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OPTIMIZING CHILLER PLANT EFFICIENCY

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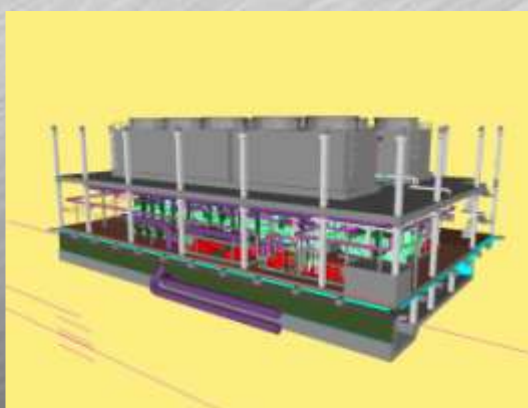
18th March 2007



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OPTIMIZING CHILLER PLANT EFFICIENCY

AGENDA

- Chiller Plant Efficiency
- Thermal Energy Storage

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AGENDA – CHILLER PLANT EFFICIENCY

- Design considerations
- Chiller configurations
- Entering Condenser Water Temperature
- Chiller versus plant energy
- Wet Bulb
- Effects of reducing ECWT
- Variable Frequency Drives
- Low Delta-T

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DESIGN CONSIDERATIONS

- Balance first cost versus operating efficiency
- Part load efficiency is important – select chillers based on NPLV
- Chiller configuration (series versus parallel) needs to be considered
- Don’t only consider chiller full load efficiency
- Consider annual load profile and ambient conditions
- Drive ECWT down for optimum plant efficiency

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CHILLER CONFIGURATIONS

- Series Counter flow is about 8% to 10% more energy efficient than parallel
- Example using 2 gpm/TR: Parallel chillers see 2 gpm/TR – Counter flow chiller see 4 gpm/TR
- Higher chiller tube velocity
- Higher Reynolds number
- Higher overall U value
- Higher Log Mean Temperature Difference (LMTD)

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ENTERING CONDENSER WATER TEMPERATURE (ECWT)

• Standard practice is around 40°C/35°C

• Lower ECWT to increase chiller efficiency

• Plastic is cheaper than copper!!!!

• Drive ECWT down during operation for optimum chiller efficiency

• Fan kW is lower than chiller kW!!!!

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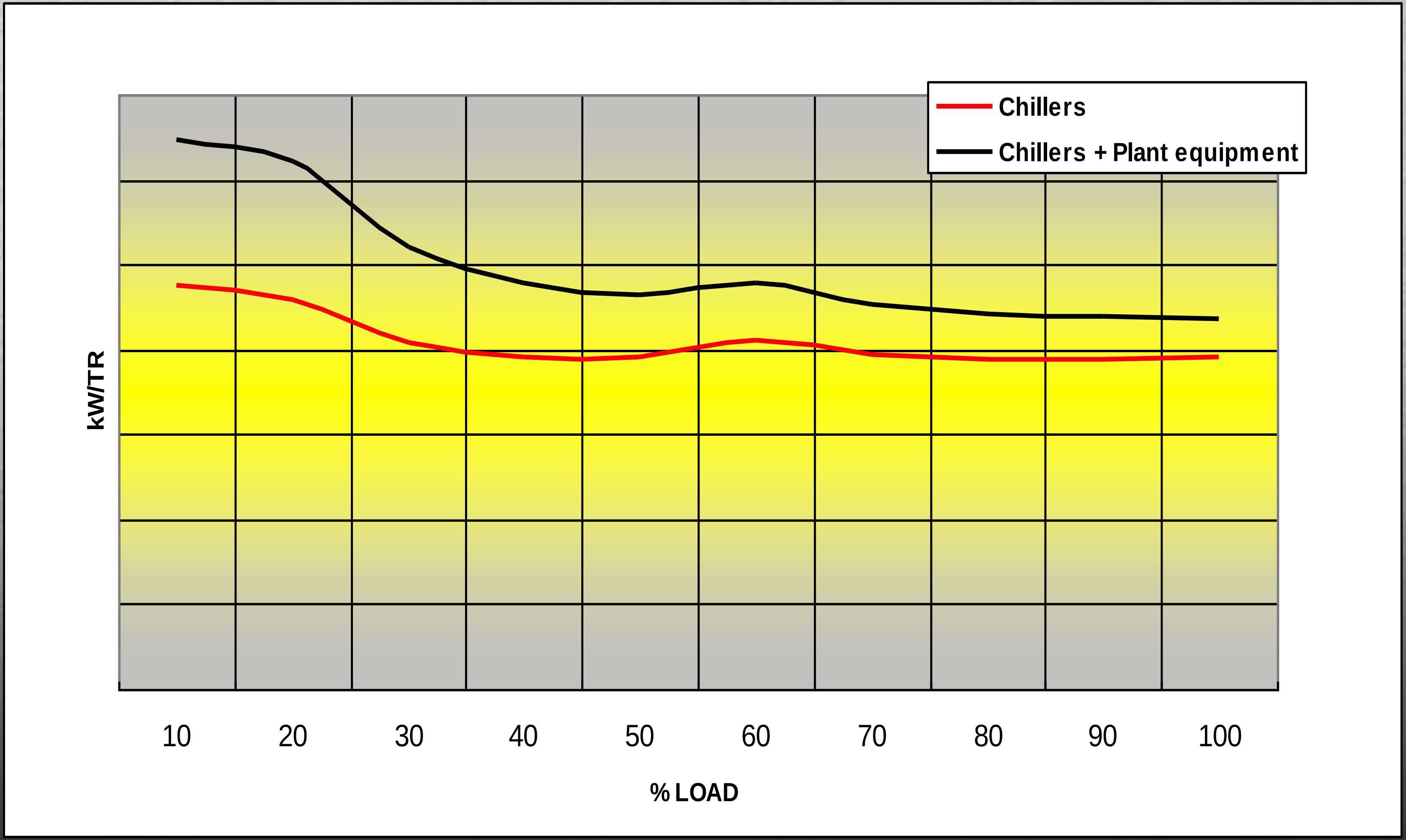
CHILLER ENERGY VERSUS PLANT ENERGY



