CHAPTER 42

FORCED-CIRCULATION AIR COOLERS

FORCED-CIRCULATION unit coolers and product coolers are designed to operate continuously within refrigerated enclosures; a cooling coil and motor-driven fan are the basic components of these coolers. These components provide cooling or freezing temperatures and proper airflow to the room. Coil defrost equipment is added for low-temperature operations when coil frosting might impede performance.

Any unit, such as a blower coil, unit cooler, product cooler, cold diffuser unit, or air-conditioning air handler is considered a forced-air cooler when operated under refrigeration conditions. Many design and construction choices are available, including (1) various coil types and fin spacing; (2) electric, gas, air, water, or hot brine defrosting; (3) discharge air velocity and direction; (4) centrifugal or propeller fans, either belt- or direct-driven; (5) ducted or nonducted; and/or (6) freestanding or ceiling-suspended, or penthouse (roof-mounted).

The fans in these units direct air over a refrigerated coil contained in an enclosure. For nearly all applications of these units, the coil lowers the airflow temperature below its dew point, which causes condensate or frost to form on the coil surface. However, the normal refrigeration load is a sensible heat load; therefore the coil surface is considered dry. Rapid and frequent defrosting on a timed cycle can maintain this dry-surface condition, or the coil and airflow can be designed to reduce frost accumulation and its effect on refrigeration capacity.

TYPES OF FORCED-CIRCULATION AIR COOLERS

Sloped-front unit coolers, often called reach-in unit coolers, range from 5 to 10 in. high (Figure 1). Their distinctive sloped fronts are designed for horizontal top mounting as a single unit, or for installation as a group of parallel connected units. Direct-drive fans are sloped to fit within the restricted return air stream, which rises past the access doors and across the ceiling of the enclosure. Airflows are usually less than 150 cfm per fan. Commonly, these units are installed in back-bar and under-the-counter fixtures, as well as in vertical, self-serve, glass door reach-in enclosures.

Low-air-velocity units feature a long, narrow profile (Figure 2). They have a dual-coil arrangement, and usually two or more fans. These units are used in above-freezing-temperature meat-cutting rooms and in carcass and floral walk-in enclosures, as well as 28°F meat carcass holding rooms. These units are designed to maintain as high a humidity as possible in the enclosure. The unit's airflow velocity is low and fins on the coil are amply spaced, which reduces the coil's wetted surface area and thus the amount of dew-point contact area for the air stream. Discharge air velocities at the coil face range from 85 to 200 fpm.

