COLMAC COIL
Manufacturing Inc.

A+ Series^{TM}
Refrigeration Catalog

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COLMAC COIL
Manufacturing Inc.

A+Series™

Refrigeration Air Coolers

"The Heat Transfer Experts"

COLMAC COIL Manufacturing Inc.

A+Series™

Colmac A+Series™ air coolers offer the most advanced and innovative features in the industry for your industrial refrigeration applications and are designed to provide you with unsurpassed levels of:

Food Safety | Worker Safety | Energy Efficiency | Reliability

A wide range of cabinet construction options are available to enhance corrosion resistance (stainless steel), and food safety (CIP). A+Series™ coil construction options give you the flexibility to match any working fluid or environment:

TUBES	FINS
Copper	Plain or Epoxy Coated Aluminum
Aluminum	304 or 316 SS
304 or 316 SS	Anti-Microbial
Galvanized Steel	Galvanized Steel

Three unique tube patterns are used to optimize cooling performance, fan power, and defrost frequency depending on the capacity requirements, working fluid used, and operating temperatures specific to your application. Other manufacturers use a single tube and fin pattern for their product lines, forcing you to accept 'one-size-fits-all' and a less than optimum solution. Not with Colmac Coil!

A number of Colmac innovations have been incorporated into the A+Series™ line as optional features, including:

ADX™ Low Charge DX Ammonia Technology
- Significantly reduced ammonia charge
- Energy efficient
- Lower first cost compared to pumped ammonia

High Performance Glycol Coolers
- Proprietary tube enhancement technology
- 30% increase in cooling capacity
- Reduced glycol pumping power

Return Air Defrost Hoods
- Captures defrost heat and moisture
- Fully insulated with optional active heating
- Collapses for shipment

Reversing Airflow Fans
- Reduces blast freezing time by as much as 20%
- Improves product quality
- Cost Effective

Anti-microbial Coil Construction
- Anti-microbial fin material actively kills pathogens
- Corrosion resistance equivalent to SS
- Good thermal performance

Epoxy Coated Fins
- 300% more corrosion resistant than plain aluminum
- Flexible - will not chip or peel
- Cost effective

Read on to learn more about A+Series™ air coolers from Colmac Coil!

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Cover photo by: Gary Jensen

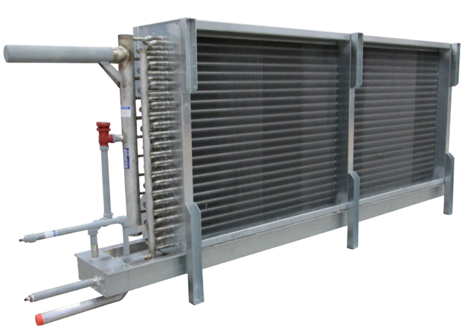
A+L High Profile

A+M Medium Profile

A+S Low Profile

A+R Process Rooms

A+D Low Profile Dual Discharge



A+B Coil Block with Drainpan

A+E Low Profile
for Commercial Applications

FEATURES

UNCRATING AND RIGGING MADE SAFE AND EASY

Colmac A+Series™ evaporators are crated and designed for fast and safe installation.

Cradle Crating System. The unique cradle crating system from Colmac is made of heavy duty 2”x8” dimensional lumber to support the full weight of the evaporator while withstanding the rigors of shipment. The cradle crate safely supports the weight of the evaporator while it is lifted into position from below. Then after the evaporator is secured to the ceiling, the crate easily comes away from the unit by gravity allowing it to be safely lowered to the ground.

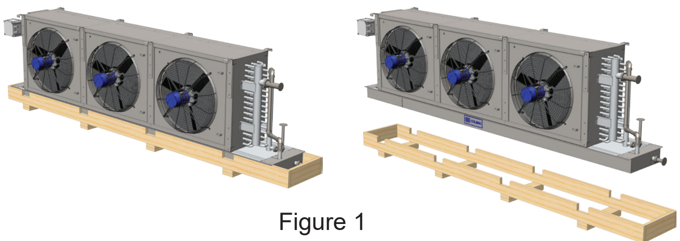


Figure 1
Cradle Crating System

Smart Hanger System. This optional patented design was developed to make the process of mounting ceiling-hung evaporators faster and safer. Smart hanger brackets and rails allow evaporator units to be hung from the ceiling without any personnel leaving the floor level. The time consuming process of aligning threaded rods into mounting holes while the unit is being lifted into position is eliminated, reducing suspended load time by as much as 75%. Side to side placement of the evaporator on the Smart Hanger rails is non-critical and therefore faster.

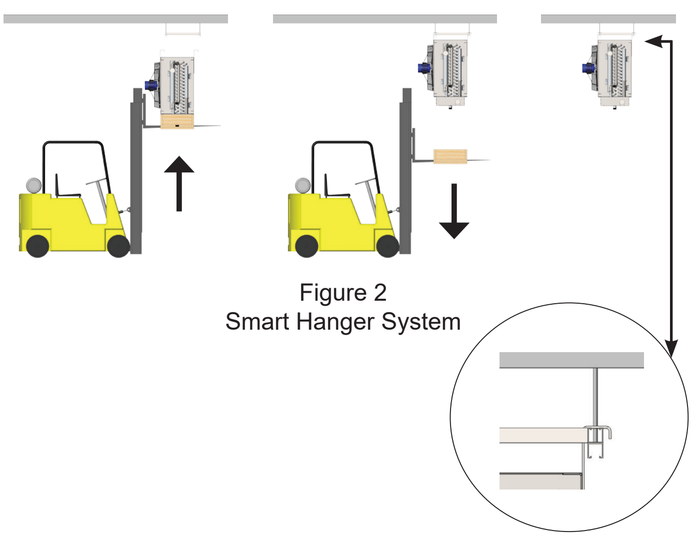


Figure 2
Smart Hanger System

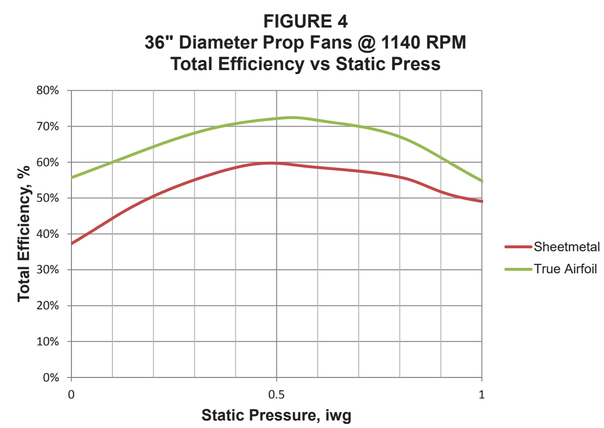
ENERGY EFFIICIENT AIRFLOW

Fans

Colmac A+Series™ evaporators use high efficiency fan blades having a true airfoil shape profile for all fan diameters greater than 24 inches. This type of fan offers several advantages over stamped steel or aluminum blades:

Figure 3
Multi-Wing Blade Cross Section

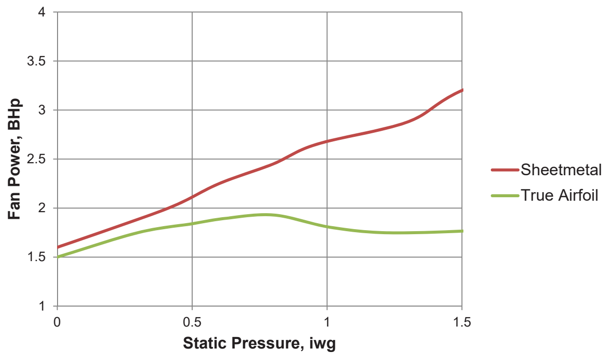
High Efficiency. The true airfoil blade shape can achieve mechanical efficiencies of 70%+. The best a stamped steel or aluminum sheetmetal blade can achieve is approximately 60%. This means Colmac A+Series™ evaporators will operate with 10% less fan power for the same cooling load, which not only translates to lower operating costs, but also lower first cost for power cabling and transforming.



Low Noise. The higher efficiency of A+Series™ fans also results in lower sound levels during operation. A wide range of fan diameters and speeds are available to allow the selection of the appropriate sound level for the application and customer requirements.

Non-overloading. Another benefit of A+Series™ fans with airfoil shape profile is the non-overloading power vs pressure characteristic curve. The power vs pressure curve is very flat which means that as frost accumulates on the evaporator and static pressure through the coil block increases, the brake power load imposed on the fan motor remains constant. Stamped steel and aluminum sheetmetal fan blades have a steeper power vs pressure curve which results in brake power (and amperage) continuing to rise as frost accumulates and static pressure increases.

FIGURE 5
36" Diameter Prop Fans @ 1140 RPM
Power vs Static Press

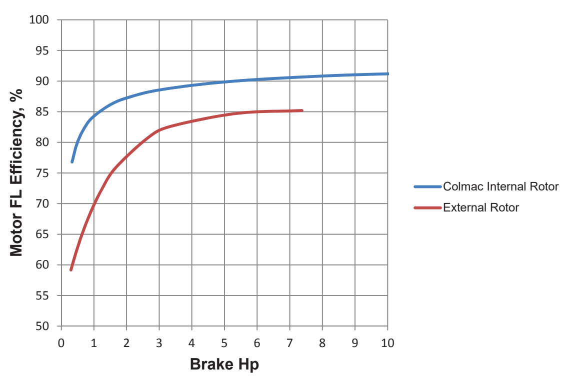


Motors

All standard fan and motor combinations on A+Series™ evaporators are optimized for maximum total efficiency. This is different from the integral external rotor fan motor units supplied by other manufacturers. While certain airflow and pressure conditions may result in total efficiencies approaching the A+Series™ efficiency, in many cases the total efficiency for integral external rotor fan motor units is inferior.

All standard fan motors supplied with A+Series™ evaporators are high efficiency, internal rotor, totally enclosed, VFD compatible. Integral horsepower motors (greater than 1 Hp) are supplied standard as NEMA Premium Efficiency. See the NEMA definition of Premium Efficiency for actually motor efficiencies. Fractional horsepower motors (1 Hp and less) are supplied standard as 80% minimum efficiency.

FIGURE 6
Motor Efficiency vs Brake Power
Internal vs External Rotor



Both 1140 rpm (6 pole) motors for high capacity applications and 850 rpm (8 pole) motors for low noise applications are available. Motors are suitable for either 50 or 60 Hz supply voltage.

A+S and A+R air coolers utilize robust C-face motors for reliability, low noise, and ease of replacement. These fractional horsepower motors are designed for 80% minimum efficiency as standard and can be supplied for washdown duty as an option.

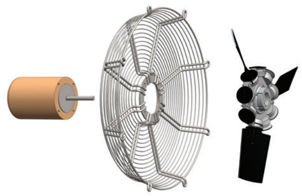
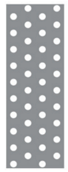


Figure 7
C-face Motor and Guard Combination A+S unit

OPTIMIZED HEAT TRANSFER

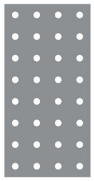
Unlike other manufacturers who offer a single "one-size-fits-all" tube pattern in their evaporators, Colmac A+Series™ evaporators feature optimized tube patterns to precisely match the operating conditions:

'I' Pattern (5/8" diameter staggered tubes)



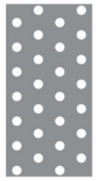
- Enhanced plate fins
- Compact pattern for highest heat transfer efficiency in high heat flux applications
- Best for high temperature wet fin applications with large TD

'T' Pattern (5/8" diameter inline tubes)



- Enhanced plate fins
- Lowest fan power
- Large secondary (fin) surface area for maximum frost carrying capacity and extended runtime between defrosts
- Best for low temperature frosted fin applications

'M' Pattern (7/8" diameter staggered tubes)



- Enhanced plate fins
- Low fan power
- Large secondary (fin) surface area for maximum frost carrying capacity and extended runtime between defrosts
- Best for:
    - Gravity flooded ammonia
    - Large capacity pumped ammonia

FEATURES

Available For Any Working Fluid

Colmac A+Series™ evaporators can be supplied to utilize any working fluid (refrigerant), either volatile or non-volatile, primary or secondary. This includes (but is not limited to):

Volatile

- Ammonia
- CO_2
- HFCs
- Liquid Nitrogen

Non-Volatile

- Glycols
- Calcium or Potassium Chloride
- Dynalene
- d-Limonene
- Potassium Formate

Circuiting is matched to each application and optimized for highest heat transfer with lowest tubeside pressure drop.

- Pumped or CPR bottom feed
- Pumped or CPR top feed
- Gravity flooded
- Direct expansion
- ADX™ Low Charge Ammonia

ADX™ LOW CHARGE AMMONIA TECHNOLOGY

The industrial refrigeration industry has always used the old rule of thumb: "Don't use DX Ammonia below 0 degrees F, it won't work!". Now with patented Colmac ADX™ technology, DX with ammonia is finally possible down to blast freezing temperatures (-40º to -50ºF). The benefits of Colmac ADX™ Low Charge Ammonia technology include:

- Dry suction – no wet suction risers to worry about
- Very low system ammonia charge
- Ultra-low evaporator ammonia charge
- Lower first cost – no recirculator pumps, smaller line sizes, simpler controls
- Lower operating costs – liquid pumping power is eliminated

Colmac ADX™ is available on all A+ Series™ evaporators.

Colmac has published the DX Ammonia Piping Handbook to explain how ADX™ works and guide the reader through the process of successfully designing an ADX™ low charge ammonia refrigeration system. See www.colmaccoil.com to download a free copy of the handbook.

HIGH PERFORMANCE GLYCOL COOLERS

Secondary refrigerants (glycols and brines) are widely used in industrial refrigeration systems as a means of (a) reducing the total ammonia charge, and (b) removing ammonia from occupied spaces (i.e. loading docks, and process rooms) and other areas highly sensitive to the risk of ammonia leaks. Unfortunately, these benefits are accompanied by a number of disadvantages including:

- Added complexity
- Increased first cost
- Increased power consumption

To minimize air cooler power consumption (added pumping power and fan power) with secondary refrigerants, Colmac A+ Series™ liquid-to-air coolers have been designed with a revolutionary new tubeside enhancement system which significantly boosts cooling performance. Compared to traditional cooler designs offered by other manufacturers, A+ Series™ liquid-to-air coolers with enhanced tubes have:

- 30% more cooling capacity
- Reduced pumping power
- Reduced fan power
- Reduced piping and insulation costs

MATERIALS OF CONSTRUCTION

A+Series™ air coolers are offered in a variety of construction materials to match the operating environment and provide the most cost effective solution.

Aluminum tubes and fins: Colmac Coil has specialized in all aluminum construction for ammonia air coolers for over 30 years. All aluminum construction offers:

- Lightest weight
- Best performance
- Lowest cost
- Fastest defrost
- Good corrosion resistance
- Patented Bi-Metallic Couplers eliminate flange union connections

Stainless steel tubes with aluminum fins: The stainless steel tubes used in this type of construction offers some added corrosion resistance and resistance to mechanical damage compared to all aluminum construction. However, the poor conductivity and higher cost of stainless steel tubes means relatively lower performance and higher cost compared to all aluminum construction.

A variety of different fin materials are available with stainless steel tubes on A+Series™ air coolers:

- Aluminum fins
- Epoxy coated aluminum fins
- 304 or 316 stainless steel fins
- Anti-microbial fins

Galvanized steel tubes and fins: In certain cases where highly alkaline cleaners are used directly on coil surfaces, galvanized steel construction may be desirable. This type of construction is significantly heavier (2 or 3 times), has significantly lower performance (12 to 15% less), and is costlier when compared to all aluminum or stainless/aluminum construction.

More detailed information on coil construction can be found in the Colmac Coil Technical Bulletin "Comparing Ammonia Evaporator Construction: Which One is Best?". Go to www.colmaccoil.com to download a free copy of this bulletin.

BREAKTHROUGH IN HYGIENIC DESIGN

Colmac specializes in hygienic coil designs for the food processing industry. A+Series™ air coolers can be supplied with the following types of coil construction to match more demanding cleaning and sanitizing requirements:

All Stainless: Both tubes and fins can be made of type 304 or type 316 stainless steel.

Anti-Microbial: Stainless steel tubes with proprietary anti-microbial fin alloy provides:

- Equivalent corrosion resistance to stainless steel tubes and fins
- Equivalent performance to stainless steel tube and aluminum fins
- Active anti-microbial action. Pathogen colony counts approach zero after just 2-3 hours exposure to this fin alloy
- Not a coating which can chip or peel off and contaminate food products

3-A Sanitary Design: The only design USDA approved for direct contact with food. Only available from Colmac Coil.

CLEANABILITY IS STANDARD

Cabinet Materials: Cabinet sheet metal is offered in galvanized steel, aluminum, or stainless steel.

Hinged Fan Panels: Fan panels on all A+S, A+M, A+L, and A+R air coolers are hinged for ease of inspection, cleaning, and service. The A+D has an optional hinged fan panel.

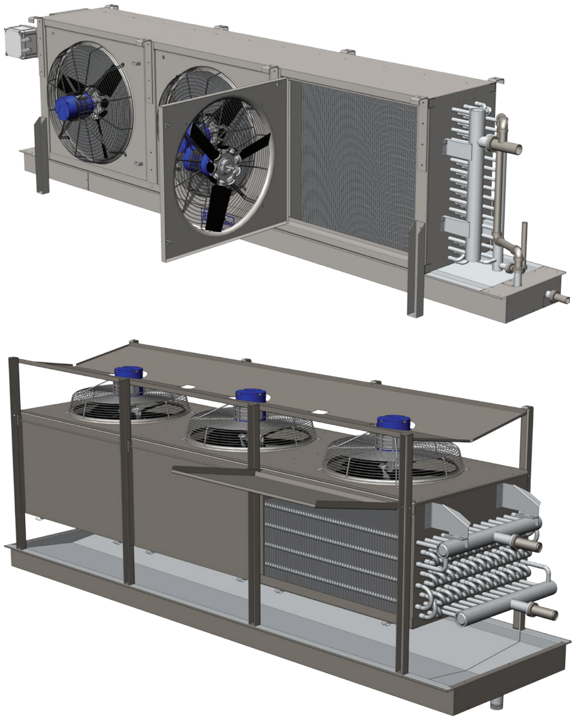


Figure 8
Hinged Access Panels

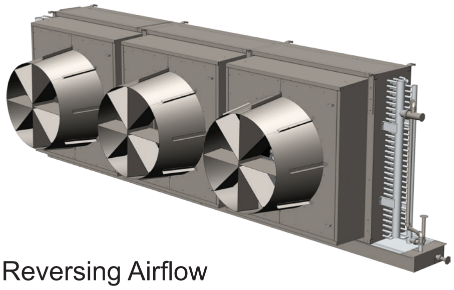
Cleaning Clearance: Care has been taken to eliminate difficult to inspect and clean areas on top of the fins and between the bottom of the fins and the drainpan. The “Triple Pitch” drainpan is designed to be easily cleaned, drain quickly, and leave no standing water after a defrost or cleaning cycle.

FEATURES

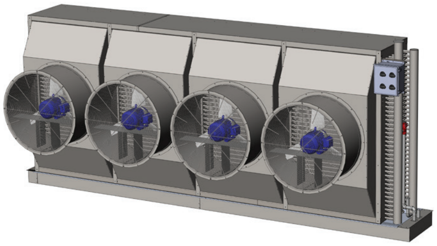
AIR DISCHARGE ARRANGEMENTS:

On applicable models, air discharge alternatives include:

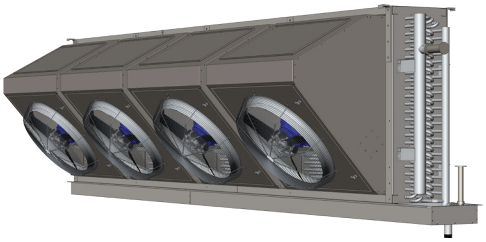
- Long throw adapters



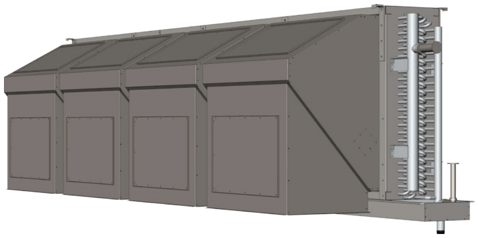
- Reversing Airflow



- 45° down discharge

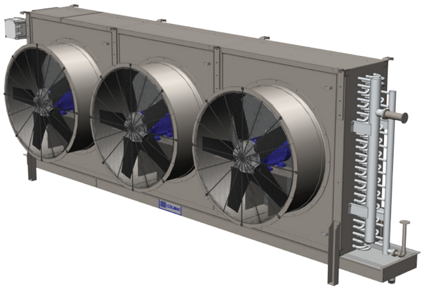


- 90° down discharge (penthouse adapters)



45° and 90° penthouse options feature heavy-duty discharge housings that tilt the fans 45° down from the vertical plane. These housings ship installed for ease of installation. Access panels are provided on penthouse adapters to permit service access.

- Fans selected for external static pressure (ESP)



FACTORY ELECTRICAL WIRING OPTIONS:

- All motors wired to a common fused or non-fused disconnect switch located in a NEMA 4X box
- Each motor wired to an individual fused or non-fused disconnect switch located in a NEMA 4X box
- All motors wired to a control panel with a common fused disconnect switch and individual IEC motor starters. All located in a NEMA 4X box.
- Customized UL508 listed control panels available for all units

OTHER OPTIONS

Re-heat coil

- Installed to re-heat air leaving the evaporator coil

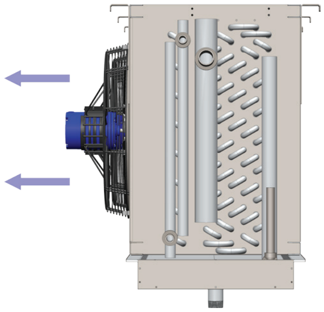


Figure 8
A+S Air Cooler With Re-Heat Coil

Variable fin spacing

- For severe frost applications, fins on the air inlet face of the coil have wider fin spacing than the remainder of the coil. The wider spacing allows for more frost build-up before defrosting becomes necessary, resulting in fewer defrosts compared to a coil without variable fin spacing.

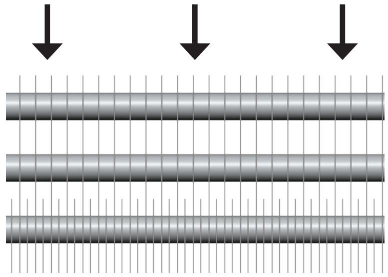


Figure 9
Variable Fin Spacing

Electric heat trace in the drain pan cover

- Use this option for conditions where the room temperature is above freezing and the drain pan cover temperature may drop below the dew point temperature of the room air, resulting in condensate forming on the cover and dripping. The heat trace keeps the drain pan cover above the room dew point temperature, and eliminates the possibility of condensation.

Extended legs

- For applications where a floor mounted coil must be elevated

Alternate voltages and 50 Hz fan motors

- Units can be designed and manufactured to be compatible with power supplies anywhere in the world.

NEW DEFROST TECHNOLOGY FROM COLMAC COIL

Colmac Coil A+Series™ air coolers are designed to:

1. Defrost faster
2. Use less energy during defrost
3. Eliminate drain pan icing problems

“Triple Pitch” Drainpan

Colmac Coil’s innovative “triple pitch” V-bottom drainpan design provides for rapid and complete drainage of melted frost and ice. The drainpan is conveniently pitched to a single drain connection on one end of the unit, simplifying drain piping. The “V” shape acts to quickly move melted frost to the center of the pan where it flows to the end of the pan and the drain. Low spots and “pooling” of melted frost in the pan are completely eliminated. Pitching the drainpan in three directions (front to center, rear to center, and end-to-end) combined with continuous hot gas loop contact has resulted in “the perfect pan”!

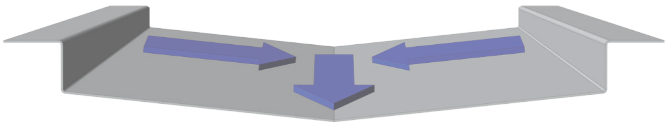


Figure 10
Triple Pitch Drain Pan

Drain connections found in other manufacturers’ drainpans are typically made of pipe nipples cut at 90 degrees and welded onto a flat hole in the drainpan sheetmetal. This type of construction distorts the drainpan and can cause incomplete drainage because of high spots around the drain outlet. Colmac Coil has solved this problem with a full radius drain outlet formed into the drainpan to eliminate the possibility of water pooling around the drain after a defrost. The Colmac A+ drainpan drains completely. No more time and money wasted de-icing drain pans!

Figure 11
Full Radius Drain Outlet

Continuous Contact Pan Loop

Other manufacturers attach the hot gas pan loop (tubes and headers) underneath the drainpan in such a way that complete contact over the length of the pan is not possible. The tubes in the drainpan loop on Colmac evaporators are held tightly in contact along the entire length of the underside of the drainpan by means of special spring tension clips. No thermal mastic paste is used or needed with the Colmac A+ design. Pan loop headers are held outside the ends of the drainpan to allow full contact of the tubes with the pan. Defrost heat is transferred to the pan surface not only by the tubes themselves, but also through the metal of the full length clips.

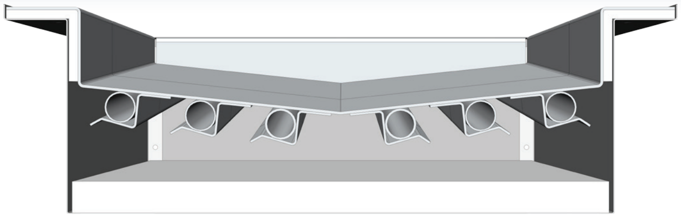


Figure 12
Continuous Contact Pan Loop

"It's All In The Piping"

Liquid Seal Hot Gas Drainpan Loop: In conventional hot gas drainpan designs, liquid refrigerant can flood the lower tubes in the drainpan hot gas loop, rendering them much less effective in heating the pan, and resulting in slow and uneven drainpan defrosting. Colmac Coil's trapped outlet design ensures that condensed, liquid refrigerant is carried out of the pan ensuring fast, complete, and uniform heating of the pan during defrost.

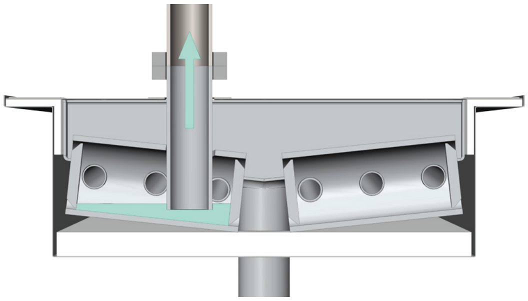


Figure 13
Liquid Seal Loop Outlet

Free Draining Liquid Connections: With conventional coil designs, the liquid connection enters the liquid header in such a way that the bottom tubes in the coil stay flooded during defrost with condensed, liquid refrigerant. The result is slow, uneven (or incomplete) defrosting of the coil. Colmac Coil has solved this problem by extending the liquid header downward and placing the liquid connection below the level of the lowest tube in the coil. This design effectively traps all of the condensed liquid refrigerant and forces it out of the coil during defrost, resulting in a fast, complete and effective defrost of the entire coil.

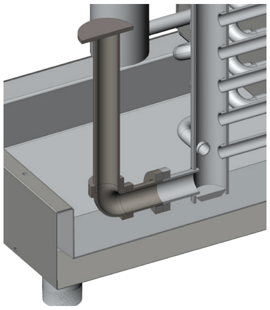


Figure 14
Trapped Liquid Connection

Vertical Liquid and Hot Gas Connections: Since nearly all piping in a refrigerated warehouse runs along the ceiling, and then vertically down to the evaporator coil connections, Colmac Coil's vertical liquid and hot gas connections eliminates the need for field installed elbows and piping required to connect to horizontal connections. The result is time and money saved on the jobsite during installation.

Return Air Defrost Hoods

As much as 60% of the energy used to defrost air coolers is lost to the room due to convection of heated air. Colmac Coil has developed a device which captures and uses the majority of this heated air. The Colmac Return Air Defrost Hood is a fully insulated series of hinged panels which collapse for shipment and then open quickly and easily into the operating position. The sturdy panels are of insulated double-wall construction with active heating to prevent condensation and frosting on the interior surfaces of the hood during defrost. Colmac Return Air Defrost Hoods can be added as an option to any A+Series™ air cooler.

Addition of these optional Return Air Defrost Hoods will result in:

- Faster defrosts
- More complete defrosts
- Reduced frost and ice on ceilings and walls
- Reduced power consumption

Figure 15
Hoods in Operation and Collapsed

A thermal finite element analysis was performed on two evaporators mounted in a single penthouse arranged for sequential defrosting, to visualize the effect of adding Colmac Return Air Defrost Hoods on heat loss during defrost. The result is a dramatic reduction in heat lost by the defrosting unit and an increase in the cooling performance of the operating unit.

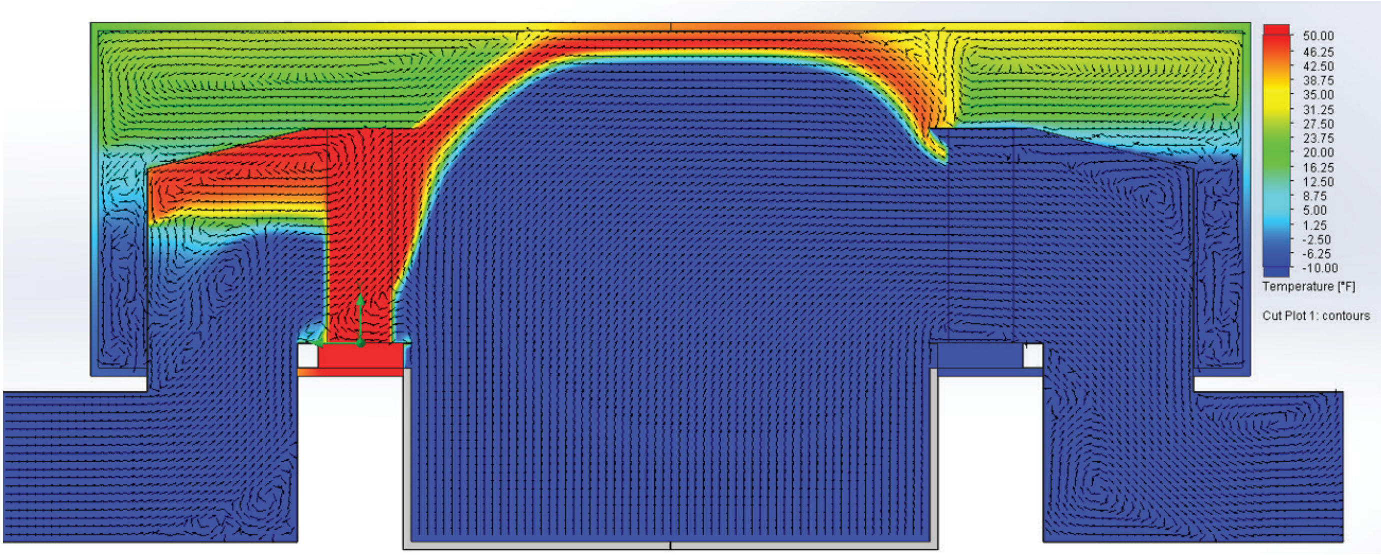


Figure 16a
Finite Element Thermal Analysis
A+L Penthouse Without Hoods

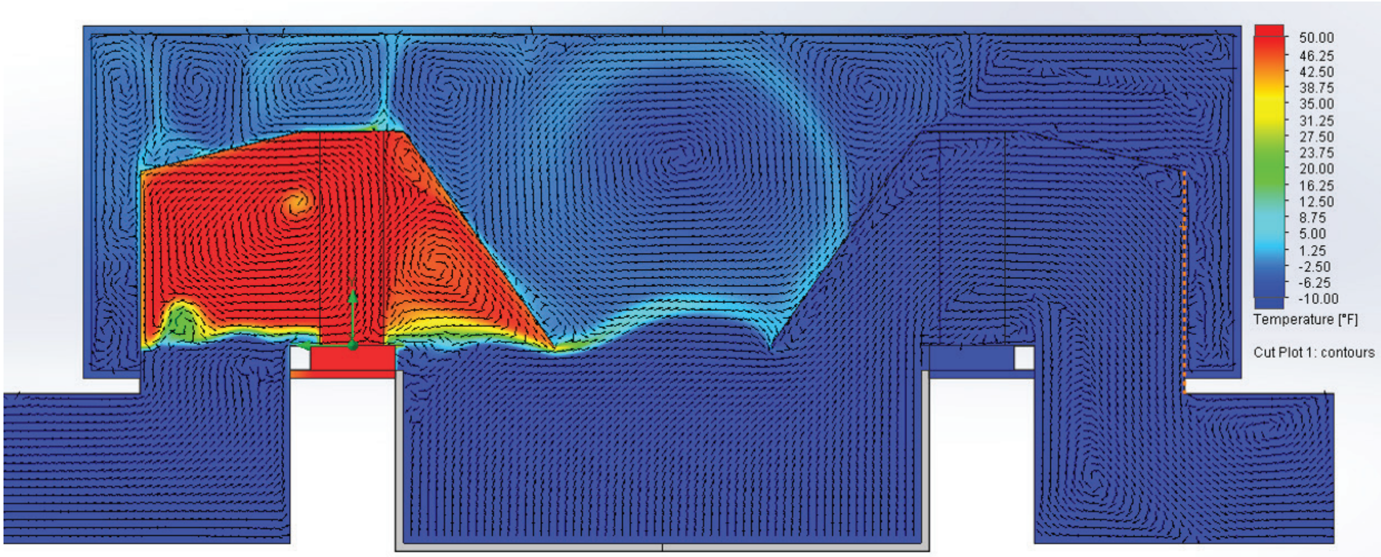


Figure 16b
Finite Element Thermal Analysis
A+L Penthouse With Hoods

FEATURES

WATER DEFROST THAT WORKS

Water defrost has many advantages:

- Fast – defrost duration is short
- Washes/cleans fin surfaces
- Energy efficient
- Simple

In spite of the benefits listed above water defrost has seen limited use, particularly at freezer temperatures, due to the perceived disadvantages of:

- Large water flowrate required
- Messy – frost and ice buildup from overspray
- Tendency of spray nozzles to foul and plug

A+Series™ air coolers with water defrost are designed to address each of these challenges.

Thermodynamically correct water flow rate: Traditionally, the amount of defrost water shown by evaporator manufacturers has been based on rules of thumb such as “1-1/2 to 2 gpm per sq foot of face area”, or “3 gpm per sq foot of top area”. These rules of thumb are overly conservative and result in higher-than-needed defrost water flow rates and pumping power. Colmac limits the defrost water flow rate to only the amount needed to heat the mass of the coil metal and melt the frost, no more.

No more overspray: Colmac Coil engineers have solved the problem of splashing and overspray with a patented system combining a special fin design to limit water leaving the edges of fins, and a drain pan designed to fully contain defrost water.

Removable, cleanable water distribution pans: Fouling and plugging of spray nozzles is mitigated by the use of removable, cleanable water distribution pans. The distribution pans are designed to be easily removable for inspection and cleaning while the evaporator remains in -place, undisturbed.

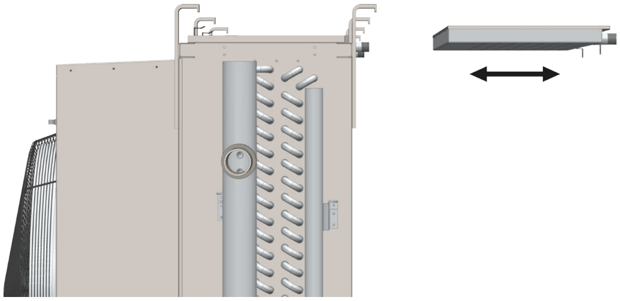


Figure 17
Removable Water Defrost Pan

PATENTED ELECTRIC DEFROST

This patented electric defrost heater element design eliminates elements “creeping” or “walking” out of the heat exchanger, which can cause damage to elements and wiring. The new proprietary design extends heater element life and reduces the risk of damage and electrical failures.

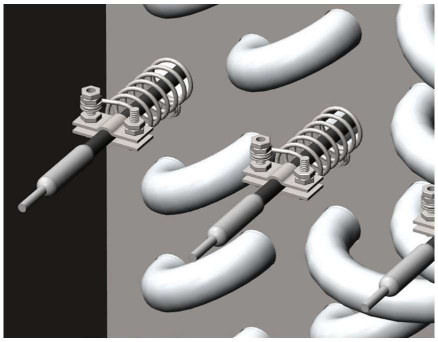


Figure 18
Heater Element
With Self Centering Spring

ONLINE SELECTION SOFTWARE

Colmac offers qualified users access to its powerful online applications software. The Refrigeration Load Simulator application accurately models and predicts the refrigeration load for an entire facility. This first-of-its-kind program calculates sensible and latent cooling loads, moisture removal rates, room rh%, fan power, defrost frequency, and other useful operating parameters. Output is saved and transferred directly to A+Pro™ air cooler selection software for accurate selection, specification, and pricing of A+Series™ air coolers.

NOTES

NOTES

COLMAC COIL
Manufacturing Inc.

Other Quality Products From Colmac Coil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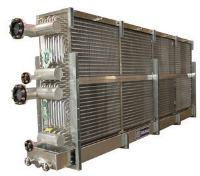
Custom Evaporators & Baudelot Coolers


Air Cooled Condensers

CE(PED) Certification, ASME Sec. VIII, Canadian Registration Number, UL508, Canadian Standards Association

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Visit www.colmaccoil.com for more information and resources:

Product Information

Product Literature

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COLMAC COIL Manufacturing Inc.

When you want Quality, specify COLMAC!

Installation, Operation, and Maintenance

A+ Series™ Air Coolers

ENG00019601 Rev A

Contents

1. SAFETY INSTRUCTIONS

To avoid serious personal injury, accidental death, or major property damage, read and follow all safety instructions in the manual and on the equipment. Maintain all safety labels in good condition. If necessary, replace labels using the provided part numbers.

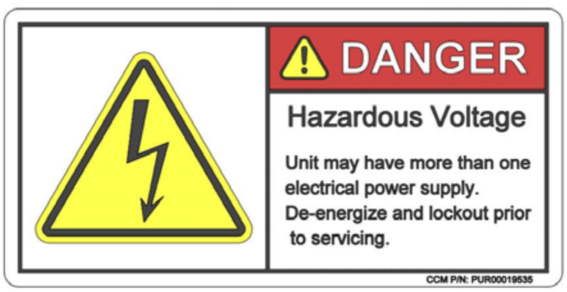
This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

DANGER indicates a hazardous situation which, if not avoided, will result in death or serious injury.

WARNING indicates a hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

NOTICE indicates instructions that pertain to safe equipment operation. Failure to follow these instructions could result in equipment damage.



