Thermal Energy Storage for Turbine Inlet Cooling

Gregory Henderson

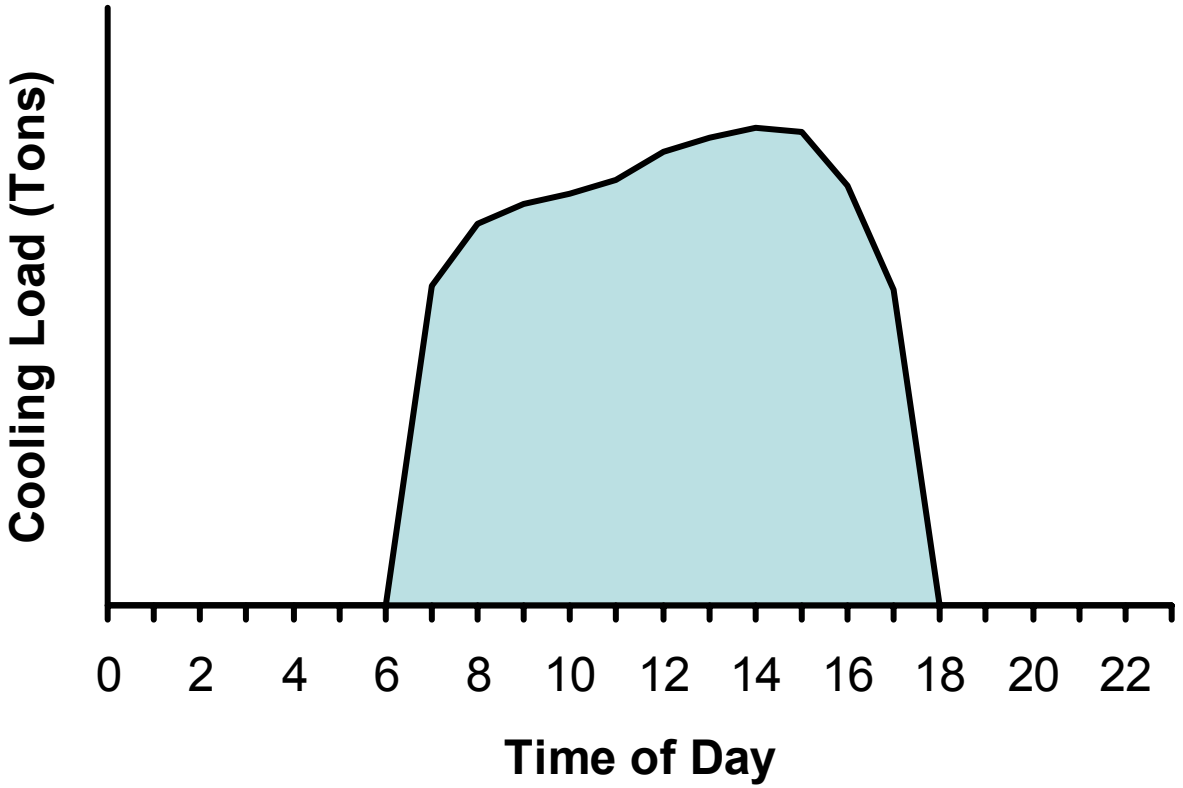
Manager, Industrial Sales – Americas

Baltimore Aircoil Company

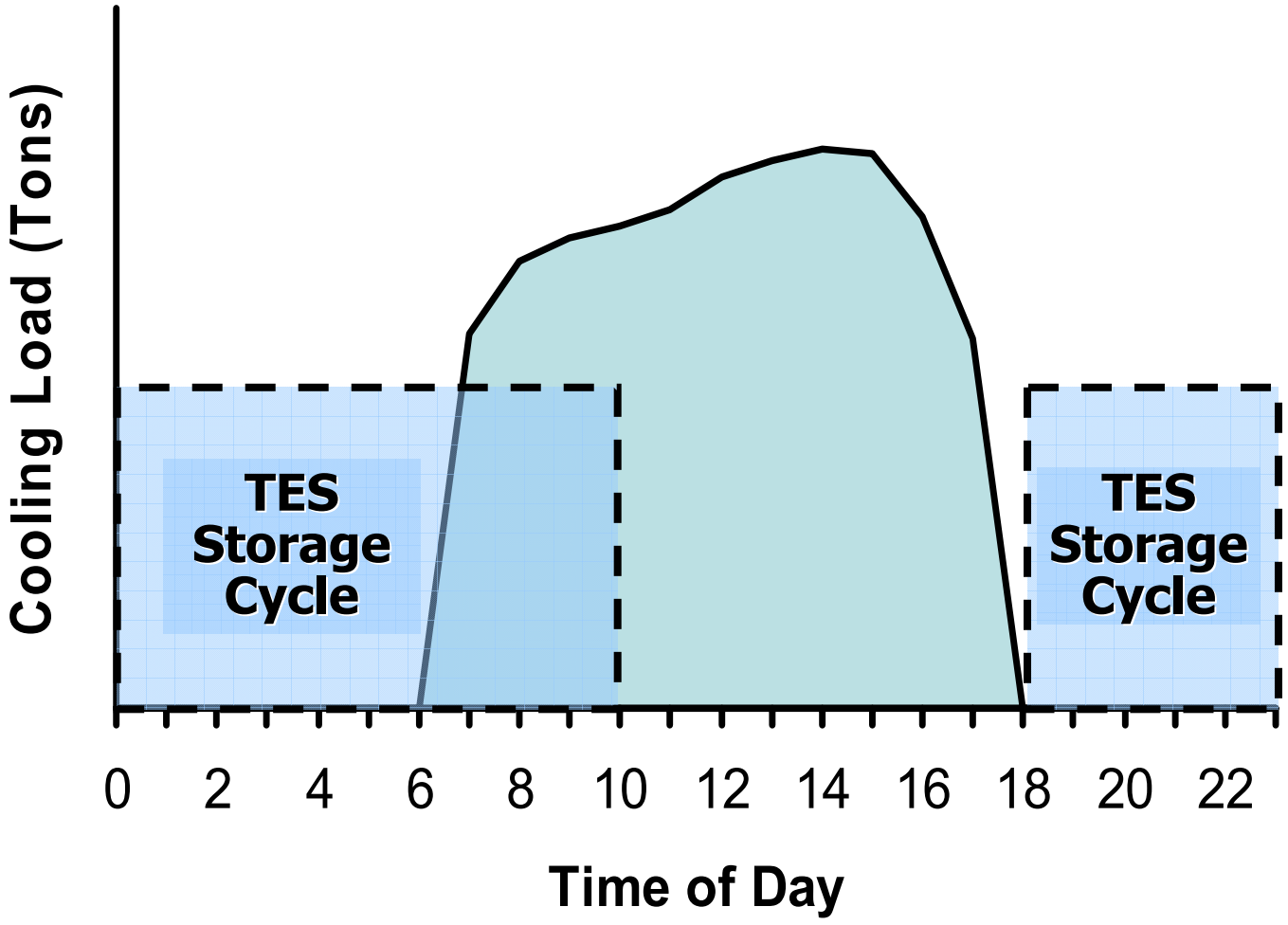
What Is Thermal Energy Storage?

Thermal Energy Storage (TES) is the process of using or a refrigeration plant to store cool water or to build ice during off-peak hours to serve part or all of an on-peak cooling requirement.