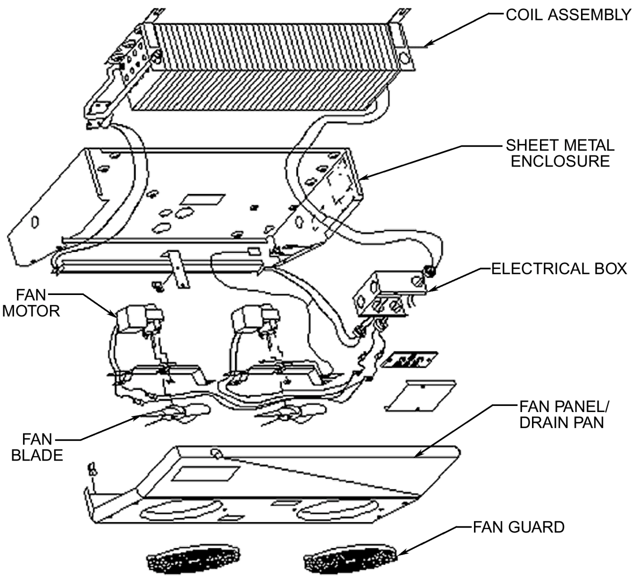

Fig. 1 Sloped-Front Unit Cooler for Reach-In Cabinets

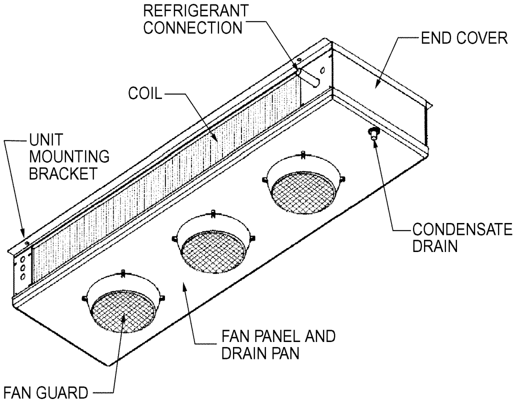

Fig. 2 Low-Air-Velocity Unit

Medium-air-velocity unit coolers originally had a half-round appearance, although the more common version (often called **low-profile units**) features a long, narrow, dual-coil unit design (Figure 3). Both types of units are equipped with higher-volume fans. They are used in vegetable preparation rooms, walk-in rooms for wrapped fresh meat, and dairy coolers. These units normally extract more

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The preparation of this chapter is assigned to TC 8.4, Air-to-Refrigerant Heat-Transfer Equipment.

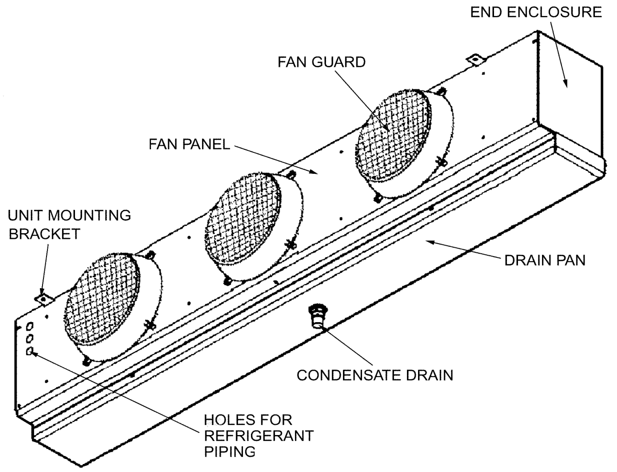

Fig. 3 Low-Profile Cooler

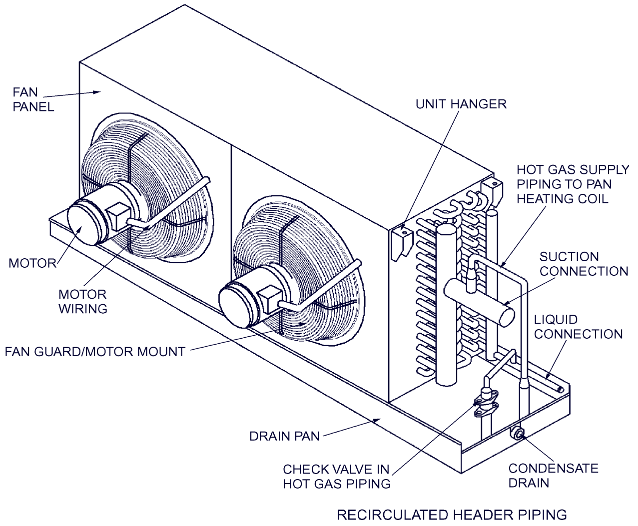

Fig. 4 Liquid Overfeed Type Unit Cooler

moisture from the ambient air than low-velocity units do. Discharge air velocities at the coil face range from 200 to 400 fpm.

Low-silhouette units are 12 to 15 in. high. Medium- or mid-height units are 18 to 30 in. high. Those over 30 in. high are classified as high-silhouette unit coolers, which are used in warehouse-sized coolers and freezers. The air velocity at the coil face can be upwards of 600 fpm. Outlet air velocities range from 1000 to 2000 fpm when the unit is equipped with cone-shaped fan discharge venturis for extended air throw.

Spray coils feature a saturated coil surface that can cool the processed air closer to the coil surface temperature than can a regular (nonsprayed) coil. In addition, the spray continuously defrosts the low-temperature coil. Unlike unit coolers, spray coolers are usually floor-mounted and discharge air vertically. The unit sections include a drain pan/sump, coil with spray section, moisture eliminators, and fan with drive. The eliminators prevent airborne spray droplets from discharging into the refrigerated area. Typically, belt-driven centrifugal fans draw air through the coil at 600 fpm or less.

