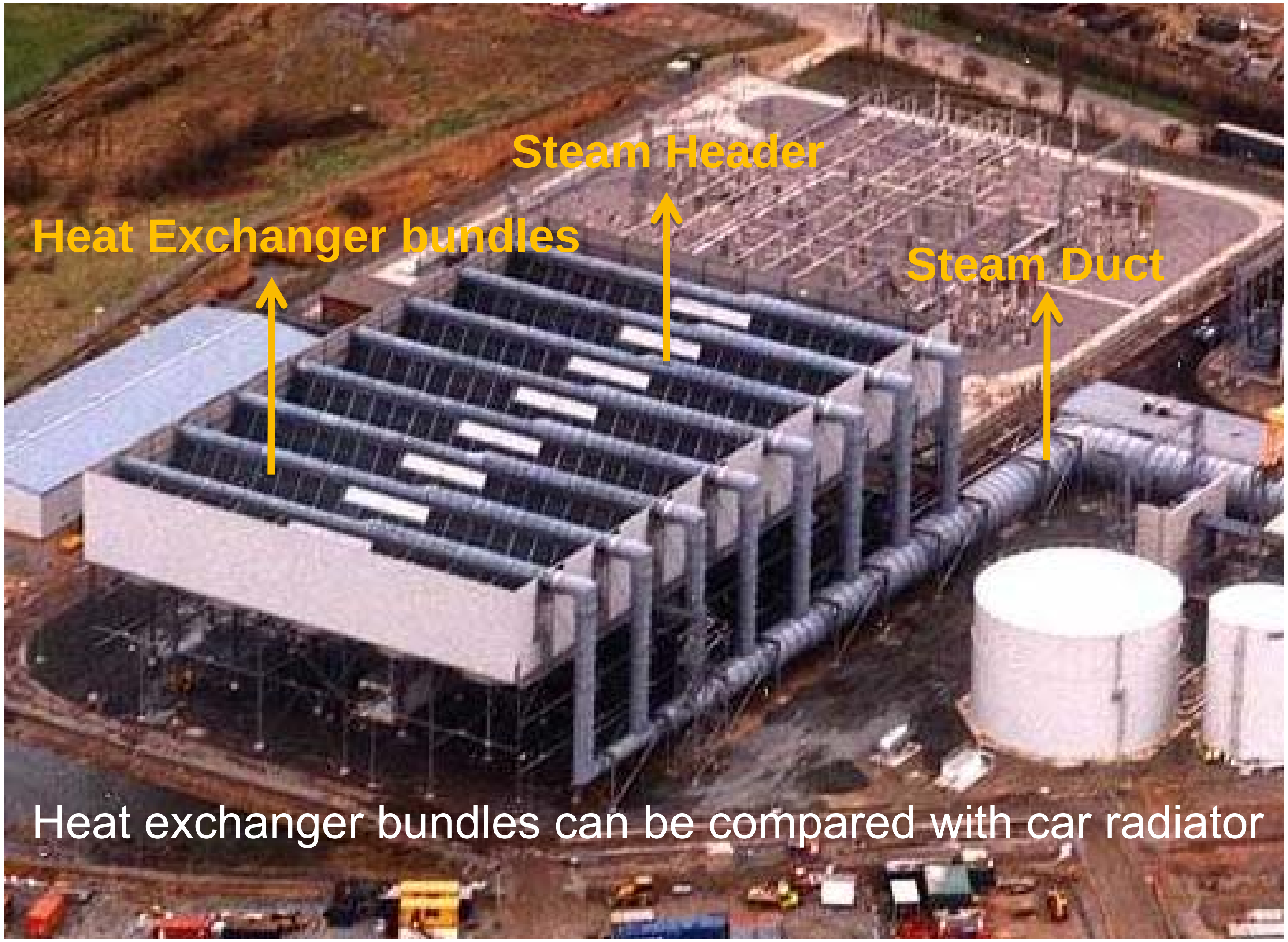


Make-up water requirements & initial investment cost

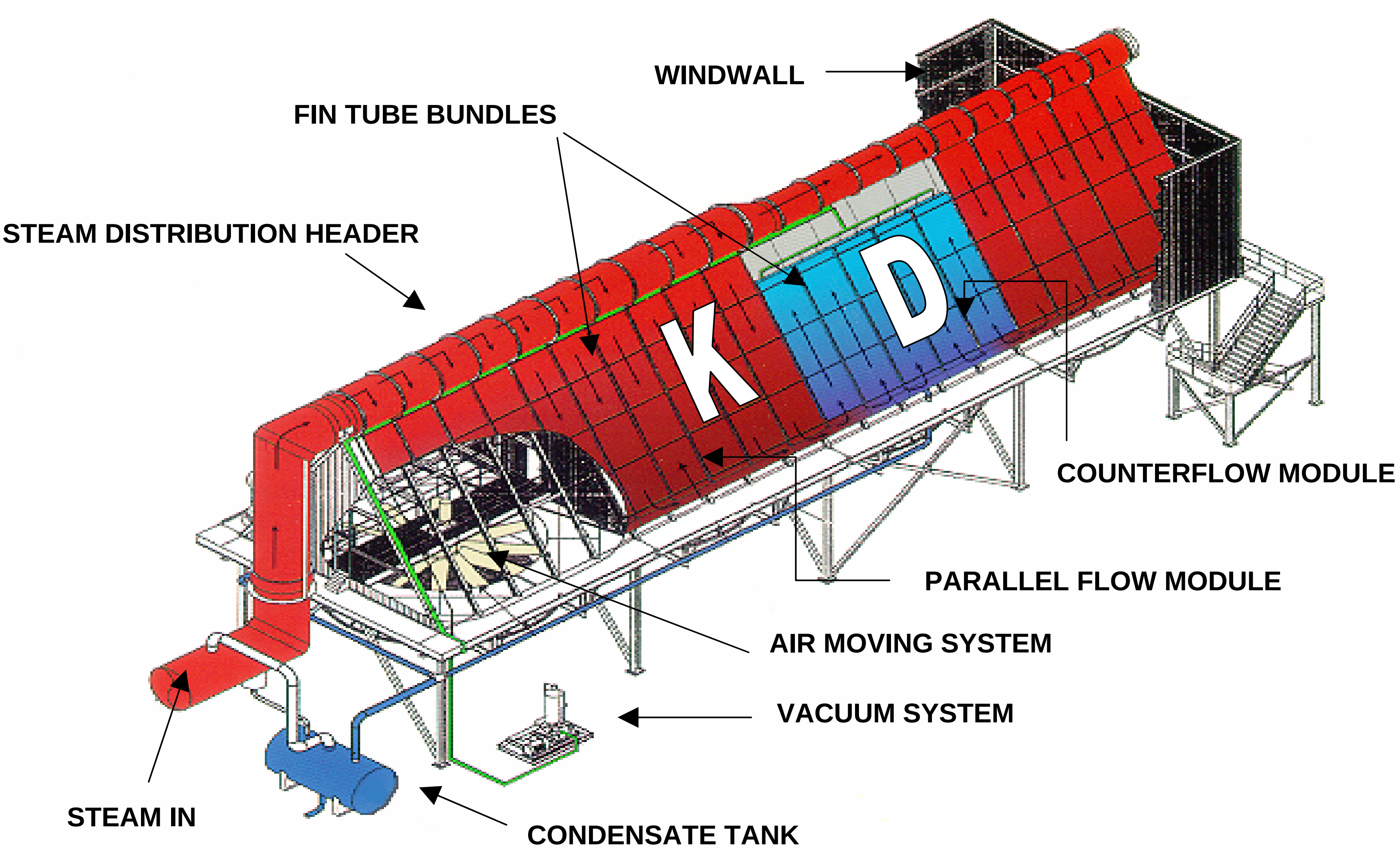
	WATER NEED	COST
DRY	LOW	HIGH
WET	HIGH	LOW
HYBRID	INTERMED.	OPTIMIZED

Dry cooling systems: the ACC

Coryton 750 MW Combined Cycle (England)

