# Operational Characteristics of Existing Dry Cooling Systems in Eskom

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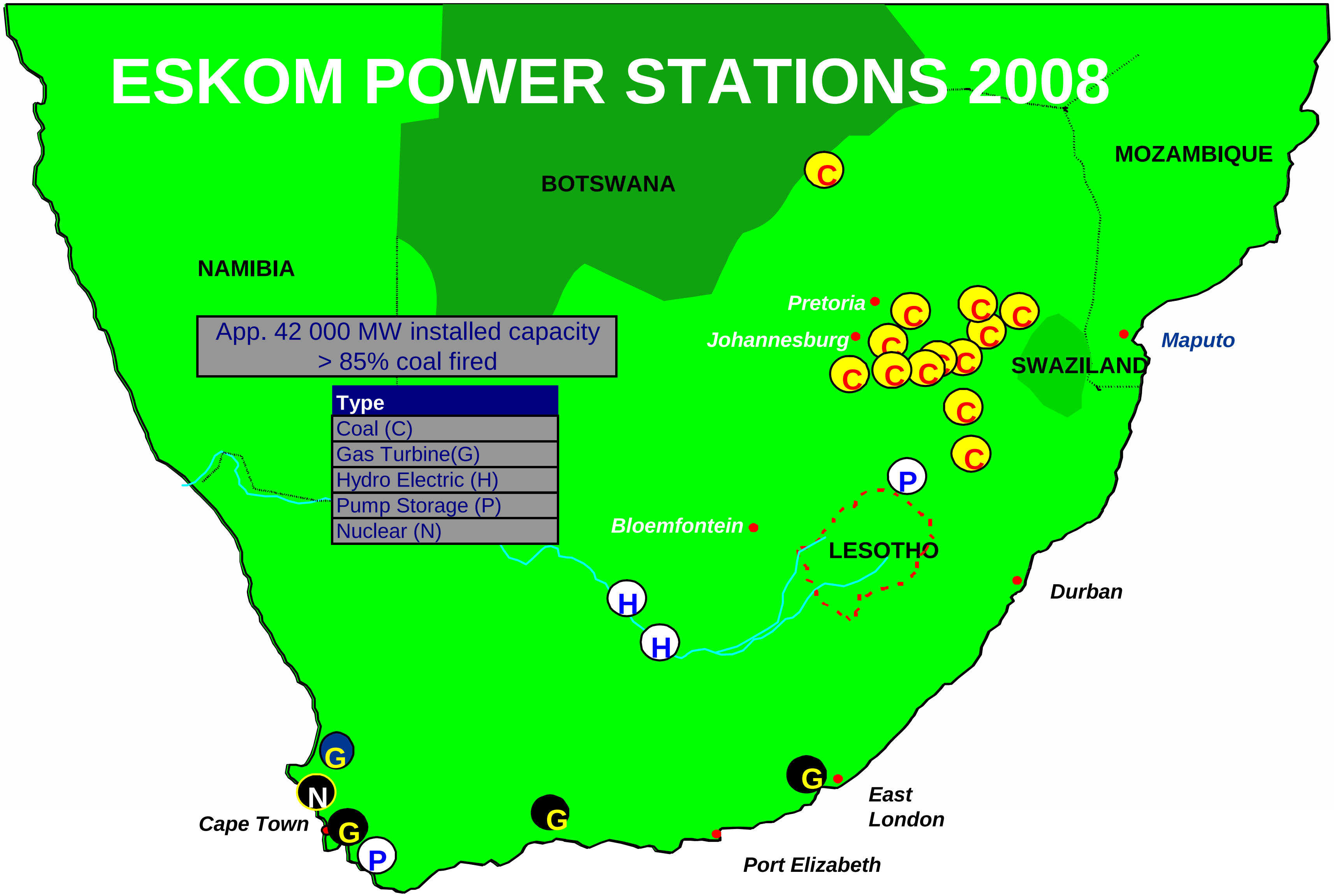
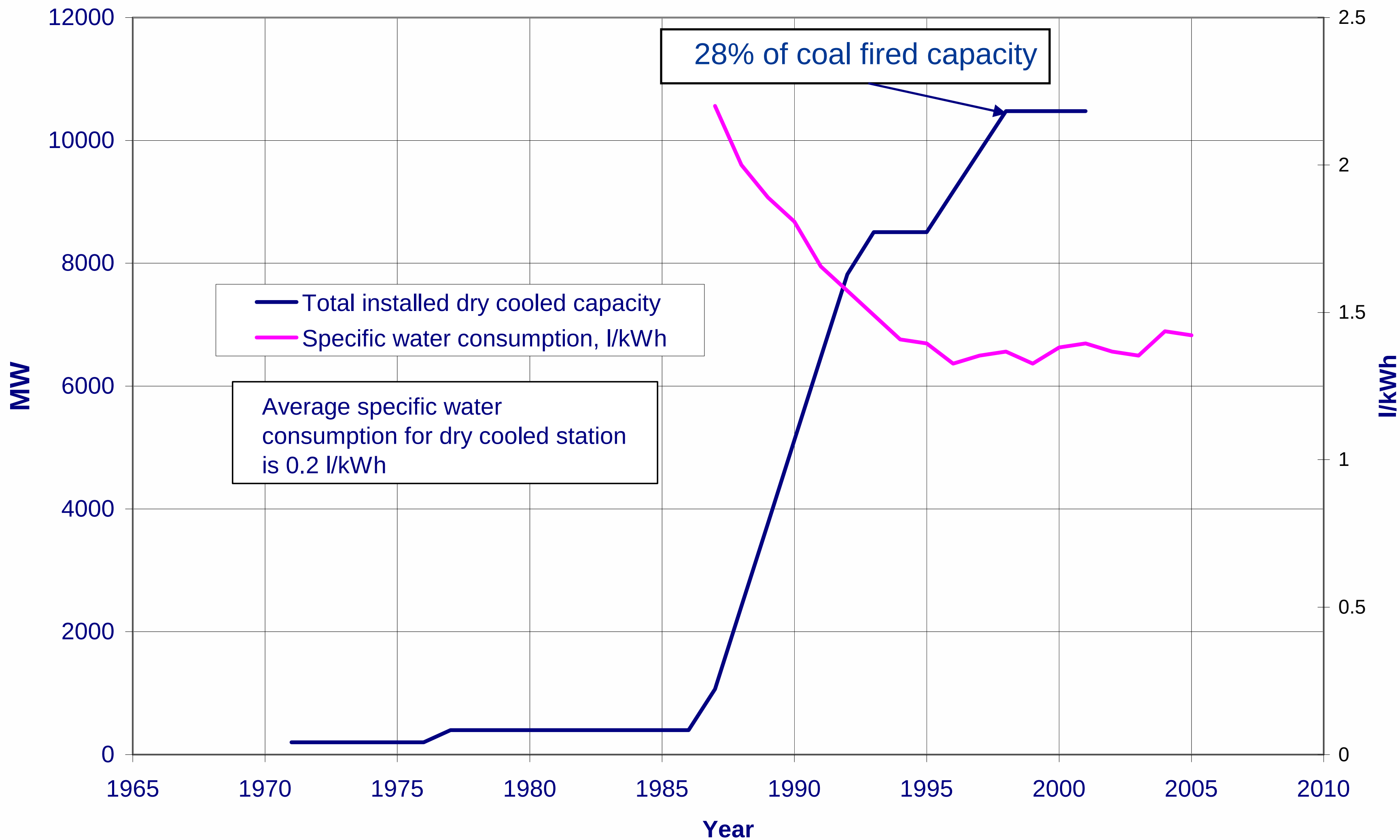
# Eskom Power Stations



