Green Data Center
CRYOGEL
Ice Ball Thermal Storage

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Tuesday, March 1, 2011
4:30 – 5:30 PM, ACC, Room 207B

CRYOGEL

Ice Ball™ Thermal Storage

San Diego, CA www.cryogel.com

Telephone (858) 457-1837 Email: tes@cryogel.com

Thermal Energy Storage (TES) (thermal battery)

Storage of energy in the form of ice.

Thermal Energy Storage - TES

Energy storage shifts electrical use from ON PEAK (day time) to OFF PEAK (night time).

Benefits include:

- Peak Demand Reduction
- Energy Conservation
- Energy Costs Savings
- Less Air Pollution - Power Plant Emissions
- Delay of New Power Plant Construction

Ice Balls - Four Inch Diameter Plastic Spheres Filled With Water

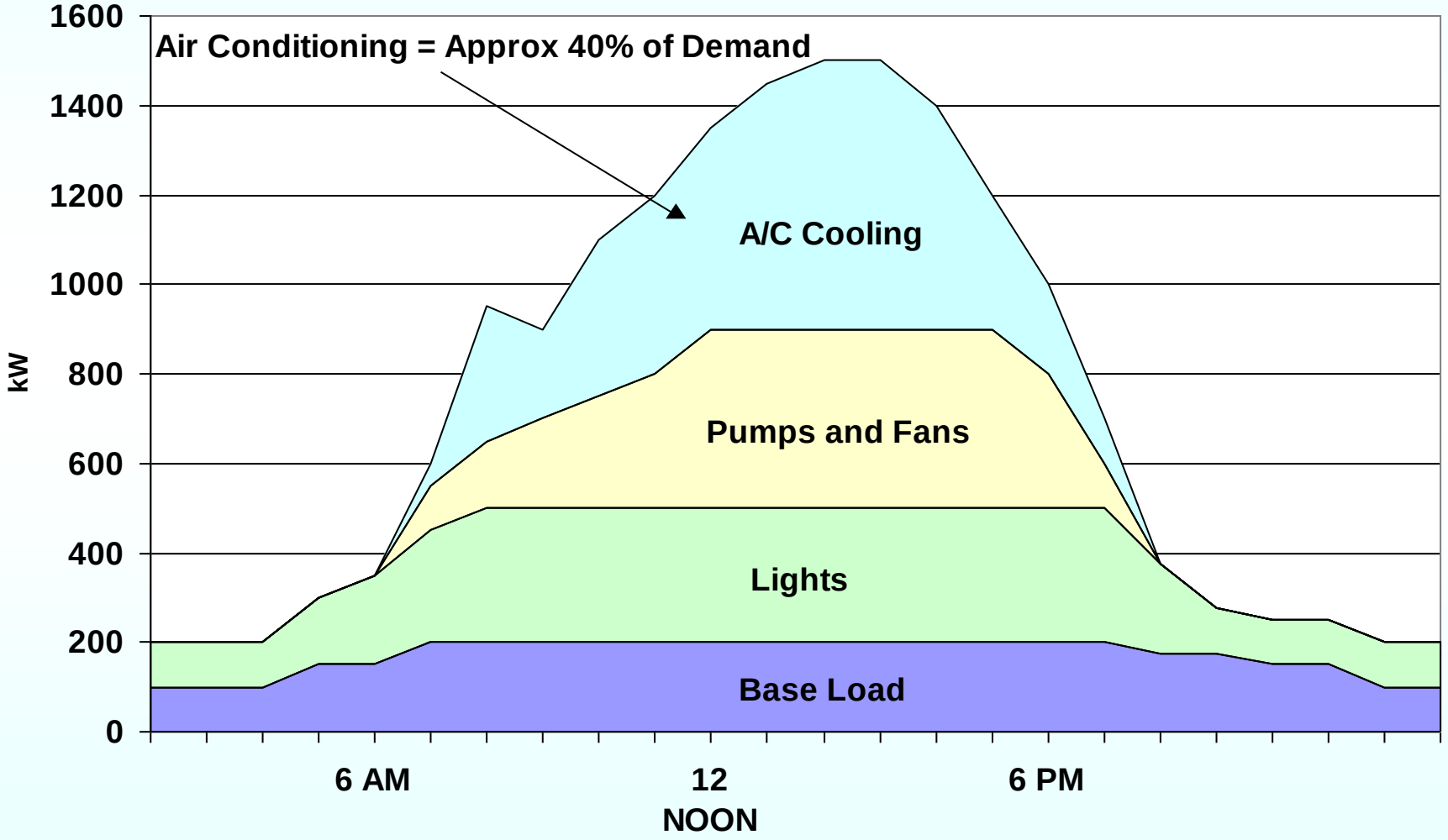
ICE BALL DESIGN

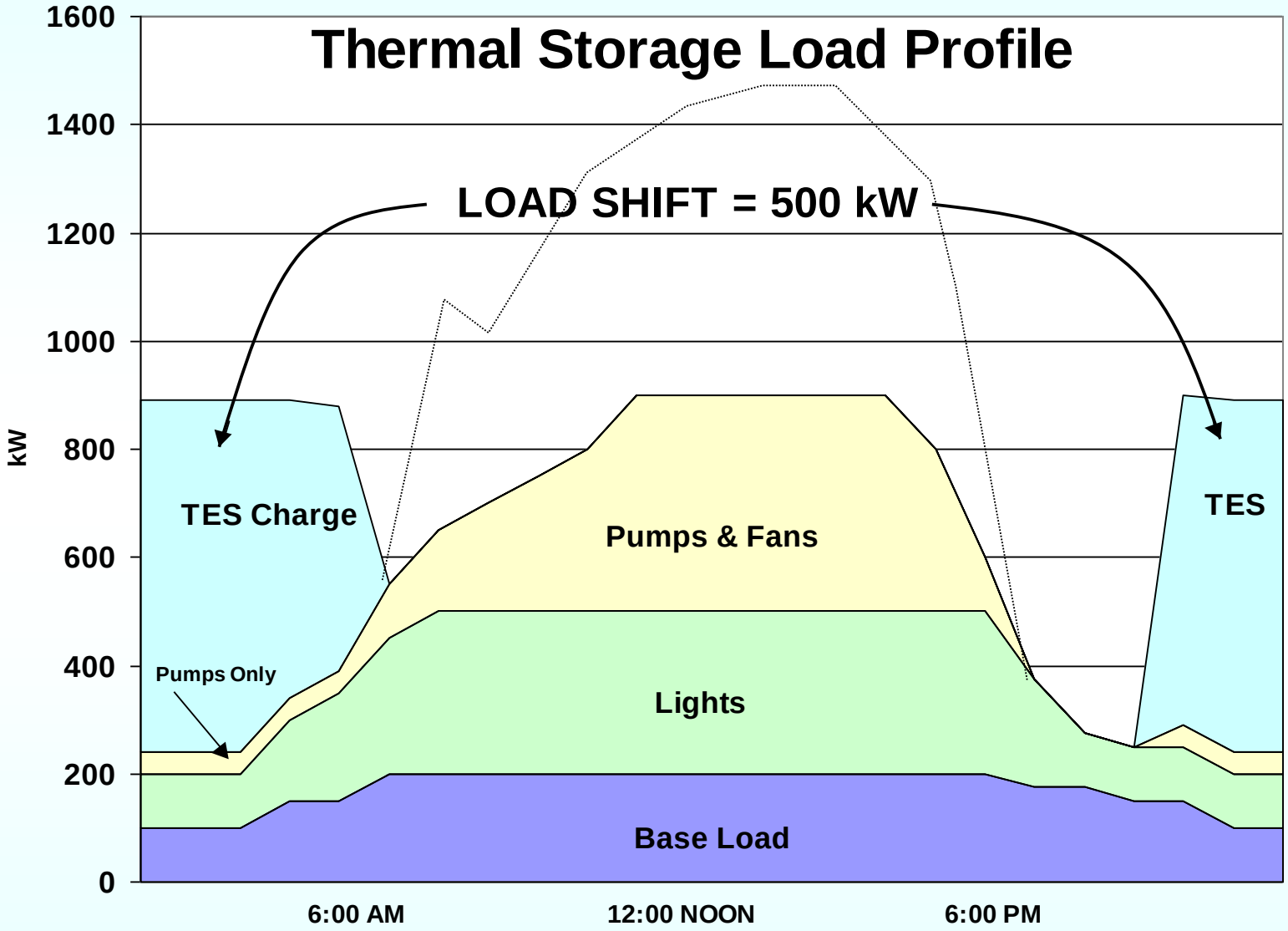
Dimples in the walls of the ball allow for expansion as water is frozen to form ice.

