CRYOGEL

Ice Ball™ Thermal Storage

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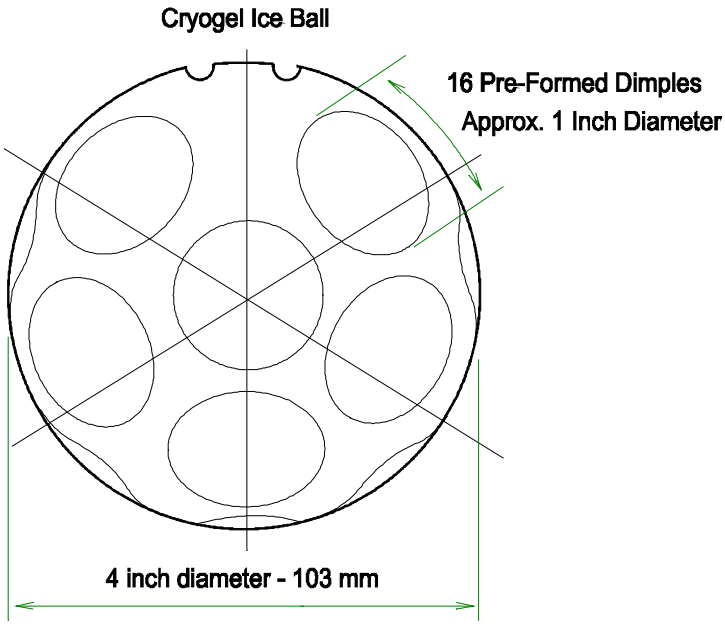
SYSTEM OPERATION AND DESCRIPTION

Cryogel Ice Balls are 4 inch (103mm) diameter spheres constructed of high-density polyethylene and filled with water to form ice for cool energy storage. Ice Balls are placed in storage tanks and are charged (frozen) and discharged (melted) by means of circulating a glycol based heat transfer fluid around the balls. During the charge mode (usually during off-peak hours at night), glycol is circulated through the Ice Balls in a storage tank and then out to a chiller where it is cooled to temperatures low enough to make ice. During the discharge mode, the same glycol solution is circulated through the Ice Balls in the storage tank. Ice Balls cool the glycol solution that is then pumped to the load to provide air conditioning or process cooling. (See typical schematics).

Cryogel Ice Balls are designed such that the expansion of freezing water inside each ball is accommodated by the outward motion of pre-formed dimples in the surface of each ball. During the melting of the ice, each ball returns to its approximate original shape. Ice Ball performance and durability to withstand changes in shape have been verified by independent laboratory testing.



Ice Balls are constructed with a proprietary high performance polyethylene polymer. HDPE

As water inside the Ice Ball freezes to form ice, the dimples flex out to allow for expansion. Without the dimples, the life of the balls would be diminished due to stretching and stressing of the plastic walls.

Patents in the U.S. and other countries protect Cryogel technology.

ADVANTAGES OF THE CRYOGEL ICE BALL™ SYSTEM

SIMPLICITY EQUALS LOWER COSTS AND HIGHER RELIABILITY

1. SIMPLICITY

Like marbles in a coffee can, Ice Balls are placed in tanks and a standard glycol heat transfer solution is circulated around the balls to freeze them at night and to melt the balls and release the cool energy the following day. There are no heat exchanger tubes and fittings, air pumps or other moving parts associated with the storage tank. Installation consists of standard tank and piping installation followed by loading the Ice Balls into storage tanks. No special stacking of containers or installation of heat exchanger tubes is required. Installation and design are simplified because Cryogel systems require fewer tanks and less piping than systems based on *"ice-on-coil tank farm"* concepts. Flow balancing across tanks is also much simpler and less expensive with fewer tanks.

2. STORAGE TANK DESIGN FLEXIBILITY

- New or Existing Tanks
- Pressure Vessels - Steel
- Atmospheric Tanks - Concrete or Steel
- Cylindrical or Rectangular Tanks
- Direct Burial of Tanks with Live Load Above the Tanks.

