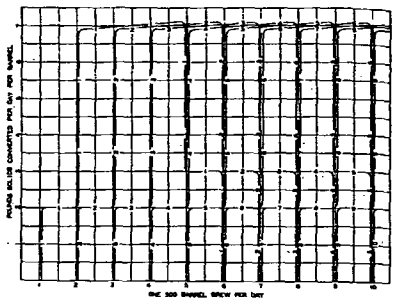
Plate Cooler (1st section)		
Number of plates	40	
Heat transfer surface per plate	4.3	sq ft
Heat transfer surface in 1st section	172	sq ft
Number of passes	5	
Number of streams per pass	4	
Water flow rate	34,000	lb/hr
Wort flow rate	17,000	lb/hr
Plate Cooler (2nd section)		
Number of plates	24	
Heat transfer surface per plate	4.3	sq ft
Heat transfer surface in 2nd section	103	sq ft
Number of passes	3	
Number of streams per pass	4	
Chilled water flow rate	52,000	lb/hr

Fermenting Cellar

After cooling, the wort is pitched with yeast and collected in a fermenting tank, where fermentation sets in according to the chemical reaction previously outlined. For each 31-gal bbl of wort, about 25 lb of solids are converted. The daily rate of conversion varies, depending on the operating procedure adopted in each plant. A representative rate might be, on the first day, 2 lb of maltose converted. The rise in temperature caused by fermentation increases this rate to 7 lb on the second day. By now the maximum desired temperature has been attained and a further rise is checked by means of an attemperator, so that on the third day another seven pounds is converted. This rate continues on through the fourth day. By now the amount of unconverted maltose remaining in the beer is greatly diminished, and because of the inhibiting action of alcohol and carbon dioxide on further yeast propagation, the action nearly halts on the fifth day when only about 3 lb are converted. Because of the decreased rate, the temperature of the beer begins to drop and by the sixth day further fermentation has been checked. It is then cooled to 29 F, filtered and transferred to the stock cellar. Complete fermentation can generally be effected in about 7 days.

Attemperators usually consist of one or two rings of 4 in. copper tubing, concentric with the walls of the tank and supported at about two-thirds of the height of the liquid. The agitation necessary for heat exchange between the attemperator and the beer is provided partly by convection, but principally by the ebullition set up by the CO_2 bubbles rising to the surface of the liquid. In estimating the heat transfer surface required, a heat transfer rate of 15 Btu per (sq ft) (hr) (F deg) has been found to be reasonable. The heat loss from tank walls and surface of the liquid may be disregarded in calculating the attemperator coil surface requirements. However, if the room temperature is allowed to drop appreciably below 50 F, the heat dissipated through metal tank walls becomes important, and depending on the degree of heat dissipation, fermentation may be retarded or even inhibited. In such instances, wooden fermenting tanks or the insulation of the tank walls and bottoms are indicated so that the control of heat removal remains in the attemperator.

The refrigeration requirements are necessarily based on the maximum volume of wort in fermentation at one time. Fig. 2 illustrates this load based on a 500 bbl per day production rate. The days are represented by the abscissa, and the pounds of solids converted per day by the ordinate. The individual brews in fermentation on any particular day are additive. For example, on the fifth day Brew No. 1 is finishing with a conversion rate of 3 lb for that day; Brew No. 5, which is just beginning the fermentation cycle is fermenting at the rate of 2 lb; while Brews No. 2, 3, and 4 are at the maximum rate of 7 lb per bbl per day each. The total solids fermented on this day is thus seen to be 26 lb per bbl for the 2500 bbl in fermentation, making a total of 13,000 lb of solids converted.



Brew 5 2 lb×500 bbl = 1000 lb
Brew 2 7 lb×500 bbl = 3500 lb
Brew 3 7 lb×500 bbl = 3500 lb
Brew 4 7 lb×500 bbl = 3500 lb
Brew 1 3 lb×500 bbl = 1500 lb

26 lb 13,000 lb

Fig. 2 .... Solids Conversion Rate

Since the heat of fermentation is 280 Btu per lb, the refrigeration load would be:

$$\frac{13{,}000 \times 280}{24 \times 12{,}000} = 12.6 \text{ tons}$$

Calculations for sizing of attemperators must take into consideration the following:

1. The internal dimensions of the fermenting tank and its capacity.
2. The temperature difference between the coolant and the fermenting beer.
3. The maximum daily sugar conversion rate.
4. The heat evolved, which is at the rate of 280 Btu per lb of fermentable sugar converted.

Assuming a square fermenting tank 13 ft sq to hold a brew of 500 bbl, and allowing 1 ft between the tank wall and the attemperator for easy cleaning, an 11 ft square attemperator can be used, giving 44 perimetrical feet of tubing.

From Fig. 2, the maximum daily conversion rate is shown to be 7 lb per barrel. Calculating for 500 bbls, at 280 Btu per lb of sugar converted,

$$7 \times 500 \times 280 = 980{,}000 \text{ Btu per day}$$
$$\text{or } 40{,}833 \text{ Btu per hr.}$$

Then assuming a 50 F fermenting beer temperature and 20 F brine, a temperature difference of 30 F deg, and a heat transfer rate of 15 Btu per (hr) (sq ft) (F deg) for the attemperator, the number of sq ft of surface required would be:

$$\frac{40{,}833}{15 \times 30} = 90.7 \text{ sq ft}$$

Considering 4 in. OD tubing which has an external area of 1.05 sq ft per ft, the number of lineal feet required would be:

$$90.7/1.05 = 86.4 \text{ ft}$$

Therefore, two attemperators, each 11 ft square, would give 88 ft of tubing, which is adequate for the conditions outlined.