# Eskom’s Dry Cooling History (Commissioning dates)

- Decision to extend Grootvlei in 1966 with dry cooling system
  - -Lack of adequate water resources close to coal fields
- 1971 Grootvlei 5, 200 MW, Indirect
- 1977 Grootvlei 6, 200 MW, Indirect
- 1987-1992, Matimba 1-6, 6 x 665 MW, Direct
- 1988-1993, Kendal 1-6, 6 x 686 MW, Indirect
- 1996-1998, Majuba 1-3, 3 x 657 MW, Direct

# Average specific water consumption

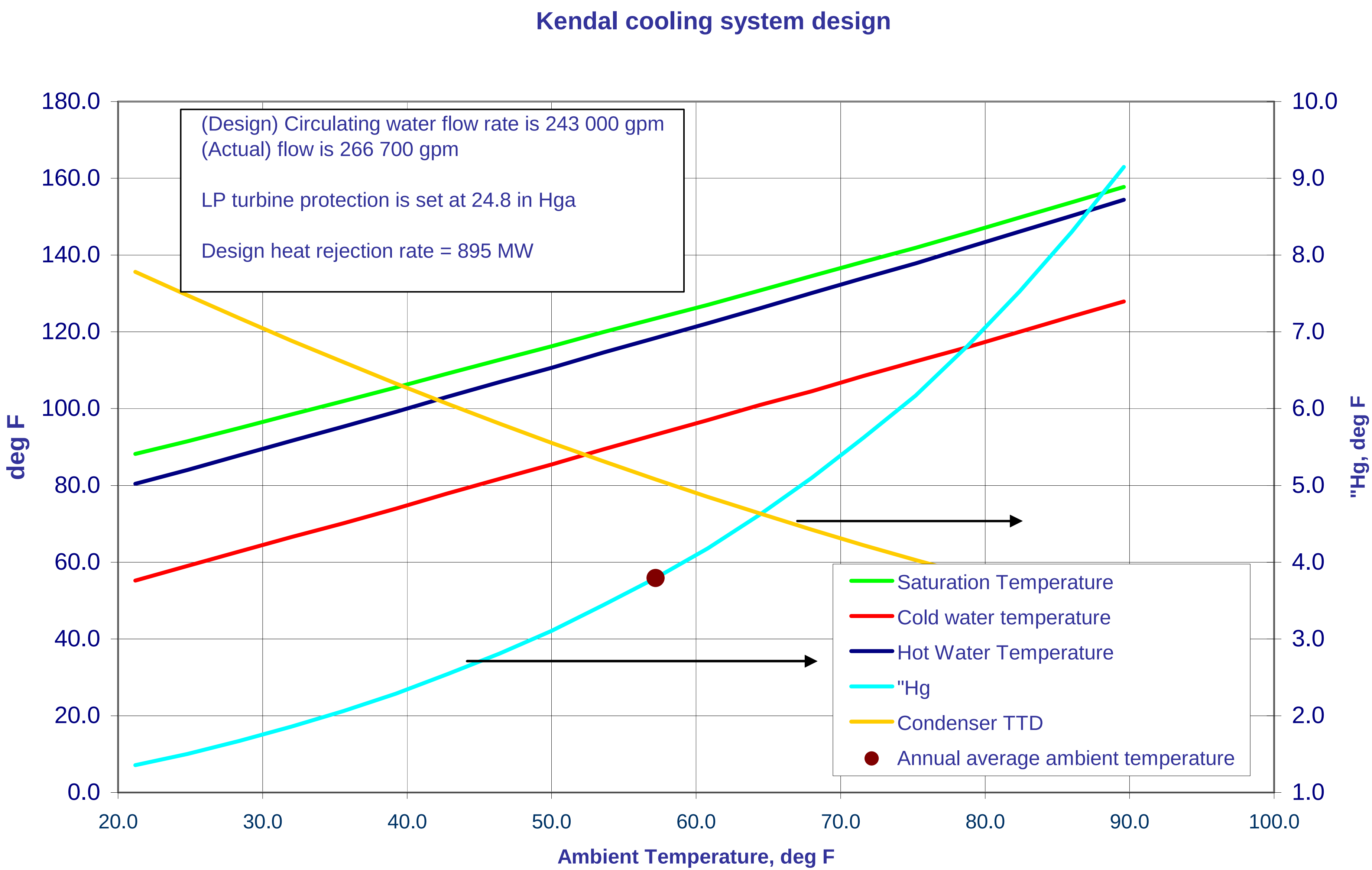


# Kendal Cooling system

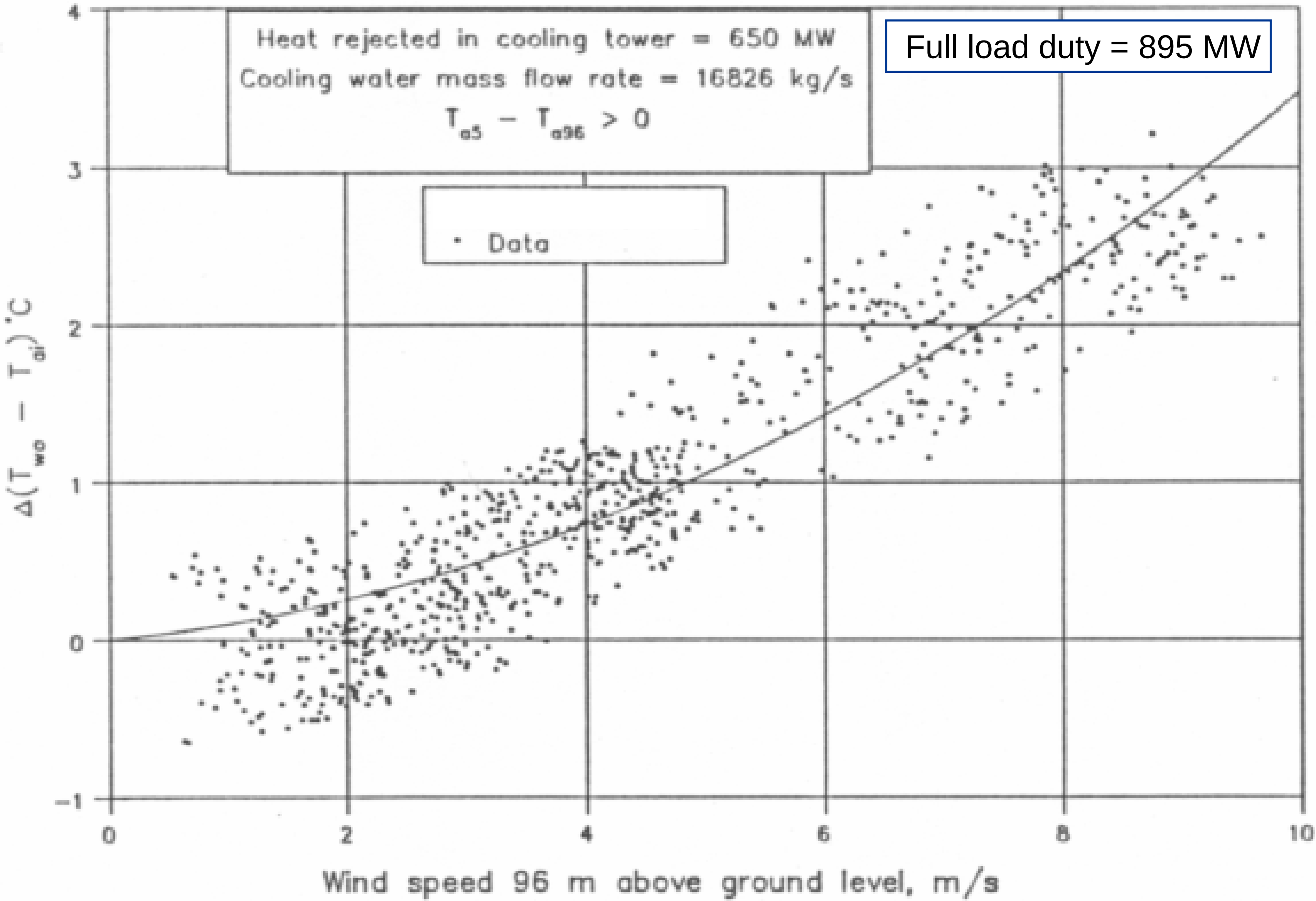
- 6 x 686 MW Electrical Output
- Surface condenser with SS tubes
- Circulating water flow: 266 700 gpm
- Galvanised heat exchanger tubes
  - 11 sectors which can be individually isolated
  - Total of 1 980 km (1 230 miles) of finned tube/tower
  - Horizontal, radial arrangement
- **Tower dimensions**
  - Diameter at tower base 144 m (462 ft)
  - Total height 165 m (541 ft)
- **Thermal design**
  - Known turbine characteristics, energy output was maximized over given ambient temperature range
- 3.4 MW auxiliary power consumption/unit
  - 3 x 50% pumps (units 1-3)

