heat required will be from one and one-half to five times as much as the heat extracted in the evaporator; cooling water requirements are proportionally high.

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

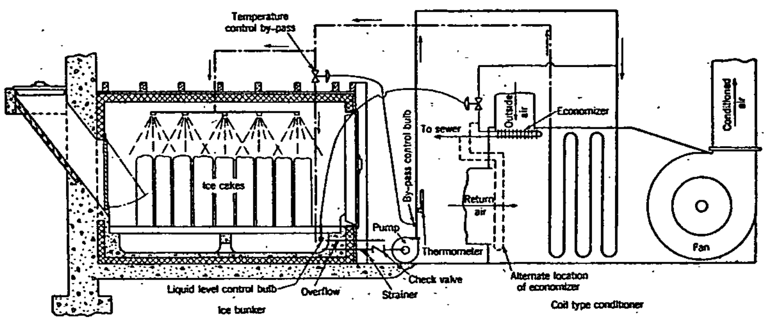

Fig. 8. Typical Ice System Showing Bunker Details

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 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. 8. 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 which 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.

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 Heat Pump

Although frequently referred to incorrectly as the reverse cycle system, the heat pump cycle is identical with the ordinary refrigeration cycle and differs only in the sense that the desired effect is rejection of the heat from the condenser rather than absorption of heat in the evaporator. A discussion of the coefficient of performance for the heat pump is found earlier in this chapter.

From an analysis of the equation for the coefficient of performance, it is evident that the economical adaption of the heat pump as a practical means of heating requires that the temperature of the source from which the heat is extracted be as high as possible and that the temperature of the sink to which the heat is rejected for heating purposes be as low as possible. Thus, with a small temperature spread between the evaporator and the condenser, six or more times as much heat may be obtained theoretically and three to five times practically as the heat equivalent of the work necessary to operate the system. There are a number of limitations, however, the most serious of which is the lack of ready availability of a practical source of heat.

The source of heat supply for the evaporator may be air, ground water or the earth itself depending upon the climate and topography:

1. 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 the lowest thus resulting in the least favorable temperature combination. Practical considerations seem to limit the use of present air systems to climates such as those encountered in the southern United States where temperatures under 20 F are not experienced.

2. Water from wells, lakes or rivers may be used. Well water is the most desirable, since its temperature is fairly constant throughout the entire year. As water temperature is relatively high, even in winter, a large amount of heat may be removed relative to the weight of water handled. Means of returning the water to the underground reservoir should be provided to prevent depletion. The disadvantages of using water include the problem of locating an adequate supply, the cost of pumping and the problem of water disposal.

3. The earth may be used as a source of heat with the refrigerant coils buried in the ground or with a heat exchanger supplied by a water-circulating coil buried in the ground. One disadvantage appears to be the large amount of heat transfer surface required.

Some of the other factors which act as limitations are: the large temperature spread when using air as a source of heat and when attempting