Software Park in Taipei, Taiwan (23,000 TH/81 MWH)

Hybrid Ice Thermal Energy Storage: All-in-one Innovative New System Concept

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The success of ice thermal storage in office building applications has received a great deal of publicity and exposure. Ice thermal storage has also been successfully implemented in all types of buildings for many of the same reasons it works in office buildings: lower first cost, lower operating cost and the ability to eliminate CFCs. In this article, we describe a new concept of ice thermal storage that combines the low chilled water temperature advantage of external melt systems with the closed system benefits of an internal melt one.

The use of low temperature water from the ice storage allows savings in piping, pumps, and air handling equipment. An ice storage system with supply and return water temperatures of 36°F (2°C) and 54°F (13°C) versus a traditional system using 44°F (7°C) to 54°F (13°C) requires almost half the water flow, pump BHP and smaller pipes. In addition, when low temperature air distribution [45°F (7°C) supply air versus traditional 55°F (13°C) air supply] is also used, additional savings are realized from smaller ductwork, smaller fans as well as less energy consumption and increased useable space. Operating costs decrease when the system is designed to take advantage of low night time electrical rates and have the flexibility to adjust to changes in peak electrical rates.

Unfortunately, despite all of the benefits, one of the major hurdles that delayed the widespread use of this technology was the fear of system designers to have an open system incorporating ice thermal energy system. However, a new innovative system design of ice-on-coil thermal energy storage now enables designers to have the benefits of low temperature ice thermal storage offered by an external melt system while still maintaining a closed loop system on the load side as offered by an internal melt one (for definitions of external and internal melt systems see sidebar *Internal vs. External Ice-on-Coil Thermal Storage* on the following page).

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It's No Longer Either Or: Freezing Water Temperature and a Closed System.

Previously, the system design for thermal energy storage enabled the engineer either to have an *open system* (external melt) supplying freezing water temperature (34°F / 1°C) from the plant to the system or; to have a *closed system* (internal melt) supplying glycol at relatively higer temperature (37°F / 3°C), the heat exchanger between the glycol side and the load side produced another temperature approach as well. It was always an either / or decision. A compromise between temperature and system.

With a new concept system design, such either / or decisions are no longer necessary. As shown in *Figure 1* on the next page, the design of the system features two separate sections: an ice-building coil section and another ice-melting finned coil section. The ice is built during off-peak hours by circulating glycol from the chiller to the coil. During peak hours, this ice is melted by circulating the warm water from the building through the finned coils. The finned coils are immersed in the freezing water and consequently, they transfer the heat from the warm water being circulated by melting more ice in the tank. *Figure 2* illustrates one possible system design layout.

System Operating Modes

The control system for the system shown in *Figure 2* directs the operations of six modes:

1. Ice build only
2. Cooling with chiller only
3. Cooling with chiller and ice
4. Cooling with ice only
5. Standby
6. Ice build and cooling.

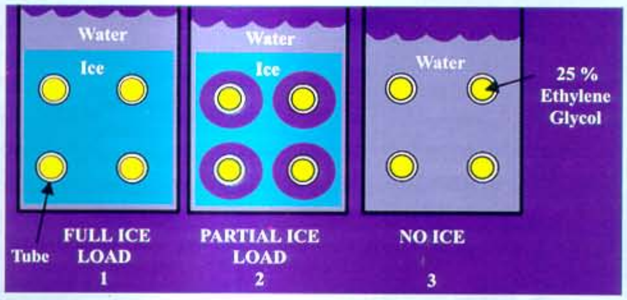
The control processor is programmed to energize the applicable mode of operation based on a time schedule matching electrical use of facility and utility rate schedule. The processor communicates with the chiller's onboard micro panel, which provides information on the operation of chillers. The microprocessor also interfaces with the Building Automation System (BAS) to obtain the cooling-required signal. The modes of operation are as follows:

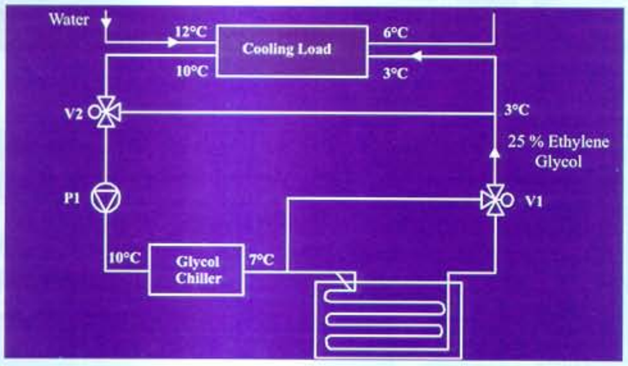
1. Ice Build Only

- Chiller operates at a reduced set point (19°F/–7°C adjustable) to make ice. The chillers load limit set point will be set at 100% (maximum output).
- Control system operates to position glycol valve such that full flow of chilled glycol will be directed through the ice coil to make ice. The valve is positioned to direct full flow of chilled glycol leaving the ice coil

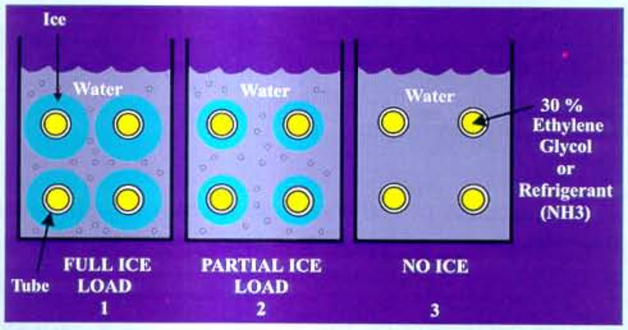
Internal vs. External Ice-on-Coil Thermal Storage

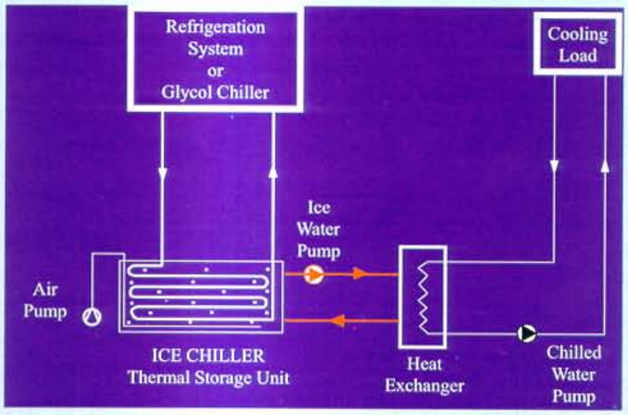
In internal melt systems, the ice is built around the coils by passing cold glycol inside the tubes during off-peak hours. Circulating worm glycol in the tubes melts ice during peak load. The ice is melted from inward out.





In external melt systems, the ice is built around the coils by passing cold refrigerant directly inside the tubes. Circulating warm water directly to the tank melts the ice around the tubes. The ice is melted from outward in.





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directly back to the chillers

- Glycol pump is operated to move chilled glycol through the chiller to the ice coil.
- Water pump is off.
- The ice build mode continues until an ice inventory sensor indicates a full charge of ice has been built.

2. Cooling with Chiller Only

- Whenever the BAS selects cooling required and the predetermined time schedule indicates cooling with chiller only mode, the control processor moves the glycol valve to direct all chilled glycol around the ice coil and the water valve to full flow to the heat exchanger with no flow through the ice tank.
- Glycol pump will be operating.
- Building chilled water pump is energized.
- The chiller micropanel will regulate chilled glycol temperature leaving chillers at the discharge temperature of 41°F (5°C). Chiller will be operated at capacity that will not exceed predetermined peak demand.