3. CRYOGEL HAS ONE OF THE MOST COMPACT SYSTEMS ON THE MARKET

Pressurized Ice Ball systems require as little as 2.0 to 2.25 cubic feet of tank volume per ton hour and atmospheric systems require 2.5 to 2.7 cubic feet per ton hour. Tanks and tank foundations can be smaller and simpler with the Cryogel system. This translates to less expensive footings and better use of your space. Equipment pad fencing, lighting, plumbing and electrical costs may also be reduced.

4. MORE SURFACE AREA MEANS BETTER HEAT TRANSFER

Cryogel Ice Balls have **over 22 square feet of surface area per Nominal ton hour**. More surface area means better heat transfer and higher energy savings. More surface area means higher instantaneous discharge capacity at lower temperatures. More surface area also means lower energy consumption for making ice at night. Remember the formula, $\mathbf{Q=UA\Delta t}$. All ice storage systems are dependent upon the surface area (A) to transfer cool energy. Ice Balls or the tubes of an ice-on-coil system are little more than heat exchangers. By comparison, the surface areas of ice-on-coil systems range between 7.5 and 17 square feet per ton hour.

5. INDEPENDENT LABORATORY TESTING

To the best of our knowledge, Cryogel has the only product on the market with independent laboratory testing, demonstrating <u>both</u> thermal performance and durability.

6. CRYOGEL PROVIDES FREE COMPUTERIZED SYSTEM SIZING

This is a free service to engineers, contractors, building owners and utilities. Cryogel's sizing software incorporates data obtained directly from the independent laboratory testing. This data has been translated into charging and discharging curves, which are based upon standard sizing parameters commonly used in sizing heat exchangers, i.e. Log Mean Temperature Differential (LMTD). These curves remove the *"black box"* mystery from storage tank sizing by allowing engineers to see exactly how the system will perform throughout the cycle.

STORAGE TANK and SYSTEM DESIGN CONCEPTS

Flexibility of the Cryogel Ice Ball system allows the use of new or existing tanks; atmospheric steel or concrete tanks; pressurized tanks, vertical or horizontal tanks, above ground or below ground tanks and tanks that are indoors or outdoors. Tanks may be cylindrical or rectangular because, like marbles in a coffee can, the spherical Ice Balls conform to the shape of the tank.

Fluid distribution pipes are installed at the top and bottom of each tank to distribute glycol evenly across all the Ice Balls. The flow of glycol solution is from the bottom to the top of the tank during the charge and discharge modes. Piping in this manner allows the chillers to operate at the highest possible temperatures and, therefore, at the most efficient operating points during the charge mode. Cryogel sizes fluid distribution headers on the basis of maximum flow rates supplied by the project designer. The total pressure drop across each tank, including headers and Ice Balls, does not normally exceed 3.5 psig during the charge or discharge mode with a 25% glycol heat transfer solution.

Cryogel distribution header concepts together with the natural arrangement of the Ice Balls and the vertical flow patterns eliminate flow bypass issues that may be found in certain competitive equipment. Low velocity through the balls insures that pressure drop is minimal and, therefore, allows the use of both ethylene and propylene glycol heat transfer fluid.

For ALL thermal storage systems involving multiple tanks, the piping leading to and from storage tanks must be balanced with respect to flow and pressure drop. Multiple tank systems will not function properly if the tanks do not receive equal flow. Standard piping practices should be observed when piping tanks with special attention to reverse piping requirements, the placement of tanks on equal branches, etc. All storage tanks should have isolation valves on the inlet and outlet of each tank. Obviously, a system with one tank will need no tank balancing at all. A two-tank system will be easier and less costly to balance than a three-tank system and so forth. Many Cryogel systems use only one large tank, thereby avoiding the costs and problems associated with tank balancing.

ATMOSPHERIC TANK OPTION

Atmospheric storage tanks may be rectangular or cylindrical; horizontal or vertical, and may be constructed of steel or concrete. Atmospheric tanks include a *"free board"* volume at the top to prevent overflow. Atmospheric vessels *"breath"* as air is displaced or returned as function of the glycol solution level above an Ice Ball hold-down grid. The hold-down grid is constructed of Fiberglas, aluminum or epoxy coated steel. The grid is placed inside the tank above the upper distribution header to prevent Ice balls from floating above the liquid surface and to prevent movement of the balls as the fluid rises and falls during charging and discharging. A polyethylene liner must be installed inside concrete tanks to prevent leakage. The interior walls of steel atmospheric tanks typically have an epoxy coating to prevent oxidation. All liners and coatings must be compatible with the glycol heat transfer fluid.