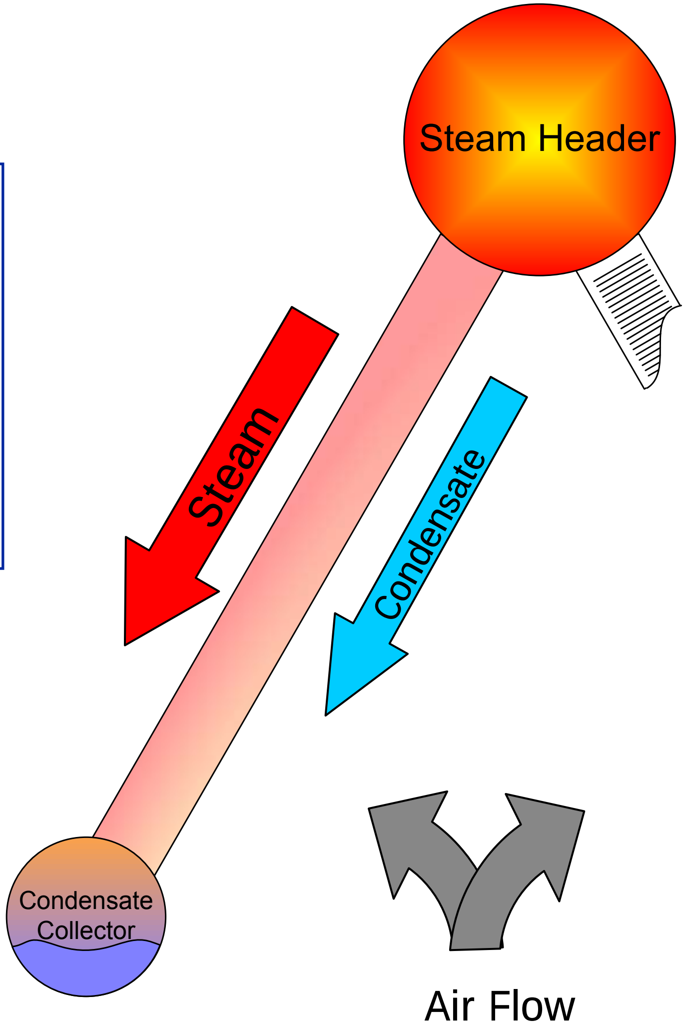


ACC: 2-stage condensation process



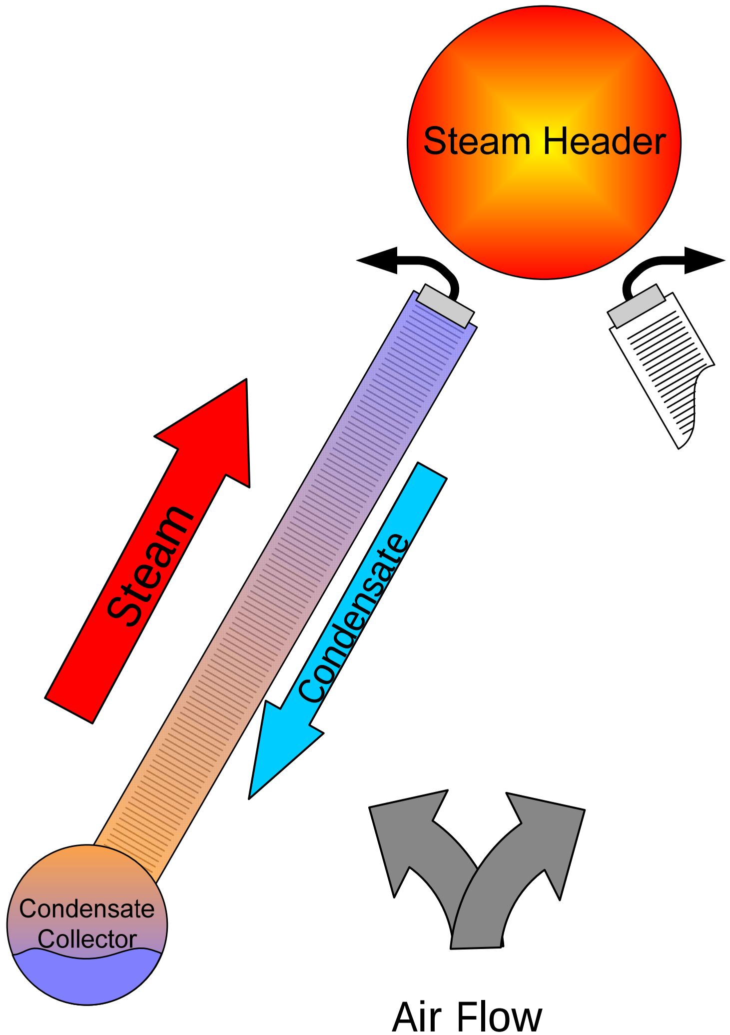
Air Cooled Condenser: K-bundles

- **Steam & Condensate travel in parallel**
- **70-80% of steam is condensed in the K's**
- **Any air in system is purged to "D" bundles**



Air Cooled Condenser: D-bundles

- **Steam & Condensate travel in opposite directions**
- **Final 20-30% of steam condensed**
- **Any air in the system is removed at the top of "D" bundles by vacuum system**
- **Condensate always warmed by steam (Minimizes sub-cooling and avoids freezing of the tubes)**

