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Five Defrost Methods For Commercial Refrigeration

▶ BY JULIUS H. RAINWATER, MEMBER ASHRAE ▶ FEATURED IN ASHRAE JOURNAL, MARCH 1959

ommercial refrigerated display and storage cabinets normally use one of five defrost methods:

- · Condensing unit off permitting natural defrost;
- · Hot gas defrost;
- · Electric defrost;
- ·Water defrost; and
- ·Other external heat source defrost.

The refrigerators described here are used in modern supermarkets to display and store perishables such as fresh meats, fresh vegetables, dairy products, frozen foods and ice cream. The display cases are of the open top type utilizing either a gravity airflow or forced airflow evaporator. The usual installation of this refrigerator includes a multiplicity of fixtures connected to a single remote condensing unit. In other words, the most often seen application includes several evaporators connected to one condensing unit. There are many applications employing a single refrigerator for each condensing unit. This single case is either remotely connected to its unit or is self-contained with its own

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When this article was written, Rainwater was director of engineering of the Warren Company, a pioneer in commercial refrigeration. He retired in 1975 from its successor, Kysor Warren, as vice president, engineering, and cofounded another company that is a predecessor of Hill PHOENIX Refrigeration. Rainwater, now 83, retired in the 1990s and lives in Conyers, Ga. He is finishing a book on his family's experiences in war, starting with the American Revolution. He is a graduate of The Georgia Institute of Technology with a degree in electrical engineering. He had a number of patents in electronic controls. built-in unit. Storage refrigerators are of the walk-in or reach-in type. The former refrigerators have one or more evaporator coils of either the gravity airflow or forced airflow type.

The temperature to be maintained in the refrigerator is one of the most important factors to be considered in the design of a defrost system. Ice cream display cases must operate with a fixture temperature between -10°F and -20°F. The refrigerant evaporates at a temperature of approximately -40°F under these conditions. Frozen food display refrigerators maintain a fixture temperature of 0 to -10°F with an evaporator temperature of -30 to -35°F. Fresh red meat refrigerators operate with a 28 to 32°F fixture temperature and an evaporator temperature of approximately 8°F. Fresh vegetable and dairy display cabinets require a temperature of 36°F to 42°F and an evaporator temperature of approximately 12°F.

The walk-in cooler or freezer must maintain a product area temperature range approximately the same as in display cases; however, the evaporating temperatures for walk-in evaporators are usually about 10 degrees higher

than those for display cases due to a smaller temperature differential between the refrigerant and product area temperatures. In the design of an efficient defrost system another factor to be considered, which is closely related to the fixture temperature, is the means for disposing of the drainage. Where the drain is subjected to temperatures well below 32°F, some means must be provided to heat the drainage system.

Other factors of importance in the selection of the defrost method are the effect on the product during the defrost period, sizing of the condensing unit, simplicity of the system and economy of the system. Certain products spoil if exposed to temperatures above their normal storage range for a prolonged period of time. Ice cream and frozen foods will thaw to an unsafe point when exposed to above 0°F temperatures for longer than one hour. Red meats begin to change to a dark color when exposed to temperatures above 36°F for longer than an hour and a half. Since some discoloration takes place during each defrost period, it is advantageous to have as few defrost periods in a day as possible. Milk stored for 48 hrs at 50°F has a bacteria growth in excess of 150 times that for milk stored at 38°F for the same period of time, thus, frequent defrost periods of prolonged duration are damaging to milk and other dairy products. Vegetables requiring less refrigeration than other products can endure higher than 38 to 42°F temperatures for long periods.

During a defrost period heat is added to the air, product fixture walls, and evaporator metal; for this reason, the condensing unit must be sized to extract this heat as quickly as possible. Some defrost systems add more heat than others in melting the same quantity of frost. Numerous defrost periods per day require that the condensing unit extract this added heat load many times during the day. The most efficient defrost method is that which requires the least interruption of the equipment operation. In reality, the defrost periods limit the capacity of the equipment as shown by the equation

Capacity of Equipment = $\frac{Cd}{24 \cdot nt}$ Btu/hr. Where *Cd* is the daily cooling demand of the system: *n* is the number

demand of the system; n is the number of defrosts per day and t is the duration of each defrost in hours.

