## Ice Systems

Cold water systems using ice as the cooling agent have been installed in many theaters, restaurants, funeral homes, churches and other places where short hours of operation and high peaks of cooling demand make this type of system desirable. A comparatively small quantity of ice in the water cooling tank of such a system can release refrigeration at a relatively rapid rate. For instance, neighborhood theaters having a peak demand of 1,200,000 Btu per hour (100 tons refrigeration) have found 8 ton capacity ice bunkers satisfactory.

In operation, the water in the air conditioning system is circulated over ice placed in an insulated box and is cooled to the 38 or 40 F range or higher if desired. This cold water is pumped from the ice bunker to air cooling coils or spray type air washers. The blowers, coils, air washer or air handling sections are the same as those parts in any system employing cold water as a refrigerant.

The ice water cooler or ice bunker is usually built at the installation in

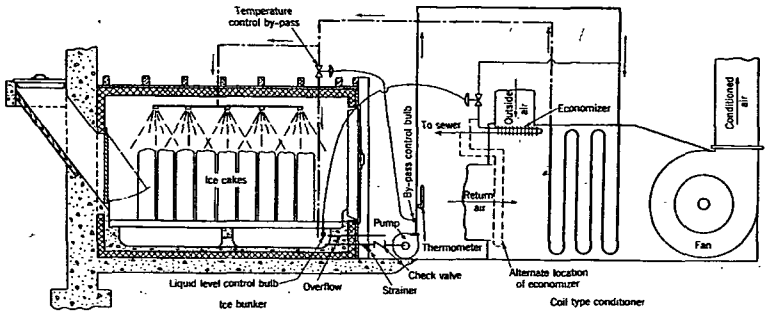


FIG. 4. TYPICAL ICE SYSTEM SHOWING BUNKER DETAILS

a location where it can easily be iced. It can be constructed of any desired material such as concrete, steel, or wood with an adequate amount of insulation to save the ice from one period of use to the next. The basic requirement is that the tank be durable and water tight. A typical bunker with connections to a coil type air conditioning system is shown in Fig. 4. About 60 cu ft of gross bunker volume are allowed per ton of ice capacity.

The shape of the bunker usually conforms to the available space. The one illustrated has overhead sprays, but if head-room is lacking the ice is placed on the floor of the bunker with the water returned around the lower part of the blocks from a perforated distribution pipe run along one side of the bunker. To secure good circulation the supply water is extracted from a similar perforated pipe on the opposite side of the bunker.

The temperature of the water is controlled at a predetermined point by a thermostat in the supply line. If the temperature drops too low, a part of the return water is by-passed directly to the sump and is not cooled over the ice. In the larger systems it is customary to install an overflow control which, as the ice melts, discards the excess water through an economizer coil. The surface of the economizer is large in relation to



the flow so that the water is warmed to 60 F or more as it is discharged from the system.

## Storage Systems

In an attempt to lower initial equipment cost and operating expense, or increase the refrigeration capacity of an existing air conditioning system, storage refrigeration has been utilized in a few applications. Some of the methods which have been adopted include the storage of refrigeration in the form of chilled water, chilled brine, ice on evaporator coils[2] and the accumulation of thin sheets of ice on copper plates in a steel tank[3]. If the peak load factor is low as compared with a long period of operation, such as in a restaurant, or if the hours of operation are short but the usage factor high as in a church, then it is possible to consider storage refrigeration. This method of accumulating refrigeration frequently makes it possible to use low cost off-peak electric power. Power costs may also be reduced by installing a smaller refrigeration plant, augmented by a storage system, and by operating it for longer periods.

## The Reverse Cycle

The reverse cycle—frequently referred to as a *heat pump*—is identical in theory with the ordinary refrigeration cycle and differs only in the sense that the desired effect is a heat source rather than a heat sink. Since a condenser delivers more heat than is picked up by the evaporator (it discharges the heat equivalent of work supplied during compression) it follows that the effectiveness of a heat pump, its coefficient of performance, is greater than that of a refrigeration cycle operating between the same temperature limits.

In heating by the reverse refrigeration cycle energy is absorbed in an evaporator from some available source of heat, pumped to a higher temperature and delivered to a condenser[4]. The heat from the condenser is used for heating purposes. The compressor acts as a heat pump whose fundamental function is to raise the potential of the heat. The theoretical ratio of the heat delivered to the work of compression, the coefficient of performance, is given in Equation 10.

$$(\text{cop}) = \frac{T_c}{T_c - T_s} \qquad (10)$$

*where*

cop = coefficient of performance.
$T_s$ = absolute temperature of evaporator.
$T_c$ = absolute temperature of condenser.

Thus, with a small spread of temperature between the evaporator and the condenser, 6 or 8 times as much heat may be obtained theoretically, and 3 to 5 times practically, as the work introduced. There are a number of limitations, however, the most serious of which is the lack of ready availability of a practical source of heat.

1. Well water is the most desirable since its temperature is higher than other sources even in the winter, and thus a large amount of heat may be removed in relation to the weight of water handled.

2. Air may be used but its specific heat is low and its temperature uncertain. When the most heat is needed, the temperature of the air is lowest, thus resulting in the least favorable temperature combination.