

$$\frac{70,000 \text{ cfm supply air}}{53.9 \text{ tons refrigeration}} = 1300 \text{ cfm per ton}$$

Air Temperature Range

$$\frac{(\text{Btu per hr sensible load})}{(\text{sp ht})(\text{lb per hr supply air})} = \frac{(\text{Btu per hr})(\text{cu ft per lb})}{(\text{sp ht})(\text{cfm})(60 \text{ min})}$$

Overall Air Temperature Range

$$\frac{(560,000 \text{ Btu})(12.57 \text{ cu ft per lb})}{(0.24)(70,000 \text{ cfm})(60 \text{ min})} = 7.0 \text{ F deg}$$

Average Air Temperature Range in Rooms

$$\frac{(451,310 \text{ Btu})(12.57 \text{ cu ft per lb})}{(0.24)(70,000 \text{ cfm})(60 \text{ min})} = 5.6 \text{ F deg}$$

Average Air Temperature Range in Precoolers

$$\frac{(116,200 \text{ Btu})(12.57 \text{ cu ft per lb})}{(0.24)(5 \text{ cars})(3000 \text{ cfm})(60 \text{ min})} = 6.7 \text{ F deg}$$

Air Temperature Range in Precooler at End of Precooling

$$\frac{(16,180 \text{ Btu})(12.57 \text{ cu ft per lb})}{(0.24)(5 \text{ cars})(3000 \text{ cfm})(60 \text{ min})} = 0.94 \text{ F deg}$$

Air Temperature Range in Storage Room

$$\frac{(16,180 \text{ Btu})(12.57 \text{ cu ft per lb})}{(0.24)(5 \text{ cars})(1000 \text{ cfm})(60 \text{ min})} = 2.8 \text{ F deg}$$

Air Temperature Rise in Fan and Ducts

$$\frac{(90,290 \text{ Btu})(12.57 \text{ cu ft per lb})}{(0.24)(70,000 \text{ cfm})(60 \text{ min})} = 1.1 \text{ F deg}$$

Design the brine spray washer for 32 F leaving air temperature. With 1.1 F deg rise in fan and ducts the air entering rooms will be 32 + 1.1 = 33.1 F deg. Assume that air leaves washer at 31 F dew point and 95 percent relative humidity at which condition (from a psychrometric chart) the air will have a moisture content of 25.3 gr per pound.

Average Moisture Gain in Rooms

$$\frac{(\text{Btu per hr latent load})(7000 \text{ gr per lb})}{(1060 \text{ Btu per lb})(\text{lb per min supply air})} = \frac{(\text{Btu per hr})(7000 \text{ gr})(\text{cu ft per lb})}{(1060 \text{ Btu})(\text{cfm})(60 \text{ min})} = \frac{(41,300 \text{ Btu})(7000 \text{ gr})(12.57 \text{ cu ft per lb})}{(1060 \text{ Btu})(70,000 \text{ cfm})(60 \text{ min})} = 0.8 \text{ gr per lb supply air}$$

The return air will then have a moisture content of 25.3 + 0.8 = 26.1 gr per lb and will have a dew-point temperature of 31.7 F. The return air dry-bulb temperature, with a 7 F deg range in temperature, will be 32 + 7 = 39 F.

The average temperature of air leaving precoolers = 33.1 + 6.7 = 39.8 F dry-bulb and 31.7 F dew point. The relative humidity will then be 73 percent.

The average air temperature leaving precoolers at end of precooling = 33.1 + 0.94 = 34.04 F dry-bulb and 31.7 dew point. The relative humidity will be 90 percent.

The air leaving the storage rooms = 33.1 + 2.8 = 35.9 F dry-bulb and 31.7 dew point. The relative humidity will be 85 percent.

REFRIGERATION SYSTEM

Assume a 2 F deg brine temperature range.

$$\text{Then } \frac{(53.9)(28 \text{ gal deg})}{2} = 755 \text{ gpm brine}$$

With a 2 F deg temperature difference between leaving air and leaving brine in washer the leaving brine temperature will be 32 - 2 = 30 F.