Simplicity of the system is important so that fewer installation and operating problems will arise. All factors must be carefully balanced to obtain an economically feasible system to give the desired results.

Condensing unit off permitting natural defrost is perhaps the most simple since little apparatus is involved. In this method, the condensing unit is simply permitted to remain off while the coil defrosts. Since there is no external heat added, other than that of the air surrounding the evaporator, this system is quite lengthy in the time required to melt the frost and as a result is limited to medium temperature (above 28°F) range fixtures.

Four ways to control this method are: manual; suction pressure control (on each off cycle); time clock initiate and terminate; and time clock initiate and suction pressure terminate. The manual control is simply opening the switch to the compressor motor when the evaporator is iced and waiting for the frost to melt before closing the switch. A defrost period of approximately three hours is required every other day.

The second means for controlling defrost is by adjusting the suction pressure control so that defrosting takes place on each off cycle. This method is limited to refrigerators which can normally operate in the 38 to 42°F range. It is frequently used in vegetable and dairy refrigerators where the air through the evaporator is circulated by fans. A typical evaporator pressure graph is illustrated in Fig. 1. "D" represents the refrigeration cycle while "A," "B," and "C" represent the off cycle. "A" is the period of time during which the ice, metal of evaporator and metal of walls surrounding evaporator are rising to a temperature of 32°F. "B" is the time representing the actual melting of the ice. "C," time in which the refrigerant is rising above 32°F, is a period of most importance in allowing the defrost water to drain clear of the fixture.

"Off Cycle" defrosting has the advantage of allowing some cooling effect during the defrost period since the circulated air is flowing around melting ice. Another advantage is that the coil, free of frost most of the time, can operate near its maximum designed capacity most of the time. Even should the heat load be such that no off time can be reached, the evaporator pressure will drop as the coil becomes iced and will eventually drop to the pressure control cut-out point and allow an off cycle defrost period.



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One disadvantage is that where remote condensing units are used, an ambient at the condensing unit lower than the evaporator temperature can cause the suction pressure to linger at a point below the pressure control cut-in point, keeping the compressor off for long periods of time during which the fixture temperature rises to an unsafe point. Many remote condensing units in the southern parts of the United States are installed outside and as a result during the winter months the ambient at the condensing unit is well below the evaporator temperature. The solution to this problem is to use a thermostat for controlling fixture temperature and a time clock for controlling the defrost.

A similar disadvantage sometimes encountered is where the refrigerant lines from the fixture to the remote condensing unit are installed in trenches or conduit with numerous other cold refrigerant suction lines, which prevent the suction pressure from rising to the required cut-in points. The use of a time clock is the solution in this instance also.

The third and fourth means for con-

trolling the defrost period both utilize time clocks. The time initiate and time terminate system merely requires that the time clock be wired to break the circuit to the condensing unit for a predetermined time. The duration of time is normally 45 min to 90 min for forced air evaporators as used in vegetable, dairy, and meat fixtures. A period of three hours or more is required for gravity airflow refrigerators.

The time initiate and suction pressure terminate means of control is similar to the straight time system except that the switching mechanism for controlling the power to the condensing unit is reenergized by the rise in suction pressure to a predetermined setting. This setting should be approximately 46 psi (gauge) for Refrigerant-12. The pressure terminate clock system has the definite advantage of allowing a complete defrost each period regardless of the quantity of frost existing on the coil and regardless of the time involved. Most pressure terminate systems have a safety time limit to terminate the defrost period by time should the pressure not rise to the pre-set point. This safety time limit is usually adjustable.

The pressure terminate clock has the disadvantage listed for the suction pressure "off cycle" defrosting where low temperature ambients are experienced at the condensing unit or suction lines.

The time clock means for control is most frequently used with meat and dairy refrigerators. A typical suction pressure vs. time graph for time clock defrosting is shown in Fig. 2. This graph is representative of a meat display system where from two to four defrost periods (A, B, C) are required per 24 hrs. Dairy and vegetable display refrigerators have similar evaporator pressure characteristics and require approximately the same number of defrost periods per day. Walk-in coolers for meats, vegetables and dairy products have defrost suction pressure characteristics similar to those shown in Fig. 2. Walk-in cooler evaporators usually require one or two defrost periods per day.

