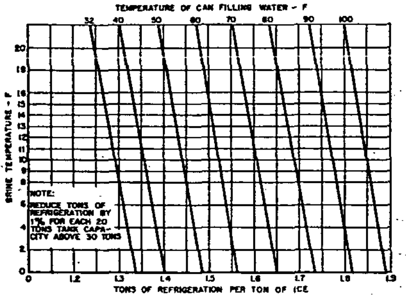


[a] Reduce tons of refrigeration by 1% for each 20 tons of tank capacity over 30 tons.

Fig. 3 .... Refrigeration Load Required to Produce Ice[a]

perature 5 or 6 F above suction temperature. These results call for about 50 sq ft of 2 in. tube surface per ton of daily ice making, with initial can water temperature of 70 F and brine of 12 F.

Tank coil designs with pipe coils in tank bottom channels, beneath the cans, resulted in better heat transfer, attaining rates of 20 to 50 Btu per (sq ft) (hr) (F deg). The inaccessibility of these coils, despite their floor area economies, limited their extensive use.

Short horizontal coils in raceways, in various arrangements, resulted in improvement in some systems, with heat transfer rates of 20 to 35 Btu per (sq ft) (hr) (F deg). Later, there appeared the trunk arrangement of short V-bent pipe nested and welded into horizontal bottom and top pipe headers. The ends of these headers terminated in a vertical shell accumulator serving as a vapor and liquid separator, while promoting rapid refrigerant recirculation through the bottom header, bent tubes and top header. The whole arrangement was enclosed in a tight brine raceway or trunk down the tank center, side or sides, and gave good results. High brine velocity between the cans was possible with this design, by pitching the tank slightly in order to secure an hydraulic gradient. Successive rows of cans were set to follow this gradient. Heat transfer rates were 100 to 120 Btu per (sq ft) (hr) (F deg). This design established the importance of mass liquid circulation.

REFRIGERATION REQUIREMENTS

The refrigeration required to produce a ton of ice in 24 hr varies with the initial can water temperature and the temperature of brine. Refrigeration includes removal of all sensible heat, latent heat of fusion, sub-cooling of ice, tank insulation losses, tank cover and radiation losses, agitation friction losses and losses involved in cooling the air for can water agitation. The refrigeration loads have been fairly well established from experience and are reliably shown in Fig. 3 which covers normally proportioned tanks of 30 to 100 tons daily capacity, including 7 to 8 percent excess weight, or tare, per commercial ton. Such tanks will contain 320 to 425-lb capacity ice cans and will be insulated with 5 in. of sheet cork or equivalent under the tank bottom, with not less than 10 in. of well packed dry granulated and regranulated cork or equivalent, around the tank sides and ends. The tank top and curbing will be not less than 2 in. thick oak-and-pine covers, loosely fitted over the entire tank area. It is assumed that the tank-supporting floor will be dry underneath, and the prevailing temperature will not exceed 60 F. Determination of the evaporator temperature and corresponding suction pressure is made after the establishment of tank load, brine temperature, evaporator surface area, and heat transfer coefficient. Rasori prepared a comprehensive chart for this purpose (Fig. 4). The chart, prepared for 300-lb ice cans, with four known factors, reveals three unknowns. It is of aid to the designer and to the investigator of a dereliction in ice tank performance.

Table 2 illustrates the comparative operating performance of efficient 300-lb can tanks, using various types of ammonia evaporator systems.

Compressor economies resulting from improved evaporator performance are important, since the annual load factors on commercial ice plants range from 40 to 80 percent.

WATER AND REFRIGERANT FORECOOLING

Refrigerant liquid forecooling improves performance in tanks containing pipe coil evaporators, because coils are better flooded when relieved of the vapor load of forecooling in the tank.

Ice can performance is not noticeably improved by water forecooling, since the can surface is extensive and removal of the sensible heat from the water down to freezing is rapid; freezing time is primarily a function of brine temperature. The forecooling load removed from the tank evaporator can be closely approximated by the difference between the refrigerating loads before and after forecooling.

Compressor power and size economies utilizing water and liquid forecooling are reflected in all cases when cooling is done at high back pressure with separate compressors. The higher back pressure usually is between 40 and 50 psig with water temperature ranging between 32 and 40 F. Under standard conditions of 20 and 185 psig (ammonia), the ihp of 1.34 per ton of refrigeration drops to 0.82 per ton at 45 psi suction. Forecooling the water 30 F deg accounts for 15.5 percent of the refrigerating load; refrigerant forecooling of 40 F accounts for an additional 15.5 percent. These combined loads, 31 percent of the total load, effect considerable power economy and a comparable saving in necessary compressor capacity.