System Schematic

Cryogel Ice Ball Thermal Storage

Atmospheric Tank System

Photos of Existing Installation of this type available on Cryogel's Web Site: http://www.cryogel.com/

Shown with load upstream of storage tanks. Load downstream is also acceptable. See pressurized system schematic for downstream piping configuration.

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Tank details and internals available from Cryogel at no cost to designer.

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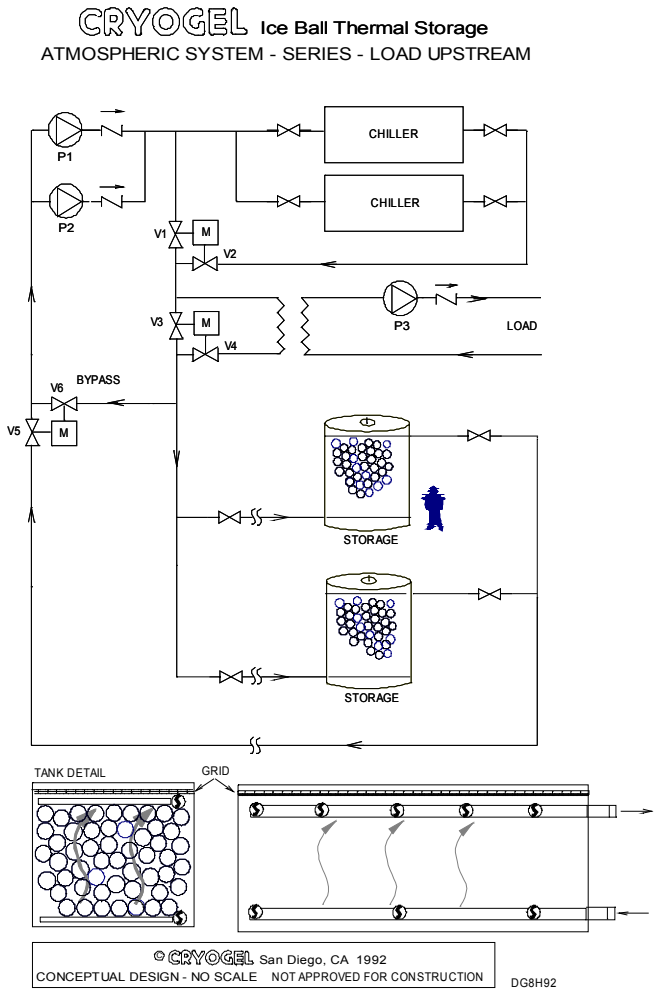

Since ice floats inside the ball during the melt mode, and since the balls are flexible, the ice remains in contact with the interior wall of each Ice Ball, which improves heat transfer between the ice and the glycol solution. While it may go without saying, the Ice Balls move only slightly due to flexure of the dimples during freezing and melting... the Ice Balls do not move around within the tank or piping.

Cryogel Ice Balls are constructed to withstand the weight of additional Ice Balls stacked above to the full height of most tanks. Resistance to crushing has also been verified by independent laboratory testing.

PRESSURIZED TANK DESIGN OPTION

Industrial grade pressure vessels may be horizontal or vertical and include manways on top for loading the Ice Balls. Automatic air vents are installed on top of each tank to insure elimination of all air within the storage tank(s). Tank(s) are designed for operating pressures as specified by the design engineer and must be constructed in accordance with local standards. The inlet and outlet pipes may exit the end or sides of each tank to allow for easy installation of piping. Pressure vessels may be located beneath parking lots or other areas with traffic above.

System Schematic

Cryogel Ice Ball Thermal Storage

Pressurized Tank System

Photos of Existing Installation of this type available on Cryogel's Web Site: http://www.cryogel.com/

Shown with load downstream of storage tanks. Load upstream is also acceptable. See atmospheric system schematic for upstream piping configuration.

