$h_c = 0.38\ (\Delta T)^{0.25}$ for top horizontal surface
$h_c = 0.20\ (\Delta T)^{0.25}$ for bottom horizontal surface

$$\text{heat gain} = \frac{1502 \times 60}{\frac{4}{12 \times 0.12} + \frac{1}{1.73}} = 38{,}300 \text{ Btuh}$$

Equivalent temperature rise per day

$$= \frac{38{,}300 \times 24}{31{,}000 \times 8.5} = 3.5 \text{ F deg per day}$$

$$\text{Tons refrigeration} = \frac{38{,}300}{12{,}000} = 3.2$$

However, the performance of typical coolers at 15 F may be as little as 20 percent of rated value, so some 15 rated tons of capacity could be needed.

2a. Same conditions as for Example 1 except for concrete tank, 20×20×20 ft, with 12 in. walls, capacity approximately 49,500 gal, consisting of 4 exposed walls and exposed top, exposed area 2000 sq ft. Thermal conductivity, k, for dense concrete, 0.7.

$$\text{Heat gain} = \frac{2000 \times 60}{\frac{1}{0.7} + \frac{1}{1.73}} = 60{,}000 \text{ Btuh}$$

$$\text{Temp rise per day} = \frac{60{,}000 \times 24}{49{,}500 \times 8.5} = 3.4 \text{ F deg per day}$$

2b. Saving possible with 4 in. of corkboard insulation, k = 0.025

$$\text{Heat gain} = \frac{2000 \times 60}{\frac{1}{0.7} + \frac{1}{1.73} + \frac{4}{12 \times 0.025}} = 7820 \text{ Btuh}$$

Saving = 87 percent.

Equipping the storage cellar with a refrigeration room of large capacity containing a considerable number of tanks is a convenient but relatively costly method of chilling wines. In practice, it is used principally by the smaller wineries where a large number of wines can be chill-proofed simultaneously. As already indicated, the rate of precipitation of cream of tartar is a time-temperature relationship, the time necessary to effect adequate precipitation being markedly dependent upon the temperature. While a period of 15 days or more may be adequate for most wines held to within a degree of their congealing points, this time is markedly prolonged by a temperature rise of only a few degrees (Fig. 5). This is one of the chief disadvantages of the previous two systems.

In operation the wine may be allowed to fall to the temperature of the room through simple placement in storage. More frequently, however, the system is supplemented by use of an external chilling apparatus. The wine from the outside storage cellar is chilled almost to refrigerated storage temperature by circulation through the shell-and-tube cooler before entering the refrigerated cellar. It is then held at constant temperature for the time required to effect adequate cream of tartar separation.

In France, Italy and North Africa, a type of direct expansion ammonia cooler incorporating mechanical agitation inside the tube or liquid side has been employed for chill-proofing of wines and for concentration of wines by freezing out water.[7] Advantages claimed are more rapid stabilization owing to the close approach to congelation possible and more rapid tartrate deposition resulting from agitation. At present, concentration of wines by freezing is not legally permitted in the United States. However, it would appear to offer considerable promise in production of better quality high alcohol type wines to supplant, perhaps in part, the practice of adding wine spirits. Concentration by freezing would increase acidity and soluble solids as well as alcohol which are generally too low in many dessert type wines made with added wine spirits.

The wine side of heat interchange surfaces frequently become coated with a deposit of tartrate material which reduces their efficiency. This is easily removed by circulation of a dilute lye solution through the system. All systems should be constructed of non-corrosive metals and the refrigerant used should be noninjurious to the wine or health, in case of leaks in the systems.

Refrigeration Requirements for Cooling Heated Must

Short-time heating of crushed red grapes (*must*) to temperatures of 190 F destroys the cellular structure and liberates the red coloring matter into the juice. The change in physical structure also permits easy separation of juice and cellular materials by pressing. When heating and cooling cycles are carried out in heat transfer units designed for rapid heat exchange, little or no change in flavor occurs. Red grapes can thus be fermented as juice and the pomace need never enter the fermenting cellar.

Present units are for the most part of the tube-in-tube type. They consist of 20 ft lengths of 4 in. pipe inside of which is mounted a single length of 3 in. pipe, connected by suitable return bends and banked together in a variety of ways. Several sections are used for heating, more for regeneration and others for cooling. It now appears that reducing the crushed mass to much below 120 F by regenerative heat transfer is impractical. Cooling from 120 to 70 F or the removal of from 85,000 to 100,000 Btu per ton of grapes passed through the units must be provided. Very few wineries have the required amount of refrigeration to successfully complete the cycle. Water as a secondary refrigerant appears most adaptable to the process at present.

Refrigeration Requirements for Chill-Proofing Brandy

A relatively minor application of refrigeration in the wine industry is chill-proofing of brandy just prior to bottling. Distilled spirits, including brandy, are aged in oak barrels at alcoholic strength somewhat higher than that at which they are usually marketed. For brandy, the proof during aging in wood is 102 to 115. During processing for bottling, the proof is generally reduced to 84 by addition of water.

The reduction of alcoholic strength results in a partial precipitation of the alcohol-soluble, water-insoluble wood extractives. These ill-defined wood-extract substances are much less soluble at low than at higher temperatures.

Consequently, in order to insure continued bottle stability, producers subject brandies to a low temperature holding period of 1 to 14 days. The temperatures used vary from about 15 to 25 F. Experience has indicated that the insoluble materials separate almost immediately upon chilling. It tends to rapidly redissolve with rising temperatures. Therefore, it is essential that the brandy be filtered at the low temperature to which it has been stabilized.

