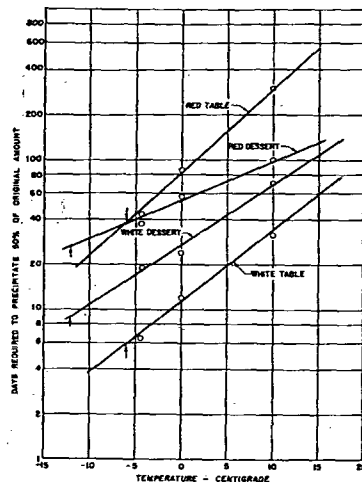




* Arrows indicate crystallization temperatures.

Fig. 5 Effect of Temperature on Precipitation of Cream of Tartar from Wines*

compromise between good refrigeration practice and convenience of operation. In the wineries producing desert wines this application is successfully made by positioning the coils as noted above, so as to be in contact with the fermenting liquid. The ebullition generated by the evolution of carbon dioxide gas during fermentation results in good convection and effective heat transfer. Soft drawn, 2-in. copper tubes, with center lines 10 to 12 in. vertically, were commonly used in the early installations. New installations are of stainless steel tubing, particularly in fermenters serving in the dual capacity as storage tanks. It is common practice to provide at least 1 ft of piping for each 100 gal of fermenter capacity.

In this system continuous cooling is possible and little supervision is required. Excessive oxidation as a result of improper pumping of the liquid over the cap must be avoided. Rather than spraying the surface, the cap should be driven into the liquid by heavy streams from high velocity nozzles. Modifications of this system include bulkheads and frameworks for keeping the cap submerged throughout fermentation, and cooling coils located in both the liquid above and below the framework.

The externally located coolers are used most commonly by wineries producing table wines exclusively. Fermentations for the most part are on a smaller scale which makes this system better suited to this type of operation. The units are principally single-pass, water-cooled, shell-and-multitube coolers, although plate-type coolers are also in use. Both types of units employ counter-flow.

The shell-and-multitube units consist of several 20 ft lengths of 3 or 4 in. iron pipe or copper tubes inside of which are mounted from three to seven $\frac{3}{4}$ or 1 in. thin-walled stainless steel tubes. The flow of wine or must through the tubes is

single-pass with stainless steel return bends connecting to the next tube length. Supports placed at intervals along the tubes to prevent sagging assist in providing turbulence of the water flow. The cooling surface varies from 120 to 250 sq ft in the various units available. They are mounted either as a single or double bank of horizontal sections of pipe.

Plate-type exchangers can be used, but the must has to be screened carefully to prevent seeds and skin particles from plugging the channels between the plates.

Performance studies conducted under actual winery conditions showed that operation of the units varied considerably. The free-run wine, after screening to remove particles of skin and seeds, was pumped through the cooling unit at rates varying from 1000 to 3000 gal per hr. The water flow through the units was found to vary from 800 to 5000 gal per hr. The average coefficient of heat transfer calculated from nearly 100 tests on various units was found to be 245 Btu per hr per sq ft of heat transfer area per deg F. The range in the overall coefficients of heat transfer in these tests varied from 111 to 390 Btu per hr per sq ft cooling area per deg mean temperature difference. Most economical use of the cooling water results when wine and water flow through the unit are approximately equal. Recently a type of portable submersible cooling unit has been employed for cooling fermentations in smaller tanks as are typically used by smaller wineries specializing in table wine production. It consists of a stainless steel plate containing a single imbedded fluid channel, comparable to several tubes with return bends, constructed by welding together two sheets previously stamped so as to form half of the channel cross section in each sheet.

The submersible heat exchanger, a form of extended surface tube, is placed vertically inside the tank of liquid and connected to a source of cold water or refrigerated coolant. Tests have indicated an overall heat transfer coefficient of 90 to 135 Btu per (hr) (F deg) (sq ft) of total surface.

Chilling Requirements for Tartrate Removal

Newly made wine contains cream of tartar (potassium bitartrate) considerably in excess of saturation. The excess of cream of tartar must be removed to avoid an undesirable deposition in bottled wine. It can be removed naturally by prolonged storage at cellar temperature or hastened by cold storage treatment at temperatures slightly above that producing conglomeration.

For the cooling of wine to precipitate cream of tartar, the lowest possible temperature is desirable. The freezing point of table wines (claret, Zinfandel, burgundy, sauterne, Riesling, chablis, etc.) is generally between 22 and 20 F, while desert wines (sherry, port, muscatel, angelica, tokay, etc.) freeze at temperatures varying from 12 to 7 F. The specific gravity for table wines varies from 0.990 to 1.00, while the specific gravity for desert wines varies from 0.985 to 1.03. Specific heat likewise varies with type of wine, and tests show it to vary from approximately 0.9 to 1.0. The chilling requirements for all types of wines are therefore usually calculated using a specific gravity of 1.03 and a specific heat of 0.9. The chilling load, however, is dependent not only upon these factors, but also upon the amount of wine handled per unit time, the average cellar temperature, and the system of chilling employed.

The solubility of cream of tartar decreases with increasing concentrations of alcohol, decreasing temperature, or both. Tests show, however, that merely chilling a wine to a temperature just above freezing is not sufficient to cause the separation of appreciable amounts of cream of tartar. To remove that portion in excess of the amount the wine will tolerate when bottled, the wine must be stored at the cool temperature for a period of time which depends upon the nature

Table 2 Cooling Rates of Wine by Circulation Through Ammonia Coolers

Wine Temp F	Time Hours	Average Rate Btu/hr	Percentage of Total Tonnage of Units
60	0	—	—
47	11	883,000	92
37	24	575,000	60
23	44	523,000	55
16	72	187,000	20

of the wine and the temperature of storage. Contrary to results that might be predicted from solubility data, the rate of precipitation from table wines is more rapid than from desert wines at the same temperature (Fig. 5). Likewise, the rate of precipitation from a white wine is faster than from a red wine. The above statements also hold for wines that are refrigerated and maintained in a completely congealed state.