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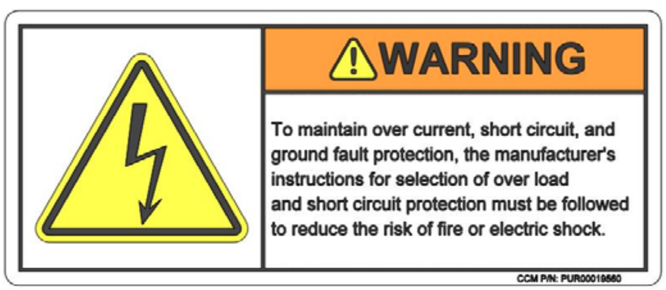

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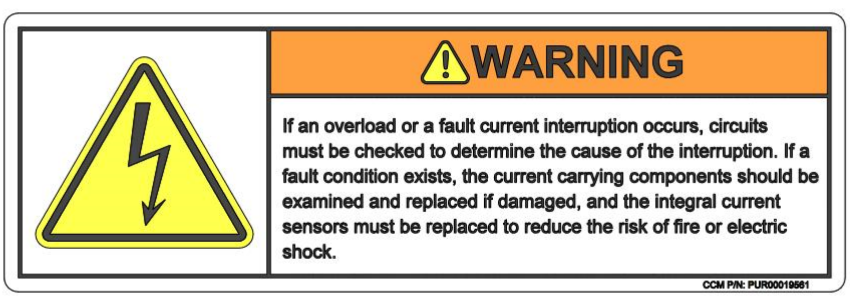

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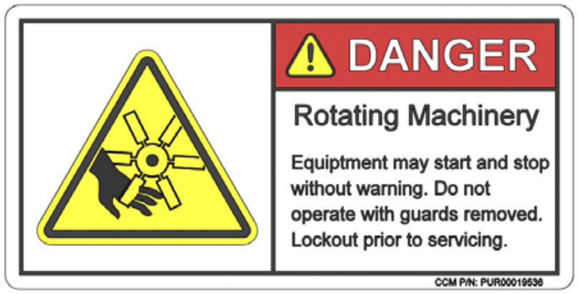

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1.1. **Refrigerant Warning**

1.1.1. A+ Series™ Evaporators may contain liquid refrigerant such as ammonia, R-22, R-507, etc. For this reason, A+ Series™ Evaporators should be installed, operated and serviced by qualified refrigeration technicians only.

1.1.2. Liquid refrigerant causes burns, which may be fatal, if it leaks and comes in contact with a person.

1.1.3. Refrigerant vapor can cause asphyxiation and or tissue burns if released to the atmosphere in the vicinity of people.

1.1.4. Liquid refrigerant that is isolated in a pipe or equipment without an adequate means of pressure relief can rupture pipe or equipment if it is allowed to warm.

1.1.5. Hot refrigerant vapor, when injected into an evaporator containing cold refrigerant, will rapidly condense. This rapid condensation can accelerate liquid slugs to dangerously high energy levels that can rupture pipes, valves and other components.

1.1.6. Please refer to various manuals from organizations such as IIAR, ASHRAE, and RETA for more information concerning the safe operation of refrigeration equipment.

2. INSTALLATION

2.1. **Inspection**

2.1.1. Damage or Shortage – Upon receipt of equipment, inspect for shortages and damage. Any shortage or damage found during initial inspection should be noted on delivery receipt. This action notifies the carrier that you intend to file a claim. Any damaged equipment is the responsibility of the carrier, and should not be returned to Colmac Coil without prior notification. If any shortage or damage is discovered after unpacking the unit, call the deliverer for a concealed damage or shortage inspection. The inspector will need related paperwork, delivery receipt, and any information indicating his liability for the damage.

2.1.2. While Colmac will gladly provide information to assist with the process, the responsibility for filing such a claim is that of the purchaser or the purchaser’s consignee.

2.1.3. Specified Equipment – Check unit nameplate for: Electrical specifications to ensure compatibility with electrical power supply. Model Nomenclature and other information to match original order.

2.1.4. Each Colmac A+ Series™ Evaporator coil is shipped with a low-pressure nitrogen charge. Slightly open the Schrader valve located on the coil connection cap to detect the presence of the charge by listening for the nitrogen escaping through the valve. After this brief test, close the valve to maintain the nitrogen charge until the unit is ready to be connected to the system piping.

2.1.5. If the unit has lost its nitrogen charge, it may have been compromised during shipment. Before installation, pressure test the coil with dry nitrogen to ensure there is not a coil leak and report the loss of the shipping charge to Colmac. If the unit will not hold pressure, please obtain the unit’s serial number, then contact your Colmac Representative for a resolution.

2.2. **Transporting and Storing**

2.2.1. Colmac A+ Series™ Evaporators are designed to facilitate safe handling with fork trucks or cranes. Use caution when handling to prevent damage to exposed components. The shipping skid should remain affixed to the unit to enable handling and to prevent damage to the pan and other components.

2.2.2. Lifting forks should be placed under appropriate areas of the wooden shipping skid for proper handling. The lifting skid may be used to lift the unit into place for either ceiling-hung or foot-mounted applications.

2.2.3. **NOTICE:** Use shipping container, or use hangers to lift unit into mounting position. Never lift unit by placing forklift in direct contact with drainpan.

2.2.4. **CAUTION:** Where the finned surface of the coil is exposed, extreme care should be taken to avoid contact with the sharp edges of the fins to minimize the chance of injury.

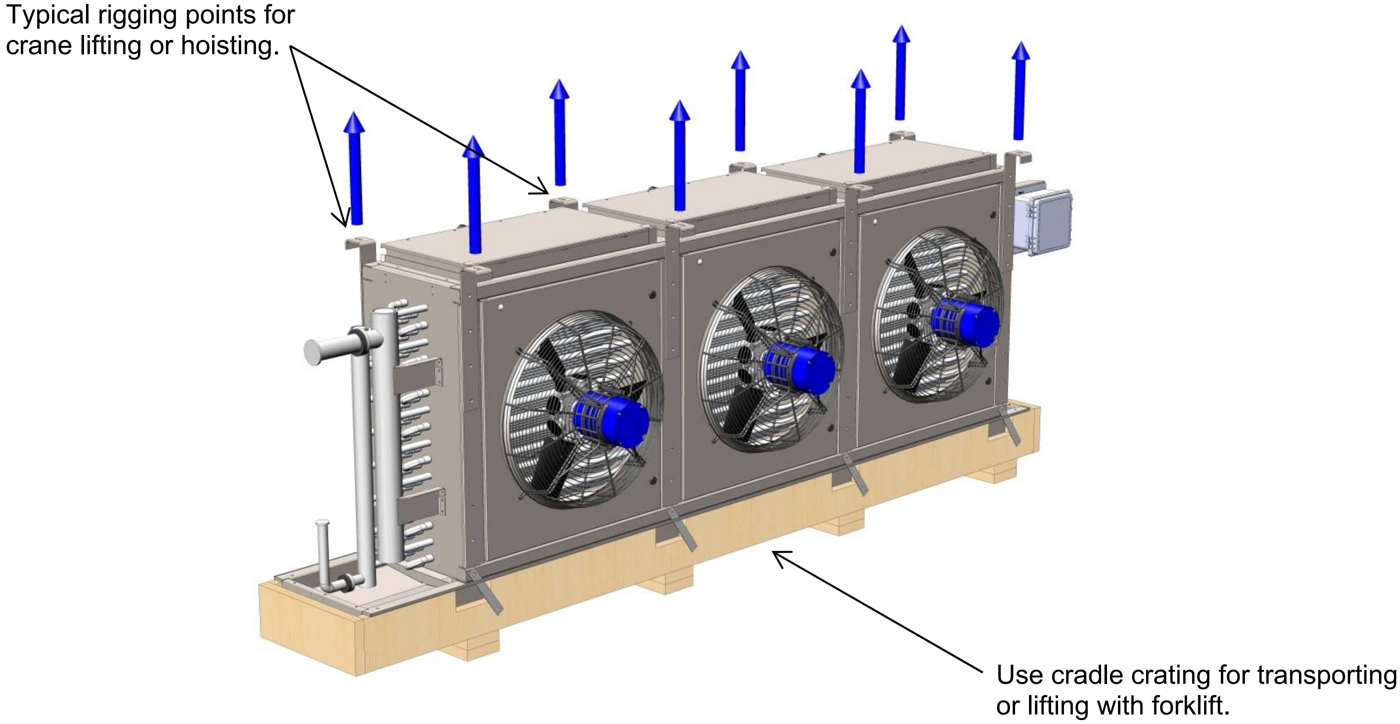
2.2.5. Store unit in a clean, dry area protected from adverse ambient conditions, and away from traffic and congestion that could cause damage.

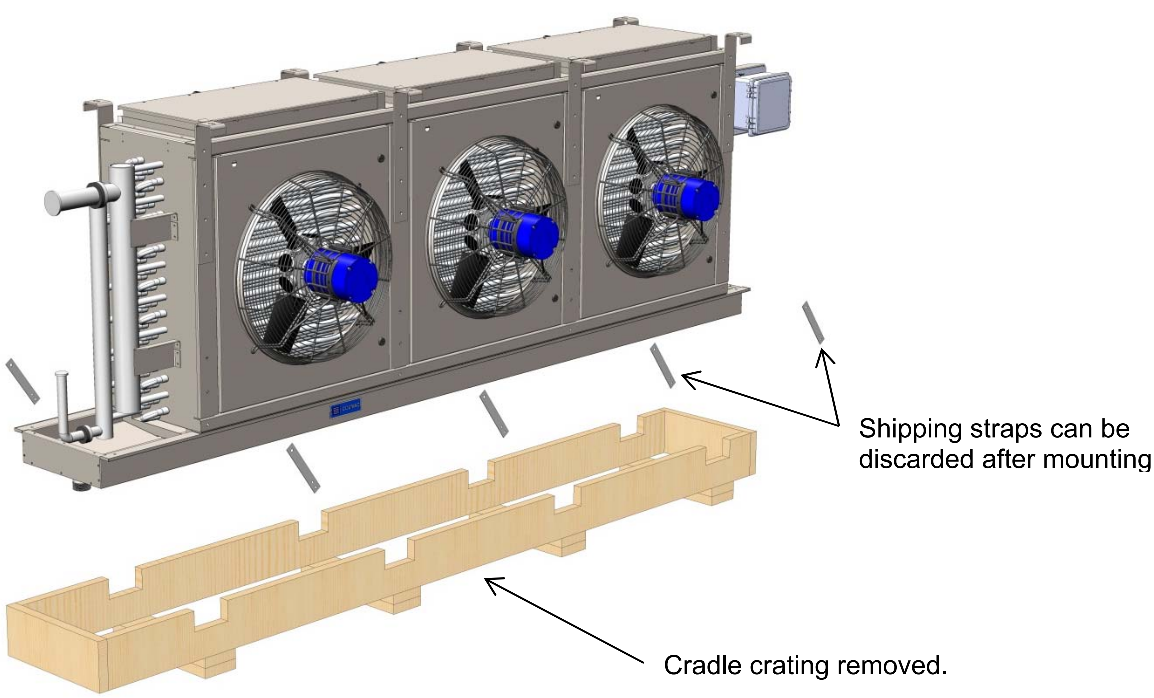
2.2.6. Units stored for long periods of time should have the fan motor shaft turned several revolutions on a monthly basis to prevent the motor bearings from seizing.

2.2.7. Use shipping container and forklift to transport unit from truck to storage area and from storage area to installation area. See Submittal drawing for weight of unit. Center of gravity is for all practical purposes the same as the physical center of the unit.

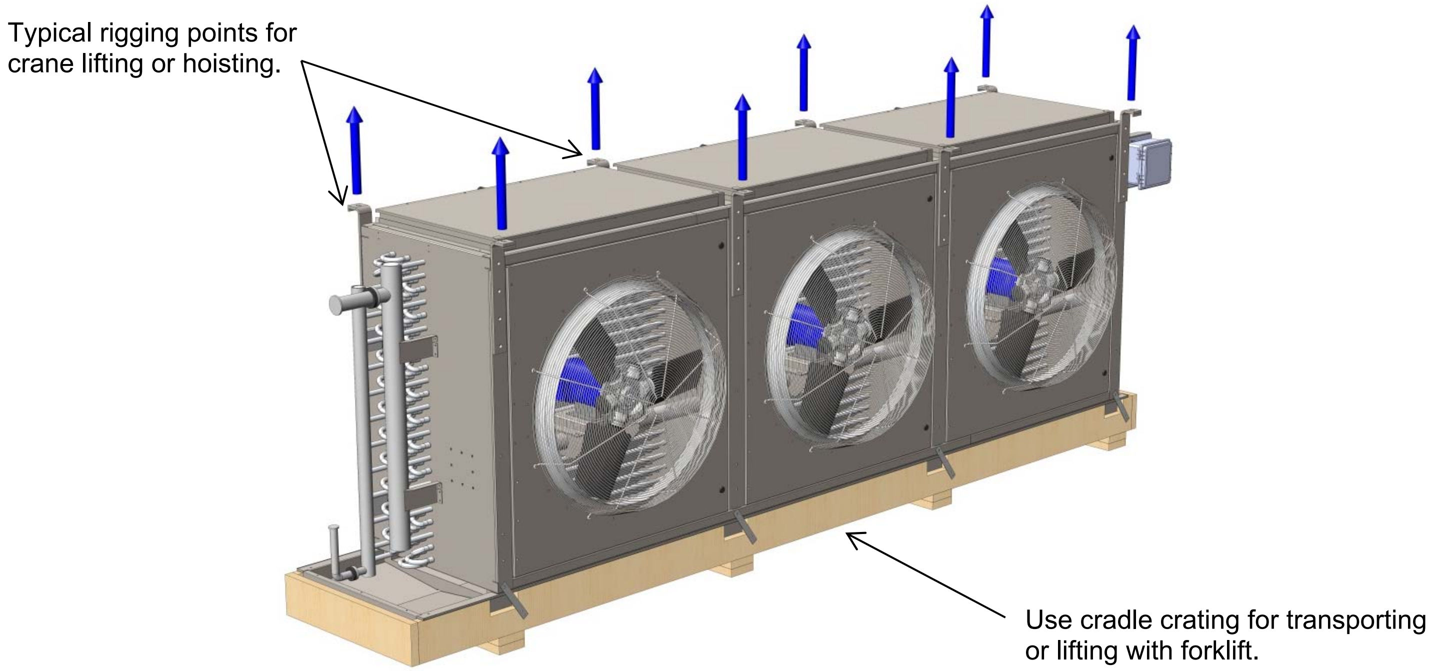
2.2.8. Shipping crating and lifting points for the A+S, A+M, A+L standard, A+L 45°, A+L penthouse and A+R are shown in graphics that follow.

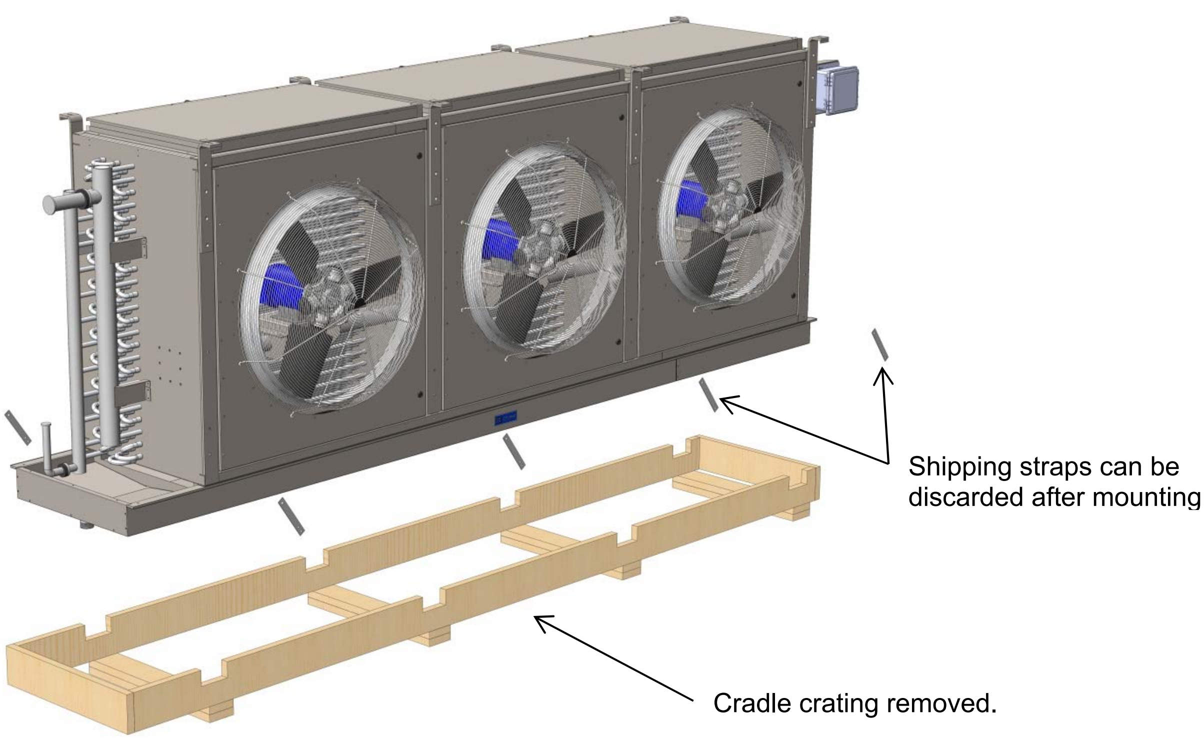
A+S Unit


Typical rigging points for
crane lifting or hoisting.
Use cradle crating for transporting
or lifting with forklift.

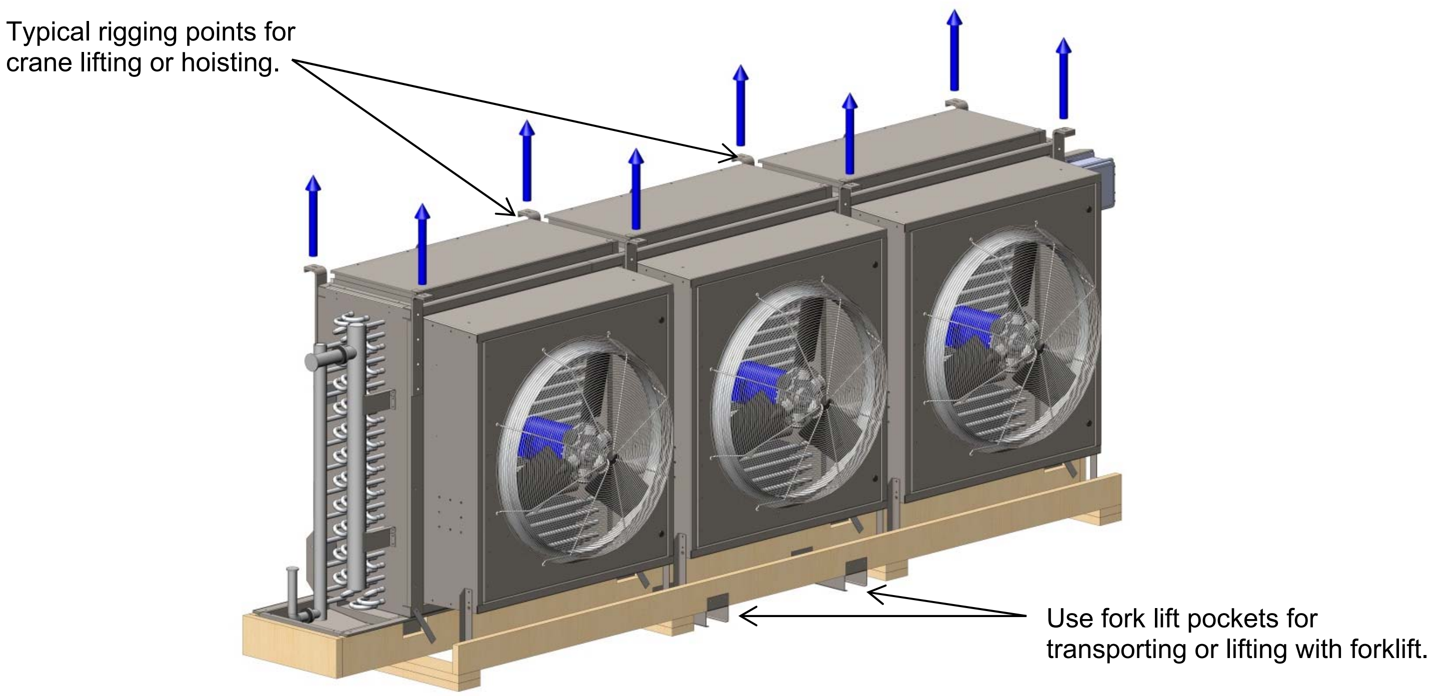

Shipping straps can be
discarded after mounting.
Cradle crating removed.

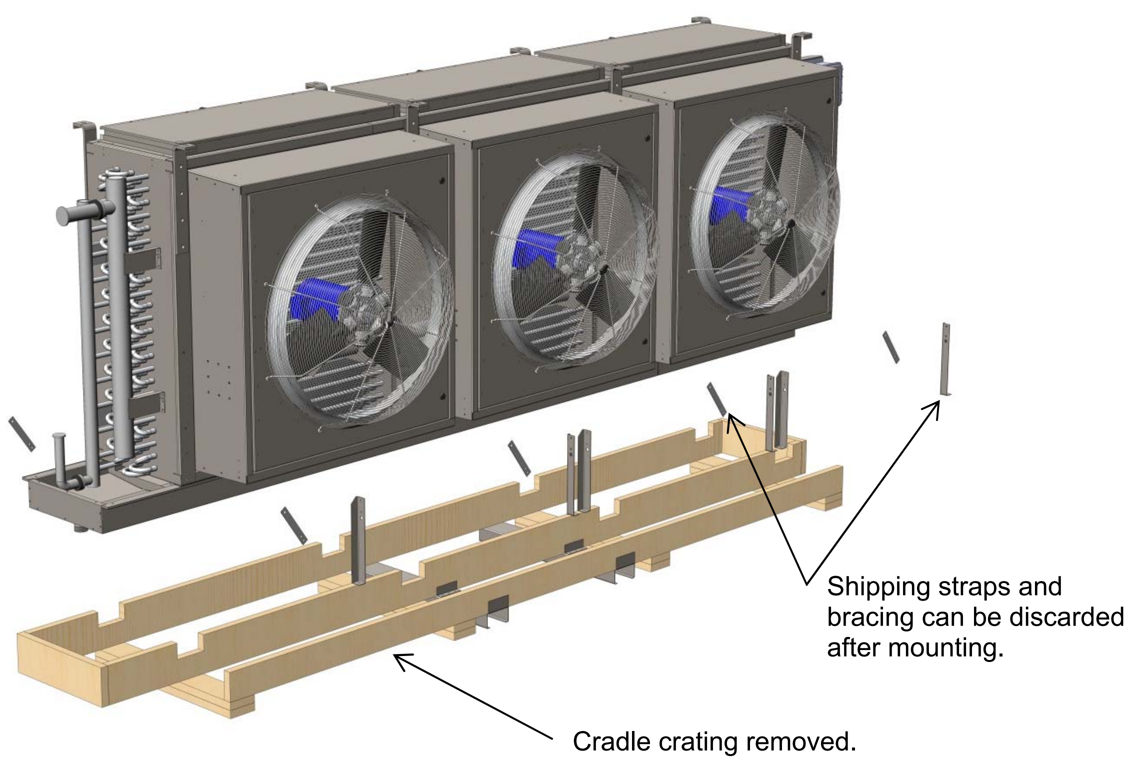
A+M Unit


Typical rigging points for crane lifting or hoisting.
Use cradle crating for transporting or lifting with forklift.

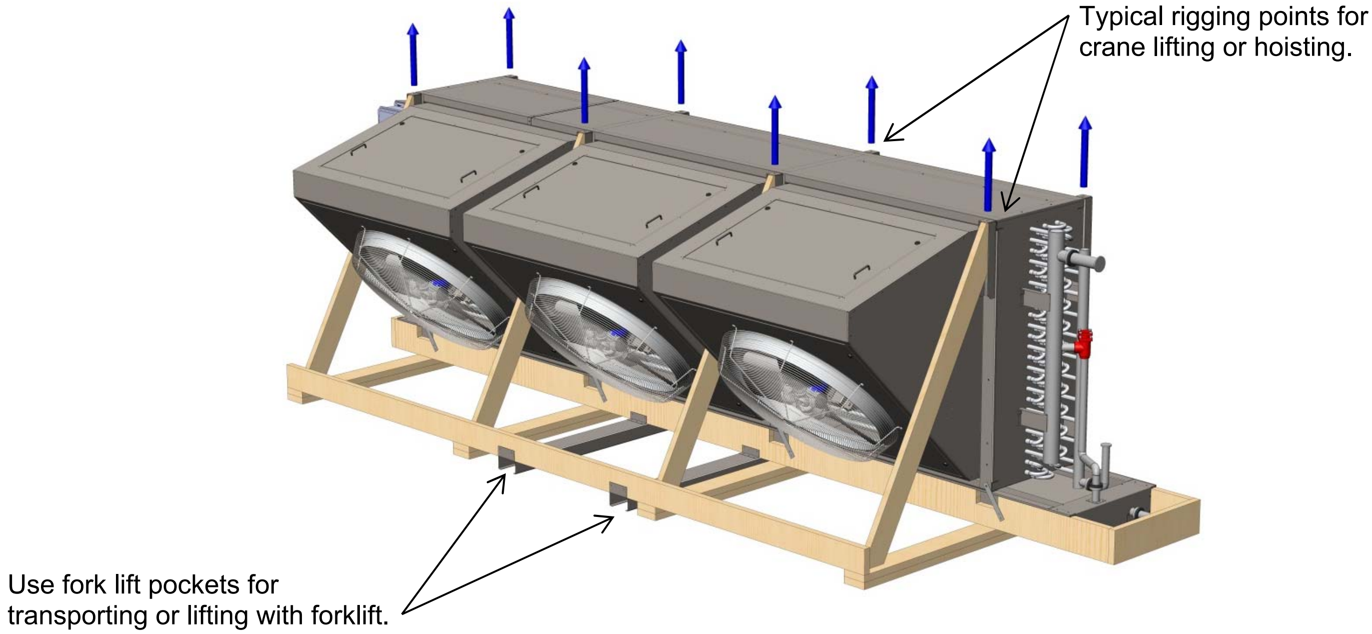

Shipping straps can be discarded after mounting.
Cradle crating removed.

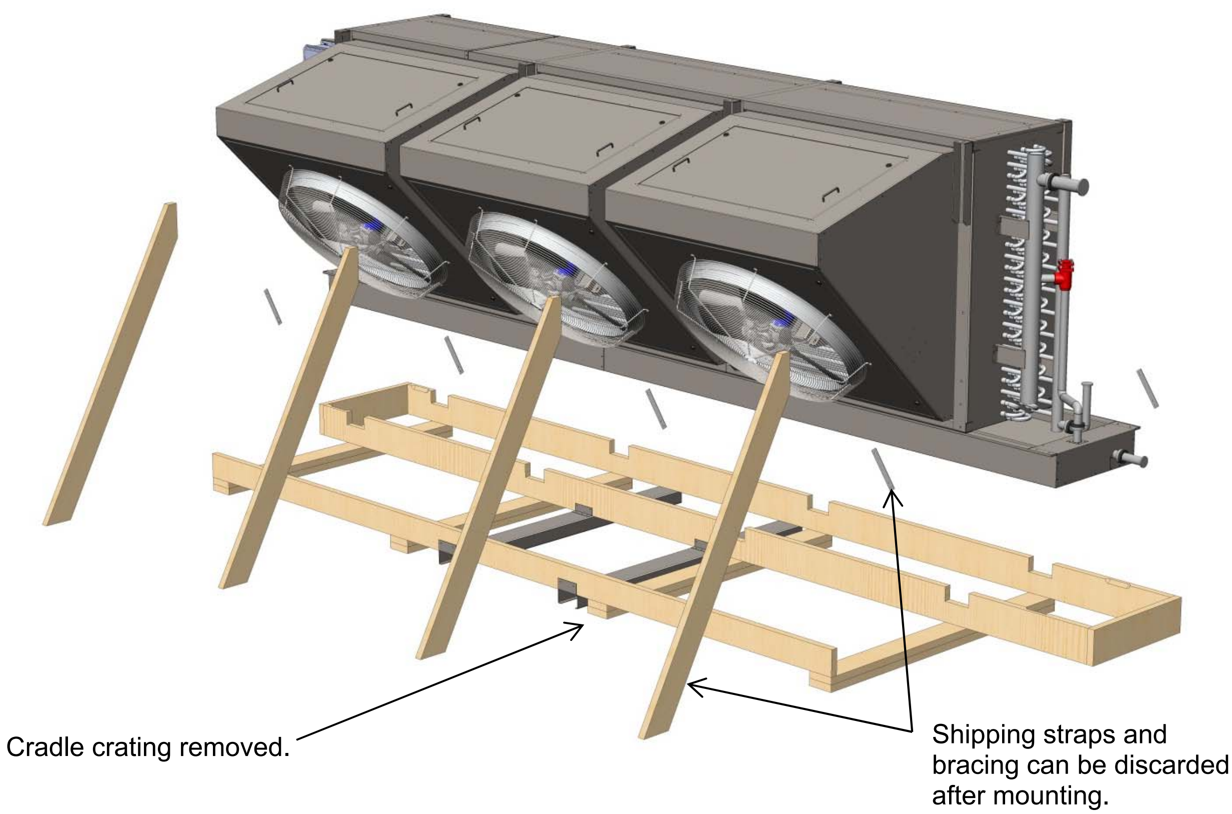
A+L Unit


Typical rigging points for
crane lifting or hoisting.
Use fork lift pockets for
transporting or lifting with forklift.

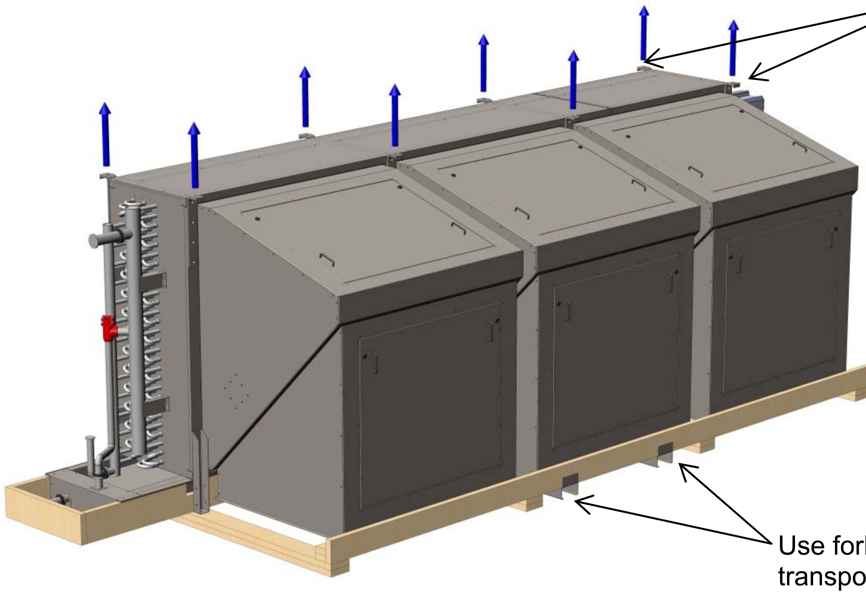

Shipping straps and
bracing can be discarded
after mounting.
Cradle crating removed.

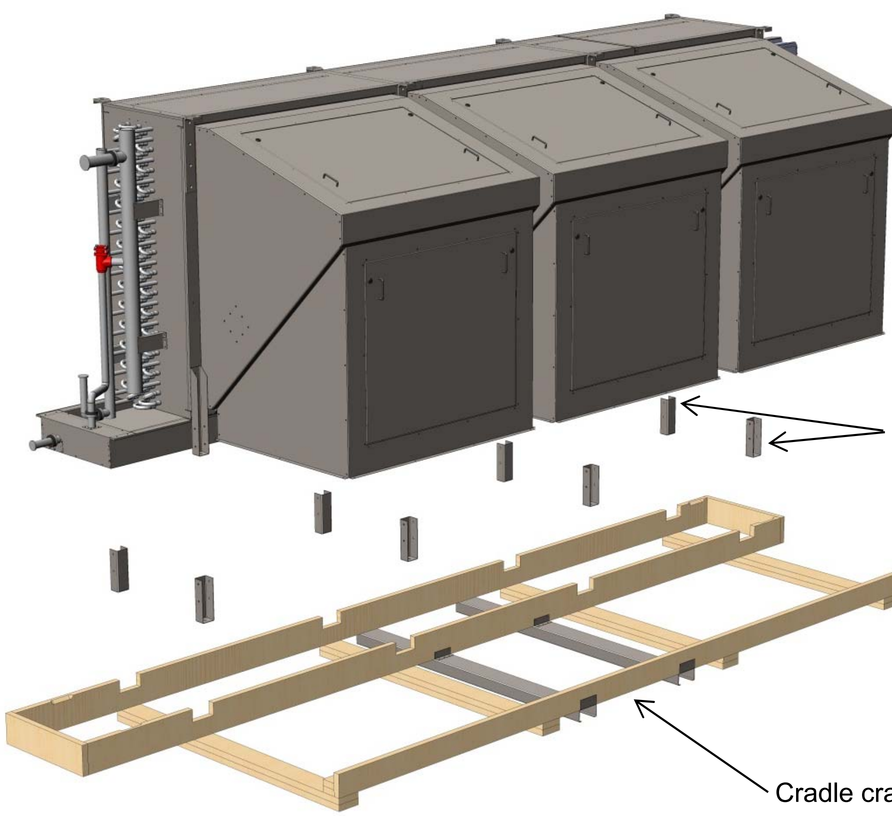
A+L 45° Unit


Typical rigging points for crane lifting or hoisting.
Use fork lift pockets for transporting or lifting with forklift.


Cradle crating removed.
Shipping straps and bracing can be discarded after mounting.

A+L Penthouse Unit





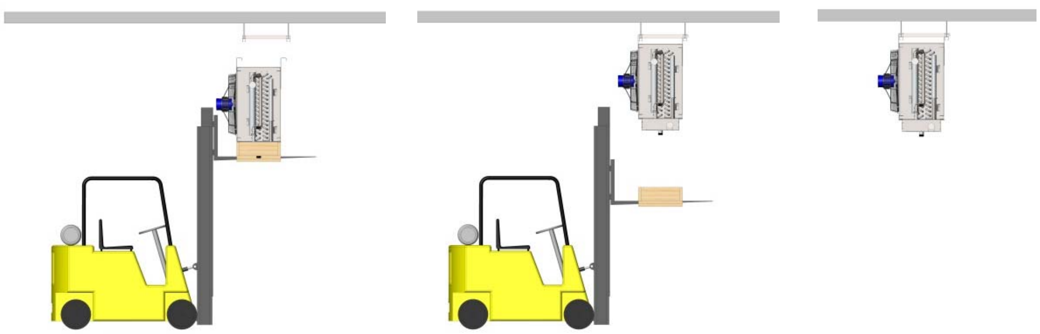
2.3. **Mounting**

2.3.1. Units are designed to be suspended from the ceiling structure. Care must be taken to ensure that the ceiling structure is adequately strong to support the weight of the unit(s). Each unit has hangers to accept two threaded rods at each end of the unit, and two between each fan bay. A rod must be used for each hanger. The installer must ensure that the size of the rod used is adequate to support the unit for any local conditions (seismic, etc.). In some cases, additional hanger bracing may be required.

2.3.2. Hanger rod and hardware selection and size are to be provided by the design engineer using sound engineering practices. For proper support, all hangers must be used.

2.3.3. The unit must be lifted to the secured hanger rods and secured in place such that the top of the unit is level and each hanger provides equal support. Securely tightened double nuts with washers, or equivalent, must be used above and below the hanger hole to minimize the chances of loosening due to vibration.

2.3.4. Units can be provided with the Colmac Smart Hanger system which reduces installation time. Smart Hanger brackets and rails allow air cooler units to be hung from the ceiling without any personnel leaving the floor level.



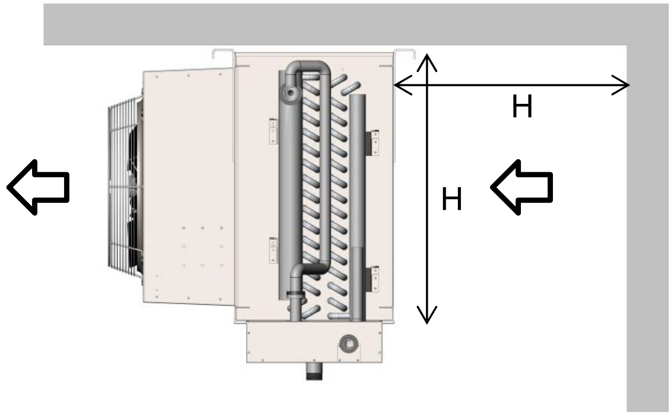
2.3.5. Adjustable legs are provided optionally for floor mounted installations. For proper support, all legs must be supported on a level structural member and must be securely positioned such that the top of the unit will be level.

2.3.6. Depending on the location and installer preference, the shipping/handling skid may be removed before or after the unit is set in its final position. Once set in position, all legs should be bolted or welded to the supporting structure to prevent movement.

2.4. **Location**

2.4.1. For best placement, units should be located in the room opposite the doors, or placed in such a way that air from open doors cannot be drawn directly into the evaporator coil. Colmac recommends against the placement of units directly over doorways. If no alternative exists except placement over doorways, steps must be taken to restrict air infiltration and mitigate dockside moisture.

2.4.2. Unit(s) should be located to permit unobstructed airflow both to and from the unit. The intake face of the unit should be located at least one unit height away from any wall or other significant obstruction. The discharge area should be adequately free and clear of obstructions, such as building structures, racks, or product, to permit the desired air throw.



2.4.3. For units with removable panels for coil cleaning, clearances should be greater for ease of access and ladder placement.

2.4.4. Units with hinged fan panels require a completely unencumbered area slightly greater than the hinged panel width.

2.4.5. In general, it is good practice to provide approximately 3-feet clearance on all sides of the unit to permit inspection, service, and maintenance.

2.4.6. If the unit has electric defrost heaters, allow for the necessary heater pull area at the end(s) of the unit, as noted on the unit drawings.

2.4.7. The unit(s) should be located so that the air pattern covers the entire room.

2.4.8. Minimize refrigerant pipe runs relative to the compressors. Minimize drain line runs.

2.4.9. The units must be mounted level for proper performance and refrigeration oil return.

2.4.10. Defrost water drain lines should be pitched away from the drain connections on the unit.

3. PIPING

3.1. **Refrigerant Piping**

3.1.1. For Ammonia applications, all refrigeration and piping components must be installed by qualified personnel in accordance with the IIAR Ammonia Refrigeration Piping Handbook and other applicable local and national codes. Piping practices for ammonia are also described in the “System Practices for Ammonia Refrigerant” chapter in the ASHRAE Refrigeration Handbook.

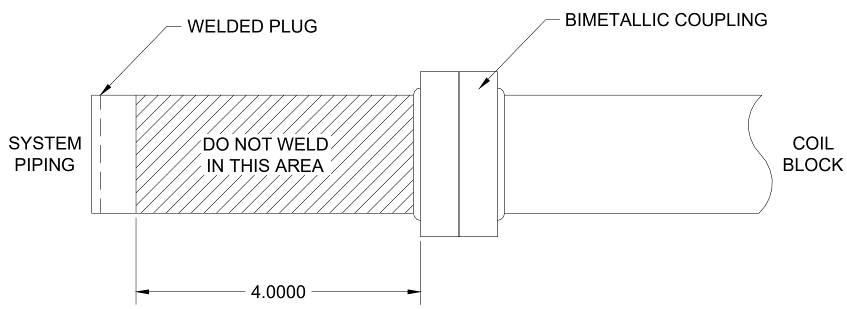
3.1.2. For Halocarbon applications, all refrigeration and piping components must be installed by qualified personnel in accordance with the “System Practices for Halocarbon Refrigerants” chapter in the ASHRAE Refrigeration Handbook and other applicable local and national codes.