Hot Gas Defrosting has many varieties all of which utilize a compressed vapor in the evaporator coil. Some systems utilize the latent heat of condensation of this compressed vapor as a

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heat source whereas others use only the sensible heat obtained from the highly superheated compressed gas.

Hot gas defrosting offers several advantages over other methods. Heat is added directly to the evaporator coils without depending upon external sprays or air delivery of the heat. By applying the heat internally, a rapid defrost is obtainable. The ice sometimes becomes loose and falls off the coils before complete melting is required. To accomplish this rapid defrost, adequate drain heaters must be designed using the hot gas itself or electric heaters. Hot gas defrosting offers an inexpensive source of heat as compared to methods using other heat sources.

This method has several weaknesses that have more or less been overcome by manufacturers. The simple hot gas system merely allows the discharge gas from the compressor to bypass the condenser through a solenoid valve and then flow directly into the evaporator coil with no metering or controlling devices in between. This simple system depends upon the compressed vapor to be condensed in the evaporator. As the defrosting progresses, the hot gas condenses in the evaporator with some remaining in the evaporator as a liquid while some goes back to the compressor to be recirculated as a compressed vapor with the heat of compression added. As time progresses more liquid remains in the coil with less refrigerant being returned to the compressor. Since the heat source is obtained from the circulated refrigerant, the systems gradually tend to run out of heat.

Another weakness is that this system depends upon high ambient temperatures and high condenser pressures. When the condenser pressure is low the discharge gas from the compressor enters the condenser rather than the evaporator, causing an extremely low condensing pressure during the defrost which can correspond to a temperature near 32°F, resulting in little or no heat transfer from the refrigerant to the frost on the evaporator.

Danger of refrigerant liquid slug backs to the compressor is another disadvantage of this system. This liquid slug back is especially harmful just after a defrost period. With reference to supermarket refrigerators, hot gas defrosting presents a more complex system with added refrigerant lines and controls to be installed in the field and as a result this method of defrosting is used chiefly on walk-in freezer evaporators and on self-contained frozen food display cabinets. As many as six remote refrigerated display cases are sometimes connected to one compressor which prohibits an economical use of a hot gas system.

There are several walk-in freezer evaporators available today using variations of hot gas defrosting which have overcome most of the disadvantages as mentioned above. (Figs. 3, 4, 5 and 6.)

The system shown schematically in Fig. 3 uses a metering orifice where the hot gas enters into the evaporator coil as an adiabatic (isothermal) expansion takes place. This orifice is sized to create a pressure in the evaporator lower than the condensing temperature of the refrigerant; as a result, the highly superheated vapor does not condense but gives up sensible heat to the frosted evaporator coil. Since condensation does not take place, the problem of liquid refrigerant slug back is over-



come. The orifice also serves to hold the suction pressure below an excessive amount.

Controls for this system include a time clock which accomplishes three periods of time during each complete defrost period. The first interval (usually two to three min) starts the compressor and stops the evaporator fans to assure an adequate supply of hot gas. During the second period, the clock opens the hot gas line solenoid valve and energizes the electric drain pan heater. This period is usually five to 10 min and occurs approximately four times per day. The last period is a delay period during which the hot gas solenoid valve opens and evaporator fans remain stopped to allow water to drip from the coil surface and to allow the evaporator to reach a lower temperature before resuming air circulation. This period requires a setting of three min.

Fig. 4 shows a hot gas system using a vapor pot. This system uses an accumulator in the suction line to trap the liquid refrigerant and, by means of a bleed tube, allows small amounts of liquid refrigerant to flow back to the compressor along with the suction gas. The bleed tube is sized to overcome the liquid refrigerant slug-back disadvantage but allows enough to pass to pick up the latent heat of vaporization in compression. This latent heat of vaporization is the source of heat utilized to melt the evaporator frost.