The temperature of the leaving brine will be 30 - 2 = 28 F.

The average brine temperature is $(30 + 28) \div 2 = 29 \text{ F}$. Select a refrigerant temperature 8 to 10 F deg below average brine, say 29 - 9 = 20 F.

By using ammonia, the evaporator pressure corresponding to 29 F is 33.5 psig.

Select a washer for 500 fpm air velocity, with consequent 70,000 + 500 = 140 sq ft washer cross sectional area. The approximate washer dimensions will be 14 ft wide $\times$ 11.5 ft high (allowing 1 1/2 ft for the water pan) $\times$ 8 ft long. The brine spray per square foot will be $755 \div 140 = 5.4 \text{ gal}$. If there are two spray banks the brine per square foot per spray bank is 2.7.

Select a brine pump with capacity of 755 gpm at 65 ft brine head at 25 psig spray pressure with a 20 hp motor.

LEMON AND GRAPEFRUIT STORAGE

Air Conditioning Equipment

For lemon and grapefruit storages, an air conditioning system to perform the following functions is required:

1. Heat or cool to maintain a constant temperature
2. Humidify to maintain a high relative humidity
3. Ventilate with outdoor air to maintain low CO₂ concentration
4. Distribute the air uniformly
5. Wash or filter the air

The type of air conditioning system commonly used consists of a fan, an air washer, and ductwork for air distribution. The conventional system uses large quantities of air, about 1 cfm per storage box or 650 cfm per carload. This results in a low temperature rise in the supply air which makes it possible to maintain the high humidities required. A variation of this method is termed in this article the *combination* system. It employs much smaller air quantities (about 1 cfm per sq ft of floor area or 300 cfm per carload) but requires the addition of auxiliary humidifying nozzles in the room to maintain high humidity. The conventional system using large air volumes seems to give better results as high air circulation tends to give uniform temperatures and humidities throughout the storage room. The air circulation must reach all parts of the room to avoid dead spots and pockets of carbon dioxide.

Normally fans of the high-speed, backward-curved-blade, centrifugal type are used as quietness of operation is not important. This type of fan is nonoverloading. Depending upon the arrangement and application, fans may be either single-width single-inlet or double-width double-inlet. Total system air resistance usually is between 1 and 2 in. water gage depending upon the type of equipment and length of duct system.

The air washer consists of a spray chamber about eight feet long having two banks of spray nozzles opposing each other and with moisture eliminators on the outlet end. The air velocity across the face area of the washer should be between 400 and 600 fpm.

At 25 to 30 psig spray pressure, a high degree of air cleaning is accomplished and the air will leave the washer very close to saturation at the water temperature. The outdoor air connection should be sized for the full washer capacity so that evaporative cooling with outdoor air can be utilized during cool nights or when the outdoor wet-bulb temperature is low. Since a saturating type washer is used, saturated or dew point air is circulated in the duct system. However, the supply air must be below the room temperature to absorb the heat load. This heat pickup in the storage space lowers the relative humidity. To maintain 84 to 88 percent rh, the supply air temperature rise must be small, thus necessitating large air volumes, unless auxiliary humidification is used.

The spray water is cooled by refrigeration. Ammonia, Refrigerants 11 or 12 are commonly used. If ammonia is used, the equipment should be sealed in a room or building separate from the storage rooms as ammonia fumes are injurious to the

Citrus Fruit Storage

fruit. With ammonia and Refrigerant 11, indirect refrigeration systems are used. Water is cooled in a shell and tube cooler (or other type of evaporator) and is then circulated through the washer sprays. An indirect system may be used with Refrigerant 12, but generally direct expansion coils are placed directly in the air washer between the two banks of sprays. Since Refrigerant 12 leaks are not injurious to the fruit, a direct expansion design can be used at a considerable saving, in most cases compared with an indirect Refrigerant 11 or ammonia job.