3.1.3. Piping is to be designed and supported independent of the evaporator to minimize the transmission of vibration, to permit expansion and contraction, and to impose no load on the evaporator connections.

3.1.4. Pipe sizes are to be established according to good engineering design practices, taking into account all applicable facets of the system: the connection size provided by Colmac should not be used to determine the system piping.

3.1.5. The nitrogen holding charge should be permitted to remain intact as long as possible. When ready to connect the refrigerant piping, slowly vent the nitrogen charge to the atmosphere, and then remove the temporary connection caps. Note that these temporary capping provisions are not intended for refrigeration service and must be removed prior to placing the coil in service.

3.1.6. Standard coil connections for units having all aluminum coil construction utilize bimetallic couplings with carbon steel stubs which can be welded directly to system piping after removal of the factory welded cap. Remove cap so that at least 4” of the connection stub remains. Do not weld within 4” of the bimetallic coupler.



3.1.7. Carbon steel connections will be Schedule 80 pipe for connections less than or equal to 1-1/2” in diameter or Schedule 40 for connections 2” in diameter and greater.

3.1.8. Standard coil connections for halocarbon systems are copper “sweat” connections.

3.1.9. Prior to charging the system with refrigerant, the entire system must be pressure tested to ensure there are no leaks and evacuated to remove moisture.

3.2. **Thermal Expansion Valves**

3.2.1. Perform the following tasks when installing a thermal expansion valve (TXV) on a direct expansion system:

- Confirm that the distributor orifice and retainer wire is in place and was not dislodged during shipping and handling. Note that some hot gas defrost systems will have a side port for hot gas located between the distributor orifice and the distributor.
- For ammonia systems, confirm that the discharge tube is removed from the outlet of the TXV.
- Install the expansion valve immediately adjacent to the distributor with no elbows, valves, or fittings in between. If a side port must be provided, the orifice must be removed to the upstream side of the port, adjacent to the TXV.
- Connect the equalizer tube.
- Secure the expansion valve bulb directly on a horizontal length of pipe, as close to the suction header as possible, but not at a trap nor downstream from a trap. The

preferred location on the pipe is in the 3, 4, 8, or 9 o'clock position. Do not place the bulb at the 6 or 12 o'clock positions.

3.2.2. CAUTION: It is recommended that a suction trap, or suction accumulator, be used on all direct expansion systems for compressor protection.

3.3. **Hot Gas Defrost Piping**

3.3.1. With this method of defrost, some of the hot discharge gas from the compressor is routed into the evaporator instead of the condenser. During hot gas defrost, the coil temperature should be high enough to melt frost and ice on the coil, but low enough so that heat and steam loss to the refrigerated space are minimized.

3.3.2. Only 1/3 of the evaporators in a system should be defrosted at one time. Example: if total evaporator capacity is 100 tons (352 kW), then evaporators with no more than 33 tons (116 kW) of capacity should be defrosted at once. Consult factory if your system does not permit this.

3.3.3. Suggested methods of piping can be seen in Figure 1 thru 4. To maintain uninterrupted gas flow and a clear, fully drainable condensing surface, hot gas is always fed through the evaporator from the top down. For a bottom feed coil, this involves feeding the suction header with hot gas, as is seen in Figure 1. For a top feed coil, like in a Top Feed Recirculated or a Direct Expansion evaporator, the liquid header/distributor is fed with hot gas. This can be seen in Figure 2 for Top Feed Recirculated and in Figure 3 for Direct Expansion. Figure 4 shows hot gas piping for gravity flooded evaporators.

3.3.4. Figures 1 through 4 show control valve groups arranged for forward-cycle hot gas defrost. With this method, hot gas is piped in series through the unit cooler, first through the hot gas drainpan loop, and then through the coil. This method requires the use of a third line to the air unit to supply hot gas. Consult the Factory for information regarding other hot gas defrost options.

3.3.5. For evaporators with cooling capacity 15 tons and greater, a soft start solenoid valve is recommended (See Figures 1 through 4). Soft Start uses a secondary, smaller solenoid capable of letting a reduced amount of hot gas into the defrost system at the beginning of defrost, while the main hot gas solenoid remains closed. Once the system is up to a pre-designated pressure (~40 psig), the main hot gas solenoid is opened, allowing the system to approach its normal operating pressure. The Soft Start system eases the unit cooler into the defrost cycle, limiting unwanted problems like check valve chatter, pipe movements, and most of all, liquid hammer. This control method is particularly useful on larger systems.

3.3.6. All hot gas piping located in cold spaces should be insulated, as well as all hot gas piping located outdoors in cold climates.

3.3.7. The amount of hot gas supplied will depend on the inlet pressure of the hot gas, and the capacity of the air unit.

3.3.8. Ammonia - Hot gas is typically supplied to evaporators by one of two methods:

- Install a pressure regulator in the compressor room at the hot gas takeoff. Set the regulator to approximately 100 psig (689.5 kPa), then size the piping to achieve 75 to 85 psig (517 to 586 kPa) condensing pressure at the evaporators, accordingly.

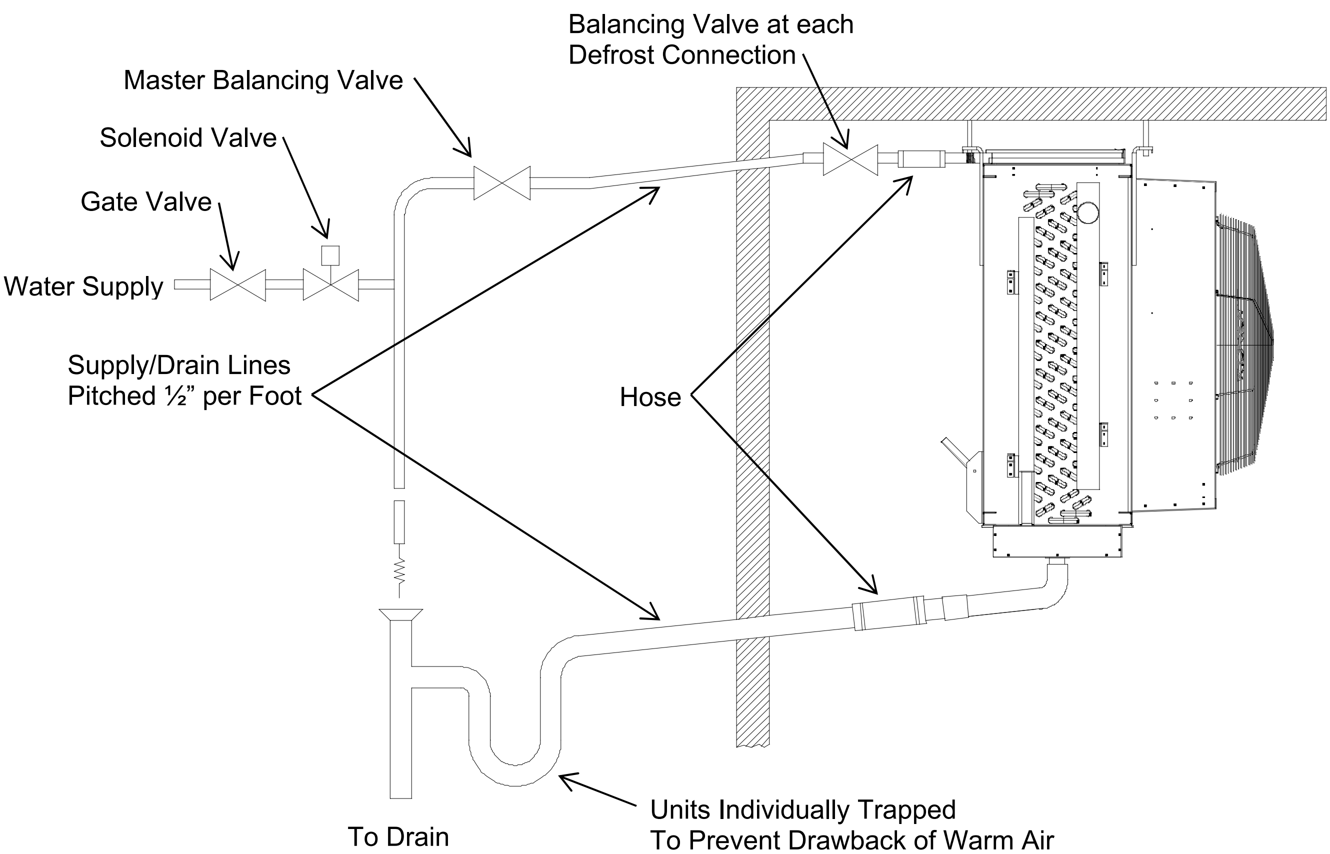
- In branches leading to each evaporator from the main hot gas line, install a pressure regulator set at approximately 75 to 85 psig (517 to 586 kPa), then size the branches accordingly.

3.3.9. Halocarbon – Hot gas piping is typically sized to accommodate twice the normal refrigerant mass flow from the evaporator. Pressure drop is not as critical for the Halocarbon defrost cycle, so refrigerant velocity can be used as the criterion for line size. It is suggested that hot gas lines are sized for the refrigerant velocity between 1000 to 2000 ft/min (5 to 10.2 m/s).

3.4. **Water Defrost Piping (Supply Water)**

3.4.1. Water defrosting consists of distributing water over the coil surface for a very short period of time, then draining the water from the piping before freezing can occur.

3.4.2. The figure below shows typical water defrost piping and controls layout for water defrosted evaporators. A solenoid valve in the water supply line to one or more defrost units, opens under control of an automatic timer to allow water to the units. Water flow to unit water distribution pans is metered by manually adjusted balancing or globe valves. A length of 1/4 in OD tubing is installed as shown in all of the figures to drain the supply piping when the solenoid valve closes, and the defrost period ends. A slope of 1/2 in. per foot is recommended for all supply lines to maintain adequate drainage. All four unit coolers are piped similarly, with the major exception being the A+D unit cooler. The A+D has two water distribution pans per side and two drainpans, and as such, requires additional consideration when piping.



3.4.3. For normal conditions, Table 2 may be used to select water supply sizes. However, if supply water pressure is lower than 30 psig (207 kPa), then the supply piping should be sized larger.

3.4.4. The following procedure should be used when sizing supply water piping:

- Choose a preliminary pipe size from Table 2.
- List the equivalent lengths of all fittings and valves given in Table 3.
- Add the sum of all equivalent lengths, to the lengths of all straight pipe runs.
- Divide the total length from step 3 by 100.
- Obtain the Pressure Loss per 100 feet of pipe from Table 6. Multiply this by the number obtained in Step 4. (This is the pressure loss through the pipe, valves and fittings due to length and flow impedances)
- List the change in elevation (+ is up, - is down) of all vertical pipe runs and determine pressure losses in pipe from the gain in elevation from Table 4. The sum of Step 5, Step 6 plus a 5 psig allowance, is the total pressure loss through pipe valves and fittings, and must not exceed the water pressure in the supply main. If it does exceed supply pressure, recalculate steps 2 through 7 with a larger pipe.

Table 2
Recommended Pipe Size, Water Defrost Supply

Pipe Size	Schedule 40 Steel		Copper & Plastic	
(IPS, inches)	GPM	L/s	GPM	L/s
1	3 to 7	(0.2 to 0.4)	3 to 7	(0.2 to 0.4)
1-1/4	8 to 15	(0.5 to 0.9)	8 to 12	(0.5 to 0.8)
1-1/2	15 to 22	(1.0 to 1.4)	13 to 20	(0.9 to 1.3)
2	23 to 40	(1.5 to 2.5)	21 to 45	(1.4 to 2.8)
2-1/2	41 to 70	(2.6 to 4.4)	46 to 80	(2.9 to 5.0)
3	71 to 130	(4.5 to 8.2)	81 to 130	(5.1 to 8.2)
4	131 to 250	(8.3 to 15.8)	131 to 270	(8.3 to 17.0)

* Based on pressure loss of 1 to 4 ft / 100 ft (100 to 400 Pa/m)

Table 3
Equivalent Length of Water Defrost Pipe Fittings, Feet

Pipe Size, (IPS, inches)	1	1-1/4	1-1/2	2	2-1/2	3	4
Solenoid	15.0	16.0	16.0	18.0	18.0	20.0	--
90° Elbow	5.2	6.6	7.4	8.5	9.3	11.0	13.0
Tee	6.6	8.7	9.9	12.0	13.0	17.0	21.0
Coupling or Gate Valve	0.8	1.1	1.2	1.5	1.7	1.9	2.5
Globe Valve	29.0	37.0	42.0	54.0	62.0	79.0	110.0
Angle Valve	17.0	18.0	18.0	21.0	22.0	28.0	38.0

Add equivalent length of all fittings to length of same straight pipe to obtain total length for use on Table 8.

Table 4
Pressure Loss Due to Elevation

Elevation, (ft)	5	7	9	12	16	23	35	46	60
Pressure Loss, (psi)	2	3	4	5	7	10	15	20	26

Table 5
Water Defrost
Recommended Drain Line Sizes

Water Flow, (GPM)	15	25	42	63	89	170	275	550
Pipe Size, (IPS, inches)	2	2.5	3	3.5	4	5	6	8

Table 6
Water Capacity, GPM
Sch 40 Pipe

Pipe Size	**Pressure Loss Per 100 ft, psi**						
(IPS, Inches)	**2**	**5**	**10**	**15**	**20**	**30**	**50**
1	8	12.8	19.1	24	27.8	33.9	44.5
1-1/4	17.4	26.9	29.7	49.5	57.4	70	91.9
1-1/2	25.9	41	60	74.1	85.5	106.5	140
2	51.4	79.6	116.7	144.7	166.9	203.2	268
2-1/2	80.9	127.6	186	229	264.6	330.8	390
3	144.3	227.6	331.6	407.2	467.7	575.4	--
4	292	469.6	671.8	826.8	961.7	--	--

** For SCH 40 steel pipe. Multiply psig values by 0.86 for PVC or Copper Pipe.

Notes:

- If the water supply pressure is unknown, it may be measured by installing a gauge and valve at the “takeoff” point. The pressure should be measured with water flowing near the desired rate.
- In some instances, (as with 2” pipe), it may be desirable to use a solenoid valve to fit the next size smaller pipe. (As with all valves and fittings, determine the correct equivalent length to calculate pressure loss)

3.5. **Defrost Drain Piping**

3.5.1. Drain connections from the drainpan should be individually trapped. Individual trapping prevents warm air from being drawn back through the drain pipe of non-defrosting units. Drain line size should be at least equivalent to the unit cooler drain connection size. For Water Defrost, use Table 5 for sizing defrost drain line sizes.

3.5.2. Within the refrigerated space, the drain line should be pitched sharply down, at least 1/2 in/ft (4 cm/m) and be as short as possible. It should also be heat traced and insulated along its entire length. Traps should be located in a warm area outside the refrigerated space. Any traps or extensive lengths of pipe located outdoors must be heated and insulated to prevent freeze up. Any such heater should be connected for continuous operation. Standard industry practice is for 20 Watts / linear foot of pipe @ 0°F (-17.8°C) and 30 Watts / linear foot of pipe @ -20°F (-28.9°C).

3.5.3. The trap requires static head to overcome the resistance to flow. For this reason, it should be located in the vertical piping at least 2' below the unit (preferably outside of the refrigerated space). The trap should not be heated if it is located in a space in which the temperature is continuously above freezing. This avoids the possibility of boiling the trap dry. The piping should include a cross or tee to facilitate cleanout.

3.5.4. All piping should be adequately supported independent of the unit so no load is imposed on the pan connection. In some cases, consideration should be given to using a union at/near the pan connection to enable disconnecting the drain line for maintenance.

3.5.5. Caution- Do not apply torque to the drain pan connection; use two wrenches to secure the pipe union.

3.5.6. Drainpan and drain lines should be inspected routinely for evidence of ice buildup. Periodic manual maintenance of icing drainpans and drain lines may be required if less than ideal frosting/defrosting conditions have existed. See the Troubleshooting chart for information regarding the diagnosis of freezing drainpans and drain lines.

3.6. **Connection Sizes**

3.6.1. Refrigerant, defrost supply, and defrost drain connection sizes are pre-determined by the factory and the customer. Connection sizes are automatically selected through the use of our proprietary selection software. More information on connection sizing can be found in the ASHRAE Refrigeration Handbook.

4. ELECTRICAL

4.1. **General**

4.1.1. All wiring must be performed by qualified personnel, in compliance with national and local codes and standards.

4.1.2. Refer to the unit nameplate and the specific certified wiring drawings for details. The nameplate contains the required electrical power characteristics and the serial number, which can be cross- referenced to the certified prints.

4.1.3. Standard motors for A+R, A+S, and A+D air coolers include internal thermal overload protection. Custom motors may require external overload relays.

4.1.4. Standard motors for A+L and A+M air coolers do not include thermal overload protection.

4.1.5. Select feeder circuit protection, branch circuit protection, motor contactors, overload relays, and wire sizes in accordance with applicable local and national codes.

4.1.6. Field wiring connections are made to at a common electrical enclosure. The electrical enclosure and internal components may differ depending on unit type and customer specification.

4.1.7. Complete electrical controls with a UL 508 Enclosed Industrial Control Panel listing can be provided at the customer's request.

4.1.8. Units equipped with electric defrost and/or special electrical controls will be provided with specific wiring diagrams.

4.2. **Variable Frequency Drives**

4.2.1. There are many factors that can contribute to the success or failure of VFDs applied to Colmac equipment, most of which are the direct responsibility of the installing electrical contractor. The general design requirements listed below represent the minimum criteria for proper VFD system design. Care should be taken to follow all of the drive manufacturer's recommendations and all applicable electrical codes and standards.

- Motors - Ensure that "Inverter Duty" rated motors are used in situations where VFDs are applied. Colmac motors that are specified as "Inverter Duty" will comply with the National Electrical Manufacturers Association (NEMA) requirements for VFD compatible motors. This type of motor construction, which includes a special winding wire insulation system as well as phase paper installed between the windings, is the accepted industry standard for inverter duty motors.

- Grounding - It is essential that the electrical system, building steel, motor and drive be properly grounded. The National Electric Code (NEC) describes the minimum requirements for grounding and bonding an electrical system for safe operation. In addition to providing a ground from the drive chassis and motor frame to earth ground, Colmac recommends a separate ground conductor from the motor frame to the VFD ground bus. Proper grounding is a critically important means of mitigating bearing current failures.

- Cabling – Conductors should be rated and sized appropriately for the motor load, voltage drop, and environmental conditions. Colmac recommends the use of shielded VFD cable for several reasons. VFD cables are specifically designed for higher voltages, manufactured to higher quality standards and provide a more consistent insulation wall thickness. VFD specific cables are designed to withstand the reflected wave and resulting corona effects. Also, minimizing the length of the conductors from the drive to the motor will help reduce the magnification of the reflected wave. Shielded cables can also help to reduce bearing pitting by directing the destructive current to ground. Both ends of the shield should be bonded and care should be taken to maintain this bond when there are interruptions in the conductor run (i.e. local motor disconnect).

- Carrier Frequencies – Colmac recommends setting the drive carrier frequency as low as possible (typically 2 kHz). Lower carrier frequencies result in higher levels of audible VFD noise, but will help to reduce destructive bearing currents.

- Line and Load Reactors – Ensure that the drive manufacturer's recommendations are followed with regard to sizing and use of line and load reactors. Issues with line voltage imbalance, reflected wave phenomena, switched power factor correction capacitors, and long line lengths can be mitigated with properly sized line and load reactors. Line lengths should be minimized whenever possible.

- Motor Speed – Generally it is not recommended to over speed motors or to operate motors at less than 25% of the motor rated speed.

5. GENERAL OPERATION

5.1. **Before Startup** - Following is a representative checklist of items to be checked prior to startup. It is not, nor is it intended to be, a comprehensive checklist for the many varying industrial refrigeration systems. Consult with a qualified system startup expert for assistance.

- Make sure unit is mounted securely using all hangers, and is level.
- Make sure unit voltage agrees with supply voltage.
- Make sure system is wired correctly and in accordance with the guidelines laid out in this IOM, as well as local and national standards that may apply.
- Check torque on all electrical connections.
- Confirm the supply voltage is within 10% of design and the phase-to-phase imbalance is within 2%.
- Make sure that all fan set screws are tight.
- Check fan direction and amperage.
- Make sure all piping is done completely and in accordance with the guidelines laid out in this IOM, as well as in accordance with standard good practice.
- Make sure that liquid supply suction and hot gas supply (as applicable) service valves are open.
- Check drainage of drain pan and drain piping by pouring water into drainpan.
- Check water defrost distribution – see “Regulating Water Flow Rate”. (Water Defrost units only)

5.2. **After Startup**

- Check the compressor for possible overload immediately after start up.
- Check fan rotation of all fans to make sure air is moving in proper direction.
- Check the air unit operation for proper refrigerant charge.
- Confirm the room thermostat and/or control system are functioning properly.
- Look and listen for any excessive vibration, severe valve chatter, water hammer, or moving pipes, and correct as necessary.
- Heavy moisture loads are usually encountered when starting a system for the first time. This will cause rapid frost buildup on the unit. During the initial pull-down we suggest that the frost buildup be watched and that the unit be defrosted manually as required.
- Evaporators with liquid feed orifices for liquid overfeed must have liquid refrigerant supplied to the coil inlet at a pressure 5 psig (35 kPa) above saturated suction pressure, and at a temperature not exceeding 30°F (16.7°C) above saturated suction temperature. Please consult factory if conditions exceed these recommendations.

5.3. **Field Adjustments** - Perform the following functions when commissioning A+ Series™ evaporators, based on the refrigerant feed system and defrost technique being employed on the particular unit. These instructions are not, nor are they intended to be, a comprehensive list of tasks required to successfully commission all A+ Series™ evaporators. Consult with a qualified system startup expert for assistance.

5.3.1. Recirculated & Controlled Pressure Receiver Feed:

- Open hand expansion valves (HEVs) slowly and observe frost/condensate formation on all return bends, top and bottom alike.
- The proper setting may be achieved by observing the frost or condensate on all return bends and opening the HEV until all return bends are evenly wetted or frosted.
- Alternatively, if the defrost relief regulator is connected to the liquid line and is equipped with a gauge, set the HEV to achieve a 5 psi rise in pressure when the liquid solenoid valve is energized.

5.3.2. Flooded Feed:

- Verify that the liquid level is at the design level in the surge drum.
- Open and adjust the liquid feed HEV to allow for the solenoid to be energized approximately 70% of the time at design temperature difference (TD).

5.3.3. Direct Expansion Feed:

- After room temperature has been achieved, check the superheat, and adjust the thermal expansion valve.
- If the coil is being starved, resulting in too much superheat at the desired room temperature, reduce the superheat setting of the valve by turning the adjusting stem counter-clockwise.
- If there is not enough superheat, increase the setting by turning the adjusting stem clockwise.
- After waiting approximately 30 minutes, re-check the superheat and re-adjust the thermal expansion valve.
- Repeat until the unit operation is stable.
- Note that 10°F is the minimum superheat required to fully stroke a conventional TXV and that 10°F superheat requires an 11 or 12°F split between the room return air temperature and the evaporating temperature.

5.3.4. Brine, Glycol or Water Feed:

- Vent the system, bleed off all air, and check for water hammer. Verify the feed solenoid valve or mixing valve function.

5.3.5. Hot Gas Defrost:

- Allow the unit to frost, then initiate the defrost cycle.
- Monitor the leaving air temperature. It should show a rise if the pump-out time is sufficient.
- Monitor the condensate flow. It should diminish to a trickle prior to hot gas termination.
- Check the bottom of the coil for residual ice or frost.
- Do not allow long hot gas times that cause coil steaming.
- If more than 15 minutes of hot gas is required, there may be system design problems.
- Monitor the bleed time. The pressure of the coil should be within 25 psig of suction pressure by the end of the bleed cycle.
- Monitor the fan delay. The free water on the coil should be frozen prior to the fans starting.
- Make adjustments to the various function times as necessary

5.3.6. Electric Defrost:

- Allow the unit to frost, then initiate the defrost cycle.
- Monitor the leaving air temperature. It should show a rise if the pump-out time is sufficient.
- Monitor the condensate flow. It should diminish to a trickle prior to heater termination.
- Check the bottom of the coil for residual ice or frost.
- Do not allow long heater on times that cause coil steaming.

- Verify the operation of the defrost termination thermostat and remove the start-up jumper, if used.
- Verify that all of the heaters are working by checking the amp draw.
- Monitor the fan delay. The free water on the coil should be frozen prior to the fans starting.
- Make adjustments to the various function times as necessary

5.3.7. Water Defrost:

- Allow the unit to frost, then initiate the defrost cycle.
- Monitor the leaving air temperature. It should show a rise if the pump-out time is sufficient.
- Monitor the water flow and check for even flow coverage, overflows or excessive splashing.
- Check the coil for any residual frost or ice.
- Monitor the fan delay. The free water on the coil should be frozen prior to the fans starting if the unit is in a freezer.
- Make adjustments to the various function times and flow rates as necessary.

5.4. **Defrost Selection**

5.4.1. Determination of defrost should be based on several variables. Energy costs, availability of sufficient supply of water or hot gas, system first cost considerations, and last but not least, the refrigerated spaces operating temperature. Air defrost can certainly not be applied in cold storage applications with temperatures below 38°F. Likewise, the use of a hot gas system in a +42°F (5.6°C) room is not appropriate. Table 1 shows recommended guidelines for defrost system selection relative to refrigerated room temperature.

Table 1
Recommended Room Temperature Ranges for Different Defrost Types

Temperature Range	Hot Gas Defrost	Water Defrost	Electric Defrost	Air Defrost
Low Temp (<20°F [-6.7°C])	YES	YES	YES	NO
Medium Temp (<38°F and >20°F [-6.7°C])	YES	YES	YES	NO
High Temp (>38°F [7.2°C])	N/A	N/A	N/A	YES

5.5. **Hot Gas Defrost Operation**

5.5.1. Condition of Operation - Hot Gas Defrost can be used for any design criteria, including Low-Temp and Medium-Temp.

5.5.2. Proper hot gas defrost operation is entirely dependent on hot refrigerant latent condensation during the defrost operation. This requires hot gas to be delivered to the evaporator at a saturation pressure necessary for condensation to occur during defrost. Typical design hot gas saturation temperatures run between 50°F (10°C) to 60°F (15.6°C). Table 7 shows the equivalent saturation pressures, for a variety of refrigerants, required at the evaporator to accommodate this temperature range.

Table 7
Hot Gas Pressures for Various Refrigerants

Refrigerant	R22	Ammonia (R717)	R507a	R404a
Hot Gas Pressure @ Evaporator	~85 to100 psig (~688 to 791 kPa)	~75 to 90 psig (~619 to 722 kPa)	~105 to 125 psig (~826 to 964 kPa)	~105 to 125 psig (~826 to 964 kPa)

5.5.3. Hot Gas Supply line pressure should be maintained at less than the system condensing pressure. This serves two purposes; the first being decreased energy losses due to excessive heat gain, and the second being that condensing pressure has a tendency to fluctuate with ambient conditions and with the load. Maintaining the Hot Gas Supply pressure at less than the system condensing pressure helps ensure a constant Hot Gas pressure at the evaporator.

5.5.4. Sequence of Hot Gas Defrost Operation

5.5.4.1. Recirculated Bottom Feed Evaporators (See Figure 1)

- Close Liquid Solenoid and continue operating fan motors.
- Pump down liquid refrigerant from coil for a period of approximately 15 minutes (or as long as required). Any cold liquid refrigerant remaining in the coil at the beginning of defrost will greatly reduce the effectiveness of the hot gas defrost operation and can extend the time required for defrost. Evidence of residual liquid refrigerant can be seen in the form of uneven melting or the absence of melting on the lower tubes of the evaporator coil.
- Stop fan motors.
- Open Hot Gas Pilot Solenoid to close Gas-Powered Suction Stop Valve.
- On Coils of 15 tons cooling capacity and larger, open Soft Start Hot Gas Solenoid to gradually bring coil up to near defrost pressure.
- Open Hot Gas Solenoid to start defrost. Duration of defrost should be long enough to clear coil and pan. Extending the defrost period longer than this is not necessarily better.
- Close Hot Gas Solenoid (and Soft Start Hot Gas Solenoid if applicable) to end defrost.
- Open Equalizing Bleed Valve to gradually bring evaporator back down to suction pressure.
- Close Hot Gas Pilot Solenoid to open the Gas-Powered Suction Stop Valve. At the same time, open the Liquid Solenoid to start cooling the coil.
- After a delay to refreeze remaining water droplets on the coil, restart the fans.

5.5.4.2. Recirculated Top Feed and Direct Expansion Evaporators (See Figure 2 and 3)

- Close Liquid Solenoid and continue operating fan motors.
- Pump down liquid refrigerant from coil for a period of approximately 15 minutes (or as long as required). Any cold liquid refrigerant remaining in the coil at the beginning of defrost will greatly reduce the effectiveness of the hot gas defrost operation. Evidence of residual liquid refrigerant can be seen in the form of uneven melting or the absence of melting on the lower tubes of the evaporator coil.
- Stop fan motors.

- Open Hot Gas Pilot Solenoid to close Gas-Powered Suction Stop Valve.
- On Coils of 15 tons cooling capacity and larger, open Soft Start Hot Gas Solenoid to gradually bring coil up to near defrost pressure.
- Open Hot Gas Solenoid to start defrost. Duration of defrost should be long enough to clear coil and pan. Extending the defrost period longer than this is not necessarily better.
- Close Hot Gas Solenoid (and Soft Start Hot Gas Solenoid if applicable) to end defrost.
- Energize the Defrost Relief Regulator to the wide open position to gradually bring the evaporator back down to suction pressure (equalize).
- Close Hot Gas Pilot Solenoid to open the Gas-Powered Suction Stop Valve. At the same time, de-energize the Defrost Regulator Valve.
- Open the Liquid Solenoid to start cooling the coil.
- After a delay to refreeze remaining water droplets on the coil, restart the fans.

5.5.4.3. Gravity Flooded Evaporators (See Figure 4)

- Close Liquid Solenoid and stop fan motors.
- Open Hot Gas Pilot Solenoid to close the two Gas-Powered Stop Valves in the coil liquid and suction lines.
- On Coils of 15 tons cooling capacity and larger, open Soft Start Hot Gas Solenoid to gradually bring coil up to near defrost pressure.
- Open Hot Gas Solenoid to start defrost. Duration of defrost should be long enough to clear coil and pan. Extending the defrost period longer than this is not necessarily better.
- Close Hot Gas Solenoid (and Soft Start Hot Gas Solenoid if applicable) to end defrost.
- Energize the Defrost Relief Regulator to the wide open position to gradually bring the evaporator back down to suction pressure (equalize).
- Close Hot Gas Pilot Solenoid to open the Gas-Powered Suction Stop Valves. At the same time, de-energize the Defrost Regulator Valve.
- Open the Liquid Solenoid.
- After a delay to refreeze remaining water droplets on the coil, restart the fans.

5.5.4.4. Setting Hot Gas Defrost Timer. Time periods should be set as follows:

- Length of defrost should be set to the minimum time necessary to melt all frost. Defrost operation beyond this point will convert liquid water to steam, leading to secondary condensation and freezing on non-heated areas of the unit cooler and introduced unwanted heat gain into the controlled space.
- Depending on frost loading conditions, defrost duration can typically last anywhere from 12 to 20 minutes, and in most cases, should never exceed 30 minutes.
- Actual defrost times must be determined from careful observation of defrost operation and adherence to the previously mentioned guidelines. Frost is usually heaviest on the air-entering side of the coil, and inspection of fins on this side can usually be used to determine if complete defrost has occurred. Periodic observation of the defrost cycle throughout the year is necessary to maintain a properly operating defrost system.

NOTICE: Once frost turns to ice, the amount of time required to melt increases. Incomplete defrosting may allow excessive ice to build up which could damage the machinery. Allowing ice to build up on the fan blades will result in excessive vibration which could lead to catastrophic failure. It is imperative that the end user inspect the unit coolers regularly for proper defrosting. Manual defrosting may be required to remove ice buildup.

5.6. **Water Defrost Operation**

5.6.1. Condition of Operation - Water Defrost can be used for all temperature ranges.

5.6.2. Sequence of Water Defrost Operation

- Stop refrigeration by closing liquid solenoid.
- Pump down liquid refrigerant from coil for a period at least equal to 15 minutes. Any liquid refrigerant that may remain in the coil during defrost will greatly reduce the effectiveness of the hot gas defrost operation. Evidence of residual liquid refrigerant during defrost can be seen in the form of uneven melting or the absence of melting on the lower tubes of the evaporator coil.
- Stop fan motors.
- Open water valve for the necessary time of defrost.
- Allow water to drain from fins.
- Bleed evaporator pressure back down to normal suction pressure.
- Start refrigeration to cool the evaporator.
- Restart fan motors.

5.6.3. Setting Water Defrost Timer

5.6.3.1. Instructions for adjustment of Defrost Timer should be shown in the Timer User's Manual.

5.6.3.2. Time periods should be set as follows:

- The delay period for pump down and fan stoppage is approximately 1 minute. With very large coils where time for pump-down after shutting the refrigerant solenoid valve may be longer, the delay period may be longer. Set the delay accordingly.
- Set the water spray to five minutes, initially. In actual practice, it may take as little as three minutes to clear frost from the coil, and only in rare instances would it take as long as fifteen minutes.
- Actual defrost times must be determined from careful observation of defrost operation and adherence to the previously mentioned guidelines. Frost is usually heaviest on the air-entering side of the coil, and inspection of fins on this side can usually be used to determine if complete defrost has occurred. Periodic observation of the defrost cycle throughout the year is necessary to maintain a properly operating defrost system. If more than fifteen minutes is required to completely remove frost, it is an indication that something may be wrong, such as inadequate water supply.
- Set drain period for two minutes. This should be ample time for water to drain off of the coil before starting up the fans.
- The frequency of defrosting will vary with room temperature and relative humidity.

NOTICE: Once frost turns to ice, the amount of time required to melt increases. Incomplete defrosting may allow excessive ice to build up which could damage the machinery. Allowing ice to build up on the fan blades will result in excessive vibration which could lead to catastrophic failure. It is imperative that the end user inspect the unit coolers regularly for proper defrosting. Manual defrosting may be required to remove ice buildup.

5.6.4. Specifying Water Defrost Temperature

5.6.4.1. Adequate temperature of the water defrost supply must be maintained throughout the defrost cycle to guarantee adequate defrost under varying room temperature conditions. Recommended water temperatures as a function of room temperature are found in Table 8.

Table 8
Recommended Water Defrost Temperatures

Room Temperature	Water Temperature
-20°F to 30°F (-28.9°C to -1.1°C)	At least 50°F (10°C)
30°F to 32°F (-1.1°C to 0°C)	At least 45°F (7.2°C)
32°F (0°C) and up	At least 40°F (4.4°C)

5.6.5. Regulating Water Flow Rate

5.6.5.1. Water flow rate is controlled by adjusting the balancing valve at each unit. Adjust flow rate to fully saturate the coil fin surfaces in defrost water, making sure not to overflow the distribution pan, which can result in undesirable splashing. In some areas, the water pressure may become very low during daytime hours due to usage in the same building or neighborhood. In such instances, it may be necessary to set the timer to defrost when adequate water pressure is available.

5.7. **Electric Defrost Operation**

5.7.1. Condition of Operation - Electric Defrost can be used for any design criteria, including Low-Temp, Medium-Temp, and High-Temp Applications.

5.7.2. Sequence of Electric Defrost Operation

- Stop refrigeration by closing liquid solenoid.
- Pump down liquid refrigerant from coil for a period at least equal to 15 minutes. Any liquid refrigerant that may remain in the coil during defrost will greatly reduce the effectiveness of the electric defrost operation. Evidence of residual liquid refrigerant during defrost can be seen in the form of uneven melting or the absence of melting on the lower tubes of the evaporator coil.
- Stop fan motors.
- Energize power to electric defrost heating elements for the necessary time of defrost.
- De-energize power to heating elements when defrost is complete.
- Start refrigeration to cool the evaporator.
- Restart fan motors.

5.7.3. Setting Electric Defrost Timer - Time periods should be set as follows:

- Length of defrost should be set to the minimum time necessary to melt all frost. Defrost operation beyond this point will convert liquid water to steam, leading to secondary condensation and freezing on non-heated areas of the unit cooler and introduced unwanted heat gain into the controlled space.
- Average defrost times can vary anywhere from fifteen to twenty minutes, and in most cases, should never exceed thirty minutes.
- Actual defrost times must be determined from careful observation of defrost operation and adherence to the previously mentioned guidelines. Frost is

usually heaviest on the air-entering side of the coil, and inspection of fins on this side can usually be used to determine if complete defrost has occurred. Periodic observation of the defrost cycle throughout the year is necessary to maintain a properly operating defrost system.

NOTICE: Once frost turns to ice, the amount of time required to melt increases. Incomplete defrosting may allow excessive ice to build up which could damage the machinery. Allowing ice to build up on the fan blades will result in excessive vibration which could lead to catastrophic failure. It is imperative that the end user inspect the unit coolers regularly for proper defrosting. Manual defrosting may be required to remove ice buildup.

5.8. **Air Defrost Operation**

5.8.1. Condition of Operation - Air Defrost can be used for High-Temp installations only.

5.8.2. Sequence of Air Defrost Operation

- Pump down liquid refrigerant from coil for a period at least equal to 15 minutes. Any liquid refrigerant that may remain in the coil during defrost will greatly reduce the effectiveness of the air defrost operation. Evidence of residual liquid refrigerant during defrost can be seen in the form of uneven melting or the absence of melting on the lower tubes of the evaporator coil.
- Allow fans to continue operating for the necessary time of defrost.
- Re-introduce refrigerant into evaporator and re-start refrigeration to cool the evaporator.

5.8.3. Setting Air Defrost Timer

5.8.3.1. Time periods should be set as follows:

- Time to defrost should be just long enough to melt all frost.

6. EMERGENCY SITUATIONS

6.1. During normal operation the units described in this IOM contain either ammonia or one of several possible halocarbon refrigerants. There are hazards and risks associated with all refrigerants. Refrigerant leaks can cause an emergency situation. Refer to the facility "Emergency Planning Policy" and "Hazardous Chemical Communication Policy" for the proper methods of dealing with any potential emergency situation resulting from a refrigerant leak.

7. MAINTENANCE

7.1. **WARNING:** Prior to any maintenance being performed, unit must be locked out and tagged out per the Lockout/Tag Out policy of the facility where installed.

7.2. Note that equipment may be damaged by incompatible cleaning agents or water condensate from defrost that is contaminated by airborne impurities. It is the responsibility of the owner/operator to be familiar with these chemicals and the room environment and to select compatible agents and materials of construction.

7.3. Refer to the certified submittals for a listing of the materials used in the specific evaporator in question.

7.4. Consult with a qualified chemical/corrosion expert to ensure compatibility and to develop a plan to address any special circumstances, such as airborne impurities.

