

**BAC**

# Ice Thermal Storage

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**Ice Thermal Storage products store cooling while shifting energy usage to off-peak hours, dramatically reducing cooling costs and stress on the electrical grid.** Environmentally friendly, ice thermal storage reduces greenhouse gas emissions and can qualify for LEED® certification credits. BAC has thousands of successful installations worldwide, and is the global leader in the application of ice thermal storage.



# BAC's Ice Thermal Storage: Promoting Sustainable Development

Thousands of Installations Worldwide  
Ranging from 90 – 125,000 Ton-Hours





# Ice Thermal Storage Benefits

## > Reduced Environmental Impact

- ▶ **LOWER GREEN HOUSE GAS EMISSIONS** – Storing energy as ice during off-peak hours, such as at night, allows the system to take advantage of cleaner, less expensive, more efficient energy sources. Also, lower ambient temperatures at night reduce energy line losses by 4-5% versus during the day.
- ▶ **FEWER “PEAKER” PLANTS** – Base energy loads are normally provided by highly efficient energy sources that are continuously providing power. As demand rises, peaker plants must be brought online. These plants tend to utilize less efficient sources. By lowering peak demand and spreading the cooling systems energy requirements more evenly over a 24 hour period, ice thermal storage can contribute to reducing the need to build new peaker plants.
- ▶ **LOWER REFRIGERANT CHARGE** – Reduced peak demand allows for the use of smaller chillers. Smaller chillers require lower refrigerant charges, which reduce the use of ozone depleting refrigerants and the overall impact on the environment.

## > Supports Clean Renewable Energy

The unpredictable nature of renewable resources and their inability to provide energy on demand make energy storage necessary in order for clean energy sources to become a viable substitute in the growing energy market. Ice thermal storage provides an economic strategy for utilizing renewable energy for cooling systems. Cloud cover and varying weather conditions can affect continuity of power from wind and solar energy sources, and there is no guarantee that energy can be reliably provided when it is needed most. Studies show that wind speeds are weaker during the day and that most wind turbines are getting less than 25% of the installed capacity during the hottest hours of the day. Ice storage can utilize renewable energy sources when they are available and provide cooling on demand.



Solar Panels



TSUM Installation



Wind Turbines



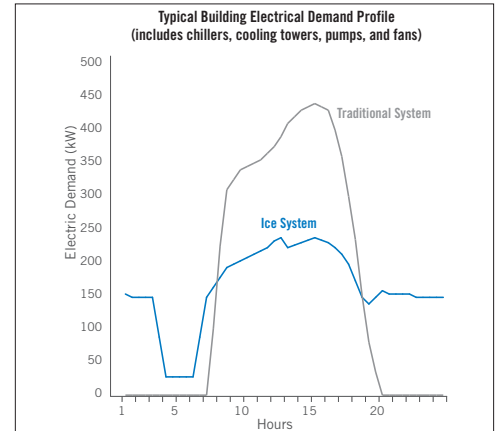
## ➤ Reduced Energy Cost

The use of electricity at night versus peak daytime hours can lead to large savings on energy bills. Ice thermal storage can lower peak electrical demand for the 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 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 cost can vary by 500-1000%.

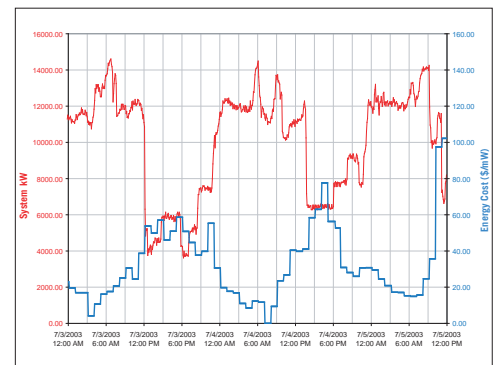
## ➤ Saves Energy

When the system is designed to take advantage of the low supply water temperature available from an ice storage system, energy use is significantly reduced.

- ▶ **REDUCED HORSEPOWER** – Low temperature chilled water utilizes lower horsepower pumps and provides low temperature air that utilizes lower horsepower fans. BAC’s patented coil configuration combined with high heat transfer steel coil material produces the lowest possible discharge temperatures.
- ▶ **INCREASED CHILLER EFFICIENCY** – Lower condensing temperatures at night, when combined with chillers operating at full load, increases the efficiency of the chiller. Chiller efficiency decreases significantly at low loads. A conventional chiller in a traditional system will operate at less than 50% capacity for half the year.



Typical Building Electrical Demand Profile



Real Time Pricing



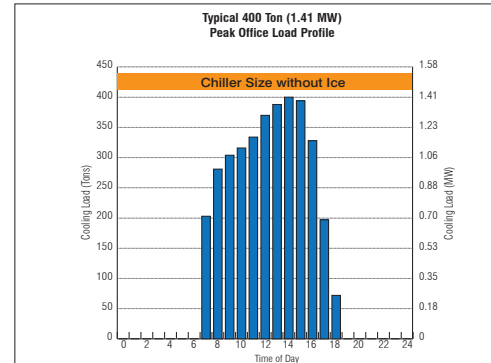
District Cooling Piping Installation

# Ice Thermal Storage Benefits

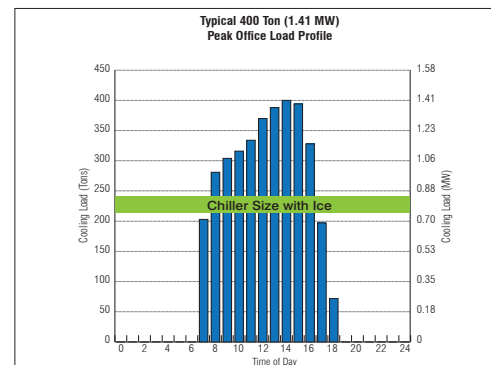
## > Low First Cost

Systems with ice thermal storage can be installed at the same or lower first cost than traditional systems when designed to take advantage of the colder supply water available from ice.

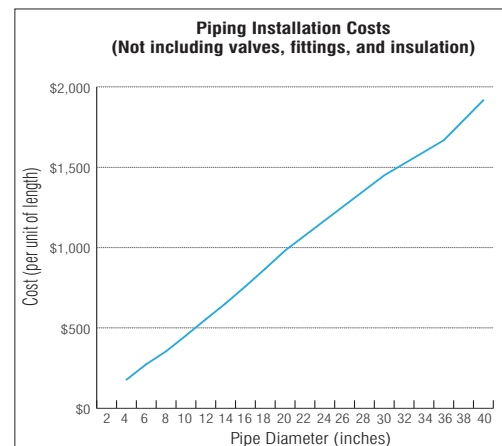
- ▶ **SMALLER CHILLER AND HEAT REJECTION EQUIPMENT** – By designing the system around 24-hour per day chiller operation, the size of chillers, cooling towers, or condensers required for an ice storage system are significantly reduced. A typical ice thermal storage design includes chillers and cooling towers that provide 50-60% of the peak cooling load.
- ▶ **REDUCED PIPING AND PUMPING SIZES** – Flow rate requirements are reduced by taking advantage of the greater temperature gradient achieved when utilizing the colder supply water available with ice. This provides substantial savings in the chilled water distribution loop. A range of 18°F (10°C) instead of the more traditional 10°F (5.5°C) results in a significant reduction in the size of pumps and piping for the chilled water system.
- ▶ **REDUCED DUCTING AND FAN SIZES** – Low supply water temperatures allow for low temperature air distribution, resulting in minimized ducting and fan horsepower (HP). Low temperature air can significantly improve air quality and occupant comfort.
- ▶ **REDUCED ELECTRICAL DISTRIBUTION** – Smaller chillers, heat rejection equipment, pumps, and fans require less horsepower, which results in smaller transformers, switchgear, wire sizes, and starter panels.
- ▶ **REDUCED GENERATOR SIZE** – The generator capacity required for back-up energy will be significantly reduced when the peak electrical load of the facility is reduced using ice storage.
- ▶ **REBATES** – Many utilities offer attractive load shift incentives and rebates which can further reduce the initial investment of the Ice Thermal Storage system significantly. Rebate amounts can range from \$500/ton shifted in Florida to \$2600/kw shifted in New York City.



Chiller Size without Ice



Chiller Size with Ice Thermal Storage System



Reduced Piping Installation Costs



## > Supports Industry Standards

Introduced in 2009, ASHRAE Standard 189.1, *Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings*, was the first code intended for commercial green building standard in the United States. It provides a total building sustainability package for those who strive to design, build and operate green buildings.

Section 7.4.5.1 of ASHRAE 189.1 requires projects to contain automatic systems, such as demand limiting or load shifting, that are capable of reducing electric peak demand by at least 10% of projected peak demand. Ice thermal storage has the capability to exceed these limits and provide a sustainable solution for a variety of applications.

## > Reduced Maintenance

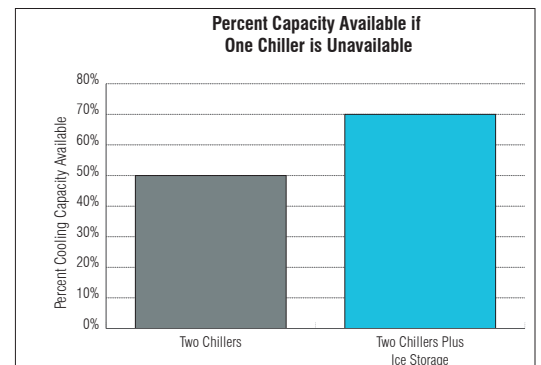
With smaller system components (chiller, cooling tower, pumps, air distribution, etc.) as compared to a conventional system design, there is less equipment to maintain. Parts and labor required to maintain the system decrease. Ice thermal storage equipment itself includes no moving parts, and therefore does not require additional maintenance.

## > Redundancy Improves System Reliability

Critical systems often require high cooling capacities to prevent damage to their systems and remain operational. In the event of chiller failure or failure of any other significant cooling system component, the cooling capacity stored in the ice can continue to be used for system cooling. Some critical facilities, such as data centers, may designate an ice thermal storage system for the sole purpose of providing emergency cooling for back-up purposes.



Reduced Maintenance with No Moving Parts



Increased Reserve Capacity

# Ice Thermal Storage and LEED®

Cost initiatives provided by utility companies to shift load to off-peak hours is due to the ability to utilize cheaper, cleaner, and more efficient energy sources. Cleaner energy usage along with reduced energy consumption by a low temperature system has a significant effect on reducing environmental impact.

The acceptance of ice thermal storage technology as a green technology is demonstrated by the potential to qualify for a significant number of LEED® points with a properly designed ice thermal storage system. LEED® was created to define the “green building” by establishing a common standard of measurement, all while raising consumer awareness of green building benefits. A voluntary certification system, LEED® promotes whole-building design practices as it recognizes environmental leadership in the building industry. For more information on LEED® refer to the “Codes and Standards” section on **page J22**.

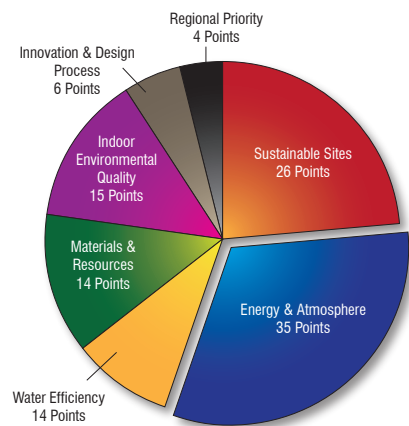
A number of LEED® 2009 credits can be earned when ice thermal storage technology is incorporated in the HVAC design.