# View of cooling towers and circulating pumps

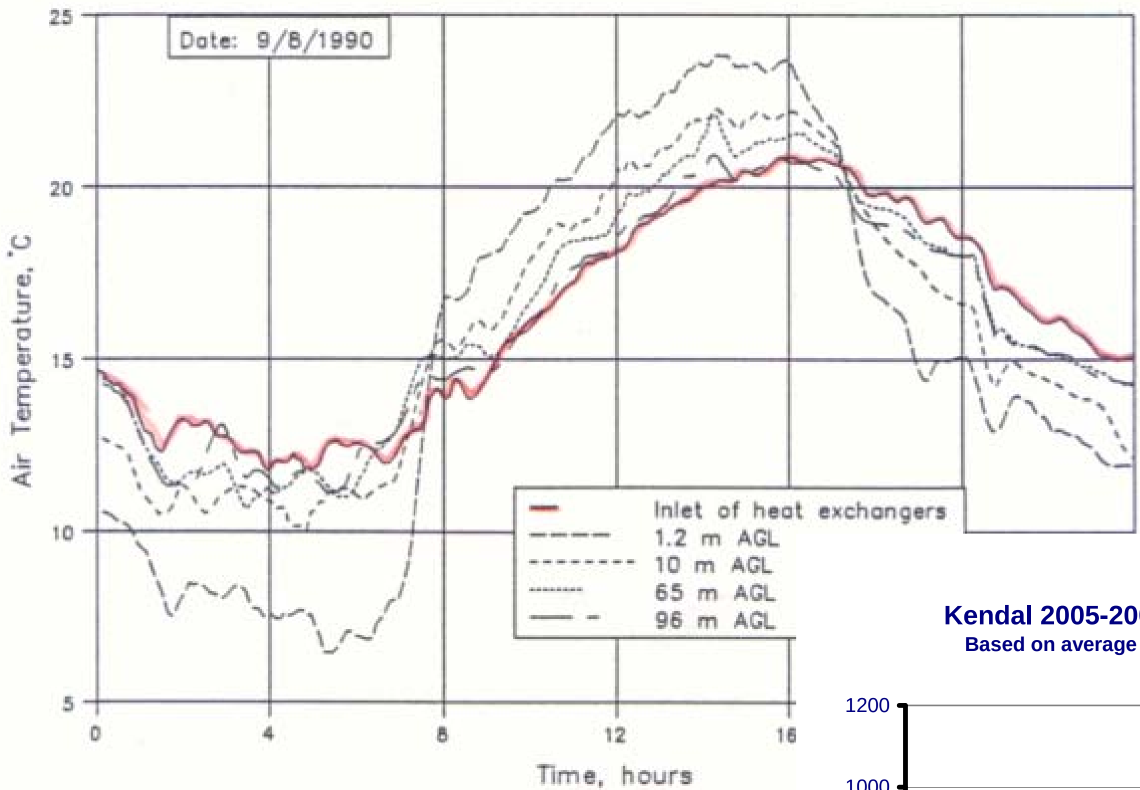
# Kendal cooling system thermal design



# Wind effect on cooling tower



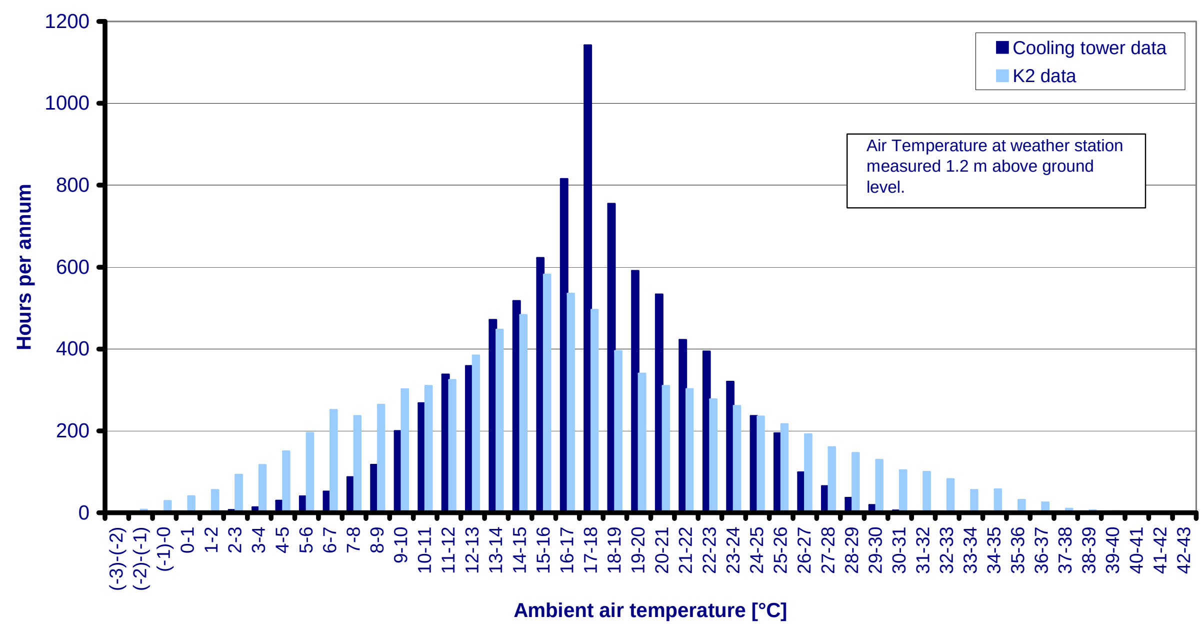
# Meteorological effects on tower performance cont.




- •Air inlet temperature different to ground level temperature
- •Average ground level temperature may differ from average air inlet temperature (4°C difference at Kendal)