The accumulator or vapor pot has a built-in heat exchanger which is incidental and, although helpful during the refrigeration cycle, offers no help to the defrost process. It is controlled by a time clock which must have a switching mechanism designed to open the hot gas solenoid valve, stop the evaporator fans and start the compressor (Fig. 3). Defrost period is terminated either by the timer or, as is done sometimes, by a thermostat which measures the temperature of the evaporator and at a pre-set point energizes a solenoid coil in the time clock which mechanically reverses the switching mechanism to the refrigeration cycle.

The heat bank method of utilizing hot gas as a defrosting means schematically depicted in Fig. 5 actually uses a re-evaporator coil immersed in an insulated tank of water (heat bank). The re-evaporator overcomes the refrigerant liquid slug back problem. The unusual feature of the heat bank principle is that a heating coil from the discharge line of the compressor also immersed in the tank of water builds up heat and stores it during the refrigeration cycle.

This heating coil also serves to prevent flood back during the refrigeration cycle by warming the suction gases in the re-evaporator. The heating coil is provided with a bypass which allows the discharge gas to go directly to the condenser during the refrigeration cycle as the temperature rises in the heat bank. During the defrost period the hot gas flows to the solenoid valve, through the frosted evaporator coil, and then through the heat bank reevaporator where heat is picked up from the hot water. The heat bank is designed with a holdback valve which maintains a low suction pressure in the re-evaporator and is set low enough to actually freeze the water. This allows the gas to not only pick up sensible heat but to pick up the latent heat of fusion given up by the freezing water. This method provides a continuous heat source not dependent upon the



ambient air temperatures or condensing pressures. It also serves to hold the suction pressure below an excessive amount.

The electrical controls for the heat bank system are similar to the other systems discussed in that a timer must assure that the compressor is running, stop the evaporator fans, and open the hot gas solenoid valve. Normal defrosting with this system requires 3 periods of 10 min each which includes a 3 min drainage period.

The system shown in Fig. 6 employs an unusual re-evaporator since it is an inner tube within the evaporator coiling. During defrost the hot gas solenoid valve opens to allow the compressed vapor to flow through this inner tube, which acts as a condenser. The heat of condensation originally derived from the heat of compression is the source of heat used to melt the frost. The liquid and vapor then flow through the check valve and constant pressure valve which acts as an automatic expansion valve to maintain a refrigerant temperature above 32°F and yet introduce enough pressure drop to cause any condensed liquid to gasify before leaving the coil. The refrigerant flowing from the constant pressure valve passes into the evaporator which serves as a re-evaporator. The actual heat used for defrosting the coil is the heat of compression of the compressor. This system is controlled with a time clock as are the other systems.

Still another system is a reverse cycle defrost method whereby a four-way solenoid valve actually reverses the flow of refrigerant during defrost to let the condenser serve as an evaporator while the evaporator acts as a condenser using the melting ice as a cooling means.

Summarizing the hot gas systems with their specific application to supermarket refrigerators, it has been established that while this method of defrosting is a good one for use on walk-in evaporators, it is too costly for use on remote display cases. The systems depicted in Figs. 3, 4 and 6 are the simplest types and overcome some of the disadvantages mentioned for the basic hot gas system. The system shown in Fig. 5 while overcoming more of the disadvantages is more complex in structure as well as in installation.

Electric Defrost, like the hot gas system, is especially applicable to low temperature refrigerators although it is frequently used in meat and dairy refrigerators to give a rapid defrost period. Electric defrost systems in most instances have heat applied externally as compared with hot gas systems where the heat is applied internally. Because of this factor and because of the limitations on the amount of electrical heat that can be applied safely, the electric defrost requires a longer interval, usually one and one-half or more times that of hot gas defrost systems. However, systems have been developed which apply electric heat from within, similar to the hot gas system shown in Fig. 6, to give rapid defrost.

In any defrost system the quantity of heat required can be stated as

 $Q_d = H_F + H_A + H_S$, where

 $Q_{d^{b}}$ is the total quantity of heat required; H_{F} is the heat necessary to

melt the frost; H_A is the heat lost to the air; and H_S is the heat necessary to warm the coil surfaces and walls to at least 34°F.