7.5. System Maintenance Schedule (recommended maximum time periods)

7.5.1. Every month

- The system should be periodically checked for proper defrosting and defrost timing due to variations in the quantity and pattern of frost.
- Frost accumulation is dependent on the following: temperature of the space, type of product stored, product loading rate, traffic, moisture content of air entering conditioned space, etc.
- It may be necessary to periodically adjust number of defrost cycles or duration of each defrost cycle to accommodate these varying conditions.

7.5.2. Every 6 months

- Check refrigeration system for charge level, oil level, and any evidence of leaks.
- Tighten all electrical connections.
- Check operation of control system and proper functioning of defrost solenoids, drain line heaters, thermostats, etc.
- Check that all safety controls are operating appropriately.

7.6. Evaporator Maintenance Schedule (recommended maximum time periods)

7.6.1. Every 6 months

- Clean the coil surface.
- Inspect defrost drain pan. Clean if necessary. Check for proper drainage.
- For Water Defrost, inspect water defrost distribution pans. Clean if necessary.
- Inspect all insulated supply and drain lines.
- Check all wiring.
- Check all motors and fans, tightening when necessary all motor mounting bolts and fan set screws.

NOTICE: Do not use alkaline detergents on Aluminum coil surfaces, as corrosion may result and cause refrigerant containment failure.

7.7. **Replacement Parts**

7.7.1. Replacement parts which are covered under the conditions of Colmac Coil's warranty (see Limited Warranty) will be reimbursed at the part cost only. For replacement parts, warranted or otherwise, contact Colmac Coil directly. When contacting Colmac Coil with the explanation of failure, have the complete model number, serial number, date of installation, and date of failure at hand.

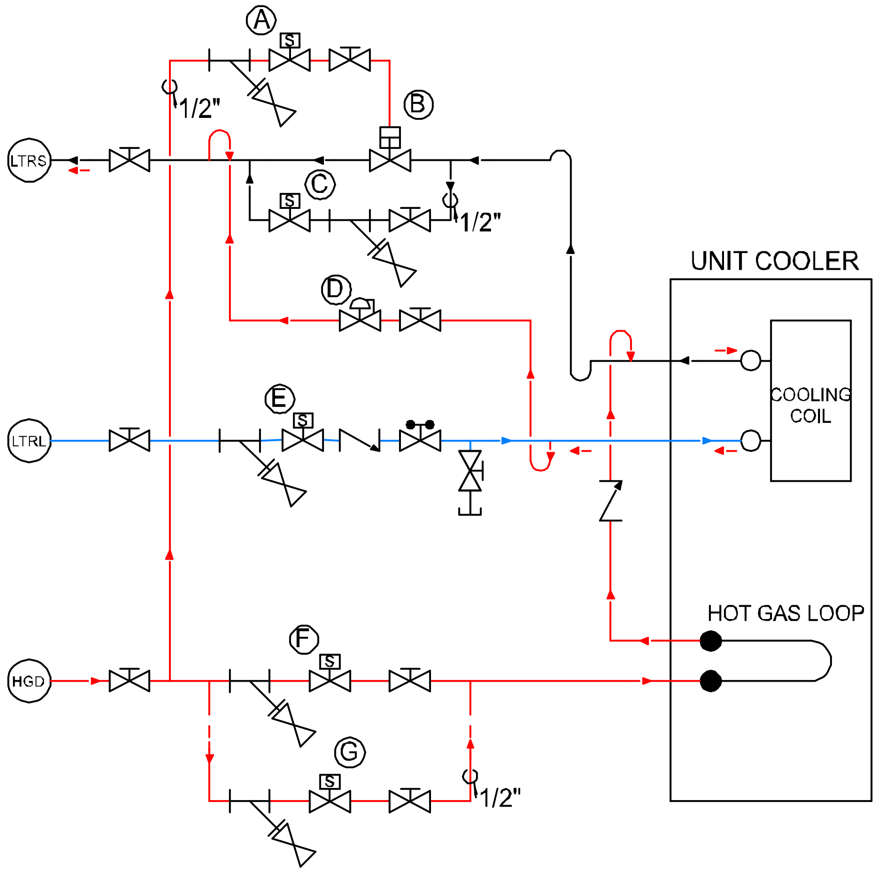
7.8. **Troubleshooting**

SYMPTOM	POSSIBLE CAUSE	POSSIBLE SOLUTION
1. Coil not clearing of frost during defrost cycle.	1. Insufficient number of defrost cycles. 2. Insufficient time for each defrost cycle. 3. Hot Gas refrigerant pressure too low. 4. Defective timer or pressure regulator. 5. Excessive air/moisture infiltration resulting in unreasonably high frost load. 6. Fan still operating during defrost.	1. Adjust timer for more defrost cycles. 2. Adjust for increased defrost duration. 3. Adjust pressure regulator/back pressure regulator for increased pressure. Check condenser fans/pumps for proper operation. 4. Replace timer/regulator. 5. Consider some form of air/moisture infiltration mitigation, i.e. dock conditioning, air curtains, improved doors 6. Cycle fans off during defrost. Check defrost timer or other fan control device for proper operation.
2. Ice building in drainpan.	1. Drain line plugged. 2. Drain line not sloped as required. 3. Unit Cooler not level. 4. Drain line heater not operating adequately. 5. Defective defrosting timer/thermostat/pressure regulator. 6. Hot Gas Piping not adequately supported, forcing hot gas loop away from drainpan. 7. Improper piping and/or inadequate flow of hot gas to pan. 8. Steam created during defrost is condensing above unit and dripping/freezing onto unheated areas of evaporator.	1. Clean drain line. 2. Adjust as necessary. 3. Adjust as necessary. 4. Repair or replace as necessary. 5. Repair or replace as necessary. 6. Add additional hot gas piping support. 7. Increase hot gas flow to drain pan. 8. See Symptom #4 below.
3. Uneven coil frosting.	1. Unit Cooler located too close to door or other room opening. 2. Unit Cooler not level, causing uneven loading. 3. Defrost cycle time too short. 4. Fans not operating correctly. 5. Liquid supply not sufficient to properly feed unit. 6. Liquid control device not open or large enough.	1. Relocate as necessary. 2. Adjust as necessary. 3. Increase duration of each defrost cycle. 4. Check fans and fan motors for proper operation. Replace or repair as needed. 5. Increase refrigerant supply to unit cooler. Check strainers, expansion valves, etc. 6. Correct or replace as necessary.

SYMPTOM	POSSIBLE CAUSE	POSSIBLE SOLUTION
4. Ice accumulating on ceiling above evaporator or in air section or around motors, fans, and fan venturis.	1. Defrost cycle time too long, “overcooking” the unit. 2. Too many defrosts cycles during a 24-hour period. 3. Defective defrosting timer/thermostat/pressure regulator.	1. Decrease duration of each defrost cycle. 2. Decrease number of defrost cycles. 3. Repair or replace as necessary.
5. Elevated Room Temperature	1. Room thermostat set incorrectly. 2. Low refrigerant charge. 3. Airflow restricted to evaporator. 4. Undersized evaporators for required heat load. 5. Fan motors not operating. 6. Insufficient refrigerant flow.	1. Check thermostat and adjust appropriately. 2. Add refrigerant. 3. Check evaporator for airflow blockage, including ice buildup, foreign matter, etc. Clean as necessary. 4. If heat load exceeds design conditions, evaporator operating conditions may have to be changed, or evaporators will need to be added to the conditioned space. 5. Check fans and fan motors for proper operation. Replace or repair as needed. 6. Check strainers, hand expansion valves, etc.
6. Frequent Fan and/or Motor Failure	1. Unit cycling too frequently, causing excessive fatigue related wear and tear. 2. Check quality of power supply.	1. Limit number of cycles, whether it is for capacity control or defrost operation. 2. Install power conditioning equipment, phase failure relays, etc.
7. Insufficient Airthrow	1. Unit too close to wall, product, etc. for proper return air supply to fan. 2. Unit obstructed with ice blockage. 3. No air throw straightener specified with unit purchase. 4. Fan and/or fan motors not operating correctly. 5. VFD fan speed too low.	1. Relocate unit to allow for unobstructed airflow. 2. See Symptoms 1-4 above. 3. Purchase optional airthrow straighteners from evaporator manufacturer. 4. Check fans and fan motors for proper operation. Replace or repair as needed. 5. Increase fan speed.

FIGURE 1

HOT GAS DEFROST PIPING
RECIRCULATED BOTTOM FEED EVAPORATOR



HAND EXPANSION VALVE

GLOBE VALVE

GAS POWERED SUCTION STOP VALVE

SOLENOID VALVE

DEFROST PRESSURE REGULATOR

CHECK VALVE

STRAINER, BLOW-OFF

DRAIN

HOT GAS FLOW

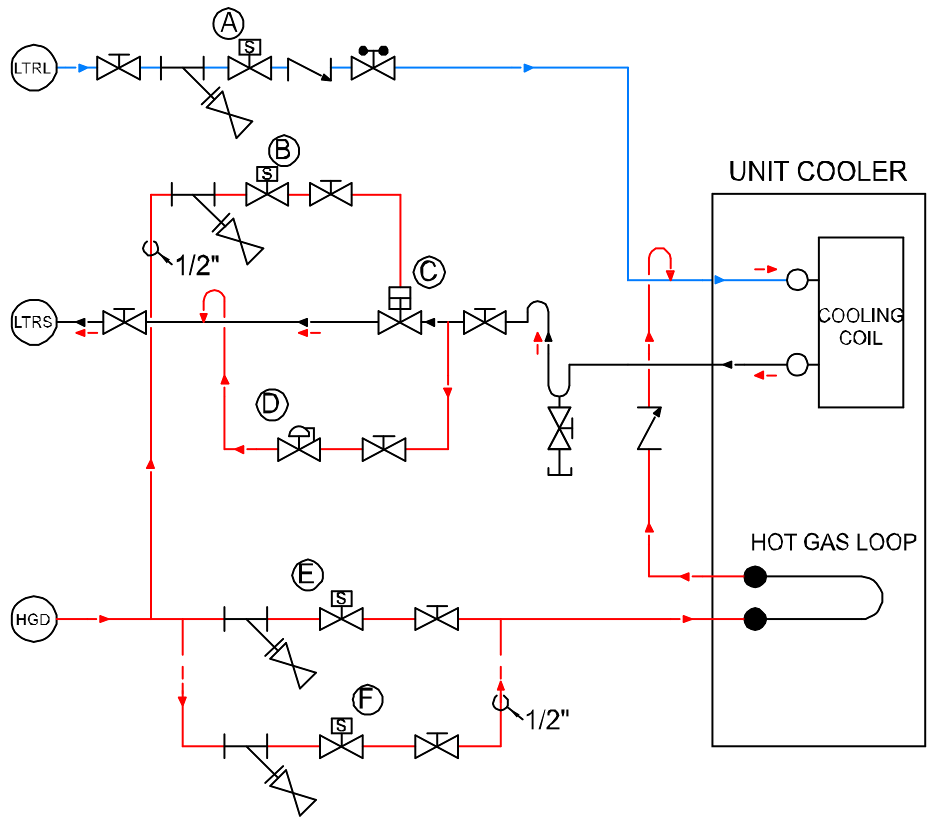
SATURATED LIQUID FLOW

SATURATED LIQUID & VAPOR FLOW

HGD	HOT GAS DEFROST SUPPLY
LTRS	LOW-TEMP RECIRCULATED SUCTION
LTRL	LOW-TEMP RECIRCULATED LIQUID
A	PILOT SOLENOID VALVE (S8 OR HS8)
B	GAS POWERED SUCTION STOP VALVE (CK2 OR HCK2)
C	EQUALIZING BLEED VALVE (S8 OR HS8)
D	DEFROST RELIEF REGULATOR (A4AK OR HA4AK)
E	LIQUID SOLENOID (S4A OR HS4A)
F	HOT GAS SOLENOID (S4A OR HS4A)
G	SOFT START HOT GAS SOLENDOID (S8 OR HS8) (RECOMENDED FOR EVAPORATORS OF 15 TONS OR GREATER COOLING CAPACITY)

FIGURE 2

HOT GAS DEFROST PIPING
RECIRCULATED TOP FEED EVAPORATOR



HAND EXPANSION VALVE

GLOBE VALVE

GAS POWERED SUCTION STOP VALVE

SOLENOID VALVE

DEFROST PRESSURE REGULATOR

CHECK VALVE

STRAINER, BLOW-OFF

DRAIN

HOT GAS FLOW

SATURATED LIQUID FLOW

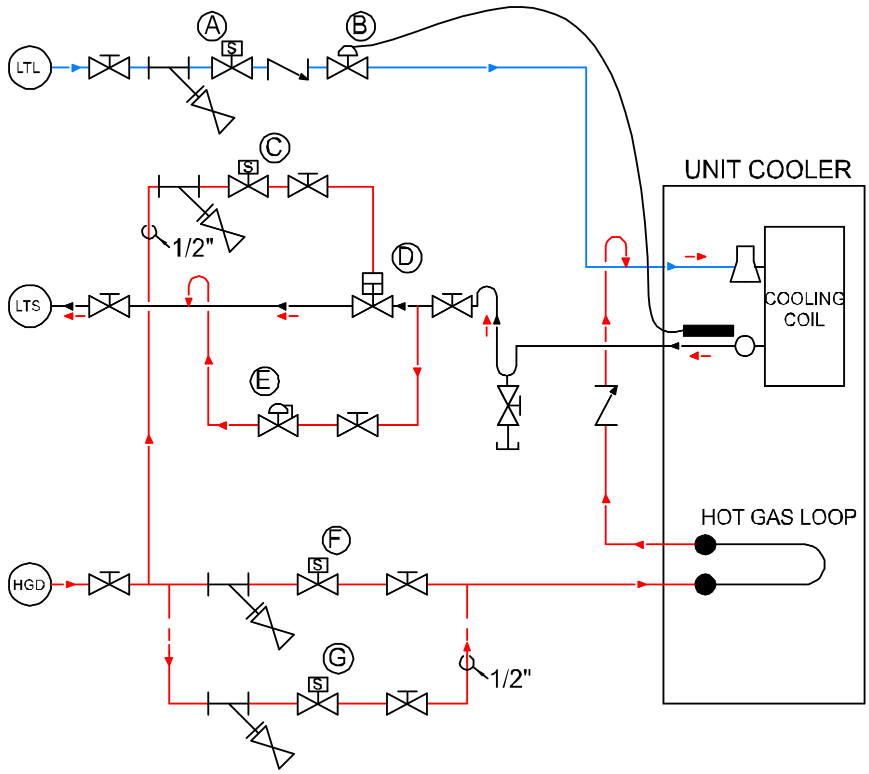
SATURATED LIQUID & VAPOR FLOW

HGD	HOT GAS DEFROST SUPPLY
LTRS	LOW-TEMP RECIRCULATED SUCTION
LTRL	LOW-TEMP RECIRCULATED LIQUID
A	LIQUID SOLENOID (S4A OR HS4A)
B	PILOT SOLENOID VALVE (S8 OR HS8)
C	GAS POWERED SUCTION STOP VALVE (CK2 OR HCK2)
D	DEFROST RELIEF REGULATOR W/ WIDE OPENING FEATURE FOR EQUALIZING (A4A OR HA4A)
E	HOT GAS SOLENOID (S4A OR HS4A)
F	SOFT START HOT GAS SOLENDOID (S8 OR HS8) (RECOMENDED FOR EVAPORATORS OF 15 TONS OR GREATER COOLING CAPACITY)

NOTE 1: DEFROST PRESSURE REGULATOR OPERATES WIDE-OPEN DURING NORMAL OPERATION, AND OPERATED AS REGULATOR DURING DEFROST.

FIGURE 3

HOT GAS DEFROST PIPING
DIRECT EXPANSION EVAPORATOR



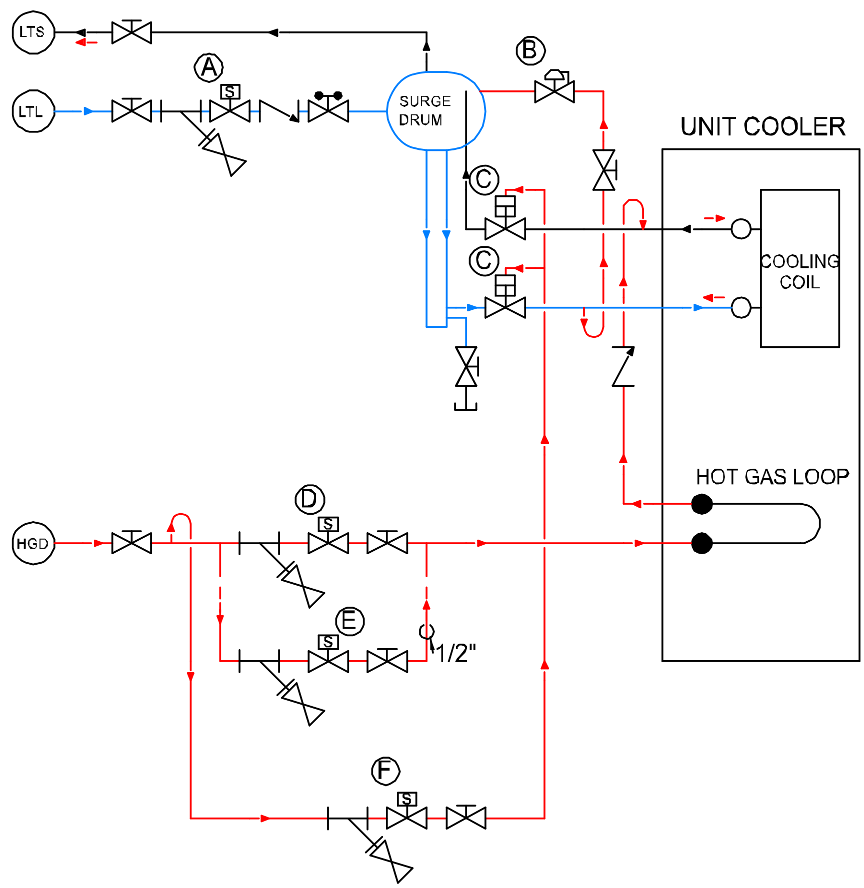
- HAND EXPANSION VALVE
- GLOBE VALVE
- GAS POWERED SUCTION STOP VALVE
- SOLENOID VALVE
- DEFROST PRESSURE REGULATOR
- THERMAL EXPANSION VALVE
- CHECK VALVE
- STRAINER, BLOW-OFF
- DRAIN
- HOT GAS FLOW
- SATURATED LIQUID FLOW
- SUPERHEATED VAPOR FLOW

HGD	HOT GAS DEFROST SUPPLY
LTS	LOW-TEMP SUCTION
LTL	LOW-TEMP LIQUID
A	LIQUID SOLENOID (S4A OR HS4A)
B	THERMAL EXPANSION VALVE
C	PILOT SOLENOID VALVE (S8 OR HS8)
D	GAS POWERED SUCTION STOP VALVE (CK2 OR HCK2)
E	DEFROST RELIEF REGULATOR W/ WIDE OPENING FEATURE FOR EQUALIZING (A4AB OR HA4AB)
F	HOT GAS SOLENOID (S4A OR HS4A)
G	SOFT START HOT GAS SOLENDOID (S8 OR HS8) (RECOMENDED FOR EVAPORATORS OF 15 TONS OR GREATER COOLING CAPACITY)

NOTE 1: DEFROST PRESSURE REGULATOR OPERATES WIDE-OPEN DURING NORMAL OPERATION, AND OPERATED AS REGULATOR DURING DEFROST.

FIGURE 4

HOT GAS DEFROST PIPING
GRAVITY FLOODED EVAPORATOR



	HAND EXPANSION VALVE	HGD	HOT GAS DEFROST SUPPLY
	GLOBE VALVE	LTS	LOW-TEMP SUCTION
	GAS POWERED SUCTION STOP VALVE	LTL	LOW-TEMP LIQUID
S	SOLENOID VALVE	A	LIQUID SOLENOID (S4A OR HS4A)
	DEFROST PRESSURE REGULATOR	B	DEFROST RELIEF REGULATOR W/ WIDE OPENING FEATURE FOR EQUALIZING (A4AB OR HA4AB)
	CHECK VALVE	C	GAS POWERED SUCTION STOP VALVE(CK2 OR HCK2)
	STRAINER, BLOW-OFF	D	HOT GAS SOLENOID (S4A OR HS4A)
	DRAIN	E	SOFT START HOT GAS SOLENDOID (S8 OR HS8) (RECOMENDED FOR EVAPORATORS OF 15 TONS OR GREATER COOLING CAPACITY)
	HOT GAS FLOW	F	PILOT SOLENOID VALVE (S8 OR HS8)
	SATURATED LIQUID FLOW		
	SATURATED LIQUID & VAPOR FLOW		

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A+L Air Cooler (AL Tube) Engineering Specifications

1. **General**
   1.1. This specification covers “A+L” type air coolers having aluminum tubes and aluminum fins intended for use in refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method. DTM rating method shall not be used.
   2.2. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. **Tubing**
   3.1. Coil block shall be constructed with alloy 3003 aluminum tubing.
   3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
   3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. **Tube Pattern**
   4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
      4.1.1. 5/8” OD - 1.5” x 1.299” equilateral staggered
      4.1.2. 5/8” OD – 1.97” (50 mm) inline
      4.1.3. 7/8” OD - 2.25” x 1.949” equilateral staggered

5. **Fins**
   5.1. Shall be aluminum 1100 alloy, no less than 0.010” (0.25 mm) thick.
   5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
   5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. **Headers**
   6.1. Headers shall be made of ASME B241, Alloy 6061 aluminum no less than ANSI schedule 40 pipes.

7. **Connections**
   7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-106/B. Bolted type flange union connections shall not be allowed.
   7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
   7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.

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7.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.
7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube welds shall be made by Tungsten Inert Gas (TIG) welding process.
9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.
9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.
10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)</u>
- 11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.
- 11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.
- 11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. <u>Type FL (Gravity Flooded)</u>
- 11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.
- 11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

11.3. <u>Type DX (Direct Expansion)</u>
- 11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.
- 11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit l oading.

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11.4. Type BW (Single Phase Liquids)
- 11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.
- 11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

12. Fans

12.1. Construction.
- 12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.
- 12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.
- 12.1.3. Fans shall be true airfoil shape and shall be non-overloading type

12.2. Fan Guards.
- 12.2.1. Fans shall be fully guarded with OSHA approved wire guards.

12.3. Direction of Air Flow
- 12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

13.2. Motor service factor shall be no less than 1.15.

13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

14.1. General
- 14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System
- 14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.
- 14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

14.3. Standard Air Section
- 14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).
- 14.3.2. Fan panels shall be hinged to allow access for maintenance and cleaning.

14.4. 45 Degree Down Discharge Air Section
- 14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

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14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

14.5. <u>Penthouse Air Section</u>

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

16. Defrost

16.1. <u>Hot Gas Defrost</u>

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

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16.2. Water Defrost.

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

16.3. Air Defrost.

16.3.1. Coil shall be arranged for air (off cycle) defrosting.

16.4. Electric Defrost.

16.4.1. General

16.4.1.1. Coil shall be arranged for electric defrosting.

16.4.2. Heating elements

16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging

17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.

17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

17.3. Crating shall support the full weight of the evaporator.

17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals

18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor

19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+L Series

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20. Ordering Information

20.1. Please Specify:

20.1.1. Complete model number.
20.1.2. Saturated suction temperature.
20.1.3. Room temperature.
20.1.4. Overfeed ratio (if pump recirculated).
20.1.5. Options or special features.

21. Optional Features

1.1. Variable Fin Spacing

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.
1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+L Air Cooler (Cu Tube) Engineering Specifications

1. General

1.1. This specification covers “A+L” type air coolers having copper tubes and aluminum fins intended for use in refrigeration systems.

2. Selection / Rating Method

2.1. Evaporators shall be selected using DT1 rating method.
2.2. DTM rating method shall not be used.
2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. Tubing

3.1. Coil block shall be constructed with UNS C12200 copper tubing certified to ASTM B-75.
3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. Tube Pattern

4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
4.1.1. 5/8” OD - 1.5” x 1.299” equilateral staggered
4.1.2. 5/8” OD – 1.97” (50 mm) inline
4.1.3. 7/8” OD - 2.25” x 1.949” equilateral staggered

5. Fins

5.1. Fins shall be selected from one of the four materials below, based on optimum performance in the operating environment.
5.1.1. Aluminum 1100 alloy, no less than 0.010” (0.25 mm) thick.
5.1.2. 304L stainless steel, no less than 0.010” ” (0.25 mm) thick.
5.1.3. Copper, no less than no less than 0.010” ” (0.25 mm) thick.
5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. Headers

6.1. Headers shall be made of UNS C12200 Type L copper tubing certified to ASTM B-88.

7. Connections

7.1. Liquid, suction, and hot gas connections shall be UNS C12200 Type L copper tubing certified to ASTM B-88. Bolted type flange union connections shall not be allowed.
7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.

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7.4. Coil connections shall be terminated with a brazed copper head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Brazing/QC

9.1. All tube and header joints shall be made with high temperature brazing filler metal certified to no less than BCuP-3 (5% Silver Solder).

9.2. All brazing shall be performed by ASME certified brazers per the requirements of the manufacturer's BPS documents. Copies of all BPS, PQR, and Brazer Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after brazing at no less than 350 psig (25 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)</u>

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. <u>Type FL (Gravity Flooded)</u>

11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

11.3. <u>Type DX (Direct Expansion)</u>

11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.

11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

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11.4. Type BW (Single Phase Liquids)

11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.

11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

12. Fans

12.1. Construction.

12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

12.1.3. Fans shall be true airfoil shape and shall be non-overloading type

12.2. Fan Guards.

12.2.1. Fans shall be fully guarded with OSHA approved wire guards.

12.3. Direction of Air Flow

12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

13.2. Motor service factor shall be no less than 1.15.

13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

14.1. General

14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System

14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

14.3. Standard Air Section

14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

14.3.2. Fan panels shall be hinged to allow access for maintenance and cleaning.

14.4. 45 Degree Down Discharge Air Section

14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

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14.5. Penthouse Air Section

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

16. Defrost

16.1. Hot Gas Defrost

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

16.2. Water Defrost.

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

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16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

16.3. Air Defrost.

16.3.1. Coil shall be arranged for air (off cycle) defrosting.

16.4. Electric Defrost.

16.4.1. General

16.4.1.1. Coil shall be arranged for electric defrosting.

16.4.2. Heating elements

16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging

17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.

17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

17.3. Crating shall support the full weight of the evaporator.

17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals

18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor

19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+L Series

20. Ordering Information

20.1. Please Specify:

20.1.1. Complete model number.

20.1.2. Saturated suction temperature.

20.1.3. Room temperature.

20.1.4. Overfeed ratio (if pump recirculated).

20.1.5. Options or special features.

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21. Optional Features

1.1. Variable Fin Spacing

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.

1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+L Air Cooler (Galvanized) Engineering Specifications

1. **General**
   1.1. This specification covers “A+L” type air coolers having galvanized steel tubes and fins intended for use in refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method.
   2.2. DTM rating method shall not be used.
   2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. **Tubing**
   3.1. Coil block shall be constructed with ASME SA-214 carbon steel tubing.
   3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
   3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. **Tube Pattern**
   4.1.1. Tube pattern shall be 7/8” OD - 2.25” x 1.949” equilateral staggered

5. **Fins**
   5.1. Shall be carbon steel, no less than 0.010” (0.25 mm) thick.
   5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
   5.3. Fin collars shall be configured so that molten zinc completely bonds the tubes and fins.

6. **Headers**
   6.1. Headers shall be made of carbon steel pipe certified to ASME SA-106/B, no less than ANSI schedule 40.

7. **Connections**
   7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-106/B. Bolted type flange union connections shall not be allowed.
   7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
   7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.
   7.4. Coil connections shall be terminated with a welded steel head at the factory. One “Schrader” type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.
   7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

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8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube and header welds shall be made by Tungsten Inert Gas (TIG) welding process.
9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.
9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.
10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)
11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.
11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.
11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.
11.2. Type FL (Gravity Flooded)
11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.
11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.
11.3. Type DX (Direct Expansion)
11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.
11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.
11.4. Type BW (Single Phase Liquids)
11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.
11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

12. Galvanizing

12.1. Carbon steel coil core to be hot-dip galvanized per ASTM A-123 for corrosion protection.

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13. Fans

13.1. Construction.

13.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

13.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

13.1.3. Fans shall be true airfoil shape and shall be non-overloading type

13.2. Fan Guards.

13.2.1. Fans shall be fully guarded with OSHA approved wire guards.

13.3. Direction of Air Flow

13.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

14. Fan Motors

14.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

14.2. Motor service factor shall be no less than 1.15.

14.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

14.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

15. Cabinet

15.1. General

15.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

15.2. Optional Smart Hanger System

15.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

15.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

15.3. Standard Air Section

15.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

15.3.2. Fan panels shall be hinged to allow access for maintenance and cleaning.

15.4. 45 Degree Down Discharge Air Section

15.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

15.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

15.5. Penthouse Air Section

15.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

15.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

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16. Drainpans

16.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

16.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

16.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

16.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

16.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

16.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

17. Defrost

17.1. <u>Hot Gas Defrost</u>

17.1.1. General

17.1.1.1. Coil shall be arranged for hot gas defrosting.

17.1.2. Pan Loop

17.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

17.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

17.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

17.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

17.1.3. Pan Loop Check Valve

17.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

17.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

17.2. <u>Water Defrost.</u>

17.2.1. General

17.2.1.1. Coil shall be arranged for water defrosting.

17.2.2. Water Distribution Pans

17.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

17.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

17.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

17.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

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17.3. Air Defrost.

17.3.1. Coil shall be arranged for air (off cycle) defrosting.

17.4. Electric Defrost.

17.4.1. General

17.4.1.1. Coil shall be arranged for electric defrosting.

17.4.2. Heating elements

17.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

17.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

17.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

17.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

18. Packaging

18.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.

18.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

18.3. Crating shall support the full weight of the evaporator.

18.4. Crating shall be removable by means of gravity only.

19. IOM Manuals

19.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

20. Approved Vendor

20.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+L Series

21. Ordering Information

21.1. Please Specify:

21.1.1. Complete model number.

21.1.2. Saturated suction temperature.

21.1.3. Room temperature.

21.1.4. Overfeed ratio (if pump recirculated).

21.1.5. Options or special features.

22. Optional Features

1.1. Variable Fin Spacing

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.

1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+L Air Cooler (SST Tube) Engineering Specifications

1. **General**
   1.1. This specification covers “A+L” type air coolers having stainless steel tubes and aluminum fins intended for use in refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method.
   2.2. DTM rating method shall not be used.
   2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. **Tubing**
   3.1. Coil block shall be constructed with 304L stainless steel tubing.
   3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
   3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. **Tube Pattern**
   4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
      4.1.1. 5/8” OD - 1.5” x 1.299” equilateral staggered
      4.1.2. 5/8” OD – 1.97” (50 mm) inline
      4.1.3. 7/8” OD - 2.25” x 1.949” equilateral staggered

5. **Fins**
   5.1. Fins shall be selected from one of the four materials below, based on optimum performance in the operating environment.
      5.1.1. Aluminum 1100 alloy, no less than 0.010” (0.25 mm) thick.
      5.1.2. 304L stainless steel, no less than 0.010” ” (0.25 mm) thick.
      5.1.3. Colmac Anti-Microbial alloy, no less than 0.010” ” (0.25 mm) thick.
         5.1.3.1. Coil core fins shall be constructed of a metal alloy that exhibits anti-microbial properties.
         5.1.3.2. Fins shall completely cover the coil tube surfaces exposed to the airstream by means of a full-length self-spacing fin collar.
         5.1.3.3. Coil coatings are not allowed. All surfaces to be a base metal alloy.
   5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
   5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. **Headers**
   6.1. Headers shall be made of 304L stainless steel pipe certified to ASME SA-240/304L, no less than ANSI schedule 40.

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7. Connections

7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-240/304L. Bolted type flange union connections shall not be allowed.

7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.

7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.

7.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube and header welds shall be made by Tungsten Inert Gas (TIG) welding process.

9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)</u>

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. <u>Type FL (Gravity Flooded)</u>

11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

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11.3. Type DX (Direct Expansion)

11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.

11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

11.4. Type BW (Single Phase Liquids)

11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.

11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

12. Fans

12.1. Construction.

12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

12.1.3. Fans shall be true airfoil shape and shall be non-overloading type

12.2. Fan Guards.

12.2.1. Fans shall be fully guarded with OSHA approved wire guards.

12.3. Direction of Air Flow

12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

13.2. Motor service factor shall be no less than 1.15.

13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

14.1. General

14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System

14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

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14.3. Standard Air Section
14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).
14.3.2. Fan panels shall be hinged to allow access for maintenance and cleaning.
14.4. 45 Degree Down Discharge Air Section
14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.
14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.
14.5. Penthouse Air Section
14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).
14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

15. Drainpans
15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.
15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.
15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.
15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.
15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.
15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

16. Defrost
16.1. Hot Gas Defrost
16.1.1. General
16.1.1.1. Coil shall be arranged for hot gas defrosting.
16.1.2. Pan Loop
16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.
16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.
16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.
16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.
16.1.3. Pan Loop Check Valve
16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

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16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

16.2. Water Defrost.

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

16.3. Air Defrost.

16.3.1. Coil shall be arranged for air (off cycle) defrosting.

16.4. Electric Defrost.

16.4.1. General

16.4.1.1. Coil shall be arranged for electric defrosting.

16.4.2. Heating elements

16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging

17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.

17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

17.3. Crating shall support the full weight of the evaporator.

17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals

18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor

19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+L Series

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20. Ordering Information

20.1. Please Specify:

20.1.1. Complete model number.
20.1.2. Saturated suction temperature.
20.1.3. Room temperature.
20.1.4. Overfeed ratio (if pump recirculated).
20.1.5. Options or special features.

21. Optional Features

1.1. Variable Fin Spacing

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.
1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+M Air Cooler (AL Tube) Engineering Specifications

1. **General**
   1.1. This specification covers "A+M" type air coolers having aluminum tubes and aluminum fins intended for use in refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method.
   2.2. DTM rating method shall not be used.
   2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. **Tubing**
   3.1. Coil block shall be constructed with alloy 3003 aluminum tubing.
   3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
   3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. **Tube Pattern**
   4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
      4.1.1. 5/8" OD - 1.5" x 1.299" equilateral staggered
      4.1.2. 5/8" OD – 1.97" (50 mm) inline
      4.1.3. 7/8" OD - 2.25" x 1.949" equilateral staggered

5. **Fins**
   5.1. Shall be aluminum 1100 alloy, no less than 0.010" (0.25 mm) thick.
   5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, "L-foot", or wrap-on type fins shall not be allowed.
   5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. **Headers**
   6.1. Headers shall be made of ASME B241, Alloy 6061 aluminum no less than ANSI schedule 40 pipes.

7. **Connections**
   7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-106/B. Bolted type flange union connections shall not be allowed.
   7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
   7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.
   7.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping

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charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube welds shall be made by Tungsten Inert Gas (TIG) welding process.

9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)</u>

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. <u>Type FL (Gravity Flooded)</u>

11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

11.3. <u>Type DX (Direct Expansion)</u>

11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.

11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

11.4. <u>Type BW (Single Phase Liquids)</u>

11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.

11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

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12. Fans

12.1. Construction.

12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

12.1.3. Fans shall be true airfoil shape and shall be non-overloading type

12.2. Fan Guards.

12.2.1. Fans shall be fully guarded with OSHA approved wire guards.

12.3. Direction of Air Flow

12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

13.2. Motor service factor shall be no less than 1.15.

13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

14.1. General

14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System

14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

14.3. Standard Air Section

14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

14.4. 45 Degree Down Discharge Air Section

14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

14.5. Penthouse Air Section

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

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15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

16. Defrost

16.1. <u>Hot Gas Defrost</u>

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

16.2. <u>Water Defrost.</u>

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

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16.3. Air Defrost.
16.3.1. Coil shall be arranged for air (off cycle) defrosting.
16.4. Electric Defrost.
16.4.1. General
16.4.1.1. Coil shall be arranged for electric defrosting.
16.4.2. Heating elements
16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.
16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.
16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging
17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.
17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.
17.3. Crating shall support the full weight of the evaporator.
17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals
18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor
19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+M Series

20. Ordering Information
20.1. Please Specify:
20.1.1. Complete model number.
20.1.2. Saturated suction temperature.
20.1.3. Room temperature.
20.1.4. Overfeed ratio (if pump recirculated).
20.1.5. Options or special features.

21. Optional Features

1.1. Variable Fin Spacing
1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.
1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+M Air Cooler (Cu Tube) Engineering Specifications

1. **General**
   1.1. This specification covers "A+M" type air coolers having copper tubes and aluminum fins intended for use in refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method.
   2.2. DTM rating method shall not be used.
   2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. **Tubing**
   3.1. Coil block shall be constructed with UNS C12200 copper tubing certified to ASTM B-75.
   3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
   3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. **Tube Pattern**
   4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
      4.1.1. 5/8" OD - 1.5" x 1.299" equilateral staggered
      4.1.2. 5/8" OD – 1.97" (50 mm) inline
      4.1.3. 7/8" OD - 2.25" x 1.949" equilateral staggered

5. **Fins**
   5.1. Fins shall be selected from one of the four materials below based on optimum performance and the environment in which the cooler will operate.
      5.1.1. Aluminum 1100 alloy, no less than 0.010" (0.25 mm) thick.
      5.1.2. 304L stainless steel, no less than 0.010" " (0.25 mm) thick.
      5.1.3. Copper, no less than no less than 0.010" " (0.25 mm) thick.
   5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, "L-foot", or wrap-on type fins shall not be allowed.
   5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. **Headers**
   6.1. Headers shall be made of UNS C12200 Type L copper tubing certified to ASTM B-88.

7. **Connections**
   7.1. Liquid, suction, and hot gas connections shall be UNS C12200 Type L copper tubing certified to ASTM B-88. Bolted type flange union connections shall not be allowed.
   7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
   7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.

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7.4. Coil connections shall be terminated with a brazed copper head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Brazing/QC

9.1. All tube and header joints shall be made with high temperature brazing filler metal certified to no less than BCuP-3 (5% Silver Solder).
9.2. All brazing shall be performed by ASME certified brazers per the requirements of the manufacturer's BPS documents. Copies of all BPS, PQR, and Brazer Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.
9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after brazing at no less than 350 psig (25 bar), dry air under water.
10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)</u>
11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.
11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.
11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. <u>Type FL (Gravity Flooded)</u>
11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.
11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

11.3. <u>Type DX (Direct Expansion)</u>
11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.
11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

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- 11.4. Type BW (Single Phase Liquids)
  - 11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.
  - 11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

12. Fans

- 12.1. Construction.
  - 12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.
  - 12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.
  - 12.1.3. Fans shall be true airfoil shape and shall be non-overloading type
- 12.2. Fan Guards.
  - 12.2.1. Fans shall be fully guarded with OSHA approved wire guards.
- 12.3. Direction of Air Flow
  - 12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

- 13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.
- 13.2. Motor service factor shall be no less than 1.15.
- 13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.
- 13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

- 14.1. General
  - 14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.
- 14.2. Optional Smart Hanger System
  - 14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.
  - 14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.
- 14.3. Standard Air Section
  - 14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).
- 14.4. 45 Degree Down Discharge Air Section
  - 14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.
  - 14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

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14.5. Penthouse Air Section

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

16. Defrost

16.1. Hot Gas Defrost

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

16.2. Water Defrost.

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

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16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.
16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.
16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

16.3. Air Defrost.
16.3.1. Coil shall be arranged for air (off cycle) defrosting.
16.4. Electric Defrost.
16.4.1. General
16.4.1.1. Coil shall be arranged for electric defrosting.
16.4.2. Heating elements
16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.
16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.
16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging
17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.
17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.
17.3. Crating shall support the full weight of the evaporator.
17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals
18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor
19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+M Series

20. Ordering Information
20.1. Please Specify:
20.1.1. Complete model number.
20.1.2. Saturated suction temperature.
20.1.3. Room temperature.
20.1.4. Overfeed ratio (if pump recirculated).
20.1.5. Options or special features.