Melted Ball **Frozen Ball**

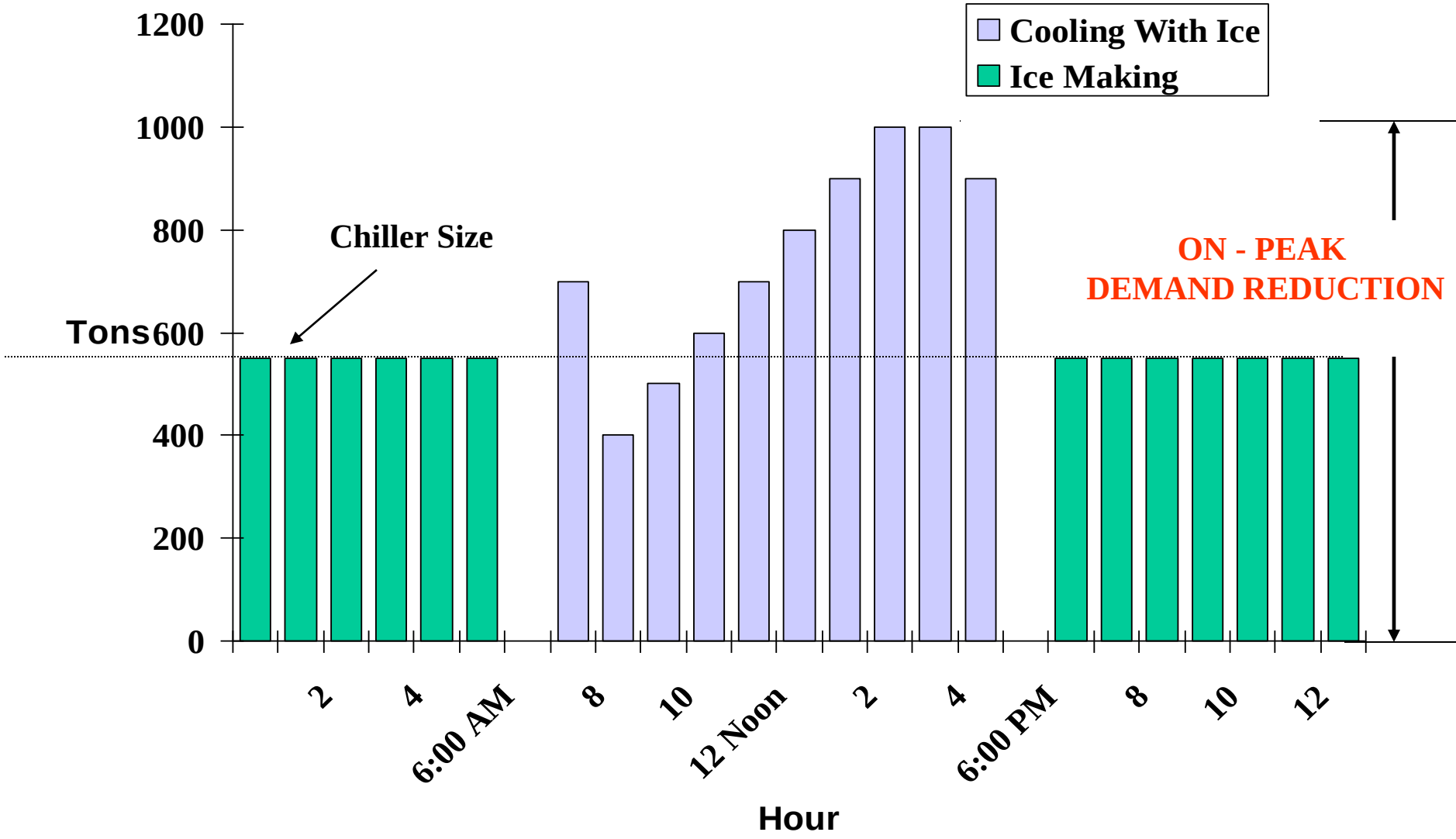
Dimples Flex Out to Allow for Ice Expansion

Building Load Profile

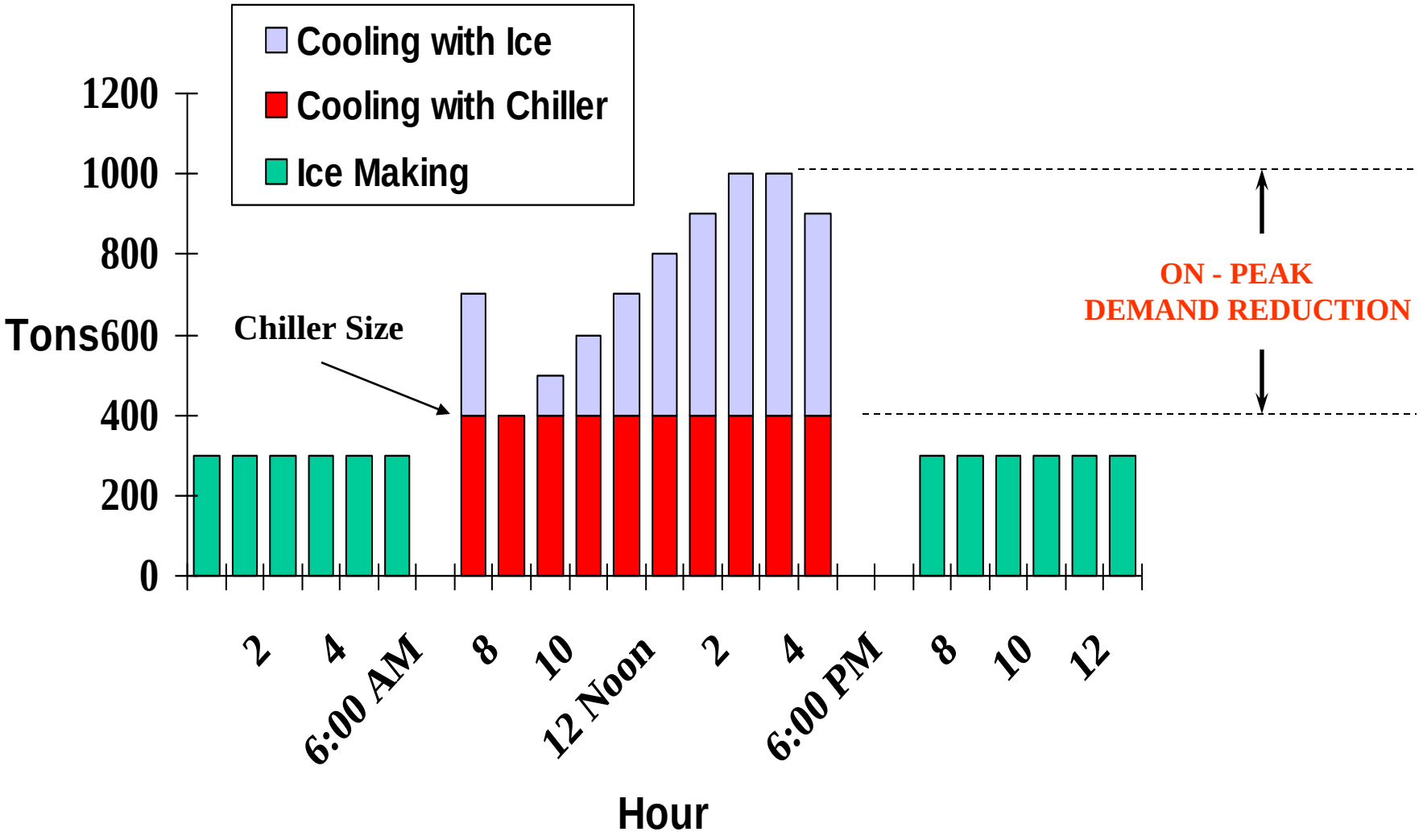




Full Storage

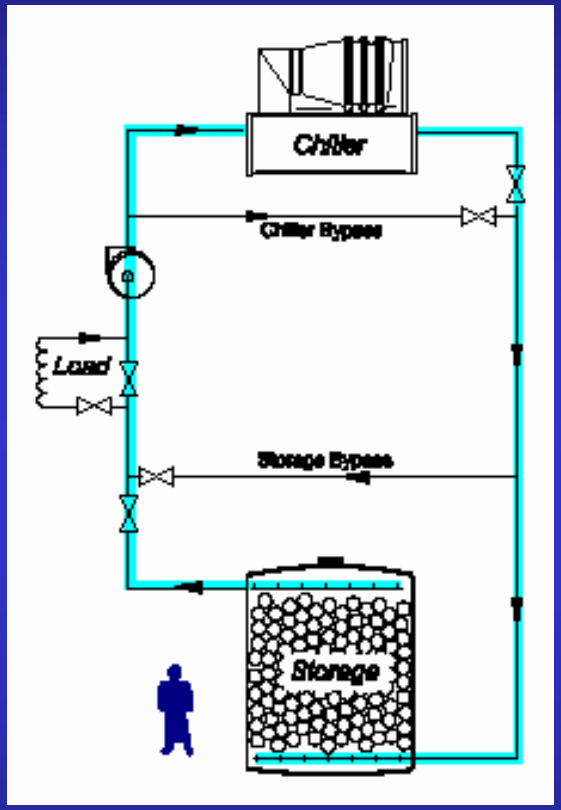


Partial Storage

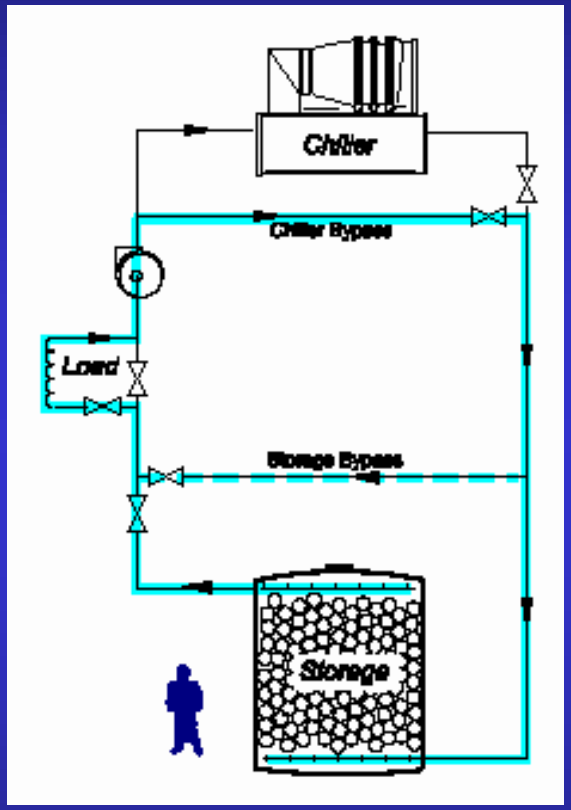


Simplified Operational Diagrams

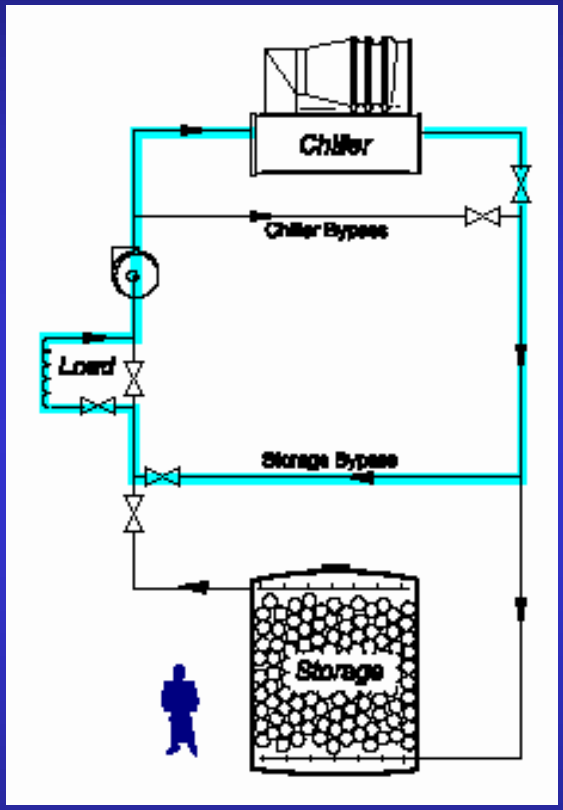
Major Components and Glycol Piping Concepts



