Aircoil™ Evaporator Application Guide

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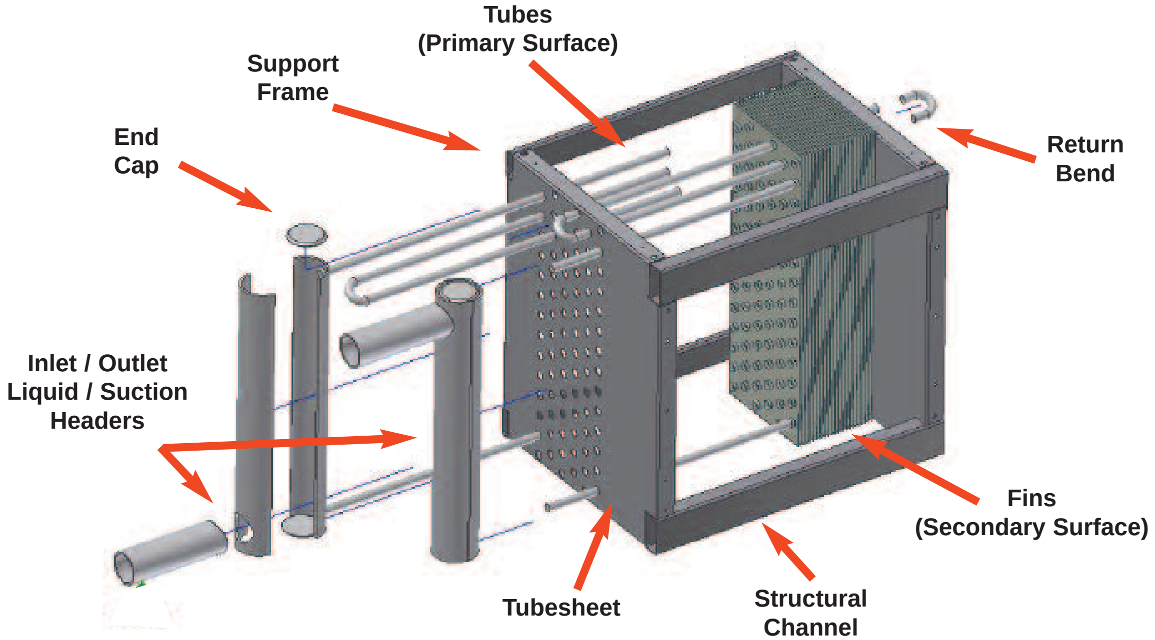
Terminology

For clarification purposes, below are terms and abbreviations used throughout this application guide.



Room Temperature – This is the room temperature that is drawn into the air unit and is used to determine the TD of the air unit. For clarification, the air that discharges from the air unit and travels to the opposite end of the room will be approximately 5°F colder. Therefore, the average room temperature will be the average of the two.

Supply Air Temperature – This is the temperature of the air as it leaves the air unit. In a draw-through unit, it is slightly warmer than the air leaving the coil face as it has absorbed the fan motor energy.

Dry Coil – A coil where water vapor will not condense or freeze onto the coil surface.

Wet Coil – Water vapor is condensed out of the air onto the coil surface. This occurs when the coil surface temperature is below the dew point of the entering air. The face velocity should be kept below 620 FPM on wet coils to prevent moisture carryover, also called "spitting."

Frosted Coil – A coil with ice or frost on the fins and tubes. This occurs when the coil surface temperature is below freezing and there is moisture condensing out of the air. There are separate ratings for wet versus frosted coils because frost acts as an insulating barrier to heat transfer, which reduces capacity.

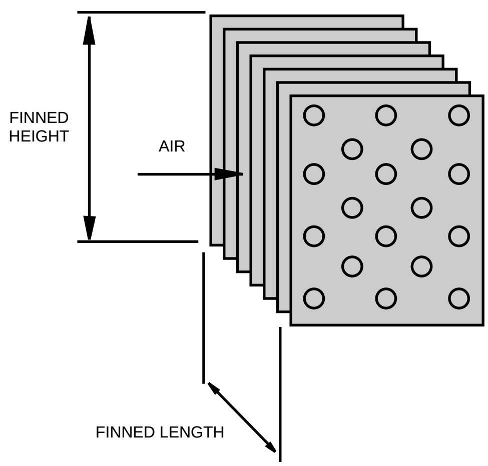
Evaporator / Air Unit / Air Handling Unit / Aircoil / Fan Coil / Product Cooler / Unit Cooler – This is a finned, tubular air to refrigerant heat exchanger with one or more fans for moving the air and a drain pan to capture the condensate.

Coil / Bare Coil / Coil Slab – This is a free standing finned, tubular air to refrigerant heat exchanger with no attached fans. It may or may not include a drain pan.

Finned Height – The height of the fin in a bare coil.

Finned Length – The length of the portion of coil tubes that are covered with fins.

Face Area – The finned height multiplied by the finned length, typically expressed in ft^2.



Face Velocity – The airflow through the coil divided by the face area of the coil; expressed in ft/min (FPM).

Finned Depth – The length of the fin in the direction of air flow.

Rows Deep – The number of tube rows that the air passes through.

Tubes High – The number of tubes in each row of the coil.

