

# TSU

## Thermal Storage Products

*Thermal Storage Products*



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# ICE CHILLER® Thermal Storage Products

## General Description

Cooling with ice thermal storage can be the most cost-effective, reliable system approach to cooling offices, schools, hospitals, malls and other buildings, and provides a steady source of low temperature fluids for process cooling applications. These systems are environmentally friendly because they help lower energy consumption and reduce greenhouse gas emissions. With thousands of successful installations worldwide, BAC is the global leader in the application of ice thermal storage.

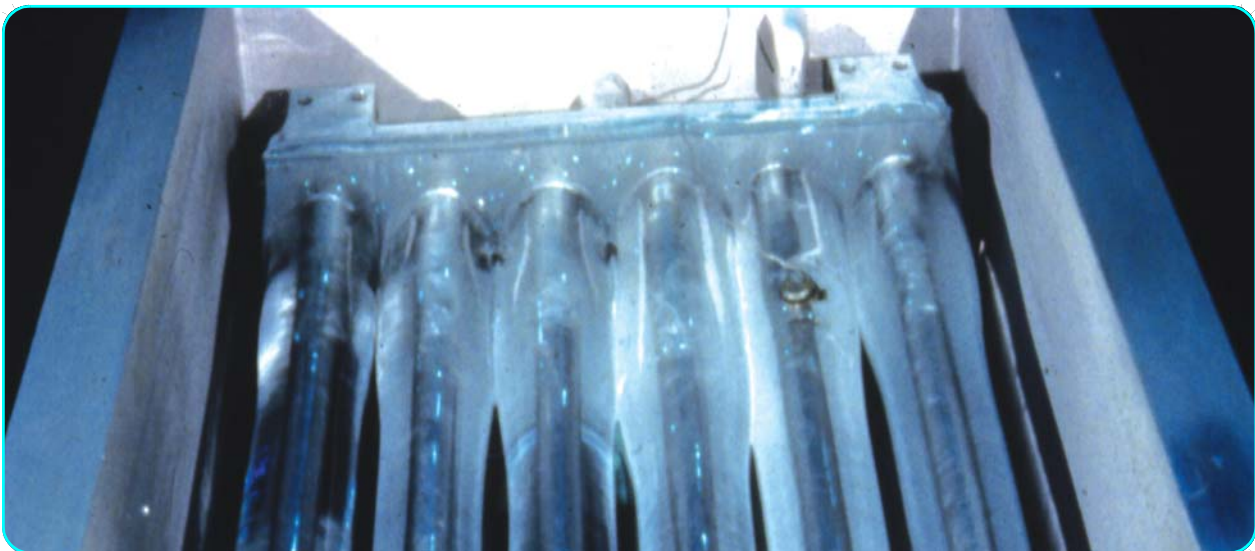
## Key Features

- Lowest first cost
- Reduced energy cost
- Variable capacity
- Improved system reliability
- Reduced maintenance
- Environmentally friendly
- Proven technology





*Thermal Storage Products*



*... because temperature matters*





# Benefits

## Lowest First Cost

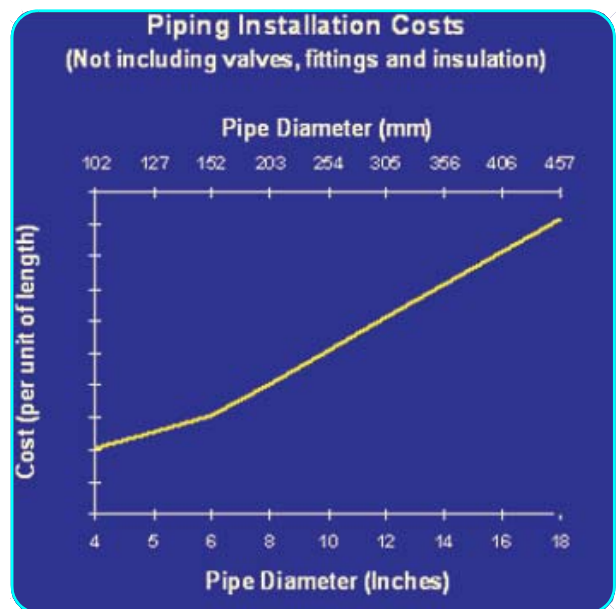
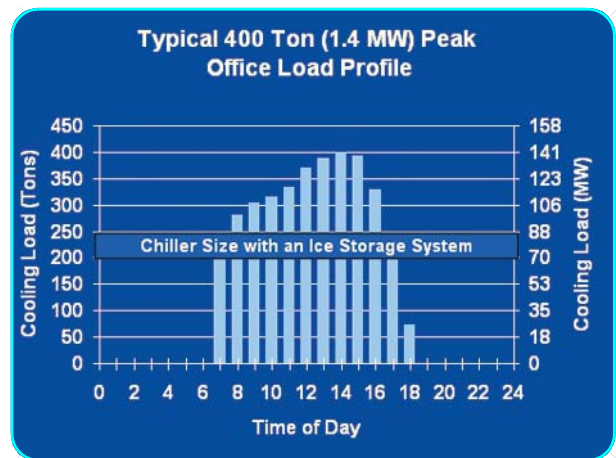
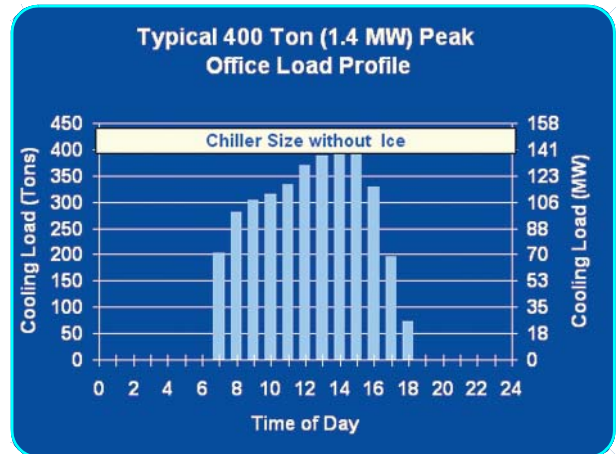
Systems with ice thermal storage can be installed at the same or lower first cost than traditional systems when designed with the colder supply water available from ice. The savings that result from the use of smaller chillers and cooling towers, reduced pump and pipe sizes and less connected horsepower, offset the cost of the ice thermal storage equipment. Additional savings can be found when using lower temperature air distribution, which allows reduced ductwork and fan sizes.

- **Smaller Chillers and Heat Rejection**

**Equipment:** By designing the system around 24-hour per day chiller operation, the size of the chillers and cooling towers or air-cooled condensers required for an ice system is significantly reduced, when compared to conventional chillers and heat rejection equipment sized for the instantaneous peak load. A typical thermal storage design includes chillers that provide 50 to 60% of the peak cooling load. The balance of the cooling requirement is provided from the ice storage system.

- **Reduced Pump and Pipe Sizes:** Pump and pipe sizes are also reduced in a properly designed ice storage system. Substantial savings in the chilled water distribution loop are realized when the system design incorporates reduced flow rates that result from using a larger temperature range in the water loop. Use of a larger temperature range, for example 10°C instead of the more traditional 5.5°C temperature range results in a reduction of pipe size. Condenser water pipe sizes are reduced due to lower flow requirements for the smaller chiller. Pump savings due to reduced chilled water and condenser water flow rates are also realized.

- **Reduced Cooling Coil and Supply Air Fan Sizes:** Cooling coils sized using lower supply water temperatures and traditional supply air temperatures are generally smaller due to fewer rows. The reduction in rows leads to lower supply fan kW.

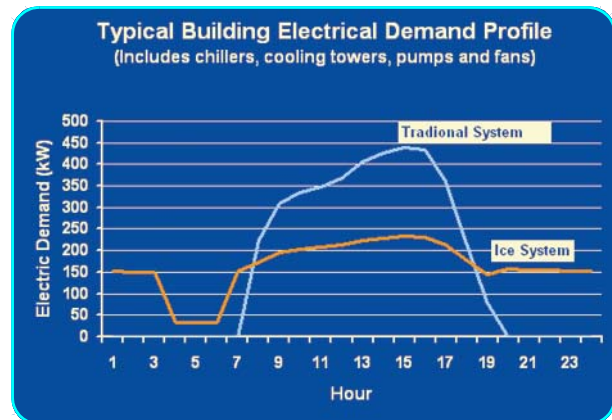


- **Reduced Air Handling Equipment:** When the air distribution is designed with lower supply air temperatures, the size of the ductwork, fans and fan motors are reduced.
- **Reduced Electrical Distribution:** Smaller chillers, heat rejection equipment and pumps require less horsepower than a traditional system, which results in smaller transformers, switchgear, wire sizes and starter panels.
- **Reduced Generator Size:** If a facility has a generator for daily or back-up power, the size of the generator will be significantly reduced when the peak electrical load of the facility is reduced using ice storage.