## > Energy and Atmosphere (EA)

- ▶ **OPTIMIZE ENERGY PERFORMANCE** - Up to 18 points available. Points can be earned in this category by improving building performance. A properly designed ice thermal storage system is capable of reducing energy costs up to 48%, therefore qualifying for the maximum number of points. Ice is made during off-peak power rates when costs are lower. Also, by taking advantage of lower water and air temperatures, ice thermal storage can reduce energy consumption which helps to achieve additional cost savings.
- ▶ **ENHANCED REFRIGERANT MANAGEMENT** - Up to 2 points available. This credit is attainable for projects that select refrigerants and refrigeration equipment that minimize the contribution of ozone depleting compounds below designated thresholds or eliminates emission. Partial ice storage systems can reduce the chiller size by up to 40% compared to conventional chilled water plants, therefore holding a smaller refrigerant charge.



United States Green Building Council



LEED Point Breakdown for New Construction



Reduced Refrigerant Charge





## > Indoor Environmental Quality (IEQ)

**ENHANCED ACOUSTICAL PERFORMANCE** – 1 point available. To qualify for this acoustical credit, background noise from HVAC systems must be reduced to 40 dBA or less. A full storage ice thermal storage system can provide chilled water during operating hours without turning on chillers and cooling towers, significantly reducing the sound contribution of HVAC equipment.

## > Innovation in Design (ID)

- ▶ **INNOVATION IN DESIGN** – Up to 5 points available. Awarded for exceptional performance, Ice thermal storage can qualify as an innovative technology that can help reduce energy consumption and carbon emissions.
- ▶ **DEMAND RESPONSE** – To encourage participation in demand response programs and technology, this new credit could be worth up to 2 points. Ice thermal storage technology is ideally suited for participation in demand response programs by shifting demand to off-peak load hours.

## > LEED Project: Taipei 101 The Worlds Tallest Green Building

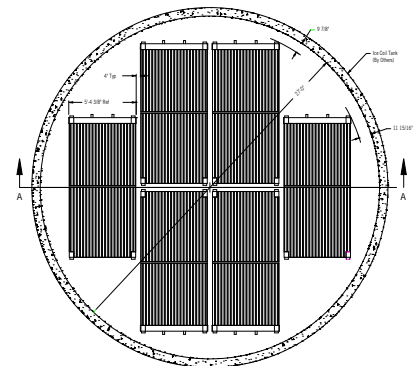
Taipei 101 received LEED Platinum certification in existing building operation and maintenance in the summer of 2011. Platinum is the highest LEED rating a building can attain. Projects that have attained this rigorous level of LEED certification are among the most sustainable buildings in the world.

Taipei 101 is located in the central government and business district of Taipei, Taiwan. The building consists of a shopping and entertainment complex and office tower. Completed in August 2002, the 101-floor tower was the world's tallest building at that time at 508 meters high.

BAC ice thermal storage equipment (36,450 ton-hours or 128.3 MWh) was selected because of its ability to provide low fluid temperatures, in this case 36°F (2°C). Low supply temperatures allowed economical selection of pressure isolation heat exchangers on the 42nd and 74th floors. Additionally, the low supply temperature allowed cold air distribution to be used throughout, thus reducing first costs and operating costs while providing improved occupant comfort.



Sound Sensitive Applications

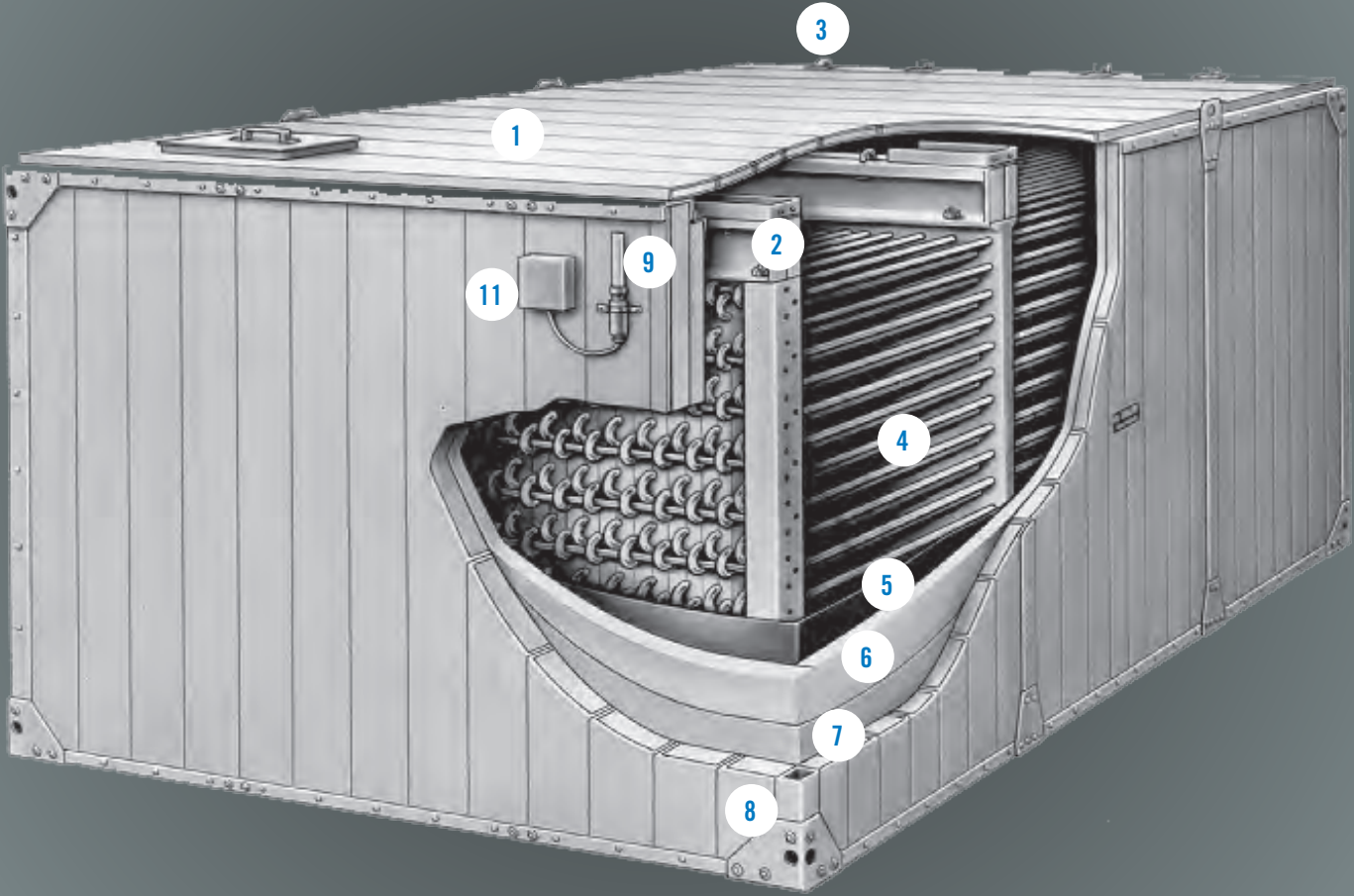


Innovation in Design



Taipei 101

# ICE CHILLER<sup>®</sup> Thermal Storage Unit for HVAC Applications



## 1 Covers

- ▶ Watertight
- ▶ G-235 (Z700 Metric) hot-dip galvanized steel panels
- ▶ Insulated with 2" expanded polystyrene insulation

## 2 Coil Support Beams

- ▶ Prevent contact between coil and primary liner

## 3 Glycol Connections

- ▶ Grooved for mechanical coupling

## 4 Galvanized Steel Coil

- ▶ Continuous serpentine, steel tubing
- ▶ Hot-dip galvanized after fabrication (HDGAF)
- ▶ Pneumatically tested at 375 psig
- ▶ Rated for 300 psig operating pressure

## 5 Primary Liner

- ▶ Single piece
- ▶ 48-hour integrity test before shipment

## 6 Extruded Polystyrene Insulation

- ▶ 1.5" thick, installed between primary and secondary liners

## 7 Secondary Liner/Vapor Barrier

- ▶ Prevents moisture from penetrating through the insulation

## 8 Wall Panels

- ▶ Heavy-gauge galvanized steel with double brake flanges
- ▶ 3" of expanded polystyrene insulation

## 9 Sight Tube

- ▶ Visual indicator of water level corresponding to the amount of ice in the unit

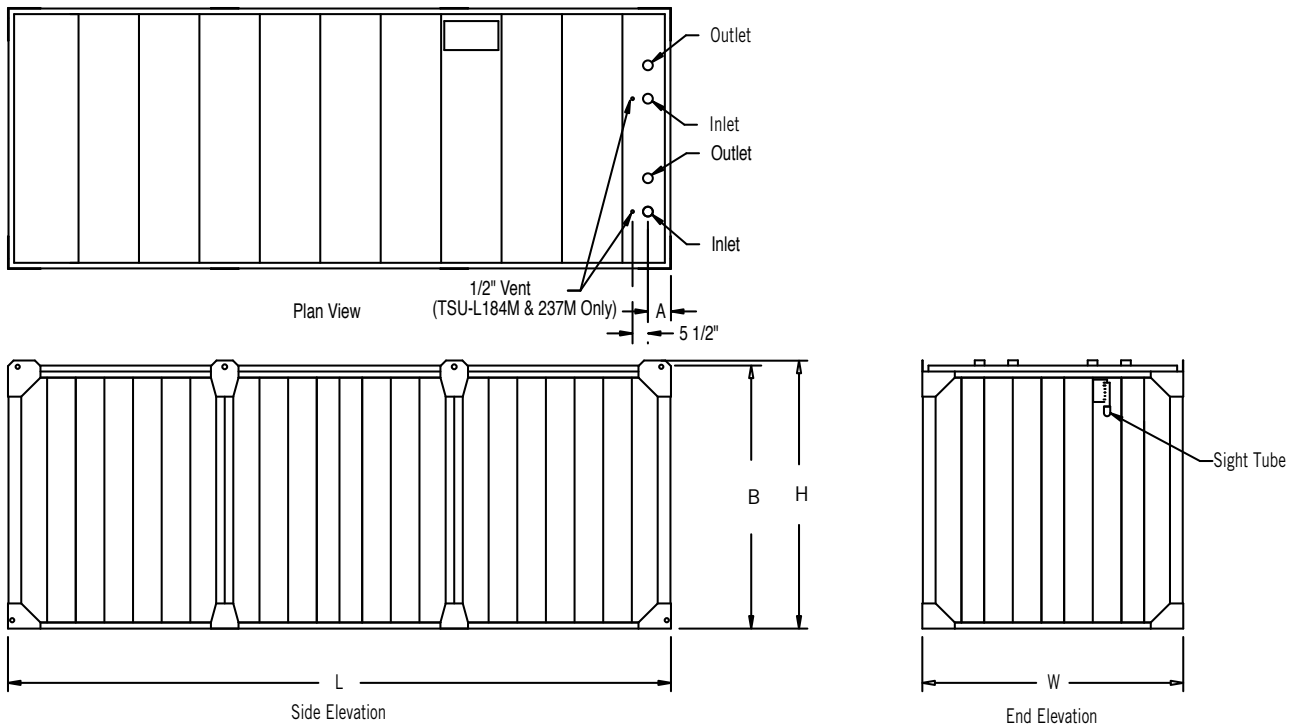
## 10 Operating Control (Not Shown)