Fin Spacing – The number of fins per inch (fpi) of finned length. Typically, this is 3, 4 or 6 fpi for industrial refrigeration applications.

Variable Fin Spacing (Vari-Fin) – For severe frost applications, fins on the air inlet face of the coil have wider spacing than the remainder of the coil. Fin spacing is 2 fins/inch (fpi) or 1.5 fpi for the first 2 rows and 4 fpi or 3 fpi, respectively, for the remaining rows. Performance must be de-rated accordingly.

Liquid Connection – This is the field connection point for the liquid supply (refrigerant inlet) to the coil. Generally this is a pipe stub for welding or brazing, a dielectric flange, or a di-electric welded coupling.

Liquid Header – This is the pipe that connects the liquid connection to all of the individual / parallel circuits in a coil. A liquid header is only used when the amount of flash gas in this header is minimal (otherwise a refrigerant distributor is used). It can be oriented either vertically or horizontally depending on the desired style of liquid feed.

Refrigerant Distributor – If there is flash gas present in the liquid feed, a distributor is used to proportionately divide the liquid and vapor flow to each circuit. It is usually a conical device with tubular leads situated around the base of the distribution cone. The refrigerant is passed through an orifice prior to impinging on the point of the cone. Distributors are always used on DX feed systems and occasionally on control pressure receiver (CPR) feed systems.

Suction Connection – This is the field connection point for the suction (refrigerant outlet) from the coil. Generally this is a pipe stub for welding or brazing, or a di-electric flange.

Evaporator Temperature / Evaporating Temperature / Coil Temperature – This is the temperature of the refrigerant in the coil, typically slightly higher than the suction temperature due to pipe friction losses.

TD (Temperature Difference) – Room Temperature minus the Coil Temperature.

ΔT (Delta T) – Room Temperature minus Discharge Air Temperature from the air unit.

Feed Types – For information on feed types (recirculated, flooded, direct expansion, etc.), see page H47.

Defrost Methods – For information on defrost methods (air, hot gas, electric, water, etc.), see page H51.

Recirculation Rate – GPM or mass flow pumped into a coil divided by the GPM or mass flow evaporated in the coil.

Defrost Condensate – The water that is melted from the coil during defrost.

Refrigerant Condensate – The refrigerant that is condensed during the hot gas defrost process.

Static Pressure Drop (in. wc) – This is the air pressure drop through the coil due to friction, generally expressed in inches water column.

External Static Pressure – The pressure losses external to the air unit, typically imposed by ductwork or the product being cooled.

Total Static Pressure – The sum of the static pressure plus the external static pressure. This is the pressure that the fan(s) is selected for.

Paddle Fan – This fan type has stamped aluminum sheet metal blades which have a slight curve. They are generally riveted to a steel hub. This type of fan is very sensitive to static pressure and generally has a very scattered air discharge pattern which contributes to a short air throw.

Axial Fan – This type of fan uses cast aluminum fan blades that have an airfoil cross section. It is capable of higher static pressures. The air throw can be up to 150 ft. or more with a long throw adaptor.

Centrifugal Fan – In this application the centrifugal fan most used is the forward curved type. It is quiet and economical to produce. It is generally used when high external static pressures are required or there are stringent sound requirements.

Drain Pan – This is the pan that is situated under the coil to collect the moisture that drains from the coil during operation or defrost.

Insulated Drain Pan – The water draining from a coil during operation is generally below the dew point of the room air which is drawn under the pan back to the air unit. The cold pan surface will sweat if not insulated. A sheet metal outer cover is added to protect the insulation.

Hot Gas Drain Pan – In rooms near or below freezing, any water in the pan will have a tendency to freeze unless heated. A coil is placed between the pan and the insulated outer cover to warm the pan to above freezing when the coil is defrosting.

Electric Drain Pan – Same as above, only with electric heaters in lieu of a hot gas coil.

Load Estimating

The selection of any refrigeration equipment must first start with an estimate of the cooling load in the room or from the process.

In some instances, this can be as simple as replacing existing equipment with known capacity, by rule of thumb, or as complicated as a detailed load and process analysis.

Refrigeration loads are primarily comprised of four segments: transmission, infiltration, product and other.

Transmission Loads – This is the heat gain that is transmitted through the walls due to the conductance of the wall, roof and floor construction materials. This heat gain is directly proportional to the temperature difference across the walls. Refrigerated spaces are very well insulated. Typically 4” or more of urethane or polystyrene insulation is used in a laminated, metal skinned panel wall.

Care and judgement should be exercised when evaluating older buildings and using insulation values of unknown origin. With the phase-out of CFCs as a foam blowing agent, many insulations are no longer as thermally efficient as the originally published values. In addition, as some insulations age, the CFC or HFC blowing agent leaches out and air with water vapor replaces it. This leads to thermal degradation. Insulations that do not have a solid vapor barrier will absorb moisture from the increased vapor pressure of the colder environment. Adjust the transmission load accordingly.

The outside color of the walls and roof also has an influence on the load if it is exposed to the sun. Darker outside surfaces will absorb heat and increase the temperature differences across the panel. White panels and roof membrane are the optimum for minimal heat gain.

Infiltration Loads – This is the portion of the load that comes from the air exchange that occurs when the doors are opened. Additionally, older buildings and /or poorly constructed buildings may have leaks which allow outside air in. Please note that colder rooms have a lower vapor pressure and air contracts as it cools, this means that outside air is always flowing into a colder space.