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Tank details, internals and inventory control design are available from Cryogel at no cost to designer.

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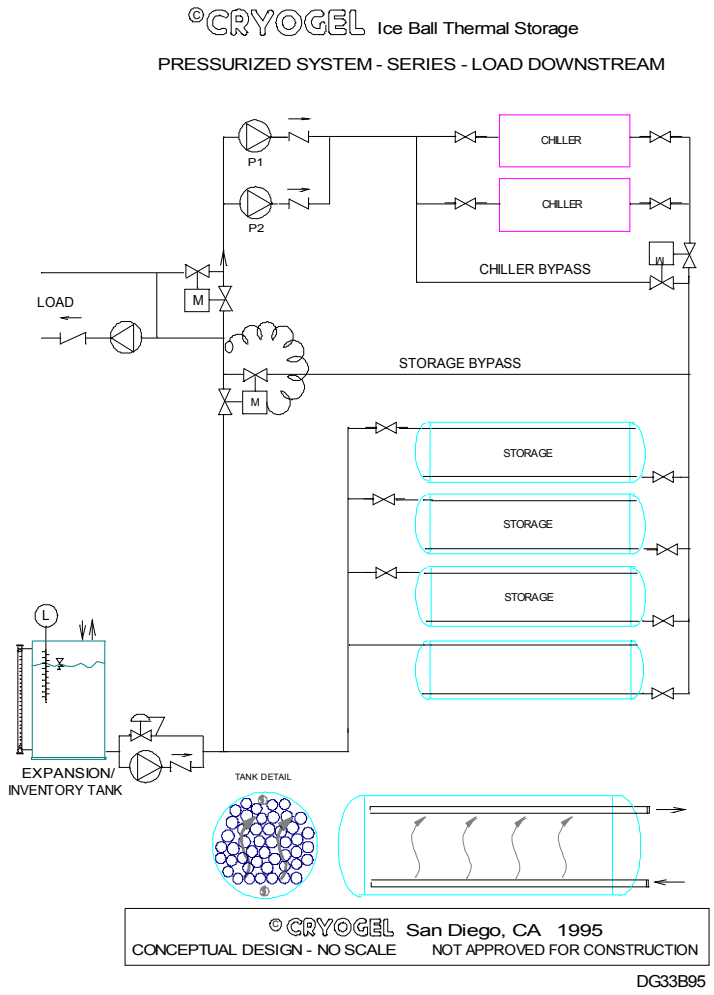


As the water freezes inside the Ice Balls and as the Ice Ball dimples flex outward, glycol solution surrounding the balls is displaced. This fluid displacement can be monitored to provide information as to the amount of ice in storage at any time. (See Ice Inventory Control.)