Charge - Ice Making



Discharge - Ice Melting

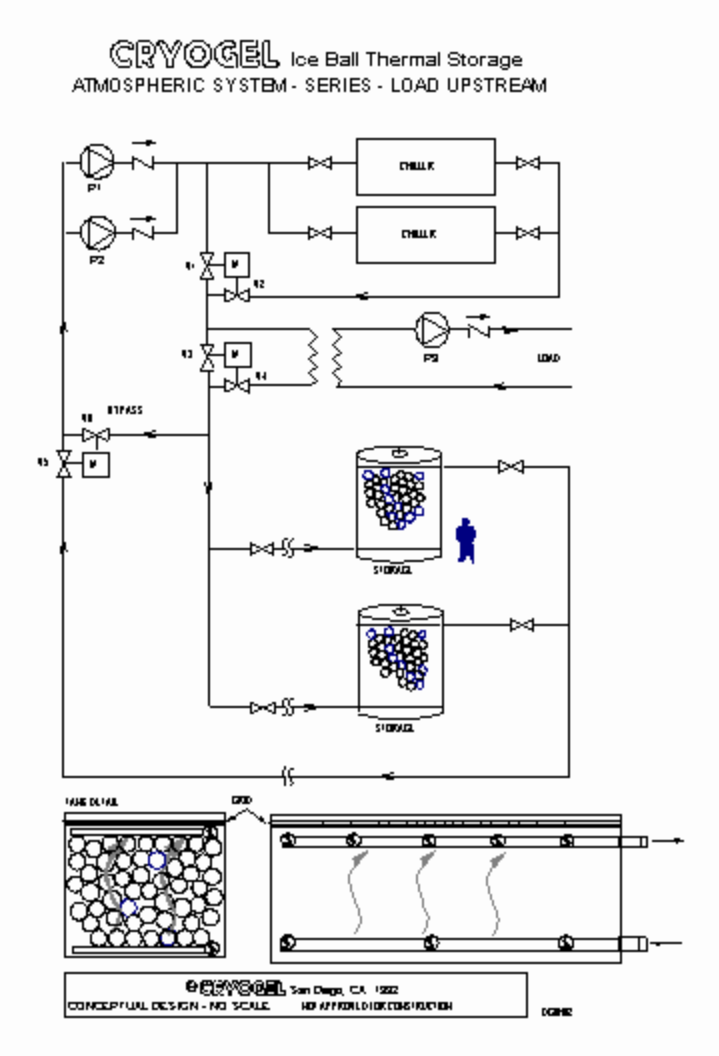


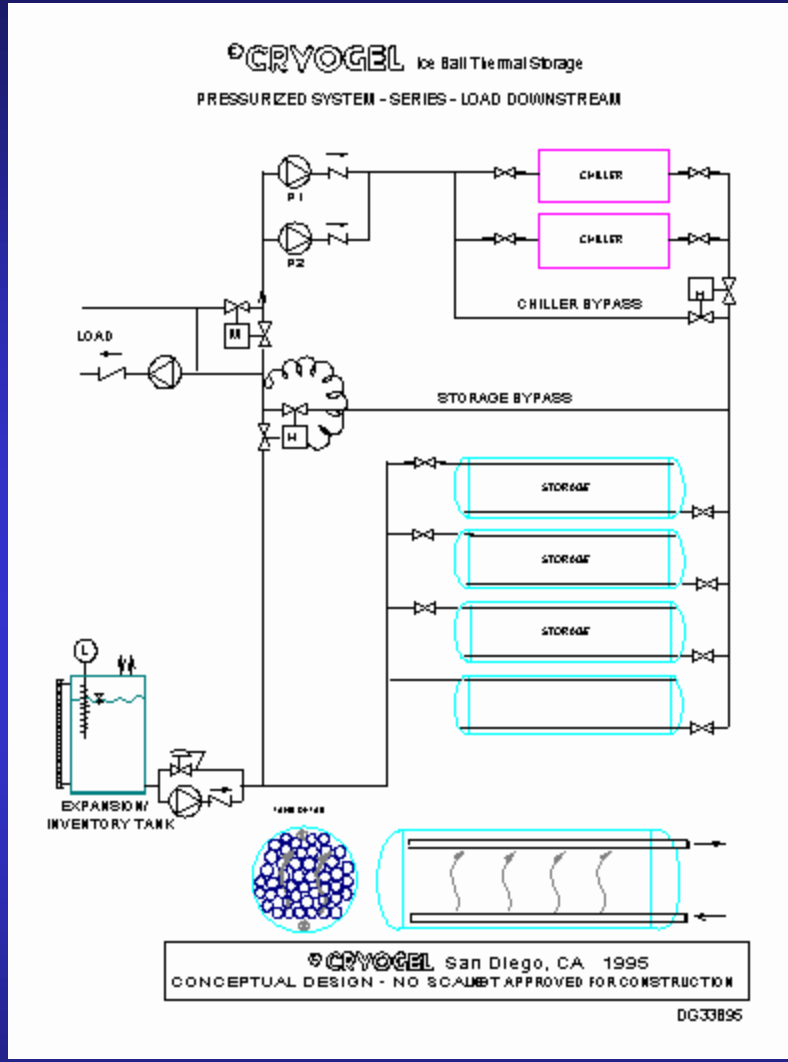
Standby Operation

Cryogel Ice Balls

Floating inside tanks - glycol/water solution transfers energy to and from balls to make ice at night and melt ice during the day.

Vertical Atmospheric Tanks - Most Economical Approach





Atmospheric or Pressurized System Configurations

Flexible and Simple

Pressurized Tanks - Horizontal or Vertical

Atmospheric Tanks - Cylindrical or Rectangular

Steel or Concrete Tanks

Above Grade or Direct Burial

Pressure Vessels

Above Grade Tanks

Horizontal Pressure Vessels

Vertical Pressure Vessels

Tanks Built to Meet Site Constraints

AIRPORTS

Cryogel Ice Balls
Installations at:
Los Angeles (LAX)
San Francisco (SFO)
and 6 other U.S. Airports

CLEAN SIMPLE RELIABLE

INDUSTRIAL QUALITY TANKS - ASME CODE

CRYOGEL

Ice Ball™ Thermal Storage

San Diego, CA www.cryogel.com

Airport central cooling system.

10,000 ton hours.

Six (6) ASME Code tanks being installed on second story of central chiller plant.