When doors are open, a flow pattern is established that consists of denser cold air flowing out of the cold room into the warmer room across the lower portion of the door. As the cold air flows out, the volume must be replaced with air that flows in from the warm room through the upper half of the door. There are equations available to predict the amount of flow.

The amount of infiltration can be roughly calculated by estimating the number of air changes in the room over a 24 hour period. A more detailed approach is to estimate the traffic flow into and out of the room and estimate the amount of door open time and subsequent air exchange.

The load is calculated from the enthalpy difference of the inside air and the infiltrated outside air times the mass of air exchanged. The enthalpy and density of the air can be extracted from a psychrometric chart.

Product Loads – Typically most product to be stored, frozen or processed enters the room at a higher temperature, which creates load. The amount of load depends on the heat content of the product, the mass of the product and the temperature drop incurred over a defined time period. If the room is below the product's freezing temperature and the product is in the room long enough to partially or fully freeze, the latent load of freezing must be taken into account. This is usually significantly higher than the sensible cooling load alone and should not be ignored.

If the product is fresh fruit or vegetables, there is a heat load from the respiration of these items.

The sensible, latent and respiration heat loads are available in the ASHRAE Refrigeration Handbook.

Other Loads – These loads consist of the additional internal items in the room that give off heat such as lights, motors, air unit fan motors, defrost loads, fork trucks and people.

Safety Factor – When all of the calculations have been completed, the result should be compared to rules of thumb to be sure that there were no omissions or errors. A safety factor is almost always incorporated into the total load.

Air Unit Operating Time – All air units operating below freezing require down time for defrosting. This time is not available for cooling, therefore the capacity of the installed air units must be proportionately larger to remove 24 hours of heat gain in less hours due to lost time due to defrost. With matched systems with air cooled condensing units, the condensing unit must be proportionately enlarged as well.

Fin Spacing

The distance between fins in a coil is generally expressed with the term fins per inch (fpi). Note: In Europe, the fin spacing is expressed directly in mm. The spacing of the fins is a trade off of the coil's ability to accumulate water, frost or dirt and its performance. In other words, greater fin density leads to higher performance but it will clog faster.

In industrial refrigeration applications, 3, 4 & 6 fins per inch are commonly used. The various fin densities have considerations as follows:

Bare Tube – This has the poorest heat transfer capacity due to the lack of overall surface area but a significant amount of moisture can be frozen on to the tube with very little effect on air flow resistance and a tolerable effect on heat transfer. Generally, only the first two rows of any coil are bare. These serve as moisture gatherers to reduce the frost load on the remaining rows.

1.5 & 2 fpi this fin spacing is generally accomplished by skipping every other fin in a 3 or 4 fpi configuration on the first two rows of a coil (BAC's Vari-Fin option). For applications where there is an intermittent high load such as above a door in a freezer that opens to an un-refrigerated room or a process room with washdown, it is good practice to use variable fin spacing such as 1.5/3 or 2/4 fpi. The first two rows are able to accumulate a significant amount of frost without clogging the air entering face of the coil.

3 fpi is used when the coil is operating below freezing and moisture laden air has a short and direct path to the coil. This will deposit the moisture directly on the fins creating a high loading rate. If the air has a chance to mix with the colder room air, the moisture loading will not be as high and 4 fpi can be used for a more economical coil selection.

4 fpi can be used in a below freezing room as noted above. This would be an example of a penthouse application or a room with vestibules into the freezer which projects the infiltrated air to the discharge side of the air unit. 4 fpi is the most common fin spacing for rooms over 32°F.

6 fpi is usually the minimum fin spacing encountered in industrial refrigeration for two reasons: hot dipped galvanizing has a tendency to clog 8 fpi or higher coils, and industrial refrigeration applications generally do not have filtered air so dirt in the coil and cleanability are issues. 6 fpi coils should only be applied in rooms with wet coils.

Application	Fin Spacing (fpi)	Room Temperature
HVAC	6 to 14	Above 45°F
Coolers	4 to 6	Above 32°F
Freezers	3	Below 32°F
High Latent Freezers	Variable	Low Temperature

Face Velocity

Face velocity is defined as the volume of air flow divided by the face area of the coil. It is usually expressed in feet per minute (FPM). When the coil is operating in any room above freezing, water can be carried off of the face of the coil and into the room at high velocities, typically over 620 FPM. To avoid this carryover (also called "spitting"), follow the guidelines below.

Coil Temperature	Room Temperature	Coil Surface	Face Velocity
Above 30°F	Above 32°F	Wet	620 FPM or Less
Below 32°F	Above 32°F	Possibly Wet	620 FPM or less
Below 32°F	Below 32°F	Frosted	No Limit (450 - 1,100 FPM)

Refrigeration Feed Types for Aircoil™ Evaporators

For a finned tube evaporator to work most efficiently, the entire inside tube surface must be covered with a thin layer of liquid refrigerant. If too little liquid refrigerant is present, portions of the tube dry out and the heat transfer coefficient drops significantly. The following feed types regulate the refrigerant feed rates in different ways.