Figure 1: Ice Coil

3. Cooling with Chiller and Ice

- Whenever BAS selects cooling required and time schedule indicates chiller and ice mode, temperature sensor on chilled water valve will operate to modulate flow through ice coil to maintain 36°F (2°C) water to building.
- Glycol valve will fully open to the heat exchanger.
- Glycol pump will be operated.
- Building chilled water pump will be energized.
- At peak load, the total cooling load is met by the combined operation of the glycol chiller and the depletion of the ice storage. At partial load conditions, the chiller operation will be automatically reduced allowing ice to satisfy demand.

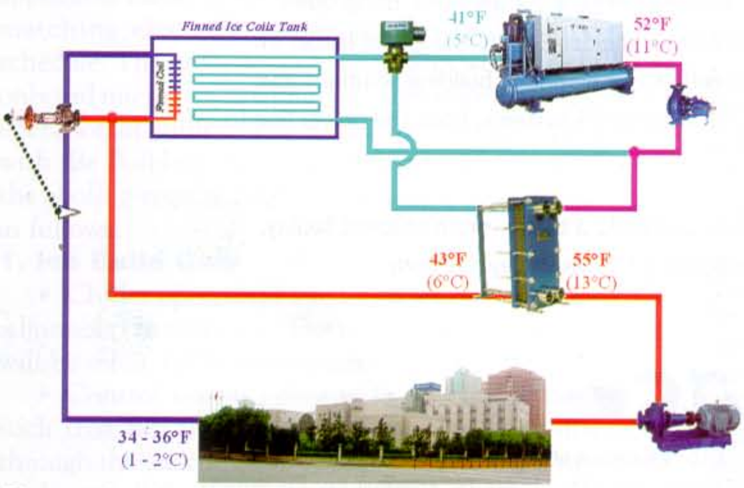

Figure 2 : System Schematic

4. Cooling with Ice Only

- Whenever BAS selects cooling required and time schedule indicates ice only mode, the control processor will operate to de-energize the chiller and allow ice to provide full cooling.
- Chilled water valve temperature sensor will operate to modulate the valve to maintain 36°F (2°C).
- Normally, as chiller is not operating, glycol pumps will not be operating.
- Building chilled water pump is energized.

5. Standby

- Whenever the BAS indicates that there is no cooling required and time schedule is not in ice build mode, the control system will be in the standby mode.
- In this mode, chiller and chiller support equipment will be off.

6. Ice Build and Cooling

- Whenever ice build time schedule is active and the cooling required signal is received from the BAS system, the control processor will modulate the chilled water valve to slightly open under control of the temperature sensor as to divert part of the flow to supply building cooling. The building supply water temperature shall be maintained at 36°F (2°C).
- The ice manager system operates to position the glycol valve such that full flow of chilled glycol will be directed through the ice coil to make ice.
- Glycol pump is operated to move chilled glycol through the chiller to the coil.

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Conclusion

Ice thermal energy storage offers the owners, designers and operators unparalleled benefits. For the owners, ice thermal energy storage saves both: initial as well as operating cost. For the designers, the system enables real system optimization and engineering economic analysis. As for the operators, it provides them with flexibility in operation as well as the ability to respond to high instantaneous peaks in the load or to accommodate the high pull down load.

The use of the new hybrid ice thermal energy storage system design concept offers even more benefits while facilitating the design process for the engineer. The new system design offers the designers the option of completely having their water side designed as a closed loop. This ensures easier system hydraulic balancing and facilitates site commissioning afterwards. The closed system concept also ensures an easier to maintain airconditioning and a cleaner system.

Using the new hybrid system design offers an *all-in-one* solution. It enables the use of closed system design while providing low chilled water temperature approaching 34°F (1°C). This ensures the lowest system initial cost and running expenses as well. Indeed, it is the "best of both worlds" in the thermal energy storage system design and operation. ❖