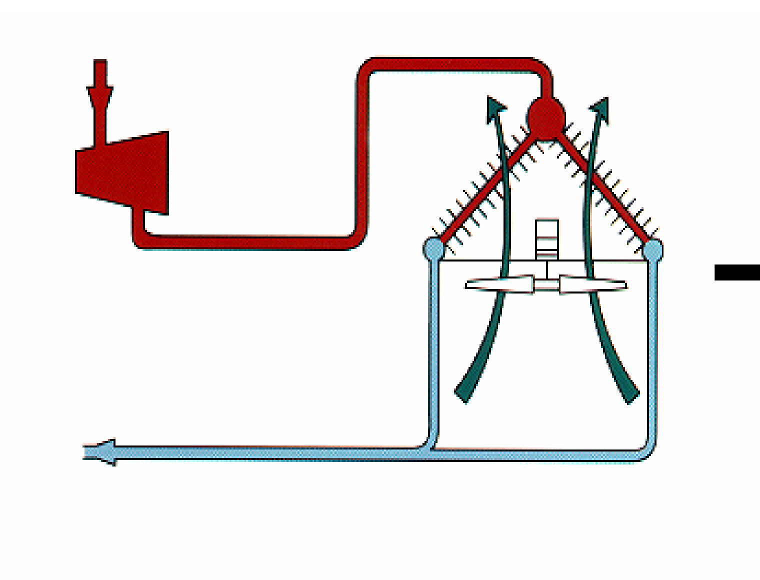


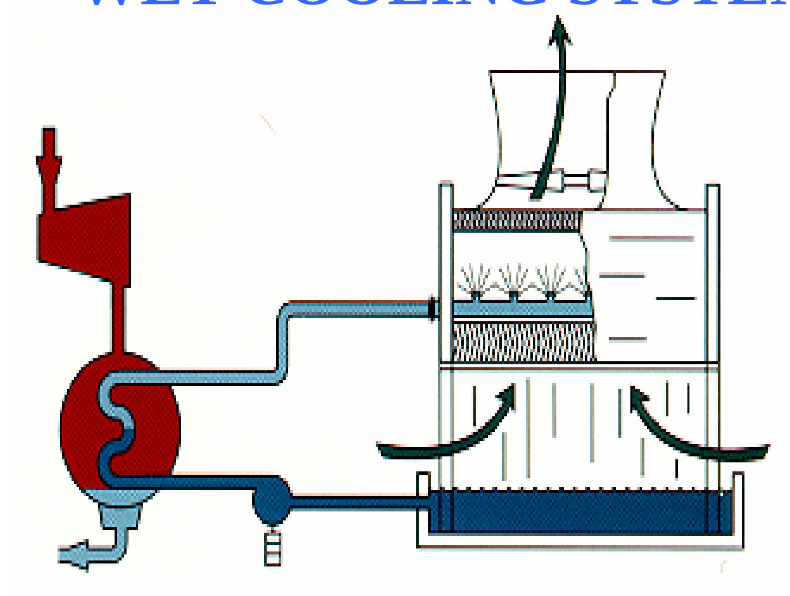
Hybrid cooling systems: the PAC system

Best available hybrid cooling technology to use the make-up water optimally !

What is a Parallel Condensing System (PAC)

