

Table 2 Load Calculations, Beef Holding

Heat Gain—Room Load	Loads, Btuh		
	Sensible Heat	Latent Heat	Total Heat
1. Transmission, infiltration, personnel, and equipment heat	128,500	3,000	131,500
2. Product heat (average, first 24 hr): a. $520 \times 560 = 0.75 \times 10 \times 0.03$ b. $520 \times 3.5 \times 0.03 \times 1070$	65,000 -59,000	59,000	65,000
3. Total heat gain (room load), Btuh (Items 1 + 2a + 2b)	134,500	62,000	196,500
Heat Removal—Coil Load	Loads, Btuh		
	Sensible Heat	Latent Heat	Total Heat
4. Air circulation, lb/hr dry air $40,000 \times 0.08 \times 60 = 192,000$	—	—	—
5. Heat removed per lb dry air, Btu (Total heat Item 3)/(Item 4) = 1.023	—	—	—
6. Air-vapor enthalpy, Btu/lb dry air: a. Air to coil, 34 F 96% rh b. Btu removed, temp drop 2.9 F deg	8.167 -700	4.227 -323	12.394 1.027
c. Air from coil, 31.1 F 100% rh	7.467	3.904	11.371
7. Coil air-vapor heat removal, Btuh (Item 4) (Item 6b)	134,500	62,000	196,500
8. Room vapor condensed to fog (Item 7) - (Item 3)	—	8,000	8,000
9. Water (ice) removed by coil $520 \times 3.5 \times 0.03 \times 144$	—	—	—
10. Total heat removal (coil load), Btuh (Items 3 + 8 + 9)	134,500	70,000	204,500

average rate for the first 24 hours (3 percent) should be used for design.

Under peak chilling and holding room conditions, water trapped and condensed out by the coils imposes a further hidden or latent load on the evaporators. This occurs in the form of heat extracted to freeze condensed water to ice, or of heat removed to chill the returning warmed and strengthened spray solution. In the absence of a more complex evaluation, this load may be considered roughly equal to the latent heat of fusion (144 Btu/lb) of the water removed.

Based on the above data, cooler loads may be calculated as illustrated in Tables 1 and 2. Transmission, infiltration, personnel, and equipment loads are estimated by standard methods. Note that sensible losses are less in the holding room than in the chilling room because of the lesser fan horsepower required.

The complete calculation is made to illustrate the heat removal process associated with the chilling-drying of the carcasses; and in particular to illustrate that the sensible heat ratio of the heat transfer taking place in the coil cannot be used to measure the amount of water removed from the space when fog is involved. In practice, the designer soon learns to make selection on the basis of total heat load alone without performing the complete calculation, but he should understand the role of fog in heat transfer under conditions of high vapor load.

Evaporator Selection

Evaporator selection requires the specification of coil capacity, refrigerant temperature, and air-vapor circulation rate. This is a procedure of approximation only, because of the inaccuracies of load determination on the one hand and of predicting sustained field performance of coils on the other. Furthermore, complete freedom of specification rarely exists; for example, air-vapor circulation rate for a given coil may be limited to avoid spray solution carry-over, or to avoid excessive fan horsepower.

Sprayed and dry coil systems can do equally well with respect to shrink, provided compressor capacity is adequate and the evaporators are correct for the system selected. Evaporator requirements vary widely with the type of system. Table 3 gives comparative evaporator data on typical successful flooded-coil installations in the chilling cooler.

The chilling capacity has been expressed as the product of the coil U-value, the total coil surface area, and temperature difference between refrigerant and room air.

The coil U-value (overall heat transfer coefficient) and air flows shown describe sustained field performance under actual chilling conditions and loads, and are not to be confused with clean-coil test ratings. The U-value varies greatly with the character of the coil and its operation. It is influenced by such variables as the ratio of extended-to-prime surface, which may, for example, range from 7-to-1 to 21-to-1 in standard dry coils; coil depth, which ranges typically from 8 to 12 rows in sprayed coils and from 4 to 6 rows in dry coils; fin spacing, which may be 3 or 4 per inch in typical dry coils; condition of the surface, which may be continuously defrosted or coated generally with frost; and air flow, which may vary from 250 to 750 cfm per sq ft coil face area.

Greater temperature differences (TD) than those shown are sometimes used, but a higher TD is valid only at high room temperatures. The lower TD (10 F) shown for dry coils is desirable to limit frosting. Many dry coil evaporators have higher ratios of extended-to-prime surface and higher air flows per square foot face area than shown.

As stated previously, sprayed and dry coil systems, well designed, can do equally well with respect to shrink. The choice between them therefore lies in evaluation of evaporator cost and capacity, operating attention required, effect of brine corrosiveness on cost and maintenance of space and equipment, cost and rate of loss of the brine, and cost and complexity of brine-handling equipment on the one hand and defrosting equipment on the other.