Water can be used as the spray medium for coil surfaces with temperatures above freezing. For coil surfaces with temperatures below freezing, a suitable chemical must be added to the water to lower the freezing point to 12°F, or lower than the coil surface temperature. Some suitable recirculating solutions include the following:

- **Sodium chloride** solution is limited to a room temperature of 10°F or higher. Its minimum freezing point is –6°F.
- **Calcium chloride** solution can be used for enclosure temperatures down to about –10°F, but its use may be prohibited in enclosures containing food products.
- **Aqueous glycol** solutions are commonly used in water and/or sprayed coil coolers operating below freezing. Food-grade propylene glycol solutions are commonly used because of their low oral toxicity, but they generally become too viscous to pump at temperatures below –13°F. Ethylene glycol solutions may be pumped at temperatures as low as –40°F. Because of its toxicity, sprayed ethylene glycol in other than sealed tunnels or freezers (no human access allowed during process) is usually prohibited by most jurisdictions. When a glycol mix is sprayed in food storage rooms, any carryover of the spray must be maintained within the limits prescribed by all applicable regulations.

All brines are hygroscopic; that is, they absorb condensate and become progressively weaker. This dilution can be corrected by continually adding salt to the solution to maintain a sufficient below-freezing temperature. Salt is extremely corrosive, and must be contained in the sprayed coil unit with suitable corrosive-resistant materials or coatings, which must be periodically inspected and maintained. All untreated brines are corrosive: neutralizing the spray solution relative to its contact material is required.

Sprayed coil units are usually installed in refrigerated enclosures requiring high humidity (e.g., chill coolers). Paradoxically, the same sprayed coil units can be used in special applications requiring low relative humidity. For such dehydration applications, both a high brine concentrate (near its eutectic point) and a large difference between the process air and the refrigerant temperature are maintained. Process air is reheated downstream from the sprayed coil to correct the dry-bulb temperature.

COMPONENTS

Draw-Through and Blow-Through Airflow

Unit fans may draw air through the cooling coil and discharge it through the fan outlet into the enclosure; or the fans may blow air through the cooling coil and discharge it from the coil face into the enclosure. Blow-through units have a slightly higher thermal efficiency because heat from the fan is removed from the forced airstream by the coil, but their air distribution pattern is less effective than the draw-through design. Draw-through fan energy adds to the heat load of the refrigerated enclosure, but heat gain from fractional horsepower or small three-phase integral fan motors is not significant. Selection of draw-through or blow-through depends more on a manufacturer's design features for the unit size required, the air throw required for the particular enclosure, and accessibility of the coil for periodic surface cleaning.

The blow-through unit design has a lower discharge air velocity because the entire coil face area is usually the discharge opening (grilles and diffusers not considered). An air throw of 33 ft or less is common for the average standard air velocity from a blow-through unit. Greater throw, in excess of 100 ft, is normal for draw-through centrifugal fan units. The propeller fan in the high-silhouette draw-through unit cooler is popular for intermediate ranges of air throw.

Fan Assemblies

Direct-drive propeller fans (motor plus blade) are popular because they are simple, economical, and can be installed in multiple assemblies in a unit cooler housing. Additionally, they require less motor power for a given airflow capacity.

The centrifugal fan assembly usually includes belts, bearings, sheaves, and coupler drives, each with inherent maintenance problems. This design is necessary, however, for applications having high air distribution static pressure losses. These applications include enclosures with ductwork runs, tunnel conveyors, and densely stacked products. Centrifugal fan-equipped units are also used in produce-ripening rooms, where a large air blast and 0.5 to 0.75 in. discharge air static is needed for proper air circulation around all the product within the enclosure. This is necessary for uniform batch ripening.

Casing

Casing materials are selected for compatibility with the enclosure environment. Aluminum, either coated or uncoated, or steel, either galvanized or suitably coated, are typical casing materials. Stainless steel is also used in food storage or preparation enclosures where sanitation must be maintained. On larger cooler units, internal framing is fabricated of sufficiently substantial material, such as galvanized steel, and casings are usually made with similar material. Some plastic casings are used in small unit coolers, while some large, ceiling-suspended units may feature all-aluminum construction to reduce weight.