Thermal Energy Storage



Thermal Energy Storage



Thermal Storage System Environmental Advantages

- Require less kWh than conventional systems
- Utilize efficient power and produce fewer carbon dioxide emissions
- Energy line losses at night are 4% to 5% lower than during the daytime

Source: *Source Energy and Environmental Impacts of Thermal Energy Storage*, California Energy Commission - February 1996

Types of Cool TES

- Chilled Water (CHW) TES (sensible heat)
- Ice TES (latent heat)
- Low Temperature Fluid (LTF) TES

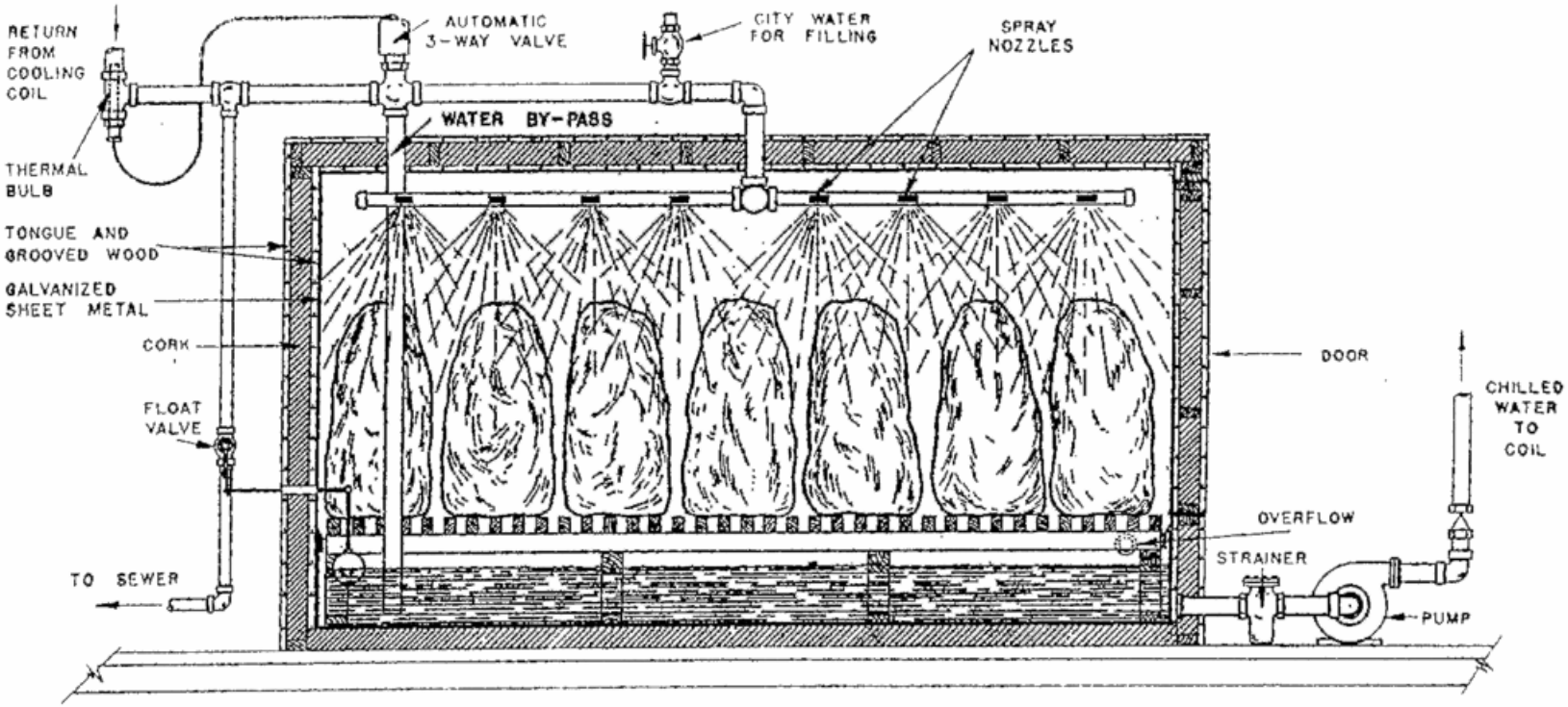
Chilled Water Storage

- Uses conventional chillers
- Temperatures of 39.2°F/4°C to 42°F/5.55°C
- An insulated tank with cooler denser CHWS stratified below warmer less dense CHWR