DRY COOLING SYSTEM + **WET COOLING SYSTEM**



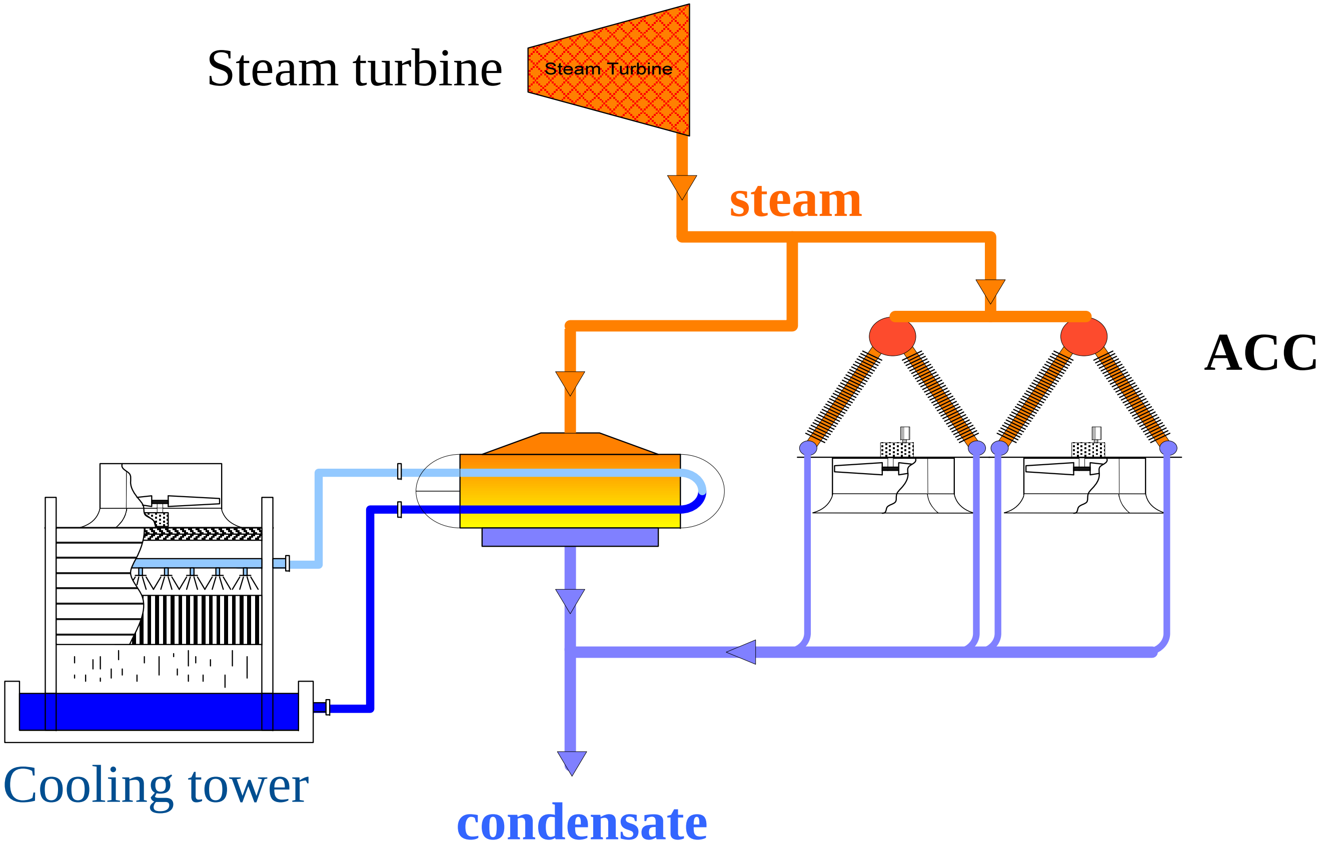


"A synergy of established cooling technologies"

What is a Parallel Condensing System (PAC)

The result is a Parallel Condensing System:

=



SSC and ACC are condensing the steam in parallel

Design of hybrid cooling systems (PAC):

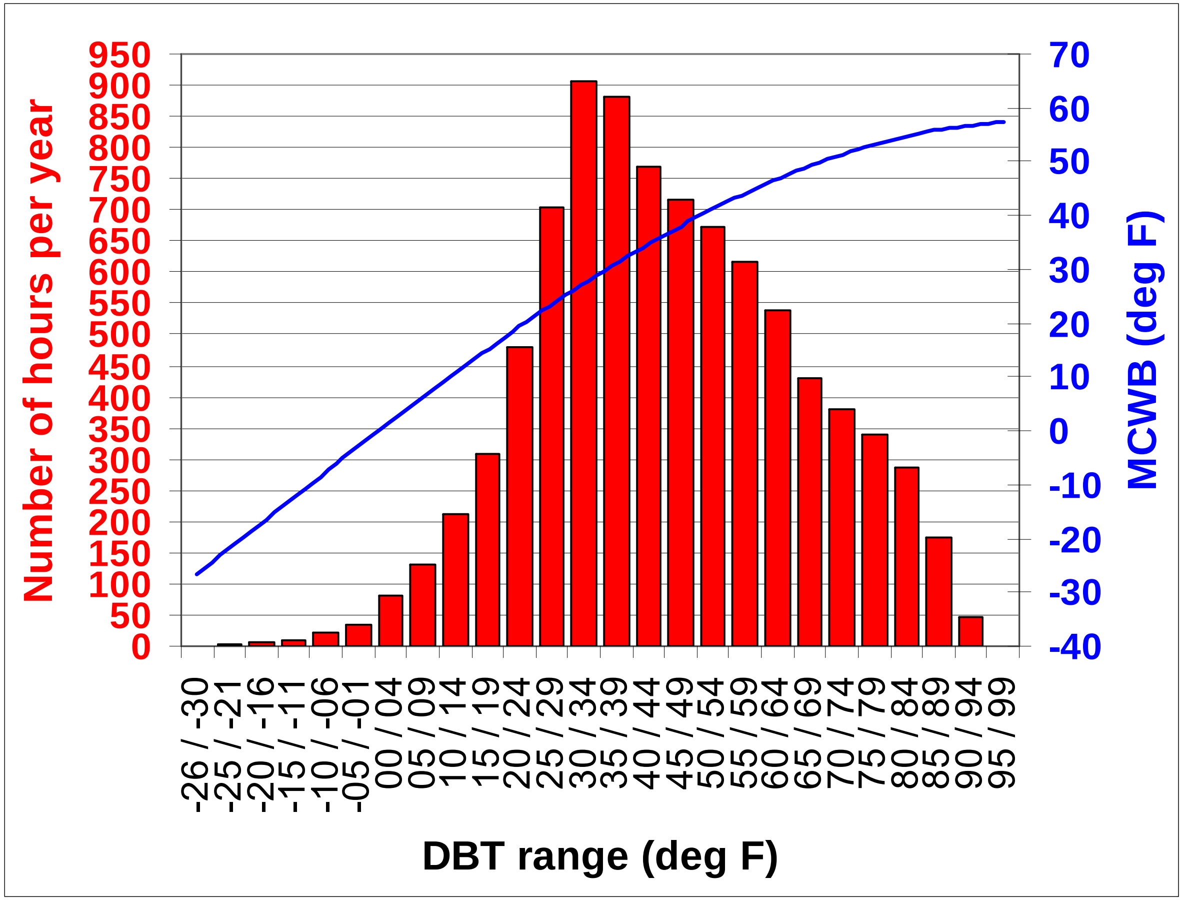
Design of Parallel Condensing Systems:

- Not enough water for wet cooling → # acre-foot per year limit
- Cost optimization: minimize dry section as much as possible
- $m'_{make\text{-}up}$ for wet section has to be integrated over 1 year

1st step: analysis of climatic data for the site

- DBT & WBT occurrence in number of hours per year
- This kind of info is not available in the ASHRAE handbook
- Can be found in Engineering Weather Data (by NCDC)

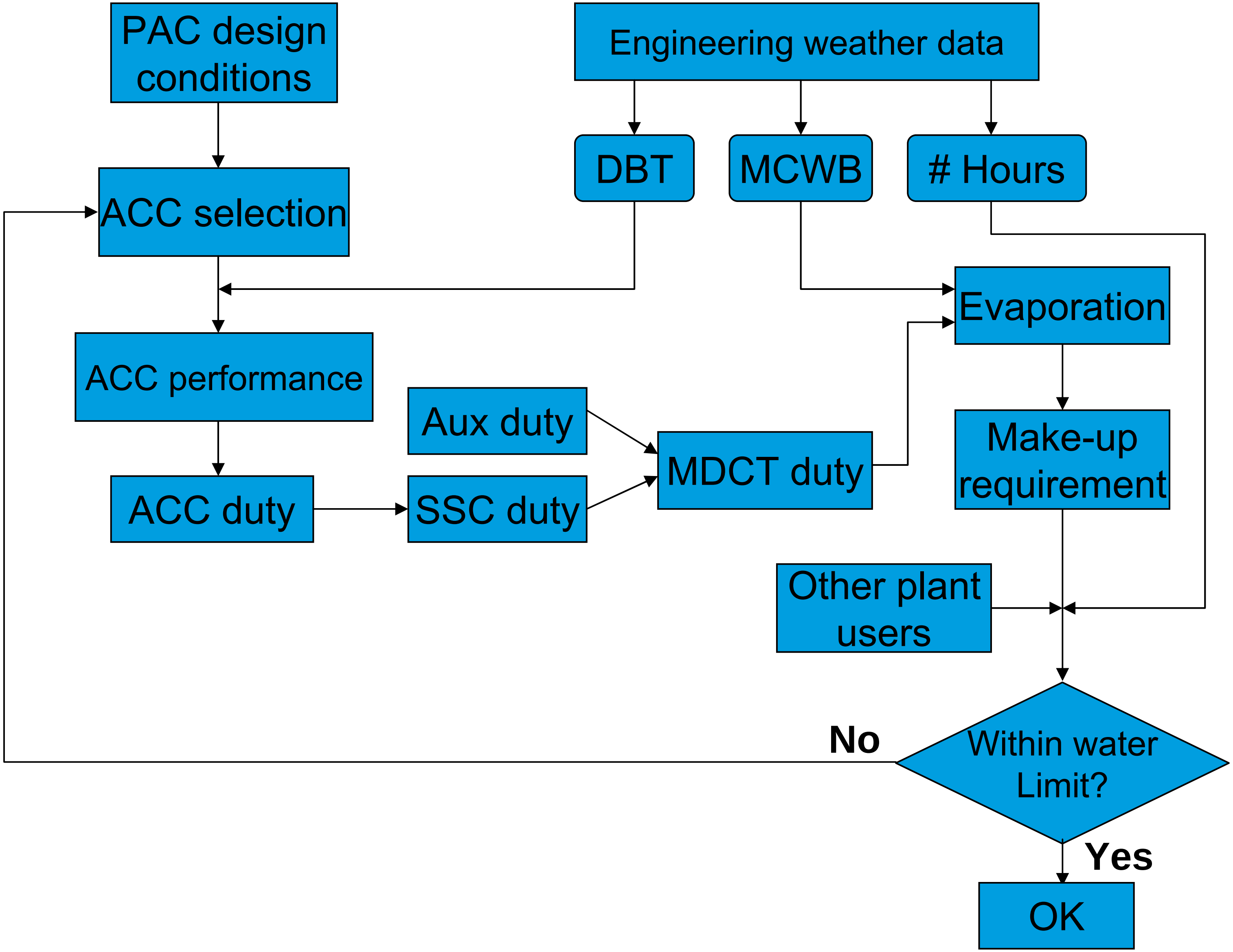
PAC systems: climatic data and control



Control hybrid:

- m'_{evap} controlled by MDCT capacity (fans)
- low DBT: ACC only
- DBT ↗ ⇒ both MDCT & ACC in operation
- Monitor $m'_{make\text{-}up}$ to stay below spec limit

