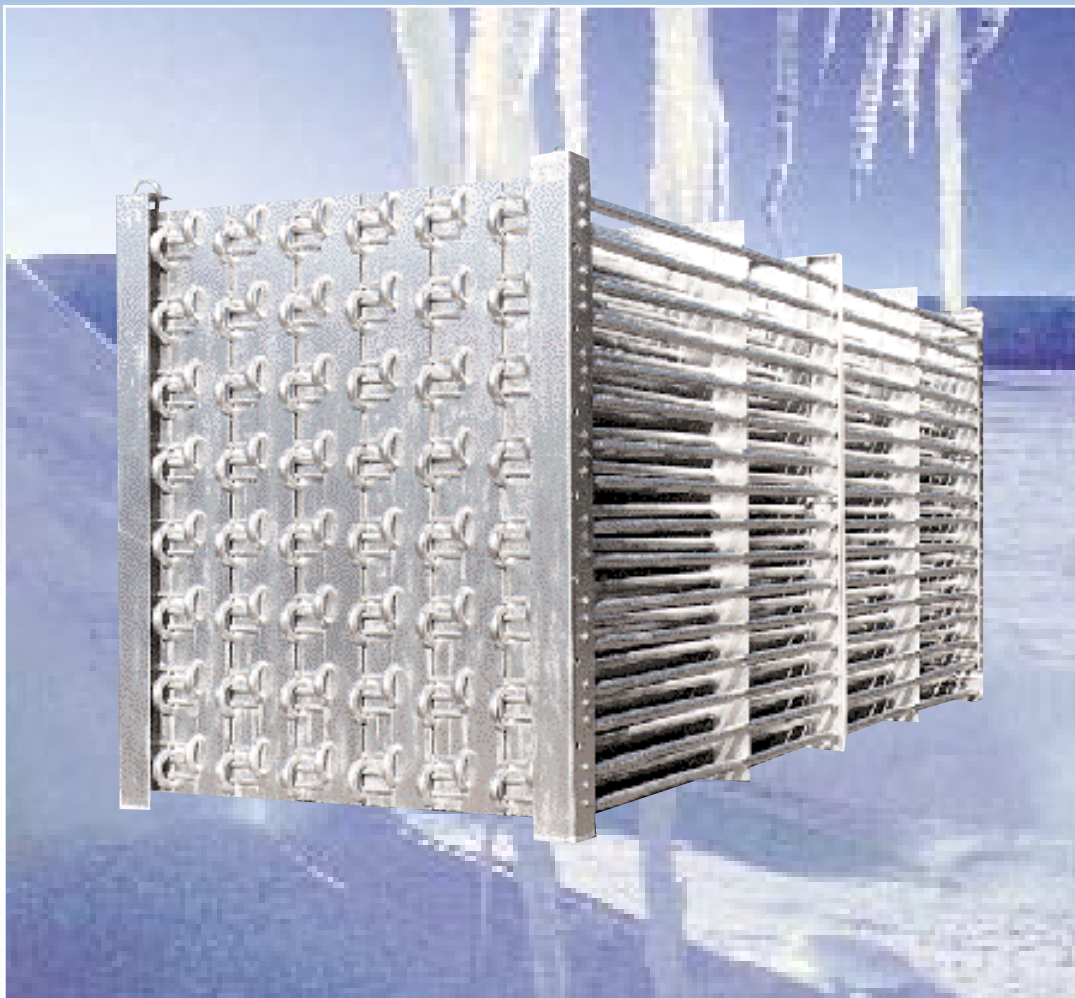




ICE COILS

FEATURING THE EXTRA-PAK™ TECHNOLOGY®



QUALITY COILS DESIGNED
FOR LARGE THERMAL STORAGE SYSTEMS

EXCLUSIVELY MARKETING BY  CALMAC

* Patent Pending



WORLDWIDE CORPORATE HEADQUARTERS

EVAPCO® Inc was founded in 1976 in Baltimore, Maryland with one manufacturing facility - principally as a manufacturer of evaporative condensers. Over its history, EVAPCO has broadened its product lines to include various design styles of evaporative condensers, closed circuit fluid coolers, cooling towers, industrial evaporators, recirculation and transfer systems, heat exchangers, pressure vessels, and **thermal storage coils**. EVAPCO products are now manufactured in four continents with its headquarters in Taneytown, Maryland.

