DTSi Dirrecktor Thermal Sciences, Inc.

REFRIGERATED WATER STORAGE SYSTEM

Air Conditioning, Process Cooling/Heating

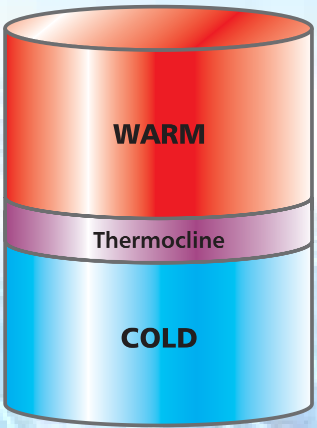
New Construction and Retrofits

STRATIFIED REFRIGERATED WATER TES SYSTEM BENEFITS

LOWER INITIAL CAPITAL COSTS
- Reduce cooling equipment capacity & cost
- Utility Company offers incentives & rebates on electricity tariffs
- Reduce numbers of chillers, cooling towers, pumps & piping sizes

LOWER OPERATING COSTS
- Number of chillers running during peak demand period can be reduced significantly
- Chiller operate & charge storage during off-peak demand period
- Cheaper utility tariff during off-peak demand period

LOWER MAINTENANCE COSTS
- Cheaper maintenance cost for smaller equipment
- Stratified water TES system is high in reliability & low in maintenance cost



ENVIRONMENTALLY FRIENDLY
- Use fresh water as storage medium
- No chemical or brine solution is required

QUICK PAYBACK
- With many offers & rebates from utility company, payback period for cost invested into TES plant equipment could be recovered quickly in 2 ~ 5 years.

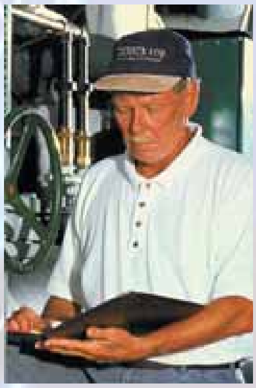
FLEXIBILITY
- Building cooling load demand can be met by either operation of chiller or TES system tank or by both of them.

RELIABILITY
- Predictable performance with high in reliability & repeatability

STRATIFIED REFRIGERATED WATER THERMAL ENERGY STORAGE (TES) SYSTEMS

Theory

Dirrecktor, Inc., has had the unfettered opportunity to observe the operations of a large number of Stratified Water TES Systems, both of the Dirrecktor patented designs and other designs. The knowledge gained from this experience yields a professional, first-hand understanding of the theory and practice of stratified water TES Systems.



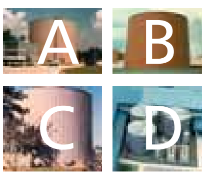
The mechanisms that operate in a Stratified Water TES System are related to both the physical properties of fresh water and the hydraulic characteristics of the stratification inducing pipework.

The two physical properties of water that are of special interest to the TES design engineers are:

1. **The Density as it varies with Temperature.**
2. **The Kinematic Viscosity at it varies with Temperature.**

These two properties provide the basic mechanism for successfully stratifying water of different temperature within a single containment vessel. The density difference between two liquids at different temperature creates buoyancy forces, which cause the warm liquid to be literally floated on top of the cool liquid. The relatively large difference in Kinematic Viscosity of liquids separated only by a few degrees in temperature suppresses any mixing of the two fluids, due to flow disturbances and free convection at the vessel walls.

The two properties of water of interest both vary in the direction of increased temperature that makes water the ideal candidate for TES Systems. That is, Density and Kinematic Viscosity both decrease with increased temperature above 4.0 Deg C.



Front cover photographs
A) Channel View High School, 1995-5200 RTH, Stratification Tank.
B) West Mesquite High School, 1996-5600 RTH, Stratification Tank.
C) Brevard Community College, 1995-4800 RTH, Stratification Tank.
D) Hill Elementary School, 1988-2500 RTH, Empty Tank.