Coil Construction

Coil construction varies from uncoated (all) aluminum tube and fin to hot-dipped galvanized (all) steel tube and fin, depending on the type of refrigerant used and the environmental exposure of the coil. The most popular unit coolers have coils with copper tubes and aluminum fins. Ammonia refrigerant evaporators are never constructed with copper tubes because ammonia corrodes copper. Also, sprayed coils are not constructed with aluminum fins unless they are completely protected with a baked-on phenolic dip coating or similar protection applied after fabrication. Coils constructed with stainless steel tubes and fins are preferred in corrosive environments, and all-stainless construction, or with aluminum fins, is preferred in environments where high standards of sanitation are maintained.

Fin spacings vary from 6 to 8 fins per inch for coils with surfaces above 32°F when latent loads are insignificant. Otherwise, 3 to 6 fins per inch is the accepted spacing for coil surfaces below 32°F, with a spacing of 4 fins per inch when latent loads exceed 15% of the total load. One and two fin(s) per inch are used when defrosting is set for once a day, such as in low-temperature supermarket display cases. Staged fins in a row of coils, such as a 1-2-4 fins per inch spacing combination, greatly reduce fin blockage due to frost accumulation (Ogawa et al. 1993).

Even distribution of the refrigerant flow to each circuit of the coil is vital for attaining maximum cooler coil performance. Distributor assemblies are used for direct-expansion halocarbon refrigerants and occasionally for large, medium-temperature ammonia units. Application requires that they be precisely sized. Distributor design and material of construction may vary to accommodate the refrigerant type and application. Application information provided by the distributor manufacturer should be closely followed, particularly regarding orifice sizing and assembly mounting orientation on the coil.

For liquid pumped recirculating systems, orifice disks are usually used in lieu of a distributor assembly. These disks are sized and installed by the coil manufacturer. They fit within the inlet (supply) header, at the connection spuds of each coil circuit. The specifying engineer may require a down-feed distributor assembly, less any orifice, if significant flash gas is anticipated.

Headers and their piping connections are part of the coil assembly. Usually, header lengths equal the coil height dimension; therefore each header is sized to the coil capacity for the application, based on refrigerant flow velocities and not on the temperature equivalent of the saturated suction temperature drop. Velocities of approximately 1500 fpm are used to compute the size of the return gas header and its connection size. In the field the connection size is often mistaken to be the recommended return line size. But the size of lines installed in the field should be based on the suction drop calculation method (see Chapters 1, 2, and 3).

Frost Control

Coils must be defrosted when frost accumulates on their surfaces. The frost (or ice) is usually greatest at the air entry side of the coil; therefore, the required defrost cycle is determined by the inlet surface condition. In contrast, a reduced secondary-surface-to-primary-surface ratio produces greater frost accumulations at the coil outlet face. A long-held theory is that the accumulation of relatively more frost at the coil entry air surface somewhat improves the heat transfer capacity of the coil. However, overall accumulated coil frost usually has two negative effects: it (1) impedes heat transfer because of its insulating effect, and (2) reduces airflow because it restricts the free airflow area within the coil. Both effects, to different degrees, are the result of combinations of airflow, fin spacing, frost density, and ambient air conditions.

Depending on the defrost method, as much as 80% of the defrost head load of the unit could be transferred into the enclosure. This heat load is not normally included as part of the enclosure heat gain calculation. The unit's refrigeration capacity rating is averaged over a 24 h period, by a factor that estimates the typical hours per day of refrigeration running time, including the defrost cycles.

As previously mentioned, a longer time between defrost cycles can be achieved by using more coil tube rows and wider fin spacing. Ice accumulation, which interferes with the airflow, should be avoided to reduce both the frequency and duration of the defrost cycles. For example, in low-temperature applications having high latent loads, unit coolers should not be located above the freezer entry or exit doors.