Apparently the only advantage of holding at a low temperature for several days is to allow the suspended material to settle to the bottom of the holding tank which thereby facilitates the filtration. Filter rates are slow at best, owing to the high viscosities of water-alcohol mixtures at low temperatures. For example, the viscosity at 32 F of 40 percent (by weight) ethanol is 7.2 centipoises, or more than four times as much as either pure ethyl alcohol or water at this temperature. In the range of temperatures used for chill-proofing the viscosity is markedly greater, which has a marked adverse effect on heat transfer coefficients.

The procedures employed by brandy producers vary. Generally insulated stainless steel tanks of 1000 to 5000 gal capacity are used for processing tanks. Some use direct expansion of refrigerant into coils installed inside the tanks while others depend on circulating the brandy through external heat exchangers with direct expansion of refrigerant, much in the same manner as the wine coolers described earlier. Holding temperatures used have been reported as low at 10 F but 18 to 20 F is more usual. Present information indicates that the temperature of the brandy as it passes the filter is that to which the brandy can be regarded as cold stable.

Brandy can be considered to have the same specific heat and density values as ethyl alcohol-water mixtures at equivalent concentrations.

Table 3 .... Volume of CO_2 Gas Absorbed in One Volume of Water

Temp, F	Pressure, in bottle, psig										
	0	10	20	30	40	50	60	70	80	90	100
32	1.71	2.9	4.0	5.2	6.3	7.4	8.6	9.7	10.9	12.2	13.4
40	1.45	2.4	3.4	4.3	5.3	6.3	7.3	8.3	9.2	10.3	11.3
50	1.19	2.0	2.8	3.6	4.4	5.2	6.0	6.8	7.6	8.5	9.5
60	1.00	1.7	2.3	3.0	3.7	4.3	5.0	5.7	6.3	7.1	7.8
70	0.85	1.4	2.0	2.5	3.1	3.7	4.2	4.8	5.4	6.1	6.6
80	0.73	1.2	1.7	2.2	2.7	3.2	3.6	4.1	4.6	5.2	5.7
90	0.63	1.0	1.5	1.9	2.3	2.7	3.2	3.6	4.0	4.5	4.9
100	0.56	0.9	1.3	1.7	2.0	2.4	2.8	3.2	3.5	3.9	4.3

PART III: CARBONATED BEVERAGES

Refrigeration equipment is required in most carbonated beverage bottling plants to cool the water used in the product, the sirup or the finished beverage. The refrigeration load varies with production conditions, and whereas small plants may utilize only about four tons of refrigeration, a large plant will require over 300 tons.

Cooling the water, sirup or finished beverage serves to: (1) obtain maximum stability of the carbonated beverage during bottle filling, which becomes very critical under present day high speed operations; (2) promote uniformity of the finished beverage; and (3) permit reducing the pressure at which the beverage is filled into the bottle.

In order to prepare carbonated water that will have the proper *life* and will show the desired sparkle and release of carbon dioxide gas when the finished beverage is served, the water is supersaturated by using carbon dioxide gas under pressure in an apparatus known as a *carbonator*. The amount of gas dissolved varies directly with the temperature of the water and the carbon dioxide gas pressure. It is found that the lower the temperature of the water, the less the gas pressure needed for a given carbonation of the water, for cold carbonated water shows less tendency to lose its gas while going through the bottle filling machines, meaning it is more stable.

For example, at 60 F and atmospheric pressure, a given volume of water will absorb an equal volume of carbon dioxide gas. If the carbon dioxide gas is supplied to the water under a pressure of two atmospheres (approximately 15 psig), the water will absorb two volumes. For each additional 15 psig, one additional volume of gas is absorbed by the water. Reducing the temperature of the water to 32 F increases the absorption by the water to 1.7 volumes. Therefore, each 15 psig additional at 32 F water temperature, gives an additional 1.7 volumes, instead of one volume, as is the case when the water temperature is 60 F.

The commonly used data on the relationship of pressure and temperature to the volumes of carbon dioxide dissolved per volume of water is presented in Table 3. Beverages of low carbonation fall below 3.5 volumes of carbon dioxide per volume of water, while the higher carbonation may run up to 5.0 volumes, depending on the product.

Types of Water Coolers

Although there is a variety of mechanical designs for water coolers, they are to be considered first as to function, namely, instantaneous or storage type based upon the rate of cooling and the volume of water hold-up. The storage type has lost position in recent years because the instantaneous cooler has better sanitation facilities, operating economy, requires less space and inherently must be soundly engineered to the actual refrigeration demands of the plant.

The cooling of water is carried out in one of a number of water cooling units of several designs: Baudelot, tank unit, cascade tray, shell-and-coil, shell-and-tube and carbonator-cooler.

The Baudelot or descending film type of cooler consists of stamped, corrugated, stainless steel sheets which resemble a washboard and in which the corrugations form channels for the refrigerant flow. The water to be cooled trickles down in a thin film from an overhead pan containing distributing holes.

The *tank* type cooler has the refrigerant expansion coils immersed in a tank of water. Other arrangements baffle the water for long flow.

The *cascade tray* type has a series of inclined trays in which the expansion coils are laid, over which the water passes in flowing by gravity from the highest tray on down to the lowest, usually in a zig-zag path.

The internal-coil or *shell-and-coil* type of unit is usually described in the beverage business as a closed system cooler. Water goes through a closed pipe coil immersed in the refrigerant. This form of cooler, since it will operate under pressure, can also be used to cool water further after it has been carbonated.

All of the above types of coolers have direct expansion or direct heat interchange between the evaporating refrigerant and the water to be cooled. Differing from these is the *brine circulation* system which is used either for special design or as precaution against the possibility of refrigerant leakage into