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CHILLER ENERGY VERSUS PLANT ENERGY

- Chiller energy is the majority of the plant energy consumption
- Need to focus on minimizing chiller energy
- Drive ECWT down, down, down!!

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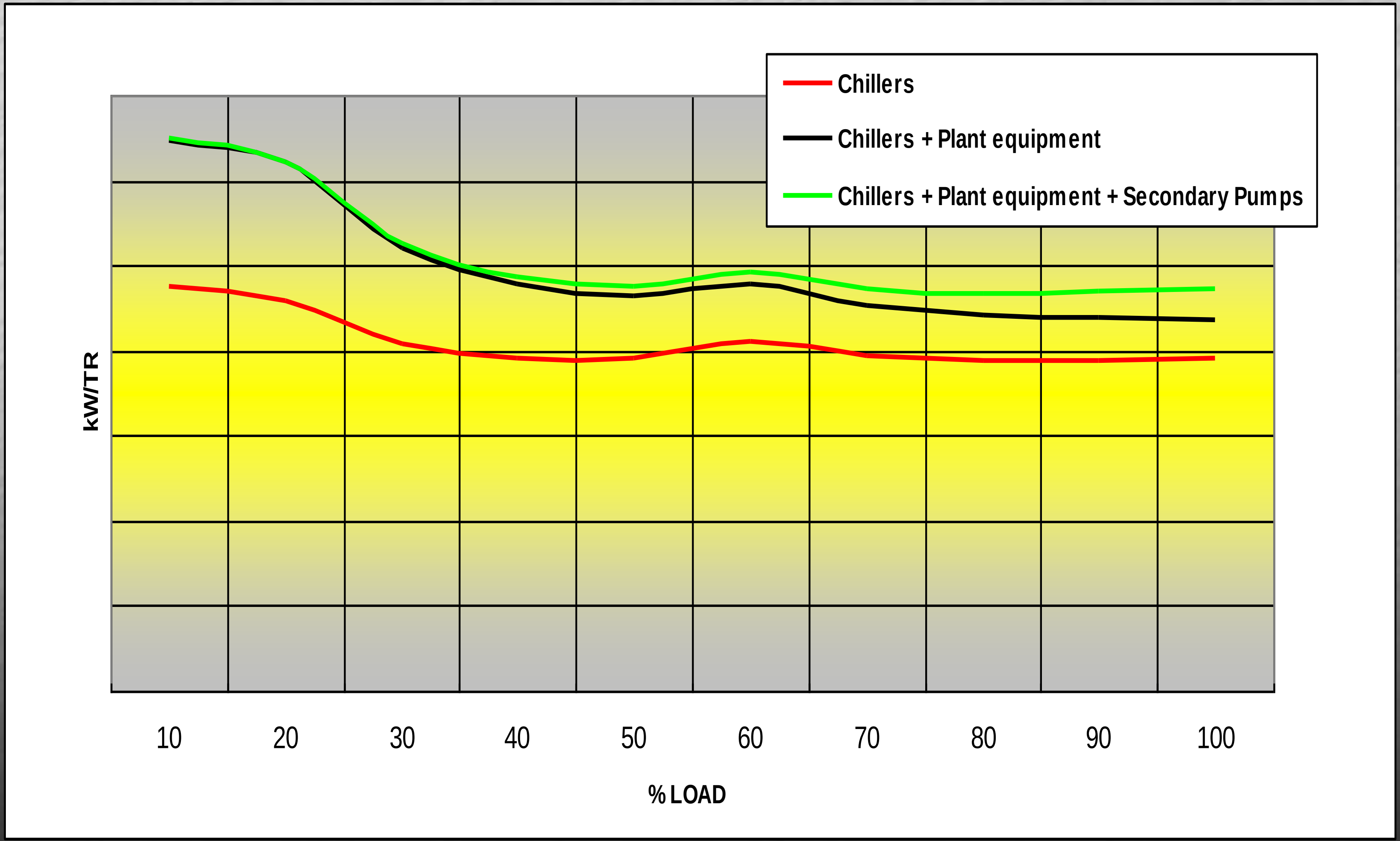
CHILLER ENERGY VERSUS PLANT ENERGY