Operational Controls

In the simplest form, electromechanical controls cycle the refrigeration system components to maintain the desired enclosure temperature and defrost cycle. Pressure-responsive modulating control valves, such as evaporator pressure regulators and head pressure controls, are also used. A temperature control could be a thermostat mounted in the enclosure, used to cycle the compressor on and off, or a liquid line solenoid valve that allows liquid refrigerant to flow to the evaporator coil. A suction pressure switch at the compressor can substitute for the wall-mounted thermostat.

Electronic controls have made electromechanical controls obsolete, except on very small unit installations. Microprocessor controllers mounted at the compressor receive and process signals from one or more temperature diode sensors and/or pressure transducers. These signals are converted to coordinate precise control of the compressor and the suction, discharge, and liquid line flow-control valves. Defrost cycling, automatic callout for service, and remote site operation checks are standard options on the typical type of microprocessor controller used in refrigeration. For large warehouses and supermarkets, an electronically based energy management system (EMS) can easily incorporate multicompressor systems into virtually any type of control system.

AIR MOVEMENT AND DISTRIBUTION

Air distribution is an important concern in the design of the refrigerated enclosure and the location of unit coolers. The direction of the air and air throw should be such that air moves where there is a heat gain. This principle implies that the air sweeps the enclosure walls and ceiling as well as to the product. Nearly all unit coolers are ceiling-mounted and should be placed (1) so they do not discharge air at any doors or openings, (2) away from doors that do not incorporate an entrance vestibule or pass to another refrigerated enclosure in order to keep from inducing additional infiltration into the enclosure, and (3) away from the airstream of another unit to avoid defrosting difficulties.

The velocity and relative humidity of air passing over an exposed product have an effect on that product's surface drying and weight loss. Air velocities up to 500 fpm over the product are typical for most freezer applications. Higher velocities require additional fan power and, in many cases, only slightly decrease the cooling time. For example, air velocities in excess of 500 fpm for freezing plastic-wrapped bread reduce freezing time very little. However, increasing the air velocity from 500 to 1000 fpm over unwrapped pizza reduces the freezing time and product exposure by almost half. This variation shows that product testing is necessary to design the special enclosures intended for blast freezing and/or automated food processing. Sample tests should yield the following information: ideal air temperature, air velocity, product weight loss, and dwell time. With this information, the proper unit or product coolers, as well as the supporting refrigeration equipment and controls, can be selected.

UNIT RATINGS

Currently, no industry standard exists for rating unit and product coolers. Part of the difficulty in developing a workable standard is that many variables are encountered. Cooler coil performance and capacities should be based on a fixed set of conditions, and they greatly depend on (1) air velocity, (2) refrigerant velocity, (3) circuit configuration, (4) refrigerant blend glide, (5) temperature difference, (6) frost condition, and (7) superheating adjustment. The most significant items are refrigerant flow rate, as related to refrigerant feed through the coil, and frost condition defrosting in low-temperature applications. The following sections discuss a number of performance differences relative to some of the available unit cooler variations.

Refrigerant Velocity

Depending on the commercially available refrigerant feed method used, both the capacity ratings of the cooler unit and its refrigerant flow rates vary. The following feed methods are used:

Dry Expansion. In this system, a thermostatically controlled, direct-expansion valve allows just enough liquid refrigerant into the cooling coil to ensure that it vaporizes at the outlet. In addition, 5 to 15% of the coil surface is used to superheat the vapor. The direct-expansion (DX) coil flow rates are usually the lowest of all the feed methods.

Recirculated Refrigerant. This system is similar to a dry expansion feed except it includes a recirculated refrigerant drum (i.e., a low pressure receiver) and a liquid refrigerant pump connected to the coil. It also has a hand expansion valve, which is the metering device used to control the flow of the entering liquid refrigerant. The coil is intentionally overfed liquid refrigerant by the pump, such that complete coil flooding eliminates superheating of the refrigerant in the evaporator. The amount of liquid refrigerant pumped through the coil may be two to six times greater (overfeed: 1 to 5) than that passed through a dry DX coil. As a result, this coil's capacity is higher than that of a dry expansion feed. To accurately calculate the rated capacity, the supply refrigerant temperature and pressure for the operating evaporator temperature should be provided by the air cooler's manufacturer (see Chapter 1 for further information).