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21. Optional Features

1.1. Variable Fin Spacing

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.

1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+M Air Cooler (Galvanized) Engineering Specifications

1. **General**
   1.1. This specification covers "A+M" type air coolers having galvanized steel tubes and fins intended for use in refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method.
   2.2. DTM rating method shall not be used.
   2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. **Tubing**
   3.1. Coil block shall be constructed with ASME SA-214 carbon steel tubing.
   3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
   3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. **Tube Pattern**
   4.1.1. Tube pattern shall be 7/8" OD - 2.25" x 1.949" equilateral staggered

5. **Fins**
   5.1. Shall be carbon steel, no less than 0.010" (0.25 mm) thick.
   5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, "L-foot", or wrap-on type fins shall not be allowed.
   5.3. Fin collars shall be configured so that molten zinc completely bonds the tubes and fins.

6. **Headers**
   6.1. Headers shall be made of carbon steel pipe certified to ASME SA-106/B, no less than ANSI schedule 40.

7. **Connections**
   7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-106/B. Bolted type flange union connections shall not be allowed.
   7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
   7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.
   7.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.
   7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

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8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube and header welds shall be made by Tungsten Inert Gas (TIG) welding process.

9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. Type FL (Gravity Flooded)

11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

11.3. Type DX (Direct Expansion)

11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.

11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

11.4. Type BW (Single Phase Liquids)

11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.

11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

12. Galvanizing

12.1. Carbon steel coil core to be hot-dip galvanized per ASTM A-123 for corrosion protection.

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13. Fans

13.1. Construction.

13.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

13.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

13.1.3. Fans shall be true airfoil shape and shall be non-overloading type

13.2. Fan Guards.

13.2.1. Fans shall be fully guarded with OSHA approved wire guards.

13.3. Direction of Air Flow

13.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

14. Fan Motors

14.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

14.2. Motor service factor shall be no less than 1.15.

14.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

14.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

15. Cabinet

15.1. General

15.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

15.2. Optional Smart Hanger System

15.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

15.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

15.3. Standard Air Section

15.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

15.4. 45 Degree Down Discharge Air Section

15.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

15.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

15.5. Penthouse Air Section

15.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

15.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

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16. Drainpans

16.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

16.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

16.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

16.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

16.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

16.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

17. Defrost

17.1. Hot Gas Defrost

17.1.1. General

17.1.1.1. Coil shall be arranged for hot gas defrosting.

17.1.2. Pan Loop

17.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

17.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

17.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

17.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

17.1.3. Pan Loop Check Valve

17.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

17.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

17.2. Water Defrost.

17.2.1. General

17.2.1.1. Coil shall be arranged for water defrosting.

17.2.2. Water Distribution Pans

17.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

17.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

17.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

17.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

17.3. Air Defrost.

17.3.1. Coil shall be arranged for air (off cycle) defrosting.

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17.4. Electric Defrost.
17.4.1. General
17.4.1.1. Coil shall be arranged for electric defrosting.
17.4.2. Heating elements
17.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.
17.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

17.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.
17.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

18. Packaging
18.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.
18.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.
18.3. Crating shall support the full weight of the evaporator.
18.4. Crating shall be removable by means of gravity only.

19. IOM Manuals
19.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

20. Approved Vendor
20.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+M Series

21. Ordering Information
21.1. Please Specify:
21.1.1. Complete model number.
21.1.2. Saturated suction temperature.
21.1.3. Room temperature.
21.1.4. Overfeed ratio (if pump recirculated).
21.1.5. Options or special features.

22. Optional Features

1.1. Variable Fin Spacing
1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.
1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+M Air Cooler (SST Tube) Engineering Specifications

1. **General**
   1.1. This specification covers “A+M” type air coolers having stainless steel tubes and aluminum fins intended for use in refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method.
   2.2. DTM rating method shall not be used.
   2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. **Tubing**
   3.1. Coil block shall be constructed with 304L stainless steel tubing.
   3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
   3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. **Tube Pattern**
   4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
      4.1.1. 5/8” OD - 1.5” x 1.299” equilateral staggered
      4.1.2. 5/8” OD – 1.97” (50 mm) inline
      4.1.3. 7/8” OD - 2.25” x 1.949” equilateral staggered

5. **Fins**
   5.1. Fins shall be selected from one of the four materials below based on optimum performance and the environment in which the cooler will operate.
      5.1.1. Aluminum 1100 alloy, no less than 0.010” (0.25 mm) thick.
      5.1.2. 304L stainless steel, no less than 0.010” ” (0.25 mm) thick.
      5.1.3. Colmac Anti-Microbial alloy, no less than 0.010” ” (0.25 mm) thick.
         5.1.3.1. Coil core fins shall be constructed of a metal alloy that exhibits anti-microbial properties.
         5.1.3.2. Fins shall completely cover the coil tube surfaces exposed to the airstream by means of a full-length self-spacing fin collar.
         5.1.3.3. Coil coatings are not allowed. All surfaces to be a base metal alloy.
   5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
   5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. **Headers**
   6.1. Headers shall be made of 304L stainless steel pipe certified to ASME SA-240/304L, no less than ANSI schedule 40.

7. **Connections**
   7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than

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schedule 40, certified to ASME SA-240/304L. Bolted type flange union connections shall not be allowed.

7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.

7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.

7.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube and header welds shall be made by Tungsten Inert Gas (TIG) welding process.

9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. Type FL (Gravity Flooded)

11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

11.3. Type DX (Direct Expansion)

11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.

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11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

11.4. Type BW (Single Phase Liquids)

11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.

11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading

12. Fans

12.1. Construction.

12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

12.1.3. Fans shall be true airfoil shape and shall be non-overloading type

12.2. Fan Guards.

12.2.1. Fans shall be fully guarded with OSHA approved wire guards.

12.3. Direction of Air Flow

12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

13.2. Motor service factor shall be no less than 1.15.

13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

14.1. General

14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System

14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

14.3. Standard Air Section

14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

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14.4. <u>45 Degree Down Discharge Air Section</u>

14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

14.5. <u>Penthouse Air Section</u>

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

16. Defrost

16.1. <u>Hot Gas Defrost</u>

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

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16.2. Water Defrost.

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

16.3. Air Defrost.

16.3.1. Coil shall be arranged for air (off cycle) defrosting.

16.4. Electric Defrost.

16.4.1. General

16.4.1.1. Coil shall be arranged for electric defrosting.

16.4.2. Heating elements

16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging

17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.

17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

17.3. Crating shall support the full weight of the evaporator.

17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals

18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor

19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+M Series

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20. Ordering Information

20.1. Please Specify:

20.1.1. Complete model number.
20.1.2. Saturated suction temperature.
20.1.3. Room temperature.
20.1.4. Overfeed ratio (if pump recirculated).
20.1.5. Options or special features.

21. Optional Features

1.1. Variable Fin Spacing

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.
1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+S Air Cooler (AL Tube) Engineering Specifications

1. **General**
   1.1. This specification covers "A+S" type air coolers having aluminum tubes and aluminum fins intended for use in refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method.
   2.2. DTM rating method shall not be used.
   2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. **Tubing**
   3.1. Coil block shall be constructed with alloy 3003 aluminum tubing.
   3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
   3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. **Tube Pattern**
   4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
      4.1.1. 5/8" OD - 1.5" x 1.299" equilateral staggered
      4.1.2. 5/8" OD – 1.97" (50 mm) inline
      4.1.3. 7/8" OD - 2.25" x 1.949" equilateral staggered

5. **Fins**
   5.1. Shall be aluminum 1100 alloy, no less than 0.010" (0.25 mm) thick.
   5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, "L-foot", or wrap-on type fins shall not be allowed.
   5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. **Headers**
   6.1. Headers shall be made of ASME B241, Alloy 6061 aluminum no less than ANSI schedule 40 pipes.

7. **Connections**
   7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-106/B. Bolted type flange union connections shall not be allowed.
   7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
   7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.
   7.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping

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charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube welds shall be made by Tungsten Inert Gas (TIG) welding process.

9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)</u>

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. <u>Type FL (Gravity Flooded)</u>

11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

11.3. <u>Type DX (Direct Expansion)</u>

11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.

11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

11.4. <u>Type BW (Single Phase Liquids)</u>

11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.

11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

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12. Fans

12.1. Construction.

12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

12.1.3. Fans shall be true airfoil shape and shall be non-overloading type

12.2. Fan Guards.

12.2.1. Fans shall be fully guarded with OSHA approved wire guards.

12.3. Direction of Air Flow

12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

13.2. Motor service factor shall be no less than 1.15.

13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

14.1. General

14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System

14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

14.3. Standard Air Section

14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

14.4. 45 Degree Down Discharge Air Section

14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

14.5. Penthouse Air Section

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

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15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

16. Defrost

16.1. <u>Hot Gas Defrost</u>

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

16.2. <u>Water Defrost.</u>

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

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16.3. Air Defrost.
- 16.3.1. Coil shall be arranged for air (off cycle) defrosting.

16.4. Electric Defrost.
- 16.4.1. General
  - 16.4.1.1. Coil shall be arranged for electric defrosting.
- 16.4.2. Heating elements
  - 16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.
  - 16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.
  - 16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.
  - 16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging

17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.

17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

17.3. Crating shall support the full weight of the evaporator.

17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals

18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor

19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+S Series

20. Ordering Information

20.1. Please Specify:
- 20.1.1. Complete model number.
- 20.1.2. Saturated suction temperature.
- 20.1.3. Room temperature.
- 20.1.4. Overfeed ratio (if pump recirculated).
- 20.1.5. Options or special features.

21. Optional Features

1.1. Variable Fin Spacing
- 1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.
- 1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+S Air Cooler (Cu Tube) Engineering Specifications

1. **General**
   1.1. This specification covers “A+S” type air coolers having copper tubes and aluminum fins intended for use in refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method.
   2.2. DTM rating method shall not be used.
   2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. **Tubing**
   3.1. Coil block shall be constructed with UNS C12200 copper tubing certified to ASTM B-75.
   3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
   3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. **Tube Pattern**
   4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
      4.1.1. 5/8” OD - 1.5” x 1.299” equilateral staggered
      4.1.2. 5/8” OD – 1.97” (50 mm) inline
      4.1.3. 7/8” OD - 2.25” x 1.949” equilateral staggered

5. **Fins**
   5.1. Fins shall be selected from one of the four materials below based on optimum performance and the environment in which the cooler will operate.
      5.1.1. Aluminum 1100 alloy, no less than 0.010” (0.25 mm) thick.
      5.1.2. 304L stainless steel, no less than 0.010” ” (0.25 mm) thick.
      5.1.3. Copper, no less than no less than 0.010” ” (0.25 mm) thick.
   5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
   5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. **Headers**
   6.1. Headers shall be made of UNS C12200 Type L copper tubing certified to ASTM B-88.

7. **Connections**
   7.1. Liquid, suction, and hot gas connections shall be UNS C12200 Type L copper tubing certified to ASTM B-88. Bolted type flange union connections shall not be allowed.
   7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
   7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.
   7.4. Coil connections shall be terminated with a brazed copper head at the factory. One

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"Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Brazing/QC

9.1. All tube and header joints shall be made with high temperature brazing filler metal certified to no less than BCuP-3 (5% Silver Solder).
9.2. All brazing shall be performed by ASME certified brazers per the requirements of the manufacturer's BPS documents. Copies of all BPS, PQR, and Brazer Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.
9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after brazing at no less than 350 psig (25 bar), dry air under water.
10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)
- 11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.
- 11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.
- 11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. Type FL (Gravity Flooded)
- 11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.
- 11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

11.3. Type DX (Direct Expansion)
- 11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.
- 11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

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11.4. Type BW (Single Phase Liquids)
- 11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.
- 11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

12. Fans

12.1. Construction.
- 12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.
- 12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.
- 12.1.3. Fans shall be true airfoil shape and shall be non-overloading type

12.2. Fan Guards.
- 12.2.1. Fans shall be fully guarded with OSHA approved wire guards.

12.3. Direction of Air Flow
- 12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

13.2. Motor service factor shall be no less than 1.15.

13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

14.1. General
- 14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System
- 14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.
- 14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

14.3. Standard Air Section
- 14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

14.4. 45 Degree Down Discharge Air Section
- 14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.
- 14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

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14.5. Penthouse Air Section

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

16. Defrost

16.1. Hot Gas Defrost

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

16.2. Water Defrost.

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

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16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.
16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.
16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

16.3. Air Defrost.
16.3.1. Coil shall be arranged for air (off cycle) defrosting.
16.4. Electric Defrost.
16.4.1. General
16.4.1.1. Coil shall be arranged for electric defrosting.
16.4.2. Heating elements
16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.
16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.
16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging
17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.
17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.
17.3. Crating shall support the full weight of the evaporator.
17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals
18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor
19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+S Series

20. Ordering Information
20.1. Please Specify:
20.1.1. Complete model number.
20.1.2. Saturated suction temperature.
20.1.3. Room temperature.
20.1.4. Overfeed ratio (if pump recirculated).
20.1.5. Options or special features.

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21. **Optional Features**

1.1. Variable Fin Spacing

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.

1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+S Air Cooler (Galvanized) Engineering Specifications

1. General

1.1. This specification covers "A+S" type air coolers having galvanized steel tubes and fins intended for use in refrigeration systems.

2. Selection / Rating Method

2.1. Evaporators shall be selected using DT1 rating method.
2.2. DTM rating method shall not be used.
2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. Tubing

3.1. Coil block shall be constructed with ASME SA-214 carbon steel tubing.
3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. Tube Pattern

4.1.1. Tube pattern shall be 7/8" OD - 2.25" x 1.949" equilateral staggered

5. Fins

5.1. Shall be carbon steel, no less than 0.010" (0.25 mm) thick.
5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, "L-foot", or wrap-on type fins shall not be allowed.
5.3. Fin collars shall be configured so that molten zinc completely bonds the tubes and fins.

6. Headers

6.1. Headers shall be made of carbon steel pipe certified to ASME SA-106/B, no less than ANSI schedule 40.

7. Connections

7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-106/B. Bolted type flange union connections shall not be allowed.
7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.
7.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.
7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

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8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube and header welds shall be made by Tungsten Inert Gas (TIG) welding process.

9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)</u>

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. <u>Type FL (Gravity Flooded)</u>

11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

11.3. <u>Type DX (Direct Expansion)</u>

11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.

11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

11.4. <u>Type BW (Single Phase Liquids)</u>

11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.

11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

12. Galvanizing

12.1. Carbon steel coil core to be hot-dip galvanized per ASTM A-123 for corrosion protection.

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13. Fans

13.1. Construction.

13.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

13.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

13.1.3. Fans shall be true airfoil shape and shall be non-overloading type

13.2. Fan Guards.

13.2.1. Fans shall be fully guarded with OSHA approved wire guards.

13.3. Direction of Air Flow

13.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

14. Fan Motors

14.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

14.2. Motor service factor shall be no less than 1.15.

14.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

14.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

15. Cabinet

15.1. General

15.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

15.2. Optional Smart Hanger System

15.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

15.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

15.3. Standard Air Section

15.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

15.4. 45 Degree Down Discharge Air Section

15.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

15.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

15.5. Penthouse Air Section

15.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

15.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

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16. Drainpans

16.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.
16.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.
16.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.
16.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.
16.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.
16.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

17. Defrost

17.1. Hot Gas Defrost
17.1.1. General
17.1.1.1. Coil shall be arranged for hot gas defrosting.
17.1.2. Pan Loop
17.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.
17.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.
17.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.
17.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.
17.1.3. Pan Loop Check Valve
17.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.
17.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

17.2. Water Defrost.
17.2.1. General
17.2.1.1. Coil shall be arranged for water defrosting.
17.2.2. Water Distribution Pans
17.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.
17.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.
17.2.2.3. Water distribution pans shall be removable for inspection and cleaning.
17.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

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17.3. Air Defrost.
17.3.1. Coil shall be arranged for air (off cycle) defrosting.
17.4. Electric Defrost.
17.4.1. General
17.4.1.1. Coil shall be arranged for electric defrosting.
17.4.2. Heating elements
17.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.
17.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

17.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.
17.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

18. Packaging
18.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.
18.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.
18.3. Crating shall support the full weight of the evaporator.
18.4. Crating shall be removable by means of gravity only.

19. IOM Manuals
19.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

20. Approved Vendor
20.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+S Series

21. Ordering Information
21.1. Please Specify:
21.1.1. Complete model number.
21.1.2. Saturated suction temperature.
21.1.3. Room temperature.
21.1.4. Overfeed ratio (if pump recirculated).
21.1.5. Options or special features.

22. Optional Features
1.1. Variable Fin Spacing
1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.
1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+S Air Cooler (SST Tube) Engineering Specifications

1. General

1.1. This specification covers "A+S" type air coolers having stainless steel tubes and aluminum fins intended for use in refrigeration systems.

2. Selection / Rating Method

2.1. Evaporators shall be selected using DT1 rating method.
2.2. DTM rating method shall not be used.
2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. Tubing

3.1. Coil block shall be constructed with 304L stainless steel tubing.
3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. Tube Pattern

4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
- 4.1.1. 5/8" OD - 1.5" x 1.299" equilateral staggered
- 4.1.2. 5/8" OD – 1.97" (50 mm) inline
- 4.1.3. 7/8" OD - 2.25" x 1.949" equilateral staggered

5. Fins

5.1. Fins shall be selected from one of the four materials below based on optimum performance and the environment in which the cooler will operate.
- 5.1.1. Aluminum 1100 alloy, no less than 0.010" (0.25 mm) thick.
- 5.1.2. 304L stainless steel, no less than 0.010" " (0.25 mm) thick.
- 5.1.3. Colmac Anti-Microbial alloy, no less than 0.010" " (0.25 mm) thick.
  - 5.1.3.1. Coil core fins shall be constructed of a metal alloy that exhibits anti-microbial properties.
  - 5.1.3.2. Fins shall completely cover the coil tube surfaces exposed to the airstream by means of a full-length self-spacing fin collar.
  - 5.1.3.3. Coil coatings are not allowed. All surfaces to be a base metal alloy.

5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, "L-foot", or wrap-on type fins shall not be allowed.
5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. Headers

6.1. Headers shall be made of 304L stainless steel pipe certified to ASME SA-240/304L, no less than ANSI schedule 40.

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7. Connections

7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-240/304L. Bolted type flange union connections shall not be allowed.

7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.

7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.

7.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube and header welds shall be made by Tungsten Inert Gas (TIG) welding process.

9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)</u>

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. <u>Type FL (Gravity Flooded)</u>

11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

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11.3. Type DX (Direct Expansion)

11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.

11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

11.4. Type BW (Single Phase Liquids)

11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.

11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

12. Fans

12.1. Construction.

12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

12.1.3. Fans shall be true airfoil shape and shall be non-overloading type

12.2. Fan Guards.

12.2.1. Fans shall be fully guarded with OSHA approved wire guards.

12.3. Direction of Air Flow

12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

13.2. Motor service factor shall be no less than 1.15.

13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

14.1. General

14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System

14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

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14.3. Standard Air Section

14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

14.4. 45 Degree Down Discharge Air Section

14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

14.5. Penthouse Air Section

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

16. Defrost

16.1. Hot Gas Defrost

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

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16.2. Water Defrost.

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

16.3. Air Defrost.

16.3.1. Coil shall be arranged for air (off cycle) defrosting.

16.4. Electric Defrost.

16.4.1. General

16.4.1.1. Coil shall be arranged for electric defrosting.

16.4.2. Heating elements

16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging

17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.

17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

17.3. Crating shall support the full weight of the evaporator.

17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals

18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor

19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+S Series

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20. Ordering Information

20.1. Please Specify:

20.1.1. Complete model number.
20.1.2. Saturated suction temperature.
20.1.3. Room temperature.
20.1.4. Overfeed ratio (if pump recirculated).
20.1.5. Options or special features.

21. Optional Features

1.1. Variable Fin Spacing

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.
1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+R Air Cooler (AL Tube) Engineering Specifications

1. **General**
   1.1. This specification covers “A+R” type air coolers having aluminum tubes and aluminum fins intended for use in ammonia refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method.
   2.2. DTM rating method shall not be used.
   2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. **Tubing**
   3.1. Coil block shall be constructed with alloy 3003 aluminum tubing.
   3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
   3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. **Tube Pattern**
   4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
      4.1.1. 5/8” OD - 1.5” x 1.299” equilateral staggered
      4.1.2. 5/8” OD – 1.97” (50 mm) inline
      4.1.3. 7/8” OD - 2.25” x 1.949” equilateral staggered

5. **Fins**
   5.1. Shall be aluminum 1100 alloy, no less than 0.010” (0.25 mm) thick.
   5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
   5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. **Headers**
   6.1. Headers shall be made of ASME B241, Alloy 6061 aluminum no less than ANSI schedule 40 pipes.

7. **Connections**
   7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-106/B. Bolted type flange union connections shall not be allowed.
   7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
   7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.
   7.4. Coil connections shall be terminated with a welded steel head at the factory. One “Schrader” type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping

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charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube welds shall be made by Tungsten Inert Gas (TIG) welding process.

9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Type RTA (Recirc Top Feed) and Type RBA (Recirc Bottom Feed)</u>

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for 5 psi pressure drop at the design ammonia flow rate.

12. Fans

12.1. <u>Construction.</u>

12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

12.1.3. Fans shall be true airfoil shape and shall be non-overloading type

12.2. <u>Fan Guards.</u>

12.2.1. Fans shall be fully guarded with OSHA approved wire guards.

12.3. <u>Direction of Air Flow</u>

12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

13.2. Motor service factor shall be no less than 1.15.

13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

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14. Cabinet

14.1. General

14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System

14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

14.3. Standard Air Section

14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

14.4. 45 Degree Down Discharge Air Section

14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

14.5. Penthouse Air Section

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1” thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

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16. Defrost

16.1. Hot Gas Defrost

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

16.2. Water Defrost.

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

16.3. Air Defrost.

16.3.1. Coil shall be arranged for air (off cycle) defrosting.

16.4. Electric Defrost.

16.4.1. General

16.4.1.1. Coil shall be arranged for electric defrosting.

16.4.2. Heating elements

16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

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16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.
16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging

17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.
17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.
17.3. Crating shall support the full weight of the evaporator.
17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals

18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor

19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+R Series

20. Ordering Information

20.1. Please Specify:
20.1.1. Complete model number.
20.1.2. Saturated suction temperature.
20.1.3. Room temperature.
20.1.4. Overfeed ratio (if pump recirculated).
20.1.5. Options or special features.

21. Optional Features

1.1. Variable Fin Spacing
1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.
1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+R Air Cooler (Cu Tube) Engineering Specifications

1. **General**
   1.1. This specification covers “A+R” type air coolers having copper tubes and aluminum fins intended for use in halocarbon refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method.
   2.2. DTM rating method shall not be used.
   2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. **Tubing**
   3.1. Coil block shall be constructed with UNS C12200 copper tubing certified to ASTM B-75.
   3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
   3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. **Tube Pattern**
   4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
      4.1.1. 5/8” OD - 1.5” x 1.299” equilateral staggered
      4.1.2. 5/8” OD – 1.97” (50 mm) inline
      4.1.3. 7/8” OD - 2.25” x 1.949” equilateral staggered

5. **Fins**
   5.1. Fins shall be selected from one of the four materials below based on optimum performance and the environment in which the cooler will operate.
      5.1.1. Aluminum 1100 alloy, no less than 0.010” (0.25 mm) thick.
      5.1.2. 304L stainless steel, no less than 0.010” ” (0.25 mm) thick.
      5.1.3. Copper, no less than no less than 0.010” ” (0.25 mm) thick.
   5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
   5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. **Headers**
   6.1. Headers shall be made of UNS C12200 Type L copper tubing certified to ASTM B-88.

7. **Connections**
   7.1. Liquid, suction, and hot gas connections shall be UNS C12200 Type L copper tubing certified to ASTM B-88. Bolted type flange union connections shall not be allowed.
   7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
   7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.
   7.4. Coil connections shall be terminated with a brazed copper head at the factory. One

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"Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Brazing/QC

9.1. All tube and header joints shall be made with high temperature brazing filler metal certified to no less than BCuP-3 (5% Silver Solder).
9.2. All brazing shall be performed by ASME certified brazers per the requirements of the manufacturer's BPS documents. Copies of all BPS, PQR, and Brazer Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.
9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after brazing at no less than 350 psig (25 bar), dry air under water.
10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Type RTA (Recirc Top Feed) and Type RBA (Recirc Bottom Feed)</u>
11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for 5 psi pressure drop at the design ammonia flow rate.

12. Fans

12.1. <u>Construction.</u>
12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.
12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.
12.1.3. Fans shall be true airfoil shape and shall be non-overloading type
12.2. <u>Fan Guards.</u>
12.2.1. Fans shall be fully guarded with OSHA approved wire guards.
12.3. <u>Direction of Air Flow</u>
12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.
13.2. Motor service factor shall be no less than 1.15.

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13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

14.1. General

14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System

14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

14.3. Standard Air Section

14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

14.4. 45 Degree Down Discharge Air Section

14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

14.5. Penthouse Air Section

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

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16. Defrost

16.1. Hot Gas Defrost

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

16.2. Water Defrost.

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

16.3. Air Defrost.

16.3.1. Coil shall be arranged for air (off cycle) defrosting.

16.4. Electric Defrost.

16.4.1. General

16.4.1.1. Coil shall be arranged for electric defrosting.

16.4.2. Heating elements

16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

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16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging

17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.

17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

17.3. Crating shall support the full weight of the evaporator.

17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals

18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor

19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+R Series

20. Ordering Information

20.1. Please Specify:

20.1.1. Complete model number.

20.1.2. Saturated suction temperature.

20.1.3. Room temperature.

20.1.4. Overfeed ratio (if pump recirculated).

20.1.5. Options or special features.

21. Optional Features

1.1. <u>Variable Fin Spacing</u>

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.

1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+R Air Cooler (Galvanized) Engineering Specifications

1. General

1.1. This specification covers "A+R" type air coolers having galvanized steel tubes and fins intended for use in ammonia refrigeration systems.

2. Selection / Rating Method

2.1. Evaporators shall be selected using DT1 rating method.
2.2. DTM rating method shall not be used.
2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. Tubing

3.1. Coil block shall be constructed with ASME SA-214 carbon steel tubing.
3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. Tube Pattern

4.1.1. Tube pattern shall be 7/8" OD - 2.25" x 1.949" equilateral staggered

5. Fins

5.1. Shall be carbon steel, no less than 0.010" (0.25 mm) thick.
5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, "L-foot", or wrap-on type fins shall not be allowed.
5.3. Fin collars shall be configured so that molten zinc completely bonds the tubes and fins.

6. Headers

6.1. Headers shall be made of carbon steel pipe certified to ASME SA-106/B, no less than ANSI schedule 40.

7. Connections

7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-106/B. Bolted type flange union connections shall not be allowed.
7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.
7.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.
7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

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8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube and header welds shall be made by Tungsten Inert Gas (TIG) welding process.

9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. Type RTA (Recirc Top Feed) and Type RBA (Recirc Bottom Feed)

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for 5 psi pressure drop at the design ammonia flow rate.

12. Galvanizing

12.1. Carbon steel coil core to be hot-dip galvanized per ASTM A-123 for corrosion protection.

13. Fans

13.1. Construction.

13.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

13.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

13.1.3. Fans shall be true airfoil shape and shall be non-overloading type

13.2. Fan Guards.

13.2.1. Fans shall be fully guarded with OSHA approved wire guards.

13.3. Direction of Air Flow

13.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

14. Fan Motors

14.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

14.2. Motor service factor shall be no less than 1.15.

14.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

14.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

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15. Cabinet

15.1. General

15.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

15.2. Optional Smart Hanger System

15.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

15.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

15.3. Standard Air Section

15.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

15.4. 45 Degree Down Discharge Air Section

15.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

15.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

15.5. Penthouse Air Section

15.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

15.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

16. Drainpans

16.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

16.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

16.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

16.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

16.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

16.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

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17. Defrost

17.1. Hot Gas Defrost

17.1.1. General

17.1.1.1. Coil shall be arranged for hot gas defrosting.

17.1.2. Pan Loop

17.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

17.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

17.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

17.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

17.1.3. Pan Loop Check Valve

17.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

17.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

17.2. Water Defrost.

17.2.1. General

17.2.1.1. Coil shall be arranged for water defrosting.

17.2.2. Water Distribution Pans

17.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

17.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

17.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

17.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

17.3. Air Defrost.

17.3.1. Coil shall be arranged for air (off cycle) defrosting.

17.4. Electric Defrost.

17.4.1. General

17.4.1.1. Coil shall be arranged for electric defrosting.

17.4.2. Heating elements

17.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

17.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

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17.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

17.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

18. Packaging

18.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.

18.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

18.3. Crating shall support the full weight of the evaporator.

18.4. Crating shall be removable by means of gravity only.

19. IOM Manuals

19.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

20. Approved Vendor

20.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+R Series

21. Ordering Information

21.1. Please Specify:

21.1.1. Complete model number.

21.1.2. Saturated suction temperature.

21.1.3. Room temperature.

21.1.4. Overfeed ratio (if pump recirculated).

21.1.5. Options or special features.

22. Optional Features

1.1. Variable Fin Spacing

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.

1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+R Air Cooler (SST Tube) Engineering Specifications

1. General

1.1. This specification covers “A+R” type air coolers having stainless steel tubes and aluminum fins intended for use in refrigeration systems.

2. Selection / Rating Method

2.1. Evaporators shall be selected using DT1 rating method.
2.2. DTM rating method shall not be used.
2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. Tubing

3.1. Coil block shall be constructed with 304L stainless steel tubing.
3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. Tube Pattern

4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
4.1.1. 5/8” OD - 1.5” x 1.299” equilateral staggered
4.1.2. 5/8” OD – 1.97” (50 mm) inline
4.1.3. 7/8” OD - 2.25” x 1.949” equilateral staggered

5. Fins

5.1. Fins shall be selected from one of the four materials below based on optimum performance and the environment in which the cooler will operate.
5.1.1. Aluminum 1100 alloy, no less than 0.010” (0.25 mm) thick.
5.1.2. 304L stainless steel, no less than 0.010” ” (0.25 mm) thick.
5.1.3. Colmac Anti-Microbial alloy, no less than 0.010” ” (0.25 mm) thick.
5.1.3.1. Coil core fins shall be constructed of a metal alloy that exhibits anti-microbial properties.
5.1.3.2. Fins shall completely cover the coil tube surfaces exposed to the airstream by means of a full-length self-spacing fin collar.
5.1.3.3. Coil coatings are not allowed. All surfaces to be a base metal alloy.
5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. Headers

6.1. Headers shall be made of 304L stainless steel pipe certified to ASME SA-240/304L, no less than ANSI schedule 40.

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7. Connections

7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-240/304L. Bolted type flange union connections shall not be allowed.

7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.

7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.

7.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube and header welds shall be made by Tungsten Inert Gas (TIG) welding process.

9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)</u>

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. <u>Type FL (Gravity Flooded)</u>

11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

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11.3. Type DX (Direct Expansion)

11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.

11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

11.4. Type BW (Single Phase Liquids)

11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.

11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

12. Fans

12.1. Construction.

12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

12.1.3. Fans shall be true airfoil shape and shall be non-overloading type

12.2. Fan Guards.

12.2.1. Fans shall be fully guarded with OSHA approved wire guards.

12.3. Direction of Air Flow

12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

13.2. Motor service factor shall be no less than 1.15.

13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

14.1. General

14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System

14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

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14.3. Standard Air Section

14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

14.4. 45 Degree Down Discharge Air Section

14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

14.5. Penthouse Air Section

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

16. Defrost

16.1. Hot Gas Defrost

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

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16.2. Water Defrost.
16.2.1. General
16.2.1.1. Coil shall be arranged for water defrosting.
16.2.2. Water Distribution Pans
16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.
16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.
16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.
16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

16.3. Air Defrost.
16.3.1. Coil shall be arranged for air (off cycle) defrosting.
16.4. Electric Defrost.
16.4.1. General
16.4.1.1. Coil shall be arranged for electric defrosting.
16.4.2. Heating elements
16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.
16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.
16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging
17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.
17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.
17.3. Crating shall support the full weight of the evaporator.
17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals
18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor
19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+R Series

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20. Ordering Information

20.1. Please Specify:

20.1.1. Complete model number.
20.1.2. Saturated suction temperature.
20.1.3. Room temperature.
20.1.4. Overfeed ratio (if pump recirculated).
20.1.5. Options or special features.

21. **Optional Features**

1.1. Variable Fin Spacing

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.
1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+D Air Cooler (AL Tube) Engineering Specifications

1. General

1.1. This specification covers “A+D” type air coolers having aluminum tubes and aluminum fins intended for use in refrigeration systems.

2. Selection / Rating Method

2.1. Evaporators shall be selected using DT1 rating method.
2.2. DTM rating method shall not be used.
2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. Tubing

3.1. Coil block shall be constructed with alloy 3003 aluminum tubing.
3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. Tube Pattern

4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
 4.1.1. 5/8” OD - 1.5” x 1.299” equilateral staggered
 4.1.2. 5/8” OD – 1.97” (50 mm) inline
 4.1.3. 7/8” OD - 2.25” x 1.949” equilateral staggered

5. Fins

5.1. Shall be aluminum 1100 alloy, no less than 0.010” (0.25 mm) thick.
5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. Headers

6.1. Headers shall be made of ASME B241, Alloy 6061 aluminum no less than ANSI schedule 40 pipes.

7. Connections

7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-106/B. Bolted type flange union connections shall not be allowed.
7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.

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7.4. Coil connections shall be terminated with a welded steel head at the factory. One “Schrader” type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube welds shall be made by Tungsten Inert Gas (TIG) welding process.

9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer’s WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer’s Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. Type RTA (Recirc Top Feed) and Type RBA (Recirc Bottom Feed)

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for 5 psi pressure drop at the design ammonia flow rate.

12. Fans

12.1. Construction.

12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

12.1.3. Fans shall be true airfoil shape and shall be non-overloading type

12.2. Fan Guards.

12.2.1. Fans shall be fully guarded with OSHA approved wire guards.

12.3. Direction of Air Flow

12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

13.2. Motor service factor shall be no less than 1.15.

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13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

14.1. General

14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System

14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

14.3. Standard Air Section

14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

14.4. 45 Degree Down Discharge Air Section

14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

14.5. Penthouse Air Section

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

16. Defrost

16.1. Hot Gas Defrost

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

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16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

16.2. Water Defrost.

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

16.3. Air Defrost.

16.3.1. Coil shall be arranged for air (off cycle) defrosting.

16.4. Electric Defrost.

16.4.1. General

16.4.1.1. Coil shall be arranged for electric defrosting.

16.4.2. Heating elements

16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

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17. Packaging

17.1. Units shall be crated on a wooden skid constructed of no less than 2” x 8” timbers.

17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

17.3. Crating shall support the full weight of the evaporator.

17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals

18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor

19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+D Series

20. Ordering Information

20.1. Please Specify:

20.1.1. Complete model number.

20.1.2. Saturated suction temperature.

20.1.3. Room temperature.

20.1.4. Overfeed ratio (if pump recirculated).

20.1.5. Options or special features.

21. Optional Features

1.1. Variable Fin Spacing

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.

1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+D Air Cooler (Cu Tube) Engineering Specifications

1. **General**
   1.1. This specification covers “A+D” type air coolers having copper tubes and aluminum fins intended for use in refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method.
   2.2. DTM rating method shall not be used.
   2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. **Tubing**
   3.1. Coil block shall be constructed with UNS C12200 copper tubing certified to ASTM B-75.
   3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
   3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. **Tube Pattern**
   4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
      4.1.1. 5/8” OD - 1.5” x 1.299” equilateral staggered
      4.1.2. 5/8” OD – 1.97” (50 mm) inline
      4.1.3. 7/8” OD - 2.25” x 1.949” equilateral staggered

5. **Fins**
   5.1. Fins shall be selected from one of the four materials below based on optimum performance and the environment in which the cooler will operate.
      5.1.1. Aluminum 1100 alloy, no less than 0.010” (0.25 mm) thick.
      5.1.2. 304L stainless steel, no less than 0.010” ” (0.25 mm) thick.
      5.1.3. Copper, no less than no less than 0.010” ” (0.25 mm) thick.
   5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
   5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. **Headers**
   6.1. Headers shall be made of UNS C12200 Type L copper tubing certified to ASTM B-88.

7. **Connections**
   7.1. Liquid, suction, and hot gas connections shall be UNS C12200 Type L copper tubing certified to ASTM B-88. Bolted type flange union connections shall not be allowed.
   7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
   7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.
   7.4. Coil connections shall be terminated with a brazed copper head at the factory. One

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"Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Brazing/QC

9.1. All tube and header joints shall be made with high temperature brazing filler metal certified to no less than BCuP-3 (5% Silver Solder).

9.2. All brazing shall be performed by ASME certified brazers per the requirements of the manufacturer's BPS documents. Copies of all BPS, PQR, and Brazer Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after brazing at no less than 350 psig (25 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)</u>

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. <u>Type FL (Gravity Flooded)</u>

11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

11.3. <u>Type DX (Direct Expansion)</u>

11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.

11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

11.4. <u>Type BW (Single Phase Liquids)</u>

11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.

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11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

12. Fans

12.1. Construction.

12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

12.1.3. Fans shall be true airfoil shape and shall be non-overloading type

12.2. Fan Guards.

12.2.1. Fans shall be fully guarded with OSHA approved wire guards.

12.3. Direction of Air Flow

12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

13.2. Motor service factor shall be no less than 1.15.

13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

14.1. General

14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System

14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

14.3. Standard Air Section

14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

14.4. 45 Degree Down Discharge Air Section

14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

14.5. Penthouse Air Section

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

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14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

16. Defrost

16.1. <u>Hot Gas Defrost</u>

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

16.2. <u>Water Defrost.</u>

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

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16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

16.3. Air Defrost.

16.3.1. Coil shall be arranged for air (off cycle) defrosting.

16.4. Electric Defrost.

16.4.1. General

16.4.1.1. Coil shall be arranged for electric defrosting.

16.4.2. Heating elements

16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging

17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.

17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

17.3. Crating shall support the full weight of the evaporator.

17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals

18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor

19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+D Series

20. Ordering Information

20.1. Please Specify:

20.1.1. Complete model number.

20.1.2. Saturated suction temperature.

20.1.3. Room temperature.

20.1.4. Overfeed ratio (if pump recirculated).

20.1.5. Options or special features.

21. Optional Features

1.1. Variable Fin Spacing

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.

