Understanding how—and why—refrigeration defrost occurs brings to light its essential role in saving on product/installation costs, weight and refrigerant charge.

Refrigeration is used to assure proper storage temperature of food products. This is most often accomplished by using the vapor compression cycle. In this technique, refrigerant vapor is compressed by a compressor, condensed into a liquid in a condenser by the rejection of heat, expanded by a restrictive device, and fed into an evaporator where heat is absorbed and returned to the compressor to complete the cycle (see Figure 1).

Most commonly, the evaporator cools air that is then used to cool the product. Due to inefficiencies of the heat-transfer process, the temperature of the refrigerant in the evaporator is 5°F–16°F (3–9 Kelvin) colder than the air temperature.

Even products that must be stored above freezing temperatures will require evaporator-surface temperatures below the freezing point of water. Using fresh meat, which is often stored at 34°F–36°F (1°C–2°C), as an example, the evaporator surface will be between 24°F–31°F (–5°C––1°C). Because ice forms at 32°F, the evaporator surface will begin to build a coating of ice referred to as “frost,” which is seen in a number of different forms.

Figure 1 This image illustrates how the basic vapor compression cycle works.
The layer of frost closest to the surface of the evaporator will tend to be a hard form of ice, similar to ice cubes. Depending on humidity, evaporator temperature and air flow, subsequent layers of frost may be more crystalline or snow-like. This is referred to as “hoar frost.” In some instances frost will not begin to form until the coil surface reaches temperatures near 26°F (-5°C), but the need for some defrost is almost universal.

Many low-temperature evaporator coils have widely spaced fins to provide space for frost to build before it seriously impedes air flow. Typical spacing for low-temperature evaporators is 4 fins per inch, but not exceeding 6 fins per inch. Medium- or high-temperature evaporators will have 6 to 8 or more fins per inch; while air-conditioning coils may have 12 or more fins per inch. Since heat-transfer capacity is directly related to the surface area of the evaporator, fewer fins per inch will require a physically larger evaporator for a given capacity. Conversely, if frost on the evaporator can be limited to small amounts, it is possible that a smaller and more economical evaporator could be used.

Although ice has a thermal conductivity approximately four times that of water (which means it conducts heat four times as well as water), as air becomes entrained in the flaky hoar frost, the frost becomes an insulator and will reduce the evaporator’s ability to absorb heat. This insulating effect, along with the restriction of air flow across the frosted evaporator, means that at some point the coil must be defrosted.

ASHRAE studies (1998 R42.3—Okarsson, Krakow and Lin 1990: Evaporator Models for operation with dry, wet and frosted finned surfaces; Part II: Evaporator Models and verification; ASHRAE Transactions 96(1):381-392.) have shown that the heat-transfer ability of the evaporator actually increases when a thin layer of frost develops. This is likely due to the increase in surface area of the tube, and a slight increase in the velocity of the air due to the reduction in area of the air passages through the evaporator. See Figure 2.

Testing has shown that the optimum time to defrost is when the evaporator loses about 10% efficiency. Traditional methods of defrost, based on time, cannot ascertain this loss of efficiency and will either waste time and energy in excessive defrosting, or never fully defrost the evaporator.

Each 1 lb of frost or ice melted will contribute an additional 144 Btu of refrigeration. Not only is the evaporator kept at optimum heat-transfer ability, but free cooling and re-humidification is provided. Common methods of defrosting include off-cycle, electric and hot-gas.

**Off-cycle defrost**

Off-cycle defrost simply involves turning off the refrigeration system while letting the fans run continuously. Since the air...
In the cooling mode, liquid refrigerant moves from the evaporator to the compressor. Although easy to install and control, electric defrost can be expensive in terms of energy use.

The chief advantage of off-cycle defrost is the simplicity and economy of installation. However, the fans must run during both cooling and defrost mode. This can use more energy than needed for proper cooling.

Electric defrost

The second-most common method of defrosting is by electric heat. The evaporators must be designed and built for this type of defrost and incorporate passages through the evaporator fins, generally parallel to the refrigeration tubing. Long electric-resistance heaters are placed into provided passages and are energized to raise the temperature of the evaporator surface above freezing.

Although simple to install and control, electric defrost can be very expensive in terms of energy use. The heaters are energized for the duration of the defrost cycle and can use about 1 kW per foot of evaporator length.

Since standard timed defrosts are usually set for three per day and may last 45–60 minutes, the power consumption can be significant. In addition, the surface temperature of the heater itself can exceed 300°F, and any melted frost that comes into contact with the element will flash into steam and re-condense on cold surfaces in the refrigerated room. Often this will appear as layers of ice on the ceiling of the room, and it will not be removed during a routine defrost. Occasionally, an electric defrost will be extended to try to remove this buildup, keeping the heaters energized beyond the time needed for defrosting the evaporator. This can actually scorch the evaporator or other room components. Electric defrost must be closely controlled to make sure it is as effective and as efficient as possible.

Hot-gas defrost

The third common type of defrost is hot gas, some versions are known as cool gas. This is the most complex and expensive to install, but the quality and effectiveness of the defrost is better than the other defrost methods. In hot-gas defrost,
the liquid refrigerant flowing through the evaporator is interrupted, and instead, a supply of gas directly from the discharge of the compressor is used. This "gas" is really superheated compressed refrigerant vapor and can easily exceed 200°F.

Since this hot vapor is actually inside the tubes of the evaporator, it applies heat to the frost where it forms on the tube. The hot gas travels throughout the entire tubing circuit, and will therefore defrost areas of the evaporator that may not be as effectively reached by electric-resistance heaters. In many cases, the flow of the hot gas is in the reverse direction from that of the cooling mode. This is called reverse-cycle hot-gas defrost and is the primary method used in supermarkets (see Figures 3 and 4).

The cool-gas version is essentially the same, except that the gas used for defrosting is obtained from the receiver, rather than directly from the compressor discharge.

In either of these two types of defrosts, the fans should not only be off during the defrost cycle, but must be held off for some time after the defrost terminates. During a defrost, water is formed on the evaporator as the ice melts. Once the defrost terminates, the water must be allowed to drain from the coil. This "drip time" prevents moisture from being blown off the coil and refreezing on the cold product or other surfaces in the room. Some evaporators are equipped with a thermostat to delay starting the fans until the coil has dried or gotten cold enough to re-freeze the remaining moisture.

Evaporator temperatures below the freezing point of water are often needed to keep foods and other products safe to use and convenient to store. Ice or frost buildup on these evaporators is inevitable but methods to remove it are well proven and easy to implement. Newer technology allows even smarter methods to be applied—now and in the future.

As stated earlier, consistent limitation of the amount of frost on the evaporator has a direct saving in installation. Limiting the amount of frost formed and assuring complete defrosting permits the use of a coil with more fins per inch. This, in turn, may allow a physically smaller and less expensive evaporator to be used—saving product cost, installation cost, weight and refrigerant charge.

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