The difficulties involved in obtaining accurate shrink figures

Table 3 Typical Evaporator Installations, Beef Chilling

Coil Description:	Design Load: 1,073,000 Btuh Coil Operation: Flooded Loading Time: 4 hr maximum		Average Carcass Weight: 560 lb Assumed Air to Coil: 33 F 100% rh Sensible Heat Ratio: 53%	
	Sprayed Coil		Dry Coil	
	Sodium Chloride	Propylene Glycol	Example A	Example B
Type of coil	Bare pipe	Finned	Finned	Finned
Fin spacing—fins/inch	—	6/inch	3/inch	4/inch
Coil depth—number of pipe rows	8-row	8-row	4-row	6-row
Ratio, extended to prime surface	16	14	8	15
Coil face area, sq ft	400	18	16	14
Coil surface area, sq ft total	—	2,400	1,100	1,650
Brine Flow (Surface Spray):				
Flow, gpm	32	40		
Flow, gpm/sq ft coil face area	2.0	2.5		
Pump horsepower	0.3	0.5		
Fan Description, Air Flow:				
Type of fan	Centrifugal	Centrifugal	Centrifugal	Propeller
Flow through coil, cfm	9,000	12,000	3,000	5,000
Flow, cfm/sq ft coil face area	550	750	200	350
Fan horsepower	3	5	1	1.5
Unit Rating* (Total Heat):				
U-value, Btuh/(sq ft) F deg	15	3.5	2.2	2.3
TD for capacity rating, F	15	15	10	10
Chilling capacity, Btuh	90,000	125,000	24,000	38,000
Temp. drop, air through coil, F	4.6	4.6	3.7	3.7
Equipment for 680 Carcasses:				
Number of units required	12	9	45	28
Total hp, fans and pumps	40	50	45	42
Coil surface per carcass, sq ft	10	40	95	90
Air flow per carcass, cfm	200	200	250	250

* TD is temperature difference between refrigerant and air.

† Ratings shown are estimated from performance of actual systems. Dry coil ratings are at average frost condition, with air flow reduced by frost obstruction. While these examples describe actual installations, they are not to be interpreted as accepted standards. Other installations employing both more and less equipment are in successful operation.

on carcasses chilled to a specified degree cause wide differences of opinion as to the coil capacity required for good chilling. While the data shown describe actual successful installations, other installations also considered to be successful may differ from them.

HOG CHILLING AND TEMPERING

The internal temperature of hog carcasses entering the chill coolers from the killing floor varies from 100 to 160 F. The specific heat is 0.50 to 0.57. The dressed weight varies from 90 to 450 lb approximately, the average being near 180 lb.

Present accepted practice requires that dressed hogs be chilled and tempered to an internal ham temperature of 37 to 39 F on an overnight basis. This limits the chilling and tempering time to 16 to 22 hr.

The cooler and refrigeration equipment must be designed so that the hogs are chilled thoroughly with no frozen parts at the time the carcasses are moved to the cutting floor. Carcass crowding, reducing exposure to circulated chilled air, and excessively high peak temperatures are detrimental to proper chilling.

The following design details of a hog chill cooler will provide:

1. Sufficiently quick chilling to retard bacterial development and prevent deterioration.
2. A cooler shrink from 1.2 to 1.5 percent. A lower shrink could be obtained with additional evaporator surface, however, the meager research and data available are not conclusive as to the benefits. A shrink below 1.2 percent could require that all

fresh cuts be rechilled before shipping to prevent off condition due to excessive moisture in the product. This extra handling could result in added cost that would offset the shrink savings.

3. Firm carcasses suitable for efficient cutting that are dry and bright without frozen surface or internal frost.

A description of the design of hog coolers is necessary for both new units as well as remodeled coolers since there exists at the present time many brine spray decks that should be equipped with modern refrigeration equipment. Most brine spray deck refrigerated coolers have rails that are unusable because of back-lash or carry-over of brine. The brine laden air results in excessive maintenance due to the corrosion and rusting of steel rails and beams.

Design of New Hog Coolers

The dressing rate of hogs and the planned hours of operation set the capacity of the hog coolers. However, on a one-shift basis it is economically sound and basically desirable to provide cooler hanging capacity for 10 hours dressing in order to (1) properly handle the chilling of large hogs that require more than 24-hour exposure in the chill room, (2) handle increased dressing volumes when market conditions warrant overtime operation, and (3) have some flexibility in the unloading and loading of the cooler during normal operations. On a two shift basis extra cooler capacity for overtime operation is not necessary.

The rail height should be 9 ft to provide adequate clearance between the floor and the largest dressed hog. This rail height is also the requirement of the M.I.D. and most