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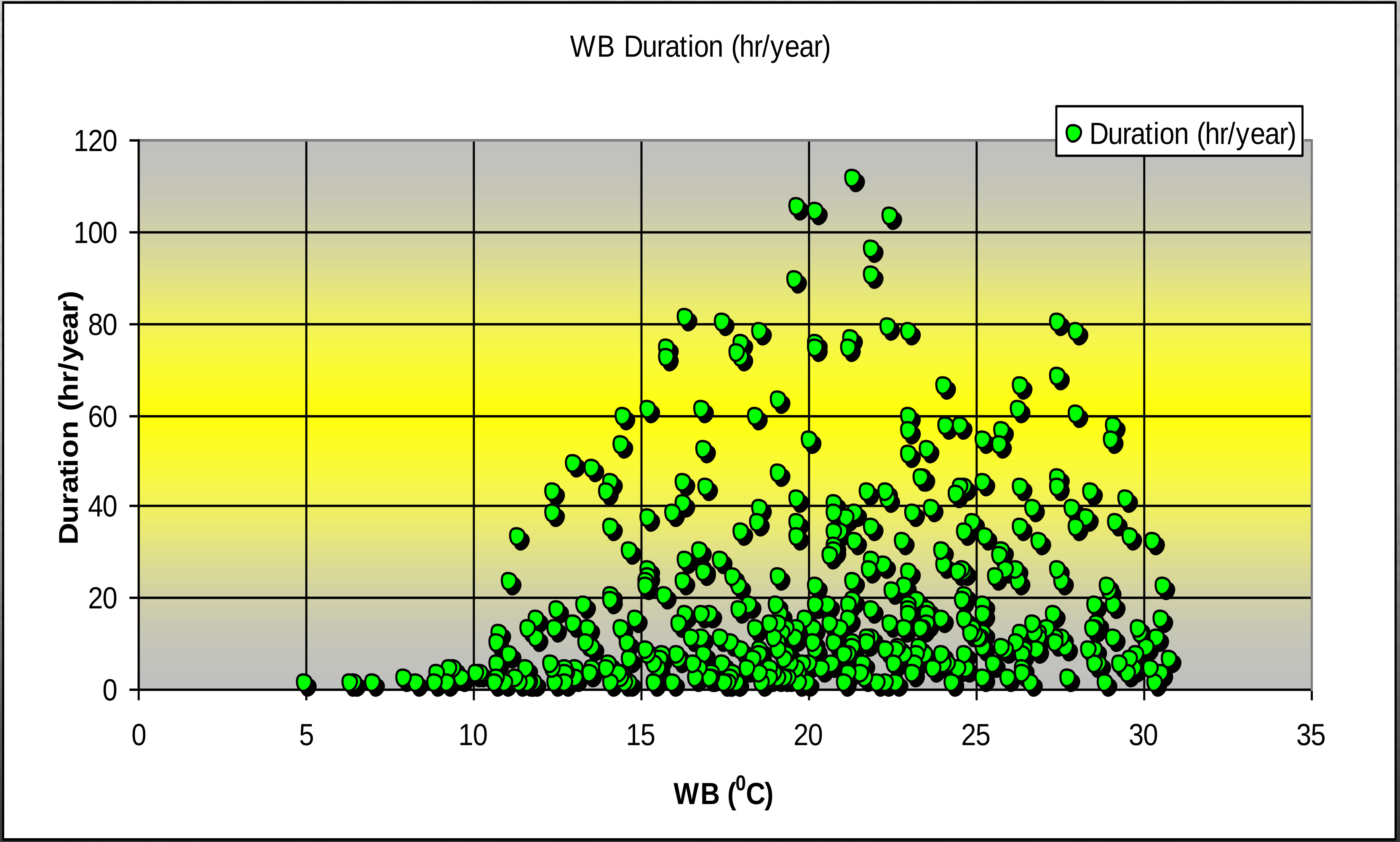
WET BULB BIN DATA FOR DUBAI



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WET BULB BIN DATA FOR DUBAI

- Maximum recorded Wet Bulb last year for Dubai was 31°C
- But for only 0.4% of the hours!!!!!
- Peak BIN hours were at about 22°C WB
- Most BIN hours were between 13°C & 28°C WB
- This allows us to drive the ECWT down
- Maximize chiller plant efficiency
- Lowest recorded WB 5°C = 8°C ECWT