Fundamental to EVAPCO's success and continued growth are its people. The company's Engineering, Marketing, and Manufacturing team consists of a highly experienced group of people ready to accept the many challenges that exist in today's market. EVAPCO's experience and commitment to excellence has provided years of continual product improvement, development of new products, and unmatched customer service.



RESEARCH CENTER

EVAPCO's unique Ice Coil design (Patent Pending) is the result of a comprehensive research and development process. Extensive research programs and experienced engineering personnel pioneering new, innovative product designs and features has become the hallmark of EVAPCO and a key factor in the company's success. This combination of research and people has led to the development of over 25 industry related U.S. patents and their foreign counterparts.



EVAPCO's leadership in product design and quality continues today in its state-of-the-art Research Center located in Taneytown, Maryland. The 40,000 square foot facility is among the largest and most advanced of its type in the HVAC and refrigeration industries.

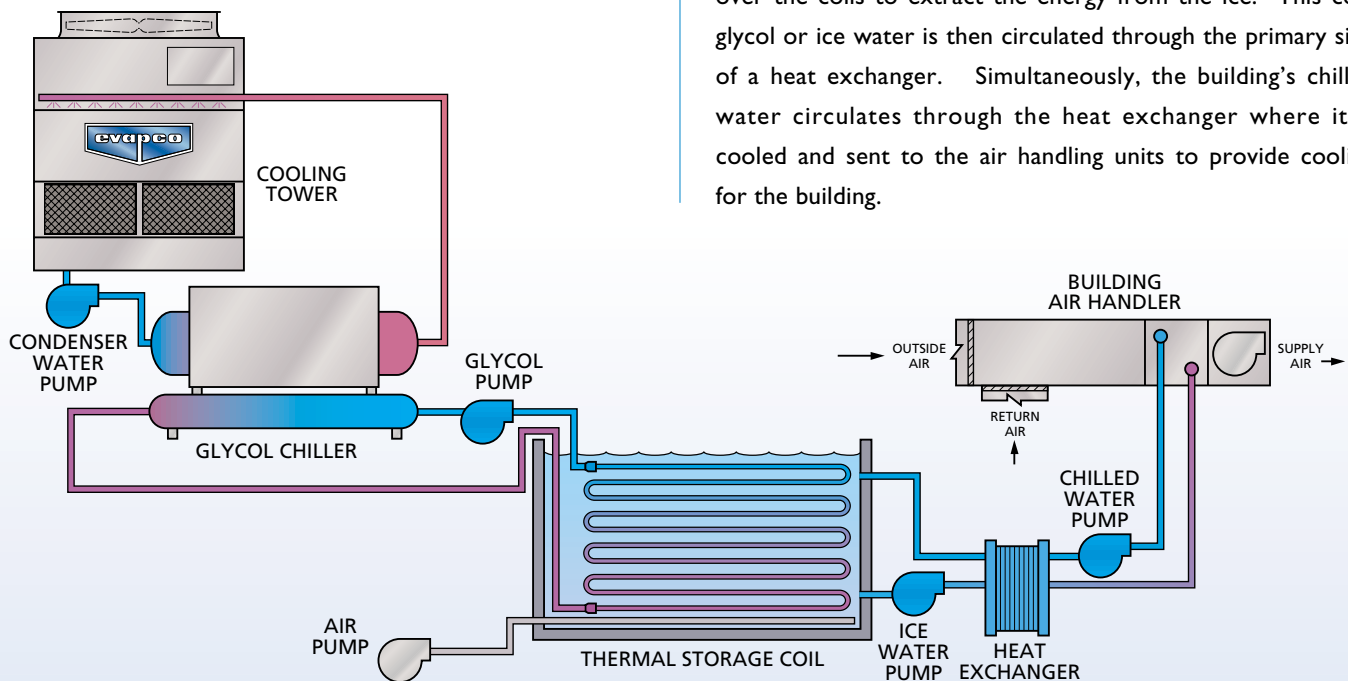
It contains an ice testing facility and highside and lowside ammonia refrigeration laboratories capable of testing evaporative condensers with capacities up to 700 tons and low temperature evaporators. It also houses several additional environmental laboratories that are primarily used for testing cooling towers up to 1200 tons in capacity.