- ▶ High-level float switch and low water cutout mounted on the outside of the tank
- ▶ Provided on all tanks

## 11 Ice Inventory Sensor (Optional)

- ▶ Differential pressure transmitter provides an electrical 4-20 mA output signal which is proportional to the amount of ice in inventory

# TSUM Engineering Data



Model Number	Weights (lbs)		Volumes (gal)		Dimensions					Connection Size
	Operating	Shipping	Tank (Water)	Coil (Glycol)	L	W	H	A	B	
TSU-237M	39,100	9,750	2,990	260	10'-7 5/8"	7'-10 3/8"	8'-0"	8 5/8"	7'-10"	2"
TSU-476M	73,900	16,750	5,840	495	19'-10 1/4"	7'-10 3/8"	8'-0"	9 3/4"	7'-10"	3"
TSU-594M	93,100	20,200	7,460	610	19'-10 1/4"	9'-9 1/4"	8'-0"	9 3/4"	7'-10"	3"
TSU-761M	113,800	24,000	9,150	790	19'-10 1/4"	11'-9 3/4"	8'-0"	9 3/4"	7'-10"	3"
TSU-L184M	31,700	8,300	2,330	205	10'-7 5/8"	7'-10 3/8"	6'-6 3/4"	8 5/8"	6'-4 3/4"	2"
TSU-L370M	59,700	14,100	4,560	385	19'-10 1/4"	7'-10 3/8"	6'-6 3/4"	9 3/4"	6'-4 3/4"	3"
TSU-L462M	75,000	17,000	5,820	477	19'-10 1/4"	9'-9 1/4"	6'-6 3/4"	9 3/4"	6'-4 3/4"	3"
TSU-L592M	91,650	20,300	7,140	602	19'-10 1/4"	11'-9 3/4"	6'-6 3/4"	9 3/4"	6'-4 3/4"	3"



## NOTES:

1. Unit should be continuously supported on a flat level surface.
2. All connections are grooved for mechanical coupling.

**Do not use for construction.** Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.



# Engineering Considerations – HVAC



## ➤ Modes of Operation

### ▶ ICE BUILD

In this operating mode, ice is built by circulating a solution of inhibited ethylene/propylene glycol through the coils contained in the ICE CHILLER® Thermal Storage Unit. **Figure 1** illustrates typical chiller supply temperatures for 8, 10, and 12 hour build cycles with a chiller flow rate associated with 5°F (2.8°C) range. As build time increases, so does minimum glycol temperature. When a larger temperature range is the basis for chiller selection, the chiller supply temperatures will be lower than shown.

### ▶ ICE BUILD WITH COOLING

When cooling loads exist during the ice build period, some of the cold 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. This reduces the possibility of damaging the cooling coil or heat exchanger by pumping cold glycol, lower than 32°F (0°C), to the equipment.

### ▶ COOLING - ICE ONLY

In this operating mode the chiller is off. The heat is rejected from the system by melting ice stored in the modular ICE CHILLER 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 is maintained by the chiller.

### ▶ COOLING - ICE WITH CHILLER

In this operating mode, cooling is provided by the combined operation of the chiller and ice storage equipment. The glycol chiller precools the warm return glycol. The partially cooled glycol solution then passes through the ICE CHILLER Thermal Storage Unit where it is cooled by the ice to the design temperature.

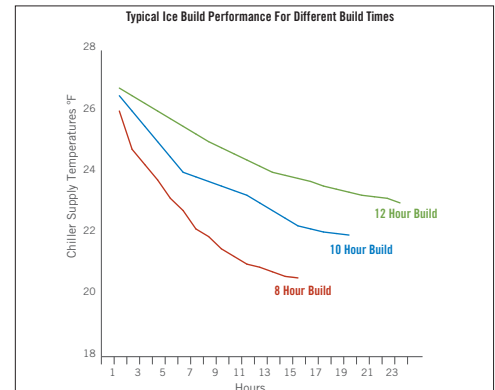


Figure 1



Modular Ice Thermal Storage Unit



**NOTE:** See page G14 and G15 for system schematics and control logic.

# Engineering Considerations – HVAC

## > System Schematics

Two basic flow schematics are applied to select ICE CHILLER® Thermal Storage Units. **Figure 2** 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.

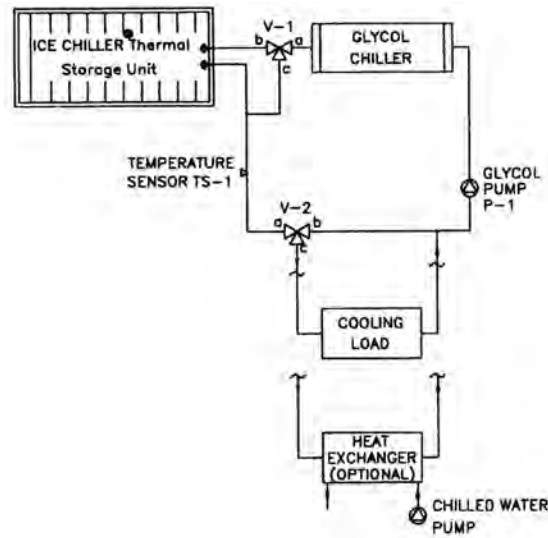


Figure 2

FOR FIGURE 2 THE FOLLOWING CONTROL LOGIC IS APPLIED

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

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 32°F (0°C), the cooling coil or heat exchanger is subject to freezing. The flow schematic illustrated in **Figure 3** 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.

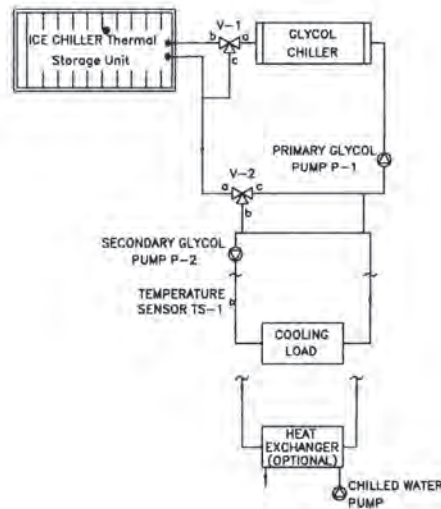


Figure 3

### FOR FIGURE 3 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 - Ice Only	Off	On	On	Modulate	A-B
Cooling - Chiller Only	On	On	On	A-C	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. 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 ice storage systems. One variation positions the chiller downstream of the ice storage equipment. By positioning the chiller downstream of the ice, the chiller is used to maintain the required supply temperature. In **Figures 2 and 3**, 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 precool 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 (kW/TR) of the chiller is improved.

# Engineering Considerations – HVAC

## > Installation

ICE CHILLER® Thermal Storage Units are designed to be installed indoors or outdoors. The units must be installed on a continuous flat level surface. The pitch of the slab must not exceed 1/8" over a 10' span. **Figure 4** details ICE CHILLER Thermal Storage 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 18" is recommended side-to-side and 3'-0" end-to-end for access to the operating controls.

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 3'. **Figure 5** illustrates the recommended overhead clearance for ICE CHILLER Thermal Storage Units.

For large ton-hour applications, BAC will provide ICE CHILLER Thermal Storage Coils for installation in field fabricated concrete tanks. 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. **Figure 6** illustrates the ICE CHILLER Thermal Storage Coil layout guidelines. For large projects that require ICE CHILLER Coils, contact your local BAC Representative for selection and dimensional information.

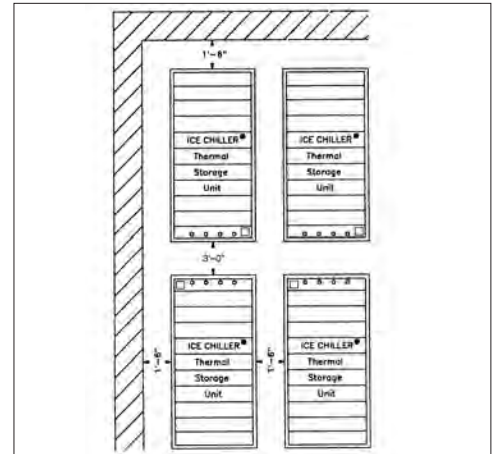


Figure 4

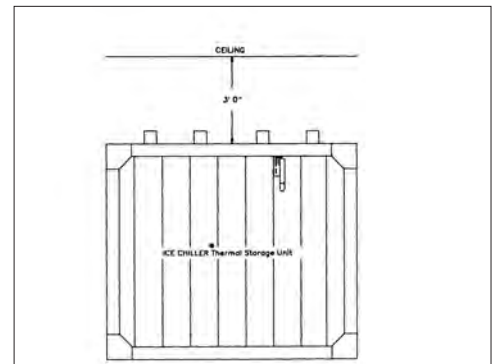


Figure 5

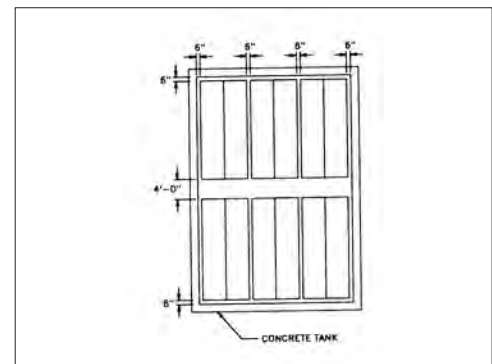


Figure 6





## > 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. **Figure 7** 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 300 psi, 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.



**NOTE:** 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.

**Figure 8** 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 as 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.

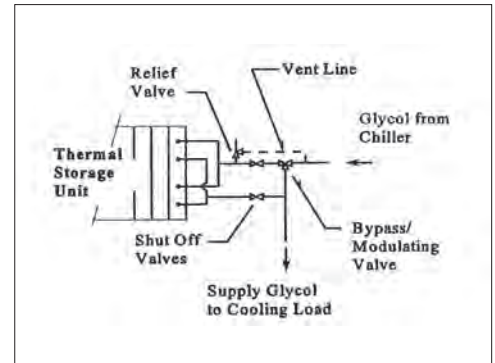


Figure 7

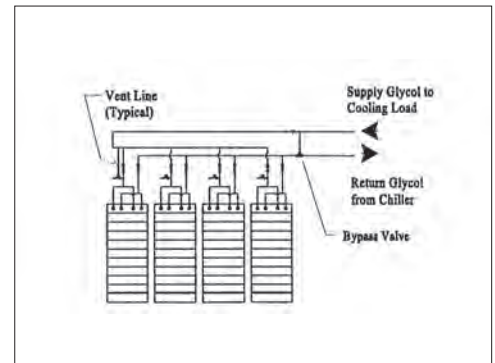


Figure 8

# Engineering Considerations – HVAC

## > Controls

To ensure efficient operation of the ICE CHILLER® Thermal Storage Units, each system is provided with factory installed operating controls. A brief description of the controls follow.

Once the ice build cycle has been initiated, the glycol chiller should run at full capacity without cycling or unloading until the ICE CHILLER Thermal Storage Units are fully charged. When the units are fully charged, the chiller should be turned off and not allowed to re-start until cooling is required. The ice build cycle is terminated by the operating control assembly. This assembly includes a low water cutout and a shut-off switch. The low water cutout prevents the ice build mode from starting if there is insufficient water in the tank. The shut-off switch will terminate the build cycle when the units are fully charged and will prevent the next ice build mode from starting until 15% of the ice has melted.