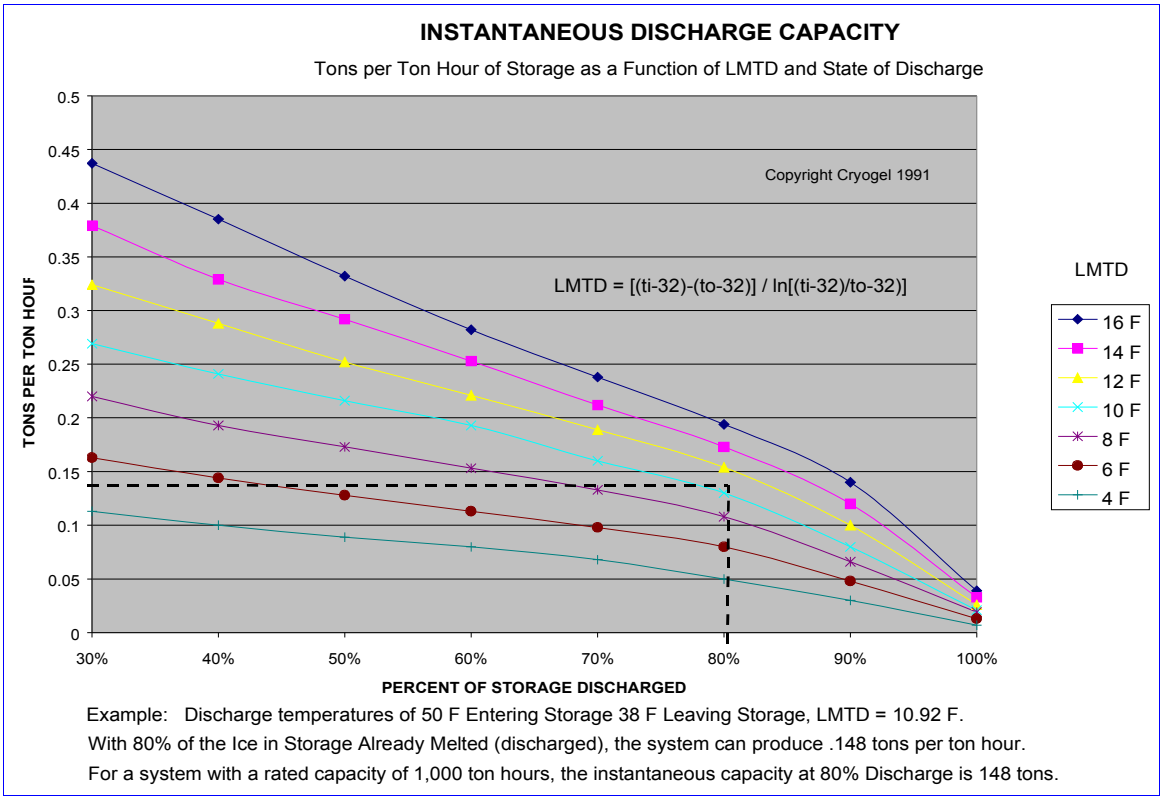
STORAGE CAPACITY AND SYSTEM SIZING

Storage capacity requirements are determined by the designer who normally develops an hourly cooling load profile. A load profile is the number of tons of cooling capacity required each hour to satisfy the air conditioning or process cooling load. The designer must also consider and specify the temperatures necessary to satisfy the load, i.e. the entering temperatures required at fan coils or heat exchangers. Ice Ball systems may be designed to provide 100% of the cooling load required (full storage) or some smaller portion of the total load (partial storage). Cryogel will assist designers with economic analysis to determine the best choice of full or partial storage.

The Rated (usable) storage capacity, specified by the design engineer, represents the number of ton hours of storage capacity that must be discharged to satisfy the cooling load. The Nominal (total) storage capacity is the actual number of ton hours that must be installed to achieve the Rated discharge capacity at the desired temperatures. The Nominal capacity is greater than Rated capacity for ALL typical ice storage systems because not all of the ice can be melted at usable rates or temperatures. If a system is sized such that 100% of the storage capacity must be discharged to satisfy the load, it is most likely sized improperly.

DISCHARGE MODE - ICE MELTING

Usually, the last hour of the discharge period is the critical hour for sizing a thermal storage system. However, it is important to confirm that the storage system is capable of satisfying every hour of a specified load profile. Sometimes the nominal storage capacity must be increased to satisfy a critical hour before the last hour.



Example: Discharge temperatures of 50 F Entering Storage 38 F Leaving Storage, LMTD = 10.92 F.
With 80% of the Ice in Storage Already Melted (discharged), the system can produce .148 tons per ton hour.
For a system with a rated capacity of 1,000 ton hours, the instantaneous capacity at 80% Discharge is 148 tons.

Cryogel sizing is based on independent laboratory test data. Cryogel has assembled that data into a set of performance curves. These curves represent the ability of the Ice Balls to transfer heat based upon the percentage of ice in the tanks and the Log Mean Temperature Differential (LMTD) across the tanks. This is similar to the methodology heat exchanger manufacturers use for sizing of their equipment.

Cryogel has developed computer software for sizing systems using temperature and capacity data supplied by the designer. This software, together with independent laboratory data, allows Cryogel to predict system performance at any point during the discharge cycle.