GENERAL DESCRIPTION

Thermal storage systems have been in existence for many years. Although many early applications involved systems installed in dairies, churches, and theatres, most current applications are used for continuous comfort cooling. The purpose of a thermal storage system is to create thermal energy and store it for use at another time.

There are several types of thermal storage systems in use today. These systems can be either the full or partial storage type. In the typical full thermal storage system, the refrigeration system (chillers) generates ice at night when electrical utility rates are typically lowest (off-peak). During the day, when utility rates are higher (on-peak), the ice is then melted to provide cooling to the building. In the partial thermal storage system, a reduced size chiller or refrigeration system operates in conjunction with the ice storage to meet the peak loads. There are several types of partial storage systems whose application is dependent on building loads, system equipment and energy costs. However, many partial storage systems are used to “shave off” peak energy demands to reduce operating costs.

The product technology that EVAPCO provides for the thermal storage industry is referred to as “ice on coils”. In this type of system, cylinders of ice are built onto the tubes of hot dipped galvanized steel coils. In most systems that use this technology, multiple banks of coils are submerged under water in field constructed concrete tanks.



THERMAL STORAGE SYSTEM SCHEMATIC

SEQUENCE OF OPERATION

Thermal storage systems use either glycol chillers or direct refrigeration systems to provide the cooling necessary to generate the ice on the tubes of the coils. However, the most common system used for comfort cooling applications utilizes glycol chillers, as is shown in the schematic below. The air conditioning system that incorporates thermal storage has major components consisting of chillers, cooling towers, heat exchangers, pumps, thermal storage coils, and the building air handling equipment. The **FULL** thermal storage system has two modes of operation; ice build and melt-out that are described below.

FULL BUILD OPERATION

ICE BUILD

During the off-peak period, the glycol chiller is operational. The glycol chilling system is generating low temperature glycol that circulates through the tubes of the thermal storage coils. The circulating glycol removes heat from the water in the tanks which causes this water to freeze onto the exterior surface of the thermal storage coils.

MELT-OUT

During the melt-out phase, the refrigeration system is off. Depending on the melt-out type, either glycol is circulated through the tubes of the coils or the tank water is circulated over the coils to extract the energy from the ice. This cold glycol or ice water is then circulated through the primary side of a heat exchanger. Simultaneously, the building's chilled water circulates through the heat exchanger where it is cooled and sent to the air handling units to provide cooling for the building.



DESIGN FEATURES

COIL CONSTRUCTION

EVAPCO manufactures its Ice Coils from high quality steel. The industrial quality coils consist of heavy wall elliptical tube circuits. Each circuit is inspected to assure the quality of the material and then tested before final assembly. After final assembly, the coil is tested at 400 psig air pressure under water to assure it is leak free. Finally, the entire coil assembly is hot-dipped galvanized to protect it from corrosion.