TES SYSTEMS OPERATING STRATEGY

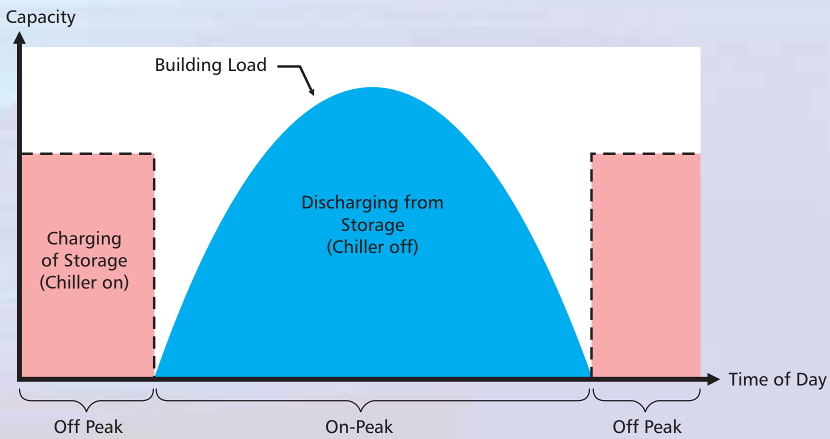
The operating strategy determines when the TES systems charge and discharge water to give maximum savings in operational cost. The main strategy is to capitalize on off-peak low utility tariff periods to charge the Chilled Water Storage (CHWS) tank and discharge during on-peak high utility tariff periods to cool the building. This will reduce the numbers of chillers running during on-peak period thus lowering electricity cost and maximum demand charges.

Basically there are two main operating strategies to adapt to:

FULL STORAGE SYSTEM

In the full storage system, maximum saving is achieved by fully utilizing the CHWS tank during on-peak period. During this period, chilled water is discharged from the tank to cool the building without running any chillers. Prior to discharging the chilled water from the tank, it will first need to be charged and this is done usually at night when the utility rate is at the lowest.

Full storage system requires more storage capacity and bigger plant equipment capacity thus incurring high capital cost investment.

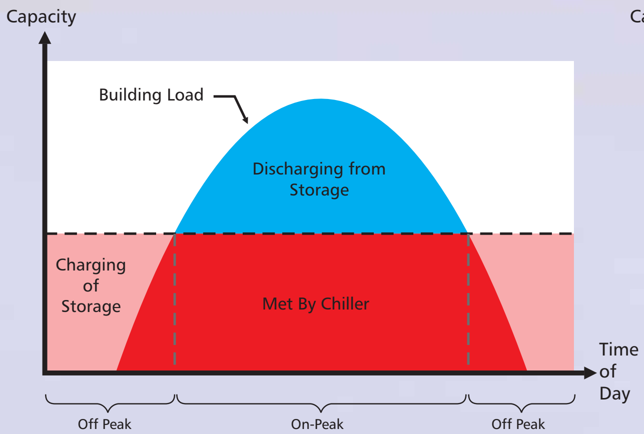


FULL STORAGE

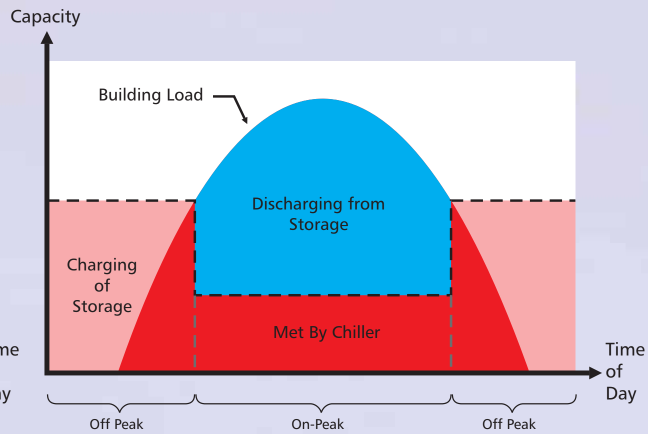
PARTIAL STORAGE SYSTEM

Partial storage strategy utilizes both the chiller and CHWS tank discharge to cool the building load at the same time. Most of the building cooling load is met by discharging chilled water from the tank and utilizes little cooling from the chillers. This will give significant operation cost saving by using less number of chillers during on-peak period.