HOSPITALS

Horizontal - Atmospheric Tanks

Horizontal - Atmospheric Tanks

Vertical Pressure Vessels - Minimum Space and Height

Clean Room Cooling

Underground Tanks

Direct Burial of Horizontal Pressure Vessels

Eliminates Space Requirement For Tanks

Allows for Vehicle Traffic or Parking Above

Horizontal Pressure Vessels for Direct Burial

Horizontal Pressure Vessel - 2,500 Ton Hours per Tank

Finished Project - Underground Tanks - Only Manways are Visible

Atmospheric Tanks

Vertical Atmospheric Tanks - Steel Cylindrical

Rectangular Concrete Atmospheric Tanks

Lower Costs - Simplified Operation

Rectangular Steel Tanks - Retrofit Ice on Coil

SCHOOLS

Vertical Atmospheric Tanks - Shop Fabricated - Ready for Shipment

Vertical Atmospheric Tanks Installed Indoors

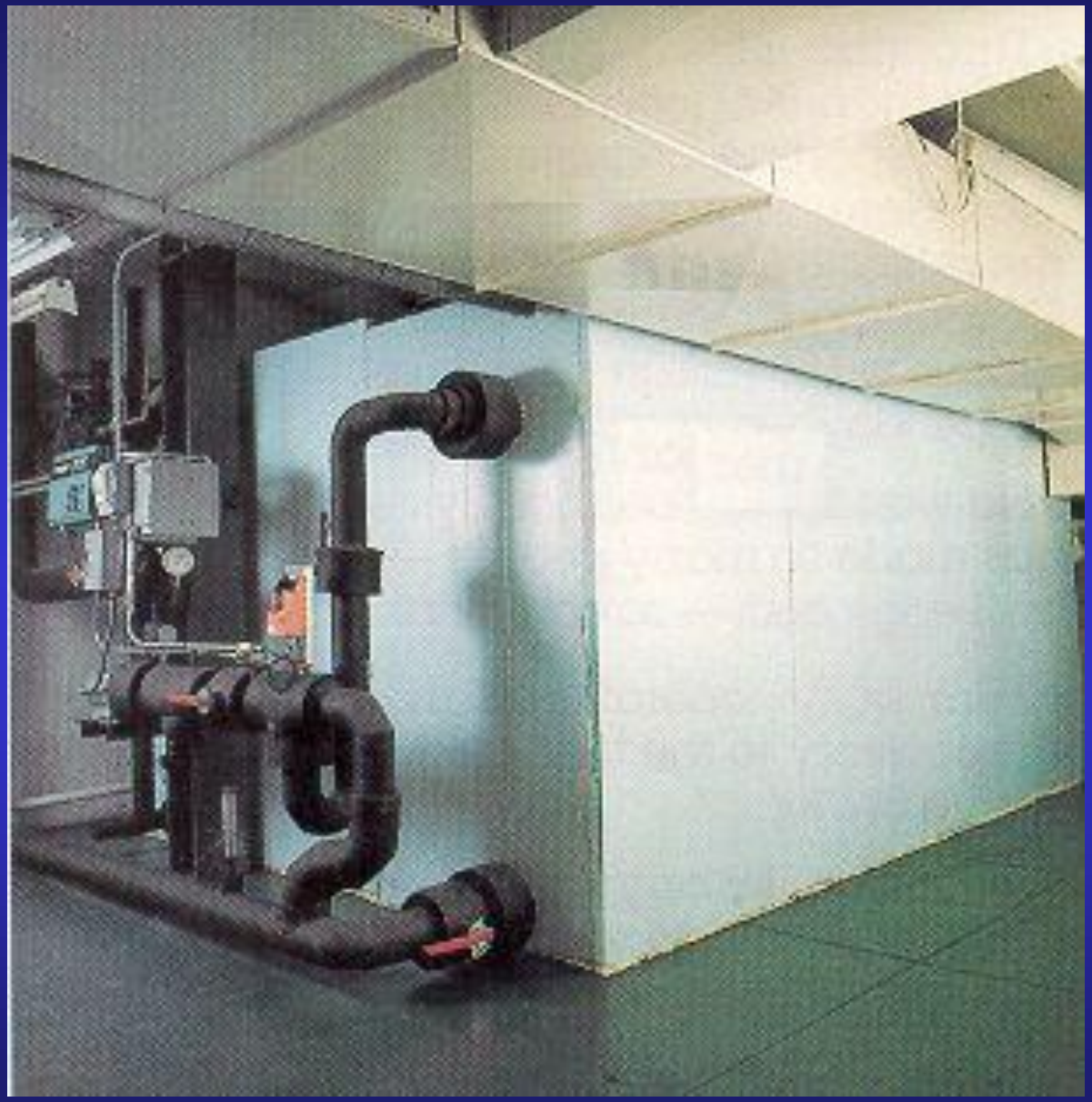
OFFICES

10,000 ton hours - concrete tank

Polyethylene Liner in Concrete Tank

Balls Below Grid with Glycol Solution

Rectangular Steel Tanks - 800 Ton Hours



Rectangular Tank Installed and Insulated in Mechanical Room

Process Cooling Applications

Brewery or Milk Cooling

Airport Preconditioned Air - PCA Systems

Batch Process and Dehumidification Options

INDUSTRIAL

Brewery Tanks with Cooling Jackets

Brewery Ice Ball Tank - Non-Toxic Propylene Glycol Application

Piping and Tanks Fully Insulated with Jacket

Retrofit in Downtown Chicago
Tanks Designed to Fit Buildings
1,000 to 20,000 ton hrs

Ice Balls in old chilled water tanks can increase capacity by a factor of 5.