**NOTE:** Multiple operating control assemblies must be wired in series so that a full build signal from any one tank will terminate the ice build cycle.

An inventory sensor that provides a 4 - 20 mA signal is available. This sensor should be used for determining the amount of ice in inventory, but not to terminate the ice build cycle. Complete operating control details are provided in the *Installation, Operation and Maintenance Manual*, that can be found at [www.BaltimoreAircoil.com](http://www.BaltimoreAircoil.com).

## > Glycol

ICE CHILLER Thermal Storage Units typically use a 25% (by weight) solution of industrially inhibited ethylene/propylene glycol for both corrosion protection and freeze protection. Industrial grade inhibited 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 5°F to 7°F (2.8°C to 3.9°C) above the glycol freeze point. The freeze point for a system with 25% by weight ethylene glycol is 13°F (10.6°C); the freeze point for a system with 25% by weight propylene glycol is 15°F (9.4°C).

Acceptable industrial grade inhibited glycol solutions are DOWTHERM® SR-1, DOWFROST® HD and UCARTHERM®. Use of other brands of glycol in ICE CHILLER Thermal Storage Products should be approved by BAC.

*DOWTHERM® SR-1, DOWFROST® and UCARTHERM® are registered trademarks of The Dow Chemical Company or its subsidiaries.*



**NOTE:** Uninhibited glycol and automotive antifreeze are NOT to be used on thermal storage applications.

## > 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 in Table 1. To assure full capacity of the ICE CHILLER Thermal Storage Unit, water treatment should not alter the freeze point of the water in the tank.



TABLE 1: WATER QUALITY GUIDELINES

Property of Water	Recommended Levels
pH	6.5 to 9.0 <sup>[1]</sup>
Total Suspended Solids	25 ppm
Total Dissolved Solids (TDS)	1,500 ppm
Conductivity	2,400 (microohms/cm)
Alkalinity as CaCO <sub>3</sub>	500 ppm <sup>[2]</sup>
Calcium Hardness as CaCO <sub>3</sub>	50 to 600 ppm <sup>[2]</sup>
Chlorides (CL)	250 ppm
Sulfates	250 ppm
Silica	150 ppm



**NOTE:** A pH of 8.3 or higher requires periodic passivation of the galvanized steel to prevent “white rust,” the accumulation of white, waxy, nonprotective zinc corrosion on galvanized steel surfaces.

## > Winterization



**NOTE:** 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 protected if the units are installed outdoors and exposed to sub-freezing ambient conditions. For this purpose, BAC can provide an optional heated enclosure, complete with a 100 W heater. Otherwise, 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.

## > Pressure Drop

The ICE CHILLER® Thermal Storage Unit is designed for low pressure drop. **Figure 9** shows the pressure drop associated with each unit for a 25% solution of industrially inhibited ethylene glycol. Data for flow rates not shown should not be extrapolated from the performance curve. Pressure drops for flow rates not presented in this chart, and for alternative fluids, are available by contacting the local BAC Representative.

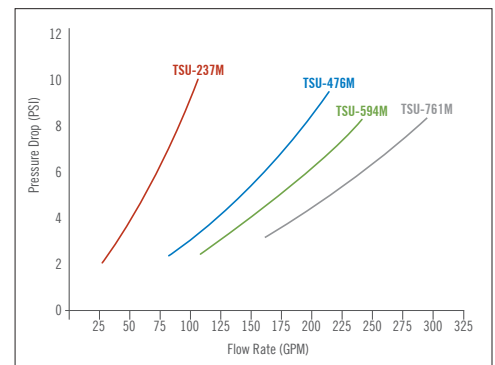
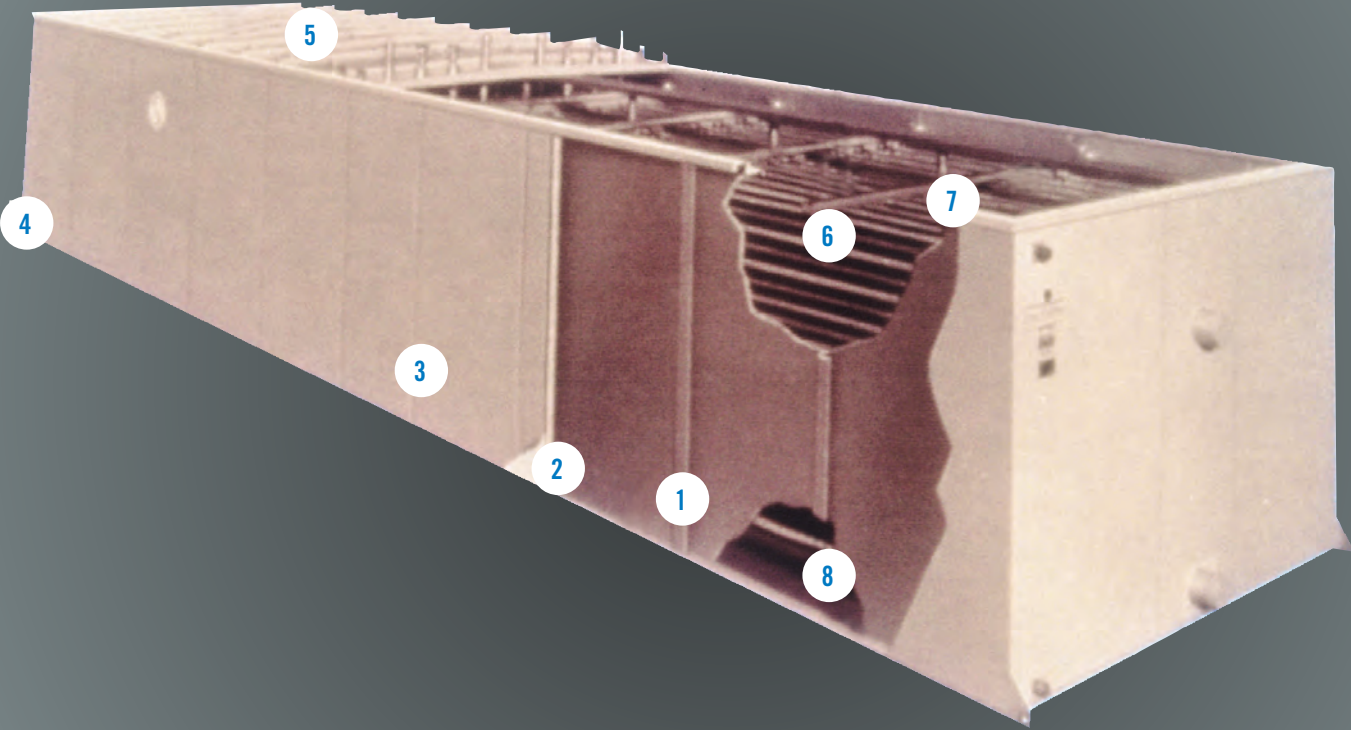


Figure 9

# ICE CHILLER<sup>®</sup> Thermal Storage Unit for Industrial and Process Cooling Applications





## 1 Tank

- ▶ The tank is constructed of heavy gauge, 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

- ▶ Expanded polystyrene insulation is provided between the tank and the exterior panels. The insulation is three inches thick (R-13) on the tank sides and ends, two inches thick (R-8) on the bottom and one inch thick 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 a thermosetting hybrid polymer.

## 4 Air Blower

- ▶ Centrifugal regenerative blower for field mounting to supply low pressure air for agitation of the water. Blower is furnished with an inline air filter, check valve and rain shield for field installation.

## 5 Covers

- ▶ Sectional insulated tank covers are provided with a thermosetting hybrid polymer. Covers are interlocking and rain shedding.

## 6 Coil

- ▶ The coil is constructed of multiple prime surface serpentine steel circuits and tested at 375 psig air pressure under water. It is encased in a steel frame, and the entire assembly is hot-dip galvanized after fabrication. For ammonia systems, purge connections are provided on each coil for oil maintenance.

## 7 ICE-LOGIC™ ICE THICKNESS CONTROLLER

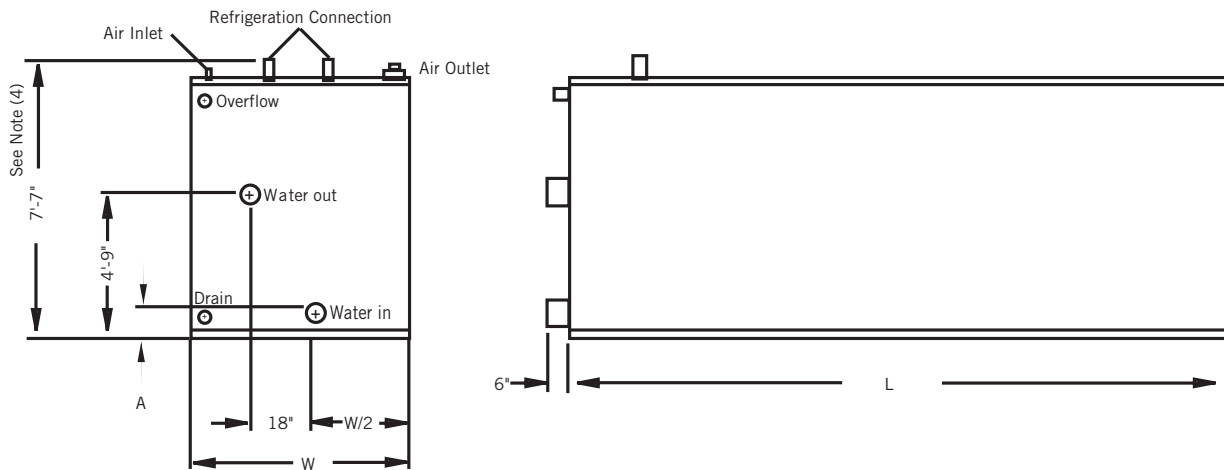
- ▶ An electronic, multi-point adjustable ice thickness control is mounted on the unit. A control relay is provided for deactivating the refrigeration system when a full build of ice is reached.

## 8 Air Distributor

- ▶ Low pressure air from the air blower is distributed below the coils through multiple perforated Schedule 40 PVC pipes.