**Kendal 2005-2006 data, Ambient air temperature distribution comparison**

**Based on average temperatures measured at Kendal Cooling towers and K2 weather station**

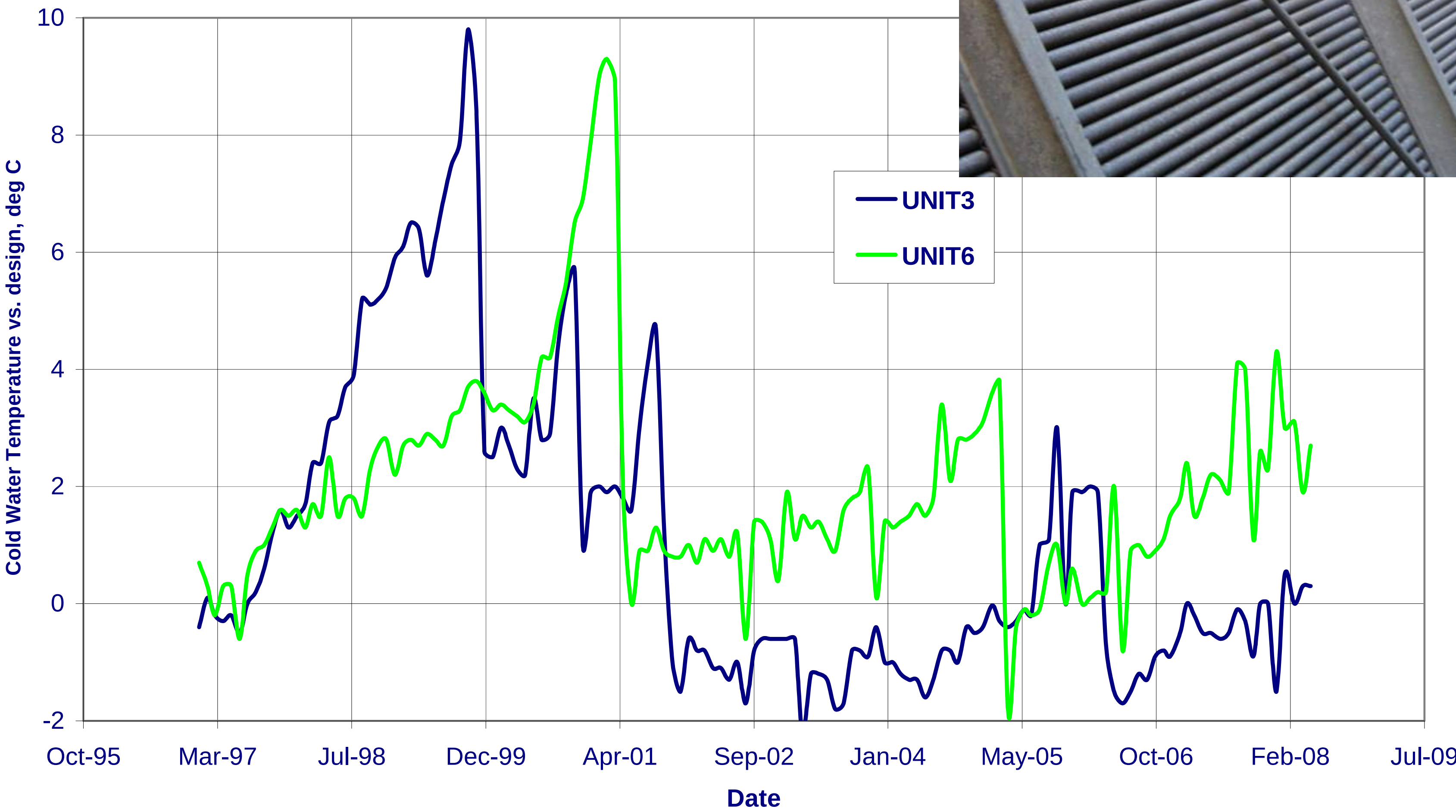


# Cooling tower performance

**Washing of heat exchangers**

**Natural fouling only**

Cooling tower performance



# Cooling system operational experience

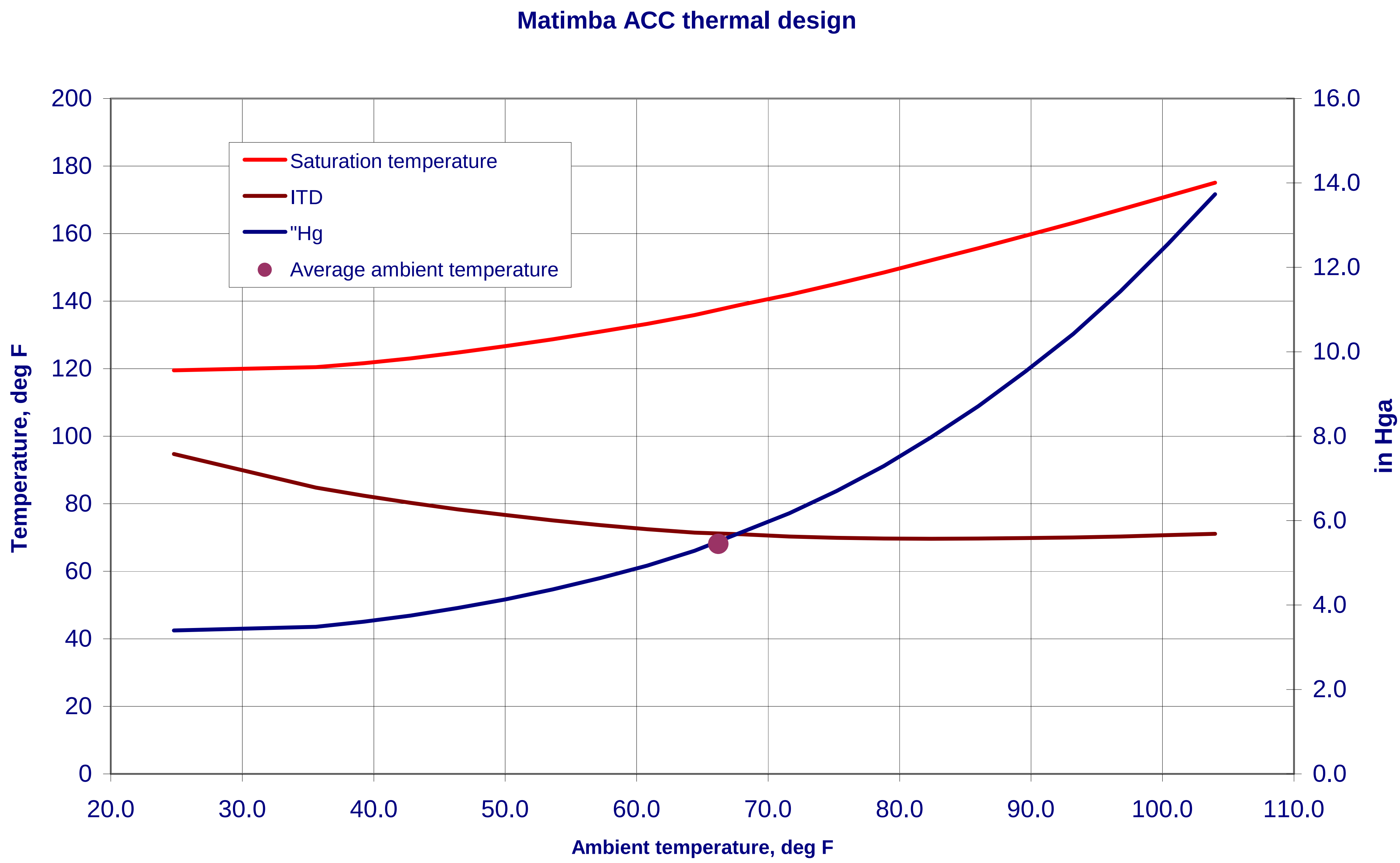
- Thermal performance is independent of wind direction
- Wind effect predictable and repeatable
- Very stable operation due to large circulating water volume
- No noise
- Tower meet design performance after 20 years of operation
- Minimal maintenance cost (circulating water pumps)
- No corrosion observed on heat exchangers
- Nitrogen blanket to prevent freezing & corrosion in drained sectors
- Limited surface area under vacuum