1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+D Air Cooler (Galvanized) Engineering Specifications

1. **General**
   1.1. This specification covers "A+D" type air coolers having galvanized steel tubes and fins intended for use in refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method.
   2.2. DTM rating method shall not be used.
   2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. **Tubing**
   3.1. Coil block shall be constructed with ASME SA-214 carbon steel tubing.
   3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
   3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. **Tube Pattern**
   4.1.1. Tube pattern shall be 7/8" OD - 2.25" x 1.949" equilateral staggered

5. **Fins**
   5.1. Shall be carbon steel, no less than 0.010" (0.25 mm) thick.
   5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, "L-foot", or wrap-on type fins shall not be allowed.
   5.3. Fin collars shall be configured so that molten zinc completely bonds the tubes and fins.

6. **Headers**
   6.1. Headers shall be made of carbon steel pipe certified to ASME SA-106/B, no less than ANSI schedule 40.

7. **Connections**
   7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-106/B. Bolted type flange union connections shall not be allowed.
   7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
   7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.
   7.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.
   7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

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8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube and header welds shall be made by Tungsten Inert Gas (TIG) welding process.

9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)</u>

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. <u>Type FL (Gravity Flooded)</u>

11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

11.3. <u>Type DX (Direct Expansion)</u>

11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.

11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

11.4. <u>Type BW (Single Phase Liquids)</u>

11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.

11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

12. Galvanizing

12.1. Carbon steel coil core to be hot-dip galvanized per ASTM A-123 for corrosion protection.

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13. Fans

13.1. Construction.

13.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

13.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

13.1.3. Fans shall be true airfoil shape and shall be non-overloading type

13.2. Fan Guards.

13.2.1. Fans shall be fully guarded with OSHA approved wire guards.

13.3. Direction of Air Flow

13.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

14. Fan Motors

14.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

14.2. Motor service factor shall be no less than 1.15.

14.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

14.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

15. Cabinet

15.1. General

15.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

15.2. Optional Smart Hanger System

15.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

15.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

15.3. Standard Air Section

15.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

15.4. 45 Degree Down Discharge Air Section

15.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

15.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

15.5. Penthouse Air Section

15.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

15.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

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16. Drainpans

16.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

16.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

16.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

16.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

16.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

16.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

17. Defrost

17.1. Hot Gas Defrost

17.1.1. General

17.1.1.1. Coil shall be arranged for hot gas defrosting.

17.1.2. Pan Loop

17.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

17.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

17.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

17.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

17.1.3. Pan Loop Check Valve

17.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

17.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

17.2. Water Defrost.

17.2.1. General

17.2.1.1. Coil shall be arranged for water defrosting.

17.2.2. Water Distribution Pans

17.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

17.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

17.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

17.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

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17.3. Air Defrost.

17.3.1. Coil shall be arranged for air (off cycle) defrosting.

17.4. Electric Defrost.

17.4.1. General

17.4.1.1. Coil shall be arranged for electric defrosting.

17.4.2. Heating elements

17.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

17.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

17.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

17.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

18. Packaging

18.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.

18.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

18.3. Crating shall support the full weight of the evaporator.

18.4. Crating shall be removable by means of gravity only.

19. IOM Manuals

19.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

20. Approved Vendor

20.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+D Series

21. Ordering Information

21.1. Please Specify:

21.1.1. Complete model number.

21.1.2. Saturated suction temperature.

21.1.3. Room temperature.

21.1.4. Overfeed ratio (if pump recirculated).

21.1.5. Options or special features.

22. Optional Features

1.1. Variable Fin Spacing

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.

1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+D Air Cooler (SST Tube) Engineering Specifications

1. General

1.1. This specification covers “A+D” type air coolers having stainless steel tubes and aluminum fins intended for use in refrigeration systems.

2. Selection / Rating Method

2.1. Evaporators shall be selected using DT1 rating method.
2.2. DTM rating method shall not be used.
2.3. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.

3. Tubing

3.1. Coil block shall be constructed with 304L stainless steel tubing.
3.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
3.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

4. Tube Pattern

4.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
- 4.1.1. 5/8” OD - 1.5” x 1.299” equilateral staggered
- 4.1.2. 5/8” OD – 1.97” (50 mm) inline
- 4.1.3. 7/8” OD - 2.25” x 1.949” equilateral staggered

5. Fins

5.1. Fins shall be selected from one of the four materials below based on optimum performance and the environment in which the cooler will operate.
- 5.1.1. Aluminum 1100 alloy, no less than 0.010” (0.25 mm) thick.
- 5.1.2. 304L stainless steel, no less than 0.010” ” (0.25 mm) thick.
- 5.1.3. Colmac Anti-Microbial alloy, no less than 0.010” ” (0.25 mm) thick.
  - 5.1.3.1. Coil core fins shall be constructed of a metal alloy that exhibits anti-microbial properties.
  - 5.1.3.2. Fins shall completely cover the coil tube surfaces exposed to the airstream by means of a full-length self-spacing fin collar.
  - 5.1.3.3. Coil coatings are not allowed. All surfaces to be a base metal alloy.

5.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
5.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

6. Headers

6.1. Headers shall be made of 304L stainless steel pipe certified to ASME SA-240/304L, no less than ANSI schedule 40.

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7. Connections

7.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-240/304L. Bolted type flange union connections shall not be allowed.

7.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.

7.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.

7.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.

7.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

8. Cleanliness

8.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

9. Welding/QC

9.1. All tube and header welds shall be made by Tungsten Inert Gas (TIG) welding process.

9.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

9.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

10. Leak Testing

10.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

10.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

11. Circuiting

11.1. <u>Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)</u>

11.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

11.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

11.2. <u>Type FL (Gravity Flooded)</u>

11.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

11.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow..

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11.3. Type DX (Direct Expansion)

11.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.

11.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

11.4. Type BW (Single Phase Liquids)

11.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.

11.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

12. Fans

12.1. Construction.

12.1.1. Propeller fans shall be constructed of cast aluminum or non-ferrous polymer, as required by the contract.

12.1.2. Hub shall be removable type for ease of service. Integral fan/motor combinations with non-removable fans shall not be allowed.

12.1.3. Fans shall be true airfoil shape and shall be non-overloading type

12.2. Fan Guards.

12.2.1. Fans shall be fully guarded with OSHA approved wire guards.

12.3. Direction of Air Flow

12.3.1. Fans and motors shall be mounted on the air leaving side of the coil for draw through operation.

13. Fan Motors

13.1. Fan motors shall be standard NEMA frame size, inverter ready, integral horsepower, induction three phase, totally enclosed severe duty, with sealed ball bearings.

13.2. Motor service factor shall be no less than 1.15.

13.3. Motors shall have internal rotor construction. External rotor construction motors shall not be allowed.

13.4. Fan motors shall be individually wired by the manufacturer to individual junction boxes on the exterior of the unit cabinet.

14. Cabinet

14.1. General

14.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

14.2. Optional Smart Hanger System

14.2.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

14.2.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

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14.3. Standard Air Section

14.3.1. Fans and motors shall be arranged for horizontal air discharge, mounted on the air leaving side of the coil section (draw through).

14.4. 45 Degree Down Discharge Air Section

14.4.1. Fans and motors shall be arranged for 45 degree down air discharge when required by contract.

14.4.2. Air discharge section to be factory mounted on the air leaving side and tilted down at 45 degree angle from the vertical plane.

14.5. Penthouse Air Section

14.5.1. Fan and motors shall be arranged for vertical down air discharge when required by the contract. Penthouse air section shall be factory mounted on the air leaving side of the coil section (draw through).

14.5.2. Access doors shall be provided to allow access to each individual fan and motor for service.

15. Drainpans

15.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

15.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

15.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

15.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

15.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.

15.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

16. Defrost

16.1. Hot Gas Defrost

16.1.1. General

16.1.1.1. Coil shall be arranged for hot gas defrosting.

16.1.2. Pan Loop

16.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

16.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

16.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

16.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

16.1.3. Pan Loop Check Valve

16.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

16.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

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16.2. Water Defrost.

16.2.1. General

16.2.1.1. Coil shall be arranged for water defrosting.

16.2.2. Water Distribution Pans

16.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

16.2.2.2. Individual water distribution pans shall be provided one per fan section in the cooler.

16.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

16.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

16.3. Air Defrost.

16.3.1. Coil shall be arranged for air (off cycle) defrosting.

16.4. Electric Defrost.

16.4.1. General

16.4.1.1. Coil shall be arranged for electric defrosting.

16.4.2. Heating elements

16.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

16.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

16.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

16.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

17. Packaging

17.1. Units shall be crated on a wooden skid constructed of no less than 2" x 8" timbers.

17.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

17.3. Crating shall support the full weight of the evaporator.

17.4. Crating shall be removable by means of gravity only.

18. IOM Manuals

18.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

19. Approved Vendor

19.1. Approved Vendor: Colmac Coil Manufacturing, Inc. Model: A+D Series

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20. Ordering Information

20.1. Please Specify:

20.1.1. Complete model number.
20.1.2. Saturated suction temperature.
20.1.3. Room temperature.
20.1.4. Overfeed ratio (if pump recirculated).
20.1.5. Options or special features.

21. Optional Features

1.1. <u>Variable Fin Spacing</u>

1.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.
1.1.2. Fin spacing in fins per inch shall be specified according to contract.

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A+B Air Cooler (AL Tube) Engineering Specifications

1. General

1.1. This specification covers “A+B” type air coolers having aluminum tubes and aluminum fins intended for use in refrigeration systems.

2. Selection / Rating Method

2.1. Evaporators shall be selected using DT1 rating method. DTM rating method shall not be used.
2.2. Evaporators shall be selected on the basis of room relative humidity as shown in the drawing.
2.3. Ratings shall be calculated to include a frost thickness as shown on the drawing.
2.4. Ratings shall be calculated using an inside tube fouling factor as shown on the drawing.
2.5. Ratings shall be calculated using an outside tube fouling factor as shown on the drawing.

3. Coil Construction

3.1. Coil shall be constructed per ASME B31.5.
3.2. Tubing
3.2.1. Coil block shall be constructed with alloy 3003 aluminum tubing.
3.2.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
3.2.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

3.3. Tube Pattern
3.3.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
3.3.1.1. 5/8” OD - 1.5” x 1.299” equilateral staggered
3.3.1.2. 5/8” OD – 1.97” (50 mm) inline
3.3.1.3. 7/8” OD - 2.25” x 1.949” equilateral staggered

3.4. Fins
3.4.1. Shall be aluminum 1100 alloy, no less than 0.010” (0.25 mm) thick.
3.4.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
3.4.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

3.5. Headers
3.5.1. Headers shall be made of ASME B241, Alloy 6061 aluminum no less than ANSI schedule 40 pipes.

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3.6. Connections

3.6.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-106/B. Bolted type flange union connections shall not be allowed.

3.6.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.

3.6.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.

3.6.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.

3.6.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

3.7. Cleanliness

3.7.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

3.8. Welding/QC

3.8.1. All tube welds shall be made by Tungsten Inert Gas (TIG) welding process.

3.8.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

3.8.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

3.9. Leak Testing

3.9.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.

3.9.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

4. Circuiting

4.1. Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)

4.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

4.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

4.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

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4.2. Type FL (Gravity Flooded)
4.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.
4.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

4.3. Type DX (Direct Expansion)
4.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.
4.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

4.4. Type BW (Single Phase Liquids)
4.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.
4.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

5. Cabinet
5.1. General
5.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

6. Drainpans
6.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.
6.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.
6.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.
6.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.
6.5. When required by the contract, drainpan shall be insulated with a minimum of 1” thick insulation.
6.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

7. Defrost
7.1. Hot Gas Defrost
7.1.1. Coil shall be arranged for hot gas defrosting.
7.1.2. Pan Loop
7.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.
7.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

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7.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

7.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

7.1.3. Pan Loop Check Valve

7.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

7.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

7.2. <u>Water Defrost</u>

7.2.1. Coil shall be arranged for water defrosting.

7.2.2. Water Distribution Pans

7.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

7.2.2.2. Individual water distribution pans shall be provided one per bay section in the cooler.

7.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

7.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

7.3. <u>Air Defrost</u>

7.3.1. Coil shall be arranged for air (off cycle) defrosting.

7.4. <u>Electric Defrost.</u>

7.4.1. Coil shall be arranged for electric defrosting.

7.4.2. Heating elements

7.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

7.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

7.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

7.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater’s position during each defrost (US Patent No. 7,712,327).

8. Optional Features

8.1. <u>Variable Fin Spacing</u>

8.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.

8.1.2. Fin spacing in fins per inch shall be specified according to contract.

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8.2. Reheat coil section
- 8.2.1. Coil core shall have a separate reheat section to heat air as it leaves the unit.

8.3. Filter Racks
- 8.3.1. Unit shall have filter racks mounted to entering air side of coil core. Filter type specified in contract.

8.4. Full Coverage Drainpan
- 8.4.1. Drainpan shall be extended to ensure that all water dripping off of the casing is caught in the drainpan.

8.5. Drainpan Cover Heat Trace
- 8.5.1. Drainpan cover shall be lined with heat trace to prevent condensation.

8.6. Hinged Drainpan
- 8.6.1. Drainpan shall be hinged to allow for maintenance and cleaning.

8.7. End Covers
- 8.7.1. Unit shall have covers enclosing the header and return bend end of unit.
- 8.7.2. End covers shall be hinged to allow for maintenance and cleaning.

8.8. Unit Support Legs
- 8.8.1. Unit shall be equipped with support legs for floor mounting.
- 8.8.2. Height from floor to bottom of unit provided according to contract.
- 8.8.3. Legs over 16” high to have additional cross bracing for added strength.

8.9. Optional Smart Hanger System
- 8.9.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.
- 8.9.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

9. Packaging
- 9.1. Units shall be crated on a wooden skid constructed of no less than 2” x 8” timbers.
- 9.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.
- 9.3. Crating shall support the full weight of the evaporator.
- 9.4. Crating shall be removable by means of gravity only.

10. IOM Manuals
- 10.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

11. Approved Vendor
- 11.1. Approved Vendor: Colmac Coil Manufacturing, Inc.   Model: A+B Series

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12. Ordering Information

12.1. Please Specify:

12.1.1. Complete model number.

12.1.2. Saturated suction temperature.

12.1.3. Room temperature.

12.1.4. Overfeed ratio (if pump recirculated).

12.1.5. Options or special features.

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A+B Air Cooler (Cu Tube) Engineering Specifications

1. General

1.1. This specification covers “A+B” type air coolers having copper tubes and aluminum fins intended for use in refrigeration systems.

2. Selection / Rating Method

2.1. Evaporators shall be selected using DT1 rating method.
2.2. DTM rating method shall not be used.
2.3. Evaporators shall be selected on the basis of room relative humidity as shown on the drawing.
2.4. Ratings shall be calculated to include a frost thickness as shown on the drawing.
2.5. Ratings shall be calculated using an inside tube fouling factor as shown on the drawing.
2.6. Ratings shall be calculated using an outside tube fouling factor as shown on the drawing.

3. Coil Construction

3.1. Coil shall be constructed per ASME B31.5.
3.2. Tubing
3.2.1. Coil block shall be constructed with UNS C12200 copper tubing certified to ASTM B-75.
3.2.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
3.2.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

3.3. Tube Pattern
3.3.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
3.3.1.1. 5/8” OD - 1.5” x 1.299” equilateral staggered
3.3.1.2. 5/8” OD - 1.97” (50 mm) inline
3.3.1.3. 7/8” OD - 2.25” x 1.949” equilateral staggered

3.4. Fins
3.4.1. Fins shall be selected from one of the four materials below, based on optimum performance in the operating environment.
3.4.1.1. Aluminum 1100 alloy, no less than 0.010” (0.25 mm) thick.
3.4.1.2. 304L stainless steel, no less than 0.010” ” (0.25 mm) thick.
3.4.1.3. Copper, no less than no less than 0.010” ” (0.25 mm) thick.
3.4.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, “L-foot”, or wrap-on type fins shall not be allowed.
3.4.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

3.5. Headers
3.5.1. Headers shall be made of UNS C12200 Type L copper tubing certified to ASTM B-88.

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3.6. Connections

3.6.1. Liquid, suction, and hot gas connections shall be UNS C12200 Type L copper tubing certified to ASTM B-88. Bolted type flange union connections shall not be allowed.

3.6.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.

3.6.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.

3.6.4. Coil connections shall be terminated with a brazed copper head at the factory. One “Schrader” type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.

3.6.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

3.7. Cleanliness

3.7.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

3.8. Brazing/QC

3.8.1. All tube and header joints shall be made with high temperature brazing filler metal certified to no less than BCuP-3 (5% Silver Solder).

3.8.2. All brazing shall be performed by ASME certified brazers per the requirements of the manufacturer’s BPS documents. Copies of all BPS, PQR, and Brazer Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.

3.8.3. Copies of the manufacturer’s Quality Control Manual shall be made available to the engineer upon request.

3.9. Leak Testing

3.9.1. Coils shall be tested for leaks after brazing at no less than 350 psig (25 bar), dry air under water.

3.9.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

4. Circuiting

4.1. Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)

4.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.

4.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

4.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

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4.2. Type FL (Gravity Flooded)
4.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.
4.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

4.3. Type DX (Direct Expansion)
4.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.
4.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

4.4. Type BW (Single Phase Liquids)
4.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.
4.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

5. Cabinet

5.1. General
5.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

6. Drainpan

6.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.
6.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.
6.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.
6.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.
6.5. When required by the contract, drainpan shall be insulated with a minimum of 1” thick insulation.
6.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

7. Defrost

7.1. Hot Gas Defrost
7.1.1. Coil shall be arranged for hot gas defrosting.
7.1.2. Pan Loop
7.1.2.1. A hot gas pan loop of round 304L stainless steel tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.
7.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

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7.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

7.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

7.1.3. Pan Loop Check Valve

7.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

7.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

7.2. <u>Water Defrost.</u>

7.2.1. Coil shall be arranged for water defrosting.

7.2.2. Water Distribution Pans

7.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

7.2.2.2. Individual water distribution pans shall be provided one per bay section in the cooler.

7.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

7.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

7.3. <u>Air Defrost.</u>

7.3.1. Coil shall be arranged for air (off cycle) defrosting.

7.4. <u>Electric Defrost</u>

7.4.1. Coil shall be arranged for electric defrosting.

7.4.2. Heating elements

7.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

7.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

7.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

7.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater’s position during each defrost (US Patent No. 7,712,327).

8. Optional Features

8.1. <u>Variable Fin Spacing</u>

8.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.

8.1.2. Fin spacing in fins per inch shall be specified according to contract.

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8.2. Reheat coil section

8.2.1. Coil core shall have a separate reheat section to heat air as it leaves the unit.

8.3. Filter Racks

8.3.1. Unit shall have filter racks mounted to entering air side of coil core. Filter type specified in contract.

8.4. Full Coverage Drainpan

8.4.1. Drainpan shall be extended to ensure that all water dripping off of the casing is caught in the drainpan.

8.5. Drainpan Cover Heat Trace

8.5.1. Drainpan cover shall be lined with heat trace to prevent condensation.

8.6. Hinged Drainpan

8.6.1. Drainpan shall be hinged to allow for maintenance and cleaning.

8.7. End Covers

8.7.1. Unit shall have covers enclosing the header and return bend end of unit.

8.7.2. End covers shall be hinged to allow for maintenance and cleaning.

8.8. Unit Support Legs

8.8.1. Unit shall be equipped with support legs for floor mounting.

8.8.2. Height from floor to bottom of unit provided according to contract.

8.8.3. Legs over 16” high to have additional cross bracing for added strength.

8.9. Optional Smart Hanger System

8.9.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.

8.9.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

9. Packaging

9.1. Units shall be crated on a wooden skid constructed of no less than 2” x 8” timbers.

9.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.

9.3. Crating shall support the full weight of the evaporator.

9.4. Crating shall be removable by means of gravity only.

10. IOM Manuals

10.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

11. Approved Vendor

11.1. Approved Vendor: Colmac Coil Manufacturing, Inc.   Model: A+B Series

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12. Ordering Information

12.1. Please Specify:

- 12.1.1. Complete model number.
- 12.1.2. Saturated suction temperature.
- 12.1.3. Room temperature.
- 12.1.4. Overfeed ratio (if pump recirculated).
- 12.1.5. Options or special features.

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A+B Air Cooler (Galvanized) Engineering Specifications

1. **General**
   1.1. This specification covers "A+B" type air coolers having galvanized steel tubes and fins intended for use in refrigeration systems.

2. **Selection / Rating Method**
   2.1. Evaporators shall be selected using DT1 rating method.
   2.2. DTM rating method shall not be used.
   2.3. Evaporators shall be selected on the basis of room relative humidity as shown on the drawing.
   2.4. Ratings shall be calculated to include a frost thickness as shown on the drawing.
   2.5. Ratings shall be calculated using an inside tube fouling factor as shown on the drawing.
   2.6. Ratings shall be calculated using an outside tube fouling factor as shown on the drawing.

3. **Coil Construction**
   3.1. Coil shall be constructed per ASME B31.5.
   3.2. Tubing
      3.2.1. Coil block shall be constructed with ASME SA-214 carbon steel tubing.
      3.2.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
      3.2.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

   3.3. Tube Pattern
      3.3.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
         3.3.1.1. 5/8" OD - 1.5" x 1.299" equilateral staggered
         3.3.1.2. 5/8" OD - 1.97" (50 mm) inline
         3.3.1.3. 7/8" OD - 2.25" x 1.949" equilateral staggered

   3.4. Fins
      3.4.1. Shall be carbon steel, no less than 0.010" (0.25 mm) thick.
      3.4.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, "L-foot", or wrap-on type fins shall not be allowed.
      3.4.3. Fin collars shall be configured so that molten zinc completely bonds the tubes and fins.

   3.5. Headers
      3.5.1. Headers shall be made of carbon steel pipe certified to ASME SA-106/B, no less than ANSI schedule 40.

   3.6. Connections
      3.6.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-106/B. Bolted type flange union connections shall not be allowed.

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3.6.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
3.6.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.
3.6.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.
3.6.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

3.7. Cleanliness

3.7.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

3.8. Welding/QC

3.8.1. All tube and header welds shall be made by Tungsten Inert Gas (TIG) welding process.
3.8.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.
3.8.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

3.9. Leak Testing

3.9.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.
3.9.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

3.10. Galvanizing

3.10.1. Carbon steel coil core to be hot-dip galvanized per ASTM A-123 for corrosion protection.

4. Circuiting

4.1. Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)

4.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.
4.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.
4.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

4.2. Type FL (Gravity Flooded)

4.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.

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4.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

4.3. Type DX (Direct Expansion)

4.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.

4.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

4.4. Type BW (Single Phase Liquids)

4.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.

4.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

5. Cabinet

5.1. General

5.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

6. Drainpan

6.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.

6.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.

6.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.

6.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.

6.5. When required by the contract, drainpan shall be insulated with a minimum of 1” thick insulation.

6.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

7. Defrost

7.1. Hot Gas Defrost

7.1.1. Coil shall be arranged for hot gas defrosting.

7.1.2. Pan Loop

7.1.2.1. A hot gas pan loop of round Alloy 3003 aluminum tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.

7.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

7.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

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7.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

7.1.3. Pan Loop Check Valve

7.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

7.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

7.2. <u>Water Defrost.</u>

7.2.1. Coil shall be arranged for water defrosting.

7.2.2. Water Distribution Pans

7.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

7.2.2.2. Individual water distribution pans shall be provided one per bay section in the cooler.

7.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

7.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

7.3. <u>Air Defrost.</u>

7.3.1. Coil shall be arranged for air (off cycle) defrosting.

7.4. <u>Electric Defrost</u>

7.4.1. Coil shall be arranged for electric defrosting.

7.4.2. Heating elements

7.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

7.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

7.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

7.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater's position during each defrost (US Patent No. 7,712,327).

8. Optional Features

8.1. <u>Variable Fin Spacing</u>

8.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.

8.1.2. Fin spacing in fins per inch shall be specified according to contract.

8.2. <u>Reheat coil section</u>

8.2.1. Coil core shall have a separate reheat section to heat air as it leaves the unit.

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8.3. Filter Racks
8.3.1. Unit shall have filter racks mounted to entering air side of coil core. Filter type specified in contract.

8.4. Full Coverage Drainpan
8.4.1. Drainpan shall be extended to ensure that all water dripping off of casing is caught in the drainpan.

8.5. Drainpan Cover Heat Trace
8.5.1. Drainpan cover shall be lined with heat trace to prevent condensation.

8.6. Hinged Drainpan
8.6.1. Drainpan shall be hinged to allow for maintenance and cleaning.

8.7. End Covers
8.7.1. Unit shall have covers enclosing the header and return bend end of unit.
8.7.2. End covers shall be hinged to allow for maintenance and cleaning.

8.8. Unit Support Legs
8.8.1. Unit shall be equipped with support legs for floor mounting.
8.8.2. Height from floor to bottom of unit provided according to contract.
8.8.3. Legs over 16” high to have additional cross bracing for added strength.

8.9. Optional Smart Hanger System
8.9.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.
8.9.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

9. Packaging
9.1. Units shall be crated on a wooden skid constructed of no less than 2” x 8” timbers.
9.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.
9.3. Crating shall support the full weight of the evaporator.
9.4. Crating shall be removable by means of gravity only.

10. IOM Manuals
10.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

11. Approved Vendor
11.1. Approved Vendor: Colmac Coil Manufacturing, Inc.   Model: A+B Series

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12. Ordering Information

12.1. Please Specify:

12.1.1. Complete model number.
12.1.2. Saturated suction temperature.
12.1.3. Room temperature.
12.1.4. Overfeed ratio (if pump recirculated).
12.1.5. Options or special features.

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A+B Air Cooler (SST) Engineering Specifications

1. General

1.1. This specification covers "A+B" type air coolers having stainless steel tubes and intended for use in refrigeration systems.

2. Selection / Rating Method

2.1. Evaporators shall be selected using DT1 rating method.
2.2. DTM rating method shall not be used.
2.3. Evaporators shall be selected on the basis of room relative humidity as shown on the drawing.
2.4. Ratings shall be calculated to include a frost thickness as shown on the drawing.
2.5. Ratings shall be calculated using an inside tube fouling factor as shown on the drawing.
2.6. Ratings shall be calculated using an outside tube fouling factor as shown on the drawing.

3. Coil Construction

3.1. Coil shall be constructed per ASME B31.5.
3.2. Tubing
- 3.2.1. Coil block shall be constructed with 304L stainless steel tubing.
- 3.2.2. Calculated working pressure of the coil tubing (per ASME Pressure Vessel Code Sec. VIII) shall be no less than 300 psig.
- 3.2.3. Tubing shall be constructed from raw material that is made in the USA, as defined by material test reports, which are to be supplied upon customer request.

3.3. Tube Pattern
- 3.3.1. Tube pattern shall be selected for optimum performance and defrost efficiency from one of the three patterns below:
  - 3.3.1.1. 5/8" OD - 1.5" x 1.299" equilateral staggered
  - 3.3.1.2. 5/8" OD - 1.97" (50 mm) inline
  - 3.3.1.3. 7/8" OD - 2.25" x 1.949" equilateral staggered

3.4. Fins
- 3.4.1. Fins shall be selected from one of the four materials below, based on optimum performance in the operating environment.
  - 3.4.1.1. Aluminum 1100 alloy, no less than 0.010" (0.25 mm) thick.
  - 3.4.1.2. 304L stainless steel, no less than 0.010" " (0.25 mm) thick.
  - 3.4.1.3. Colmac Anti-Microbial alloy, no less than 0.010" " (0.25 mm) thick.
    - 3.4.1.3.1. Coil core fins shall be constructed of a metal alloy that exhibits anti-microbial properties.
    - 3.4.1.3.2. Fins shall completely cover the coil tube surfaces exposed to the airstream by means of a full-length self-spacing fin collar.
    - 3.4.1.3.3. Coil coatings are not allowed. All surfaces to be a base metal alloy.
- 3.4.2. Fins shall be continuous flat or configured plate type with full length, self-spacing collars. Spiral, "L-foot", or wrap-on type fins shall not be allowed.
- 3.4.3. Tubes shall be expanded into fin collars to form a tight mechanical bond between tube and fin.

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3.5. Headers
- 3.5.1. Headers shall be made of 304L stainless steel pipe certified to ASME SA-240/304L, no less than ANSI schedule 40.

3.6. Connections
- 3.6.1. Liquid, suction, and hot gas connections shall be carbon steel pipe no less than schedule 40, certified to ASME SA-240/304L. Bolted type flange union connections shall not be allowed.
- 3.6.2. In the case of pumped bottom feed, liquid and hot gas connections shall be oriented vertically up.
- 3.6.3. In the case of pumped bottom feed, liquid connection to coil header pipe shall be below the level of the lowest tube in the coil to effectively trap condensate during defrost.
- 3.6.4. Coil connections shall be terminated with a welded steel head at the factory. One "Schrader" type valve shall be provided by the manufacturer mounted at the factory in one of the coil connection terminations for the purpose of measuring the shipping charge upon arrival at the jobsite.
- 3.6.5. The manufacturer shall charge each coil with a shipping charge of 5-20 psig dry air or nitrogen. A label on the coil connection near the Schrader valve shall be provided indicating the factory charge pressure.

3.7. Cleanliness
- 3.7.1. The manufacturer shall insure that the coils are free from internal dirt, scale, and water.

3.8. Welding/QC
- 3.8.1. All tube and header welds shall be made by Tungsten Inert Gas (TIG) welding process.
- 3.8.2. All welds shall be performed by ASME certified welders per the requirements of the manufacturer's WPS documents. Copies of all WPS, PQR, and Welder Qualification documents used in the fabrication of the coil shall be made available to the engineer upon request.
- 3.8.3. Copies of the manufacturer's Quality Control Manual shall be made available to the engineer upon request.

3.9. Leak Testing
- 3.9.1. Coils shall be tested for leaks after welding at no less than 500 psig (35 bar), dry air under water.
- 3.9.2. Test certificates for each coil shall be provided by the manufacturer to the engineer upon request.

4. Circuiting

4.1. Types RT and RB (Recirc Top Feed and Recirc Bottom Feed)
- 4.1.1. Liquid overfeed orifices shall be installed at the entrance to each coil circuit, sized for a maximum 5 psi pressure drop at the design refrigerant flow rate.
- 4.1.2. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.
- 4.1.3. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

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4.2. Type FL (Gravity Flooded)
  4.2.1. Units with vertical header arrangements shall have circuiting designed for parallel flow of refrigerant relative to direction of air flow.
  4.2.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to the direction of air flow.

4.3. Type DX (Direct Expansion)
  4.3.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction of air flow to maximize suction gas superheat for best operation of thermostatic expansion valves.
  4.3.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

4.4. Type BW (Single Phase Liquids)
  4.4.1. Units with vertical header arrangements shall have circuiting designed for counter flow of refrigerant relative to direction.
  4.4.2. Units with horizontal header arrangements shall have circuiting designed for cross flow of refrigerant relative to direction of air flow. Circuits must have crossover circuiting to equalize circuit loading.

5. Cabinet

5.1. General
  5.1.1. Standard construction shall be of G90 mill Galvanized Steel, Alloy 5052 Aluminum, or 304L Stainless Steel as required in the contract. Painted or coated cabinet parts shall not be allowed.

6. Drainpan

6.1. The inner drainpan shall be constructed of Alloy 5052 Aluminum.
6.2. Drainpan shall be designed to cover the coil section of the cooler cabinet.
6.3. Drainpan to be triple pitch, V-bottom design, such that water flows front to center, rear to center, and end to end to a single drain.
6.4. Drain outlet shall be constructed as a full radius, formed directly into the drain pan to eliminate the possibility of water pooling around the drain connection.
6.5. When required by the contract, drainpan shall be insulated with a minimum of 1" thick insulation.
  6.5.1. The insulation shall be fully covered with a sheet metal insulation shield of mill galvanized steel, aluminum, or 304L stainless steel as required by the contract.

7. Defrost

7.1. Hot Gas Defrost
  7.1.1. Coil shall be arranged for hot gas defrosting.
  7.1.2. Pan Loop
    7.1.2.1. A hot gas pan loop of round 304L stainless steel tubing shall be provided to warm the inner drainpan during defrost. Pan loop designs using square tubing or cross-sections other than round shall not be allowed.
      7.1.2.1.1. Pan loop headers are to be held outside the ends of the drain pan to allow for full contact of the tubes with the pan.

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7.1.2.1.2. The pan loop shall be attached to the underside of the inner drainpan by means of full length clips designed to keep the pan loop in tight contact with the pan by spring force. The pan loop shall not be mounted in the drainpan where it can contact the defrost water.

7.1.2.1.3. The pan loop outlet pipe shall be arranged such that a liquid seal is formed below the lowest hot gas pan tube.

7.1.3. Pan Loop Check Valve

7.1.3.1. When defrost condensate is being lifted into an overhead condensate return line, a properly sized in-line check valve shall be installed by the manufacturer. Check valve is to be installed between the outlet of the pan loop and the coil per the piping diagram provided by the manufacturer.

7.1.3.2. All portions of the check valve and piping shall be held within the footprint of the drainpan.

7.2. <u>Water Defrost.</u>

7.2.1. Coil shall be arranged for water defrosting.

7.2.2. Water Distribution Pans

7.2.2.1. Water shall be distributed evenly over the coil fin surfaces by means of water distribution pans.

7.2.2.2. Individual water distribution pans shall be provided one per bay section in the cooler.

7.2.2.3. Water distribution pans shall be removable for inspection and cleaning.

7.2.2.4. Defrost water flow shall be thermodynamically calculated and specified by coil manufacturer such that the flow rate is the minimum needed to heat the mass of coil metal and melt the frost.

7.3. <u>Air Defrost.</u>

7.3.1. Coil shall be arranged for air (off cycle) defrosting.

7.4. <u>Electric Defrost</u>

7.4.1. Coil shall be arranged for electric defrosting.

7.4.2. Heating elements

7.4.2.1. Heating elements shall be tubular type, UL listed, with stainless steel sheath.

7.4.2.2. Elements shall be inserted into the fin collars, and spaced throughout the coil core such that the coil core is completely clear of frost and ice at the end of each defrost.

7.4.2.3. Heating elements shall be wired to a common NEMA 3R (minimum) panel.

7.4.2.4. Heated elements shall be attached to coil core by means of a self-centering spring that acts to reset the heater’s position during each defrost (US Patent No. 7,712,327).

8. Optional Features

8.1. <u>Variable Fin Spacing</u>

8.1.1. Coil core fins shall be arranged for highest frost capacity by varying the fin spacing for the air entering rows of tubes.

8.1.2. Fin spacing in fins per inch shall be specified according to contract.

8.2. <u>Reheat coil section</u>

8.2.1. Coil core shall have a separate reheat section to heat air as it leaves the unit.

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8.3. Filter Racks
  8.3.1. Unit shall have filter racks mounted to entering air side of coil core. Filter type specified in contract.

8.4. Full Coverage Drainpan
  8.4.1. Drainpan shall be extended to ensure that all water dripping off of the fans, motors or casing is caught in the drainpan.

8.5. Drainpan Cover Heat Trace
  8.5.1. Drainpan cover shall be lined with heat trace to prevent condensation.

8.6. Hinged Drainpan
  8.6.1. Drainpan shall be hinged to allow for maintenance and cleaning.

8.7. End Covers
  8.7.1. Unit shall have covers enclosing the header and return bend end of unit.
  8.7.2. End covers shall be hinged to allow for maintenance and cleaning.

8.8. Unit Support Legs
  8.8.1. Unit shall be equipped with support legs for floor mounting.
  8.8.2. Height from floor to bottom of unit provided according to contract.
  8.8.3. Legs over 16” high to have additional cross bracing for added strength.

8.9. Smart Hanger System
  8.9.1. When specified, units shall be provided with Colmac Smart Hanger brackets that will allow the unit to be suspended from pre-mounted structural channels provided by the manufacturer.
  8.9.2. Hanger brackets shall be adjustable in the vertical direction to allow for various mounting heights.

9. Packaging

9.1. Units shall be crated on a wooden skid constructed of no less than 2” x 8” timbers.
9.2. Units shall be crated fully assembled (including drainpan) in an upright position ready for mounting in the field.
9.3. Crating shall support the full weight of the evaporator.
9.4. Crating shall be removable by means of gravity only.

10. IOM Manuals

10.1. Installation, Operation, and Maintenance Manuals shall be provided. Number of copies and routings shall be provided per the requirements of the contract.

11. Approved Vendor

11.1. Approved Vendor: Colmac Coil Manufacturing, Inc.   Model: A+B Series

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12. Ordering Information

12.1. Please Specify:

12.1.1. Complete model number.

12.1.2. Saturated suction temperature.

12.1.3. Room temperature.

12.1.4. Overfeed ratio (if pump recirculated).

12.1.5. Options or special features.

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DX AMMONIA PIPING HANDBOOK
4th Edition

Bruce I. Nelson, P.E.

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I. Background

Ammonia refrigeration systems have traditionally employed evaporators supplied with liquid by either gravity flooding (with surge drums), or pumped overfeed (either with mechanical pumps or discharge gas-driven vessels). Both of these designs typically use bottom feed coil circuiting which feeds liquid ammonia at the lowest point in the coil circuit and causes the ammonia to flow upward and "percolate" through the coil in ascending passes to the outlet at the top of the circuit. These coil designs also typically use large diameter tubing which means relatively large coil internal volume. This combination of refrigerant feed, circuiting, and tube diameter, results in the greatest evaporator charge inventory possible.

End users of ammonia refrigeration systems are increasingly interested in reducing the charge of ammonia in evaporators (and in the overall system) in the interest of minimizing the risk to workers and products associated with ammonia leaks. One very effective way to significantly reduce evaporator ammonia charge is to design and operate the evaporator using dry expansion (DX) circuiting and controls. Using DX ammonia can reduce the evaporator charge by as much as 30 to 50 times compared to bottom feed flooded or pumped designs. The magnitude of this reduction in ammonia charge may also mitigate regulatory requirements (PSM, RMP), and potentially reduce insurance risk and premiums.