Recirculated

Recirculated feed is when a coil has more liquid refrigerant flowing through it than it evaporates. The recirculation rate is defined as the mass circulated divided by the mass evaporated. Overfeeding the coil ensures that the entire internal surface of the coil is wet with liquid refrigerant for maximum heat transfer efficiency. The minimum and maximum recirculation rates are governed by the following parameters:

The minimum rate must be enough to ensure that there is sufficient liquid refrigerant present at the outlet of every circuit to prevent dry tube wall areas. This would be enough liquid to create a full film around the complete internal perimeter of the coil. It is a function of the surface tension, viscosity and velocity of the refrigerant and the roughness of the tube surface. Bear in mind that most coils have many parallel circuits that may not be identical in design or loading. Therefore, the heavier loaded and longer circuits will force a higher recirculation rate for the lighter loaded and shorter circuits. If the minimum overfeed rate is not met, the coil's capacity will drop off significantly and rapidly, as the vapor heat transfer coefficient is much lower than the boiling liquid coefficient.

Any excess overfeed beyond the minimum required rate will progressively diminish the coil capacity by adding internal pressure drop to the coil. This pressure drop comes from the shear and friction losses of moving additional liquid refrigerant through the coil. As the internal pressure drop goes up, the saturated temperature goes up as well. The capacity of a coil is decreased with higher temperatures. In addition, the overfed liquid creates additional pressure drop in the suction pipes back to the compressor room.

Ammonia overfeed rates can be as low as 2:1 with low temperature applications where the exit of the tube will have high velocities. A properly circuited coil should not require more than a 3:1 overfeed rate. However, there are instances where the minimum orifice diameter is dictated by clogging, hot gas and oil passage considerations. In these instances, the overfeed rate on small coils with short circuit lengths can be as high as 5 or 6:1.

Now that we have discussed the amount of overfeed, let's look at the direction. A coil can be fed in to the bottom and up through the circuits (recirc bottom), in to the top and down through the circuits (recirc top), or, rarely, horizontally through the coil.

Top feed coils are generally used when there is no hot gas defrost to "back flush" the coil. They have the benefit of a lower refrigerant charge during part load operation and they are free draining upon shut down. Top feed coils can be hot gas defrosted but the orifices at the beginning of each circuit will limit the hot gas flow. This is the reason for a lower evaporating limit of 10° to 20°F on hot gas defrosted, conventionally top fed coils.

Bottom feed coils will have roughly the same refrigerant charge at design conditions as a top fed coil. This is due to equivalent velocity sweep through the coil. At part load, this velocity sweep slows down and liquid will accumulate in the coil. At very low loads, the coil will be almost full of liquid refrigerant. Care must be exercised in the system design to provide this liquid reserve to fill the coil and to accommodate the liquid surge when a load is suddenly applied and the liquid is sent back to the compressor room.

Even in consideration of the greater charge, bottom fed coils are preferred for low temperature applications, below +10˚F coil temperatures, because of superior defrosting characteristics. The hot gas is usually fed into the suction of the coil and flows down hill and against the normal refrigerant flow. This warms and sweeps the oil out of the coil. From the hot gas perspective, an orifice is encountered at the end of each circuit, which will pass condensed refrigerant at a rate proportional to the pressure differential across the orifice. This is approximately the hot gas supply pressure to the coil, less the setting of the defrost relief regulator. This orifice governs the pressure drop of each circuit, effectively ensuring a balanced flow through each circuit. If a circuit is totally defrosted and there is little condensation occurring, the orifice will pass gas, which will severely limit the mass flow, greatly reducing the false load back to the compressors.

Flooded

Gravity flooded coils are the simplest arrangement; there are no feed control valves to the coil. A refrigerant level is maintained in the surge drum and the static head differential feeds the refrigerant through the coil. The elevation of the liquid level relative to the top of the coil and the piping design are the controlling parameters.

The liquid refrigerant is supplied to the coil by gravity from a surge drum that is elevated above the unit. The refrigerant vapor and any un-evaporated liquid is swept up the outlet pipe to the surge drum for separation and recirculation due to the density difference of pure liquid refrigerant and the refrigerant liquid/vapor mixture. The make-up liquid refrigerant is supplied to the surge drum to maintain a set level.

Direct Expansion

Uses a thermal expansion valve (TXV) to control the flow of refrigerant into the coil. A TD (temperature difference) of 12°F is required to create 10°F of superheat, which is the minimum required to fully stroke the ammonia duty thermal expansion valve. This results in a performance decrease over a fully wetted, recirculated or flooded feed coil.

Coils that are fed with a thermal expansion valve are known as direct expansion (DX) fed coils. The thermal expansion valve can be as basic as a conventional bulb and diaphragm type or as sophisticated as a pulsed or stepper motor electronic valve.

The control parameter for a DX fed coil is the superheat at the outlet of the coil. Superheat is created by limiting the rate of liquid refrigerant flow into the coil, so that all of it boils off and the remaining vapor absorbs additional heat from the room air. This superheated vapor temperature is compared to the saturated temperature that corresponds with the coil outlet pressure. The feed valve is controlled to maintain a set amount of superheat.

Because superheat is generated from the room air temperature, it can never be greater than the coil TD, less the slight (1-2˚F) temperature difference required for heat transfer to occur between the room air on the outside of the coil and the refrigerant vapor on the inside. Coils typically have multiple parallel circuits, which have slightly different flow characteristics. The superheat that is sensed at the outlet of the coil is an average of all circuits.