Load Profiles and System Sizing

Hourly Cooling Load Profiles are Required

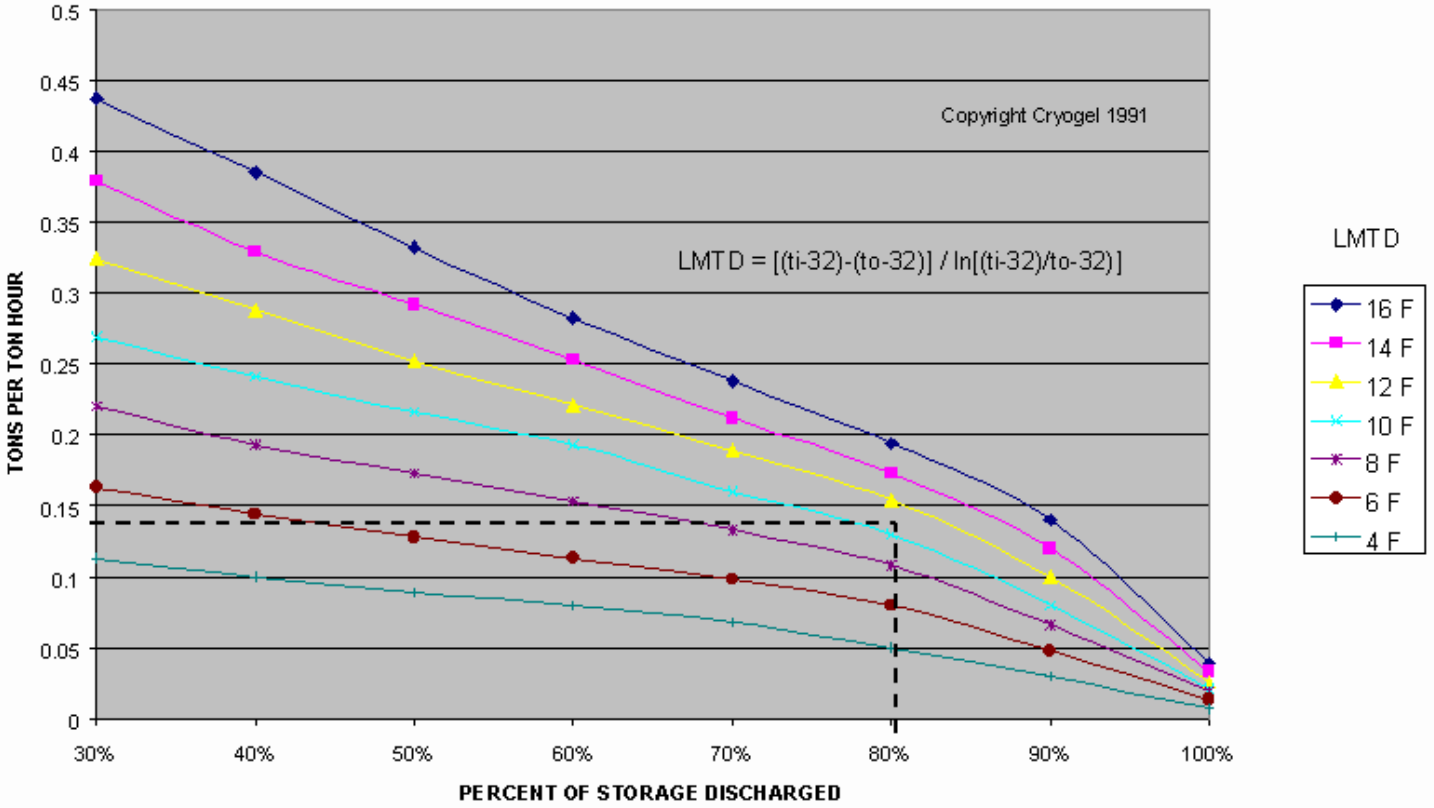
Full Storage Options

Partial Storage Options

Performance Curves from Independent Labs

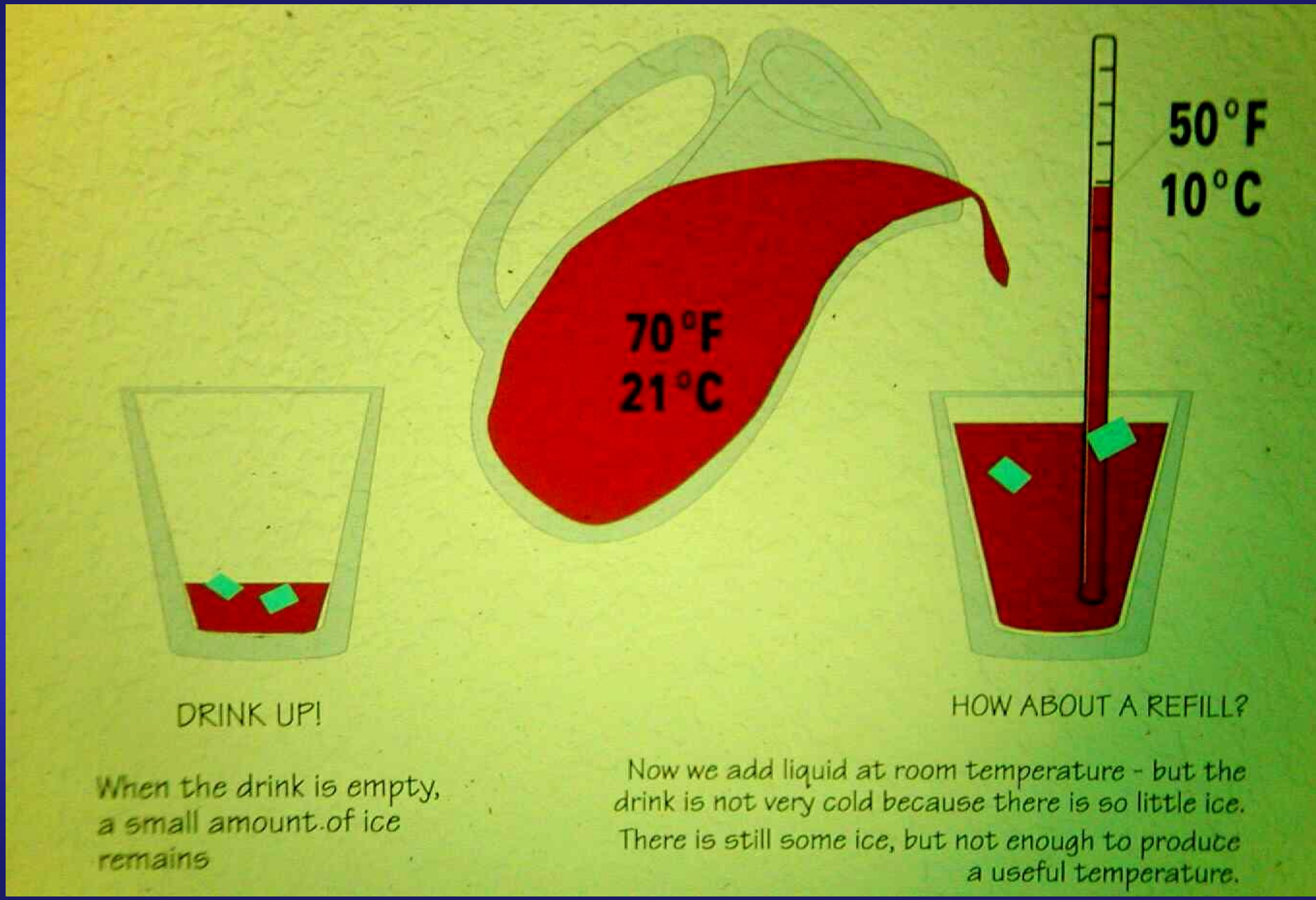
INSTANTANEOUS DISCHARGE CAPACITY

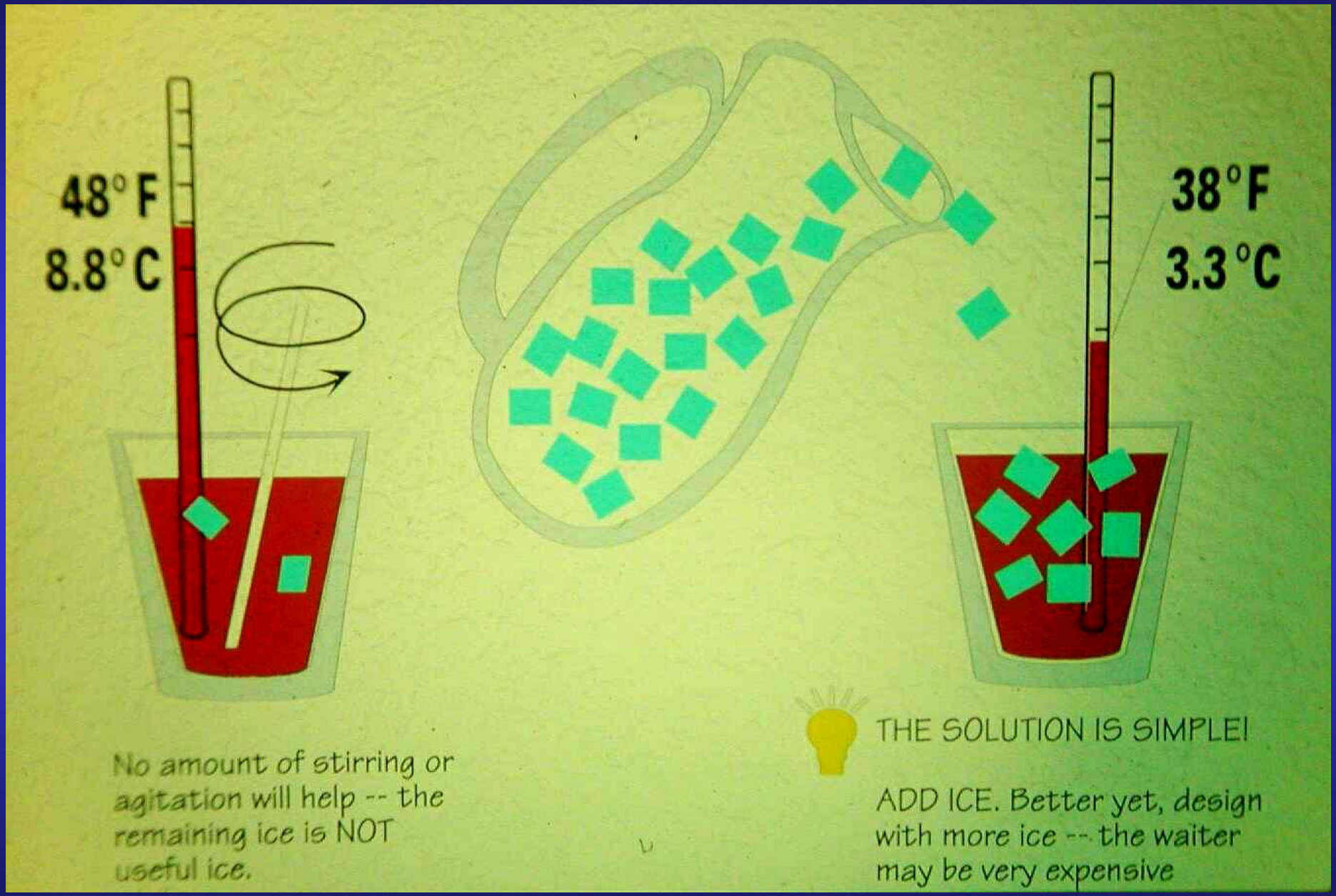
Tons per Ton Hour of Storage as a Function of LMTD and State of Discharge



Example: Discharge temperatures of 50 F Entering Storage 38 F Leaving Storage, LMTD = 10.92 F.
With 80% of the Ice in Storage Already Melted (discharged), the system can produce .148 tons per ton hour.
For a system with a rated capacity of 1,000 ton hours, the instantaneous capacity at 80% Discharge is 148 tons.

Thermal Performance Curves Based on Independent Lab Testing





Gross Capacity
NOMINAL CAPACITY

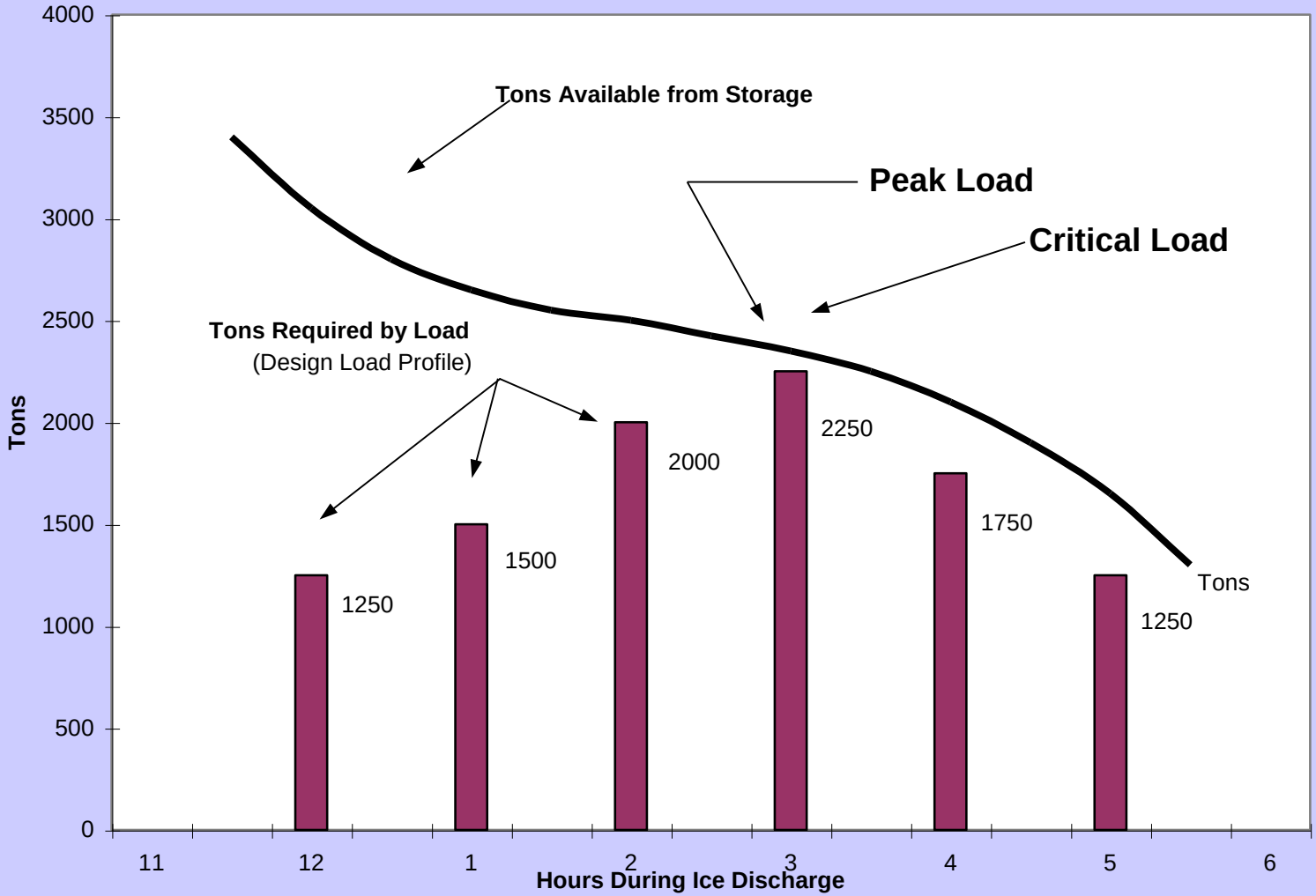
ICE NOT USED

Net Capacity
RATED CAPACITY

IT IS NEVER POSSIBLE TO USE 100%
OF THE THERMAL STORAGE CAPACITY
AT USEFUL TEMPERATURES

Total Load = 10,000 Ton Hours
(Rated Storage Capacity)