Considering first H_F , the heat necessary to melt the frost is in direct proportion to the weight of frost and its temperature at the time defrost is instigated. A given volume of frost does not always contain the same weight in water. A comparatively light frost load at 20°F to 25°F would be considerably heavier than the same volume of frost at -20°F or -30°F. For an ice cream display fixture with frost at -40°F at the time defrost is instigated, H_F can be calculated to be 198 Btu required to melt one pound of frost and raise its temperature to 50°F as it drips from the drain. It is good practice to allow as a rule of thumb 200 Btu/lb of frost to be melted for all evaporators, both low and high temperature, as this allows a factor of safety and is an aid in the ever-important post defrost drainage period. The exact weight of frost is a variable depending upon the conditions at which the evaporator is operating.

Approximate weights of frost for any given refrigerator operating under normal conditions can be obtained experimentally in the laboratory. Under normal operating conditions it has been determined experimentally that a typical 12 ft frozen food open top display cabinet employing a finned evaporator coil with forced air circulation will collect from one to two pounds of frost per day. A similar display case for fresh meats would collect from three to five pounds of frost per day whereas a similar forced air type dairy refrigerator would collect from five to

seven pounds of frost. Under abnormal conditions, where the circulated air is constantly disturbed by store drafts and external air, these weights can increase as much as 100%.

The heat lost to the air, H_A , is a variable depending upon the length of time necessary to accomplish defrost and the difference in the temperature of the air blowing over the melting ice and the cold wall and product surfaces that it can see. Air having a specific heat of .0192 Btu/cu ft/°F will pick up 19.2 Btu/min for 1000 cfm circulated per degree rise in temperature. As the air rises to a temperature above that of the product and walls, it will lose the same 19.2 Btu/min for each 1000 cfm for each degree it drops in temperature as it flows over the colder product. Thus, the air returning to the evaporator during defrost can reach a point where it is colder than the air leaving the evaporator. The heat lost to the air depends upon so many variables that it is difficult to calculate its exact value. However, the values of H_{F} , and H_{s} can be calculated and then arriving at a total defrost Q_d experimentally in the laboratory, the value for H_A can be isolated. For a 12 ft open self-service frozen food fixture which depends on the fans running during defrost to transfer the defrost heat to the coil surfaces, a value for H_A would be approximately 4250 Btu for a 25 min defrost period. The shorter the defrost, the less heat is lost to the air. A good design for an electric defrost system is one where the air is stopped from flowing through the evaporator by means of automatic vanes or hoods to trap the hot air.

Where the air is not flowing, other

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means must be provided for transferring the electric heat to the frost. This can be accomplished by inserting the heaters in the evaporator coil. However, this complicates manufacturing and field servicing problems and, as a result, in long length evaporators, it is usually best to utilize the flowing air as a heat transfer agent. Tests demonstrate that since the flowing air provides a good heat exchanger vehicle, the duration of defrost is about the same as other direct contact methods, except for systems where the heating elements are physically in the refrigerant of the evaporator.

The heat, $H_{\rm S}$, absorbed by the coil and wall surfaces is in direct proportion to the weight of these surfaces and the total number of degrees that the metal must warm up. Using the specific heat for aluminum, and steel and selecting a 12 ft frozen food self-service fixture which has a copper tube aluminum finned coil surrounded with steel plates all of known weights, the value of H_S for a rise in temperature from -40°F to 40°F is approximately 1800 Btu. The period of time required to warm up the coil and wall surfaces is usually the determining factor in the total time of defrost.

Using the same 12 ft self-service frozen food case as an example, if during a defrost period 1 lb of frost is melted the value for Q_d would be 200 Btu plus 4250 Btu plus 1800 Btu = 6250 Btu or 4400 watt for a 25 min defrost period. In a system of this type the heat actually required to remove the frost is the smallest value. It has been proven in the laboratory and field that during any defrost period, regardless of the weight of frost, the actual time required to complete a defrost period does not vary more than a few minutes with the electric heat input being constant at 250 Btu/min for the above example freezer. However, if the coil becomes completely iced so that air flow is stopped, a long time (40 to 50 min) is required before normal heat transfer can take place in order to proceed into the normal defrost time.

Most walk-in freezer evaporators are of such a compact design that good heat transfer from electric heaters to the frost can be accomplished without the fans running and as a result a more rapid defrost period is obtainable. Since the factor H_A is in direct proportion to the time involved, a more rapid defrost period will greatly reduce this factor and the shorter defrost period can be obtained with less electric heat for a given evaporator.