This operating strategy utilizes less storage capacity and smaller plant equipment capacity thus lowering the capital cost investment of the system.



PARTIAL STORAGE - LOAD LEVELING

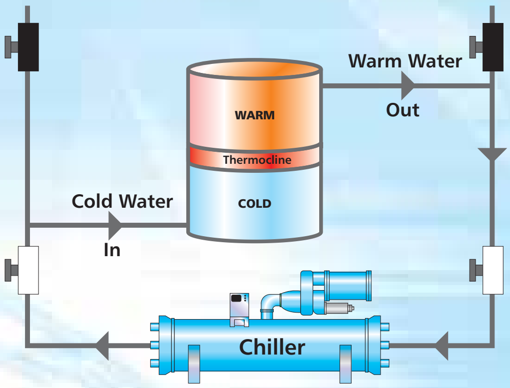


PARTIAL STORAGE - DEMAND LIMITING

CHILLED WATER STORAGE SYSTEM OPERATION

Charging of CHWS Tank during Off-Peak Period

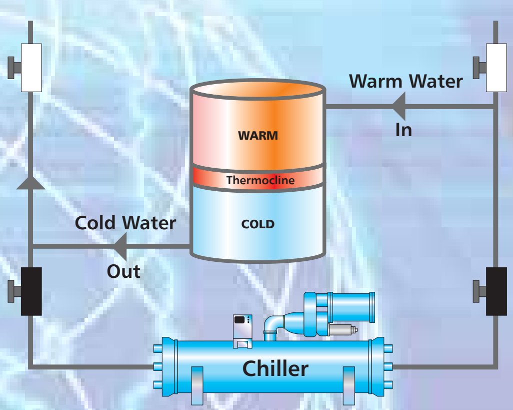
During charging mode operation, chilled water from the chiller is pumped into the tank bottom diffuser. The cold and dense water will remain at the bottom of the tank forming a layer of cold water. A thermocline layer is formed between the chilled water and the warm water, which prevents them from mixing. As more and more chilled water is pumped into the bottom of the tank the warm water is displaced and the thermocline layer rises. The warm water exits through the top diffuser of the tank and returns to the chiller to form a continuous loop. The volume of water in the tank remains the same.



CHARGING CHILLED WATER STORAGE

Discharging of CHWS Tank during On-Peak Period

When cooling is needed, chilled water is withdrawn from the bottom of the tank and pumped to the building air-handling unit for cooling. The warm water from the building air-handling unit is then pumped back to the top of the tank to form a loop. Now the CHWS tank takes over the function of the chiller to cool the building (Full storage) or sharing the building load with the chiller (Partial storage).



DISCHARGING CHILLED WATER STORAGE

PROJECT PROFILE

BATHESDA MEMORIAL HOSPITAL

Bathesda Memorial Hospital

Cooling System	Refrigerated Water
Peak Cooling load	1,150 Ton-hours
TES System	
TES type	Stratified Refrigerated Water, Atmospherically pressurized
Reservoir Sizes	65 Feet Diameter x 40 Feet high
Operating Temperature	Charging - 41°F Discharging - 42°F Spent Water - 56°F
Total Storage Capacity	10,100 RTh
Available Storage capacity	9,125 RTh
Maximum Usable Storage Capacity	9,480 RTh

DTSI WATER STRATIFICATION TES SYSTEM

DTSI offers the design of Stratified water TES Systems that successfully keeps the warm and cool water volumes separated by a minimum volume of mixed water. The performance of the CHWS tanks is a function of both the Stratification header design and the aspect ratio of the CHWS tank.

