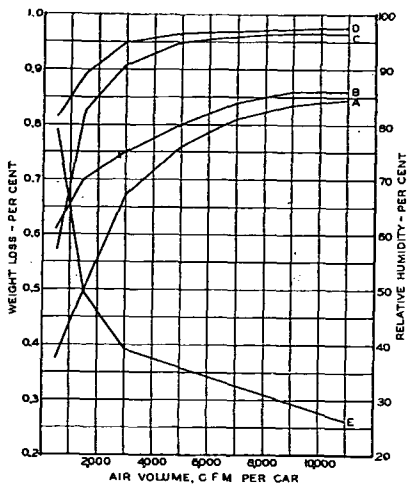

A = Calculated relative humidity during the first hour of precooling.
B = Observed humidity during the first hour of precooling.
C = Calculated humidity at the time the fruit temperature reached the precooling temperature.
D = Observed humidity at the end of the precooling period.
E = Observed weight loss at the end of 4 days.

Fig. 3 .... Effect of Air Volume on the Relative Humidity and Weight Loss During 4 Days' Precooling with 34 F Supply Air Entering the Room

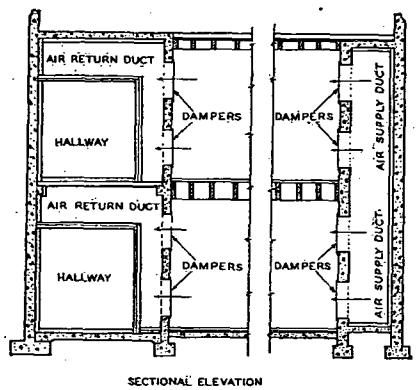

Fig. 4 .... Typical Precooler and Storage Rooms for Oranges

Table 4 .... Percentages of Severe Rind Defects and Decay Developed During Four Days Precooling and 10 Days Storage under Conditions of Standard Refrigeration with Varying Amounts of Air—Supply Air Temperature, 34 F

Air Volume, Cfm per Car	*Percentage of Severe Rind Defects + Decay*	*Percentage of Weight Loss*
11,000	1.48	0.26
3,000	1.84	0.39
1,500	2.04	0.48
500	3.09	0.79
*Check, not Precooled	2.08	0.50

* 14 days' storage under conditions of standard refrigeration.

tual damage to the fruit occurs as the volume decreases below 1500 cfm per car.

The *relative humidity* of the air in the rooms during precooling has a direct relation to the weight loss and severe rind defects. Humidity is just as important as temperature in preventing grade and quality deterioration of oranges during precooling and shipment to the market. A high relative humidity can be maintained in precooler rooms without resorting to the use of auxiliary sprays and complicated controls, simply by using a sufficient air volume and the brine spray system. Fig. 3 indicates the weight loss during four days precooling with different air volumes; the observed humidities for the first hour of precooling and at the end of four days precooling; and the calculated humidities during the first hours of precooling and at the end of the precooling period. The results as given for the calculated humidities during the first hour were derived from the actual precooling rate for the same period of time.

The design and construction of a building for precooling and storage determines the operating practice and conditions that can be maintained. It is important to coordinate the engineering of the building with that of the refrigeration and air distribution system before construction of either is started.

Fig. 4 indicates the arrangement of air ducts, brine spray and general floor plan for a typical precooling and storage plant. The air ducts and brine spray chamber are of sufficient size to reduce friction losses to a minimum. The brine spray chamber is long enough to assure efficient heat transfer. The air as it is being recirculated makes a minimum number of right angle turns. All the air ducts and brine spray chamber extend the full height of the building. The dampers, both supply and exhaust in each individual room, are operated simultaneously, thereby simplifying air volume control.

Precooling may also be accomplished in the refrigerator car after it has been loaded. There are three different methods of car precooling (Fig. 5), one by means of portable fans installed at the top opening of the bunker at each end of the car, using salt and ice in the bunker as a source of refrigeration. The second method has stationary or portable refrigerating units, which force low temperature air into the car and around the fruit. The third and the most satisfactory method is to precool the fruit in the cars in transit, by means of stationary fans permanently located under the floor racks at both ends of the refrigerator car. The fans, which are operated from the wheels of the car, deliver the air to the bottom of the ice bunkers, then up through the ice in the bunkers and out at the top opening of the bunker. The fans are operated mechanically when the car is in motion or by electric motor during stationary precooling.