Flooded. This system has a liquid reservoir (surge drum or accumulator) located next to each unit or set of units. The surge drum is filled with a subcooled refrigerant and connected to the cooler coil. To ensure gravity flow of the refrigerant and a completely wet internal coil surface, the liquid level in the surge drum must be equal to the top of the coil. The capacity of gravity-recirculated feed is usually the highest attainable, in part because large coil tubes (≥1 in. OD) are required so that virtually no evaporator pressure drop exists. In flooded gravity systems, the relative position of the surge drum to the air cooler, as well as their interconnecting piping and valves, are all important for proper operation. The intended location of these components and valves should be provided by the manufacturer.

Brine. In this chapter the term "brine" encompasses any liquid or solution that absorbs heat within the coil without a change in state; these fluids are also called secondary refrigerants. Aqueous glycols, ethylene, and propylene are well accepted and thus most often used. Food-grade propylene glycol should be used in refrigerated food-processing applications. Calcium chloride in water or sodium chloride in water (for extra-low-temperature applications) and R-30 can be used only under tightly controlled and monitored conditions. For corrosion protection, most of these solutions must be neutralized or inhibited (preferably by the chemical manufacturer) prior to being introduced into the system.

The capacity rating for a brine coil depends on the thermal properties of the brine (freeze point, thermal conductivity, viscosity, specific heat, density) and its flow rate within the coil. This rating is usually obtained by special request from the coil manufacturer. Generally, coils handling a commercial type of inhibited glycol solution will have about 11% less capacity at low temperatures and 14% less capacity at medium temperatures than comparable direct-expansion halocarbon refrigerants. The glycol temperature must run 8 to 10°F lower than the comparable saturated suction temperature of a comparable DX coil to obtain the same capacity.

Frost Condition

Frost accumulation on the coil and its defrosting are perhaps the most indeterminate variables that affect the capacity rating of forced-air coolers. Ogawa et al. (1993) showed that a light frost accumulation slightly improves the heat transfer of the coil. A continuous accumulation has a varying result, depending on the airflow. Performance suffers when airflow through the coil is reduced because the frosting of the coil surface increases the air-side static pressure (e.g., as in prop-fan unit coolers). But if the airflow through a frosting coil is maintained (e.g., a variable-speed fan arrangement), the frost will reduce the capacity somewhere between 2 to 10% (Kondepudi and O'Neal 1990, Rite and Crawford 1991). The thermal resistance of the frost (ice) varies with time and temperature, and ice pack growth is a product of operating at a surface temperature below the air dew point. Ultimately, defrosting is the only way to return to rated performance. This is usually initiated when unit performance drops to 75 to 80% of rated.

Controlled lab tests also showed that frost growth on a finned surface is not uniform with coil depth. Fin spacing is by far the biggest factor in restricting the airflow through the coil. For DX coils, the location of the superheat region in the coil had the most effect on uniformity. Oskarsson et al. (1990) discussed the effect of the length of time of frosting on uniformity. The industry generally considers that ice formation is uniform through a coil with a wide fin spacing, i.e., <5 fins/in. This spacing is used to determine an interfin free-air area in order to estimate the air static pressure drop through a coil operating under frosting conditions.

Defrosting

The defrost cycle may be initiated and terminated in a number of ways. The microprocessor control, which has largely replaced the mechanical time clock, has reduced energy use and helped to maintain product quality (by reducing the temperature rise in the enclosure during the defrost cycle). Accurate, short-time defrosting is now a health-safety concern. Too long a defrost cycle can result in an unacceptable product core temperature rise. Such conditions are now beginning to be vigorously monitored by most local and state health departments. In addition, proper defrost initiation and termination are needed. Accurate defrosting also provides better protection for the refrigeration equipment. Improper and/or incomplete defrosting can damage the compressor and evaporator coil, to the extent that irreparable refrigerant leaks develop when ice is allowed to build up and crush one or more of the coil tubes. The following defrosting methods are in use.