Nominal Storage Capacity = 10,869 Ton Hours

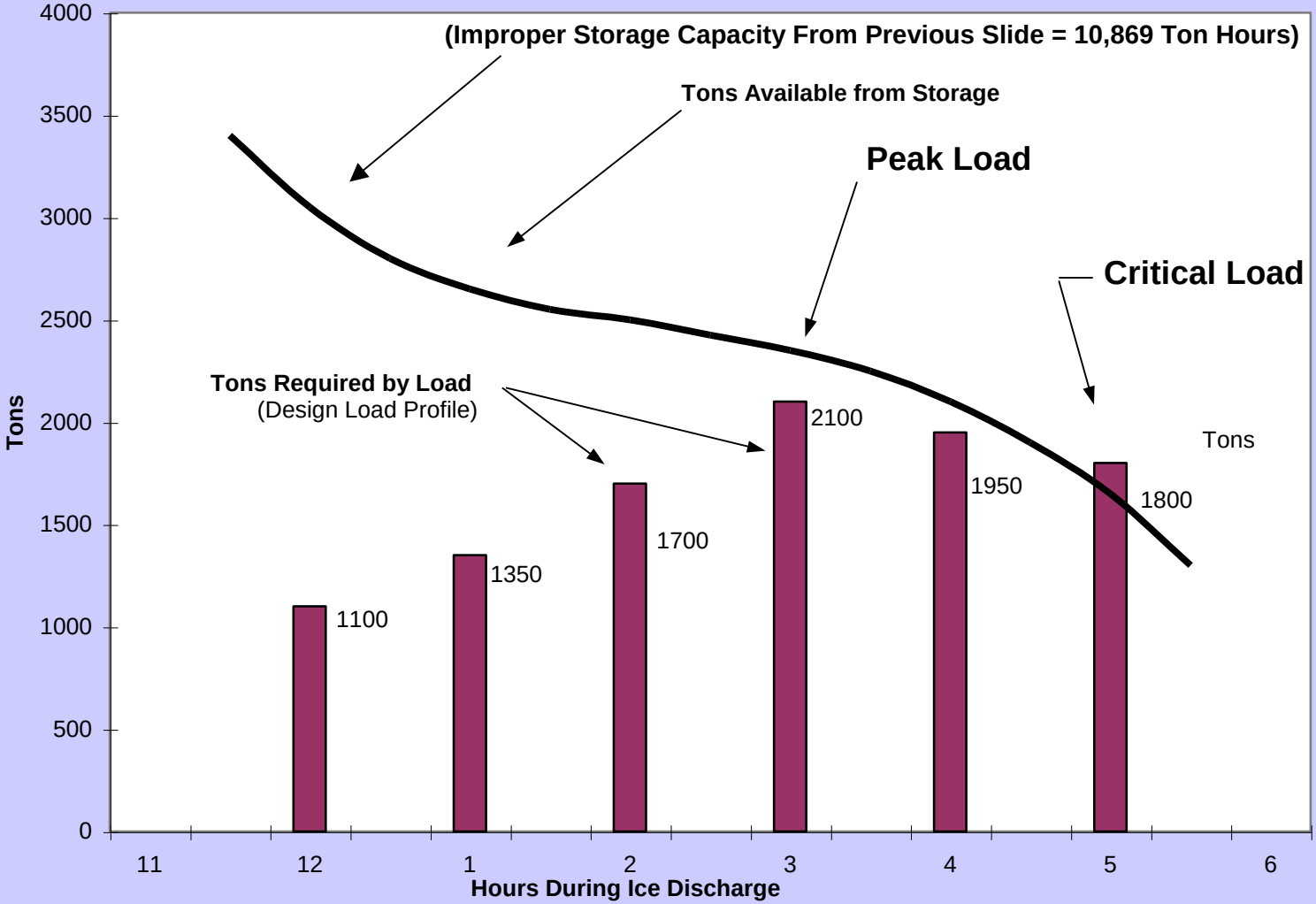


Correct Storage Sizing - Tons Available Exceed Tons Required at Every Hour

Total Load = 10,000 Ton Hours

(Rated Storage Capacity)

Nominal Capacity Required = 11,400 Ton Hours



Incorrect Sizing - Tons Available Below Tons Required at Critical Last Hour

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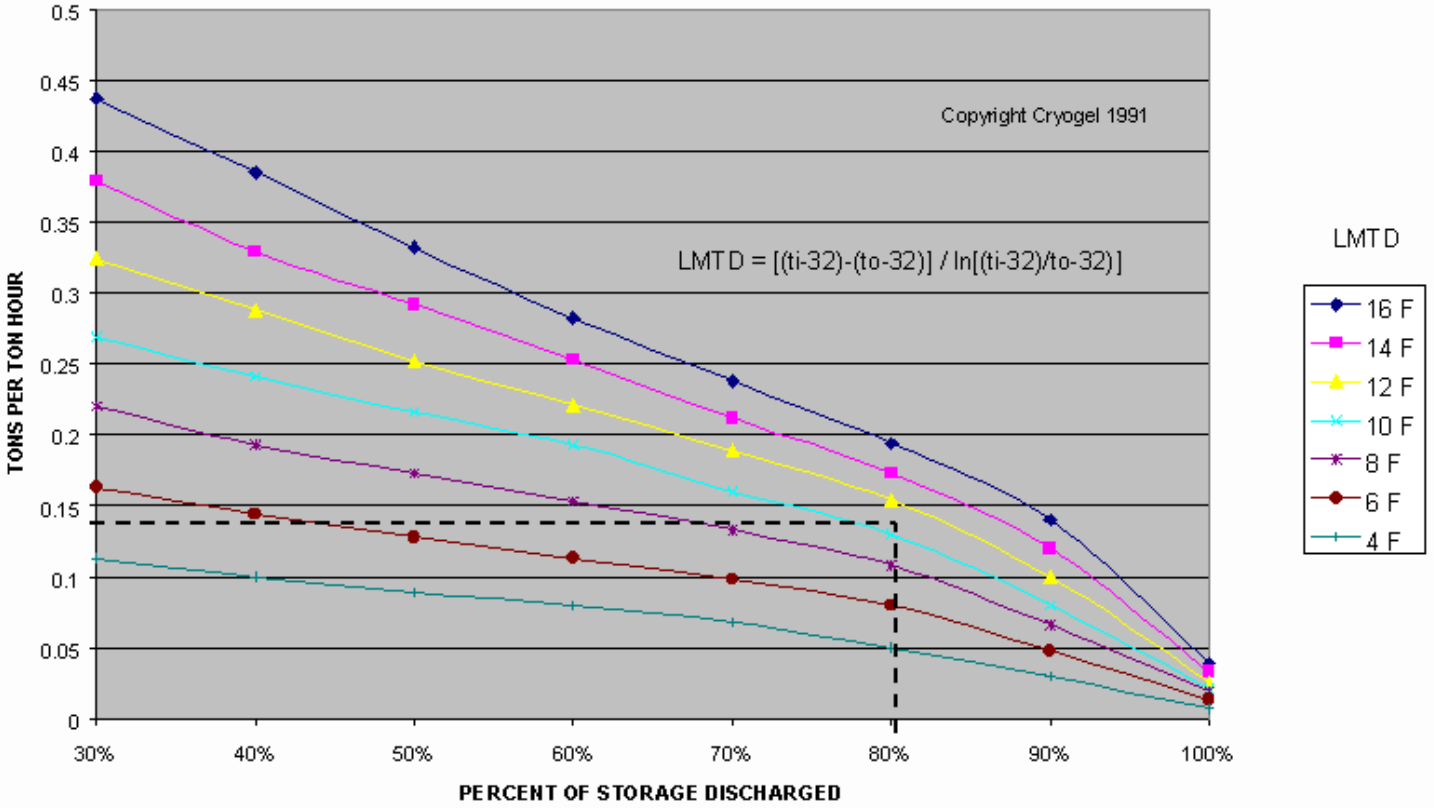
Tons per Ton Hour of Storage as a Function of LMTD and State of Discharge



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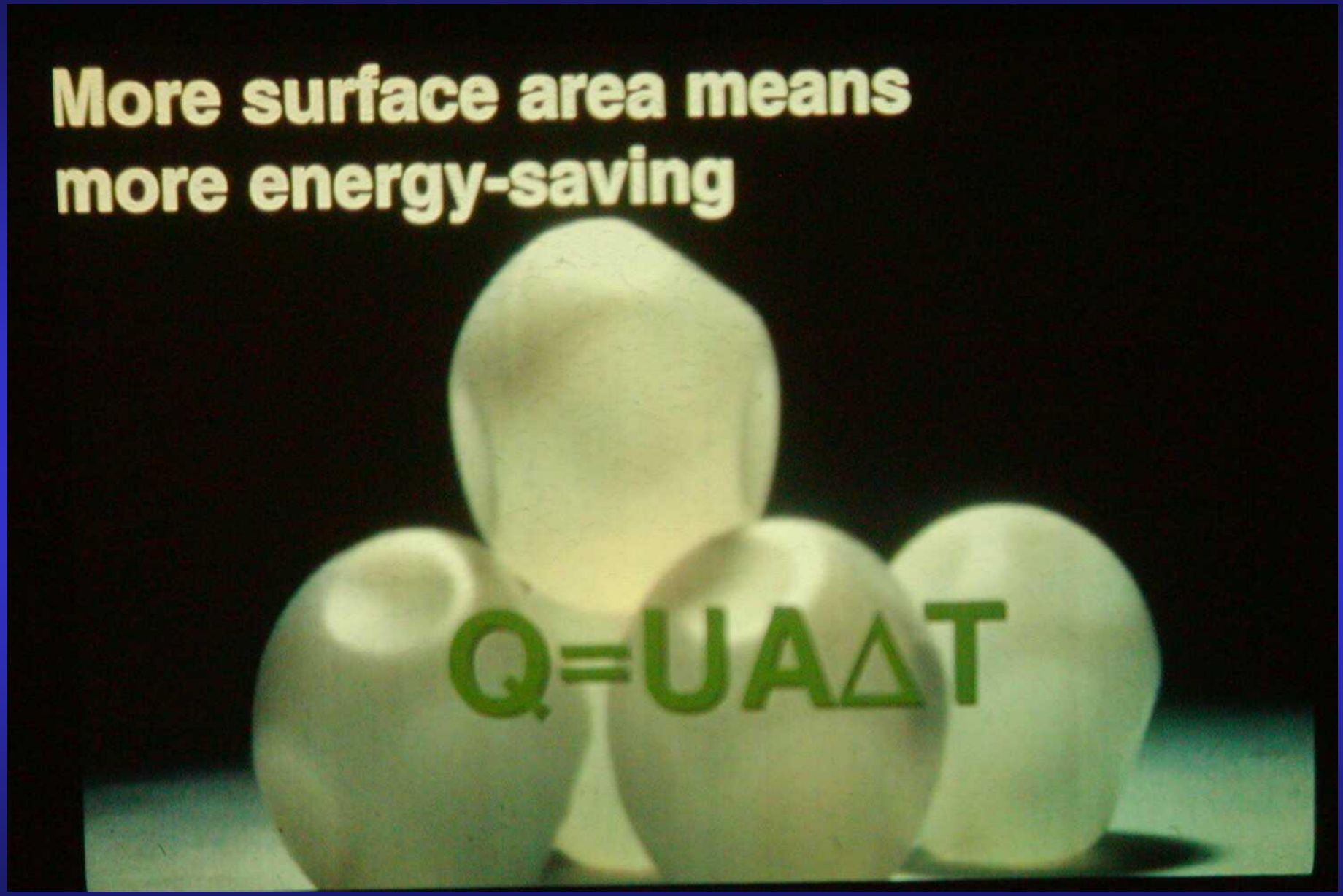