# TSU (E, F & G) Engineering Data

## NOMINAL 5' WIDE UNITS: MODELS TSU-125E TO TSU-235E AND TSU-145F TO TSU-270F



Model Number	LBS of Ice <sup>[2]</sup>		Approx. Shipping Weight (lbs)	Approx. Operating Weight (lbs)	Air Pump (HP)	Water Volume (gal)	Pull Down Volume (gal)	Coil Volume (ft <sup>3</sup> )	R-717 Charge (lbs) <sup>[5]</sup>	Water Conn. In/Out	W	L	A
	Gravity Flooded	Pump Recirculated											
<b>E Series</b>													
TSU-125E	9,330	10,808	5,500	23,500	3	2,080	270	9	245	3"	5'-3 1/8"	10'-1"	4.5"
TSU-155E	11,410	12,250	6,230	28,000	3	2,520	320	10	275	3"	5'-3 1/8"	12'-1"	4.5"
TSU-180E	13,580	14,580	7,070	32,600	3	2,960	380	12	325	3"	5'-3 1/8"	14'-1"	4.5"
TSU-210E	15,660	16,740	8,090	37,400	3	3,400	440	13	355	4"	5'-3 1/8"	16'-0"	5"
TSU-235E	17,830	18,910	8,830	41,900	3	3,840	490	15	410	4"	5'-3 1/8"	18'-0"	5"
<b>F Series</b>													
TSU-145F	10,660	11,500	5,730	23,700	3	2,070	40	10	275	3"	5'-3 1/8"	10'-1"	4.5"
TSU-175F	13,080	14,080	6,500	28,100	3	2,510	45	12	325	3"	5'-3 1/8"	12'-1"	4.5"
TSU-205F	15,490	16,580	7,370	32,800	3	2,950	55	13	355	3"	5'-3 1/8"	14'-1"	4.5"
TSU-240F	17,910	18,990	8,370	37,600	3	3,390	65	15	410	4"	5'-3 1/8"	16'-0"	5"
TSU-270F	20,330	21,490	9,140	42,100	3	3,820	70	17	460	4"	5'-3 1/8"	18'-0"	5"

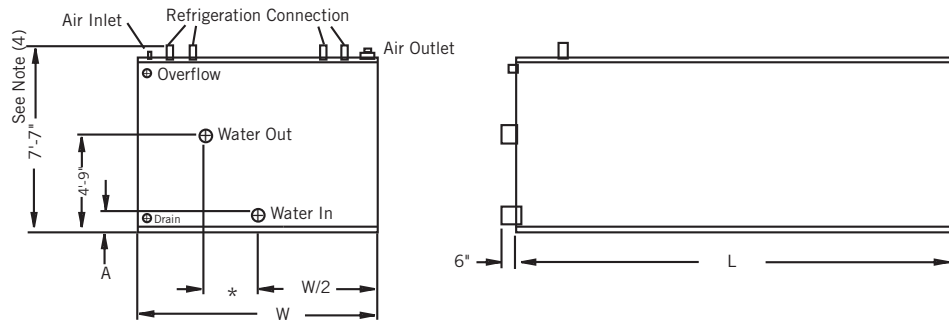


### NOTES:

- All dimensions are in feet and inches. Weights are in pounds.
- Pounds of ice capacity is based on R-717. For other refrigerants, consult your BAC Representative.
- Dimensions showing location of connections are approximate and should not be used for prefabrication of connecting piping.
- Dimension is installed height. Coils are capped for shipping and storage. Add 3 inches for shipping height.
- Refrigerant charge listed is operating charge for gravity flooded system at 15°F (-9°C). For other feed systems, consult your BAC Representative.
- ICE CHILLER® Thermal Storage Units should be continuously supported on a flat level surface.



## NOMINAL 8' AND 10' WIDE UNITS: MODELS TSU-190E TO TSU-505E AND TSU-220F TO TSU-580F



\*18" On TSU-190E-365E; TSU-220F-420F  
\*16" On TSU-290E-505E; TSU-330F-580F

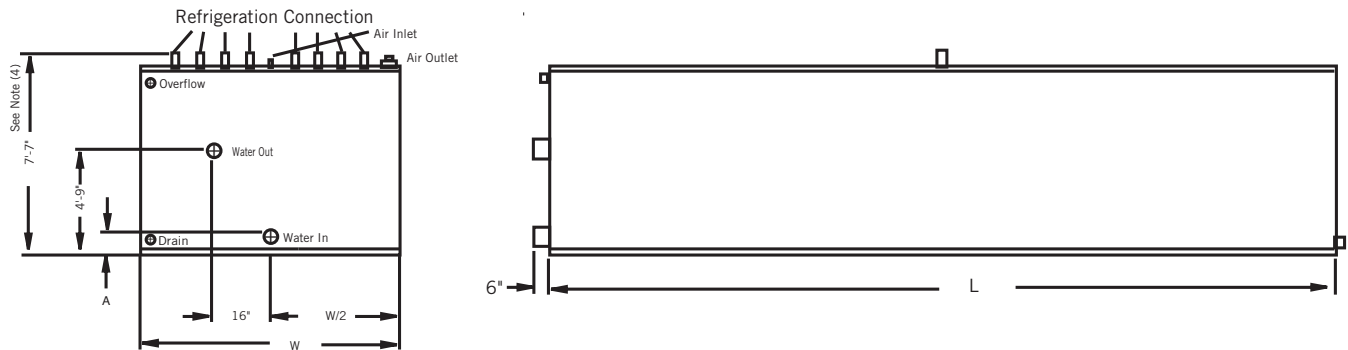
Model Number	LBS of Ice <sup>(2)</sup>		Approx. Shipping Weight (lbs)	Approx. Operating Weight (lbs)	Air Pump (HP)	Water Volume (gal)	Pull Down Volume (gal)	Coil Volume (ft <sup>3</sup> )	R-717 Charge (lbs) <sup>(5)</sup>	Water Conn. In/Out	W	L	A
	Gravity Flooded	Pump Recirculated											
<b>E Series</b>													
TSU-190E	14,410	15,580	7,670	36,200	3	3,300	420	15	410	4"	7'-10 1/2"	10'-1"	5"
TSU-230E	17,580	18,910	8,740	43,200	3	4,000	510	17	465	4"	7'-10 1/2"	12'-1"	5"
TSU-280E	20,910	22,490	9,700	50,200	3	4,700	600	19	515	4"	7'-10 1/2"	14'-1"	5"
TSU-320E	24,240	25,910	11,120	57,700	3	5,400	700	22	600	4"	7'-10 1/2"	16'-0"	5"
TSU-365E	27,570	29,240	12,100	64,500	3	6,100	800	24	650	6"	7'-10 1/2"	18'-0"	6"
TSU-290E	21,740	23,490	9,950	53,400	3	5,040	640	21	570	6"	9'-9 3/8"	12'-1"	6"
TSU-345E	25,820	27,820	11,200	62,000	3	5,920	760	23	625	6"	9'-9 3/8"	14'-1"	6"
TSU-395E	29,900	32,070	12,900	71,300	3	6,800	860	26	705	6"	9'-9 3/8"	16'-0"	6"
TSU-450E	33,990	36,150	14,050	80,000	3	7,080	980	29	790	6"	9'-9 3/8"	18'-0"	6"
TSU-505E	37,980	40,070	14,700	88,600	3	8,550	1090	32	870	6"	9'-9 3/8"	20'-0"	6"
<b>F Series</b>													
TSU-220F	16,410	17,660	8,040	36,500	3	3,290	60	16	435	4"	7'-10 1/2"	10'-1"	5"
TSU-265F	20,240	21,490	9,150	43,600	3	3,990	70	19	515	4"	7'-10 1/2"	12'-1"	5"
TSU-320F	23,990	25,660	10,180	50,600	3	4,680	90	21	570	4"	7'-10 1/2"	14'-1"	5"
TSU-370F	27,660	29,400	11,700	58,100	3	5,380	100	24	650	4"	7'-10 1/2"	16'-0"	5"
TSU-420F	31,400	33,240	12,730	65,100	3	6,070	110	26	705	6"	7'-10 1/2"	18'-0"	6"
TSU-330F	24,990	26,820	10,460	53,900	3	5,020	95	23	625	6"	9'-9 3/8"	12'-1"	6"
TSU-395F	29,650	31,740	11,780	62,510	3	5,890	110	26	705	6"	9'-9 3/8"	14'-1"	6"
TSU-455F	34,150	36,240	13,430	71,800	3	6,770	130	29	790	6"	9'-9 3/8"	16'-0"	6"
TSU-515F	38,820	40,980	14,650	80,500	3	7,640	140	32	870	6"	9'-9 3/8"	18'-0"	6"
TSU-580F	43,480	45,570	15,370	89,200	3	8,520	160	35	950	6"	9'-9 3/8"	20'-0"	6"



**NOTE:** See notes on previous page.

# TSU (E, F & G) Engineering Data

## NOMINAL 10' WIDE UNITS (CONTINUED): MODELS TSU-590E TO TSU-1080E AND TSU-675F TO TSU-1230F



Model Number	LBS of Ice <sup>[2]</sup>		Approx. Shipping Weight (lbs)	Approx. Operating Weight (lbs)	Air Pump (HP)	Water Volume (gal)	Pull Down Volume (gal)	Coil Volume (ft <sup>3</sup> )	R-717 Charge (lbs) <sup>[5]</sup>	Water Conn. In/Out	W	L	A
	Gravity Flooded	Pump Recirculated											
<b>E Series</b>													
TSU-590E	44,650	48,150	18,200	106,900	3	10,240	1,320	42	1,140	6"	9'-9 3/8"	23'-11"	6"
TSU-700E	52,560	56,560	20,820	124,500	3	12,030	1,540	47	1,275	6"	9'-9 3/8"	27'-11"	6"
TSU-810E	60,730	64,890	24,300	144,400	5	13,790	1,760	53	1,440	8"	9'-9 3/8"	31'-10"	7"
TSU-910E	68,890	73,220	26,600	160,200	5	15,540	1,990	58	1,575	8"	9'-9 3/8"	35'-10"	7"
TSU-1080E	80,630	85,130	30,060	186,200	5	18,180	2,330	67	1,820	8"	9'-9 3/8"	41'-9"	7"
<b>F Series</b>													
TSU-675F	51,150	54,980	19,240	107,900	3	10,200	190	46	1,250	6"	9'-9 3/8"	23'-11"	6"
TSU-800F	60,140	64,220	21,960	125,600	3	11,980	230	52	1,410	6"	9'-9 3/8"	27'-11"	6"
TSU-920F	69,470	73,800	25,380	143,700	5	13,700	260	59	1,600	8"	9'-9 3/8"	31'-10"	7"
TSU-1040F	78,891	83,300	27,820	161,300	5	15,480	290	65	1,765	8"	9'-9 3/8"	35'-10"	7"
TSU-1230F	92,460	96,130	31,460	187,500	5	18,100	340	74	2,010	8"	9'-9 3/8"	41'-9"	7"

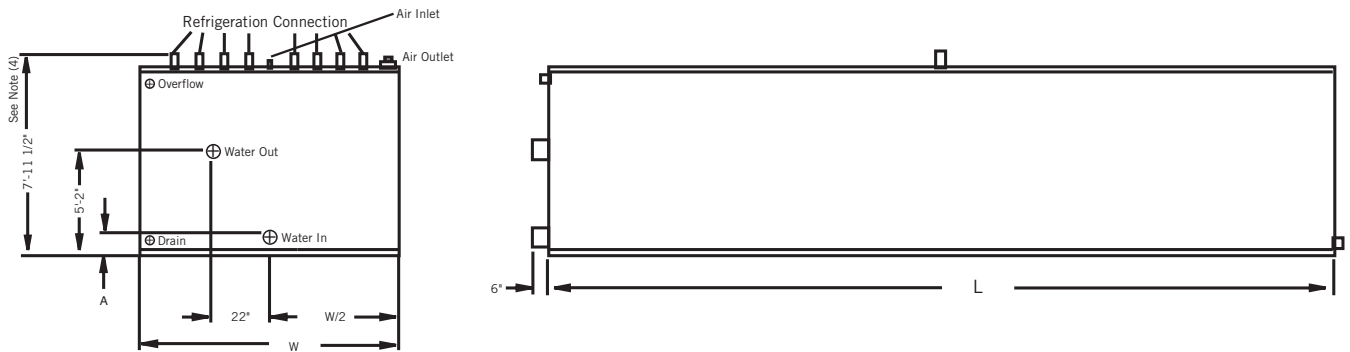


### NOTES:

- All dimensions are in feet and inches. Weights are in pounds.
- Pounds of ice capacity is based on R-717. For other refrigerants, consult your BAC Representative.
- Dimensions showing location of connections are approximate and should not be used for prefabrication of connecting piping.
- Dimension is installed height. Coils are capped for shipping and storage. Add 3 inches for shipping height.
- Refrigerant charge listed is operating charge for gravity flooded system at 15°F (-9°C). For other feed systems, consult your BAC Representative.
- ICE CHILLER® Thermal Storage Units should be continuously supported on a flat level surface.