For Enclosure Air Temperature Above 35°F. Enclosure air that is 35°F or slightly warmer can be used to defrost a cooler coil. Fans are left on and defrosting occurs during the compressor off cycles. However, some of the moisture on the coil surface evaporates, which is undesirable for a low-humidity application. The following methods of control are commonly used:

- If the refrigeration cycle is interrupted by a **defrost timer**, the continually circulating air melts the coil frost and ice. The timer can operate either the compressor or a liquid-line solenoid valve.
- An oversized unit cooler controlled by a **wall thermostat** defrosts during its normal off-on cycling. The thermostat can control a refrigeration solenoid in a multiple-coil system or the compressor in a unitary installation. *Note*: An oversized unit is sized to handle a 24 h cooling load in 16 h.
- A **pressure control** can be used for slightly oversized unitary equipment. A low-pressure switch connected to the compressor suction line is set at a cut-out point such that the design suction pressure corresponds to the saturated temperature required to handle the maximum enclosure load. The suction pressure at the compressor drops and causes the compressor motor to stop as the enclosure load fluctuates, or as the oversized compressor overcomes the maximum loading.

The thermostatic expansion valve on the unit cooler controls the evaporator temperature by regulating its liquid refrigerant flow, which varies with the load. The cut-in point, which restarts the compressor motor, should be set at the suction pressure that corresponds to the equivalent saturated temperature of the desired refrigerated enclosure air temperature. The pressure differential between the cut-in and cut-out points corresponds to the temperature difference between the enclosure air and the coil temperatures. The pressure settings should allow for the pressure drop in the suction line.

For Enclosure Air Temperature Below 35°F. Whenever the enclosure air is below 35°F, supplementary heat must be introduced into the enclosure to defrost the coil surface and drain pan. Unfortunately, some of this defrost heat remains in the enclosure until the unit starts operation after completion of the defrost cycle. The following supplemental heat sources are used for defrosting:

- **Gas defrosting** can be the fastest and most efficient method if an adequate supply of hot gas is available. Besides performing the defrost function, the hot refrigerant discharge gas internally clears the coil and drain pan tube assembly of accumulated compressor oil. This aids in returning the oil to the compressor. Gas defrosting is used for small, commercial single and multiplex units, as well as for large, industrial central plants; it is broadly used on most low-temperature applications. Hot-gas defrosting also increases the capacity of a large, continuously operating compressor system because it removes some of the load from the condenser as it alternately defrosts the multiple evaporators. This method of defrost puts the least amount of heat into the enclosure ambient. A further improvement on hot-gas defrosting is the use of latent gas (sometimes called cool gas) from the top part of the receiver.
- **Electric defrost** effectiveness depends on the location of the electric heating elements. The elements can be either attached to the finned coil surface or inserted inside special fin holes or dummy tubes in the coil element. Electric defrost can be efficient and rapid. It is simple to operate and maintain, but it does dissipate the most heat into the enclosure, and, depending on energy costs, may not be as economical to operate as gas defrosting.
- **Heated air** may be circulated in a loop within freezer units that are constructed so as to isolate the frosted coil from the cold enclosure air. This is mostly done in packaged units, with the use of dampers to isolate the cooling coil. Once the coil is isolated, the unit's airflow is heated by a hot gas reheat coil or electric heating elements. The heated air circulates within the unit to perform the defrost. This heated air also must heat a drain pan, which is needed in all enclosures at temperatures of 34°F or less. Some units have specially constructed housings and ducting to draw warm air from adjoining areas.
- **Water defrost** is the quickest method of defrosting a unit. It is efficient and effective for rapid cleaning of the complete coil surface. Water defrost can be performed manually or on an automatic timed cycle. This method becomes less desirable as the enclosure temperature decreases much below freezing, but it has been successfully used in applications as low as –40°F. Water defrost is used more for large units used for cooling industrial products. This application typically has a large reservoir of warm condenser water provided by heat reclaim from the water-cooled condenser.
- **Hot brine** can be used to defrost brine-cooled coils by remotely heating the brine for the defrost cycle. This system heats from within the coil and is as rapid as hot-gas defrost. The heat source can be steam, electric resistance elements, or condenser water.