Thermocline Thickness:

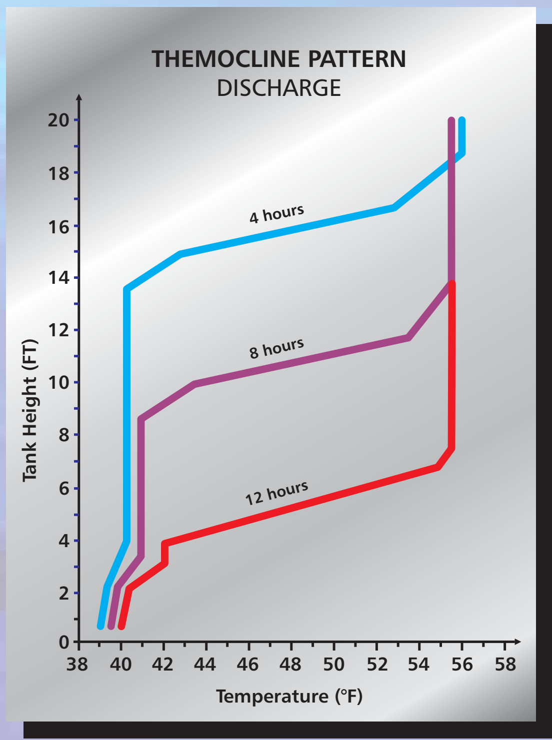
The thickness of the thermocline is a function of the stratification header design and the flow rate through the header. Typical thickness varies from 0.7 to 1.3 meters. With the Dirrecktor system header, the harder the system is pumped, the narrower the thermocline becomes, up to the point where the water collision velocity with the tank shell equals the fall rate of the thermocline. Beyond the critical velocity, sag is introduced into the thermocline causing ripple action and thermocline thickness growth. The typical Dirrecktor Thermocline thickness is within 0.5 to 0.8 meters.

Hydraulic Pressure Drop

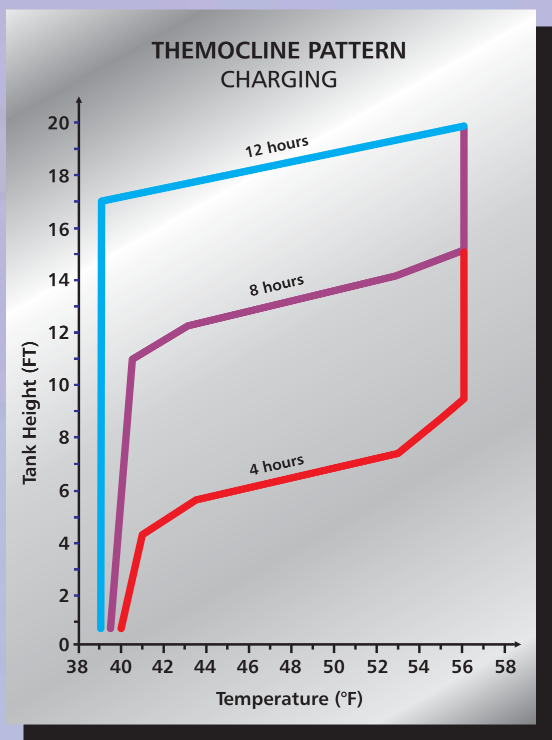
The pressure drop in the Dirrecktor header system is typically below 1 Psig of water at rated Flow. The design utilizes a directed flow splitting approach to evenly distribute the water to the expulsion nozzles. The nozzles are distributed radically around the area centroid of the tanks, and the directed flow dividing elements of the system assure that each nozzle is fed with the same volume of water. The flow velocity is gradually reduced in the header system from 1.5 M/s in the feeder pipework to 0.1M/s at the nozzle exit. The large circular nozzles expel the water parallel to the water surface or tank base, inducing secondary water movement only in a parallel layer. The results are superior hydraulic and thermocline performance.