PAC system design



Make-up water requirements wet cooling

Water losses should be compensated by make-up water:

$m'_{make\text{-}up} = m'_{evap} + m'_{blow\text{-}down} + m'_{drift}$

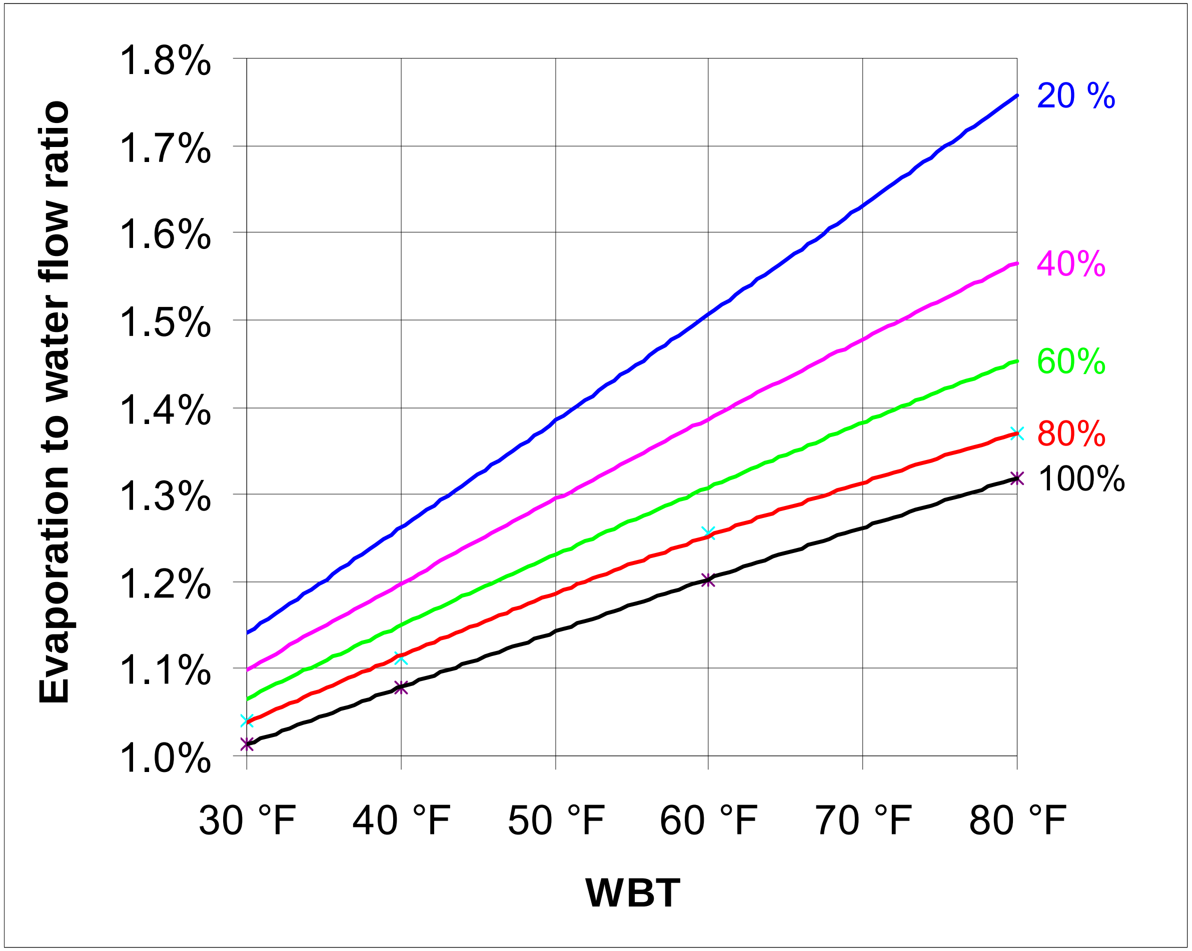
m'_{drift} → 0.0005 % - 0.001 % of water flow rate @ inlet tower

$m'_{blow\text{-}down}$ → function of # cycles of concentration (COC)

It is easily shown that: $m'_{make\text{-}up} = m'_{evap} \left[\frac{COC}{COC - 1} \right]$