- Visible structure

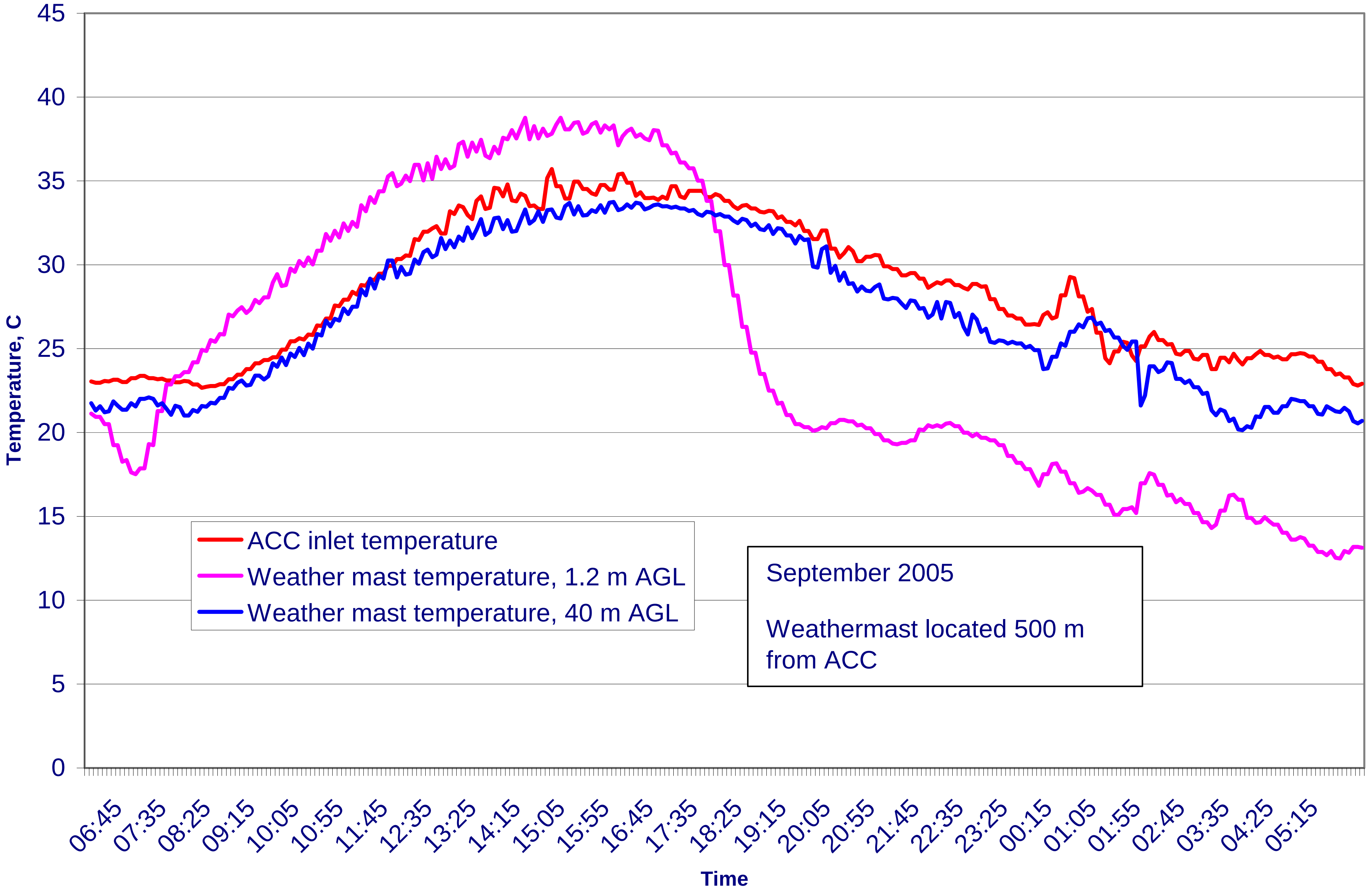
# Matimba design

- 6 x 665 MW Output
- Design: Known turbine characteristics, energy output was maximized over given ambient temperature range
- Ave. back pressure 18.6 kPa (5.5 in Hga)
- LP turbine protection: 65 kPa (19.2 in Hga)
- Average steam velocity 80 m/s at 18.6kPa
- Station orientated with prevailing wind direction towards boiler
- 2 x 5 m (16.4 ft) exhaust ducts
- **ACC details per unit**
  - 48 fans, 30 ft diameter
  - 8 streets with 6 fans per street
  - Street length 70.8 m (232 ft)
  - 45 m (147.6 ft) air inlet opening
  - 12 MW auxiliary power consumption
- Total platform footprint 35 700 m$^2$ (8.8 acre)