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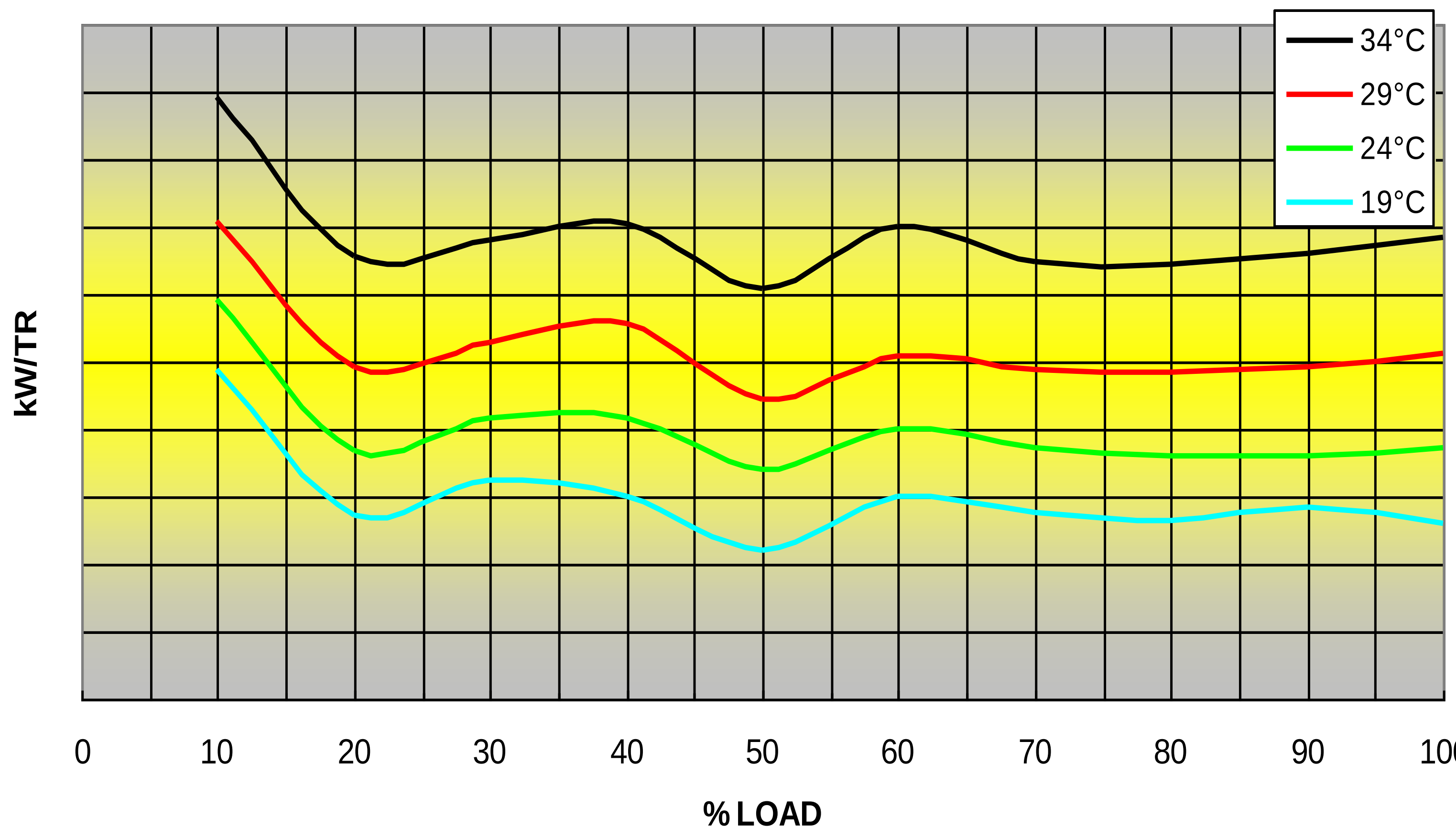
EFFECT OF REDUCING ECWT ON CHILLER EFFICIENCY



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VARIABLE FREQUENCY DRIVES (VFD)

- Don’t necessarily add VFDs to all motors
- VFDs consume 3% to 5% more energy at full speed – immediate penalty in kW and cost
- CHW and Cond pumps should not always have VFD – small portion of overall plant load
- Secondary pumps are good candidates for VFD to control for continuously variable load
- Cooling Towers should not necessarily have VFD –consider bypass for few hours at low WB

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LOW DELTA-T

- Low Delta-T is bad news!!!
- Energy Transfer Stations (ETS) should be well designed and controlled to maintain delta-T
- Low delta-T = higher flow rate
- Pressure drop increases by $(\text{flow})^2$
- Energy increases by $(\text{flow})^3$
- 10% drop in delta-T = 10% increase in flow = 33% increase in pumping energy!!!!!

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LOW DELTA-T

- Consider higher overall system delta-T?
- Design building AHUs for higher delta-T
- Lower system flows
- Smaller distribution pipe sizes
- Lower pumping energy
- Savings in operating energy

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AGENDA – THERMAL ENERGY STORAGE (TES)

- Introduction to Thermal Energy Storage (TES)
- Applications conducive to TES
- Comparisons of TES Technologies
- Inherent characteristics of TES
- TES Tank Configurations
- Chilled Water Tank TES Operation
- Conclusions

INTRODUCTION TO THERMAL ENERGY STORAGE (TES)

- Most systems have storage, e.g.
  - Computer battery
  - Car fuel tank
  - Municipality's potable water tanks
  - Domestic hot water heater
- Thermal Energy Storage (TES)
  - Provides thermal capacitance (a battery)
  - Cooling can be produced during low-load times
  - Cooling is stored, then used for high loads

OPTIMIZING CHILLER PLANT EFFICIENCY

APPLICATIONS CONDUCIVE TO TES

- Where cooling loads vary with time of day
- Where use of TES reduces required chiller capacity
- Retrofit capacity expansions
- Where utility rates promote load management
  - Time-of-Day energy differences ($/kWh)
  - Especially if “on-peak” periods are short (<10 hrs/day)

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APPLICATIONS CONDUCIVE TO TES

- Where TES has a secondary use:
  - Back-up cooling
  - Fire protection
  - Chilled Water make-up, etc