Defrost Control. For the most part, defrosting is done with the fan turned off. Inadequate defrost time and over-defrosting both can degrade overall performance; thus, a defrost cycle is best ended by monitoring temperature. A thermostat may be mounted within the cooler coil to sense a rise in the temperature of the finned or tube surface. A temperature of at least 45°F indicates the removal of frost and automatically returns the unit to the cooling cycle.

Fan operation is delayed, usually by the same thermostat, until the coil surface temperature approaches its normal operating level. This practice prevents unnecessary heating of the enclosure after defrost. It also prevents drops of defrost water from being blown off the coil surface, which avoids icing of the fan blade, guard, and orifice ring. In some applications, fan delay after defrost is essential to prevent a rapid buildup of ambient air pressure, which could structurally damage the enclosure.

Initiation of defrost can be automated by time clocks, running time monitors, or air pressure differential controls, or by monitoring the air temperature difference through the coil (which increases as frost accumulation reduces the airflow). Adequate supplementary heat for the drain pan and condensate drain lines should be considered. It is not uncommon for two methods to run simultaneously (e.g., hot-gas and electric) to simplify drain pan defrosting and shorten the defrost cycle. Drain lines should be properly pitched, insulated, and trapped outside the freezer, preferably when traversing a warm area.

Basic Cooling Capacity

Most rating tables state gross capacity and assume that the fan assembly or defrost heat is included as part of the enclosure load calculation. Some manufacturers' cooler coil ratings may appear as sensible capacity; others may be listed as total capacity, which includes both sensible and latent capacities. Some ratings include reduction factors to account for frost accumulation in low-temperature applications or for some unusual condition. Others include capacity multiplier factors for various refrigerants.

The published rating, defined as the basic cooling capacity, is based on the temperature difference between the inlet air and the refrigerant in the coil [Btu/h per degree TD (temperature difference)]. The coil inlet air temperature is considered to be the same as the enclosure air temperature, and the refrigerant temperature is assumed to be the temperature equivalent to the saturated pressure at the coil outlet. This practice is common for both cooler and freezer enclosure (unit coolers) applications. For heavy-duty use, such as for a blast freezer or process conveyor work, manufacturer's ratings may be based somewhat differently, such as on the average of the coil inlet-to-outlet air temperatures considered as the enclosure temperature.

The TD necessary to obtain the unit cooler capacity varies with the application. It may be as low as 8°F for wet storage coolers and as high as 25°F for gut storage and workrooms. The TD can be related to the desired humidity requirements. The smaller the TD, the less dehumidification as a result of coil operation. The following information gives general guidance for selecting a proper TD for medium-temperature applications above 25°F saturated suction:

- For a *very high* relative humidity (about 90%), a temperature difference of 8 to 10°F is common.
- For a *high* relative humidity (approximately 80%), a temperature difference of 10 to 12°F is recommended.
- For a *medium* relative humidity (approximately 75%), a temperature difference of 12 to 16°F is recommended.

Temperature differences above these limits usually result in low enclosure humidities, which dry the product. However, for packaged products and workrooms, a TD of 25 to 30°F is not unusual. Paper storage or similar products also require a low humidity level. Here, a TD of 20 to 30°F may be necessary.

For low-temperature applications below 25°F saturated suction, the temperature difference is generally kept below 15°F because of system economics and frequency of defrosting rather than for humidity control.

Pending the industry adapting to ASHRAE *Standard* 25 for unit cooler testing for ratings and ARI *Standard* 420 for unit cooler rating procedure and subsequent manufacturers' certified ratings, it is advisable that the specifying engineer check the individual manufacturer's literature for all such rating factors.

INSTALLATION AND OPERATION

Whenever possible, refrigerating air-cooling units should be located away from enclosure entrance doors and passageways. This practice helps reduce coil frost accumulation and fan blade icing. The cooler manufacturer's installation, start-up, and operation instructions generally give the best information. On installation, the unit nameplate data (model, refrigerant type, electrical data, warning notices, certification emblems, etc.) should be recorded. This information should be compared to the job specifications and to the manufacturer's instructions for correctness.

MORE INFORMATION

Additional information on the selection, ratings, installation, and maintenance of cooler units is available from the manufacturers of that type of equipment. Chapters 8 through 28 of this volume have specific product cooling information.

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