Thermocline Formation

The thermocline is formed over the stratified region, This natural stratification gives added advantageous over other cold and water separation method. The thermocline is formed at steep temperature gradient changes of the chilled water, usually in the temperature region of 42°F to 60°F. This acts as a natural barrier that separates the colder and denser water from the warm and less dense water. The thinner the thermocline layer, the chance for temperature mixing reduces. The thermocline layer rises in a stable condition as the storage is charged longer. Figure 1 & 2 shows the typical discharge thermocline pattern and the typical charging themocline formation after different hours of charge time.



Typical Discharge Thermocline Pattern
FIGURE 1

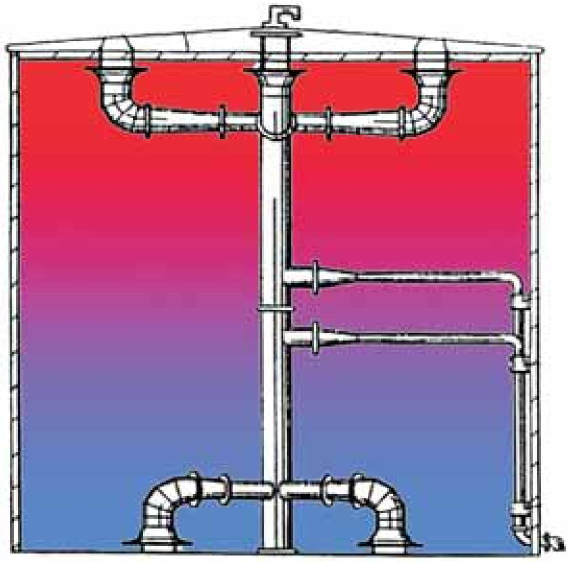


Typical Charging Thermocline Pattern
FIGURE 2

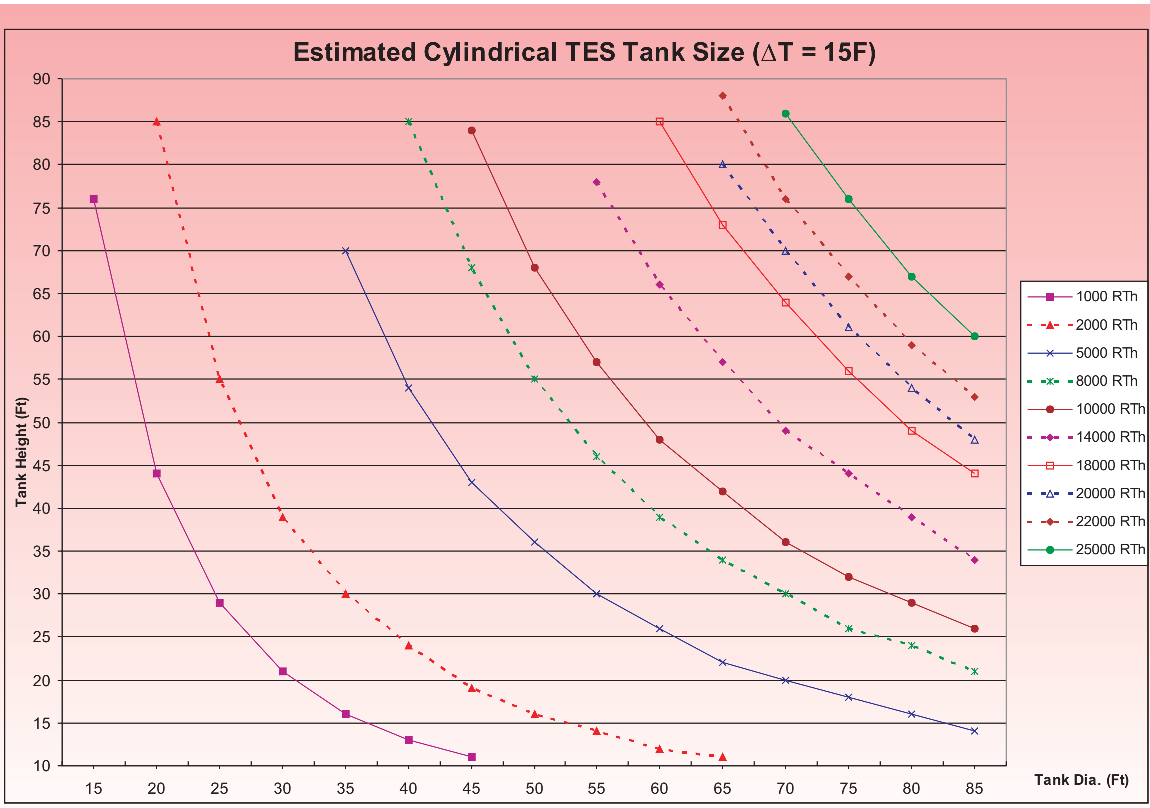
DTSI PATENTED DIFFUSER PIPING SYSTEM

DTSI CHWS tank incorporates a water distribution system including a generally centrally positioned, vertically-oriented pipe extending from the bottom to about the top of the tank. A flange is positioned about mid-way of the pipe for separating an upper section of the pipe from a lower section. A water return line is coupled to the pipe above the flange and a water extraction line is connected to the pipe below the flange.

A plurality of circumferential spaced cool water conduits are connected to the pipe generally adjacent to the top of the tank. Each of the conduits comprises a first section radially extending from the pipe, a 90° elbow coupled to the first section and a bell-shaped diffuser coupled to the elbow. An apparatus is connected between each outlet and a tank support structure holds each of the upwardly turned outlets in a common horizontal plane. The support apparatus positions each of the outlets in a level plane so that water exiting the outlets flows uniformly from all edges of each outlet.