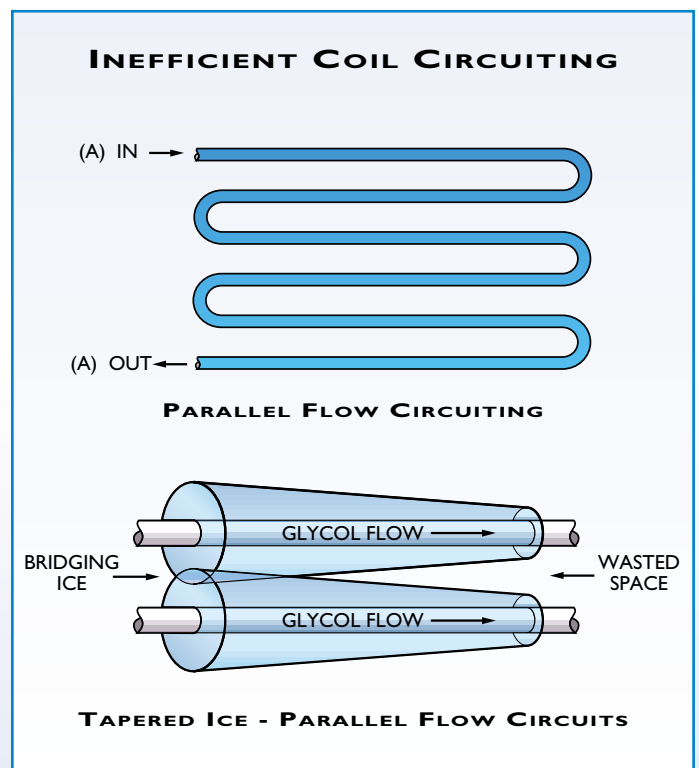
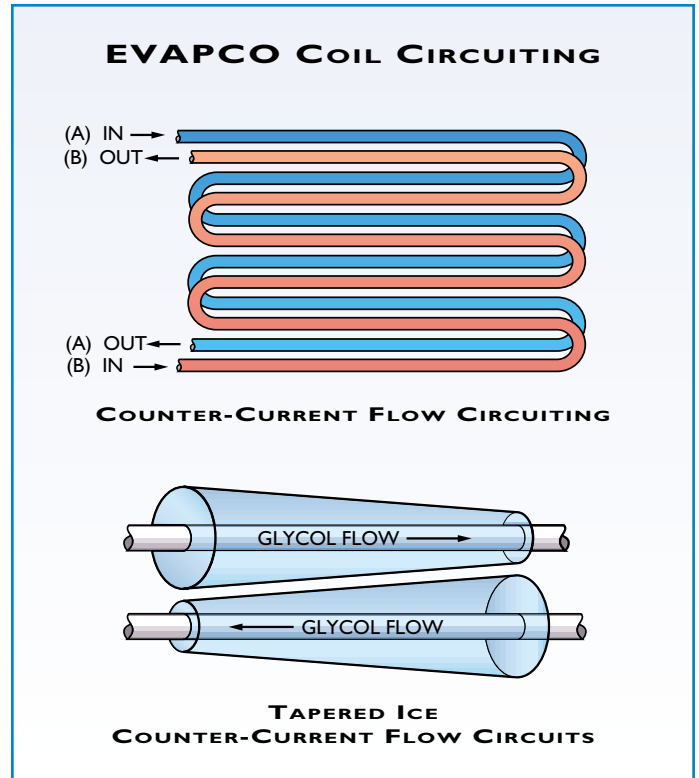
Each EVAPCO Ice Coil is provided with schedule 40 PVC air agitation pipes that are installed under the coil assembly. The perforated PVC tubing is designed to properly distribute air below the coil as part of the air agitation system. Note that on large installations where multiple coils are stacked vertically, only the bottom coils are furnished with air agitation piping.

COIL CIRCUITING

How the ice coil is circuited is an issue that must be considered when designing for thermal storage systems. Various refrigerants are used as the cooling medium, however, for most air conditioning applications, an aqueous solution of ethylene glycol is used. For air conditioning applications where the suction temperatures are not extremely low, 25 to 30 percent glycol solutions are normally used.

When using a glycol solution, the temperature of the glycol increases as it flows through the ice coil during the build cycle. This gives thick ice near the inlets of the coil and thin ice near the outlets. Therefore, the resulting cylinders of ice tend to be tapered. Since the tube spacing is dependent upon the design ice build thickness, the useful volume for the ice to build is affected as well. If the coil is set up for parallel circuiting, the tapering ice can lead to wasted volume in the thermal storage tank (See the illustration shown). At typical temperatures, the tapering of ice for parallel circuits can penalize the total storage of a coil by approximately twenty percent.

The solution to the above-mentioned problem is to modify the method of coil circuiting. The EVAPCO Ice Coils are circuited for counter-current flow (See the illustration shown), which alleviates this problem. The tapered ice cylinders nest with each other and make efficient use of the coil/tank volume (See the illustration shown). The end result is that the same amount of ice can be built with the counter-current glycol configuration as can be built with an idealized constant temperature directly evaporating refrigerant, where the cylindrical sections of ice would have no tapering.





THE EVAPCO EXTRA-PAK™ ADVANTAGE (PATENT PENDING)

COIL DESIGN

Ice on coil technology has been around for many years in various applications such as dairies and theaters. In recent years, however, the application of thermal storage technology has shifted from the industrial to the commercial air conditioning sector. During this time, very little has changed in the design of thermal storage coils. There are only a few manufacturers that offer ice on coil technology; of which, several designs are currently in use for most applications. For the smaller applications, there are systems that use plastic coiled tubing installed in pre-fabricated tanks. For the majority of larger applications, multiple steel coils are commonly placed in field erected concrete tanks. It is the latter technology on which EVAPCO focused its efforts. Therefore, EVAPCO set forth on an intensive research and development program to create the first major technological advancement this product has seen in many years.