Simplified Installation

Tanks Set in Concrete or Steel Saddles

Ice Ball Installation

Tank Insulation Options

Setting Tank in Saddles - Minimum Foundation Concrete Required

Raising Ice Balls Freight Container to Top of Tank

Pouring Balls Into Tank - Tank is 2/3 Full of Water to Aid Installation

Ice Balls Floating in Water - Water Assist by Breaking the fall of the Balls

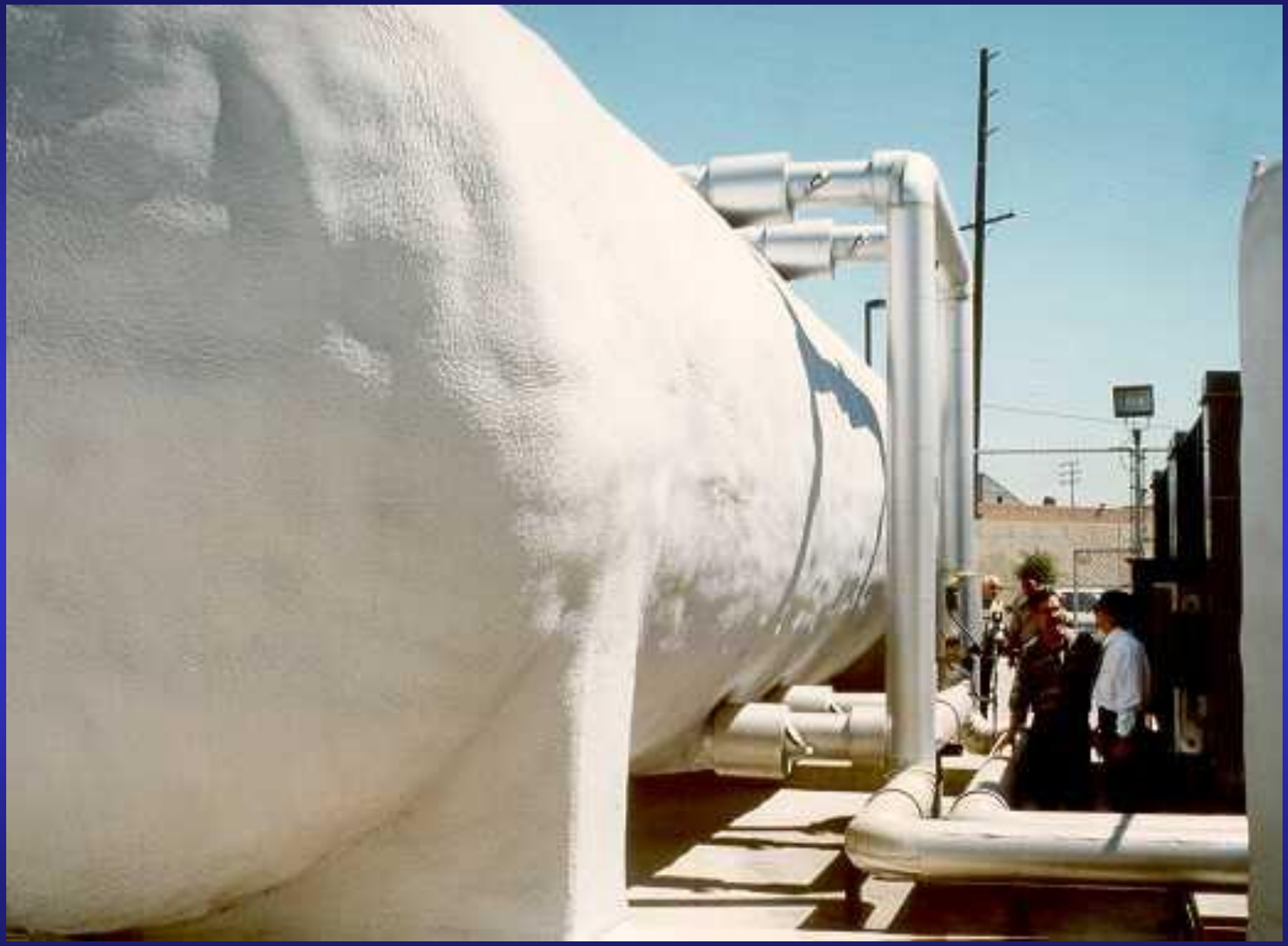
Balls Float to Spread Out Through the Length of the Tank

Final Insulation and Jacket Installed

Project Installation Complete

Urethane Foam Insulation Sprayed Directly onto Tank

Completed Tank with Urethane Foam Insulation



Tanks Fully Insulated with Urethane Foam and UV Top Coat

Advantages

- **Flexibility - atmospheric, pressurized, steel, or concrete tanks**

- **Tanks may be virtually any size or shape to fit site constraints**
(cylindrical, rectangular, horizontal or vertical)

- **Direct Burial Option - Will Support Overhead Traffic**

- **Highest heat transfer surface area in TES industry**
(22 sq ft/th vs. 7.5, 14, and 17 for ice-on-coil equipment.)

- **Low pressure drop**
(ethylene or propylene glycol - lower pumping costs)

… more Advantages

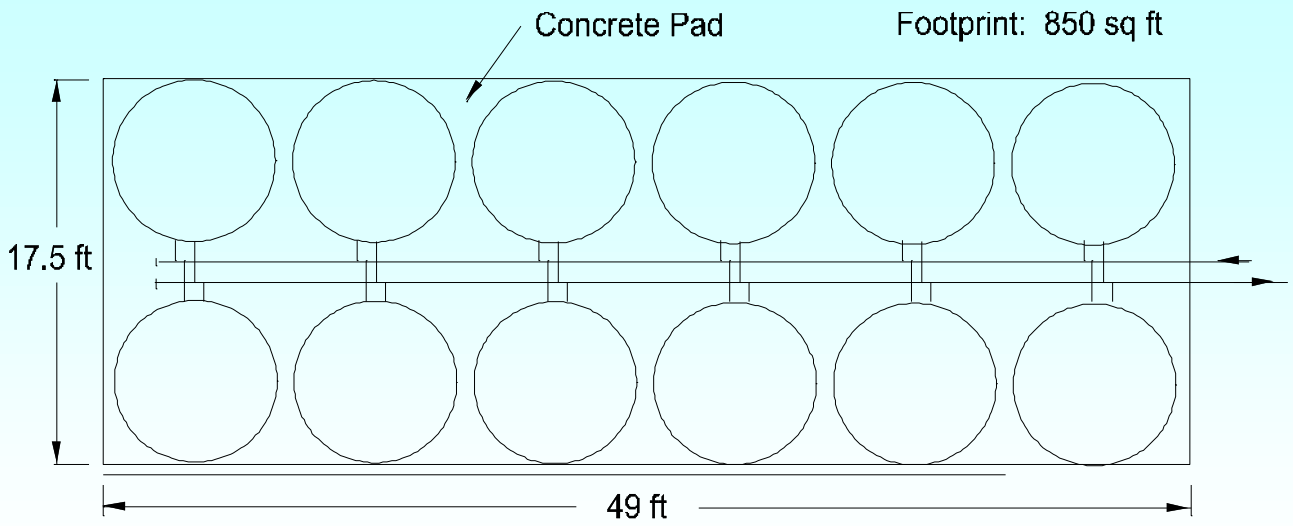
- **No possibility of over-charging**
  (no ice caps, no bridging, no channeling, no tank buldging)