Storage

Cold storage (40 F) at shipping point should be used only to keep an adequate supply of fruit on hand to carry over short periods of adverse weather conditions that hamper harvesting operations and otherwise would interfere with shipping schedules. Under ordinary circumstances several days' supply is sufficient. *Long storage is never desirable* because the consumers prefer fresh oranges whatever the geographic origin.

In contrast to many other fruits, oranges have a long harvesting season, and a moderately long life after picking, which can be extended somewhat by low-temperature storage. However, California oranges ordinarily deteriorate faster in storage than if left on the tree under normal weather conditions (Fig. 6). Under some conditions granulation, or hardening of the juice sacs, may also increase more rapidly in storage.

The effect of storage on *juice quality* is variable. The ability of any individual lot of fruit to retain its original fresh flavor depends to a large extent upon its original acidity. The juice quality is closely associated with the ratio of total solubie solids to acid. As the acid decreases the juice tastes sweeter and eventually becomes flat and insipid. Fruit of low initial acidity may not lose any more acid than one with high acidity but the change in flavor will be much greater. Slightly off, or stale flavors are also more readily detected in juices of low acidity.

During storage or shipment under the most favorable conditions the juice content of oranges decreases at the rate of about one per cent per week. Under less favorable conditions which have a tendency to increase the rates of respiration and transpiration, the nutritional loss will be greater.

After they have been packed, oranges are transferred to the precooling rooms or to refrigerator cars by hand by power driven trucks, or by conveyors. In the cars they are loaded flat with a chimney type load. If transferred to the precooling rooms they may be stacked on the floor or on pallets suitable for power trucks. In stacking on the floor or on pallets, it is important that space between palleta and containers be sufficient to allow uniform distribution of air.

After the room has been filled, the fruit is cooled rapidly to the desired storage temperature, after which the air volume is reduced to approximately 1200 cfm per car, and held at this value until the fruit is removed from the room. The temperature of the supply air entering the room should be not more than 2 F below the selected storage temperature of the fruit.

Recommended Storage Conditions

Recommended conditions for orange storage are:

Minimum air volume* per car (during precooling), cfm	3000
Minimum air volume per car after fruit temp reaches storage temp, cfm	1200
Fruit temperature, F	36
Supply air temp entering room, F	34
Outdoor air—approximately, cfm per car	10
Relative humidity of supply air—minimum %	95

* Total volume of supply air entering the storage room, not to be confused with secondary or induced air circulation resulting from air low in temperature and volume supplied at high velocities.

Since the bulk of the California orange crop is sold in distant markets the transportation problem is similar to that encountered in refrigerated storage. All other factors being equal, the deterioration in grade and quality in transit is limited by the length of time in transit, type of refrigeration and rate of cooling. The length of time required to reduce the temperature to a point below 45 F has a direct bearing on grade deterioration in transit. The minimum weight and grade losses occur when the fruit is first precooled to 39 to 40 F and

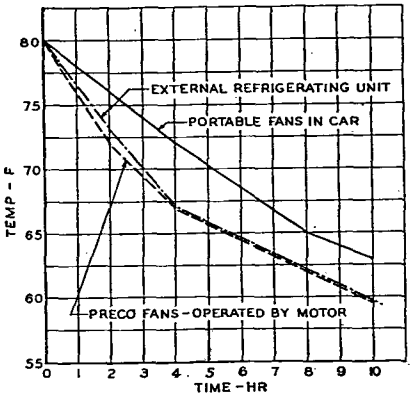

Fig. 5 .... Rate of Precooling Oranges in Refrigerator Car

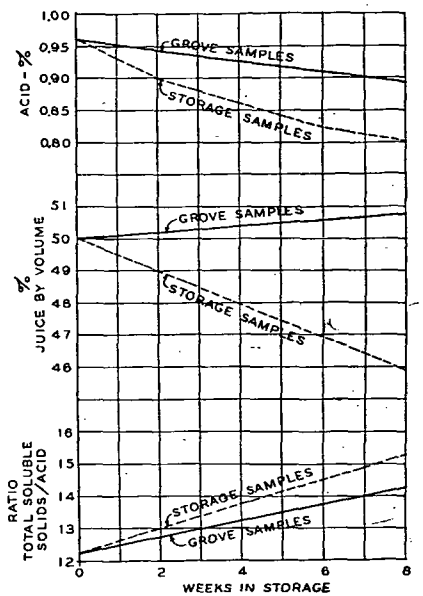

Fig. 6 ....Change in Citric Acid, Juice Content and Ratio of Total Soluble Solid to Acid for Oranges During Low-Temperature Storage and on the Tree.