For medium temperature meat and dairy refrigerators, even though the coils collect more frost, a shorter defrost period is obtainable due to the higher temperature of the metal surfaces at the time defrost is instigated. A period of 15 min two to three times per day is normally required for self-service refrigerators. Since the time period is shorter, the value H_A is greatly decreased and less wattage is required even though more frost is to be melted.

Fig. 7 represents a cross section of a typical modern self-service frozen food case with location of fan, evaporator, drain, electric heater, and air path indicated. Fig. 8 is a temperature vs. time graph of a defrost period for a 12 ft freezer of the type represented in Fig. 7. The thermocouples measured





the temperature of the outer surface of one of the evaporator tubes and the water temperature in the drain cup. The drain cup is the last point the water reaches before flowing into the exterior drain pipes.

Controls for any electric defrost system consist of a time clock which must energize the electric heaters, stop the compressor motor, and stop the evaporator fan if required. The termination may be one of three ways: (1) timer terminate; (2) pressure terminate by the rise in suction gas pressure; and (3) temperature terminate by a rise in the evaporator surface temperature or air temperature. The advantages and disadvantages described for controls in the unit-off, natural-defrost method apply to electric defrosting. Water Defrost employs a spray of water utilizing the sensible heat of the water as a heat source. The drains are usually electrically heated for this system. The water is circulated by a pump controlled by a time clock. The timer stops the compressor during defrost and energizes the electric drain heater. Water has an excellent thermal capacity available for defrost-

SUMMARY

Commercial refrigerators used in modern food markets utilize numerous defrost systems with many variations of controlling the time of defrost. In the design or selection of a method, it is well to consider the following factors:

- Type of refrigerator installation giving special consideration to long lengths of multiple cases, walk-in storage refrigerators, and self-contained refrigerators.
- Temperature maintained in the refrigerator with due consideration given to the temperature of the drain areas.
- Durability of the perishable products displayed or stored when subjected to temperatures above their critical points.
- Complexity of system with respect to installation and cost. Improved efficiency of the complete refrigeration system with fewer and shorter defrosts.
- Available heat sources and method of transferring to frost.

- Actual heat required to melt frost is relatively small when compared with heat lost to air and heat necessary to warm the coil and wall surfaces above 34°F. Heat lost to air is in direct proportion to duration of defrost time and becomes a large factor in long defrost periods where air is utilized to transfer heat to the frost.
- Time required to warm coil and wall surfaces is determining factor in total defrost period.
- Time required to warm coil and wall surfaces being a constant for a given system and being the determining factor in total time of defrost means that regardless of amount of frost, the total time of defrost is fairly constant for a given system unless the coil is iced to a solid point permitting little or no air circulation.
- Application of time controls to use pressure or temperature terminating means is a solution to varying icing conditions.



ing. A one ton evaporator normally requires seven gpm for a period not longer than five minutes. In analyzing the thermal capacity of water, it is of interest that if seven gpm of water flows for five minutes and has a temperature change of only 10 degrees in passing over the frost and

Advertisement formerly in this space.

melting it, 10 kW of electricity would be required to do the same work assuming that there was no difference in the loss to air. Obviously, introducing 10 kW to a one ton coil would tend to damage the coil; consequently, it is necessary to introduce electric heat at a lower rate for a longer time.

Water defrost systems are most applicable to large evaporators for walk-in freezers and coolers.

Other External Heat Source Defrost.

Additional heat sources are possible by using a fluid such as glycol as a heat transfer vehicle. This secondary fluid is pre-heated by electricity, steam, or other methods to add sufficient quantities of heat to obtain rapid defrosting. Where the heat is applied by circulating the secondary fluid in an inner tube of the evaporator coiling, a rapid defrost is accomplished with a minimum of heat lost to the surrounding air.

This method is most applicable to large low temperature evaporators as used in frozen food walk-ins.

Defrost controls for a system of this type must include a time clock which will stop the compressor, start the fluid (glycol) circulating pump, turn on the heat applied to the fluid, and then terminate defrost similar to other methods discussed for other systems.

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