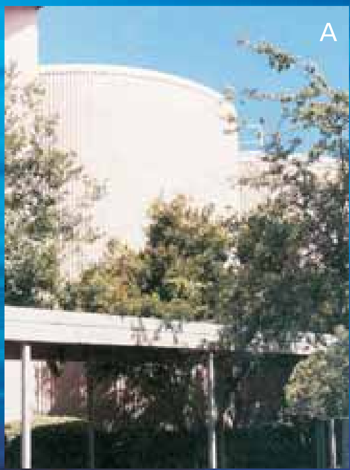


DTSi Diffuser Pipe System



DTSi

Dirrecktor Thermal Sciences, Inc.



A) A.C. Neilsen Company, 1983-7,000 RTH, Stratification Tank.
B) Chico's Distribution Facility, 2003-4000 RTH, Stratification Tank.
C) The Kingdom Center, 2000-28000 RTH, Stratification Tank.
D) Pioneer Federal Bank, 1980-3200 RTH, Stratification Tank.

DIRRECKTOR Thermal Sciences Inc.
Florida, USA.

COMPANY OVERVIEW

Dirrecktor Thermal Sciences, Inc. was incorporated in 1995. DTSi has the technical expertise to design and construct stratified water thermal energy storage, and state of the art pumping and control systems dating back to 1979. It was in the same year that DTSi designed and constructed the first purpose built stratified chilled water storage system.

Since that time, DTSi has a project portfolio in excess of more than forty TES systems, including 35,000 tons of chillers with 200,000 RTh of thermal energy storage. At DTSi, Thermal Energy Storage Systems is a matured and well-understood technology that is employed with professional confidence derived from years of hands-on experience. We have established sound engineering principles for the technologies applications that offer a cost and time effective method of design implementation. DTSI, Engineering, Procurement & Construction (EPC) systems are delivered on time, developed within budget, commissioned rigorously, and operate properly.

ANMAS CORPORATION SDN BHD
(404787-H)

No. 175B, Jalan SS2/24, 47300 Petaling Jaya,
Selangor Darul Eshan, Malaysia.
Tel: (603) 7873 6606, Fax: (603) 7873 6676
Email: mail@anmascorp.com
Website: **www.anmascorp.com**