Chilled Water Storage

Moorefield, WV 1.64 MG
Engineering by Metcalf & Eddy

Ice TES

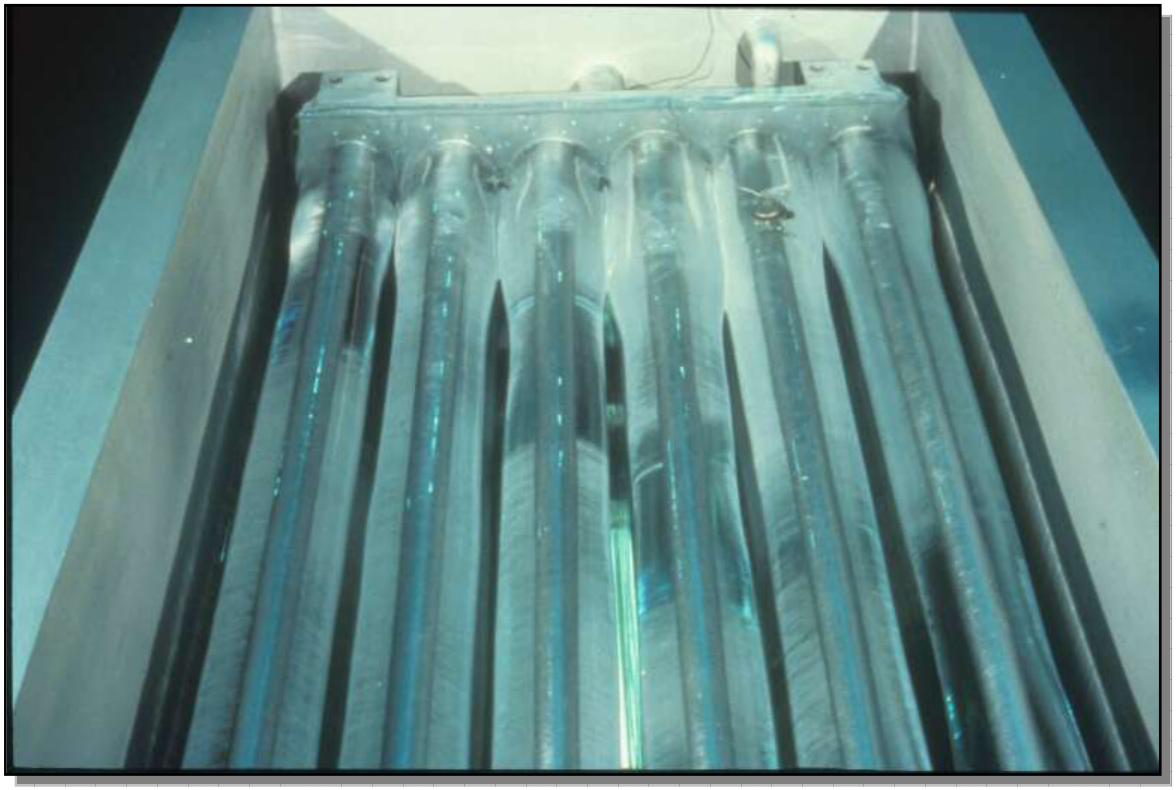


68. Ice Bunker Air Conditioning System, 1934.
Trane Air Conditioning Manual, The Trane Co, La Crosse, Wisconsin, 1934, p200.