In general, both table and desert wines can be rendered cold stable by holding constantly at temperatures within 1 deg of their congealing temperature, or until tests show that the concentration product (Kcp) for potassium bitartrate in the wine equals, or is less than, the solubility product constant (Ksp) of saturated solutions of potassium bitartrate at 20 C. Methods for conducting the analyses and the formulas and tables required for calculating the constants are given by Berg and Keefer.⁴ This state will occur in 15 days or less for most wines where no steps are taken to speed up the operation. Determinations for potassium and total tartrate content, percent alcohol (v/v), and pH enable the winemaker to follow changes in concentrations product with the aid of the tables noted above.

Residence time under refrigeration can be reduced by seeding with clean refrigeration lees, and by agitation, or both. The Australian wine industry has secured greater reduction in tartrate content and shorter chilling periods by seeding with 1 gal of precipitated cream of tartar lees per 1000 gal. When the wines are slowly agitated at just about the congealing temperature, only 4 to 5 days are needed to accomplish the desired results.

Chilling is not effective in preventing calcium tartrate deposition. Wines containing calcium in excess of 225 mg per gal will almost certainly deposit crystals of calcium tartrate if held a sufficient time after bottling.

Methods of Chill Proofing Wines

Methods of chilling wine can be divided into three classifications: (1) those in which the chilling apparatus is mounted inside the chilling tank; (2) those in which the chilling apparatus is external to the chilling tank, and (3) those in which the chilling tanks are located in refrigerated rooms. The refrigeration load differs considerably for each method, as does also the method of operation required.

Systems in which the chilling apparatus is mounted in the tank, when used as the primary chilling unit, should be designed to effect uniformity of temperature within the tank, and to decrease any tendency for water to freeze out the chilling surfaces. Failure to do so in the past largely accounts for the disrepute this system possesses presently. Chilling apparatus mounted in storage tanks serves a very useful role in maintaining previously chilled wines at constant temperature levels during the holding period required for tartrate deposition in non-refrigerated cellars.

The external chilling units are usually shell-and-multitube coolers with the wine flow through the tubes and the refriger-

ant expanded into the shell. Wine from a storage tank is circulated through the unit until it reaches the desired temperature. The system should be designed to supply sufficient refrigeration capacity to chill the contents of the tank rapidly. Wine warms in storage more rapidly than is believed, and frequently this factor has not been taken into consideration in the calculation of the refrigeration load. Because of this condition, the total refrigeration load is best split unevenly between two or more units. The larger unit is used for reducing the wine to chilling temperature, while the smaller unit is used to hold it at constant temperature for the required chilling period.

Estimation of Refrigeration Loads for Holding Wine at Cold Stabilization Temperatures

Schreffler,⁵ reviewing some of the practical problems in winery refrigeration, showed the marked decrease in wine cooling rate as the circulated wine temperature is lowered toward the desired minimum. His data for two 40 ton ammonia units used in parallel to chill a wine from 60 to 16 F, 90,000 gallons in insulated concrete tanks, were used to prepare Table 2.

Schreffler also stated that 90,000 gallons of wine at 15 F introduced into a 90,000 gal concrete tank of 12 in. walls and 4 in. of cork insulation gains about 3 F deg per week at 75 F ambient temperature. Under similar conditions for an uninsulated concrete tank, wine gains 1 to 1.25 F deg per day. Thus the saving in holding refrigeration load from use of 4 in. of cork insulation is approximately 60 percent (about 1.1 tons of refrigeration as 3 tons for the uninsulated tank).

Holstein⁶ uses the approximate relationships to estimate the equivalent tons of refrigeration for wine cooling as follows:

$$q_r = \frac{0.652 W (t_i - t_f)}{1000} \quad (1)$$

where

- q_r = cooling load, tons of refrigeration.
- W = quantity of wine cooled, gallons per hour.
- t_i = initial temperature of wine, Fahrenheit.
- t_f = final temperature of wine, Fahrenheit.

Schreffler also reported observed and calculated values for temperature gains of chilled wine. Redwood tanks of 31,000 gal capacity were equipped with 407 ft of 1½ in. OD stainless tubing divided into three separate expansion coils for direct expansion of Refrigerant 12, amounting to 160 sq ft of heat transfer surface. The estimated overall coefficient of heat transfer for maintaining wine at 18 F was 12 Btu per (hr) (F deg) (sq ft). The temperature rise per day in the 31,000 gal redwood tanks without refrigeration was estimated by calculation to be 2.5 F deg per day, and a rise of 3 F deg per day was observed.

Refrigeration capacity for holding can be estimated by the procedure of the following examples.

- Capacity of redwood tank 31,000 gallons.
Inside dimensions: height 25 feet, avg. diameter 14.5 ft.
Wood thickness 4 in.; thermal conductivity k 0.12 (est.).
Vertical cylindrical surface 1170 sq ft
Bottom and head surface 332 sq ft
Total surface 1502 sq ft
Wine temp. 15 F, ambient temp. 75 F.

Radiation coefficient, $h_r = 0.90$ Btu per (hr) (F deg) (sq ft)

$$\text{(estimated from } h_r = \frac{0.173((0.01T_s)^4 - (0.01T_a)^4)}{T_s - T_a})$$

Mean convection coefficient to air, $h_c = 0.83$ estimated from $h_c = 0.3 (\Delta T)^{0.25}$ for vertical surface