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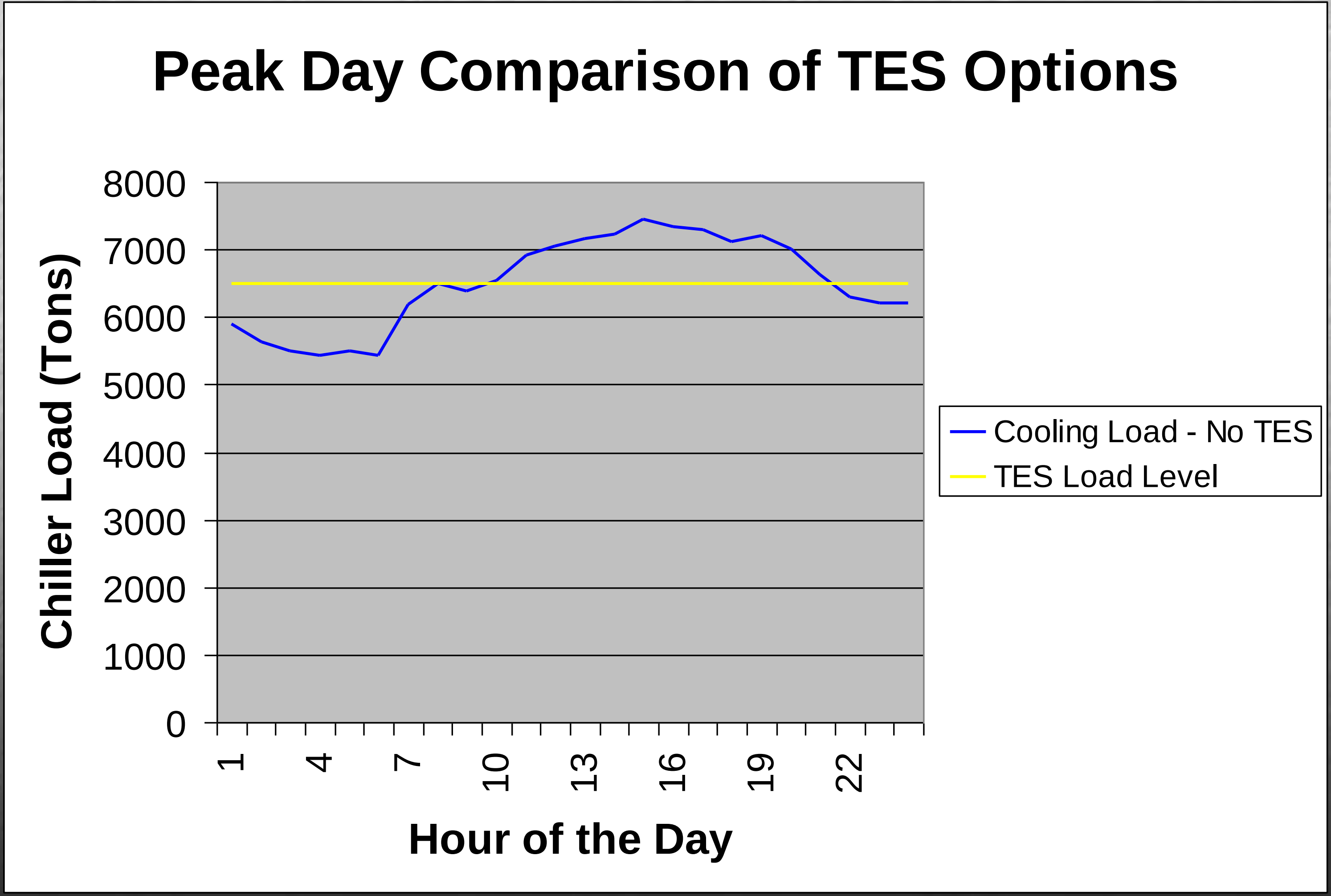
APPLICATIONS CONDUCIVE TO TES



COMPARISON OF TES TECHNOLOGIES

- TES Technologies include:
  - Latent Heat TES – stored as phase change e.g. ice
  - Sensible Heat TES – stratified fluid e.g chilled water or low temperature fluid
- Each TES technology has inherent advantages and limitations
- Important to understand attributes when applying TES

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INHERENT CHARACTERISTICS OF TES

	Ice	CHW	LTF
Energy Efficiency	fair	excellent	good
Simplicity and Reliability	fair	excellent	good
Site Remotely from Chillers	poor	excellent	excellent
Ease of Retrofit	fair	excellent	good
Dual-use as Fire Protection	poor	excellent	poor
Rapid Discharge Capability	fair	good	good
Volume	good	poor	fair
Footprint	good	fair	good
Low Temp Capability	good	poor	excellent

OPTIMIZING CHILLER PLANT EFFICIENCY

INHERENT CHARACTERISTICS OF TES

- Chilled Water TES Tank is normally optimum for District Cooling Systems
  - Does not require low temperature fluid
  - Can be sited remote from chillers
  - Energy efficient
  - Simple and reliable
  - Dual use as fire protection if required
  - No moving parts

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TES TANK CONFIGURATIONS

- Tanks can be buried, but about twice the cost
- Chilled Water TES Tanks
  - –height-to-diameter ratios typically between 2.5-to-1 to 1-to-6)
  - –Too tall & thin, or too short & wide, increases cost
  - –Minimum depth of 10-12m preferred; 6-8m is practical

TES TANK CONFIGURATIONS

- Maximizing height has benefits:
  - Reduces “footprint” or plot plan area
  - Reduces Delta P between vented tank & hi-pressure system
  - Ideal to have fluid level as system high point
  - But, it may add to foundation cost, if soil is inadequate

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CHILLED WATER TES TANK OPERATION

- Stratified TES is sensible heat - energy is stored as a temperature change
- Colder water is stored below warmer water as cold water is more dense
- Separation is based on stratification
- Stratification is a natural phenomenon that occurs in bodies of water such as lakes and oceans

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CHILLED WATER TES TANK OPERATION

- Stratified water has a very narrow transition - (thermocline) between cold and warm water
- Thermocline moves up and down during charge and discharge of TES
- Thermocline keeps cold and warm water separated and prevents mixing
- The tank remains full of water (or fluid)

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OPTIMIZING CHILLER PLANT EFFICIENCY

CHILLED WATER TES TANK OPERATION

- Diffusers are installed in top and bottom of tank.
- Each diffuser used to charge and discharge
- Diffusers protect the water from mixing to avoid disturbing the stratification in the tank.