Ice TES

- Water to ice off-peak; then melted on-peak to provide cooling
- Requires chillers that can provide low temperature brine (22°F/-5.6°C minimum) to freeze the water in the ice tank
- Requires only 1/4 to 1/6 of the space required for chilled water storage (~3Ft^3/Ton-Hour)
  - Takes advantage of the latent heat of ice (144 BTU/lb)
- Only ~60% of chillers and heat rejection equipment required
- Requires less plan area than instantaneous chiller system
- Colder supply water temperature (34°F/1°C to 44°F/6.67°C)

Ice TES



Ice TES

Low Temperature Fluid (LTF) TES

- Similar to CHW TES, but using fluid temperatures < 39°F/3.89°C
- Lower supply temperature (36°F/2.22°C to 39°F/3.89°C)

Summary of TES-TIC Examples

- 25 examples, over 24 years
- 107 CTs, from 1 to 175 MW, new & retrofit
- **Ice**, **CHW** and **LTF** TES
- 2.3 million T-hrs total; 92,000 T-hrs avg.
- TIC for avg. of 6 hrs/day; range 4-13 hrs/d
- Hot weather net power augmentation:
  - range 10 to 42%; most are 20 to 31%.

Example TES-TIC - Riyadh, KSA

Electric utility power generation facility:

10 existing 75 MW Combustion Turb's (CTs)

At design ambient air temp of 50 °C (122 °F), power output only 75-80% of nominal rating.

Saudi Electricity Co. (national electric utility):

- Needs to meet rapidly increasing demand
- Could add 3 more CTs for 30% more power
- Instead chose Turbine Inlet Cooling (TIC)
- TIC has lower capital $/kW than new CTs.

TES Solution / Results

Add TIC (at 3,100 T per CT x 10 CTs).

Do not install 31,000 T (non-TES) chiller plant;

instead, only 11,000 T, running 17-hrs/night,

plus193,000 T-hr (31,000 T x 6 hr) **CHW** TES.

TES adds 48 MW x 6 hrs net on-peak power;

+ over $10 million in net capital cost savings!!

TIC-TES adds 180 MW (30%) net increase,

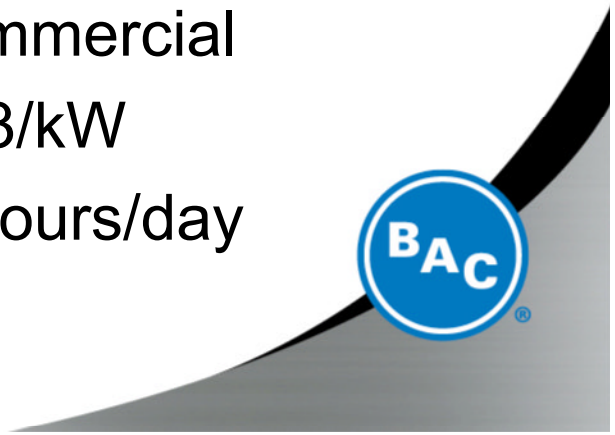
and adds power at <1/2 $/kW of new CTs.

Chilled Water (CHW) TES for TIC

- Saudi Electricity Company - Riyadh, Kingdom of Saudi Arabia (2005)
- 193,000 ton-hrs **CHW** TES, with 45.5 / 86.1 ºF CHWS / R temps
- 140 ft diameter x 70 ft high (8 million gallon) CHW TES tank
- Provides Turbine Inlet Cooling for 30% more net power in hot weather

Turbine Inlet Cooling with CHW TES

	Entire Installation (TIC w/ **CHW** TES)	Storage Portion Only (**CHW** TES sub-sys)
Location	Saudi Arabia	Saudi Arabia
Year in operation	2005	2005
Peak power	180 MW	48 MW
Energy storage	288 MWh	288 MWh
Projected life	30+ years	30+ years
Round-trip effic'cy	near 100%	near 100%
Classification	commercial	commercial
Unit capital cost	$250/kW	$83/kW
Dispatch period	6 hours/day	6 hours/day



TES-TIC Potential in the U.S.

Assume:

- ~300 GW of total installed CT capacity
- ~50% is to be retrofit with TES-TIC
- ~20% output enhancement from TES-TIC

Then TES-TIC could provide:

- ~30,000 MW of hot weather peaking power, typically at only $200-400/kW, including
- ~180,000 MWh of Energy Storage per day