## BAC Ice Storage

| Similar Model | TSU-237M |
|---|---|
| Latent Capacity (Ton-Hours | 237 |
| Approx. Shipping Weight (Pounds) | 9,750 |
| Approx. Operating Weight (Pounds) | 39,100 |
| Tank Water Volume (Gallons) | 2,990 |
| Coil Glycol Volume (Gallons) | 260 |
| Connection Size (Inches) | 2” |
| Unit Width | 7’ 10-3\8” |
| Unit Length | 10’ 7-5\8” |

## OPERATING STRATEGIES

The next step in selecting thermal storage equipment is to define an operating strategy. Choices include either full or partial storage. Partial storage operating strategies can be categorized as either demand limiting or load leveling. The operating strategy used is dependent upon the load profile, utility rate structure, energy cost and equipment first cost. Full storage systems eliminate the need to operate the chiller during the utility on–peak period by storing the required cooling capacity during off–peak periods. This strategy shifts the largest amount of electrical demand and results in the lowest operating costs. However, the equipment first cost is considerably higher than partial storage systems due to larger chiller and storage requirements. Unlike full storage systems, the chiller must operate during the on–peak period when a partial storage operating strategy is used. There are two types of partial storage operating strategies. The first is demand limiting. With the demand limiting operating strategy, the non–storage system loads establish the peak demand for the facility. Items that contribute to the non–storage system loads include lights, equipment, appliances, fans, motors etc. The thermal storage equipment is selected so the chiller operation does not increase the facility’s non–storage demand. This operating strategy provides the lowest operating costs for partial storage systems. This strategy also requires less storage capacity and smaller chillers than a full storage design.

The disadvantages of the demand limiting operating strategy are that the storage requirement and chiller capacity are larger than required for a load leveling operating strategy. This results in a longer payback period.

The second partial storage operating strategy is load leveling. By distributing the cooling load equally over a 24–hour period, this operating strategy reduces the size of the thermal storage equipment and chiller when compared to either full storage or demand limiting strategies. This results in the lowest possible first cost and shortest payback period. Since the chiller operates fully loaded during the on–peak period, operating costs are higher than either demand limiting or full storage operating strategies.

## MODES OF OPERATION

The modular ICE CHILLER® 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 through the coils contained in the ICE CHILLER® Thermal Storage Unit. Figure 2 illustrates typical chiller supply temperatures for 8, 10 and 12 hour build cycles. For a typical 10–hour build time, the supply glycol temperature is never lower than 22°F. As the graph illustrates, for build times exceeding 10 hours, the minimum glycol temperature is greater than 22°F. For build times less than 10 hours, the minimum glycol temperature will be lower than 22°F at the end of the build cycle. This performance is based on a chiller flow rate associated with a 5°F range. When a larger temperature range is the basis of the chiller selection, the chiller supply temperatures will be lower than shown in figure 2

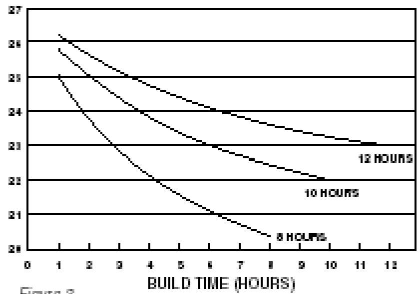


*Figure 2*
*Chiller Supply Temperatures*

**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.
This reduces the possibility of damaging the cooling coil or heat exchanger by pumping cold glycol, lower than 32°F, 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® 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 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.

## SYSTEM SCHEMATICS

Two basic flow schematics are applied to select BAC's ICE CHILLER® Thermal Storage Units. Figure 3 illustrates a single piping loop with the chiller installed upstream of the thermal storage equipment. This

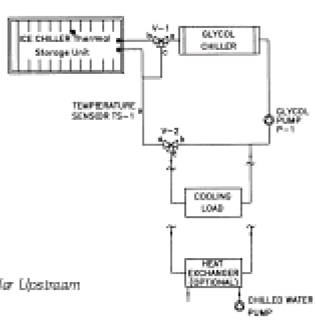


*Figure 3*
*Single Loop – Chiller Upstream*

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. For this schematic 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, the cooling coil or heat exchanger is subject to freezing.

The flow schematic illustrated in Figure 4 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.

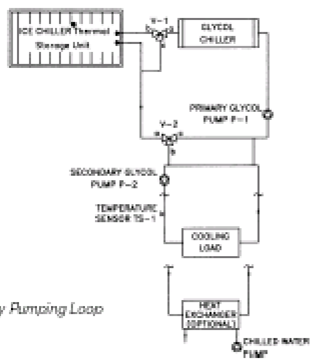


*Figure 4*
*Primary/Secondary Pumping Loop*
*Chiller Upstream*

For this schematic, 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 | A-C | 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. 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 Figure 3 and Figure 4, 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.

## 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 (tonnage) and glycol discharge temperature must be evaluated when designing a thermal storage system. Different glycol discharge temperatures are required for various operating modes which affect the chiller capacity. The chiller tonnage provided at 22°F is considerably less than the chiller tonnage with a 44°F glycol discharge temperature.

Chillers selected for use with the BAC's ICE CHILLER® Thermal Storage Units should be able to provide 22°F 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 22°F.

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

| CHILLER TYPE | NOMINAL TONNAGE RANGE |
|---|---|
| Reciprocating | 10 - 240 |
| Rotary screw | 120 - 1,200 |
| Centrifugal | 160 - 2,000+ |

Centrifugal and rotary screw chillers have the highest efficiencies with ranges from 0.6 to 0.75 kW/ton at 44°F chiller discharge temperature and 0.87 to 1.1 kW/ton when providing 22°F glycol. Reciprocating chillers are less efficient and have efficiencies ranging from 0.85 to 1.1 when providing 44°F glycol and 1.1 to 1.3 kW/ton when making ice at 22°F.

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 vapor 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 nighttime 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. Nominal capacity of the chiller is based on cooling water to 44°F.

| GLYCOL DISCHARGE TEMPERATURE | PERCENT OF NOMINAL CAPACITY |
|---|---|
| 44°F | 97% |
| 36°F | 85% |
| 22°F | 66% |

Nominal capacity ratings are based on:

85°F condenser water or 115°F condensing temperature for cooling operation

80°F condenser water or 105°F 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).

## 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 5°F to 7°F above the glycol freeze point. The freeze point for a system with 25% ethylene glycol is 14°F.

Two acceptable industrial grade inhibited ethylene glycol solutions are Dow's DOWTHERM® SR–1 and Union Carbide's UCARTHERM®. Use of other brands of ethylene glycol in BAC's ICE CHILLER® Thermal Storage Products should be approved by BAC.

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