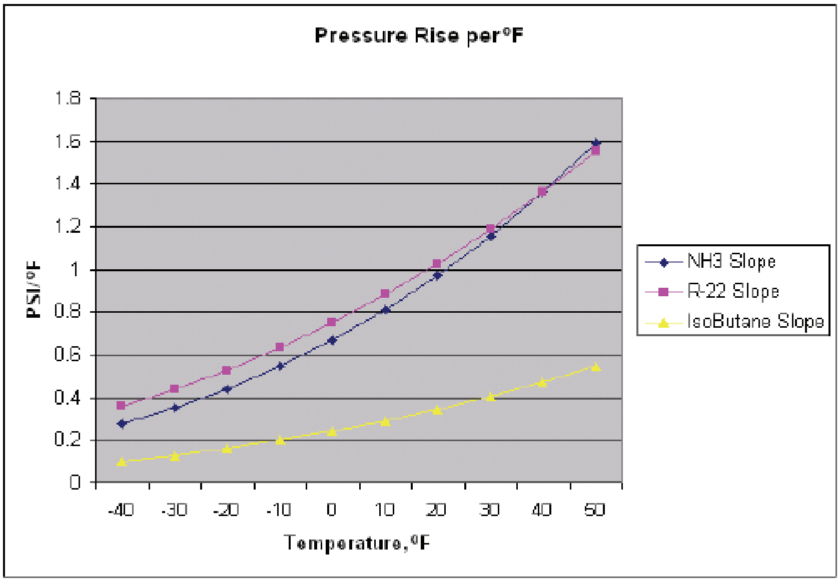
Most conventional TXVs require 6˚F superheat to overcome the internal spring pressure and lift the needle off from the seat and initiate the flow of refrigerant. From there, 4˚F of additional superheat is required to fully open the valve. In other words, a 10 ton valve has no capacity at 6˚F of superheat, 5 tons of capacity at 8˚F and 10 tons of capacity and 10˚F of superheat. Keep in mind that an 11˚or 12˚F TD over the coil is required to create the 10˚F of superheat.

If a coil is forced to operate at a lower superheat, the TXV cannot fully open. For instance, an 8˚F superheat will result in the TXV flowing at 50% of design capacity. This will starve the coil and the obvious fix is to install a larger TXV. This in turn, results in a valve that controls over a 2˚F range. Therefore it will have a greater tendency to overfeed, followed by underfeeding, resulting in cyclical operation, and valve hunting.

Conversely, if the superheat is greater than 10˚F, an additional portion of the coil will be inefficiently used to heat refrigerant vapor. Therefore, it is most efficient to limit the superheat to the 10˚F minimum requirement.

DX feed is more common on halocarbon refrigerants than ammonia. The thermal expansion valve essentially controls the volume of liquid that enters the coil. Ammonia requires approximately 0.25 in^3/sec/ton and R-22 requires 0.73 in^3/sec/ton. For this reason ammonia is more difficult to control with a TXV.

Please refer to the following graph. It shows that ammonia has less pressure available per degree of temperature to open the valve. This makes it more difficult for the TXV to control. Ammonia TXVs use ammonia in the bulb to drive the diaphragm. Halocarbon TXVs use an isobutane based charge which has a flatter line in relation to the R-22 for improved performance.



Once the proper temperatures have been established to make a thermal expansion valve work properly, the next challenge is distribution. When the high temperature / high pressure refrigerant passes through the expansion valve the pressure drops and 5-20% of the refrigerant is vaporized as it cools the remaining liquid. This vapor, called flash gas, has to be sent through the coil with an equal percentage going through each parallel circuit. A distributor uses geometrical symmetry and pressure drop to evenly balance the flow through all circuits.

Refrigeration

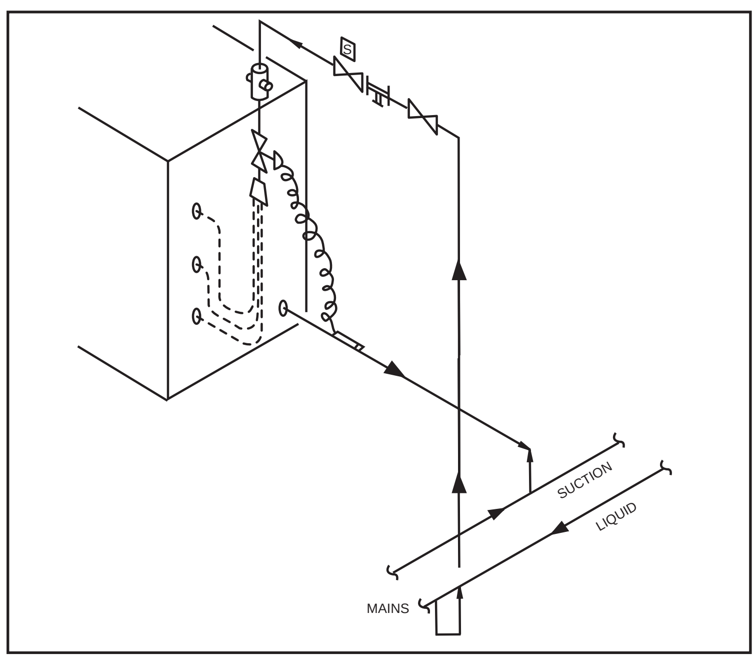
For the longevity of the thermal expansion valve, there should be a minimal amount of pressure drop across the valve's piston and seat. This prevents erosion and wire drawing. The pressure drop is instead taken across the distributor. After passing through the TXV, the refrigerant passes through an orifice at the inlet to the distributor and part of the pressure drop occurs. The flow downstream of the orifice is a somewhat homogenous mix of vapor and liquid. This mixture then passes over a cone with an outlet at the base for each circuit. Each outlet connects to a small diameter (3/16" to 3/8") piece of tubing that is 18" to 48" long. The small diameter of this tubing creates a significant amount of pressure drop, which governs the distribution to each circuit. When the coil is designed, the orifice size, number of circuits and distributor lead length and quantity are all precisely engineered for the maximum and minimum liquid supply temperatures. The accuracy of this information when the coil is ordered is critical to its performance. The presence of subcooling which was not incorporated into the design can significantly reduce coil performance.