## Reduced Energy Cost

An ice thermal storage system reduces peak demand, shifts energy usage to non-peak hours, saves energy, and reduces energy costs.

- **Reduces Peak Demand and Shifts Energy Usage:** With less connected horsepower, ice storage can lower peak electrical demand for the HVAC or process cooling system by 50% or more. Since most electrical rates include demand charges during peak demand times and/or higher day versus night kWh charges, savings on electrical bills can be substantial. In areas with "real time pricing", where the electric rate varies hour by hour based on the market price of electricity, day to night kWh costs can vary by 500 to 1000%. The use of electricity at night versus peak daytime hours can lead to large savings on energy bills.



- **Saves Energy:** In addition, total annual kilowatt-hours used are less when the system is designed taking advantage of the low supply water temperature available from the ice storage system. Lower kWh consumption is possible for five reasons:
  1. Although making ice requires more energy than producing chilled water, the efficiency penalty is not as large since the ice is made at night when condensing temperatures are lower, increasing the efficiency of the chiller.
  2. Ice systems typically operate the chiller at full load. Chillers are inefficient when run with low loads during the spring and fall. A typical chiller will operate at less than 30% capacity for half the year.
  3. Reduced pumping horsepower.
  4. Reduced fan horsepower due to lower air pressure drop across the cooling coil. A higher chilled water temperature differential across the cooling coil usually results in fewer rows and therefore a lower pressure drop.
  5. The ability to recover waste heat from the chiller for heating water both night and day.

Additional kWh savings are possible if the air distribution is designed to take advantage of the low temperatures available from the ice storage system. As the electric industry continues to deregulate, and time-of-use rates, real time pricing schedules and negotiated power prices become standard, ice storage can provide even greater future savings in operating costs.

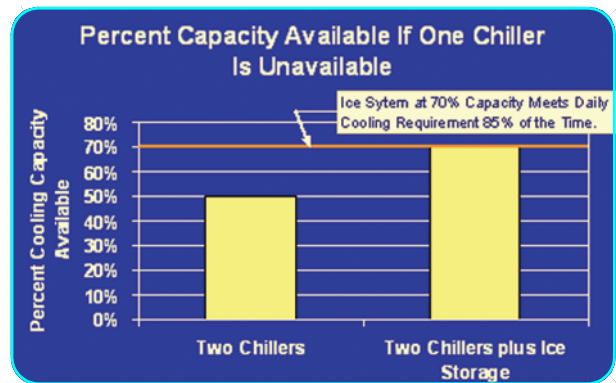
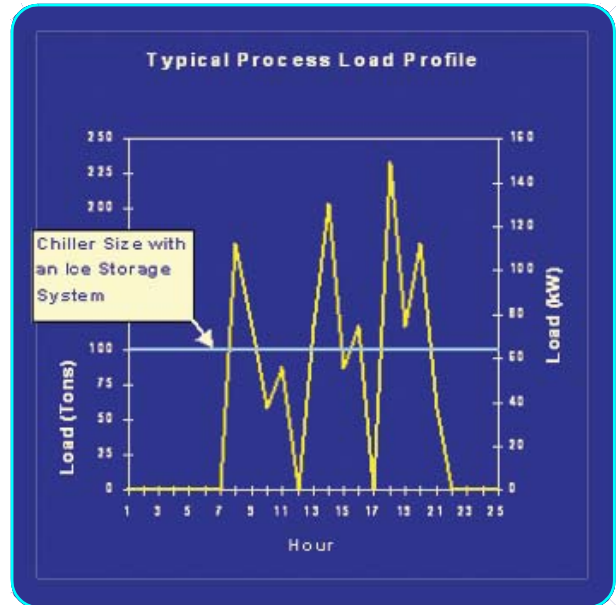
### Variable Capacity

The ice thermal storage system will maintain a constant supply temperature regardless of the variations in instantaneous cooling demand. The flow and entering water temperature set the instantaneous capacity.

### Improved System Reliability

Ice storage systems provide the reliability necessary to ensure air-conditioning is available. With traditional systems, installing multiple chillers provides redundancy. In the event of a mechanical failure of one chiller, the second chiller provides limited cooling capacity. The maximum available cooling for the traditional system would only be 50% on a design day.

Most ice storage systems utilize two chillers in addition to the ice storage equipment. Two chillers are designed to provide approximately 60% of the required cooling on a design day while the ice storage provides the remaining 40% of the cooling capacity. In the event only one chiller is available to provide cooling during the day, up to 70% of the cooling capacity is available. The one operable chiller provides 30% of the cooling requirement while the ice provides up to 40%. Based on typical HVAC load profiles and ASHRAE weather data, 70% of the cooling capacity would meet the total daily cooling requirements 85% of the time.



### Reduced Maintenance

The ice thermal storage coils have no moving parts so very little maintenance is required. Because the chillers, pumps and heat rejection equipment are smaller, ice storage systems will have less maintenance than a traditional system. The ice thermal storage system also allows a chiller to undergo routine maintenance during the day when the ice storage can handle the system load.

### Environmentally Friendly

Reducing energy consumption and using electricity at night will reduce global warming. Electricity generated at night generally has a lower heat rate (lower fuel use per power output), and therefore lower carbon dioxide and greenhouse gas emissions resulting in less global warming. The California Energy Commission concluded that the use of electricity at night created a 31% reduction in air emissions over the use of electricity during the day.

With smaller chillers, an ice thermal storage system reduces the amount of refrigerant in a system. Most refrigerants in use today are slated to be banned in the future under the Montreal Protocol because they contribute to global warming. Using smaller amounts of refrigerant helps to save the ozone and reduce global warming.



## Proven Technology

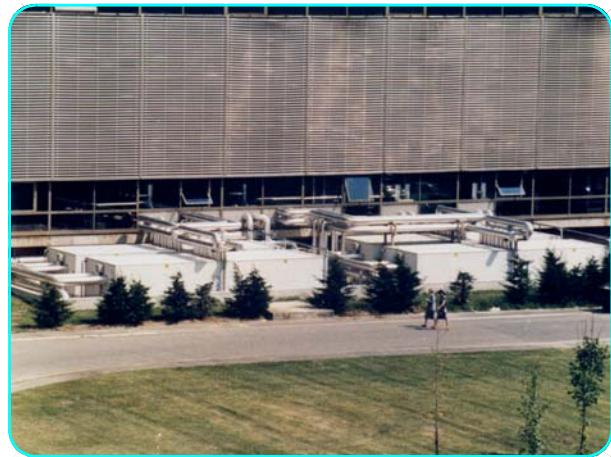
BAC has successfully applied ice thermal storage technology to thousands of installations worldwide. BAC has the application and system experience to assist you in the design, installation and operation of your ice storage system. B.A.C. has supplied ICE CHILLER® Thermal Storage Products for projects that range in size from 90 to 125,000 ton-hours (0,3 to 441,3 MWh). Installations include office buildings, hospitals, manufacturing processes, schools, universities, sports arenas, produce storage facilities, hotels and district cooling applications.

The ICE CHILLER® Product line includes a variety of factory-assembled units. For large applications, where space is limited or factory-assembled units are not cost effective, ICE CHILLER® Thermal Storage Coils are available for installation in field-erected tanks.

The BAC product offering provides system design flexibility. Ice can be built using ammonia or various glycols on steel coils and is used to provide either chilled water or glycol to the cooling system. This flexibility, combined with a broad range of application experiences, allows B.A.C. to provide a cost-effective product to meet your specific requirements.

### CNES - Toulouse (France)

The cooling plant of the Centre Nationale d'Etudes Spatiales (CNES) in Toulouse, incorporated 3 centrifugal chillers, each 3 MW cooling capacity. As the facilities grew in size over the years, the plant became short of capacity on peak cooling load days. Rather than adding another chiller to increase the maximum cooling capacity, CNES wanted a more energy and cost efficient solution. An 11 MWh Ice Thermal Storage System, proved to be the most economical. During daytime the chillers run continuously at maximum capacity and thus at highest efficiency. At night ice is built to take advantage of the lower off-peak electricity costs.