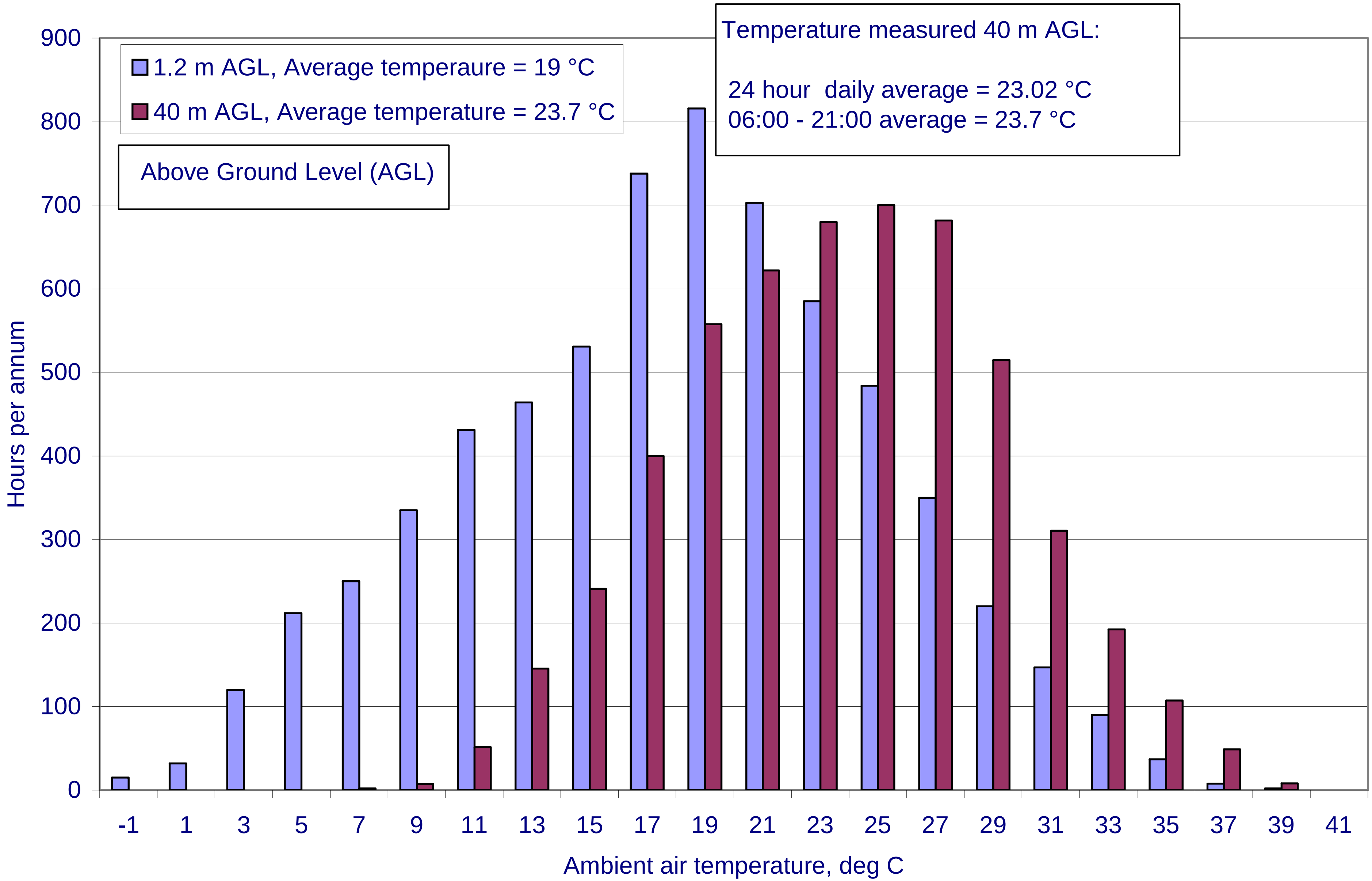
# Matimba thermal design



# Matimba air inlet temperature to ACC



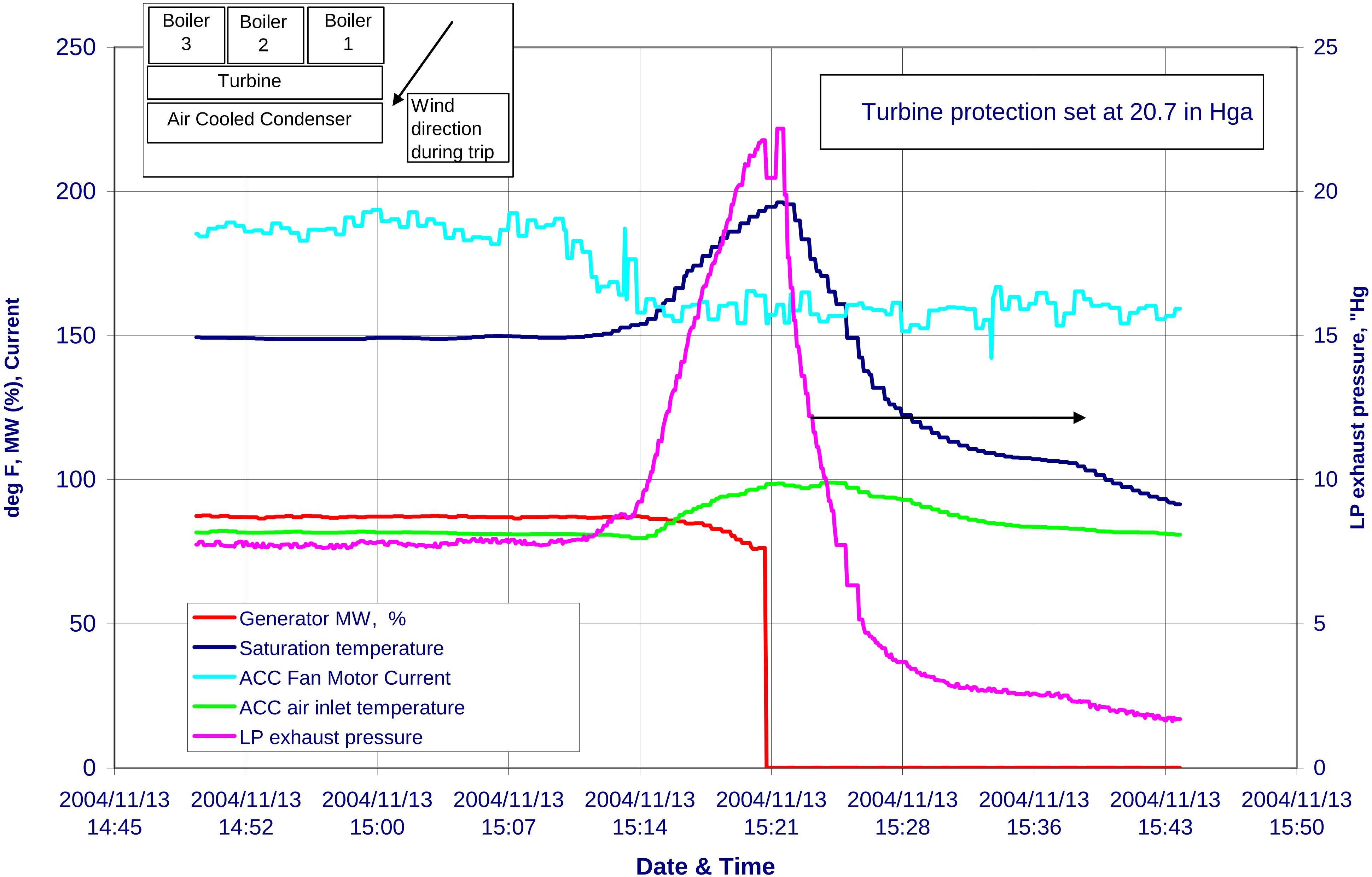
# Annual temperature profile



# Air inlet temperature to ACC

- ACC draw air from higher elevations
- Ground temperature data, say 1.2 m AGL, is not representative and as an average is about 4°C conservative (Matimba site).
  - Similar for indirect system
- The instantaneous difference between ground level, 1.2 m AGL, air temperature and ACC inlet temperature can be as high as 5-8 °C at Matimba
- The seasonal air temperature variation experienced by the ACC is less than that measured at ground level.
  - ACC experience smaller temperature variation than the extreme maximum and minimum measured on the mast at ground level.
- The variation in air temperature as a function of height above ground level to be considered for new designs depending on the daily and seasonal power demand profile