Distributor

Care should be taken when piping DX coils. The high pressure liquid feed, if not subcooled, should be routed to minimize ambient heat gain, as the flash gas in the liquid line will severely limit the thermal expansion valve's capacity and wear the seat of the valve. The branch take off to feed each air unit should come off from the bottom of the supply header to avoid vapor entrainment. The thermal expansion valve should be mounted in line and immediately adjacent to the distributor without any elbows or other flow altering fittings. The liquid solenoid should then be mounted as close to the expansion valve as practical, as the refrigerant downstream of the solenoid will bleed off through the expansion valve. This will leave a void and potentially cause water hammer when the solenoid reopens. A strainer, upstream of the solenoid valve is good practice.

Direct expansion coils do, however, have their place. In high temperature applications, the supply pressure of the pump recirculated liquid must have enough pressure to overcome the suction pressure regulator and coil pressure drop. The price of the larger DX coils has to be weighed against the total price of a recirculator package and smaller recirculated coils.

A suction line with a vertical lift and a minimum refrigerant charge requirement are two additional reasons to choose DX over other types of feed.



Typical piping for DX Coils

Defrost Methods

A summary of the various mechanisms to remove frost accumulation from the coil follows.

No Defrost

There are two requirements for a coil to accumulate frost:

- The air flowing over the coil is cooled to or below its dewpoint temperature, resulting in the condensation of water vapor.
- Some portion of the coil surface has to be below freezing.

If both of these conditions are not met, the coil will not frost and a defrost mechanism is not necessary.

Air Defrost

In situations where the room air temperature is above freezing, defrost can be accomplished by stopping the flow of refrigerant to the coil and allowing it to warm up, thus melting the accumulated frost as the fans continue to run, drawing warm room air over the coil. Industry literature generally lists a 36˚F minimum room temperature for air defrost. Note: Another method of defrost may be required in warm rooms where moisture removal is critical.

Hot Gas Defrost – Coil Only

As shown by the previous section, in applications where the room temperature falls below 36˚F or where moisture removal is paramount, an external source of defrost heat is required. Most industrial refrigeration systems utilize a central ammonia compressor room. This is an ideal source for hot ammonia gas and the latent heat it contains. It requires the discharge gas from the compressor to be piped in a header to the vicinity of the air units with a branch take off to each air unit.

The basics of a hot gas defrost are as follows:

1. Either a time clock, elapsed run timer, frost sensor or manual control will initiate the defrost process.
2. The liquid solenoid is de-energized and the residual refrigerant charge is boiled out of the unit. This process generally takes 20 minutes.
3. Fans turn off.
4. The suction solenoid is closed or elevated to a pressure corresponding to 47˚F (70 psig for ammonia).
5. The hot gas solenoid is energized allowing hot ammonia vapor to enter the coil and condense, thus giving up its latent heat to melt the accumulated frost. This generally takes 8 -15 minutes.
6. After the frost has melted, a small bleed solenoid will open, gradually (1-3 minutes) reducing the pressure in the coil back to the prevailing suction pressure. On higher temperature coils (above 10˚F evaporating temperature) this step is often skipped.
7. If the face velocity of the coil is below 625 FPM, then the liquid and suction solenoids are opened and the fans are turned on. If the face velocity is above 625 FPM, there is a 2-5 minute time delay to refreeze the residual defrost water on to the coil to prevent moisture carry-over when the fans re-start.

Hot Gas Defrost – Unit

When a coil is applied in a room that is 32˚F or below, the drain pan needs to be heated during the defrost process as well. It is recommended to use a hot gas pan on rooms that operate at 33˚ and 34˚F as well. This is because the pan is radiating to the colder underside of the coil and could be colder than the room temperature. Additionally, a 2˚F swing in room temperature is quite possible.

A cautionary note on condensate induced hydraulic shock (applies to both hot gas defrost options) : When warm refrigerant vapor is introduced into a cold environment, it will condense. The resulting reduction in volume will cause a temporary low pressure area. If liquid refrigerant is present and the tube or cavity is small enough for liquid slugs or plugs to form, these slugs will collide with each other or the end of the pipe with extreme force. The force is the product of the mass of the slug times its actual vapor propelled velocity and it's acoustic velocity. It is this acoustic velocity component that generates sufficient energy to rupture pipes.