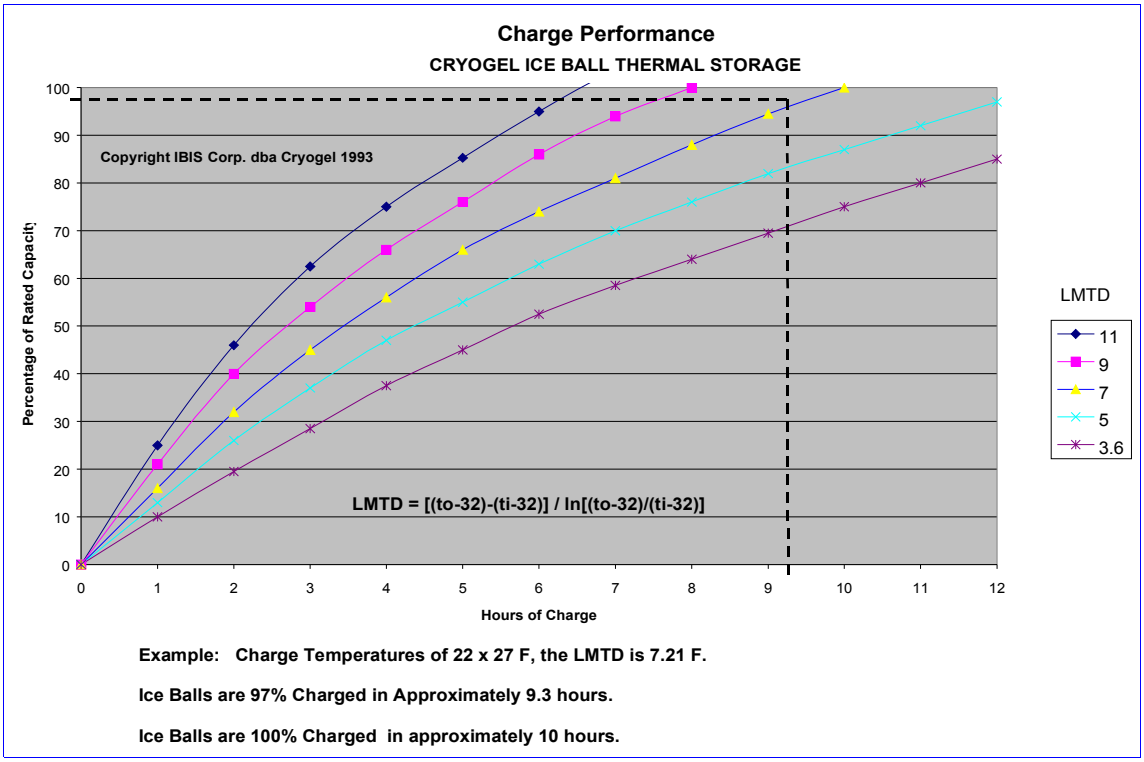
It is important to notice that for the discharge cycle, lower temperatures required at the load will result in lower LMTD. This will result in lower instantaneous capacity and lower discharge rates. To compensate for lower design temperatures, the number of Nominal ton hours must be increased. Most thermal storage manufacturers consider a practical discharge temperature leaving to be 38°F. While additional cooling may be removed from the storage tank above this temperature, the temperature may not be low enough to satisfy the cooling load. In simple terms, lower specified discharge temperatures mean that the thermal storage systems must be increased in size.

A storage by-pass line with modulating valves is normally utilized to control the rate of discharge from the storage tank(s). Flow across these valves (and the storage tank(s)) during discharge is governed by design temperatures, instantaneous cooling load and the percentage of ice in the storage tank(s).

CHARGING MODE - ICE MAKING

Charging a thermal storage system can be accomplished with any chiller capable for producing ice-making temperatures. Reciprocating, rotary screw or multi-stage centrifugal chillers are normally specified in thermal storage systems. The chiller reduces the glycol temperature to 22 - 24°F, depending on system design, to freeze the Ice Balls. Normal chiller shut-off is set at 20°F as means of keeping the chiller fully loaded during the charge cycle. As everyone with a freezer knows, it is possible to make ice freeze faster by reducing the temperature. This fact is illustrated by Cryogel charge performance curves which compare charge time to the temperatures (LMTD) produced by the chiller. It is also clear that more energy is required to produce lower temperatures.