Top Diffuser

Bottom Diffuser

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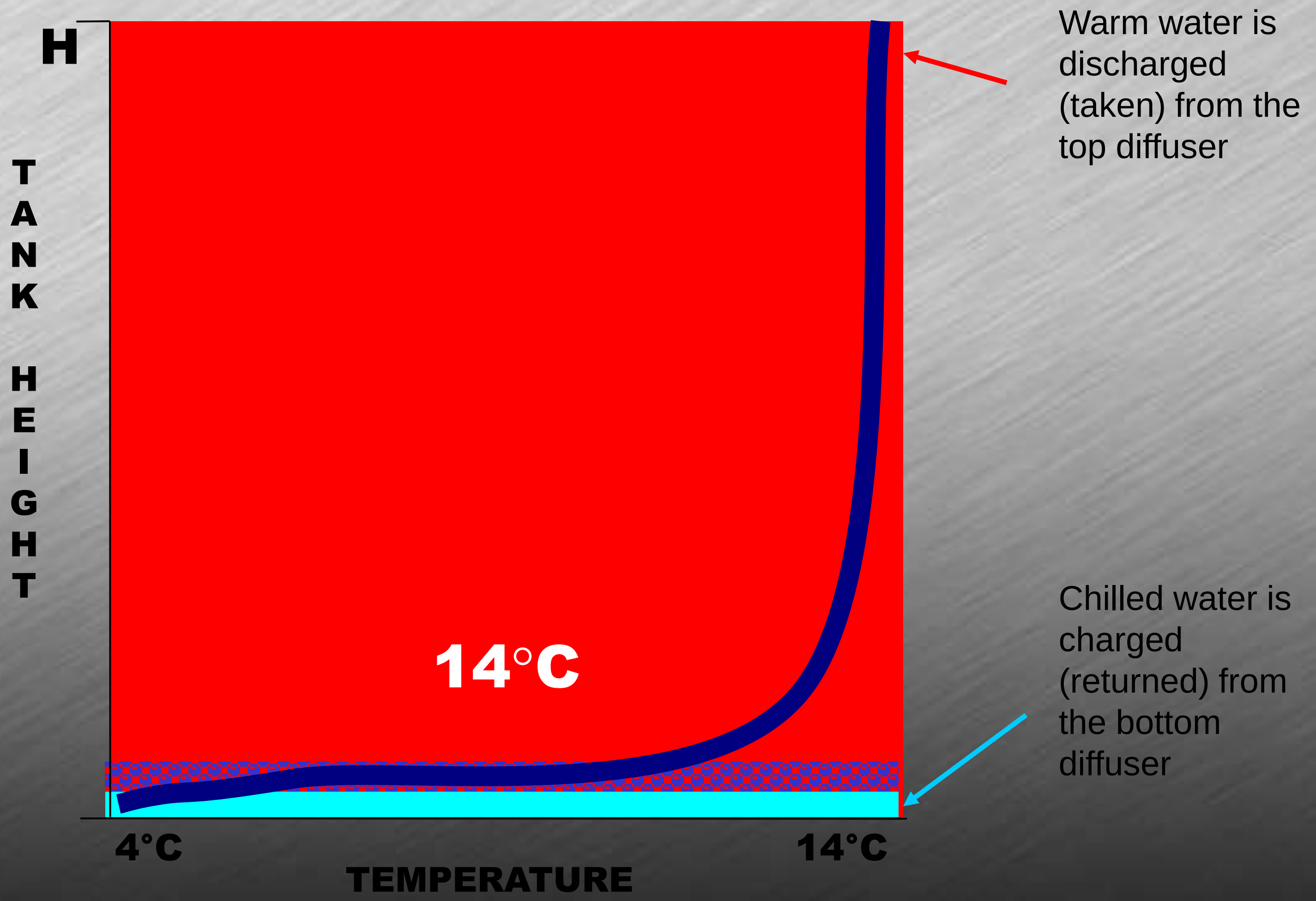
CHILLED WATER TES TANK OPERATION



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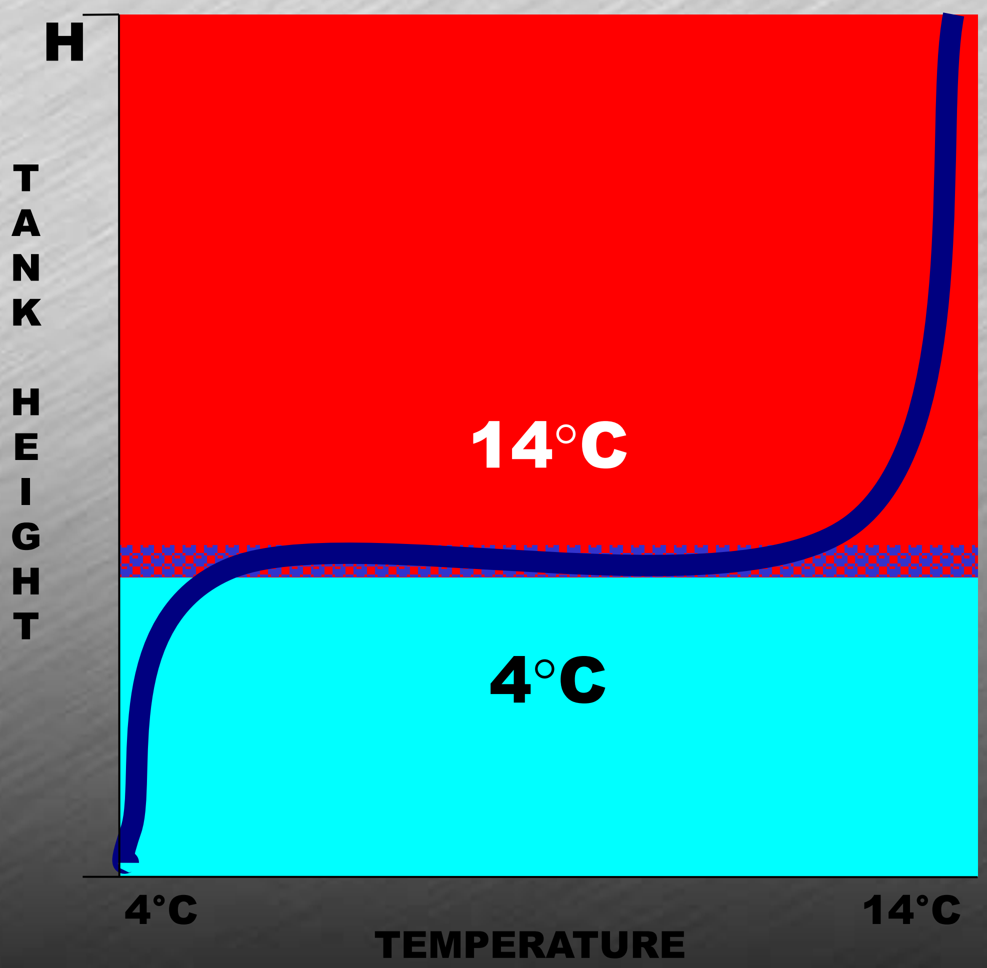