CNES

### CSELT - Turin (Italy)

Designing a high quality and reliable climate control system with a low first cost and a low operating cost for the new CSELT (Centro SIP Elaborazione Telecomunicazioni) Research Centre was an ambitious goal. This requirement however was fully met by using standard glycol chillers with a 13 MWh BAC Thermal Storage System. During the night ice is built to provide part of the cooling capacity for the next day. In the daytime the water from the cooling load is first cooled by the chillers and then further cooled to the design temperature by the BAC Thermal Storage System. This series arrangement, with the chiller upstream in the most favourable position, is only possible due to the high melt off capacity offered by the BAC ICE CHILLER® which guarantees a constant low leaving water temperature from the Thermal Storage System.



CSELT

### Academic Hospital - Groningen (Netherlands)

The cooling for the HVAC system in the new Academic Hospital in Groningen is provided by a standard 650 kW glycol chiller and a 6 MWh BAC ICE CHILLER® Thermal Storage System. The system design makes full use of the low leaving water temperatures available from the ICE CHILLER® Thermal Storage System by placing the chiller upstream and in series with the ICE CHILLER®. This provides the most economical solution, an overall low energy cost and a great flexibility in the cooling plant operation.



Academic Hospital

### KBC - Leuven (Belgium)

This new 90.000 m<sup>2</sup> building for the KBC bank headquarter has a total daily cooling load of 26 MWh with a peak of 3 MW. The HVAC system selected by the owner included a Thermal Storage System because of its low first cost, economical operating cost and high system reliability. A 1 MW chiller combined with a 10 MWh BAC Thermal Storage System can easily satisfy the 3MW peak cooling load. Energy costs are lower than with a conventional system because electrical demand charges and expensive day rates are reduced to a minimum.



KBC Bank

### Granada Centre - Riyadh (Saudi Arabia)

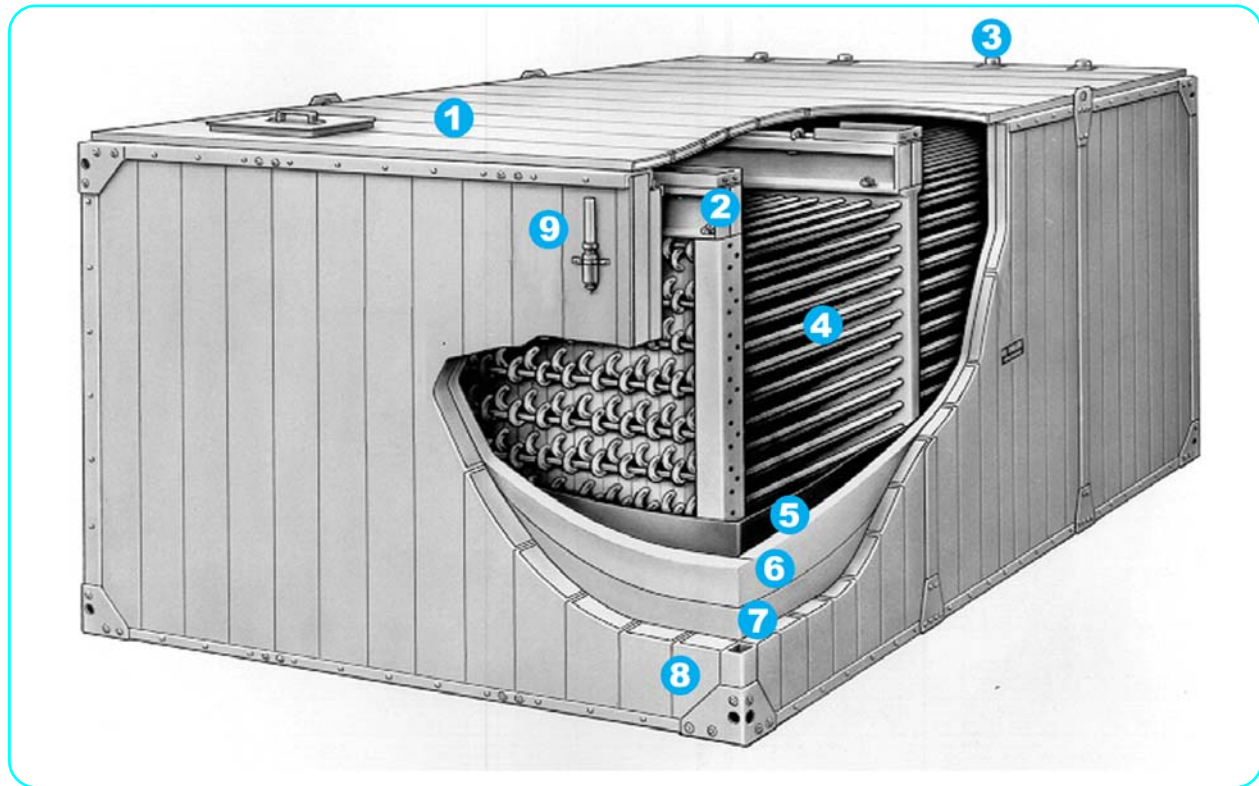
The designers of the Granada Centre in Riyadh, Saudi Arabia were confronted with a limited electrical power supply to the new site. This forced the client to consider all possible load shifting alternatives. After careful review of the available options it was decided to limit the power demand of the chillers and shift the generation of cooling to off-peak periods. From the maximum cooling demand, being 14.250 kW, about 8.000 kW is delivered directly by the chillers. The remaining cooling will come from the ice storage units. The ice storage plant includes 22 ice storage tanks model TSU 761 M with a total ice storage capacity of 58.800 kWh.



Granada Centre



# Construction Details TSU-M - Internal Melt Application



## 1. Covers

- Watertight
- Heavy-gauge Z600 Hot-dip galvanized steel panels
- Insulated with 50 mm extruded polystyrene insulation

## 2. Coil Support Beams

- Prevent contact between coil and primary liner

## 3. Glycol Connections

- Threaded connections
- Flanged connections (optional)

## 4. Galvanised Steel Coil

- Hot-dip galvanized after fabrication (HDGAF)
- Steel tubing, encased in a steel framework
- Pneumatically tested at 13 bar
- Rated for 10 bar operating pressure

## 5. Primary Liner

- Single piece

- 48-hour integrity test before shipment

## 6. Extruded Polystyrene Insulation

- 110 mm of total insulation
- 20 mm of insulation between primary and secondary liner
- Contributes to total insulating value of 3,1m°C/W

## 7. Secondary Liner/Vapor Barrier

- Prevents moisture from penetrating through the insulation

## 8. Wall Panel

- Heavy-gauge galvanized steel with double brake flanges
- Extruded polystyrene insulation
- Contributes to total insulating value of 3,1m°C/W

## 9. Sight Tube

- Visual indicator of the amount of ice remaining in unit

## 10. Ice Inventory Sensor (Optional) - Not Shown

- Mechanical Water Level Difference Transmitter provides an electrical 4-20 mA output signal which is proportional to the amount of ice in inventory

## Custom Coils for Internal Melt Application (TSU-M)

BAC will manufacture custom ICE CHILLER<sup>®</sup> Thermal Storage Coils to meet project specific requirements. BAC has done extensive research and testing on the build and melt characteristics of ice storage. This research and testing has resulted in selection capabilities unmatched by any other company in the industry.

BAC can predict the temperatures required on an hour by hour basis for building ice on custom coils, over a variety of conditions and build times. The physical space available, load profile, discharge temperatures, chiller capacity and operating sequences can be evaluated to find the design that best meets the application.

The ICE CHILLER<sup>®</sup> Thermal Storage Coils are constructed of continuous 26,7 mm O.D. all prime surface serpentine steel tubing. The coils are assembled in a structural steel frame designed to support the weight of the coil stack with a full ice build. After fabrication the coils are tested for leaks using 13 bar air pressure under water, then hot-dip galvanized for corrosion protection.

The coils are configured to provide countercurrent glycol flow in adjacent circuits for maximum storage capacity.

Individual coils can be factory-assembled into modules of two (2) coils for optimization of transport cost and reduction of site assembly time. Glycol manifolds are coated with zinc-rich, cold galvanizing finish at the factory. Necessary support steel and lifting lugs are provided on the modules to allow for lifting into and final positioning within the storage tank.