EVAPCO, an innovator in coil technology, with patents for its Thermal-Pak Coil and the Thermal-Pak Finned Coil designs, used this expertise to develop an ice coil that features the Extra-Pak™ technology. Before creating a new design, EVAPCO examined the existing ice on steel coil technology which uses 1.05" diameter round tubes.

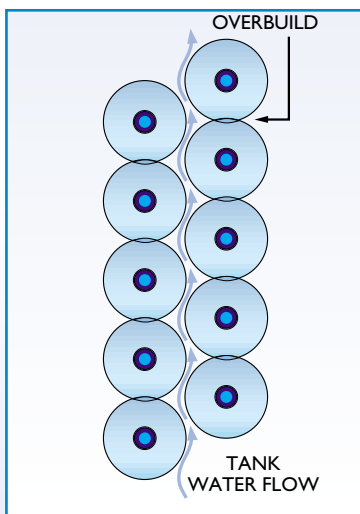
The current thermal storage coil technology is shown in the figure below. In general, the configuration of the coil is such that round tubes are evenly spaced in both the horizontal and vertical dimensions. In the round tube design, round cylinders of ice will build on the tubes, as the figure indicates.

The geometry of the coil configuration allows the cylinders of ice to bridge vertically but provides a clearance gap between rows in the horizontal dimensions. The clearance gap is necessary for circulation of the tank water and to maintain an open, serpentine passageway between the ice cylinders, which allows efficient heat transfer between the tank water and

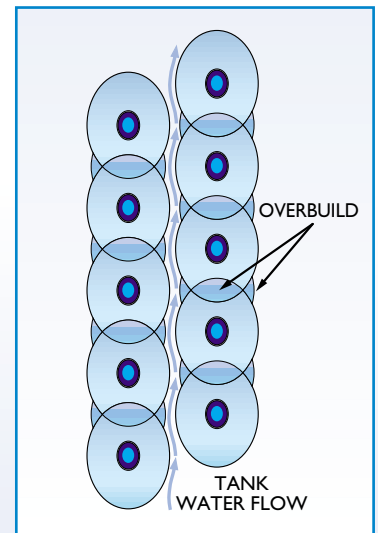
the ice on the tubes of the coil. Therefore, for this coil configuration to provide maximum heat transfer there exists a defined amount of ice that can be built (i.e. packing efficiency) for the round tube design. Packing efficiency is defined as the ratio of the volume of ice actually formed and stored in comparison to the available space for ice around the coil assembly excluding the necessary clearance spaces. The packing efficiency of the ice coil is where EVAPCO concentrated its research efforts. The reason is simple; the thermal storage capability of the ice coil is based upon how much ice can be built in a given coil volume.

After analyzing and testing the current round tube technology, EVAPCO found limitations in this design and determined a better design was possible. EVAPCO called on its experience in elliptical tube coil design to develop a superior ice coil. The result is a state of the art elliptical tube ice coil that provides improved performance over the round tube design. Hence, the Extra-Pak™ technology for thermal storage coils was born.

The EVAPCO Ice Coil featuring the Extra-Pak™ technology is shown in the figure below. The EVAPCO Ice Coil configuration has similar vertical and horizontal spacing as the round tube coil but uses elliptical tubes. Due to the non-circular shape of the ice that builds on the elliptical tubes, as shown below, an increase in packing efficiency over the round tube design is achieved. Because the ice is an elliptical shape, it can be slightly overbuilt (note the areas of overbuild in the sketch shown below) but still provide an adequate clearance gap between the ice cylinders. Remember, an adequate clearance gap is necessary to allow the tank water to be in free contact with the ice on the tubes to ensure heat transfer efficiency. Therefore, the packing efficiency of EVAPCO's elliptical tube design is greater than the current technology. In summary, EVAPCO has developed an ice coil with new technology that builds more pounds of ice per foot of tube (i.e. greater capacity) than any ice coil on the market today.