## NOMINAL 12' WIDE UNITS: MODELS TSU-840F TO TSU-1520F AND TSU-940G TO TSU-1710G



Model Number	LBS of Ice <sup>[2]</sup>		Approx. Shipping Weight (lbs)	Approx. Operating Weight (lbs)	Air Pump (HP)	Water Volume (gal)	Pull Down Volume (gal)	Coil Volume (ft <sup>3</sup> )	R-717 Charge (lbs) <sup>[5]</sup>	Water Conn. In/Out	W	L	A
	Gravity Flooded	Pump Recirculated											
<b>F Series</b>													
TSU-840F	62,980	68,310	24,120	146,500	5	14,240	1,800	55	1,490	8"	11'-9"	23'-11"	7"
TSU-990F	74,470	80,470	26,900	170,000	5	16,650	2,100	63	1,710	8"	11'-9"	27'-11"	7"
TSU-1140F	85,880	92,960	31,460	200,600	5	19,080	2,320	71	1,925	8"	11'-9"	31'-10"	7"
TSU-1290F	97,380	105,210	34,340	218,800	5	21,500	2,710	78	2,115	8"	11'-9"	35'-10"	7"
TSU-1520F	114,540	123,280	38,660	254,400	5	25,150	2,900	90	2,440	8"	11'-9"	41'-9"	7"
<b>G Series</b>													
TSU-940G	70,890	75,970	25,440	147,700	5	13,960	280	61	1,655	8"	11'-9"	23'-11"	7"
TSU-1110G	83,880	89,630	28,340	171,400	5	16,350	330	70	1,900	8"	11'-9"	27'-11"	7"
TSU-1280G	96,880	102,380	33,220	196,900	5	18,730	380	79	2,145	8"	11'-9"	31'-10"	7"
TSU-1450G	109,540	114,790	36,260	220,600	5	21,110	420	87	2,360	8"	11'-9"	35'-10"	7"
TSU-1710G	129,120	132,700	40,820	256,400	5	24,690	490	100	2,710	8"	11'-9"	41'-9"	7"



### NOTES:

- All dimensions are in feet and inches. Weights are in pounds.
- Pounds of Ice Capacity is based on R-717. For other refrigerants, consult your BAC Representative.
- Dimensions showing location of connections are approximate and should not be used for prefabrication of connecting piping.
- Dimension is installed height. Coils are capped for shipping and storage. Add 3 inches for shipping height.
- Refrigerant charge listed is operating charge for gravity flooded system at 15°F (-9°C). For other feed systems, consult your BAC Representative.
- ICE CHILLER® Thermal Storage Units should be continuously supported on a flat level surface.



# Engineering Considerations – Refrigeration

## ► Suitable For: Industrial Refrigeration, Process Cooling, and Batch Cooling

For industrial applications, stored cooling using ICE CHILLER® Thermal Storage Units provides many opportunities for savings: smaller compressors and likewise smaller system components and electrical equipment; shifting or leveling of energy usage peaks; and efficient use of equipment. Also, since ice storage systems are sized to operate primarily at full capacity, compressor wear from capacity adjustment is minimized, providing maintenance savings over the life of the compressor. Stored cooling from ICE CHILLER Thermal Storage Units supplies consistently low temperature water, making it appropriate for daily and/or infrequent cooling loads in many industrial processes such as:

- Bakeries
- Dairies
- Breweries, Wineries, Distilleries
- Chemical/Plastics Manufacturers
- Laboratories
- Food Product Cooling
- Bottling Process
- Vegetable/Fruit Cooling

### ► PRINCIPLE OF OPERATION

The basic ice storage system includes an ICE CHILLER Thermal Storage Unit, a refrigeration system, and ice water pump as shown in **Figure 10**.

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 air 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 ice water pump is started, and the meltout cycle begins. Warm water returning from the load circulates through the ICE CHILLER Thermal Storage Unit and is cooled by direct contact with the melting ice. During this cycle, the tank water is agitated to provide more uniform ice melting and a constant supply water temperature of 34°F (1°C) to 36°F (2°C).

For a closed chilled water loop, see **Figure 11**. 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 Thermal Storage Unit.

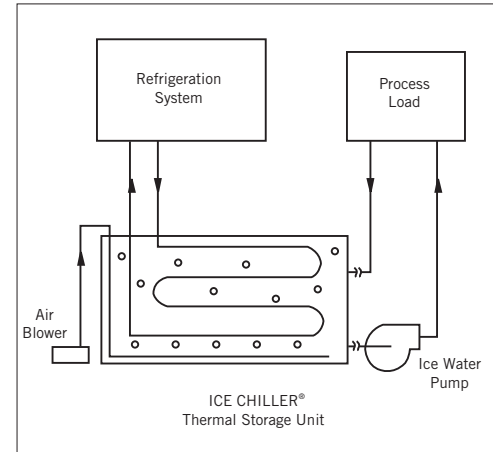


Figure 10

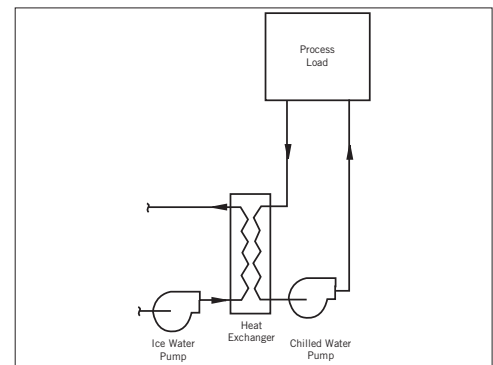


Figure 11



## > Energy Efficient Design

The ICE CHILLER® Thermal Storage Unit coils are designed for efficient energy use in building ice and constant leaving water temperatures during the meltout cycle.

Compared to traditional ice builders used in the past for industrial refrigeration, the ICE CHILLER Thermal Storage Unit design with its smaller diameter coil circuits and thinner ice (**Figure 12**) results in more evaporator surface per ton-hour of latent storage. Ice builds to a thin 2.0 inches, which results in more than a 16% gain in refrigeration system efficiency by permitting compressor operation at higher suction pressures.

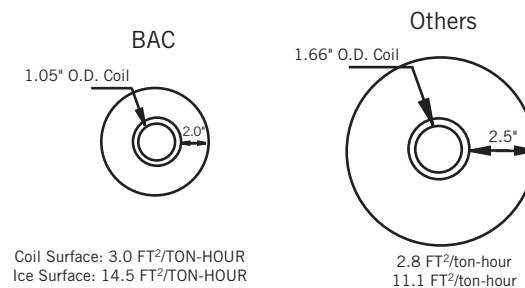


Figure 12

The ICE CHILLER Thermal Storage Unit is specifically designed to provide consistent 34- 36°F supply water temperatures throughout the melt cycle. Two keys to maintaining this consistently low temperature are an extensive ice surface area and direct contact of the water to be cooled with the ice. As shown in **Figure 12**, the unique BAC coil design provides over 30% more ice surface than traditional designs. This provides a greater surface area for the warm return water to come into direct contact, making consistent cold temperatures available throughout the entire melt cycle.

The ICE CHILLER Thermal Storage Unit is designed for efficient operation with either of two liquid refrigerant feed systems: gravity flooded with surge drum or pumped recirculation. With either arrangement, liquid refrigerant is supplied to the coils at a rate several times greater than that required to satisfy the load. This excess flow rate thoroughly wets the entire internal surface of the coil, assuring high heat transfer coefficients throughout to efficiently utilize the entire coil surface for ice building.

# Engineering Considerations – Refrigeration

## > System Design Flexibility

The system design involving an ICE CHILLER® Thermal Storage Unit can range from full storage to partial storage of the cooling load requirements.

- ▶ **Full Storage** – With full storage, the ICE CHILLER Thermal Storage Unit generates and stores ice to handle the entire cooling load. The refrigeration system operates to build the ice only during no-load periods when utility rates are usually lowest. This design offers the maximum energy cost savings, but requires the largest ice storage capacity and refrigeration system.
- ▶ **Partial Storage** – A partial storage system builds ice during no-load periods as with the full storage system. However, the refrigeration system continues to operate during the cooling load period. The compressor operation supplements the stored cooling capacity of the ICE CHILLER Thermal Storage Unit to satisfy the cooling requirements. Since a portion of the cooling requirement is supplied by the refrigeration system, a partial storage system will require less storage capacity.
- ▶ **Parallel Chilled Water Evaporator** – The most common type of partial ice storage is the parallel evaporator system. During the melt cycle, cooling is provided by the refrigeration system to a separate evaporator for direct water chilling. By using a separate evaporator, the refrigeration system gains system efficiency from operation at higher suction pressures.

The refrigeration system will operate continuously during full design load. At less than full load the compressor operates only as needed to supplement the ICE CHILLER Thermal Storage Unit. When the load is less than 50% of design, this system can operate in the full storage mode. Systems which often operate at part load can benefit most from a partial system with equipment sizes typically over 50% smaller than required for full storage. For additional information on ICE CHILLER Thermal Storage Units and their system design options consult your BAC Representative.

- ▶ **System Load** – The system load is the amount of cooling capacity that must be generated and stored, expressed in ton-hours or Btu. (1 ton-hour = 12,000 Btu = 83.3 pounds of ice). This load is equal to the area under the typical system load profile curve (**Figure 13**).



## > Thermal Storage Unit Selection

### ▶ Full Storage

1. From the system load profile (**Figure 13**) establish the required system cooling capacity in ton-hours. This is the ton-hours of storage required.
2. Determine the build time, which is the number of hours with no load that is available for ice building. If less than ten (10) hours, consult your BAC Representative.
3. For a gravity flooded ammonia feed system, continue the selection with the gravity flooded procedure on **pages G30 and G31**. For a pump recirculated ammonia feed system, continue the selection with the pump recirculated procedure on **pages G31 and G32**.

### ▶ Parallel Chilled Water Evaporator Partial Storage

1. From the system load profile (**Figure 13**), establish the required system cooling capacity in ton-hours and the number of hours this cooling is needed.
2. Determine the cooling capacity in tons of the compressor operating with the parallel evaporator (**Figure 14**) during the cooling load hours established in Step 1.
3. Multiply the cooling capacity of the compressor operating with parallel evaporator found in Step 2 times the number of cooling load hours found in Step 1. This gives the capacity in ton-hours that will be handled by direct refrigeration during the cooling period.
4. Subtract the direct cooling ton-hours found in Step 3 from the total system cooling capacity found in Step 1. This is the storage capacity in ton-hours that are required in ice storage.
5. Determine the build time, which is the number of hours with the compressor dedicated to ice building. If less than ten hours, consult your local BAC Representative.
6. For gravity flooded ammonia feed system, continue the selection with the gravity procedure on **pages G30 and G31**. For a pump recirculated ammonia feed system, continue the selection with the pump recirculated procedure on **pages G31 and G32**.