DX ammonia has been used for some time in medium and high temperature systems (suction temperatures above +20 degrees F) with some success. However, in spite of the charge reduction advantages mentioned above, to date DX ammonia has not been applied successfully at freezer temperatures. At suction temperatures below about +20F, the following particular characteristics of ammonia result in extremely poor performance of evaporators unless addressed and mitigated:

1. Separation of liquid and vapor phases. The very high ratio of vapor to liquid specific volume of ammonia at low temperatures combined with its very high latent heat of vaporization causes an unavoidable separation of vapor and liquid phases inside evaporator tubes. This separation of phases causes the liquid ammonia present to run along the very bottom of the tubes leaving the top of the tubes completely "dry". The result is extremely poor evaporator performance and lower-than-expected suction temperatures during operation. To solve this problem Colmac has developed (and patented) an enhancement technique, which when applied to the inside of evaporator tubes, causes the liquid ammonia present to coat the entire inside surface of the tubes by capillary action. Performance with Colmac enhanced tube technology results in good DX ammonia performance even at low temperatures, which heretofore has not been possible.
2. Refrigerant distributor technology. Traditionally the distribution of expanded refrigerant to multiple parallel evaporator circuits has been done using a refrigerant distributor having a fixed orifice plate. This design depends on a relatively large pressure drop (approximately 40-45 psi) across the fixed orifice to thoroughly mix and equally distribute the liquid and vapor phases before they enter the distributor tubes and evaporator circuits. This relatively high pressure drop across the distributor reduces the

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pressure drop available for the expansion valve, and consequently limits how low condensing pressure can be allowed to fall during periods of low ambient temperature. The very high latent heat of vaporization of ammonia results in low refrigerant mass flow rate and consequently a very small orifice diameter for a given cooling load (the orifice can be as small as 1/16" diameter in some cases). This small orifice size is prone to fouling and being blocked by even small size debris. Other disadvantages of this distributor design include:

   a. Performance is very sensitive to liquid temperature (subcooling) at the expansion valve.
   b. Operating range is small, at most 50% to 125% of rated capacity.
   c. The orifice and distributor tubes may restrict the flow of hot gas during a hot gas defrost cycle if the distributor is used for distribution of the hot gas.
   d. The maximum number of parallel evaporator circuits available in a single distributor is limited to only 15.

To address these shortcomings Colmac has developed and patented a new refrigerant distributor technology, the Colmac Tank Distributor, having the following characteristics:

   a. Refrigerant pressure drop across the Tank Distributor during operation is very low, only 2-4 psi.
   b. Any oil or debris entering the Tank Distributor is captured in a drop leg (which is integral to the design) before it can enter the coil and foul tube surfaces.
   c. Performance of the Tank Distributor is completely insensitive to liquid temperature (subcooling).
   d. Graduated orifices in each distributor tube allow equal distribution of refrigerant to all circuits over an extremely wide operating range of 0% to 700% of rated capacity.
   e. Graduated orifices and large diameter distributor tubes allow full flow (minimal restriction) of hot gas during hot gas defrost.
   f. The number of parallel evaporator circuits possible in a single Tank Distributor can be as high as 48.

3. <u>Removal of water from ammonia</u>. As described elsewhere (Nelson 2010), even small amounts of water (1-3%) in the ammonia will significantly penalize DX ammonia evaporator performance. This very negative effect of small amounts of water on evaporator performance has not been fully recognized in the past, but must be addressed during the design of the DX ammonia system. Water must be effectively removed during operation, particularly in freezing systems which operate at suction pressures below one atmosphere (in a vacuum). Proper design and arrangement of accumulator vessel(s) and defrost condensate return piping will result in continuous removal and isolation of water-laden ammonia from the system and is described in this Handbook.

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Colmac has developed, tested, and patented (Nelson 2011) a new Low Temperature DX Ammonia system which correctly addresses all of the above issues peculiar to ammonia as a refrigerant that have heretofore prevented its use at low suction temperatures. It is now possible to successfully apply DX ammonia at suction temperatures down to -50 degrees F. This Piping Handbook is intended to guide the reader through the process of successfully designing and implementing DX Ammonia from +50F to -50F and realizing the benefits of:

- Dramatically reduced ammonia charge
- Simplified controls
- Energy efficient dry suction line
- Reduced line sizes
- Elimination of ammonia recirculator pumps

II. Patents

The Colmac Advanced DX Ammonia system and evaporator technology described in this Piping Handbook are covered by one or more of the following US Patents:

6,843,509
7,597,137
7,958,738
8,474,276
8,783,057

III. System Configuration

Colmac Advanced DX Ammonia can be applied to any temperature level and system configuration. P&ID diagrams for various typical systems are shown in Appendix A, simplified for purposes of clarity. Selection and system piping details (relief valves, purgers, isolation valves, vessel designs, etc) should follow industry guidelines as found in the IIAR Ammonia Piping Handbook (IIAR 2004). The diagrams are not intended to present an exhaustive range of configurations – every industrial refrigeration system will have unique features and requirements. This information is presented to illustrate the general system features particular to a successful DX Ammonia design. Note that it is always good practice to install an air purger on any industrial ammonia system. For the sake of simplicity air purgers are not shown in these P&IDs. The reader is referred to the purger manufacturer for proper piping, installation, and operation of their equipment.

1. Single Stage with Single or Multiple Temperature Levels - Figure A1

   This system is very simple with only a single compressor suction pressure level and a single suction accumulator vessel. Evaporators can be operated at multiple temperatures by using back pressure regulating valves (BPRV) for the higher temperature level(s). Depending on how much of the load is at the higher temperature level(s), this system can be very energy inefficient. A typical application for this P&ID

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would be a fruit and/or vegetable storage facility. Expected charge for this type of system is in the range of 6.5 to 7 lbs of ammonia per ton of refrigeration.

Important features in Figure A1 required for proper DX ammonia operation include:

a. Defrost condensate from hot gas defrosting units is returned to the suction accumulator. This effectively captures any water in the ammonia in this vessel where it will be distilled over time and can then be removed from the system.
b. Defrost condensate returning from hot gas defrosting units is utilized in the flooded plate heat exchanger to subcool the high pressure liquid. When there is insufficient condensate to keep the subcooler flooded, makeup liquid is added via a makeup line to maintain a liquid level in the accumulator sufficient to achieve the required amount of subcooling. Conversely, the heat generated by subcooling must equal or exceed the amount of heat needed to vaporize all of the defrost condensate returning from hot gas defrosting evaporators. This will be the case provided the number of defrosts per day does not exceed around (6) x 10 minutes each (hot gas on time) assuming a room temperature of 32 deg F. If the frost load is high enough to require more than (6) x defrosts per day, then the subcooling load will not be high enough to vaporize all the defrost condensate and a liquid transfer system must be added to transfer the excess liquid refrigerant from the suction accumulator back to the high pressure receiver.
c. The liquid line pressure is nominally reduced by a pressure reducing valve (PRV) downstream of the subcooler heat exchanger. The purpose of the PRV is to stabilize the liquid line pressure which improves the operation of expansion valves (reduces the potential for hunting).
d. Any oil leaving the oil separator as vapor will be condensed back to liquid in the condenser and settle to the bottom of the high pressure receiver. The liquid supply to the liquid line should be taken from a point 2-3" up from the bottom of the receiver vessel on the end opposite the connection coming from the outlet of the condenser. This will result in a process of secondary oil separation in the pool of high pressure liquid in the receiver and will significantly reduce the amount of oil circulated to the evaporators.
e. When liquid injection oil cooling is used as shown in this P&ID, liquid for oil cooling should be taken from a drop leg located between the inlet connection (coming from the condenser outlet) and outlet connection (to the liquid line). The drop leg gives priority liquid to the compressors for cooling and also returns any accumulated oil.
f. Hot gas for defrosting is taken from the top of the high pressure receiver to minimize the amount of oil sent to the evaporators in the hot gas. Forcing the hot gas to pass through the receiver vessel serves to desuperheat and "de-oil" the gas prior to entering the hot gas line.
g. A pressure reducing valve (PRV) can be installed in the hot gas line to manage the pressure and flow of hot gas for defrosting adding to system stability.

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2. Single Stage Economized Screw w/ Multiple Temperatures (Te > -20 deg F) - Figure A2

   This system configuration is widely used in cold storage warehouses due to its cost effectiveness, simplicity, and flexibility. Recent developments with liquid injection oil cooling of screw compressors as shown in this P&ID have significantly reduced the energy penalty traditionally associated with this oil cooling method. This P&ID is intended for systems which have the low side operating at positive pressures. If the low side pressure is less than about 4 - 5 psig then an oil pot must be added to the low temperature accumulator to safely drain oil. Expected charge for this type of system is in the range of 6.5 to 7 lbs of ammonia per ton of refrigeration.

   Important features in Figure A2 required for proper DX ammonia operation include:

   a. Defrost condensate from hot gas defrosting units is returned to the high pressure suction accumulator. This effectively captures any water in the ammonia in this vessel where it will be distilled over time and then removed from the system.
   b. Defrost condensate returning from hot gas defrosting units is utilized in the flooded plate heat exchanger to subcool the high pressure liquid. When there is insufficient condensate to keep the subcooler flooded, makeup liquid is added via a makeup line to maintain a liquid level in the accumulator sufficient to achieve the required amount of subcooling. Conversely, the heat generated by subcooling must equal or exceed the amount of heat needed to vaporize all of the defrost condensate returning from hot gas defrosting evaporators. This will be the case provided the number of defrosts per day does not exceed around (6) x 10 minute (hot gas on time) defrosts in 32 deg F rooms and (2) x 15 minute (hot gas on time) defrosts in -10 to -20 deg F rooms. If the frost load is high enough to require more defrosts per day than this, then the subcooling load may not be high enough to vaporize all the defrost condensate and a liquid transfer system should be added to transfer the excess liquid refrigerant from the suction accumulator back to the high pressure receiver (see Figure A3).
   c. An electric heater is shown in the drop leg of the low pressure suction accumulator to heat any oil that may have accumulated. If the low side pressure is less than about 4 - 5 psig then an oil pot must be added to the low temperature accumulator to safely drain oil.
   d. The liquid line pressure is nominally reduced by a pressure reducing valve (PRV) downstream of the subcooler heat exchanger. The purpose of the PRV is to stabilize the liquid line pressure which improves the operation of expansion valves (reduces the potential for hunting).
   e. Any oil leaving the oil separator as vapor will be condensed back to liquid in the condenser and settle to the bottom of the high pressure receiver. The liquid supply to the liquid line should be taken from a point 2-3" up from the bottom of the receiver vessel on the end opposite the connection coming from the outlet of the condenser. This will result in a process of secondary oil separation in the pool of high pressure liquid in the receiver and will significantly reduce the amount of oil circulated to the evaporators.

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f. When liquid injection oil cooling is used as shown in this P&ID, liquid for oil cooling should be taken from a drop leg located between the inlet connection (coming from the condenser outlet) and outlet connection (to the liquid line). The drop leg gives priority liquid to the compressors for cooling and also returns any accumulated oil.
g. Hot gas for defrosting is taken from the top of the high pressure receiver to minimize the amount of oil sent to the evaporators in the hot gas. Forcing the hot gas to pass through the receiver vessel serves to desuperheat and "de-oil" the gas prior to entering the hot gas line.
h. A pressure reducing valve (PRV) can be installed in the hot gas line to manage the pressure and flow of hot gas for defrosting adding to system stability.

3. Single Stage Economized Screw w/ Multiple Temperatures - Figure A3

This system configuration is similar to Figure A2 in that it shows an economized screw compressor system with multiple temperature levels typical of a freezer cold storage facility. Here, however, a transfer line is added between the high and low temperature suction accumulators to allow excess liquid to move to the low temperature accumulator. A liquid transfer system is incorporated with the low temperature accumulator to move the excess liquid back to the high pressure receiver as needed. The liquid transfer system shown will be required when the number of defrosts exceeds approximately (6) x defrosts per day in medium temperature (32 deg F) rooms and/or (2) x defrosts per day in freezer rooms. The system shown is also appropriate for freezing where the low side pressure is below 0 psig with the necessary oil pot installed on the low temperature accumulator. Expected charge for this type of system is in the range of 6.5 to 7 lbs of ammonia per ton of refrigeration.

Important features in Figure A3 required for proper DX ammonia operation include:

a. Defrost condensate from hot gas defrosting units is returned to the high pressure suction accumulator. This effectively captures any water in the ammonia in this vessel where it can be distilled and removed.
b. Defrost condensate returning from hot gas defrosting units is utilized in the flooded plate heat exchanger to subcool the high pressure liquid. When there is insufficient condensate to keep the subcooler flooded, makeup liquid is added via a makeup line to maintain a liquid level in the accumulator sufficient to achieve the required amount of subcooling. When the number of defrosts exceeds approximately (6) x defrosts per day in medium temperature (32 deg F) rooms and/or (2) x defrosts per day in freezer rooms, it is likely that excess defrost condensate will have to be drained from the high temperature accumulator to the low temperature accumulator via the transfer line. From there this excess liquid is transferred back to the high pressure receiver using the liquid transfer system shown.
c. The water still shown in this system is heated by high pressure liquid. The vent line from the still is connected to the low pressure suction accumulator in order to achieve the greatest distilling effect possible. It should only be necessary to operate the still during startup and commissioning in order to initially dry out

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the system. After the first few weeks of operation most of the water will have been removed from the system and the line from the high pressure accumulator to the still should be closed and the still left idle. With systems which operate the low side in a vacuum (blast freezing), the still should be operated once or twice per year to remove any water that may have accumulated in the ammonia.

d. The liquid line pressure is nominally reduced by a pressure reducing valve (PRV) downstream of the subcooler heat exchanger. The purpose of the PRV is to stabilize the liquid line pressure which improves the operation of expansion valves (reduces the potential for hunting).
e. Any oil leaving the oil separator as vapor will be condensed back to liquid in the condenser and settle to the bottom of the high pressure receiver. The liquid supply to the liquid line should be taken from a point 2-3" up from the bottom of the receiver vessel on the end opposite the connection coming from the outlet of the condenser. This will result in a process of secondary oil separation in the pool of high pressure liquid in the receiver and will significantly reduce the amount of oil circulated to the evaporators.
f. When liquid injection oil cooling is used as shown in this P&ID, liquid for oil cooling should be taken from a drop leg located between the inlet connection (coming from the condenser outlet) and outlet connection (to the liquid line). The drop leg gives priority liquid to the compressors for cooling and also returns any accumulated oil.
g. Hot gas for defrosting is taken from the top of the high pressure receiver to minimize the amount of oil sent to the evaporators in the hot gas. Forcing the hot gas to pass through the receiver vessel serves to desuperheat and "de-oil" the gas prior to entering the hot gas line.
h. A pressure reducing valve (PRV) can be installed in the hot gas line to manage the pressure and flow of hot gas for defrosting adding to system stability.

4. Single Stage (Screw) Glycol Med Temperature/DX Low Temperature - Figure A4

Figure A4 shows a very low ammonia charge design which utilizes a secondary refrigerant (glycol) for the high temperature rooms. The system uses a plate type water cooled condenser to further reduce the ammonia charge. This in combination with low charge DX evaporators in the low temperature rooms produces a system with an ammonia charge in the range of only 3 lbs of ammonia per ton of refrigeration.

Important features in Figure A4 required for proper DX ammonia operation include:

a. Defrost condensate from hot gas defrosting units is returned to the high temperature accumulator which also acts as the glycol chiller surge drum. This effectively captures any water in the ammonia in this vessel where it will be distilled over time and removed as necessary.
b. The plate type condenser sends makeup liquid to the glycol chiller surge drum via a high side float valve. This vessel handles the surge volume of liquid for the system. Priority high pressure liquid for the low temperature evaporators is sent

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first to a boil-out coil in the low temperature accumulator and then then to a plate type DX subcooler.

c. The liquid line pressure is nominally reduced by a pressure reducing valve (PRV) downstream of the subcooler heat exchanger. The purpose of the PRV is to stabilize the liquid line pressure which improves the operation of expansion valves (reduces the potential for hunting).
d. A heated oil pot is shown in the drop leg of the low temperature suction accumulator.
e. Oil is cooled using cooling tower water.
f. A pressure reducing valve (PRV) can be installed in the hot gas line to manage the pressure and flow of hot gas for defrosting adding to system stability.

5. Two Stage Screw with Intercooling - Figure A5

Two stage compression as shown in Figure A5 offers higher energy efficiency compared to the single stage refrigeration system configurations shown. This will be the design of choice when either very low operating costs and/or when blast freezing temperatures are required. The glycol oil cooling method shown in this P&ID minimizes the system ammonia charge and also offers the possibility of heat reclaim, underfloor heating, etc. Expected charge for this type of system is in the range of 6.5 to 7 lbs of ammonia per ton of refrigeration.

Important features in Figure A5 required for proper DX ammonia operation include:

a. Defrost condensate from hot gas defrosting units is returned to the high pressure suction accumulator/intercooler. This effectively captures any water in the ammonia in this vessel where it will be distilled over time and removed as necessary.
b. Defrost condensate returning from hot gas defrosting units is utilized in the flooded plate heat exchanger piped to the high temperature suction accumulator/intercooler to subcool the high pressure liquid. The condensate also quenches the booster discharge gas. When there is insufficient condensate to keep the subcooler flooded and quench the booster discharge gas, makeup liquid is added via a makeup line controlled on liquid level in the accumulator.
c. The liquid line pressure is nominally reduced by a pressure reducing valve (PRV) downstream of the subcooler heat exchanger. The purpose of the PRV is to stabilize the liquid line pressure which improves the operation of expansion valves (reduces the potential for hunting).
d. In this system a high pressure pilot receiver is used in lieu of a high pressure receiver. Priority liquid from the pilot receiver is sent first to a boil-out coil in the low pressure accumulator to boil off any incidental liquid which may return from the low temperature evaporators in the case of an upset condition. The liquid line then continues to the flooded plate heat exchanger to be subcooled. A high side float valve sends the remaining liquid in the pilot receiver to the high temperature accumulator/intercooler vessel. The liquid level in the pilot HP receiver will surge slightly as evaporators go in and out of defrost. Because the

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pilot receiver is relatively small, the high temperature accumulator/intercooler must be sized large enough to most, in not all, of the system charge.

e. A pressure reducing valve (PRV) can be installed in the hot gas line to manage the pressure and flow of hot gas for defrosting adding to system stability.
f. Glycol oil cooling shown in this diagram not only reduces system ammonia charge, but also conveniently allows the heated glycol to be used for underfloor heating, heat reclaim, etc.

6. Two Stage Reciprocating with Intercooling - Figure A6

Two stage compression with VFD speed controlled direct drive reciprocating compressors as shown in Figure A6 represents the state-of-the-art low charge ammonia system configuration. This system will operate with significantly lower power consumption (as much as 50% less) than any of the designs mentioned above, particularly the traditional constant speed single stage screw compressor configurations. compared to the single stage refrigeration system configurations shown. Modern reciprocating compressor technology does not require cylinder head (oil) cooling, and when applied with recommended oil separator technology exhibits little to no oil carryover. Expected charge for this type of system is in the range of 6.5 to 7 lbs of ammonia per ton of refrigeration.

Important features in Figure A6 required for proper DX ammonia operation include:

a. Defrost condensate from hot gas defrosting units is returned to the high pressure suction accumulator/intercooler. This effectively captures any water in the ammonia in this vessel where it will be distilled over time and removed as necessary.
b. Defrost condensate returning from hot gas defrosting units is utilized in the flooded plate heat exchanger piped to the high temperature suction accumulator/intercooler to subcool the high pressure liquid. The condensate also quenches the booster discharge gas. When there is insufficient condensate to keep the subcooler flooded and quench the booster discharge gas, makeup liquid is added via a makeup line controlled on liquid level in the accumulator.
c. The liquid line pressure is nominally reduced by a pressure reducing valve (PRV) downstream of the subcooler heat exchanger. The purpose of the PRV is to stabilize the liquid line pressure which improves the operation of expansion valves (reduces the potential for hunting).
d. In this system a high pressure pilot receiver is used in lieu of a high pressure receiver. Priority liquid from the pilot receiver is sent first to a boil-out coil in the low pressure accumulator to boil off any incidental liquid which may return from the low temperature evaporators in the case of an upset condition. The liquid line then continues to the flooded plate heat exchanger to be subcooled. A high side float valve sends the remaining liquid in the pilot receiver to the high temperature accumulator/intercooler vessel. The liquid level in the pilot HP receiver will surge slightly as evaporators go in and out of defrost. Because the pilot receiver is relatively small, the high temperature accumulator/intercooler must be sized large enough to most, in not all, of the system charge.

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e. A pressure reducing valve (PRV) can be installed in the hot gas line to manage the pressure and flow of hot gas for defrosting adding to system stability.

IV. System Stability

With liquid overfeed and gravity flooded systems, liquid return to the recirculator vessel or the surge drum is normal and expected through the wet suction line. The recirculator vessel or surge drum effectively separates returning liquid from vapor and ensures that the dry suction line carries only vapor back to the compressor.

DX systems, on the other hand, are designed to operate with a dry suction line and are by definition more sensitive to liquid floodback. Industrial DX systems should incorporate a suction accumulator vessel to prevent liquid slugging of the compressor during a floodback event, however, excessive floodback from evaporators can cause high level alarming and system shutdown until the excess liquid in the suction accumulator can be transferred back to the high pressure side of the system. Stable and smooth operation of the system and the evaporator expansion valve(s) is critical to avoiding liquid floodback. Instabilities and/or rapid changes in discharge and suction pressures during operation are the typical cause of unstable operation of expansion valves and should be considered carefully by the system designer and operator(s).

Rapid changes in system discharge pressure can cause system instabilities in a number of ways. A sudden reduction in discharge pressure can result in undesirable flashing of liquid refrigerant in liquid lines and will also be accompanied by a sympathetic, albeit smaller, reduction in suction pressure. A sudden increase in discharge pressure will be accompanied by a sympathetic, albeit smaller, increase in suction pressure. An increase in suction pressure, if large enough and rapid enough, will suppress boiling in the evaporators which can directly lead to liquid floodback from the evaporators to the suction accumulator.

Rapid changes in discharge pressure are normally caused by one or more of the following events:

a. Condenser fans cycling on and off,
b. Evaporative condenser pumps cycling on and off,
c. Evaporator(s) initiating hot gas defrost,
d. Compressor(s) cycling on and off

**NOTE: Design the system to limit the rate of change in condensing temperature to no more than 5 deg F/minute.

Rapid changes in system suction pressure can also result in system instability and poor performance. A sudden increase in suction pressure can result in liquid floodback from DX evaporators. This sudden increase in suction pressure raises the temperature of the evaporator, reduces the imposed load, and results in liquid refrigerant exiting the evaporator before the expansion valve can respond and reduce the flow of refrigerant entering the evaporator accordingly.

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Rapid changes in suction pressure are normally caused by:

a. Compressor(s) cycling on and off
b. Multiple liquid feed solenoids cycling on and off
c. Evaporator fans cycling on and off
d. Evaporators starting or finishing defrost
e. Sudden changes in imposed load on evaporators

**NOTE: Design the system to limit the rate of change in suction temperature to no more than 2 deg F/minute.

Following are recommended system design features which will serve to maximize system pressure stability and minimize the potential for liquid floodback from evaporators.

1. Condenser Fans
   a. Use of VFD fan speed control instead of fan cycling for control of head pressure is recommended.

2. Condenser Pumps
   a. It is recommended that evaporative condenser sump water pumps be operated continuously rather than cycling on and off, provided ambient weather conditions allow. Continuous running is also recommended to minimize corrosion on galvanized condenser tube bundles.

3. Compressor Capacity Control
   a. Use of VFD speed control for capacity where possible and appropriate.
   b. Limit capacity loading/unloading steps (on/off) to no more than 10% of total system capacity.
   c. Limit the rate of change of suction temperature (speed of screw compressor slide valve movement) to no greater than 2 deg F/minute.

4. Evaporator Defrost
   a. Defrost the minimum number of evaporators at one time.
   b. Use a bleed line or a two-step valve with pressure bleed feature to equalize pressure slowly at the end of defrost.

5. Evaporator Fans
   a. Fan speed and cooling capacity can be controlled by VFD, however the following guidelines must be observed when applied to DX evaporators:
      o Rate of change in fan speed must be gradual and limited to result in no more than 2 deg F/minute change in suction temperature.
      o Minimum fan speed must be set to no less than 25% of full speed.
   b. If fans are going to be cycled on/off for capacity control, no more than 10% of the total number of evaporator fans should be cycled on or off at the same time.

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6. Liquid Feed Solenoids
    a. Avoid cycling multiple liquid feed solenoids all at the same time. i.e. Liquid feed solenoids should be cycled sequentially.
7. Sudden changes in load on Evaporators
    a. Avoid locating evaporator directly above doorways.
    b. Mitigate intermittent process loads located close to evaporators.

V. Evaporator Selection and Operation

1. DT1 vs DTM ratings

As explained in detail elsewhere (Nelson 2012(a)) evaporator manufacturers typically present their capacity ratings using one of two definitions of temperature difference, DT1 or DTM. Some manufacturers publish ratings based on both DT1 and DTM and allow the designer to choose the preferred definition:

DT1 = Air On Temperature – Evaporator Temperature
DTM = Average (“Room”) Air Temperature – Evaporator Temperature

Figure 1 below graphically illustrates these two definitions of temperature difference for the same evaporator and their effect on LMTD (Log Mean Temperature Difference), and hence rated capacity. In this example, the same evaporator having a -20 deg F evaporating temperature rated using DTM “produces” 33.3% (DTM LMTD of 9.6 deg F versus DT1 LMTD of 7.2 deg F) more capacity than the same evaporator rated using DT1!

In short, by using the DTM rating method a manufacturer can show cooling capacities that are much higher (30 to 40% higher), and so offer a lower cost evaporator with much less surface area than the manufacturer using the DT1 rating method.

Unfortunately, one cannot get “something for nothing”. Even though evaporators selected using DTM ratings will be cheaper initially because they have less surface area, they will cause the system to run at a lower suction pressure with higher operating costs than evaporators selected using DT1 ratings. This difference in operating cost between DTM and DT1 evaporators has been calculated and the incremental return on investment shown to dramatically favor selecting evaporators using DT1 ratings (Nelson 2012(b)). Additionally, in the same article the author shows that the basic DTM assumption that the average air temperature within the evaporator equals the average room temperature is a fundamentally flawed and false assumption because of air entrainment and mixing in the room.

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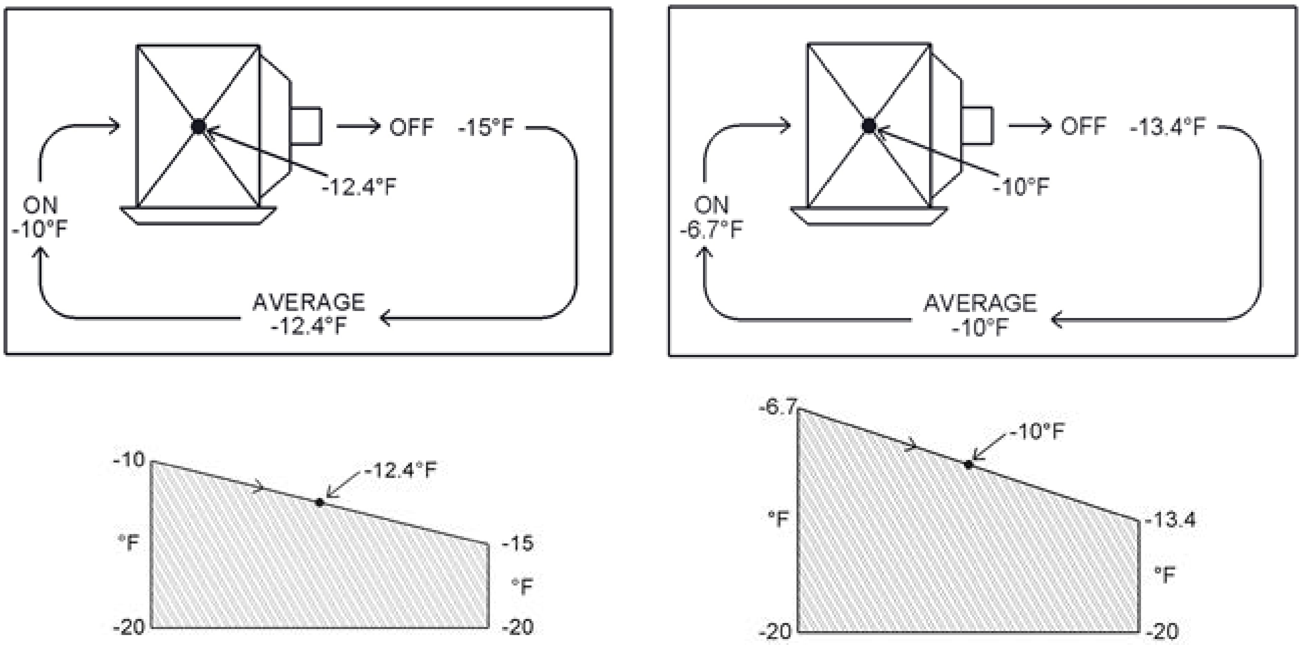
FIGURE 1
TEMPERATURE PROFILES FOR DT1 VS DTM

(a) DT1 = 10F (Air On) Temp Difference **(b) DTM = 10F (Average) Temp Difference**



DT1 LMTD = 7.2 F DTM LMTD = 9.6 F

In conclusion, Colmac highly recommends that evaporators be selected using DT1 ratings rather than DTM.

2. Sensible Heat Ratio, Room Relative Humidity (rh%), and Evaporator Ratings

   Accurate prediction of the refrigeration load, both sensible and latent components, is important to proper refrigeration system equipment selection and successful operation (Nelson 2012(a)). Various types of sensible cooling loads must be anticipated and included in the calculation, such as: lighting, electric motors, forklifts, product cooling/freezing, transmission of heat through walls, ceilings, and floors, and cooling of infiltration air. Latent cooling loads are present whenever moisture is added to the air in the refrigerated space. Sources of introduced moisture typically include: infiltration air, respiring food products, surface moisture on products, packaging and other objects entering the space, residual water left on floors after wash down (process rooms), human respiration, and humidification equipment (above freezing).

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Room relative humidity (rh%), which is the indication of how nearly the air in the refrigerated space is saturated with water vapor, will be the equilibrium condition resulting from the balance of moisture introduced into the space with the moisture removed from space by the evaporator coils (Cleland 2012). Colmac has developed a Refrigeration Load Simulator software program which allows the calculation of refrigeration loads and prediction of relative humidity to more accurately size A+Series™ air coolers using A+Pro software.

3. Optimizing System TD

The product being stored or processed normally determines the room air temperature in a refrigerated facility. Appropriate temperatures for storing and processing various foods and food products can be found elsewhere (ASHRAE 2009).

Once the room temperature is determined, the evaporator temperature must be decided upon by the designer. Compressor power and energy consumption is a strong function of the suction pressure and temperature. The higher the suction pressure the more efficiently the compressor will run and the less power will be consumed. Energy efficiency can be characterized by a ratio termed Coefficient of Performance (COP), defined as:

$$COP = \frac{Useful\ Output}{Input} \tag{2}$$

In the case of a refrigeration compressor,

$$COP = \frac{Cooling\ Capacity, kW}{Input\ Power, kW} \tag{3}$$

Figure 3 below shows typical ammonia screw compressor COP vs SST (Saturated Suction Temperature). The figure assumes 2-Stage compression is used below a suction temperature of -20 deg F.

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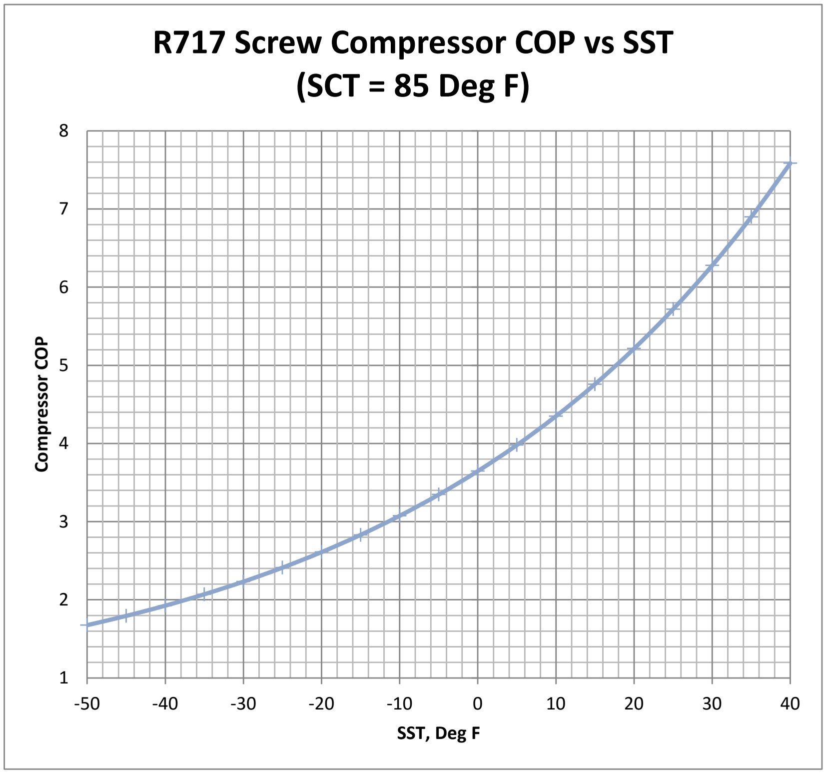
FIGURE 3



It would appear from Figure 3 that a smaller TD (TD = Room Temperature – Evaporator Temperature) would always be desirable from an energy consumption standpoint since the smaller the TD, the higher the evaporator (SST) temperature and compressor COP. This, however, is not the case.

Heat is transferred from the room via the air circulated by the evaporators. The cooling capacity of an evaporator can be characterized by the NTU-effectiveness equation. This equation indicates that for a constant cooling capacity and evaporator effectiveness (an expression of how closely the leaving air temperature approaches the evaporating temperature), the flow rate of the air will be inversely proportional to the TD.

$$\dot{q} = \dot{m} \cdot C_p \cdot \varepsilon \cdot TD \qquad (4)$$

Where:
$\dot{q} = Cooling\ Capacity$
$\dot{m} = Mass\ Flowrate\ of\ Air$
$C_p = Specific\ Heat\ of\ Air$
$\varepsilon = Evaporator\ NTU - Effectiveness$
$TD = Air\ On\ Temperature - Evaporating\ Temperature$

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Evaporator effectiveness is, in fact, very nearly constant over the typical narrow operating range of a refrigeration evaporator. The effectiveness equation shows that as TD becomes smaller, the air flowrate must become larger in the same proportion for a given cooling capacity.

Fan power can be calculated using a simple equation as follows:

$$\dot{W}_{fan} = \frac{\dot{Q} \cdot dp}{\emptyset_{tot}} \tag{5}$$

Where:
$\dot{W}_{fan} = Fan\ Power$
$\dot{Q} = Volumetric\ Flowrate\ of\ Air$
$dp = Total\ Pressure\ Across\ Fan\ (Static + Dynamic)$
$\emptyset_{tot} = Total\ Fan\ Efficiency$

The air pressure drop through the evaporator coil, and therefore fan power, will be affected by:

1. The coil face velocity,
2. Tube diameter, spacing, and pattern,
3. Number of coil rows deep,
4. Fin spacing and pattern
5. Frost thickness

The relationships above indicate that compressor COP will decrease with increasing TD while Fan COP will increase with increasing TD. Figure 4 shows these relationships for an example evaporator coil having 8 rows deep and 3 FPI fin spacing.