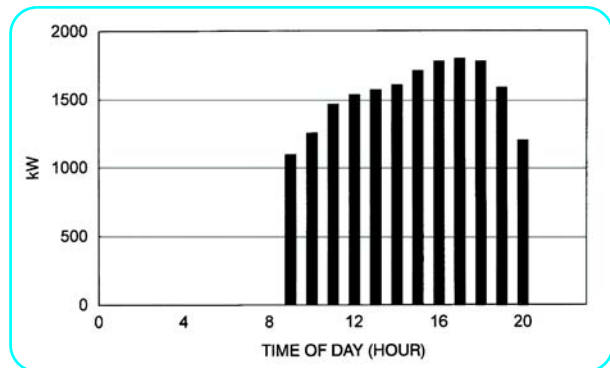
## Load Profile

A daily load profile is the hour-by-hour representation of cooling loads for a 24-hour period. Most HVAC applications use a daily load profile to determine the amount of storage required. Some HVAC systems apply a weekly load profile. For conventional air-conditioning systems, chillers are selected based on the peak cooling load. For ice storage systems, the chillers are selected based on the kWh of cooling required and a defined operating strategy. Thermal storage systems provide much flexibility for varying operating strategies as long as the total kWh selected are not exceeded. This is why an accurate load profile must be provided when designing an ice storage system.

Load profiles take many different shapes based on the application. The figure above illustrates a typical HVAC load profile for an office building with a 1750 kW peak cooling load and a 12-hour cooling requirement. The shape of this curve is representative of most HVAC applications. For preliminary equipment selections, BAC's ICE CHILLER<sup>®</sup> Thermal Storage Unit Selection Program can generate a similar load profile. Information required is the estimated building peak cooling load and duration of the cooling load.



Installation of Coil Module



Typical HVAC Load Profile

... because temperature matters



The Air-Conditioning & Refrigeration Institute (ARI) has published Guideline T, "Specifying the Thermal Performance of Cool Storage Equipment." The purpose of Guideline T is to establish the minimum user specified data and supplier specified performance data. Design data provided by the engineer includes: System Loads, Flow Rates and Temperatures.

## Operating Strategies

Once the load profile is generated, the next step in selecting Thermal Storage equipment is to define an operating strategy or in other words, determine the hours per day during which the glycol chiller is allowed to operate.

Which operating strategy to use is dependent upon the load profile (application), the utility rate structure, the energy cost and the equipment first cost. In other words, the economical balance between the system installation and operating cost or the payback period must be calculated.

There are 2 different operating strategies, either full or partial storage.

**Full Storage Systems** store all the cooling capacity required during the off peak periods and eliminate the need to operate the chiller(s) during the utility on-peak period. This strategy shifts the largest amount of electrical demand and results in the lowest operating cost. However, the equipment first cost is considerably higher than partial storage systems due to larger chiller and storage requirement and full storage is therefore seldom used.

**Partial Storage Systems** require that the chiller(s) operate also during the on-peak period. The partial storage system allowing the glycol chiller to run for 24 hours per day at its full capacity is most commonly used as it results in the smallest chiller selection. In many cases, the smaller chiller selection is the driving force for an ice storage system because of lower installed electrical kW, smaller refrigerant charge, smaller cooling towers or other heat rejection equipment (lower noise), smaller standby chillers (if required), lower capital and maintenance cost, ...

Other partial storage operating strategies stop the chiller a few hours per day when electricity cost are high and/or where non-cooling electricity usage are important (so when the chiller operation would increase the electrical demand). It is however important to know that the more hours the chiller is stopped during the day, the larger its size will be. Furthermore, if the chiller is stopped during the cooling period, the size of the storage equipment needs to be increased. If the chiller is stopped during the non-cooling period, the ice build time is reduced and therefore lower glycol temperatures are required and the chiller COP is reduced.

Besides determining when the chiller should run or be stopped, an other aspect of operating strategy is if during melt-out, priority is given to the chiller or to the ice to cover the presented cooling load.

In a **chiller priority system** the chiller always operates at full capacity. When the cooling load exceeds the chiller performance, the excess is covered by the melting ice. A constant portion of the load is covered by the chiller while the variation in load is covered by the ice.

In an **ice priority system**, a constant part of the load is covered by the ice, where the variation in load is taken by the chiller. Because the chiller does not continuously operate at its maximum capacity, it will be oversized versus the chiller priority system. Ice priority systems result in oversized ice and chiller selections and are therefore seldom used.

Normal practice is that partial storage systems using chiller priority with 24h chiller operation are most commonly used.





## Modes of Operation

The modular ICE CHILLER<sup>®</sup> Thermal Storage Unit can operate in any of five distinct operating modes. These modes of operation provide the flexibility required by building operators to meet their daily HVAC cooling requirements.

**Ice Build:** In this operating mode, ice is built by circulating a 25% solution (by weight) of inhibited ethylene glycol at negative temperatures through the coils contained in the ICE CHILLER<sup>®</sup> Thermal Storage Unit. During this operating mode, the chiller's operating conditions are monitored and the chiller is turned off when the minimum supply glycol temperature off the chiller is reached. Optionally, the ICE LOGIC Ice Quantity Meter is available to control the chiller operation. The figure illustrates typical chiller supply temperatures for 8, 10 and 12 hour build cycles.



Chiller Supply Temperatures

For a typical 10-hour build time, the supply glycol temperature is never lower than  $-5,5^{\circ}\text{C}$ . As the graph illustrates, for build times exceeding 10 hours, the minimum glycol temperature is greater than  $-5,5^{\circ}\text{C}$ . For build times less than 10 hours, the minimum glycol temperature will be lower than  $-5,5^{\circ}\text{C}$  at the end of the build cycle. This performance is based on a chiller flow rate associated with a  $3^{\circ}\text{C}$  range. When a larger temperature range is the basis of the chiller selection, the chiller supply temperatures will be lower than shown in the figure above.

**Ice Build with Cooling:** When cooling loads exist during the ice build period, some of the cold ethylene glycol used to build ice is diverted to the cooling load to provide the required cooling. The amount of glycol diverted is determined by the building loop set point temperature. BAC recommends that this mode of operation be applied on systems using primary/secondary pumping (See further for system schematic). This reduces the possibility of damaging the cooling coil or heat exchanger by pumping cold glycol, lower than  $0^{\circ}\text{C}$ , to this equipment.

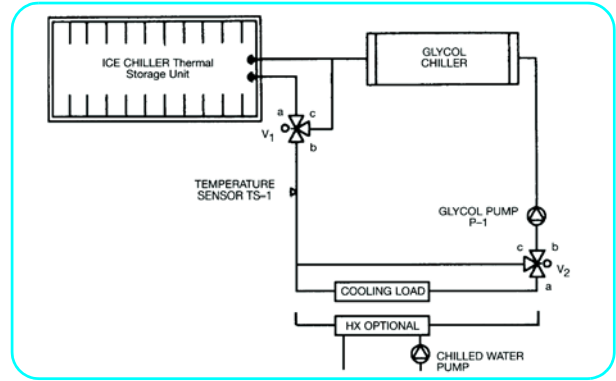
**Cooling – Ice only:** In this operating mode the chiller is off. The warm return ethylene glycol solution is cooled to the desired set point temperature by melting ice stored in the modular ICE CHILLER<sup>®</sup> Thermal Storage Unit.

**Cooling – Chiller only:** In this operating mode the chiller supplies all the building cooling requirements. Glycol flow is diverted around the thermal storage equipment to allow the cold supply glycol to flow directly to the cooling load. Temperature set points are maintained by the chiller.

**Cooling – Ice with Chiller:** In this operating mode, cooling is provided by the combined operation of the chiller and thermal storage equipment. The glycol chiller pre-cools the warm return glycol. The partially cooled glycol solution then passes through the ICE CHILLER<sup>®</sup> Thermal Storage Unit where it is cooled by the ice to the design temperature.

### System Schematics

Two basic flow schematics are applied to select ICE CHILLER® Thermal Storage Units. The figure illustrates a single piping loop with the chiller installed upstream of the thermal storage equipment. This design allows the thermal storage system to operate in four of the five possible operating modes. They are Ice Build, Cooling-Ice Only, Cooling-Chiller Only and Cooling-Ice with Chiller.



Single loop – Chiller Upstream

For this figure the following control logic is applied:

MODE	CHILLER	P-1	V-1	V-2
Ice Build	On	On	A-B	C-B
Cooling – Ice Only	Off	On	Modulate	A-B
Cooling – Chiller Only	On	On	C-B	A-B
Cooling – Ice with Chiller	On	On	Modulate	A-B

Valve V-1 modulates in response to temperature sensor, TS-1. Valve V-2 could be positioned to either maintain a constant flow, less than P-1, or modulate in response to the return glycol temperature from the cooling load.

