relief from coil to suction line, to permit a build-up of coil pressure and melting of the ice coating by transfer of heat out of the air flowing across the coils. Refrigeration therefore continues during the defrosting period, but at a drastically reduced rate. Room air defrost is slow; the time required may vary from 30 minutes to several hours if the coils are undersized for dry coil operation.

Unit coolers may be defrosted by any one or combinations of the three methods. All methods involve a reduction in chilling capacity varying with the time loss and the heat input. Hot gas and coil spray defrost interrupt the chilling only for short periods but introduce some heat into the space. Room air defrost severely reduces the chilling rate for long periods, but the heat required to vaporize the ice is obtained entirely from the room air. This method is generally considered impractical in air temperatures below 40 F, because of the long defrosting periods encountered. However, it is practicable in air temperatures as low as 35 F if the coils are large enough to avoid excessive icing.

*Evaporator controls* customarily employed in carcass chilling and holding rooms include (1) refrigerant feed controls, (2) evaporator pressure controls, and (3) air circulation control.

1. *Refrigerant feed controls* are designed to maintain under varying load as high a liquid level in the coil as can be carried without excessive liquid spill-over into the suction line. This is accomplished by the use of an *expansion valve* that throttles the liquid from supply pressure (typically 150 psig) to evaporating pressure (usually 20 psig or higher). The throttling of the liquid flashes some of it to gas, which chills the remaining liquid to saturation temperature at the lower pressure. The flashed gas, if it does not bypass the coil, tends to reduce flooding of the interior coil surface and thus lower coil efficiency.

The valve used may be a hand expansion valve controlled manually by operator judgment alone, a thermal expansion valve governed by the degree of superheat of the suction gas, or a float valve (or solenoid valve operated by a float switch) governed by the level of feed liquid in a surge drum placed in the coil suction line. This surge drum-suction trap permits the ammonia flashed to gas in the throttling process to flow directly to the suction line, bypassing the coil. It may be small and placed just high enough so that its level governs that in the coils by gravity transfer. Or, as in the ammonia recirculation system, it may be placed below coil level so that the liquid is pumped mechanically through the coils in much greater quantity than required for evaporation. In the latter case it is sized large enough to carry its normal operating level plus all the liquid flowing through the coils, thus effectively preventing liquid spill-over to the compressors. Nevertheless, it is necessary in all cases to provide further protection at the compressors against return of liquid.

Manual and thermal expansion valves do not provide good coil flooding under varying loads, and do not bypass the flashed feed gas around the coils, hence evaporators so controlled are usually rated 10 to 15 percent less in capacity than those controlled by float valve or ammonia recirculation.

2. *Evaporator pressure controls* provide a means of regulating coil temperature, and thereby the rate of refrigeration, by varying evaporating pressure within the coil. This is accomplished by the use of a throttling valve in the evaporator suction line downstream from the surge drum suction trap. All such valves impose a definite loss on the refrigeration system, and the amount of the loss varies directly with the pressure drop through the valve. This increases the work of compression for a given refrigeration effect.

The valve used to control evaporating pressure may be a manual suction valve set solely by operator judgment, a back pressure valve actuated by coil pressure or temperature, or a back pressure valve actuated by a temperature sensing element located at some point in the room. Manual suction valves require excessive attention when loads fluctuate. The coil-controlled back pressure valve seeks to hold a constant coil temperature, but this does not control room temperature unless the load is constant. Only the room-controlled *compensated* back pressure valve responds to room temperature.

3. *Air circulation control* is frequently used when an evaporator must handle separate load conditions that differ greatly in magnitude, such as the load in chilling rooms that are also used as holding rooms or the negligible load for week-ends. Control can be accomplished to a degree by the use of two-speed fan motors (operated at reduced speed during the periods of light load) or by turning the fans off and on.