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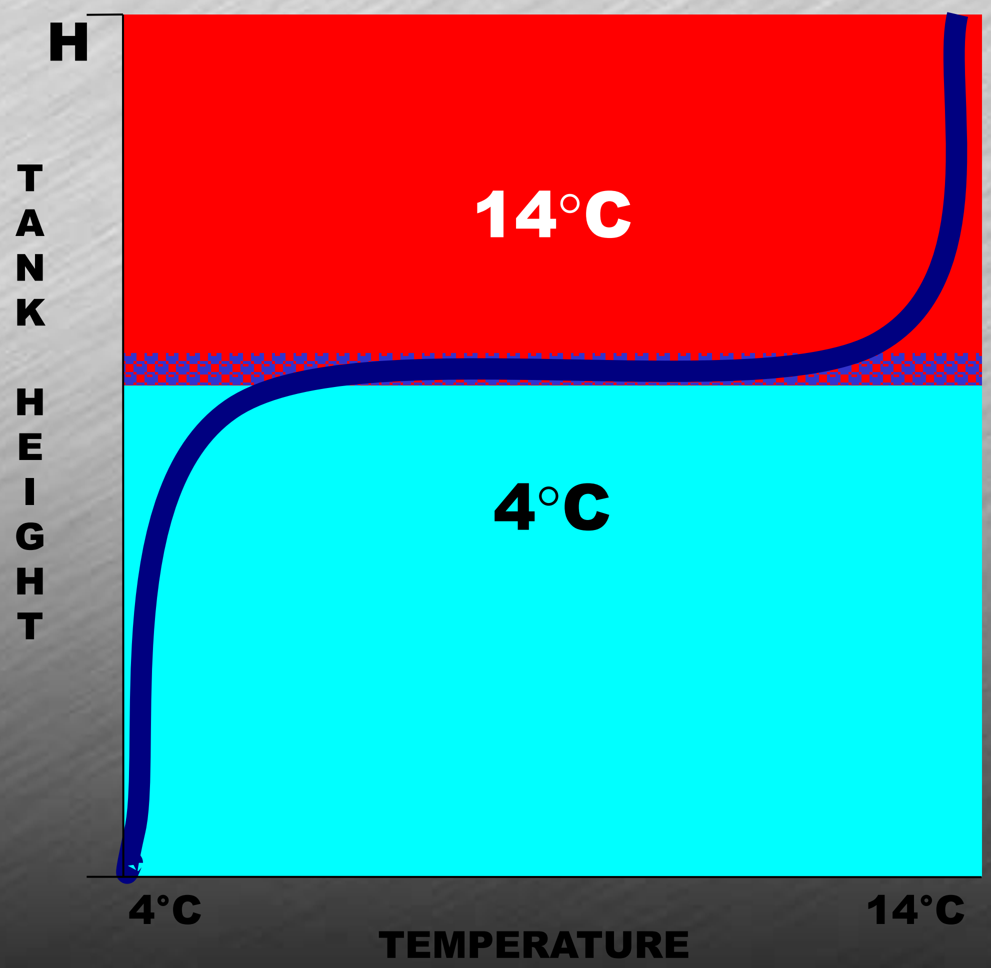

