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Engineers Newsletter

An Engineering Strategy For Ice Storage

Background

Two earlier **Engineers Newsletters** provided basic thermal storage concepts and their reasons for existence. Like all nascent engineering concepts, there is a "shakeout" period. We are still in that period. But, a relatively small number of storage methods seem to be emerging as leaders.

Trane **Applications Engineering Manual SYS-AM-10** broadly describes one important ice storage concept that uses conventional chillers, unpressurized storage tanks and an ordinary chilled water distribution system. The purpose of this newsletter is to focus on a particular arrangement of these components and the reasons why this system will become the "system of choice" for a number of justified future projects.

Economics

Ice storage is economics driven. With current maturity of "instantaneous cooling" technology and equipment, no other reason justifies the concept without some controversy.

Electric utilities are in the driver's seat. Their rate structure defines the justification. Without suitable utility rate structure justification, ice storage is nearly always an economic loser. The utilities have it within their power to emphasize or de-emphasize ice storage by altering rate structures.

Since electric rates vary widely from place to place, we see great regional differences in the application of ice storage systems. An engineering strategy that works out for one location may be inappropriate 50 miles away.

Electric power customers pay for power in two ways: Kwh - an energy charge or Kw - a demand charge.

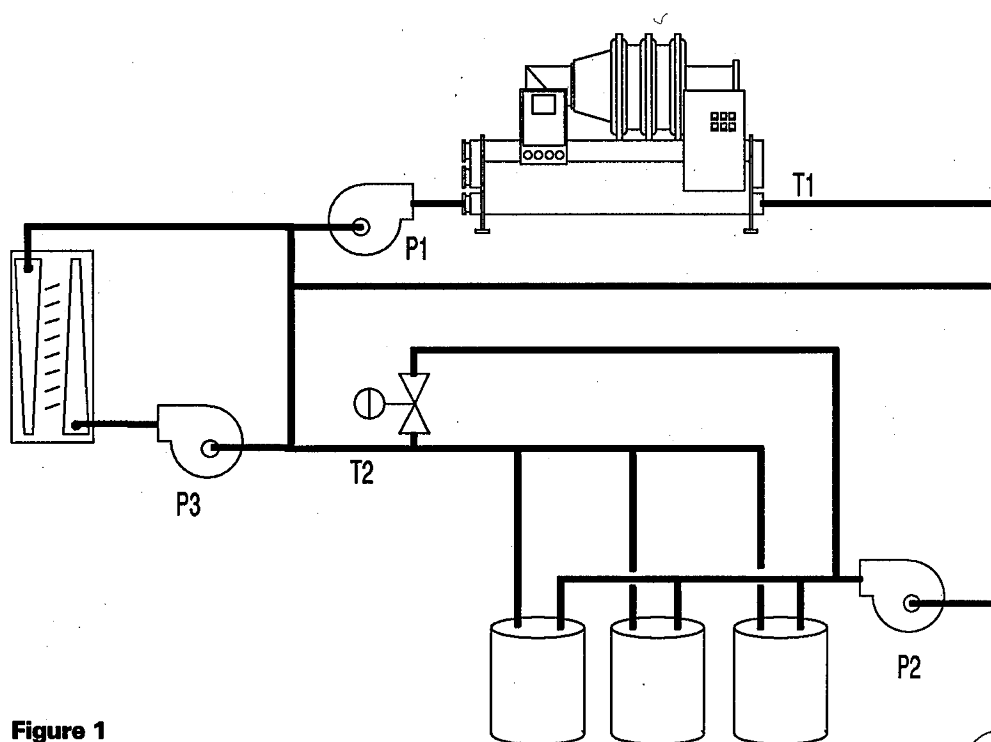

Figure 1

Since **demand** charges are time-sensitive, they drive ice storage systems by themselves. Alone, a high **energy** charge makes no economic impact on the justification for ice storage. Energy charges need to be framed in a "time-of-day" environment. When the energy charge rate differential between one time of day and another becomes large enough, ice storage justification improves.

Either way, the cost of electricity is an operating expense. So, the cost differences are used to "pay back" the initial investment cost increase. A payback period can be calculated and used on ice storage. Herein lies one of the problems with ice storage. Since the utility can change its rate structure rather easily, payback calculations are volatile. Anyone who makes a storage system decision based on a long payback period is taking a risk that the rate structure will turn sour during the projected payback period.