**ROUND TUBE
ICE COIL**



**EVAPCO
ELLIPTICAL TUBE
ICE COIL**



APPLICATION INFORMATION

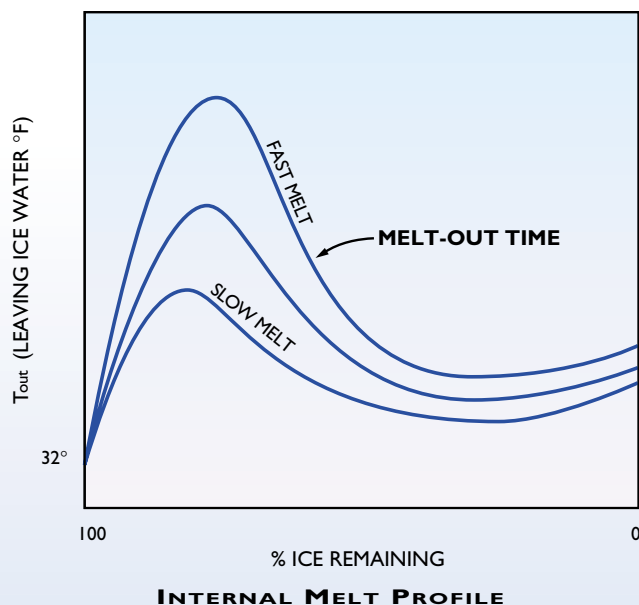
MELT-OUT

As was previously mentioned, there are a variety of methods that are used to generate ice on the tubes of the thermal storage coils. Ammonia or Freon refrigeration systems, or more commonly in HVAC applications, glycol chillers, generate the thermal energy to freeze the tank water onto the thermal storage coils. Similarly, there are several methods to melt the ice that has formed on the tubes of the coil. The two common methods for melting the ice are referred to as **internal** or **external** melt and are described below.

INTERNAL MELT

In an internal melt system, the ice on the tubes is melted from the inside out, hence, the name internal melt. In the internal melt system, the glycol that cools the building circulates through the thermal storage coils melting the ice that was generated during the ice build. The tank water never leaves the tank in an internal melt system.

There are distinct melt-out performance characteristics associated with an internal melt system. Early in the melt-out cycle, the leaving glycol temperature rises and then drops off later in the cycle. As shown in the figure below, the temperature rises more for a fast melt system than it does for a slow melt system. The reason for this is that the surface area of the heat exchanger is limited to the inside surface of the melting cylinder of ice early in the melt-out cycle. There is only a small stagnant annulus of melted ice in

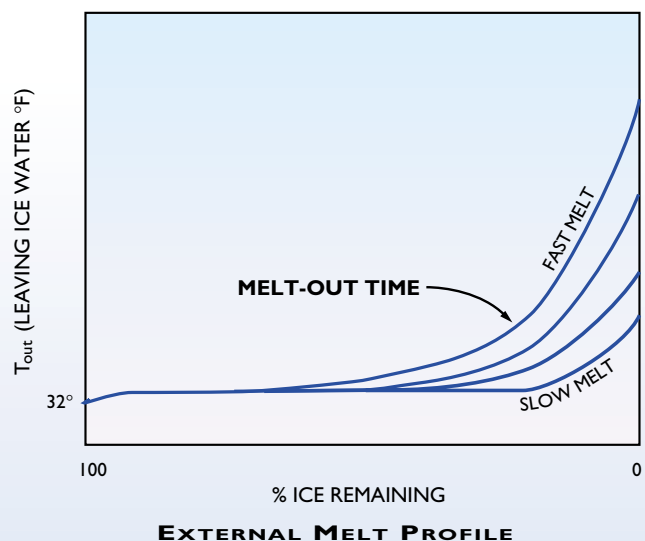


between the warmer coil and the 32°F ice. Later in the cycle, the ice annulus break up into the agitated (ice water) section of the tank and the pieces of ice cylinders are melted from the inside and the outside surfaces. As a result, a load profile with smaller loads at the beginning of the melt-out cycle and higher loads at the end of the melt-out cycle may be best suited for internal melt.

EXTERNAL MELT

In an external melt system, the ice on the tubes is melted from the outside in. The 32°F tank water is circulated to the load or through the building to provide the required cooling. Warm water returns from the system and melts a portion of the ice.