When the building loop contains chilled water, a heat exchanger must be installed to separate the glycol loop from the building’s chilled water loop. On applications where an existing water chiller is available, it can be installed in the chilled water loop to reduce the load on the thermal storage system.

This design should not be used when there is a requirement to build ice and provide cooling.

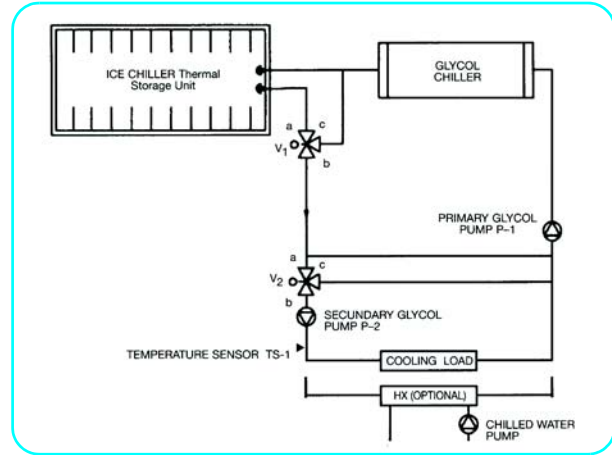
This would require the cold return glycol from the thermal storage equipment be pumped to the cooling load or heat exchanger. Since the glycol temperature is below 0°C, the cooling coil or heat exchanger is subject to freezing. The flow schematic illustrated in the figure details a primary/secondary pumping loop with the chiller located upstream of the thermal storage equipment. This design allows the system to operate in all five operating modes.

For this figure the following control logic is applied:

MODE	CHILLER	P-1	P-2	V-1	V-2
Ice Build	On	On	Off	A-B	A-C
Ice Build with Cooling	On	On	On	A-B	Modulate
Cooling - Chiller Only	On	On	On	C-B	A-B
Cooling – Ice Only	Off	On	On	Modulate	A-B
Cooling – Ice with Chiller	On	On	On	Modulate	A-B



Valve V-1 and Valve V-2 modulate, depending on the operating mode, in response to temperature sensor, TS-1. The benefit provided by the primary/secondary pumping loop is that the system can build ice and provide cooling without fear of freezing a cooling coil or heat exchanger. This system design also allows for different flow rates in each of the pumping loops. When the flow rates in the pumping loops are different, the glycol flow rate in the primary loop should be greater than or equal to the glycol flow rate in the secondary loop. If not, colder supply glycol temperatures from the primary loop are needed to guarantee the design TS-1 set point (because there is always a mix with warm return glycol from the secondary loop. This reduces the chiller COP. At very large flow rate differences, negative glycol temperatures out of the TSU would be needed to obtain TS-1 (which is impossible))



**Primary/Secondary Pumping Loop – Chiller Upstream**

As in the single loop schematic, a heat exchanger and a base water chiller can be added to the system schematic.

Variations to these schematics are possible but these are the most common for thermal storage systems. One common variation positions the chiller downstream of the thermal storage equipment. This design is used when the glycol temperatures off the ice cannot be maintained for the entire cooling period. By positioning the chiller downstream of the ice, the chiller is used to maintain the required supply temperature. In both of the above figures, the chiller is installed upstream of the ice. This offers two significant advantages compared to system designs that locate the chiller downstream of the ice. First, the chiller operates at higher glycol temperatures to pre-cool the return glycol. This enables the chiller to operate at a higher capacity, which reduces the amount of ice required. Second, since the chiller is operating at higher evaporator temperatures, the efficiency of the chiller is improved.



## Chiller Performance

Most packaged chillers can provide a wide range of glycol discharge temperatures and are suited for thermal storage applications. Chiller types applied to thermal storage applications include reciprocating, rotary screw and centrifugal. The chiller type used depends on capacity, glycol discharge temperature, efficiency, condenser type, and refrigerant. Chiller capacity and glycol discharge temperature must be evaluated when designing a thermal storage system. Different glycol discharge temperatures are required for various operating modes that affect the chiller capacity. The chiller capacity provided at  $-5,5^{\circ}\text{C}$  is considerably less than the chiller capacity with a  $6^{\circ}\text{C}$  glycol discharge temperature.

Chillers selected for use with the BAC's ICE CHILLER<sup>®</sup> Thermal Storage Units should be able to provide  $-5,5^{\circ}\text{C}$  glycol when applied to a 10-hour build cycle. Longer build times result in higher glycol temperatures at the end of the build period while shorter build times require the chiller to supply glycol colder than  $-5,5^{\circ}\text{C}$ .

The chiller capacity required could limit the use of a specific chiller type on small applications. The nominal capacity range for each chiller type is shown in the table below.

Chiller Type	Nominal Capacity (kW) Range
Reciprocating	50 – 850 kW
Rotary Screw	450 – 4200 kW
Centrifugal	600 – 7000 kW+

Centrifugal and rotary screw chillers have the highest efficiencies with COP's from 5,9 to 4,7 at  $6^{\circ}\text{C}$  chiller discharge temperature and 4,0 to 3,2 when providing  $-5,5^{\circ}\text{C}$  glycol. Reciprocating chillers are less efficient and have COP's ranging from 4,1 to 3,2 when providing  $6^{\circ}\text{C}$  glycol and 3,2 to 2,7 when making ice at  $-5,5^{\circ}\text{C}$ .

The heat rejection function of an ice storage system can be handled by any of three types of refrigerant condensers: air-cooled, water-cooled or evaporative.

An air-cooled condenser removes heat from the refrigerant and condenses it by forcing air over an extended surface coil through which the refrigerant vapour is circulated. The latent heat of the refrigerant is removed by sensibly heating the air. The condenser capacity is determined by the ambient dry bulb temperature.

A water-cooled condenser with a cooling tower rejects heat from a refrigeration system in two steps. First, the refrigerant is condensed by the water flow in the condenser. Second, heat is rejected to the atmosphere as the condenser water is cooled by a cooling tower.

The evaporative condenser combines a water-cooled condenser and cooling tower in one piece of equipment. It eliminates the sensible heat transfer step of the condenser water. This allows a condensing temperature substantially closer to the design wet-bulb temperature.

Variations in condensing temperatures should be considered when evaluating chiller performance. Reduced night-time ambient dry bulb and wet bulb temperatures offer lower condensing temperatures which help offset the reduction in chiller capacity and chiller efficiency.



The percent of nominal chiller capacity at various glycol discharge temperatures are shown below.

Glycol Discharge Temperature	Percent of Nominal Capacity*
6,0 °C	97 %
2,0 °C	85 %
-5,5 °C	66 %

**Note:** \* Nominal capacity of the chiller is based on cooling water to 6°C.

Nominal capacity ratings are based on:

- 30°C condenser water or 46°C condensing temperature for cooling operation
- 26,5°C condenser water or 40,5°C condensing temperature for ice build operation

The refrigerant types for chillers also vary. Centrifugal chillers are available for use with R-134a, R-123 and R-22. Reciprocating and rotary screw chillers are available for use with R-134a, R-22 and R-717 (ammonia).



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# Engineering Specifications TSU-M

## 1.0 ICE CHILLER® Thermal Storage Unit

**1.1 General:** The ICE CHILLER® Thermal Storage Unit shall be Baltimore Aircoil Model TSU-\_\_\_\_\_. Overall unit dimensions shall not exceed approximately \_\_\_\_\_ m by \_\_\_\_\_ m with an overall height not exceeding \_\_\_\_\_ m. The operating weight shall not exceed \_\_\_\_\_ kg

**1.2 Thermal Capacity:** Each unit shall have a latent kWh storage capacity of \_\_\_\_\_ kWh to be generated in \_\_\_\_\_ hours when supplied with \_\_\_\_\_ l/s of a 25% (by weight) solution of industrially inhibited ethylene/propylene glycol. The minimum glycol temperature

required during the ice build operating mode shall be \_\_\_\_\_ °C. Rated system performance shall be provided in the format recommended by the Air-Conditioning & Refrigeration Institute (ARI) Guideline T. The thermal storage units shall be modular in design. Unit design shall allow units of different sizes to be installed in order to optimize unit selection and minimize space requirements. Tanks sizes can be mixed due to internal piping arrangements that create a balanced flow due to uniform pressure drop through the coil circuits.