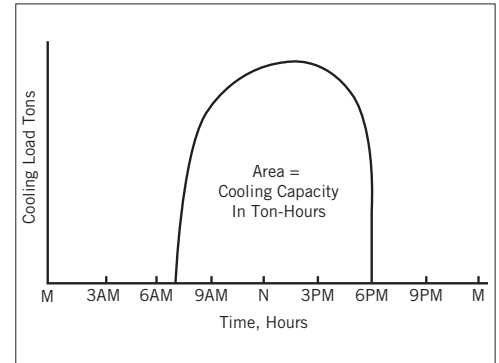


Figure 13

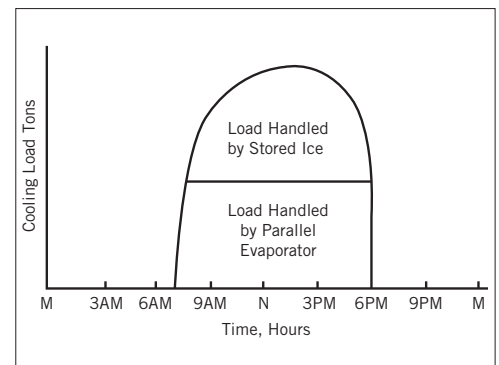


Figure 14

# Unit Selection - Ammonia

## SELECTION PROCEDURE – GRAVITY FLOODED

1. Enter **Table 2** and read down the base ton-hours column to the capacity which meets or exceeds the ton-hours of storage required. Select either an E, F, or G series unit. (Units are grouped by tank width in **Table 2**. Refer to **pages G22** thru **G25** for unit dimensions.)

2. Read the selected unit from the model number column on the left.

3. Calculate the Storage Factor for the selected unit.

$$\frac{\text{Base Ton-Hours}}{\text{Ton-Hours of Storage Required}} = \text{Storage Factor}$$

4. Using the Storage Factor from Step 3 and the available build time, enter **Table 3** to find the design evaporator temperature.

5. Determine the design compressor capacity in tons.

$$\frac{\text{Ton-Hours of Storage Required}}{\text{Build Time (hrs)}} = \text{Compressor Tons}$$

6. Using the design conditions from Steps 4 and 5, select a compressor. (Note: The evaporator temperature must be adjusted for the system suction line losses to arrive at the compressor saturated suction temperature.)
7. Once the compressor has been selected, use the compressor manufacturer's heat rejection data to size a BAC Evaporative Condenser or Cooling Tower.

## EXAMPLE: Gravity Flooded Ammonia

**Given:** 16,700 lbs ice required storage capacity, 14 hours available build time

To get ton-hours of storage required:

$$\frac{16,700 \text{ lbs ice required storage capacity}}{83.3 \text{ lbs ice per Ton-Hour}} = 201 \text{ Ton-Hours}$$

1. Enter the base ton-hours column of **Table 2** and find 211 ton-hours, which is the smallest value that meets or exceeds the 201 ton-hours of storage required.

2. Read to the left to find the selected model number, in this case a TSU-230E.

3. Calculate the Storage Factor.

$$\frac{211 \text{ Ton-Hours of Storage Required}}{201 \text{ Ton-Hours of Storage Required}} = 1.05$$

4. Using the Storage Factor of 1.05 from Step 3 and the build time of 14 hours, enter **Table 3** to find the design evaporator temperature of 19.9°F.

5. Calculate the design compressor capacity.

$$\frac{201 \text{ Ton-Hours of Storage Required}}{14 \text{ Hours of Build Time}} = 14.4 \text{ Tons}$$

6. Based on the design evaporator conditions of 14.4 tons at a 19.9°F evaporator temperature (17.9°F saturated suction temperature, with 2.0°F estimated suction line losses), select an ammonia refrigerant compressor.

7. Select a BAC Evaporative Condenser or Cooling Tower to match the compressor manufacturer's heat rejection requirements.



## APPLICATION NOTES:

1. To use the selection procedures, the ton-hours of storage capacity required and the available build time must first be known. For guidance on estimating these values refer to the TSU selection on **page G29** or contact your local BAC Representative.
2. The evaporator temperatures for each build time are "average" values. During the build cycle, the temperature will initially be about 8°F (-13°C) above the "average" and gradually drop through the cycle to about 4°F (-15°C) below the "average" when full ice is reached. Throughout the cycle the refrigeration system should be allowed to run fully loaded. Reciprocating and rotary screw compressors are suitable for this duty. If in doubt about the use of a particular compressor, review the application with the compressor manufacturer.

3. The capacities of all BAC ICE CHILLER® Thermal Storage Units are based on latent storage (ice) only. The temperature of the water supplied from the storage tank for most system designs will be 34°(-1°C) - 36°F (-2°C) throughout the latent storage discharge (melt) cycle. For specific system design requirements, contact your local BAC Representative.
4. For selections based on other refrigerants, contact your local BAC Representative.
5. These procedures assume that no system cooling load occurs while ice is being formed. For ICE CHILLER Thermal Storage Unit selections involving systems with continuous cooling loads consult your local BAC Representative.





**Table 2.** Base Storage Capacity (ton-hours) For Gravity Flooded Ammonia Feed<sup>[1]</sup>

TSUE-Series Units		F-Series Units		F-Series Units	
Model Number	Base Ton-Hrs	Model Number	Base Ton-Hrs	Model Number	Base Ton-Hrs
TSU-125E	112	TSU-145F	128	TSU-840F	756
TSU-155E	137	TSU-175F	157	TSU-990F	894
TSU-180E	163	TSU-205F	186	TSU-1140F	1,031
TSU-210E	188	TSU-240F	215	TSU-1290F	1,169
TSU-235E	214	TSU-270F	244	TSU-1520F	1,375
TSU-190E	173	TSU-220F	197	<b>G-Series Units</b>	
TSU-230E	211	TSU-265F	243		
TSU-280E	251	TSU-320F	288	Model Number	Base Ton-Hrs
TSU-320E	291	TSU-370F	332	TSU-940G	851
TSU-365E	331	TSU-420F	377	TSU-1110G	1,007
TSU-290E	261	TSU-330F	300	TSU-1280G	1,163
TSU-345E	310	TSU-395F	356	TSU-1450G	1,315
TSU-395E	359	TSU-455F	410	TSU-1710G	1,550
TSU-450E	408	TSU-515F	466		
TSU-505E	456	TSU-580F	522		
TSU-590E	536	TSU-675F	614		
TSU-700E	631	TSU-800F	722		
TSU-810E	729	TSU-920F	834		
TSU-910E	827	TSU-1040F	947		
TSU-1080E	968	TSU-1230F	1,110		

**SELECTION PROCEDURE – PUMP RECIRCULATED**

- Enter **Table 4** and read down the base ton-hours column to the capacity which meets or exceeds the ton-hours of storage required. Select either an E, F, or G Series unit. (Units are grouped by tank width in **Table 4**. Refer to **pages G22** thru **G25** for unit dimensions.)
- Read the selected unit from the model number column on the left.
- Calculate the Storage Factor for the selected unit.
 
$$\frac{\text{Base Ton-Hours}}{\text{Ton-Hours of Storage Required}} = \text{Storage Factor}$$
- Using the Storage Factor from Step 3 and the available build time, enter **Table 5** to find the design evaporator temperature.
- Determine the design compressor capacity in tons.
 
$$\frac{\text{Ton-Hours of Storage Required}}{\text{Build Time (hrs)}} = \text{Compressor Tons}$$
- Using the design conditions from Steps 4 and 5, select a compressor. Note: The evaporator temperature must be adjusted for the system suction line losses to arrive at the compressor saturated suction temperature.
- Once the compressor has been selected, use the compressor manufacturer's heat rejection data to size a BAC Evaporative Condenser or Cooling Tower.

**Table 3.** Design Evaporator Temperature (°F) for Gravity Flooded Ammonia Feed<sup>[1]</sup>

Storage Factor	Build Time (hrs)				
	10	11	12	13	14
1.00	14.3	15.7	17.2	18.3	19.4
1.05	15.6	16.8	18.1	19.0	19.9
1.10	16.5	17.7	18.9	19.7	20.5
1.15	17.4	18.5	19.6	20.3	21.1
1.20	18.1	19.1	20.2	20.9	21.7
1.25	18.8	19.7	20.7	21.4	22.1
1.30	19.4	20.3	21.2	21.9	22.6



**NOTE:**

- Interpolation between values is permitted, but extrapolation of values is not.

**EXAMPLE:** Pump Recirculated Ammonia

**GIVEN:** 700 ton-hours required storage, 11 hours available build time

- Enter the base ton-hours column of **Table 4** and find 771 ton-hours, which is the smallest value that meets or exceeds the 700 ton-hours of storage required.
- Read to the left to find the selected model number, in this case a TSU-800F.
- Calculate the Storage Factor.
 
$$\frac{771 \text{ Base Ton-Hour}}{700 \text{ Ton-Hours of Storage Required}} = 1.10$$
- Using the Storage Factor of 1.10 from Step 3 and the build time of 11 hours, enter **Table 5** to find the design evaporator temperature of 17.7 °F.
- Calculate the design compressor capacity.
 
$$\frac{700 \text{ Ton-Hours of Storage Required}}{11 \text{ Hours Build Time}} = 63.6 \text{ Tons}$$
- Based on the design evaporator conditions of 63.6 tons at a 17.7 °F evaporator temperature (15.7 °F saturated suction temperature, with 2.0 °F estimated suction line losses), select an ammonia refrigerant compressor.
- Select a BAC Evaporative Condenser or Cooling Tower to match the compressor manufacturer's heat rejection requirements.

# Unit Selection - Ammonia

**Table 4.** Base Storage Capacity (ton-hours) For Pump Recirculated Ammonia Feed<sup>(1)</sup>

E Series Units		F-Series Units		F-Series Units	
Model Number	Base Ton-Hours	Model Number	Base Ton-Hours	Model Number	Base Ton-Hours
TSU-125E	121	TSU-145F	138	TSU-840F	820
TSU-155E	147	TSU-175F	169	TSU-990F	966
TSU-180E	175	TSU-205F	199	TSU-1140F	1,116
TSU-210E	201	TSU-240F	228	TSU-1290F	1,263
TSU-235E	227	TSU-270F	258	TSU-1520F	1,480
TSU-190E	187	TSU-220F	212	<b>G-Series Units</b>	
TSU-230E	227	TSU-265F	258		
TSU-280E	270	TSU-320F	308		
TSU-320E	311	TSU-370F	353		
TSU-365E	351	TSU-420F	399		
TSU-290E	282	TSU-330F	322	TSU-940G	912
TSU-345E	334	TSU-395F	381	TSU-1110G	1,076
TSU-395E	385	TSU-455F	435	TSU-1280G	1,229
TSU-450E	434	TSU-515F	492	TSU-1450G	1,378
TSU-505E	481	TSU-580F	547	TSU-1710G	1,593
TSU-590E	578	TSU-675F	660		
TSU-700E	679	TSU-800F	771		
TSU-810E	779	TSU-920F	886		
TSU-910E	879	TSU-1040F	1,000		
TSU-1080E	1,022	TSU-1230F	1,154		

**Table 5.** Design Evaporator Temperature (°F) for Pump Recirculated Ammonia Feed<sup>(1)</sup>

Storage Factor	Build Time (hrs)				
	10	11	12	13	14
1.00	14.3	15.7	17.1	18.1	19.1
1.05	15.5	16.8	18.1	19.0	20.0
1.10	16.5	17.7	19.0	19.9	20.8
1.15	17.4	18.5	19.7	20.5	21.4
1.20	18.3	19.3	20.4	21.2	22.0
1.25	19.0	20.0	21.0	21.7	22.5
1.30	19.7	20.6	21.6	22.3	23.0



**NOTE:**

1. Interpolation between values is permitted, but extrapolation of values is not.

# Custom Coils



When space is limited and a fully customized thermal storage solution is desired, BAC manufactures custom ice thermal storage coils that will 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.