## BEEF CARCASS CHILLING AND HOLDING COOLERS

### The Chilling and Holding Function

The function of the chilling and holding coolers is to chill the freshly slaughtered and dressed carcass halves or sides to storage temperature in minimum time, with controlled drying of the surfaces, and to provide storage under optimum conditions of temperature, humidity, and air motion. Excessive shrinkage, bone taint or sour rounds, surface slime or mold, discoloration, and freezing must be avoided. The carcass must be delivered with the bright, fresh appearance demanded by the trade.

Although the basic principles involved are identical, in certain aspects, beef and hog carcass chilling differ substantially. The massive beef carcass is only partially chilled (although shippable) at the end of the standard overnight period—whereas the average hog carcass may be fully chilled (but not ready for cutting) in 5 to 6 hr while the balance of the period accomplishes temperature equalization only. The beef carcass retains on its surface a large amount of wash and shroud water, which provides much evaporative cooling in addition to that derived from actual shrinkage; but evaporative cooling of the hog carcass, which retains very little wash water and is not shrouded, occurs only through actual shrinkage. Although it must subsequently be tempered well for cutting, the hog carcass, including the skin, and scheduled for in-plant processing, can tolerate a certain amount of surface freezing; but the beef carcass, without skin and destined largely for sale as fresh cuts, must be chilled in air temperatures sufficiently high to avoid freezing and damage to appearance. Nevertheless, as a result of the retained surface water, shrouded beef carcasses can be chilled with an actual overnight shrink of ¾ to 1 percent, whereas equally good practice on hog carcasses will result in 1¼ to 1¾ percent shrink.

The bulk of the beef chilling is done overnight (18 to 24 hr) in chilling rooms having large refrigeration and air circulation capacity. The balance of the chilling, and temperature equalization, occur during a subsequent holding or storage period that averages perhaps one day, but frequently extends to two or three, usually in a separate holding room having low refrigeration and air circulation capacity.

### Cooler Layout and Capacity

The carcass halves or sides are supported by hooks suspended from one-wheel trolleys running on overhead rails. These are generally pushed from the dressing floor to the chilling rooms by powered conveyor chains equipped with fingers that engage the trolleys, then distributed manually over the chilling and holding room rail system. Chilling and holding room rails are commonly placed on 3½ to 4 ft centers, with pull-out or sorting rails between in the holding rooms. The rails must be placed a minimum of two feet from the nearest obstructions such as a wall or building column, and the tops of the rails must be at least 11 ft above the floor. The supporting beams should be placed 2½ ft (or more if ceiling-suspended refrigeration units are to be used) below the ceiling, for optimum air distribution. Regulations applying to some of these dimensions, applicable to new construction in plants engaged in inter-state commerce, are issued by the the Meat Inspection Division of the USDA.

Carcass sides should be so placed on the rails in both chilling and holding coolers that they do not touch each other, to



assure effective air circulation. Required spacing varies with the size of the carcass, averaging 2½ feet per two sides of beef. In practice, however, sides are often crowded more closely together.

The chilling room should be of such size that the last carcass loaded into it does not materially retard the chilling of the first carcass. While size is not as critical as in the case of the hog carcass chill room, because of the slower chill, a capacity exceeding four hours' kill will result in unnecessary shrink. Holding coolers may be as large as desired, because of the more uniform temperature and humidity that can be maintained in them.

While overall plant chilling and holding room capacities vary widely, chilling coolers generally require a capacity equal to the daily kill, and holding coolers twice the daily kill.

### The Beef Carcass

The dressed beef carcasses, split into two sides, range in weight from approximately 300 to 1000 pounds, averaging about 550 pounds per head. Specific heats of carcass components range from 0.50 for fat to 0.80 or more for lean muscle, averaging about 0.75 Btu per (lb) (F deg) for the carcass as a whole.

The body temperature of the beef animal at slaughter is about 102 F. After slaughter, and continuing for 30 hours or more, changes occur that generate heat and tend to increase carcass temperature, while heat loss from the surface tends to lower it.