## 2.0 Construction Details

**2.1 Tank:** The tank shall be constructed of heavy-gauge Z600 galvanized steel panels and include double brake flanges for structural strength. The tank walls shall be supplied with a minimum of 110 mm of insulation that provides a total insulating value of 3,1 m °C/W. The tank design shall utilize two liners. The 1,5 mm E.P.D.M. liners shall be of single piece construction and be suitable for low temperature applications. Liners shall be separated from each other by 20 mm of extruded polystyrene insulation. The tank bottom shall be insulated with 70 mm extruded, polystyrene insulation.

**2.2 Covers:** The ICE CHILLER® Thermal Storage Unit shall be provided with watertight, sectional covers constructed of Z600 hot-dip galvanized steel. The covers shall be insulated with a minimum of 50 mm of extruded polystyrene insulation.

**2.3 Heat Transfer Section:** Contained within the tank shall be a steel heat exchanger that is constructed of 26,7 mm O.D., all prime surface serpentine steel tubing encased in a steel framework. The coil, which is hot-dip galvanized after fabrication, shall be tested at 1300 kPa air

pressure under water and rated for 1000 kPa operating pressure. The coil circuits are configured to provide maximum storage capacity. Each unit shall be supplied with threaded connections.

**2.4 Sight Tube:** Each ICE CHILLER® Thermal Storage Unit shall be provided with a sight tube mounted on the end of each unit. The sight tube, which shall be fabricated from clear plastic pipe, displays the tank water level and corresponding ice inventory. Optionally, the exclusive BAC ICE LOGIC Ice Quantity Controller is available for both manual and automatic chiller control.

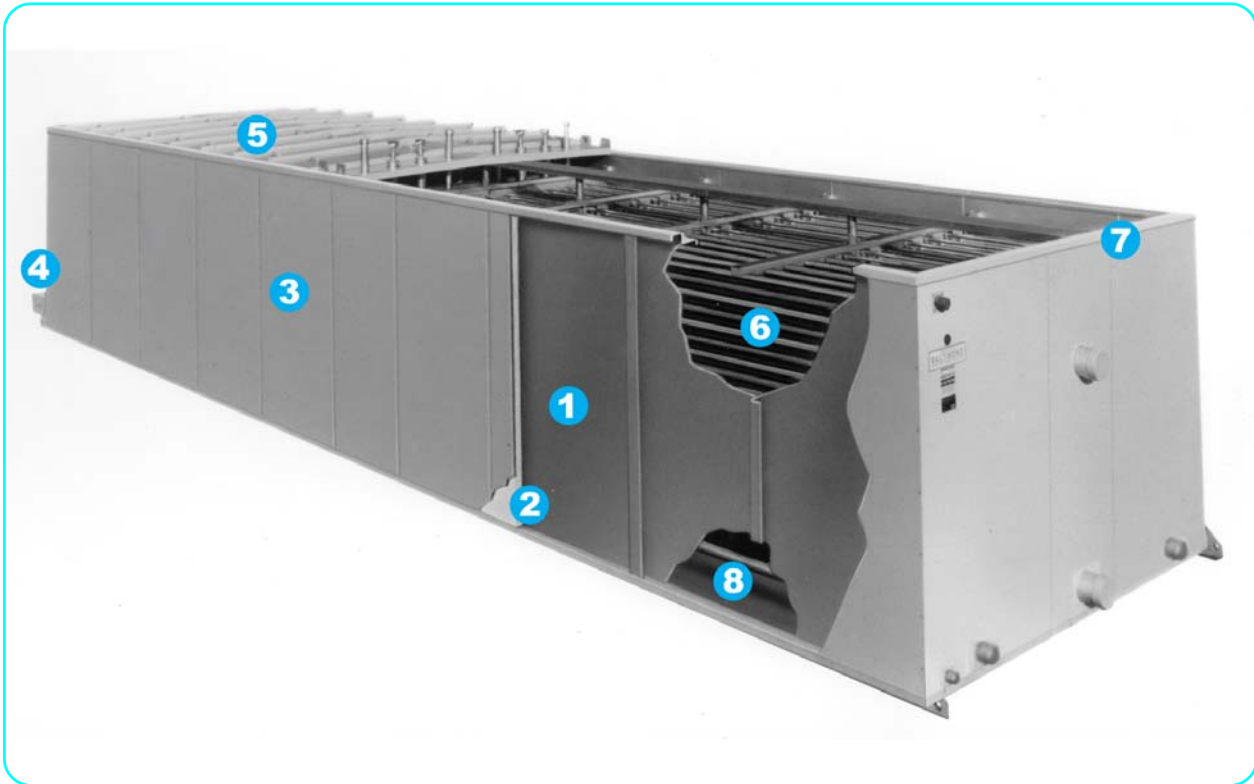
**2.5 Heat Transfer Fluid System:** The heat transfer fluid shall be an industrially inhibited, 25% by weight, ethylene glycol solution specifically designed for HVAC applications. The 25% (by weight) solution is designed to provide freeze/burst and corrosion protection as well as efficient heat transfer in water based, closed loop systems. Corrosion inhibitors shall be provided to keep pipes free of corrosion without fouling.

TSU





# Construction Details TSU-C/D - External Melt Application



## 1. Tank

The tank is constructed of heavy-gauge, Z600 hot-dip galvanized steel, reinforced with full-length structural steel angles beneath and on all four sides. All seams are welded to ensure watertight construction. A zinc rich coating is applied to all exposed edges and welds.

## 2. Insulation

Extruded polystyrene insulation is provided between the tank and the exterior panels. The insulation is 80 mm thick on the tank sides and ends, and 50 mm thick on the bottom and inside the covers

## 3. Exterior Panels

Exterior panels sealed at all seams provide a complete vapor barrier and protect the insulation. They are furnished with BAC's exclusive BALTIBOND® Corrosion Protection System.

## 4. Air Pump

Centrifugal regenerative blower for field mounting to supply low pressure air for agitation of the water. Pump is complete with a weather protected inlet air filter and is suitable for outdoor applications.

## 5. Covers

Sectional insulated tank covers are provided with BAC's exclusive BALTIBOND® Corrosion Protection System.

## 6. Galvanized Steel Coil

- Hot-dip galvanized after fabrication (HDGAF)
- Steel tubing encased in a steel framework
- Pneumatically tested at 15 bar (31bar) for glycol (ammonia) applications
- Rated for 10 bar (22 bar) operating pressure

## 7. ICE-LOGIC Ice Thickness Controller (Not Shown)

An electronic, multi-point ice thickness control is mounted on the unit. A control relay is provided to deactivate the refrigeration system when a full build of ice is reached.

## 8. Air Distribution

Low pressure air from the air pump is distributed below the coils through multiple perforated PVC pipes.

## Custom Coils for External Melt Application (TSU-C/D)

BAC will manufacture custom ICE CHILLER® Thermal Storage Coils to meet project specific requirements. B.A.C. has done extensive research and testing on the build and melt characteristics of ice storage. This research and testing has resulted in selection capabilities unmatched by any other company in the industry.

BAC can predict the temperatures required on an hour by hour basis for building ice on custom coils, over a variety of conditions and build times. The physical space available, load profile, discharge temperatures, chiller capacity and operating sequences can be evaluated to find the design that best meets the application.



Coils installed in Concrete Tank

The ICE CHILLER® Thermal Storage Coils are constructed of continuous 26,7 mm O.D. all prime surface serpentine steel tubing. The coils are assembled in a structural steel frame designed to support the weight of the coil stack with a full ice build for glycol (ammonia) application. After fabrication the coils are tested for leaks using 15 bar (31bar) air pressure under water, then hot-dip galvanized for corrosion protection.

The coils are configured to provide countercurrent glycol flow in adjacent circuits for maximum storage capacity.

Individual coils can be factory-assembled into modules of two (2) coils for optimization of transport cost and reduction of site assembly time. Glycol manifolds are coated with zinc-rich, cold galvanizing finish at the factory. Necessary support steel and lifting lugs are provided on the modules to allow for lifting into and final positioning within the storage tank.

### Modes of Operation

The ICE CHILLER® Thermal Storage Unit operates in two main operating modes or cycles. A possible combination of these cycles of operation provides the flexibility to meet the daily HVAC or cooling requirements. Long periods of simultaneously circulating glycol or ammonia through the coil tubes and circulating water through the ICE CHILLER® should however be avoided to optimise system performance.

**Ice Build:** In this operating cycle, ice is built by circulating ammonia or a 30% solution (by weight) of inhibited ethylene/propylene glycol through the coils contained in the ICE CHILLER® Thermal Storage Unit. The below table illustrates typical temperatures for 8, 10, 12 and 14 hour build cycles. At the start of the ice build cycle, the temperature will be higher while at the end of the ice build cycle, the temperatures will be lower.