The following curves allow designers to choose the most economical chiller operation based on the number of off-peak hours available for making ice. By using the longest possible charge period, the smallest chillers and most economical operating temperatures may be selected.



INVENTORY TANK AND CONTROL PACKAGE

Pressurized storage systems include an inventory tank and inventory control package. **(The inventory package is not required and is not used with atmospheric storage tanks.)** As Ice Balls in the storage tank freeze and expand, glycol solution is displaced. The displaced fluid is forced into the inventory tank and the inventory tank level rises. This level increase provides an approximation of the amount of ice in storage. During discharge, the displaced glycol is returned to the storage tank by means of a small pump in the inventory control package (see inventory control explanation and schematics).

The inventory tank is an atmospheric vessel that *"breathes"* when air is displaced or returned as a function of liquid level. The inventory tank and control system are installed above ground. The tank interior is coated with an epoxy or equal lining, which is compatible with the glycol solution. Air leaves the inventory tank through a standard air purge valve and returns by means of a standard vacuum breaker.

The inventory tank is insulated in the same manner as the ice storage tanks. Coal tar or equal is applied to the exterior bottom of the tank to prevent condensation from causing oxidation of the tank bottom.

A level probe is installed in the inventory tank for monitoring purposes only. This probe typically produces a 4 to 20 mA signal and is connected to the ice storage automation system to provide information as to the estimated amount of ice in the storage tank at any time during the charge or discharge cycles. This level probe may not be used for chiller control nor should it used for calculation of storage capacity.

The inventory control package consists of a pump, adjustable pressure sustaining valve, pressure switch and controls. The pump includes a TEFC motor and is suitable for indoor or outdoor operation. The control panel, which includes a starter and overload assembly with an HOA switch, is enclosed in a weather tight NEMA 4 enclosure. The control is mounted on a steel base plate, pre-piped and pre-wired by Cryogel and is ready for connection by the installing contractor.

STORAGE TANK INSULATION

Storage tanks are typically field insulated with external insulation. For outdoor tanks, the insulation may be rigid 100% closed cell urethane foam. Foam should be applied to a minimum thickness of 2 inches or with a minimum insulation value of R-12. Of course, the insulation value is dependent upon local temperature and humidity. Foam insulation on the tanks is sealed with a protective urethane spray coating which is appropriate for this application. Cryogel strongly recommends **against** the use of urethane foam spray insulation in an indoor application. Indoor tanks should be insulated with fiberglass or other insulation, which will not burn or produce toxic fumes in case of fire. Similar R valves are required with all types of insulation.

HEAT TRANSFER FLUID

The heat transfer fluid is a glycol/water solution with a glycol concentration no less than 25% by volume. The heat transfer fluid must be inhibited ethylene or propylene glycol, as manufactured by DOW Chemical or HOUGHTON Chemical. The fluid and concentration must be acceptable to ancillary equipment manufacturers, including chiller and heat exchanger manufacturer. Contamination of the heat transfer fluid with any chemicals other than glycol may damage the plastic Ice Balls and other plastic or elastomer components of the system. New and retrofit systems and components must be properly flushed with a 1 - 2% solution of trisodium phosphate (TSP) and flushed with clean water according to the glycol manufacturer's instructions, prior to installation of the glycol. Water used to dilute glycol concentrate must meet minimum water quality standards as determined by the glycol manufacturer. (See Installation Instructions.)

INSTALLATION

Ice Balls are shipped in cardboard shipping containers, with approximately 1,000 balls each. The shipping container sets on a pallet to ease handling during initial unloading and installation of the Ice Balls. Ice Balls are delivered in a fully charged and sealed condition. Like marbles in a coffee can, Ice Balls fill the tanks in proper arrangement to insure optimum flow between each ball. Proper filling is possible due to the spherical configuration of the Ice Balls. This eliminates costs associated with field labor for stacking storage media or installing heat exchangers in the tanks.

Detailed Installation Instructions are available by contacting Cryogel at:

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