Electric utilities have another way to encourage ice storage. They often provide "seed money" in the form of an up-front rebate to the owner of an ice storage system. This is an even more powerful incentive because it does not depend on the passage of time. An owner can take the money to the bank as soon as he starts using the system.

Conventional Machinery

As indicated before, one type of ice storage system uses conventional machinery. . . standard water chillers of either the reciprocating or centrifugal type, ordinary unpressurized water storage vessels and conventional chilled water distribution equipment. The tanks are equipped with heat transfer surface so that a circulation of antifreeze solution removes the heat of fusion from uncirculated water in the tank. During the period of cooling release, warm system fluid is circulated, thus melting the ice. Advantages here are cost and maintainability. One-of-a-kind systems and equipment usually seem to present building owners with unwelcome surprises years later.

Figure 1 shows a specific configuration of these components. At first glance, this arrangement seems to violate basic principles of hydraulic system design. Further examination, however, reveals strong reasons for this peculiar scheme.

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Critical Modes Of Operation

To be fully successful an ice storage system needs to be able to perform in five basic modes of operation:

1) Build Ice: In this mode, the chiller loop and the tank loop are active. The chiller temperature controller is set for the low design temperature necessary to freeze the tank water into ice.

2) Burn Ice: The chiller loop is inactive, but the tank loop and system loop are active. A mixing valve can be used to serve as a "low temperature limiting" device for water entering the system loop. Otherwise, low temperature fluid may be pumped directly to air handlers.

3) Build Ice And Cool Direct: This mode is commonly used when small nighttime loads coexist with the "time window" for ice building. Care must be used to size the chiller so that this mode of operation can be accommodated.

4) Burn Ice And Cool Direct: For systems that employ "partial storage," the stored ice cooling capacity is not normally sufficient to meet all daytime loads. In order to handle peak loads, the system must be able to control both the time and amount of chiller capacity used in combination with stored ice capacity.

5) Save Ice: This mode is actually a close relative to mode 4. In order for stored ice to fulfill its primary mission, it must be available during times of peak electrical usage. Ice must be "saved" during the earlier hours of a peak cooling day so it can be ready at the peak hours.

Any ice storage system that uses the same heat transfer surface to make ice and to chill water cannot execute mode 5. So called "ice shucker" systems fall into this category. Once the ice is produced, it is stored in a tank that also contains the system chilled water. Ice melting cannot be controlled and thus ice cannot be saved simultaneously with chilled water circulation.

This is a critical difference between these two kinds of ice storage systems. If ice cannot be saved to be used during the peak electrical usage periods, a fundamental reason for ice storage becomes unexecutable. The system cannot meet its promise of removing cooling loads from the peak electrical usage hours.

Control

The physical arrangement of independent pumping loops permits simplified control. Further, there are no system valves that need to be repositioned for the different modes of operation. Instead, the five modes of operation are performed by: Selecting the appropriate pumps to operate and setting the two controllers for the appropriate temperatures.

Table 1 shows the correct settings for the five modes of operation. In mode 4, chiller electrical demand limiting is used to tailor ice husbandry so as to not use it all before it is really needed.

Table 1

Mode	P1 (gpm)	P2 (gpm)	P3 (gpm)	T1 (F)	T2 (F)
1	1000	1000	Off	24	—
2	Off	1000	800	Off	40
3	1000	1000	800	24	40
4	1000	1000	800	40	40
5	1000	Off	800	40	—

During nonpeak cooling load days, it may be advisable to not use any ice at all. Cooling via ice storage is always less efficient than direct chilled water cooling. Thus, if there is no **energy** rate penalty (only a **demand** penalty), the most economical strategy is to save ice and cool directly.

While not complicated, execution of these control strategies is best performed by some kind of an energy management system. No ice storage system should go in without an energy management system to control the critical timing functions. One slip up in a peak month can kill the entire year's projected savings.

Programming a Tracer® 100 system, for example, to perform these five modes of operation at the right times is not difficult. After the patterns are established, scheduling is performed as if each of the five modes were an individual device to be cycled. Demand limiting is confined to mode selection and to chiller operation in mode 4.

Once the complete system is understood, this ice storage system becomes a valuable strategic weapon in any designer's arsenal. Given the current interest in thermal storage, no designer should be without it. ●