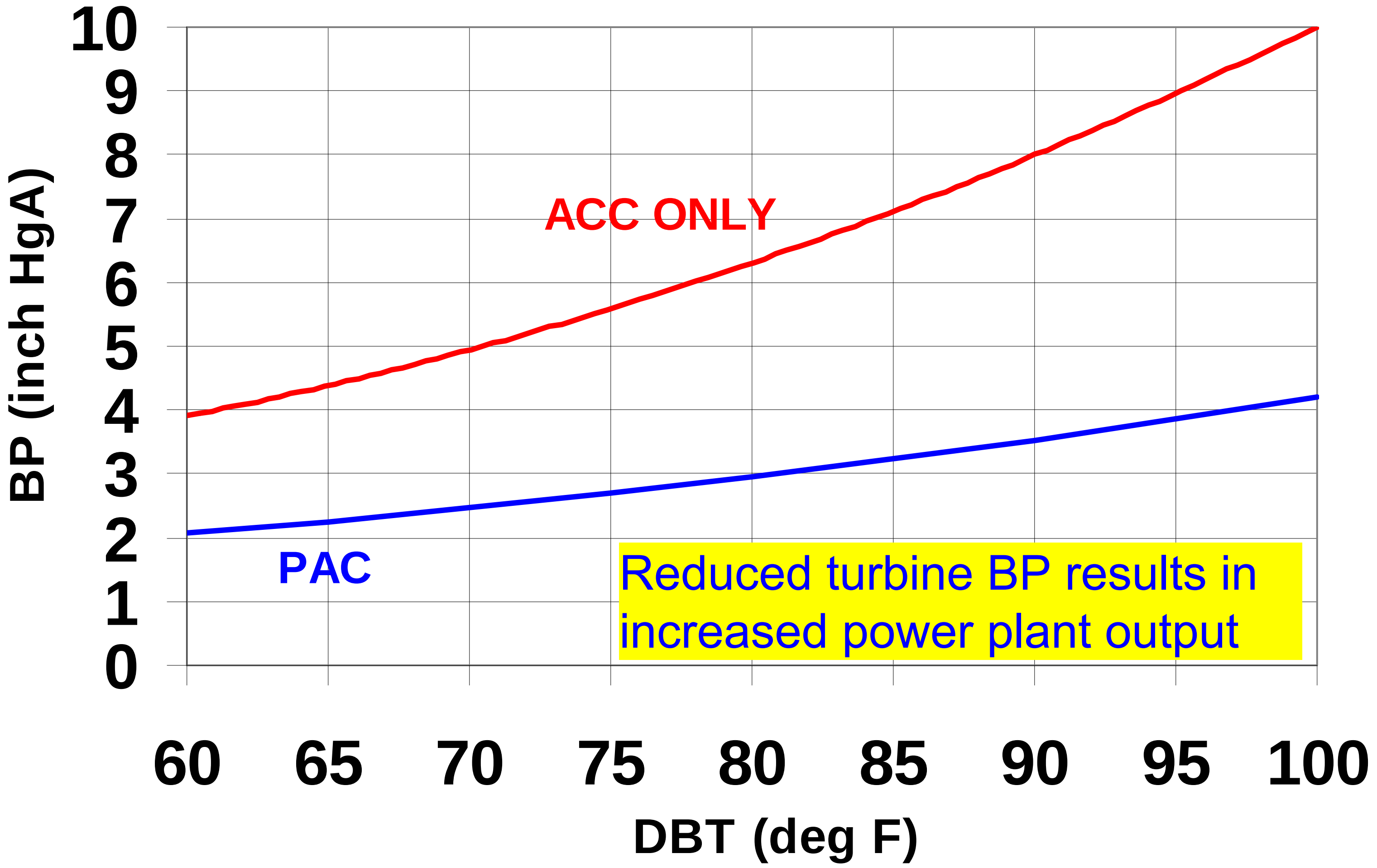
Climatic data input: m'_{evap} is function of WBT & RH
→ refer to next slide

Evaporation rate as function of WBT & RH



Performance of PAC systems

Example (Comanche): reduced BP in summer with PAC



Differences between PAC and PA tower

Item	PA Tower	PAC system
Heat rejection configuration	Series	Parallel
Purpose	Plume abatement	Water conservation
Heat rejection mode dry	Sensible heat	Latent heat
Fluid to dry section	Hot water from SSC	Steam from ST
Summer operation mode	Wet duty ≈ 100 %	Wet duty << 100 %
Water conservation capab.	Limited to ≈ 20 %	> 50 % possible
Tube quality dry section	Corrosion resistant	Ordinary CS is OK

Major advantages PAC systems compared to PA towers:

- If 100 % duty can be handled by the dry section in winter → NO PLUME !
- Water consumption can be matched to the amount of water available → water savings is not limited to 20 % like for plume abated cooling towers

Conclusions

1. If there is no water available for the power plant cooling system, than an ACC is the way to go (high investment + perf.↓ @ hot ambient).

2. If a very limited amount of water is available, air inlet spray cooling can be used to enhance the ACC performance at dry and hot conditions.

3. If there is some water available, but not enough for a wet cooling tower than a hybrid cooling system may be the most economical choice.

4. PAC systems are used more and more in the power industry, because it is a combination of established cooling technologies.

5. Although PA towers may save some water when the dry section is involved, the water savings are rather limited (max. 20 %).

Hybrid Cooling Systems and ACC's

QUESTIONS ?