The most massive part of the carcass is the round, and at any given stage of the chilling cycle its center will show the highest temperature of all carcass parts. This *deep round* temperature (about 105 F when the carcass enters the chilling cooler) is therefore universally used as a measure of chilling progress. The temperature must be taken accurately if it is to be significant. Incorrect techniques in common use will show temperatures as much as 10 F deg lower than actual deep round temperature. An accurate technique that yields consistent results with ordinary care is shown in Fig. 1. This employs a fast-reacting easily-read 8-inch stem dial thermometer, calibrated before and after tests, inserted upward to the full 8-inch depth through the hole in the aitch bone.

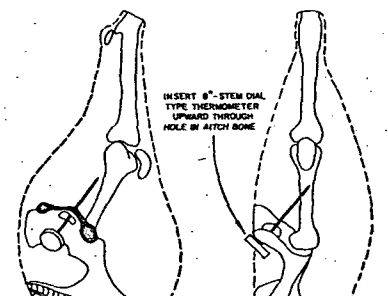



Fig. 1 .... Deep Round Temperature Measurement in Beef Carcass

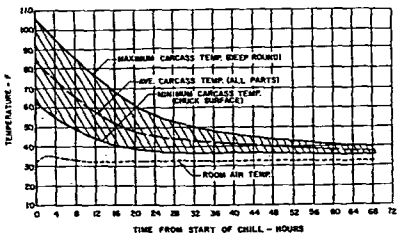



Fig. 2 .... Typical Beef Carcass Chilling-Holding Temperature Curves

At the time of slaughter, the water content of the beef muscle is approximately 300 percent of dry weight (75 percent of total weight). Thereafter a gradual drying of the surface takes place, resulting in weight loss or shrinkage. Shrinkage and its measurement are greatly affected by the final operations in the dressing process: weighing, washing, and shrouding. *Weighing must be done prior to washing and shrouding if the weights are to reflect actual product shrinkage.* The beef carcass retains on its surface and carries into the cooler a large amount of wash and shroud water, loss of which does not constitute actual product loss.

The amount of wash water retained by the carcass depends on its condition and on washing techniques. A typical amount retained per carcass is 8 lb, part of which is lost by drip and part by evaporation. Water pressures used in washing vary from 50 to 300 psig, and tempreatures from 60 to 100 F.

The shrouds which are cloths saturated in warm (120 to 130 F) weak (under 20 Salometer) brine and applied to outer surfaces of better grades of beef in an attempt to enhance appearance, remain in place throughout the chill period but are removed before the carcasses are transferred to the holding rooms. The cloths used weigh about 10 lb wet and 4 lb dry per carcass (two sides.) These lose about 6 lb of water per carcass in the chilling cooler, partially by drip but largely by evaporation.

To minimize spoilage, the carcass should be reduced to a uniform temperature of about 35 F as rapidly as possible. In practice, deep round temperatures of 60 F (accurately measured as in Fig. 1), with surface temperatures of 35 to 45 F, are common at the end of a 20-hour chill.

A certain dryness of the carcass surface is necessary during storage to prevent formation of surface slime. Exposed beef muscle chilled to an actual temperature of 36 F will not slime readily if dried at the surface to a water content of 90 percent of dry weight (47.4 percent of total weight). Such a surface is in vapor pressure equilibrium with a surrounding atmosphere at the same temperature (36 F) and 96 percent relative humidity. In practice, a room atmosphere at 32 to 34 F and 90–95 percent relative humidity will maintain a *well-chilled* carcass in non-eliming condition.[4]

### The Chilling-Drying Process

The chilling of the shrouded beef carcass occurs to some extent by sensible transfer of heat to the surrounding air, but primarily by evaporation of water from its surface. Curves of carcass temperature during a typical chilling-holding cycle are shown in Fig. 2. Note that some heat loss occurs before the carcass enters the chilling cooler.

Sensible transfer of heat from the warm carcass to the cool