## ▶ MINIMAL SPACING REQUIREMENTS

BAC Ice Thermal Storage Coils are designed to be stacked in custom built tanks. Each coil is assembled in a durable structural steel frame constructed to support the weight of the coil stack with a full ice build. Concrete tanks can be built below ground and buried. The above ground space can then be utilized for a multitude of purposes including parking lots, playgrounds, and landscaping.

## ▶ CUSTOM COIL SELECTION

BAC utilizes hour-by-hour project specific temperature and load profile predictions for project selections. Many design factors are taken into consideration including, the physical space available, load profile, discharge temperatures, chiller capacity, and operating sequence. With both internal melt and external melt capability, BAC can provide a custom solution that best meets the project needs.

## ▶ PATENTED VARIABLE SPACING TECHNOLOGY

BAC coils are designed with patented variable spacing technology and counter current glycol flows in adjacent circuits. This coil configuration maintains water flow around the coils, and is “self-correcting” to allow ice melt close to design limit without manual operator intervention. BAC coils are constructed with high heat transfer steel coil material that produces constant, low discharge temperatures, and maximum storage capacity. These low discharge temperatures increase the efficiency of the entire cooling system.

## ▶ QUALITY DESIGN AND CONSTRUCTION

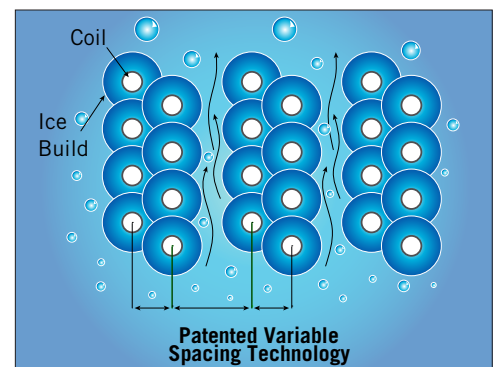
BAC is ISO 9001:2010 certified and all products undergo closely controlled manufacturing processes to ensure the highest quality design and standards. Ice thermal storage coils are constructed of continuous 1.05” O.D. (outside diameter) prime surface serpentine steel tubing, with no intermediate butt welds, and are leak tested at the factory up to 375 psig.



Plaza Robles Before



Plaza Robles After



Patented Variable Spacing Technology

# Proven Technology

BAC has successfully applied ice storage technology to thousands of installations worldwide, ranging in size from 90 to 125,000 ton-hours (0.3 to 441.3 MWh). BAC has the applications knowledge and experience to assist in the design, installation, and operation of any ice thermal storage system. Installations include office buildings, hospitals, manufacturing processes, schools, universities, sports arenas, produce storage facilities, hotels, and district cooling applications.

The ICE CHILLER® Product includes a variety of factory-assembled units. For large applications, where space is limited, ICE CHILLER Thermal Storage Coils are available for installation in customer supplied field-erected tanks.

BAC's Ice Thermal Storage product line offers system design flexibility. Ice thermal storage can be built using various refrigerants or glycols in steel coils to provide either chilled water or chilled glycol to the cooling system. This flexibility, combined with a broad range of application experiences, allows BAC to provide a cost effective product to meet your specific requirements.

## ▶ **JOHNS HOPKINS APPLIED PHYSICS LAB**

The Johns Hopkins University Applied Physics Lab in Laurel, MD installed 5,600 ton-hours (19.8 MWh) of ICE CHILLER Thermal Storage Coils in underground rectangular tanks to cool the Steven Mueller Building which houses offices, labs and clean rooms. Another 2,800 ton-hours (9.9 MWh) of ICE CHILLER Thermal Storage Coils were added to cool adjacent office and lab buildings. The ice thermal storage allowed the Applied Physics Lab to save over \$150,000 per year on its electric bill.

## ▶ **CCTV**

As one of the most important supporting facilities of the 2008 Beijing Olympic Games, the CCTV headquarters is the largest cultural facility and construction project ever approved by the Chinese State Development and Planning Commission. The two main buildings are a series of horizontal and vertical sections, establishing it as an architecturally one of a kind 'earthbound' structure rather than a traditional skyscraper. The CCTV tower allows China State Television to broadcast more than 200 channels. They were limited to only 16 channels in their previous facility.



TSUM Installation Catonsville Community College



BAC ICE Coil Installation Camden Yards



Johns Hopkins Applied Physics Lab



As a significant building, it was essential that CCTV utilize an advanced and reliable air conditioning system. Television stations produce a great deal of heat from large light loads in studios and electronics equipment which also require lower than normal operating temperatures. Furthermore, a reliable emergency cooling system is essential in case of a power failure. BAC's Ice Thermal storage was the best solution, utilizing 24 sets of external-melt coils (TSC-950S) which provide 22,800 ton-hours of ice thermal storage capacity.

Using an external melt ice thermal storage system, BAC Ice Thermal Storage equipment supplies constant cold water at 34° F (1.1°C). A system like this reduces operation costs by supplying a constant source of cold water while also providing emergency cooling capacity. BAC Ice Thermal Storage is used during peak energy periods to reduce the electric demand and achieve the lowest operating cost. During mild weather, the ice thermal storage system can meet all of the peak hour cooling requirements, eliminating the need to run the chillers during peak demand periods.



CCTV

## > Emergency Cooling

### ▶ VERIZON

Verizon, the provider of telephone service to a large portion of the east coast, uses an ICE CHILLER® Thermal Storage Unit to provide back-up cooling to one of its computer centers in Silver Spring, MD. If the chiller that provides cooling goes down for any reason, the system immediately switches over to the ice thermal storage system for cooling. The pump on the ice thermal storage system is on continuous power back-up with the computers. There is enough ice to provide cooling to the entire system for 30 minutes. This gives Verizon enough time to clear the alarm or get the back-up generator running and the chiller back on line.



Verizon



# Proven Technology

## ▶ STEVENSON UNIVERSITY

Modular ICE CHILLER® Thermal Storage Units were part of an expansion that doubled the size of this private college in Baltimore, MD. The new facilities added 135,700 ft<sup>2</sup> (12,620 m<sup>2</sup>) of space to the campus and include a 400-seat auditorium and theater, gymnasium, student center, video center, computer classrooms, kitchen and administrative offices. The architect designed the new buildings with the intention that the structure be part of the visual space. This reduced the space allotted for the mechanical equipment. The engineer designed a low temperature air system that delivers 45°F (7°C) air temperature to VAV series fan powered boxes. The use of smaller piping and ductwork made it possible to avoid architectural changes that would affect the aesthetics of the design.



Stevenson University

## ▶ FRIENDSHIP ANNEX 3 OFFICE BUILDING

The HVAC renovation of Friendship Annex (FANX) in Baltimore, MD received the “Outstanding Engineering Achievement of the Year Award” from the Engineering Society of Baltimore. Low temperature air distribution cools these renovated buildings. To meet federal guidelines, a comprehensive study of five alternate systems was made using life cycle costing. The analysis showed ice thermal storage with low temperature chilled water and low temperature air to be the most economical system. A total of 15,230 ton-hours (53.8 MWh) of ICE CHILLER Thermal Storage Units were installed for the two buildings.



Friendship Annex 3 Office Building

## > Retrofit

## ▶ MERCHANDISE MART

Merchandise Mart in Chicago, Illinois, installed 26,400 ton-hours (93.2 MWh) of ICE CHILLER Thermal Storage Coils in a retrofit of the building’s air-conditioning system. The Merchandise Mart was built in 1930. The increased air-conditioning load on the building from computers, other electrical equipment, and increased people density made the old system too small. With low temperature water, ice thermal storage allowed the retrofit of the air conditioning system to go ahead without replacing piping and ductwork. Increasing the temperature ranges on the piping and air distribution system allowed the Merchandise Mart to install an ice storage system at a lower first cost than a conventional system.



Merchandise Mart



## > District Cooling

### ▶ NOVA SOUTHEASTERN UNIVERSITY

Located in steamy Fort Lauderdale, FL, NSU is one of the nation's largest independent universities. In 2009 NSU began phase 1 of its expansion project and set out to find a cooling solution for their growing campus. Their goal was to provide chilled water to the entire university from one central energy plant. In 2008, Hill York installed the first BAC ice tank, with a cooling capacity of 2,220 tons and 19,800 ton-hours of ice storage capacity.

In 2015, NSU completed phase 2 of the cooling system as the campus further expands, installing three more BAC ice thermal systems, total 79,200 ton-hours of ice storage capacity, making it one of the largest thermal energy storage systems in the United States.

The ice thermal storage system used at NSU is a sustainable alternative to traditional cooling that stores energy as ice during off-peak hours, allowing the system to take advantage of cleaner and more efficient energy sources.

To avoid the high cost of electricity during peak hours, the chillers at NSU are turned off during on-peak periods to reduce running cost. With ice melting providing the cooling needs on the campus, the plant is able to achieve running cost of less than \$8/hour during peak hours.



NOVA Southeastern University

### ▶ VEOLIA

Veolia Energy Baltimore Cooling has supplied chilled water and related HVAC building services to downtown Baltimore business corridor since 1996. Delivering more than 32,000 tons of cooling capacity and approximately 76,000 ton-hours of low temperature chilled water to cool 48 customers with more than 11.5 million square feet of conditioned space, the district cooling system is one of the largest ice thermal storage systems in the country. Customers served include university facilities, several Federal, State and City government facilities, public housing complexes, prestigious office buildings, healthcare facilities, and hotels in downtown and Inner Harbor East. Veolia's district cooling plant utilizes stacked BAC coils in both steel and concrete tanks. The flexibility and stackability of BAC ice coils allowed the cooling plant to overcome the limitations and site constraints of a congested downtown area.



Veolia

# Proven Technology

## > Food Processing

### ▶ ZIPPY'S RESTAURANT CENTRAL FACILITY

At Zippy's in Honolulu, HI, food is cooked in a central kitchen where it is cooled and packaged for use in local Zippy's restaurants. The FDA requires that the food in the cooking vessels be cooled to 45°F (7°C) in less than one hour to prevent contamination. The cooking vessels in the kitchen need varying amounts of cooling depending on the dish that is being prepared, and when it finishes its cooking cycle. Because of the varying cooling load from day to day and hour to hour and the need for a quick cool down period, standard chillers are not a good match for this application. Ice thermal storage with its variable capacity and low supply temperature is an excellent match for this process cooling application.



Zippy's

## > Power Generation

### ▶ WOLVERINE POWER

Wolverine Power, located in central Michigan, is a generation and transmission electric cooperative. For a new generating plant with (2) 22-megawatt Rolls Royce turbines, Wolverine Power elected to use ice thermal storage for their turbine inlet air cooling. They installed 7,610 ton-hours (26.9 MWH) of ICE CHILLER® Thermal Storage Units to generate 40°F (4.4°C) chilled water, which provides 55°F (13°C) inlet air. The generating plant's ice storage capacity can be used over a 16-hour period as partial storage or over a 4-hour period as full storage, depending on the value of power on the open market. During peak summer time, the increased power capacity is worth up to \$3,500 per hour in electricity sales.



Wolverine Power