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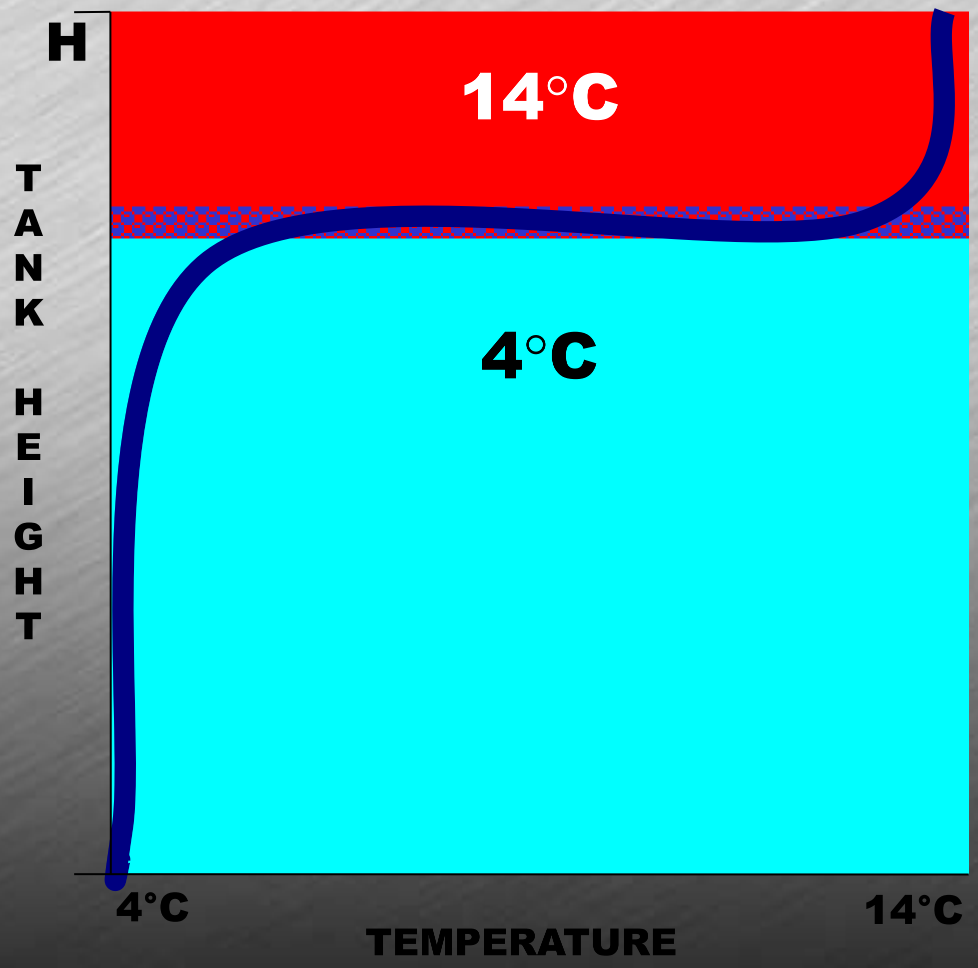

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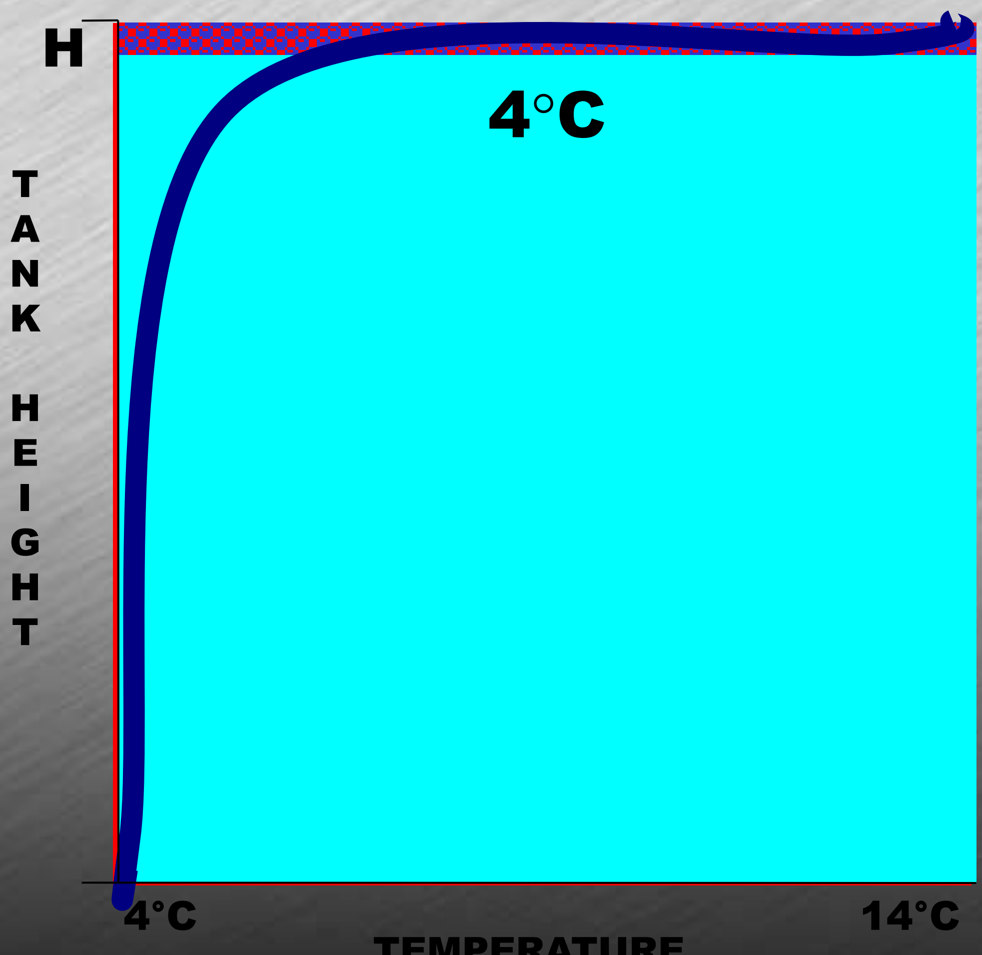

CONCLUSIONS FOR TES

- Reduces required chiller plant capacity
- Can reduce operating cost
- Provides emergency back-up
- But TES tanks are large
- Not economical if chiller plant capacity is not reduced
- Need load profile to fully asses benefits of TES

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QUESTIONS?

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