# Majuba unit 1 trip during unsteady wind period



# Summary of wind effect at Matimba

- Energy loss relatively small
- Capacity loss during incidents is a concern
  - High risk periods are normally of short duration during unsteady windy period preceding a thunder storm
  - 12 units trips occurred at Matimba during first 7 years of operation
  - Unreliable power production
  - Output dependent on wind direction, wind speed and ambient temperature
- “Exposed” units, 1 and 6, are generally more susceptible to wind effects
  - Deterioration in fan performance is the predominant factor, more than hot air plume recirculation.
- Large operating margin to be maintained between condenser pressure and turbine protection setting.

# Matimba modifications to minimise wind effect

- Modifications are limited due to position of ACC
- Modifications simulated with Computational Fluid Dynamic models
- Cladding removed between ACC and turbine house
  - Improve air flow to ACC when wind is from boiler
  - Negligible effect in performance with wind towards boiler
- Cladding removed from turbine building above turbine floor and turbine house roof vents modified
- Weather mast erected with visual indication in the unit control room
- Daily weather forecast received from the Weather Service
- Automatic vacuum de-loader as well as vacuum rate of change run-back added to unit control system

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# Reliability of ACC

- During commissioning a large percentage of fan blades cracked, most of which were repaired.
- Up to 40% of dephlegmator surface area was ineffective due to condensate build-up. Rectified by modification.
- Fan gearbox oil temperatures very high, typically above 90 °C
  - Annual oil changes required.
- Natural and artificial fouling on air side removed by semi-automatic high pressure water cleaning system
- Significant corrosion in exhaust duct and tube inlet area

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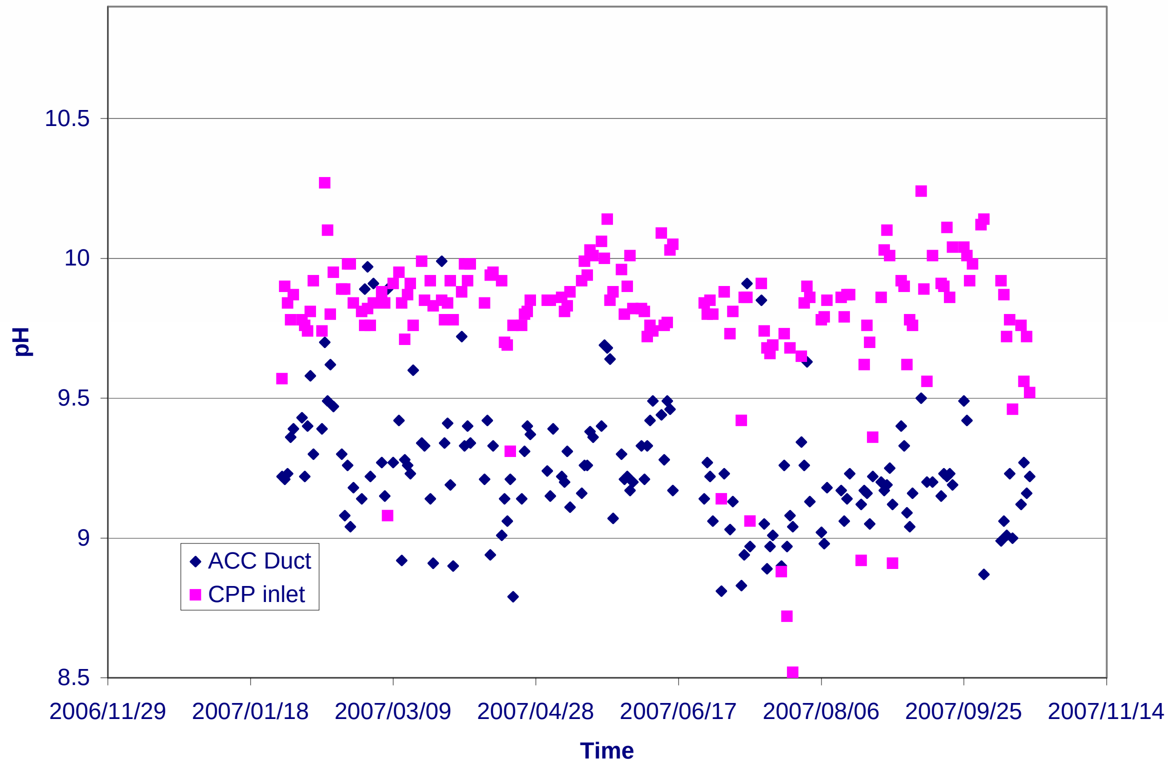
# Corroded tube entry with trough wall perforation

# Corrosion cont.

- Steam pH increased to 9.6 - 9.8 with great success in minimising steam side erosion
- Condensate extracted from ACC duct indicated that the liquid has a lower pH compared to the bulk condensate or steam
- This mechanism is subject to a separate EPRI investigation



# Conclusion

- Both direct and indirect dry cooling systems can be applied successfully in coal fired stations
- Specific water consumption if dry cooled station of both types is approximately 0.2 l/kWh
- Significant progress was made towards understanding environmental effects on the performance of dry cooling systems
- Average annual ambient temperature was underestimated in original specification
- Lessons learnt on existing installations should be incorporated in the specifications for new solutions

# Acknowledgement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