For a carbon dioxide concentration of 0.1 percent, about 72 cfm of outdoor air per carload must be provided for lemons stored at 58 F or grapefruit stored at 60 F. The difference between the total supply air quantity (i.e., 650 cfm per carload for conventional or 300 cfm for combination system) and the minimum outdoor air quantity will be the recirculated or return air quantity.

For temperature control both winter and summer, preheating and reheating coils should be provided as well as refrigeration. Heating coils may be steam, hot water, or electric depending upon sources of heat available and energy costs. The refrigeration should be controlled by a dew point thermostat in the air washer discharge. On an indirect system it would control a three-way mixing valve on the suction of the air washer spray pump. If a room thermostat is used, it would control the air washer bypass dampers and also the reheat coil.

A thermostat in contact with the mixed recirculated and outdoor air would control the preheat coil, and either an outdoor dry-bulb economizer thermostat or an outdoor wet-bulb thermostat would control the outdoor and return air mixing dampers. Other control combinations may be used, but constant dew-point control to maintain the required relative humidity is the most important control function with a conventional system. With a combination system, the humidity may be easily and positively controlled by means of a room humidistat acting upon a solenoid valve in the air line feeding the stomizing water spray nozzles. Capacities of humidifying nozzles are given in Table 6.

Air Distribution

Air distribution ducts may be made of galvanized sheet metal or aluminum but, unless insulated, they will sweat because of the high humidities in the storage rooms. Therefore, it has proved economical to build the ducts of one inch thick insulating board with a protective coating on both sides. The high humidity apparently does not cause deterioration of the insulating board if properly coated, and the ducts dry out during the off season when the storage is empty.

The duct systems are sized in the usual manner for a constant pressure drop per 100 ft of length with the total pressure drop based on the longest run. The starting supply duct velocity at the fan should be not more than 1700 fpm for sheet metal ducts or 1500 fpm for wood or cane fiber ducts. High-velocity type distributing outlets or nozzles, which induce a high secondary air movement (about one and one half to two times the primary air), are often used. These ejector nozzles are generally conical in shape with an angle of convergence of 12 to 14 degrees (Fig. 11). The nozzle length should be about three times the outlet diameter, giving a coefficient of discharge of 0.94. The conical nozzles are usually made of sheet

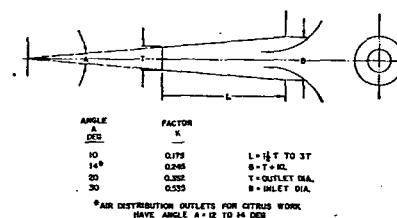


Table 6 Capacities of Humidifying Nozzles

Manufacturer	Type	Size	Pressure, lb per Sq In.			Moisture Capacity, lb per Hr	Free Air Required, Cfm
			Air	Steam	Water		
Binks	Water Syphon	164	30	0	0	4.5	1.00
			40	0	0	4.9	1.25
			60	0	0	5.7	1.75
Binks	Water Pressure	174	40	30	30	17.0	1.00
			40	30	30	23.0	1.25
			60	30	30	37.0	1.75
Parks Cramer	Water Syphon	N4	30	0	0	4.0	1.0
		N6	30	0	0	6.0	1.3
		N8	30	0	0	8.0	1.5
		N10	30	0	0	10.0	1.7
		N12	30	0	0	12.0	2.0
		N15	30	0	0	15.0	2.5
Armstrong	Steam (1/8 in. orifice)	K-2		2		9.0	
				5		15.0	
				10		25.0	
				15		35.0	
				2		18.0	
				5		33.0	
	(1/4 in. orifice)	K-2		2		240.0	
				5		510.0	
				10		960.0	
				15		1410.0	
				2			
				5			
	(1 1/4 in. orifice)	K-4		2			
				5			
				10			
				15			
				2			
				5			