**Ice Melt:** In this operation cycle the warm return water is cooled by direct contact between the water and the ice, melting ice stored in the modular ICE CHILLER<sup>®</sup> Thermal Storage Unit.

## System Schematics

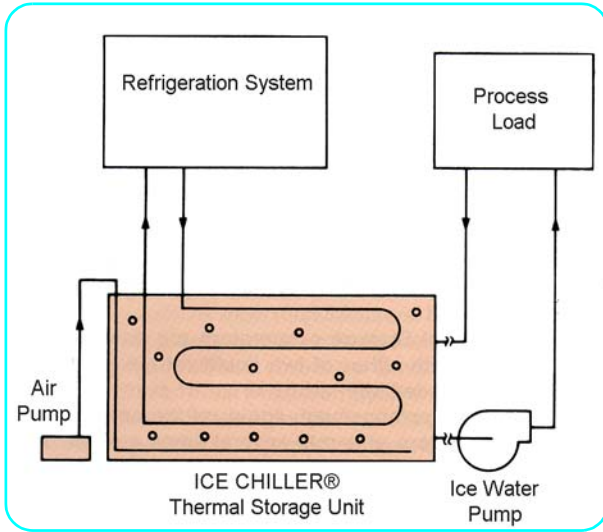
The basic ice storage system includes an ICE CHILLER<sup>®</sup> Thermal Storage Unit, a refrigeration system and ice water pump as shown below. The ICE CHILLER<sup>®</sup> Unit consists of a multiple tube serpentine coil submerged in an insulated tank of water. Both the coil and tank are constructed from hot-dip galvanized steel for corrosion protection.

When no cooling load exists, the refrigeration system operates to build ice on the outside surface of the coil. This refrigeration effect is provided by feeding refrigerant directly into the coil. To increase the heat transfer during the ice build cycle the water is agitated by air bubbles from a low pressure distribution system beneath the coil. When the ice has reached design thickness, BAC's exclusive ICE-LOGIC Ice Thickness Controller sends a signal to turn off the refrigeration system.

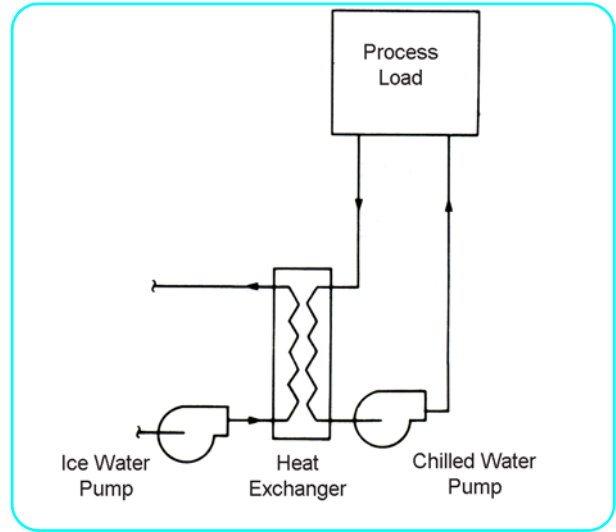
When chilled water is required for cooling, the chilled water pump is started, and the melt out cycle begins. Warm water returning from the load circulates through the ICE CHILLER<sup>®</sup> tank and is cooled by direct contact with the melting ice. During this cycle, the tank water is also agitated to enhance heat transfer and typically provides a constant supply water temperature of 1°C or less.

For a closed chilled water loop see figure below. With this system, warm return water from the load is pumped through a heat exchanger and cooled by the ice water circuit from the ICE CHILLER® Unit.

For more detailed information on the design and operation of BAC ICE CHILLER® Thermal Storage Units, contact your local BAC Balticare Representative.



Basic Scheme – External Melt



Scheme with Intermediate Heat Exchanger



# Engineering Specifications TSU-C/D

## 1.0 ICE CHILLER® Thermal Storage Unit

**1.1 General:** The ICE CHILLER® Thermal Storage Unit shall be Baltimore Aircoil Model TSU-\_\_\_\_\_. Overall unit dimensions shall not exceed approximately \_\_\_\_ m by \_\_\_\_ m with an overall height not exceeding \_\_\_\_ m. The operating weight shall not exceed \_\_\_\_\_ kg

**1.2 Thermal Capacity:** Each unit shall have a thermal storage capacity of \_\_\_\_\_ kWh operating with \_\_\_\_\_ refrigerant and

a build time of \_\_\_\_\_ hours at a \_\_\_\_\_ °C nominal evaporator temperature.

**1.3 Experience:** Manufacturers submitting bids for equipment in this specification shall have a standard production model of this unit, which has been manufactured and in use for 3 years. The manufacturer shall offer evidence that the equipment has been successfully operated on a minimum of 50 applications, which utilize the same refrigerant and meltout arrangement specified.

## 2.0 Construction Details

**2.1 Tank:** The tank shall be constructed of heavy gauge Z600 hot-dip galvanized steel and reinforced with full-length structural angles underneath and on all four sides. All seams shall be welded to ensure watertight construction. A zinc rich coating shall be applied to all exposed edges and welds.

**2.2 Coil:** The coil shall be constructed of prime surface serpentine steel circuits and shall be tested at 15 bar (31 bar for ammonia applications) air pressure under water. The coil shall be encased in a steel frame and the entire assembly hot-dip galvanized after fabrication. For use with Ammonia refrigerant, the coil shall be complete with purge connection for oil maintenance.

**2.3 Insulation:** Extruded polystyrene insulation shall be provided between the tank and the exterior panels. The insulation shall be 80 mm thick on the tank sides and ends, and 50 mm thick on the bottom and inside the covers.

**2.4 Exterior Panels:** Exterior panels sealed at all seams provide a complete vapour barrier and protect the insulation. They are furnished with B.A.C.'s exclusive BALTIBOND® Corrosion Protection System.

**2.5 Covers:** The ICE CHILLER® unit(s) shall be provided with sectional insulated steel covers provided with the BALTIBOND® Corrosion Protection System.

**2.6 Ice Thickness Control:** A sensing element shall be mounted on the coil to deactivate the refrigerant compressor at a full build of ice.

**2.7 Air pump:** Centrifugal regenerative blower for field mounting to supply low pressure air for agitation of the water. Pump is complete with a weather protected inlet air filter, and is suitable for outdoor applications.

**2.8 Air Distributor:** Low pressure air shall be distributed through multiple perforated PVC pipes.



Thermal Storage Products

... because temperature matters

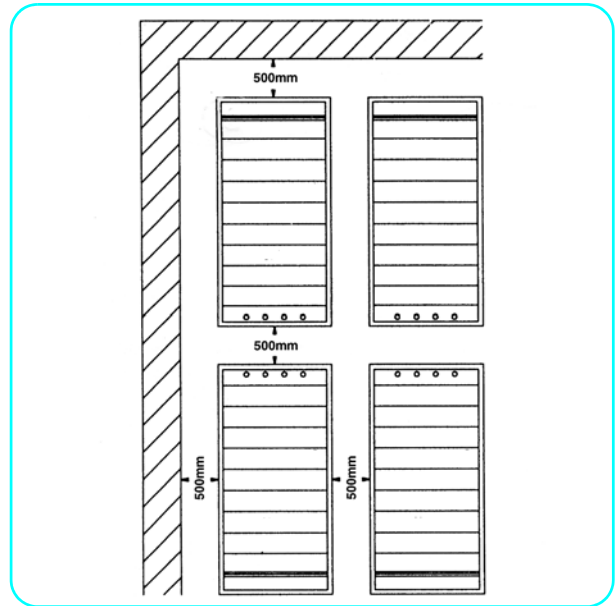


# Engineering Considerations ICE CHILLER® Products

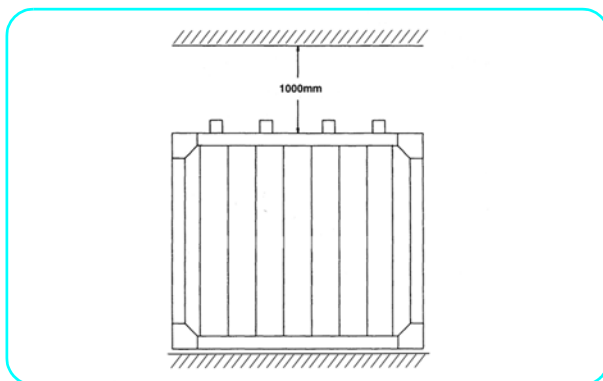
## Installation

ICE CHILLER® Thermal Storage Units must be installed on a continuous flat level surface. The pitch of the slab must not exceed 3 mm over a 3 metre span – See Figure: Unit Layout Guidelines. The units should be positioned so there is sufficient clearance between units and adjacent walls to allow easy access. When multiple units are installed, a minimum of 50 cm is recommended between units.