This situation can be avoided, by reducing the amount of residual liquid present when hot gas is injected, or controlling the rate of hot gas injection. Which in turn, controls the rate of vapor contraction.

Water Defrost

While hot gas is the most popular method of evaporator defrost, there are situations where there are no other loads in the plant that are generating hot gas, such as a spiral freezer with a small or no holding freezer or production loads. When this is the case, water defrost is the most often used alternative.

The prerequisite to water defrost is an ample supply of sufficiently warm (> 60˚F) water. This water is cascaded over the coil from a drip pan style of distribution tray at a rate of approximately 4 GPM per ft^2 of plan fin area (coil length times the coil depth in the direction of air flow). This flow rate continues until all of the frost is melted off of the coil, generally 10-15 minutes.

The coil should be pumped out prior to the start of the water flow, as the warm water will cause rapid boiling of the refrigerant. This will overload the defrost relief regulator and potentially cause unsafe high pressures. However, the pressure on the coil has to be raised to the pressure corresponding with the defrost water temperature or the defrost water will be refrigerated.

The water quantity required for defrost is large enough to avoid needlessly dumping it down the drain. It can either be captured in a tank, reheated with hot gas, or pumped to the evaporative condenser sump, if it does not contain any contaminants that are harmful to the condenser.

The water piping should supply the unit from above. If in a freezer, it should be heat traced and insulated. The branch connections to the distribution pans on the unit should be flexible hose to allow removal of the distribution pans for cleaning.

This large flow rate also requires care with regard to the condensate water piping from the drain pan. The larger flow rates require large drain pipes, sufficient fall from the unit is required before trapping so that the static head can overcome the pressure drop of the water flow through the trap. Ideally, the trap should be located outside of the conditioned space and as low as possible. A standpipe vent should also be incorporated to prevent drain line backup into the drain pan and subsequent pan overflow.

Electric Defrost

The predominate method of defrosting DX halocarbon coils is with electric heaters in the coil and pan if necessary. The electric heaters are rigid, insertion type that feed in from the end(s) of the coil. They can be installed in any coil that does not get hot dip galvanized, such as, aluminum and stainless steel tube/aluminum fin. Some heaters require a pull space for replacement that is equal to the length of the heater. BAC uses flexible heaters to reduce pull space.

These heaters are either inserted into unused tube openings or holes in the fin stack. The presence of electric heaters requires a high temperature switch for safety reasons. This switch is generally set at 45˚F and is used to terminate the defrost cycle. Consult the manufacturer's literature for the amount of wattage required on any given coil. If the unit has an electrically heated drain pan, the heating elements are generally mounted on the underside of an insulated drain pan. They are held in place with clips.

There is an energy consideration with electric defrost. Typically 11 watts per square foot of total surface area is required to defrost a freezer coil. On a halocarbon split system, the defrost amperage is generally less than the compressor amperage. The heaters only operate with the compressor off, so the total electrical load does not increase during defrost. On a central system, where the compressors stay operating, the defrost heater load is additive to the overall electrical demand. In addition, this heat has to be purchased directly as opposed to a free diversion of hot gas that is a byproduct of the refrigerated load.

Refrigeration

Condensate Water Piping

When a coil defrosts, the melted frost collects in the drain pan. From there it has to be routed to a drain hub, outside onto the ground or onto the roof. Even if a coil does not frost, it will shed water as the air is dehumidified while it is cooled. This condition also requires condensate drain piping.

All air units are supplied with drain pans beneath the coil. The factory will have provided a generously sized connection on that drain pan. That line size is generally sufficient to handle the largest anticipated water flow. Dehumidification condensate flow can range from 0.033 GPM/1000 CFM in high TD air conditioning applications to 0.006 GPM/1000 CFM in 40˚F rooms with a 10˚F TD. The following formula is a good approximation for most refrigeration applications:

$$\text{GPM} = \text{CFM}\,(T_{in} - 30)/\ 1{,}810{,}000$$

For defrost water flow, the following formula provides a reasonable approximation:

Total Gallons @ Total Surface (ft^2)/75

Peak GPM @ Total Surface (ft^2)/300

The flow from the drain pan is driven by gravity only. The piping from the drain pan should immediately drop from the pan to pick up some velocity and static head before encountering the friction loss of any fittings. Due to height and clearance considerations this drop is generally in the 6" range. It is imperative that the piping is sufficiently sized for minimal pressure drop. To avoid air locking in the drain line, sewer flow is recommended.

The air surrounding the coil is the coldest air in the vicinity, which will have the lowest vapor pressure. Air will migrate up the condensate drain line to this area of low pressure and create a frosted mess in a freezer and excessive coil load in a cooler. For this reason, a P-trap is installed in the drain line to block this air migration. The placement of this P-trap is governed by two requirements; A) it should be placed outside of the frozen space to prevent freeze-up if the heat tracing fails, and B) it should be mounted at least two feet below the drain pan to allow sufficient static head to overcome the trap's frictional losses and not back water up into the pan.