Refrigerant liquid forecooling is usually accomplished in double-pipe stand coolers of 2 and 3 in. pipe or 1¼ and 2 in. pipe, with the high pressure liquid refrigerant flowing through the inner pipe. With small operations, an ammonia coil in an outside pipe shell suffices. Still another method is to expand the high pressure liquid into a shell vessel or intermediate trap carried at high back pressure, conducting the expanded liquid of 45 psi to the ice tank evaporator. In this system the refrigerant liquid required for high back pressure water forecooling is cooled separately in a coil within the intermediate trap.

Water forecooling is accomplished in insulated, still or agitated water storage tanks. The evaporator surface may take the form of close nested coils of galvanized full weight 2 in. pipe in circular unagitated tanks, or vertical flooded flat coil stands of 1¼ in. galvanized full weight steel pipe in agitated tanks. The heat transfer rate rises from 10 Btu per (sq ft) (hr) (F deg) in still tanks to 20 Btu per (sq ft) (hr) (F deg) in agitated tanks. Cooled water is drained or pumped to the can fillers. The tanks are large enough to contain two to four times the volume of water required per hour.

All tank surfaces must be protected against steel contacting the water, preferably by galvanizing or surfacing with some odorless and tasteless asphaltic compound. All piping, flanges, bolts and nuts must be galvanized.

A preferable type of cooler is a shallow tank 18 to 30 in. deep in which are set up stands of 2 in. pipe *Baudelot coolers* and over which water is continuously pumped at the rate of 2 gpm per ft of stand length. The tank and Baudelot cooler are in an insulated cabin with the circulating pump outside. The same circulating pump serves to fill the ice can filling tank. The heat transfer rate with simple expansion is 40 to 50 Btu per (sq ft) (hr) (F deg). With the Baudelot coolers full flooded from a level controlled accumulator above, connected with large, liberal, full sized vapor and liquid legs, a heat transfer up to 100 may be obtained. A modified Baudelot cooler consists of inclined pipes with a confined open water raceway beneath each pipe to facilitate high water velocity from end to end. Transfer rates above 100 are secured.

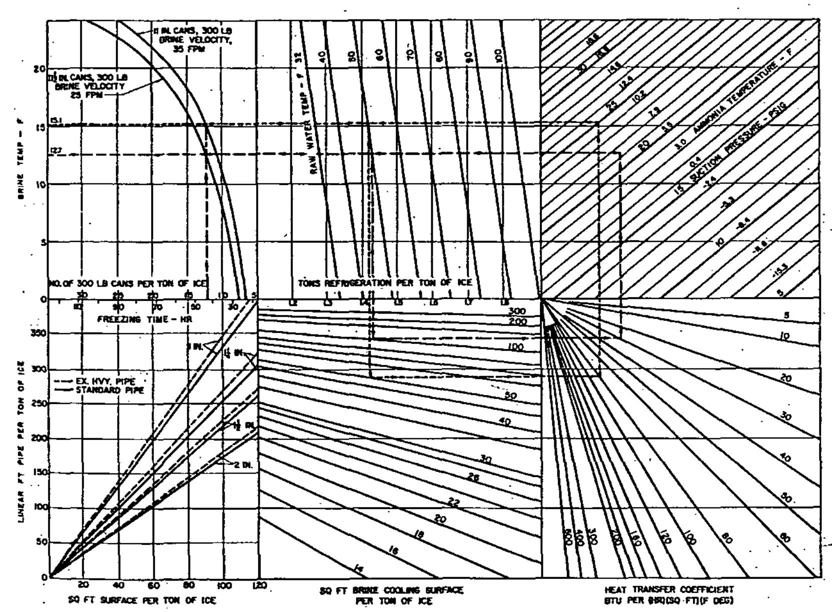
BRINE AGITATORS

The purpose of so-called *agitation* is to circulate the brine to facilitate the conduction and transfer of heat. Originally,

Table 2 .... Typical Operating Performance Data with Various Types of Ammonia Evaporators[a,b]

Type of Evaporator	Flooded Vertical Coil Between Can Lanes, 240 ft 1¼ in. pipe	Bottom Coil and Vertical Coil Raceways, 180 ft 1¼ in. pipe	Horizontal, Single-Pass, Shell-and-Tube, 2-in. OD tubes	Enclosed Bent Pipe Trunk, 70 ft 1¼ in. pipe
Surface per ton of ice daily output, sq ft	104	78	50	30.5
Brine velocity through cans, fpm	15	20	25	30
Heat transfer, Btu per (sq ft) (hr) (F deg)	20	30	75	120
Evaporator temp, F	3.0	3.7	6.7	6.7
Evaporator pressure, psig	18.0	18.5	21.0	21.0
Required actual compressor displacement, cfm per ton of ice	5.9	5.82	5.43	5.43

[a] For 11 × 22 cans, 300-lb capacity.
[b] Refrigerating load = 1.6 tons per ton of ice, water temperature = 50 F, brine temperature = 12 F, condenser pressure = 185 psig, 10.5 cans per ton.



[a] For 300-lb capacity ice cans.

Fig. 4 .... Determination of Evaporator Temperature and Corresponding Suction Pressure[a]