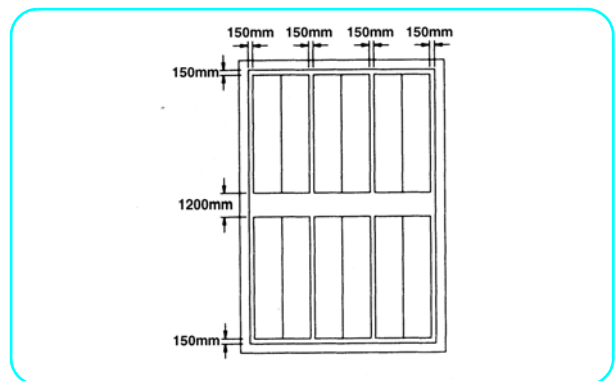
When installed indoors, the access and slab requirements described above also apply. The units should be placed close to a floor drain in the event they need to be drained. The minimum height requirement above the tank for proper pipe installation is 1 metre. The below figure illustrates the recommended overhead clearance for ICE CHILLER® Thermal Storage Units. BAC's ICE CHILLER® Thermal Storage Units are available unassembled when the units must be installed indoors and access is limited. Erection of unassembled units will require factory personnel to assist in the field assembly of this equipment. Contact the local BAC-Balticare Representative for additional details. For large applications, BAC will provide ICE CHILLER® Thermal Storage Coils for installation in field fabricated concrete tanks. This product offering demonstrates BAC's product design and flexibility. When coils are required, BAC's manufacturing capabilities allow coils to be manufactured in the size and configuration necessary to meet specific site and performance requirements. The concrete tank design is to be completed by a qualified structural engineer. The below figure illustrates the ICE CHILLER® Thermal Storage Coil layout guidelines. Buoyancy forces due to the density difference between ice and water require that hold-down angles be installed on top of the coils. This will prohibit the coils from floating in an overcharged condition. For large projects that require ICE CHILLER® Coils, contact the local BAC Balticare Representative for selection and dimensional information.



Unit Layout Guidelines



Recommended Overhead Clearance



Coil Layout Guidelines



## Unit Piping

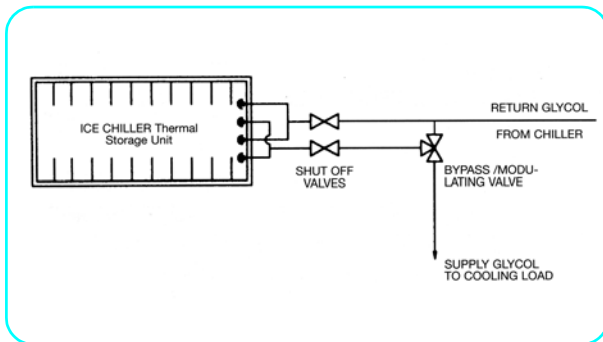
Piping to the ICE CHILLER® Thermal Storage Unit should follow established piping guidelines. The coil connections on the unit are galvanized steel and are grooved for mechanical coupling.

For single tank applications, each pair of manifolded coil connections should include a shut off valve so the unit can be isolated from the system. Below figure illustrates the valve arrangement for a single unit. It is recommended that the piping include a bypass circuit to allow operation of the system without the ICE CHILLER® Thermal Storage Unit in the piping loop. This bypass can be incorporated into the piping design by installing a three-way/modulating valve. This valve can also be used to control the leaving glycol temperature from the thermal storage unit. Temperature and pressure taps should be installed to allow for easier flow balancing and system troubleshooting. A relief valve, set at a maximum of 10 bar, must be installed between the shut off valves and the coil connections to protect the coils from excessive pressures due to hydraulic expansion. The relief valve should be vented to a portion of the system, which can accommodate expansion.

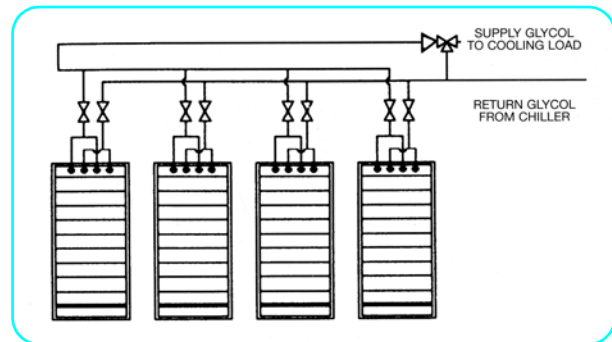
**CAUTION:** The system must include an expansion tank to accommodate changes in fluid volume. Adequately sized air vents must be installed at the high points in the piping loop to remove trapped air from the system. In cases where the piping to the storage tanks is at the highest elevation in the loop, purge valves must be installed in the piping on top of the units to remove excess air from the system.

Below figure illustrates reverse return piping for multiple units installed in parallel. The use of reverse return piping is recommended to ensure balanced flow to each unit. Shut off valves at each unit can be used instead of balancing valves.

When large quantities of ICE CHILLER® Thermal Storage Units are installed, the system should be divided into groups of units. Then, balancing of each unit can be eliminated and a common balancing valve for each group of units installed. Shut off valves for isolating individual units should be installed but not used for balancing glycol flow to the unit.



Single Unit Valve Arrangement



Reverse Return Piping

## Controls

An inventory control that provides a 4 –20 mA signal is available. This control should be used for determining the amount of ice in inventory and to terminate the ice build cycle. Complete operating control details are provided in the Operating and Maintenance Manual.

## Glycol

ICE CHILLER® Thermal Storage Units typically use a 25% (by weight) solution of industrially inhibited ethylene glycol for both corrosion protection and freeze protection. Industrial grade inhibited ethylene glycol is specifically designed to prevent corrosion in HVAC and heat transfer equipment. Inhibitors are used to prevent the ethylene glycol from becoming acidic and to protect the metal components in the thermal storage system. The system's lowest operating temperature

should be 3°C to 4°C above the glycol freeze point. The freeze point for a system with 25% (by weight) ethylene glycol is -12°C.

**CAUTION:**

1. Uninhibited ethylene glycol and automotive antifreeze solutions are NOT to be used on thermal storage applications.
2. Ethylene glycol solutions are NOT compatible with galvanised steel parts. Therefore glycol piping should only be galvanised at the outside.

**Water Treatment**

In the near freezing temperatures of the ICE CHILLER® Thermal Storage Unit, scale and corrosion are naturally minimized. Therefore, water treatment for these two conditions may not be required or may require minimal attention unless the water is corrosive in nature. To control biological growth, a biocide may be needed to prevent the spread of iron bacteria or other organisms. For specific recommendations, consult a reputable local water treatment company and follow the guidelines below:

Property of Water	Range
PH	7.0 to 9.0 <sup>(1)</sup>
Hardness as CaCO <sub>3</sub>	30 to 50 mg/l
Alkalinity as CaCO <sub>3</sub>	500 mg/l max.
Total Dissolved Solids	1000 mg/l max.
Chlorides	125 mg/l max. as Cl
Sulfates	125 mg/l max.
Conductivity	700 µS/cm at 0°C <sup>(2)</sup>

Notes:

1. A water pH of 8.3 or higher will require periodic passivation of the galvanised steel to prevent "white rust", the accumulation of white, waxy, non-protective zinc corrosion products on galvanised steel surfaces.
2. Maximum conductivity of 700 µS/cm at 0°C is important for proper operation of the ICE LOGIC ice quantity controller.

If water treatment is implemented to the system, to assure full capacity of the ICE CHILLER® Thermal Storage Unit, the water treatment should not alter the freeze point of water.

**Winterization**

Precautions must be taken to protect the unit and associated piping from freezing conditions. Heat tracing and insulation should be installed on all piping connected to the unit. The sight tube, operating controls and optional inventory sensor must be heat traced and insulated. It is not necessary to drain the unit during cold weather. Freezing of the water contained in the unit during the winter will not damage the coil or unit.

**Pressure Drop**

The ICE CHILLER® Thermal Storage Unit is designed for low pressure drop. Pressure drops, for different flow rates and for alternative fluids, are available by contacting the local BAC Balticare Representative.

**Warranties**

Please refer to the Limitation of Warranties applicable to and in effect at the time of the sale/purchase of these products.