When the air unit is located in a frozen space, the condensate drain line will have to be heat traced, then insulated to contain the heat in the pipe. The heat tracing can either be an electrical tape wrapped around the pipe or an insertion type heater mounted inside of the pipe. If it is internal, be sure to consider the effect of the heater on the water flow and oversize the pipe if necessary. The amount of heat tracing is dependent upon the heat loss to the ambient air, which is a function of room temperature and insulation R-value.

Galvanized pipe is the traditional material used for drain piping. It is a must in a freezer, where a heat tape failure could allow freeze-up. It is good design practice to use tees and plugs in lieu of elbows in order to allow the use of a snake to clear a frozen line. PVC lines have been used in high temperature, above freezing rooms, although PVC has a tendency to sag resulting in a poor installation appearance and can trap water in the low points.

Unit Placement

The placement of air units is critical to the success of an installation. There are a number of items to be considered when designing the room layout and air unit placement.

Obstructions – The air unit should have an inlet clearance equal to the height of the unit. The discharge air flow of the unit should be unimpeded by pipes, racks, structural members, etc.

Piping Access – Consider where the refrigerant headers that will feed the air unit are, or will be, located. There should be an easy route between the room and the headers. There should be room to mount the valves external to the refrigerated space to lessen the chance of refrigerant leaks into the room. There should be a nearby floor drain for condensate or other pathway to an above freezing room.

Protection – The air unit should be located in an area that provides protection from fork truck traffic.

Structural Requirements – Steel air units can weigh up to 6 - 8 tons. The building steel should be sufficient to hold the weight, and the units should be positioned to minimize the amount of steel required.

Air Flow – For a room to have even temperature distribution, the air must circulate completely and freely about the room. As the air leaves the air unit, consider where that air is accumulating and its return path.

The colder air that leaves the air unit will be denser than the room air causing it to sink. The discharge stream velocity must be high enough to keep moving to the end of the room. This terminal velocity is generally accepted as 100-150 FPM.

Warehouses- Racked

The flow should be directed down every other aisle if possible, with the alternating aisles left for return air flow. Flow across the tops of racks is very disruptive and leaves no clear return path for the air.

Air units placed opposite from the doors in freezers will have to penetrate the warm air pocket that rises up from the open doors. This will require a high velocity. Conversely, air units placed on the dock wall of a freezer will be subjected to high infiltration loads unless internal vestibules are used.

A standard freezer unit with cast aluminum fan blades will throw the air approximately 100 ft. If channeled by an aisle with a clear return path, this can increase up to 150 ft. The use of long throw adaptors increases the average fan discharge velocity to over 2,500 FPM. This can boost the throw distance to over 200 ft. Consult your local BAC Representative for unit specific ratings.

Warehouses and Coolers – Unracked

Unracked rooms generally have ceiling heights of 10 to 18 feet. Therefore, the airstream does not have to fall far to be disrupted by pallets or totes. Evaporators with paddle wheel fans will only throw 50 to 60 feet in these conditions. Axial fan units will throw up to 100 feet. The airflow out of an evaporator without long throw adaptors will diverge out by approximately 10° to 15° per side.

Shipping Docks

Most shipping docks use AS style evaporators on the freezer wall blowing towards the truck doors. This distance is short enough for the velocity to be high enough to penetrate the infiltrated air from the truck openings. Some designers use large centrifugal fan air units for their lower sound output. They are generally located to throw air the length of the dock, perpendicular to the trucks. Because of the high amount of fork truck traffic on docks, placing the air units in a protected area or installing a protective curb is good practice.

Process Rooms

These rooms typically have production lines that are staffed by people who will be sensitive to drafts, especially in rooms below 45°F. For this reason, AR units with their “umbrella” airflow pattern will move the most air with the lowest velocity air distribution. The radius of air throw on an AR unit is approximately 30 ft.

Blast Freezers

Quick and effective freezing in a blast cell is primarily dependent upon air flow through the pallets. For this reason the air flow in a blast cell should be through the lowest number of pallets. Because most blast cells utilize air units with cast aluminum fan blades, there is a practical external pressure limit of 1/2” to 3/4” WC. If the air flow is forced through more than three pallets, a high static pressure drop will occur which will significantly reduce the volume of air flow, which in turn hinders the blast cells overall performance.

Typical Applications – Quick Reference

		Model Types						Defrost Options					Possible Options			
Applications	Room Temps (°F)	AS	AM	AL	AR	AC	Custom	Air	Hot-Gas Coil	Hot-Gas Unit	Water	Electric	Re-Heat	EcoArmor™ Protection System	Full Coverage Pans	Heat Taped Pan Covers
Blast Freezers	-45 to -20			X			X			X	X	X				
Candy Storage	65			X				X					X			
Cold Storage Warehouse	-20 to 20	1*	X	X		X				X		X				
Coolers- Meat & Poultry	28	X	X	X					X	X				X	X	X
Coolers- General	35	X	X	X					X	X						
Coolers- Milk	32	X							X	X						
Docks	35 to 45	X				X			X	X			X			
Hog or Beef - Chill	28			X			X	X		X	X				X	X
Ice Cream Storage	-20		X	X						X		X				
Process Areas	35 to 45	X			X	X		X						X	X	X
Air-Handler Coils	32 to 80						X	X	X							

Note: 1* AS units are on occasion used in freezers under perfect circumstances, normally only use AS units for 32ºF and above.