The melt-out performances of external and internal melt systems are very different. At the start of the melt-out cycle, there is a lot of surface area available for the transfer of heat from the ice to the tank water. So, at the early stages of the melt-out cycle, the temperature of the ice water is around 32°F. During the melt, the ice is consumed and the surface area decreases. As the surface area decreases, the rate of thermal energy that is transferred from the ice to the tank water is reduced. With approximately 50 percent of the ice left on the tubes, the tank water temperature begins to rise. As can be seen in the figure shown below, the ice water temperature continues to rise until all of the ice has been melted. Again, as the figure illustrates, fast melt systems tend to have higher leaving ice water temperatures than slow melt systems. Therefore, an application that has higher loads early in the melt-out cycle and low loads at the end of the melt-out cycle would best be suited for external melt.





MEASURING ICE

There are several methods of measuring the amount of ice in the tank of the thermal storage system. One method of measuring ice is by tank water level. Since ice is less dense than water, as water is converted into ice during the build cycle, the tank water level will rise. Therefore, the amount of ice in the tank can be determined from this increase in water level. As the ice melts during the melt-out cycle, the tank water level is still a good indicator of the inventory of ice in the tank.

However, there are a few items to consider when using water level as a way of ice inventory. If large, shallow tanks are used, the water level may rise only a few inches. Measuring a large quantity of ice with such a small change in tank water level may not be very accurate. In addition, since the tank water is very cold, it will continually condense moisture out of the ambient environment and the air from the agitation system. Over a long operating period, the additional moisture that has condensed in the tank will affect the tank water level and mistakenly indicate more ice in storage than actually exists. A drain down of the tank or zeroing the amount of ice should be built into the thermal storage system controls to avoid this problem.

Another way to measure the amount of ice in the tank is to measure the size of the cylinders of ice. There are ice thickness controllers that can sense the thickness of the ice by conductivity. In addition, several thickness controllers could be placed on the tube of the coil to measure levels of ice thickness to detect stages (percentage of full build) in the build cycle. When the full build is reached, the controllers can shut off the glycol flow to the ice coils.

Although ice building on tubes is very uniform, the melting process is not. The ice melts faster in the area of the bubblers, and it breaks off the tubes in chunks later in the melt-out cycle. As a result, ice thickness control is not to be used as a measure of ice inventory during the melt-out process.

Since both of the above-mentioned methods of ice inventory have their pros and cons, it may be advantageous to consider multiple types of controllers when designing the controls for the thermal storage system. The designer of the system should consider all of these options to ensure that the control system is appropriate for the application.

AIR AGITATION SYSTEM

The air agitation system is an essential part of the thermal storage system. The essential component of the air agitation system is the

bubbler. For most HVAC applications, with total head requirements less than 15 psig, the bubbler is a rotary, positive displacement, air pump or a regenerative blower. In addition, distribution piping from the bubbler is connected to perforated PVC pipes that are located underneath the ice coils.

The air system is necessary for proper operation of the thermal storage system. The air system is necessary to agitate the tank water during the initial build period and the tank cool down. Factory testing has shown that once the first portion of ice has been built, the air system can be shut off. **However, operation of the air system is absolutely essential for satisfactory melt-out performance.**

When designing the air agitation system the following data should be incorporated. The air agitation rate should be **0.1 SCFM per square foot of tank plan area**. The air distribution piping has an **internal pressure drop of 0.25 psig**, which must be added to the hydrostatic head to properly size the air pump.

EQUIPMENT SELECTION

For any of your thermal storage applications, contact **Calmac Manufacturing Corporation at 201-569-0420** for sizing and selection of ice coils. Since each application is unique, the size and quantity of ice coils will vary. However, with the proper information, Calmac can select the best option for your application. The information that Calmac requires for ice coil selection is as follows:

- Tank dimensions L x W x H
- Storage Capacity in Ton-Hrs.
- Building load profile
- Build time in hours
- Melt-out time in hours
- Required supply and return temperatures for the load
- Melt-out type (Internal/External)
- Glycol solution percentage
- Glycol flowrate in gallons per minute (GPM)
- Compressor capacity data

With the above information, Calmac can select the quantity and size of ice coils best suited for your application. The output of data will be as follows:

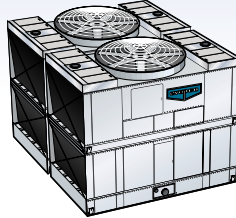
- Coil dimension L x W x H
- Coil capacity in Ton-Hrs.
- Number of coils required
- Average glycol charging temperatures (Supply/Return)
- Glycol pressure drop
- Ice coil thermal performance in ARI guideline T format



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