About 13 lb of CO_2 are generated for each barrel of beer fermented, most of which is collected and liquefied for later use in the brewery for carbonating, for counter pressure in transfer operations, and for the bottling lines.

Adequate fresh air must be provided in open tank fermenting cellar to safely dilute the CO_2 emanating from the fermenters. The amount permissible should be such that there is no health hazard to the men working in these spaces. Concentrations below one percent are considered entirely safe. Increasing amounts reduce the efficiency of the worker and concentrations of four percent make the performance of work for protracted periods untenable. Since it is heavier than air, CO_2 tends to settle to the floor from where it may be withdrawn by means of scupper connections at the floor level. Fresh air may be introduced through the ceiling, the openings being located so as not to remove or disturb the layer of protective CO_2 gas on top of the fermenting beer.

Stock Cellar

The stock cellar is a refrigerated room containing tanks into which the cooled beer from the fermenter is transferred for the purpose of aging and settling. New filtering methods have obviated the need for settling, as all suspended solids are removed during the transfer from the fermenter. The retention of beer in the stock cellar is a matter of the brewer's discretion and may be from 3 weeks to 3 months.

While the CO_2 pollution of the air in the stock cellar is far less than in the fermenting room, adequate provision must be made to supply fresh air in sufficient amounts to keep the concentration below 1 percent.

Finishing Cellar

In the finishing cellar the beer is polished by filtration, and is then carbonated by any of a number of different methods. The filtering is usually done through a series of cellulose pulp filters, the number of filters used depending on the brilliance desired in the finished product. After this final processing, it is transferred to the racking room for filling into kegs, or to the government cellar for bottling.

Kraeusen Cellar

Instead of the usual carbonating method, some brewers prefer to carbonate by means of the Kraeusen method, for which a Kraeusen cellar is substituted for the finishing cellar. This cellar contains a number of tanks capable of retaining a pressure of about 20 psig. Because the retention period is from 7 to 14 days, a greater capacity is required here than in the case of a finishing cellar. In transferring beer from the stock cellar, it is blended with about 20 percent of beer that had been brewed only a few days prior and which is just coming to the Kraeusen stage of fermentation. It is introduced into a closed pressure tank and as fermentation is established the evolved CO_2 gradually raises the pressure within the vessel. More and more CO_2 is retained in solution as the pressure increases, the retention of gas being a direct function of pressure and an inverse function of temperature. At a specified pressure the excess is relieved by means of a closely regulated relief valve, the pressure being such that the desired amount of CO_2 is dissolved in the beer.

Heat is generated by this secondary fermentation, but the temperature of the liquid does not rise to as high a temperature as it did in the fermenter because the fermentable sugars are only available from the 20 percent which has been added as Kraeusen. Furthermore, the bulk of the liquid had a lower starting temperature, having come from the stock cellar at about 29 F. A temperature of from 42 to 44 F may be reached at the peak, after which the liquid cools to the ambient temperature of the room. This cooling can be accelerated in the tanks by means of attemperators through which a brine such as propylene glycol is circulated. Since additional heat is generated, the calculations for the refrigeration required include that of lowering the liquid temperature from 44 to 29 F and maintaining this temperature for several days to coagulate any chill-hazing proteins that may have been introduced in the Kraeusen. These coagulated proteins are retained in the filter when the beer is finally transferred to the racking machine or to the government cellar.

STORAGE

Hop Storage

Hops should be stored at a temperature of from 29 to 32 F with a relative humidity of 50 to 60 percent and with very little air motion, to prevent excessive drying. Sweating of the bales should not be permitted, as this would carry off the light aromatic esters which would deteriorate the fine hop character.

Yeast Culture Room

In the yeast culture room, yeast is propagated to be used in re-seeding and replacing yeast that has lost its virility. A relative humidity of 80 percent is required to prevent the yeast from hardening on the vat walls. The CO_2 blanket on top of the vats should not be disturbed by excessive air motion.

CO_2 Collection

Carbon dioxide gas produced as a by-product of fermentation is collected in closed fermenters, compressed and stored in pressure tanks for later use, when it is used for final carbonation, counter-pressure in storage and finishing tanks, transfer and in bottling and canning of the product. In the past the CO_2 was stored in the gaseous state at about 250 psig. However, more recently, practice in most of the medium and large breweries is to collect the gas, and after thorough washing and purification it is liquefied and stored as liquid. Carbonic acid gas stored in the liquid state occupies about $^1/_{48}$ of the volume of an equal weight of gas at the same pressure at room temperature.

It has been shown that from each barrel of wort fermented, about 13 lb of CO_2 is generated over a period of 5 days, though not at a constant daily rate. Brews must therefore be scheduled as nearly as possible to provide the gas as required for production; to balance the supply of gas with demand, storage must be provided.

Of the 13 lb per bbl of gas generated, about 6 lb is collected, the gas at the beginning and at the end of the fermentation cycle not being suitable is discarded because of excessive air content and other impurities.

From the fermenting tank, the gas is piped through a foam trap to a gas pressure booster. A water-column safety relief tank protects the fermenting tanks from excessive gas pressure and the surplus gas is here discharged to the outside. The booster raises the pressure from 1 psig to 5 to 6 psig to compensate for friction head loss in the long lines to the compressor and to increase its capacity. A compressor of the two-stage type with water injection to remove the heat of compression increases the pressure to 250 psig. The entrained injection water is separated from the compressed gas by means of a knock-out tank and is usually collected, cooled and reinjected. The compressed gas is then deodorized.

CO_2 Liquefaction

From tables of the properties of CO_2, the condensing temperatures at several pressures are:

−20 F	200.35 psig
−14 F	225.14 psig
− 8 F	251.96 psig