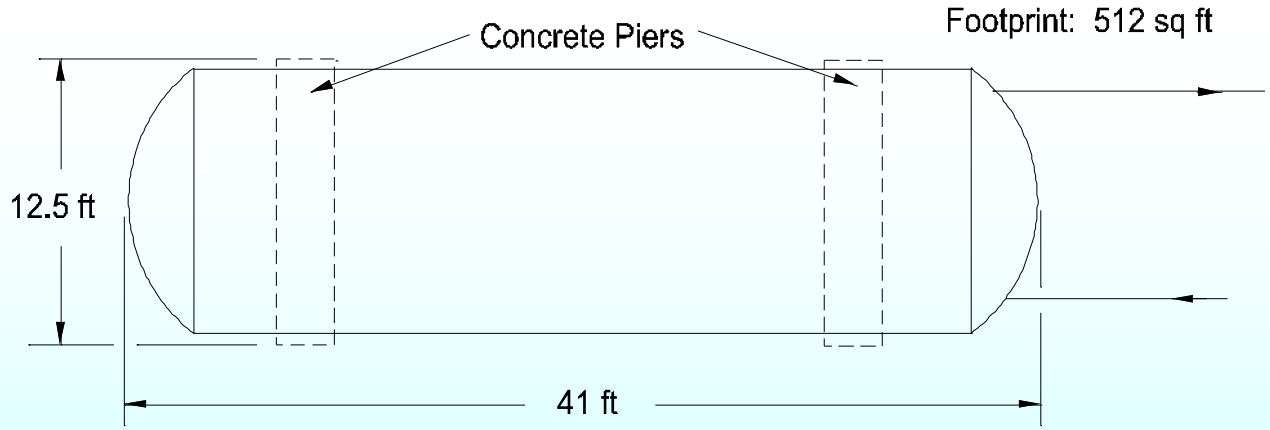
- **Retrofit using existing chilled water or ice-on-coil tanks**

- **Single large tanks vs. tank farms**
  (smaller foot print - no balancing or multiple tank piping costs - positive air purge from glycol loop)

- **Redundancy**
  (independent units - no tubing, fittings, no single-leak shut-down)

- **Installed cost savings**
  (piping, balancing, real estate, concrete pads or foundations)





Simplified Piping/Installation and Space Savings = Lower Installed Cost

Nominal Capacity 1,950 ton hours

Thermal Storage - Done Right

Cryogel

Ice Ball Thermal Storage

Rotary Screw Chillers

Variable Speed Drive Pumps

CRYOGEL

Ice Ball™ Thermal Storage

San Diego, CA www.cryogel.com

Futuristic office building with thermal storage air conditioning.

Under construction in Far East.

Summary - Thermal Storage Benefits

Different Shades of Green

Building Owner
- Reduce Energy Costs
- Reduce Energy Use and Mechanical Equipment Size
- Operational Flexibility and Back-up

Electric Utility
- Reduce Source Energy Use at Power Plant by 8-34%
- Delay or Avoid Power Plant Construction
- More Efficient Operation - Improved Profit

Environmental Benefits
- Reduced Fossil Fuel Consumption
- Reduced CO_2 Emissions 30 to 50% vs. absorption
- Reduced NOx Emissions
- Avoid or Delay Power Plant Site Impact

Thermal Energy Storage

Economic Benefits To:

Electric Energy Producers

Building Owners

Society/ Environment

Cryogel

Ice Ball Thermal Storage

San Diego, CA USA

www.cryogel.com

Energy Challenges...

- **Oil Supplies and Prices are Uncertain**
- **Coal Produces High Emissions**
- **Demand Grows as the Economy Grows**

Build new generating capacity?

OR

Use existing capacity more efficiently?

Options

Build New Capacity OR Shift Existing Loads

- **New Capacity**
  - **Years to Locate, Permit and Construct**
  - **Higher Cost per kW than TES**
  - **Uncertain technology (Clean Coal)**
  - **Environmental Damage**
- **Thermal Energy Storage (TES) Shifts Loads**
  - **Relatively Fast Implementation**
  - **Lower Cost per kW than New Capacity**
  - **Proven Technology**
  - **Environmentally Friendly**
- **Other - Pumped Hydro, Compressed Air**

RESULTS AND OVERVIEW

California Energy Commission Report "Source Energy and Environmental Impacts of Thermal Energy Storage”

Reference and Credits: Some Data and Conclusions in the Presentation are taken from the California Energy Commission Study.

Study Available on Request

Energy Savings for Electric Utilities - 10% to 43%

In California, source energy savings from TES during the next 10 years could be enough to supply the electrical energy needs of approximately 200,000 homes for a year. [1]

Ref. 1: California Energy Commission Report , "Source Energy and Environmental Impacts of Thermal Energy Storage" P500-95-005

TES Reduces Source Energy Usage [1]

Electric Power Plants Running at Full Capacity Not at Part Load or Idle Conditions (Spinning Reserve)

Transmission Line Losses 3 to 7% Lower at Night vs. On Peak

1. California Energy Commission Report "Source Energy and Environmental Impacts of Thermal Energy Storage"

Thermal Storage May Use Less Energy

- **Keep chillers and other equipment operating at high load which is their most efficient condition**
- **Chillers operate at night when ambient temperatures are lower**
- **Pumping energy is lower due to larger DT and smaller condenser water GPM**
- **Fan energy is lower due to colder supply air temperatures which lowers the volume of air required.** [1]

Cryogel Ice Ball Thermal Storage

Energy Savings for Building Owners - As Much as 12%

New, high efficiency TES systems use fewer kilowatt-hours for cooling. System monitoring shows as much as 12% fewer annual kWh than comparable non-storage systems. TES systems operate in a fully loaded condition during the night and are, therefore, more efficient. TES systems can also operate with smaller pumps and fans.

In California alone, TES could save enough energy during the next decade to supply the electrical needs of approximately 900,000 homes for a year. [1]

Cryogel Ice Ball Thermal Storage

Air Quality-Environmental Benefits

By reducing fuel use and transmission losses for power plants, air polluting emissions are reduced. At building sites, TES can reduce CFC's by employing smaller chillers with less refrigerant.

In 10 years, TES could reduce CO_2 by 260,000 tons and NO_x emissions by 600 tons annually in California alone. Such an environmental impact is roughly equivalent to shutting down 3 large baseload power plants (750 MW) or 25 peaking power plants (100 MW). [1]

UTILITY RATE DESIGN COMPONENTS

Demand Charge Differential - Day/Night **$ per kW**

Energy Charge Differential - Day/Night **$ per kWh**

Transmission and Distribution Differential **$ per kWh**

Incentives for Demand Shift **$ per ton** **OR** **$ per kW**

IMPLEMENTATION

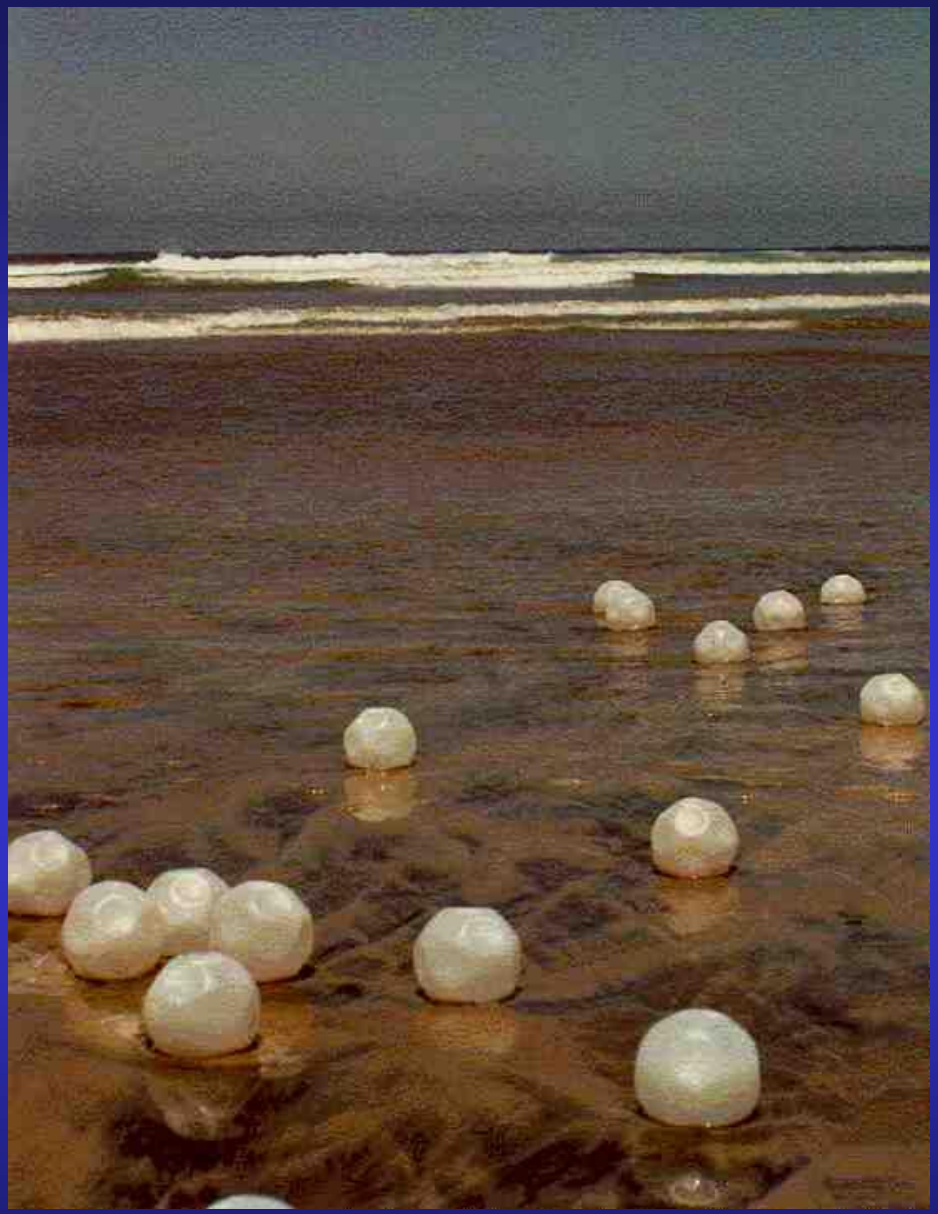
Time of Use Rates (TOU)

Real Time Pricing (RTP)

Time Sensitive Demand Building Codes

Smart Meters - Interval Meters

National or State Energy Policy



No - they don't grow in the ocean. Ice Balls are Manufactured in California.
More than 20 Million Ice Balls shipped since 1990.