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FIGURE 4

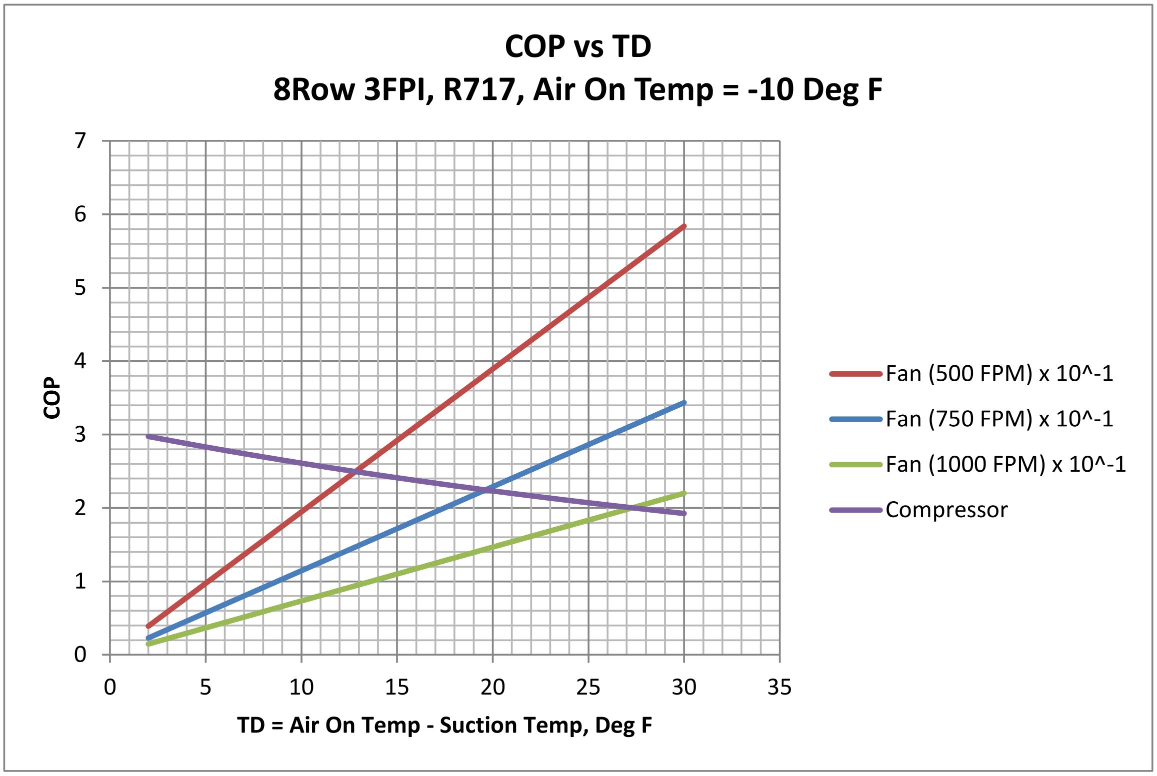

Figure 4 implies there will be some maximum combined COP for compressor and fans which will represent the optimum operating TD in terms of energy efficiency. This combined COP is shown below in Figures 5, 6, and 7, for a typical ammonia evaporator coil having the following characteristics:

Tubing: 7/8" OD Aluminum
Tube Pattern: 2.25" Staggered
Fins: Configured Aluminum Plate Type
Rows Deep: 8
Face Velocity: 500, 750, and 1000 FPM
Fin Spacing: 2, 3, and 4 FPI
Air On Temperature: -10 deg F
Frost Thickness: 0 mm

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FIGURE 5

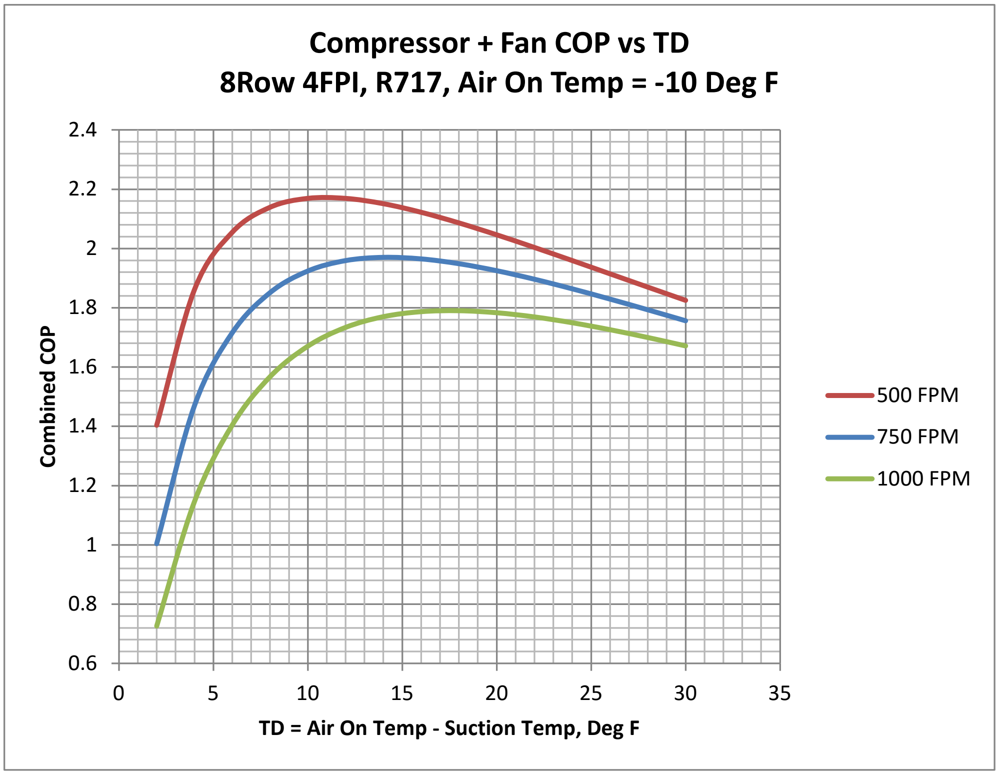

FIGURE 6

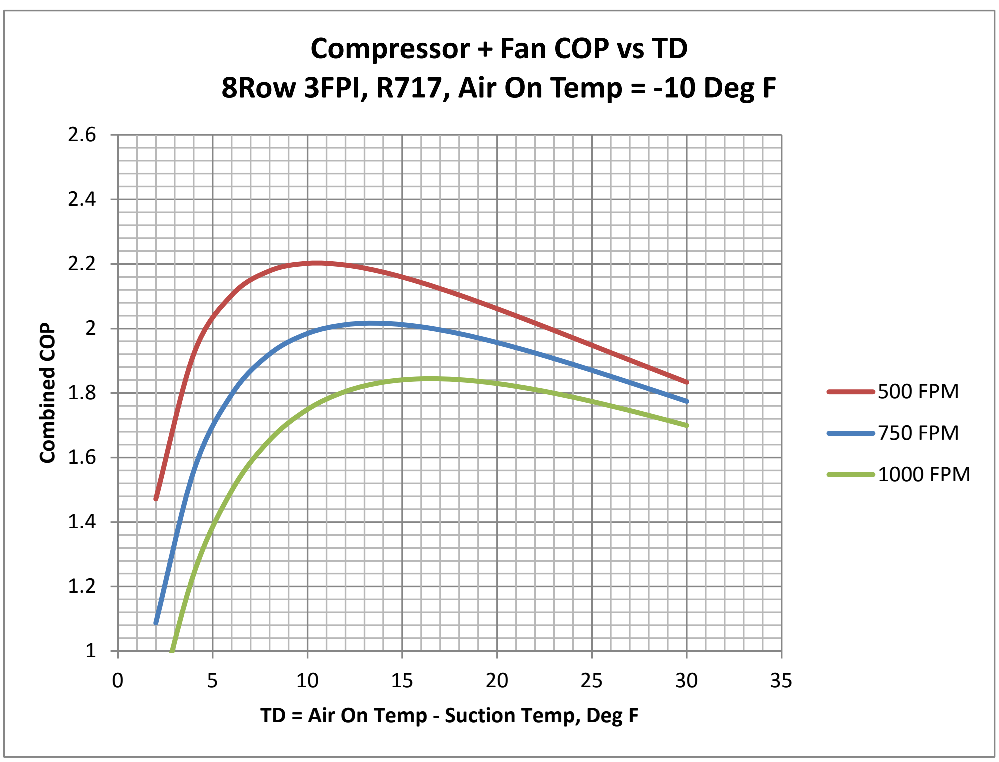

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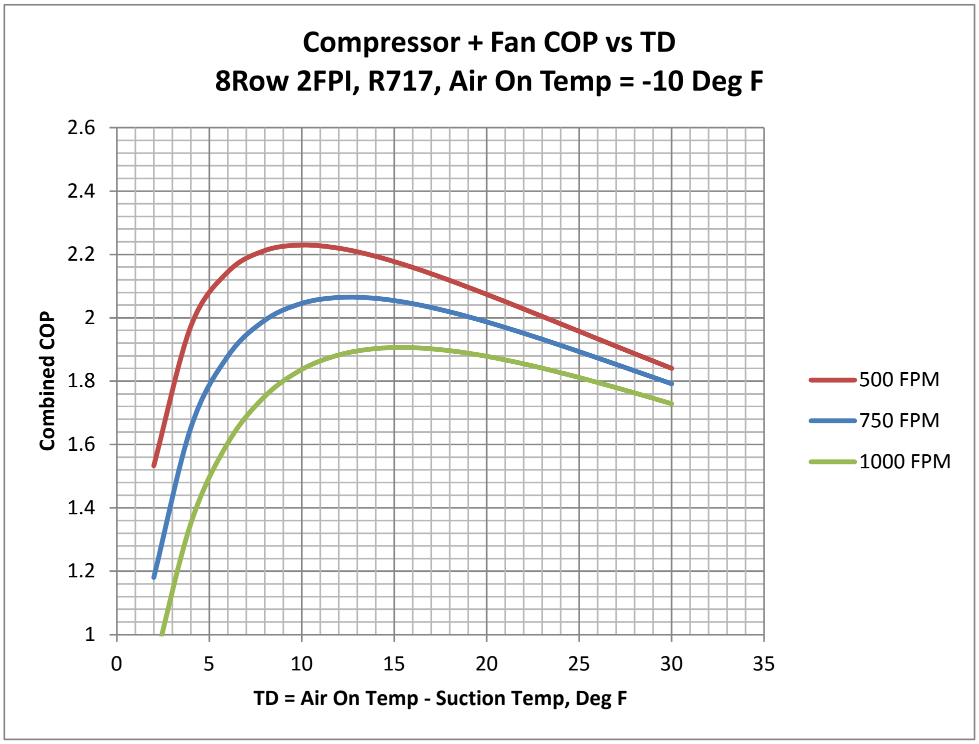
FIGURE 7



The following is observed from Figures 5 through 7:

a. Combined COP is a very strong function of coil face velocity. COP at 500 FPM is approximately 10% higher than COP at 750 FPM and 20% higher than COP at 1000 FPM.
b. Combined COP increases as the distance between fins is increased. Coils with 2FPI spacing will have higher combined COP than coils with 3FPI, which will have higher COP than 4FPI.
c. The optimum (maximum) TD increases with increasing face velocity.
d. In all cases, combined COP decreases very rapidly below about 7 deg F TD.

In order to make the final decision about selecting the optimum TD, the cost of power as well as installed cost of the compressor(s) and evaporators must be known (or estimated). These variables can then be combined to calculate the incremental return on investment comparing different evaporator designs (face velocity and fin spacing) in terms of first cost vs operating cost.

Since these costs are highly variable, the final return on investment calculation must be made on a case-by-case basis and presented to the client in a way which allows the final decision to be made given the project financial constraints and requirements.

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Conclusions:

1. *For highest system COP / energy efficiency, select evaporators for the lowest face velocity and widest fin spacing financially practical. Colmac recommends maximum face velocity of 600 FPM and fin spacing of 3 FPI or wider (lower FPI).*
2. *For coil face velocities between 500 and 750 FPM a design TD between 10 deg F and 15 deg F is recommended.*
3. *Final optimized evaporator design and TD must be determined based on specific project financial constraints and acceptable return on investment.*

4. Effect of TD on Expansion Valve (EV) Operation

With direct expansion (DX) evaporators the flow of refrigerant to the evaporator is metered by an automatic expansion valve in response to a control signal measured at the evaporator outlet. The control signal is normally the amount of superheat in the refrigerant suction gas. The theoretical maximum amount of suction gas superheat that can be generated is equal to the operating TD (TD = Air On Temperature – Evaporating Temperature).

The amount of superheat required for stable operation (modulation) of the expansion valve varies with the type of valve employed and with the evaporator dynamics. Two basic types of expansion valves are currently available on the market, Thermostatic (TEV) and Electronic (EEV). Both use superheat in the suction gas as the control signal.

Thermostatic expansion valves measure and mechanically calculate superheat by means of a temperature sensing bulb and pressure equalizing line. These valves and their operation are described in detail by the valve manufacturers. The advantage of this type of valve is their low cost and compactness. With this type of valve, temperature sensing is accomplished by a refrigerant-filled bulb strapped to the outside of the coil suction connection. A disadvantage of this system is the additional superheat required to overcome the thermal resistance of the pipe wall. This additional superheat forces the operating TD to be approximately 5 deg F greater than for an electronic expansion valve that uses a temperature transducer to measure temperature directly.

Electronic expansion valves operate based on a signal received from a superheat controller which reads suction gas temperature and pressure from a combination of sensors. The expansion valve itself may operate based on an “open/close” (pulsing) principle or on a motorized positioning principle. Advantages of this type of valve include more accurate and responsive sensing of superheat which allows stable operation at smaller TD than thermostatic type valves. PID control parameters can also be adjusted in the controller to “fine tune” operation over a wide range of conditions. The primary disadvantage of electronic expansion valves is the higher first cost compared to thermostatic valves. This, however, is changing as valve manufacturers are finding lower cost solutions and beginning to offer cost competitive electronic valves to the market.

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Minimum recommended TD and superheat settings for both types of expansion valves are shown in Table 2 below:

TABLE 2
MINIMUM RECOMMENDED DX AMMONIA TD AND SUPERHEAT SETTING

Expansion Valve Type	Minimum Recommended TD, deg F	Recommended Superheat Setting, deg F
Thermostatic	15	10
Electronic	12	8

Note: Colmac offers factory supplied and mounted expansion valves and controllers, both thermostatic and electronic type.

5. The Effect of Frost Accumulation on Evaporator Performance

The evaporators are the only component in the refrigeration system which lose cooling capacity over time due to the accumulation of frost. Capacity is lost due to a) reduced airflow caused by increasing air pressure drop, and b) the insulating characteristics of frost on coil fins.

The rate of frost accumulation on an evaporator will vary drastically depending the room relative humidity and the coil operating TD. The faster frost accumulates the faster airflow and evaporator cooling capacity are reduced. Nelson (2015) describes this phenomenon and how to select the optimum coil fin spacing and tube pattern for a given set of operating conditions.

It is important to understand the room operating conditions and correctly predict the air Sensible Heat Ratio (SHR) to select the optimum fin spacing and tube pattern. In essence, when the air sensible heat ratio is low - i.e. the accumulation of frost is rapid - it is important to select evaporators with wide (3 fins per inch or less) fin spacing. Inline (vs staggered) tube patterns are also recommended for heavy frost load conditions as this type of coil construction will extend operating time between defrosts.

Air-Borne Ice Crystals

This type of frost is formed quite differently from the frost formed by deposition as explained above. It accumulates on evaporator surfaces by a different mechanism, and is more difficult to quantify and predict.

Rather than accumulate relatively uniformly over the entire coil surface as is the case with frost formed by deposition, air-borne ice crystals accumulate on the leading edges of the coil fins and have the primary effect of restricting airflow. This type of frost is more difficult to predict since its formation depends on not only the condition of the air

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outside the refrigerated space, but also on the condition of doorways and how they are operated.

When evaporators are located directly above doorways where air-borne ice crystals are formed this type of frost can accumulate very quickly and have serious consequences in terms of degraded performance and inability to defrost effectively due to excessive accumulation of hoar frost and ice. In one particular case observed by the author, two identical evaporators were installed in the same refrigerated space (a -10 deg F freezer) along the same wall, one directly over the doorway and the second offset between doorways. The evaporator directly over the doorway had chronic problems with rapid, heavy accumulation of frost, and with defrost issues related to accumulation of ice on the unit cabinet and in the drainpan. The evaporator located only 20 feet away between doorways, operated without accumulating ice on the cabinet and or in the pan and defrosted normally and effectively. *It is therefore recommended that evaporators not be located directly above doorways whenever possible.*

If it is known that the evaporator will be exposed to this type of frost, variable fin spacing is recommended. That is, a fin spacing arrangement which has fins on the first one to two rows on the air entering side of the coil spaced wider than in the remaining rows. Typical arrangements are 1 / 2 fpi (fins per inch), 1.5 / 3 fpi, and 2 / 4 fpi.

VI. Condenser Selection and Operation

A number of different types of condensers are available for use with ammonia.

- Water Cooled
- Air Cooled
- Evaporative
- Hybrid (Adiabatic) Air-Evaporative

In certain cases the type of compression equipment (screw vs reciprocating) selected and the expected maximum ambient temperature will determine whether or not air cooled condensing will be possible. In other cases the availability (or unavailability) of water may require the use of air cooled condensing. The good news is that DX ammonia is compatible with all types of condensing systems!

Proper selection and operation of ammonia condensing equipment is outlined in the condenser manufacturers' literature.

It is recommended that the system designer carefully consider the following points when selecting/designing condensing equipment:

- Energy efficiency
- Part load operation
- Low ambient operation
- Internal volume and ammonia charge
- Gas inlet and liquid outlet piping

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- Purging of non-condensable gases
- VFD condenser fan control (highly recommended)
- Refrigerant side pressure drop

VII. Subcooling

Refrigerant liquid leaving the condenser is typically at or near saturation temperature and pressure. If the liquid has not been subcooled before it enters the liquid line, any drop in pressure, and/or any heat input, will cause the liquid to boil and "flash gas" will be formed. Because of the very large volume occupied by vapor compared to liquid, the flash gas increases the refrigerant velocity and causes an excessive pressure drop in the liquid line, This reduces the capacity and interferes with the operation of the expansion valve, and consequently will reduce system capacity. Adequate subcooling of the liquid will prevent the formation of flash gas in liquid lines.

Subcooling the liquid after it leaves the receiver is therefore a necessity for proper system operation. Note that any subcooling done within the condenser or between the condenser and the receiver will be eliminated in the receiver due to the equalizer line. The amount of subcooling required corresponds to the liquid line pressure drop and heat gain. The pressure drop is the sum of 1) the loss in pressure due to elevation gain in the liquid line, 2) liquid line pressure drop due to friction, and 3) pressure drop through service and control valves.

Table 5 shows the pressure drop in liquid lines produced by elevation gain between the receiver and evaporators with ammonia.

TABLE 5

Pressure Drop in Ammonia Liquid Lines Due to Elevation Gain			
Elevation Gain		Pressure Drop	
ft	m	psi	kPa
1	0.3	0.3	1.9
5	1.5	1.4	9.3
10	3.0	2.7	18.7
15	4.6	4.1	28.0
20	6.1	5.4	37.3
25	7.6	6.8	46.7
30	9.1	8.1	56.0
35	10.7	9.5	65.4
40	12.2	10.8	74.7
45	13.7	12.2	84.0
50	15.2	13.5	93.4

Once the total liquid line pressure drop (the sum of elevation pressure drop plus frictional pressure drop plus pressure drop through valves) is calculated, the required amount of subcooling to prevent flash gas in the line can be determined from Table 6. Note that the

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amount of subcooling required for a given pressure drop increases as condensing temperature decreases.

TABLE 6

Total Liquid Line		Required Amount of Subcooling (Ammonia)					
Pressure Drop		120F (49C) SCT		95F (35C) SCT		65F (18C) SCT	
psi	kPa	deg F	deg C	deg F	deg C	deg F	deg C
1	6.9	0.2	0.1	0.3	0.2	0.5	0.3
4	27.6	1.0	0.5	1.3	0.7	1.9	1.0
6	41.4	1.4	0.8	1.9	1.1	2.8	1.6
8	55.2	1.9	1.1	2.6	1.4	3.8	2.1
10	68.9	2.4	1.3	3.2	1.8	4.7	2.6
12	82.7	2.9	1.6	3.8	2.1	5.6	3.1
14	96.5	3.4	1.9	4.5	2.5	6.6	3.7
16	110.3	3.8	2.1	5.1	2.8	7.5	4.2
18	124.1	4.3	2.4	5.8	3.2	8.5	4.7
20	137.9	4.8	2.7	6.4	3.6	9.4	5.2
25	172.4	6.0	3.3	8.0	4.4	11.8	6.5
30	206.8	7.2	4.0	9.6	5.3	14.1	7.8
35	241.3	8.4	4.7	11.2	6.2	16.5	9.2
40	275.8	9.6	5.3	12.8	7.1	18.8	10.5
45	310.3	10.8	6.0	14.4	8.0	21.2	11.8
50	344.7	12.0	6.7	16.0	8.9	23.5	13.1

A commonly used method of subcooling liquid refrigerant is termed Mechanical Subcooling. This is the COLMAC RECOMMENDED method of liquid subcooling and refers to using a portion of liquid refrigerant from the uncooled liquid line to evaporate and cool the remaining liquid. A heat exchanger (typically a plate type exchanger) is installed in the liquid line in such a way as to cool the liquid refrigerant on one side of the exchanger by evaporating a relatively small amount of the refrigerant on the other side of the exchanger. The evaporating side refrigerant is metered by a TXV or motorized valve in response to liquid line temperature and the evaporated refrigerant then returned to the suction line. This method of subcooling produces predictable results under all conditions, and is required to ensure proper operation of Colmac DX Ammonia evaporator controls. With mechanical subcooling there is no net loss of refrigerating effect or system energy efficiency.

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Alternate methods for subcooling refrigerant liquid can be applied, but have various drawbacks:

Ambient Subcooling. This involves using a separate circuit within the condenser to route liquid refrigerant from the receiver to the system causing the refrigerant to approach the ambient air temperature. This is a relatively simple design, however the amount of subcooling will be limited to the condenser TD. This may not be a sufficient amount of subcooling to avoid formation of flash gas during certain times of the year. Therefore, this method of subcooling is NOT recommended.

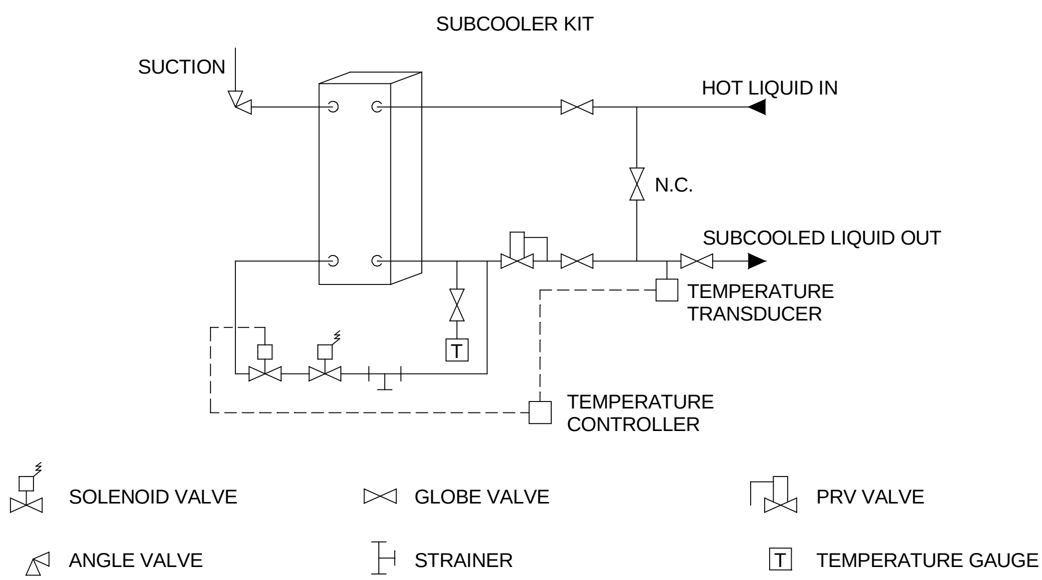
Liquid Pumping. Here a liquid pump is installed at the exit of the receiver to pressurize the liquid line sufficiently to overcome the total pressure drop due to friction and elevation gain. While effective at eliminating flash gas regardless of operating conditions, this method adds complexity and will cause the liquid line to operate at a pressure which is higher than condensing pressure. As with ambient subcooling, this method is NOT recommended.

NOTE: Referring to Figures A1-A3, liquid temperature leaving the mechanical subcooler is shown as 40 deg F. This liquid temperature is conservative and should prevent the formation of flash gas in liquid lines in most if not all cases.

Subcooler Piping:

Figure 12 below illustrates typical mechanical subcooler heat exchanger piping.

FIGURE 12



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To ensure effective liquid subcooling, be sure to observe the following rules:

1. Size piping and valves for the maximum refrigerant flow condition anticipated, i.e. lowest head pressure / highest suction pressure. This condition typically occurs during winter months.
2. Always insulate liquid lines to prevent heat gain and loss of subcooling.
3. Locate subcooler heat exchanger downstream of the receiver at the entrance to the liquid line, NOT between the condenser and receiver. See P&ID examples above.
4. Use good piping practice, as can be found in the IIAR Ammonia Refrigeration Piping Handbook (IIAR 2004).

Mechanical Subcooler Selection:

Colmac offers pre-engineered Mechanical Subcoolers which are factory piped and packaged in a free-standing frame, and include the following components:

- Stainless steel plate-type subcooling heat exchanger
- Electronic expansion valve and temperature controller
- Service (isolation) valves
- Pressure reducing valve for controlled leaving liquid line pressure
- UL listed and wired control panel

See separate Engineering Bulletin for subcooler selection and specification details.

VIII. Piping – General

1. Cleanliness. The small internal passages found in expansion valves (and other control valves) in DX ammonia systems are particularly sensitive to fouling and plugging with relatively small amounts of dirt and debris. For this reason, particular care needs to be taken during the installation of system piping to ensure cleanliness and to minimize the introduction of weld scale and dust, and other types of dirt and debris.

2. Evacuation Prior to Charging the System with Ammonia. Because the performance of DX ammonia evaporators is dramatically affected by even small amounts of water, it is very important to follow good pressure testing and evacuation procedures prior to charging the system with ammonia. Recommended evacuation procedure can be found in the separate Colmac Engineering Bulletin on this topic.

IX. Liquid Lines

Industry-accepted methods and practice for proper sizing and arrangement of liquid lines can be found in the IIAR Ammonia Refrigeration Piping Handbook (IIAR 2004). Additionally, follow the guidelines explained below.

1. Design mass flowrate. Liquid lines must be sized appropriately for the type of line (condenser to receiver, receiver to expansion valve, etc.) and the expected maximum mass flow rate condition. The maximum mass flow rate condition will occur when discharge pressure is at its minimum, suction pressure is at its maximum, and

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compressors are running fully loaded. Typically this would occur with floating head pressure systems during winter months. Designing liquid lines for the hottest day of the year (commonly taken as the "design point") will likely lead to undersized liquid lines and higher-than-expected pressure drop with the potential of forming flash gas in the liquid line.

2. Insulation. Insulation of liquid lines downstream of the liquid subcooler becomes critically important in DX ammonia systems to avoid heat gain and the potential for developing flash gas in the liquid line upstream of the expansion valves. Use good quality insulation systems with adequate insulation value and protection against physical and weather damage.
3. Type of Expansion Valve. Three types of expansion valves are commonly used in DX systems: 1) Thermostatic, 2) Motorized, and 3) Pulse-width Modulating. Thermostatic and motorized valves modulate in response to the imposed load on the coil and so liquid lines should be sized for the maximum expected design mass flow rate (see paragraph V.1. above). Pulse-width modulating (PWM) expansion valves, on the other hand, alternate between wide open and fully closed at a rate which corresponds to the duty called for by the electronic controller. Because the mass flow rate of refrigerant will be determined by the wide open capacity of the PWM valve, the "local" liquid line from the liquid supply main to the individual evaporator must be sized to handle the maximum capacity of the valve. When PWM valves are used, the liquid supply main line must be sized to handle this "wide open capacity" by using a diversity factor based on the number of evaporators expected to be operating at the same time divided by the total number of evaporators.
4. Pressure Regulating Valve. As shown in Figures A1-A3, the liquid line pressure leaving the subcooler assembly is maintained at 75 psig by a pressure regulating valve. When defrost hot gas pressure is regulated to maintain 90 psig (also shown in Figures A1-A3) this pressure differential allows defrost condensate leaving the evaporators during defrost to be fed directly back into the liquid line and sent to other operating evaporators.
5. Pipe material specifications. Refer to the IIAR Ammonia Refrigeration Piping Handbook (IIAR 2004) and ANSI/IIAR Standard 2-2008 (IIAR 2008) for detailed pipe material specification requirements for ammonia liquid piping.

X. Suction Lines

Unlike pumped ammonia systems, no wet suction lines are needed for DX ammonia. Although they should be pitched and trapped to accommodate the occasional presence of liquid, suction line pressure drop should be calculated to reflect dry operation. Refer to the IIAR Ammonia Refrigeration Piping Handbook (IIAR 2004) for proper sizing and arrangement of dry suction lines. Additionally, follow the guidelines explained below.

1. Design mass flowrate. As with liquid lines, dry suction lines should be sized for the expected maximum mass flow rate condition. Again, the maximum mass flow rate condition will occur when discharge pressure is at its minimum, suction pressure is at its maximum, and compressors are running fully loaded.

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2. Trapped vertical risers. Suction lines with vertical upflow (suction "risers") must be installed with a p-trap at the bottom (entrance) of the riser and discharge into the top of the overhead suction main pipe. When varying loads on the evaporator are expected, a double riser design should be used. Refer to the IIAR Ammonia Refrigeration Piping Handbook (IIAR 2004) for examples of double suction riser designs.
3. Pitched suction lines. Suction lines must be pitched a minimum of 1/8" per foot toward the suction accumulator to facilitate good drainage of any liquid refrigerant and/or oil that enters the suction line.
4. Pipe material specifications. Particular attention must be paid to carbon steel pipe material specifications in low temperature (suction temperatures below -20 deg F), which may require impact testing. Refer to the IIAR Ammonia Refrigeration Piping Handbook (IIAR 2004) and ANSI/IIAR Standard 2 (IIAR 2008) for detailed pipe material specifications and requirements.

XI. Hot Gas Lines

Industry-accepted methods and practice for proper sizing and arrangement of hot gas lines can be found in the IIAR Ammonia Refrigeration Piping Handbook (IIAR 2004). Additionally, follow the guidelines explained below.

1. Design mass flowrate. Hot gas (defrost) lines should be sized for the mass flow rate corresponding to the maximum number and size of evaporators expected to defrost at the same time. Conventional wisdom maintains that each individual evaporator requires a flow of hot gas equal to 2 x times the flow required during cooling, and so this would limit the number of evaporators being defrosted at the same time to a maximum of 1/3 the total number of evaporators in the facility (the "two-to-one rule"). However, evaporators equipped with Colmac Smart Hot Gas™ controls can effectively defrost an evaporator with hot gas flowing to the evaporator for only 8 to 10 minutes. With an effective building management control system, and depending on the frost load and frequency of defrosting, it is possible to limit the amount of defrost hot gas flowing at any given time to only that required for the largest single evaporator in the facility. This approach obviously has the potential to reduce the hot gas line and PRV size and cost. Expected mass flow rate of hot gas for defrost of a given sized evaporator can be calculated using the method described below in the Hot Gas Defrost section.
2. Insulation. Insulation of hot gas lines is critically important to ensure fast defrosting. Use good quality insulation systems with adequate insulation value and protection against physical and weather damage.
3. Pressure Regulating Valve. As shown in Figures A1-A3, the hot gas line coming from the compressor discharge line is maintained at 90 psig by a pressure regulating valve. When defrost hot gas pressure is regulated to maintain 90 psig and the liquid line is maintained at 75 psig (also shown in Figures A1-A3) this pressure differential allows defrost condensate leaving the evaporators during defrost to be fed directly back into the liquid line and sent to other operating evaporators. Maintaining the hot gas line pressure at the reduced 90 psig also minimizes heat loss to the surrounding ambient.

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4. Pitched hot gas lines and drip legs. Hot gas lines must be pitched a minimum of 1/8" per foot toward the evaporators to facilitate good drainage of any condensed refrigerant ("condensate") to drip legs installed ahead of the evaporator control valve group(s).
5. Liquid drainers. As hot gas for defrost travels from the engine room to the evaporators some of its energy will be released to heat up the piping itself, and some released due to heat loss through insulation. Condensate will therefore form in the hot gas piping which must then be effectively trapped and drained before it reaches the evaporators. Unless it is effectively removed, accumulating condensed liquid upstream of hot gas solenoid valves will cause cavitation on the seats of the solenoid valves when the valve is closed (Jensen 2013). Condensate will collect in drip legs (described above) and must be returned to either a nearby suction line, or a condensate return line. Use a liquid drainer or an appropriately sized steam trap to allow only liquid to leave the drip leg. Using liquid drainers also effectively keeps hot gas lines continually heated and ready to supply full flow of hot gas to evaporators immediately on demand for defrosting.
6. Pipe material specifications. Refer to the IIAR Ammonia Refrigeration Piping Handbook (IIAR 2004) and ANSI/IIAR Standard 2-2008 (IIAR 2008) for detailed pipe material specification requirements for ammonia hot gas piping.

XII. Effects of Water in Ammonia and Its Removal

As explained in detail elsewhere (Nelson 2010), the presence of even small amounts of water in ammonia has a significant negative effect on DX evaporator performance. Unfortunately, water is difficult to entirely keep out of industrial ammonia refrigeration systems for a number of reasons: Residual water in pressure vessels left from hydro-testing, incomplete evacuation of the system prior to startup, leaks in parts of the system which normally operate in a vacuum, etc.

This residual water goes into solution with the ammonia and increases and the boiling point (bubble point) temperature. At a concentration of 20% (by mass) water in ammonia, the boiling point rises to approximately 10 deg F above the boiling point of pure ammonia at the same pressure. See Figure 13 below.

As the ammonia-water liquid enters the evaporator circuit it begins to boil. Because of the large difference in vapor pressures of ammonia and water, only ammonia vapor is generated during the evaporation process, leaving the water behind in the remaining liquid. So the evaporation process results in an increase in water concentration and a corresponding increase in the boiling point of the refrigerant as it passes through the coil circuit. In the case of an evaporator operating with a 10 deg F TD, the refrigerant will stop boiling once the water concentration reaches about 20% since the boiling point will have risen by 10 deg F. This cessation of boiling will occur at some point along the length of the evaporator circuit, the point at which boiling stops depending on the initial concentration of water and suction pressure. At the point where the increase in the water concentration has caused an increase in the boiling point equal to the coil TD, liquid refrigerant will exit the evaporator and enter the suction line.

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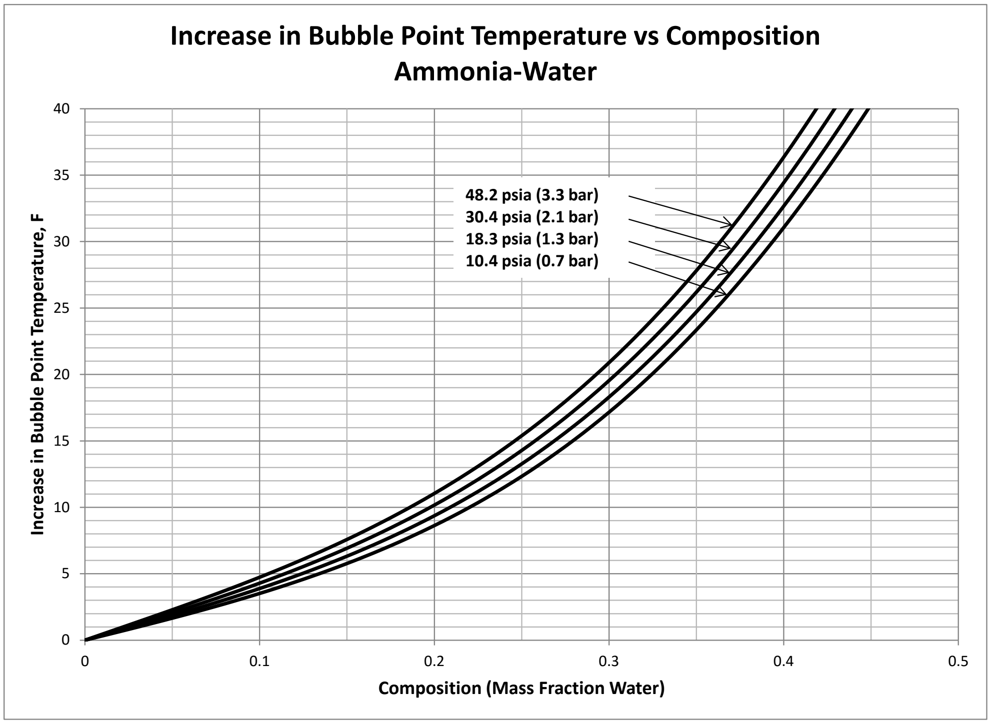
Figure 13 below shows the increase in boiling point (bubble point) for various initial water concentrations in ammonia at various pressures.

FIGURE 13



An example of the increase in bubble point temperature over the circuit length of an evaporator, represented by the change in vapor quality, is shown in Figure 14 below for an initial water concentration in ammonia of 3% at a pressure of 10.4 psia (-40 deg F SST). In this example the bubble point (Tbub) has increased by 10 deg F at a vapor quality of approx. 0.89.

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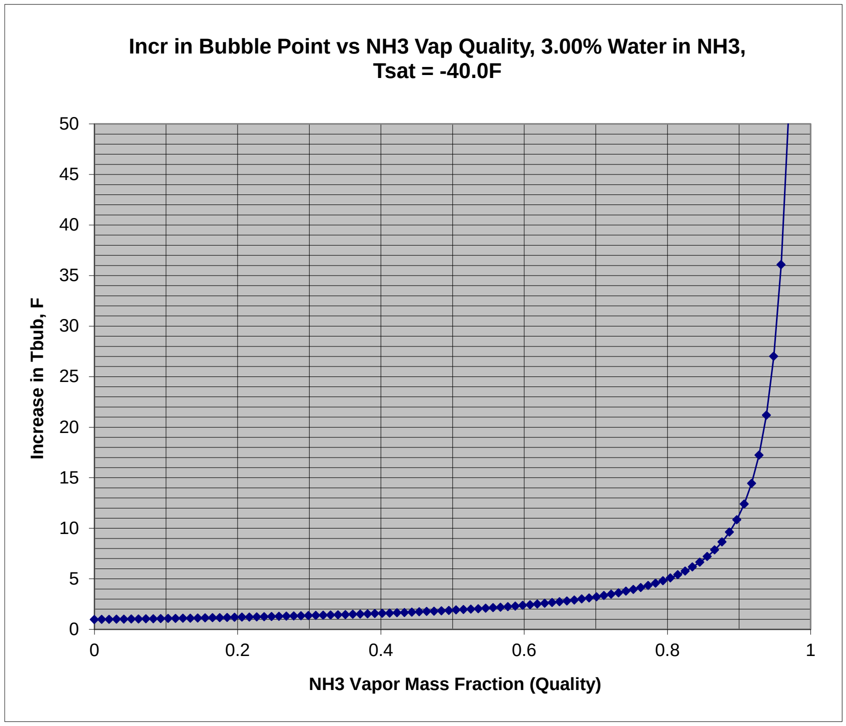
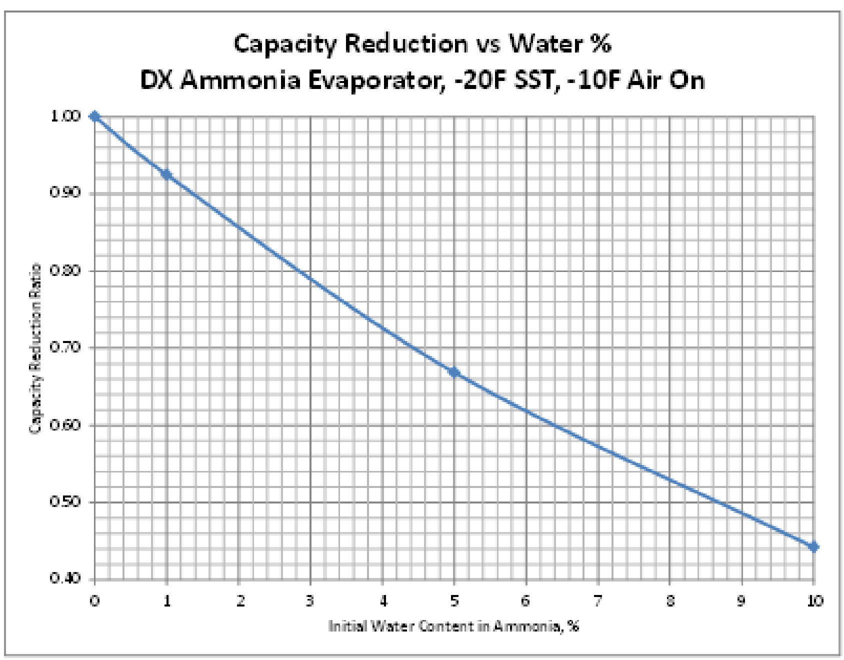
FIGURE 14



This increase in bubble point significantly reduces the mean temperature difference and therefore the cooling capacity of the evaporator is reduced as illustrated in Figure 15.

FIGURE 15



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In addition to the performance penalty seen when relatively small amounts of water are present in the ammonia, this also means that the mass fraction (1 – 0.89) = 0.11, or 11% of the mass of refrigerant exiting the evaporator as liquid will have to be captured downstream in the suction accumulator.

Knowing that ammonia-water liquid of approximately 20% water concentration will unavoidably leave the evaporators whenever even small amounts of water are present in the ammonia is important for the designer to understand. The suction accumulator must therefore be properly designed to perform the following functions:

i. Separate liquid and vapor refrigerant and allow only vapor to return to the compressor,
ii. Capture and distill (by heating) ammonia-water liquid to a concentration that can safely be removed from the system for disposal.
iii. Transfer excess trapped liquid to the high pressure receiver, or into the reduced pressure liquid line.

1. Separation

Liquid-vapor separation in suction accumulator vessels is well understood and design methods well documented. Refer to recognized published sizing and design methods (Stoecker 1988, Wiencke 2002).

Colmac offers a range of pre-engineered factory assembled suction accumulator packages specifically suited to operation with DX ammonia. See separate Engineering Bulletin for selection and specification details.

2. Distillation and Disposal of Ammonia-Water Solution (Ammonium Hydroxide)

Distillation:

Ammonia is highly soluble in water due to the polarity of NH3 molecules and their ability to form very strong hydrogen bonds (Nelson 2010). This high solubility makes ammonia-water a good working fluid pair in absorption refrigeration machines, taking advantage of the large vapor pressure differences between the ammonia vapor and weak solution. However, this same behavior makes water removal from ammonia refrigeration systems somewhat challenging.

As mentioned above, ammonia-water solution concentrated to approximately 20% water will return from evaporators via the suction line to be trapped in the suction accumulator. This aqueous ammonia solution, called Ammonium Hydroxide, at a concentration of 80% ammonia (20% water) would be very difficult to safely remove from the system for disposal. Further distillation of the solution is needed to bring the ammonia concentration in the solution down to the practical minimum before it is removed.

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The only practical way to distill the Ammonium Hydroxide is by heating in a separate distillation vessel, called a "still". Ammonium Hydroxide trapped in the suction accumulator drains by gravity into the still where it is heated to a temperature corresponding to the point on a Phase Equilibrium diagram where the slope of the dew point line changes rapidly from nearly vertical to more nearly flat. This point is shown on Figure 16 as 'Point A'. Below this temperature (between 100 and 120 deg F), nearly pure ammonia vapor will leave the still and travel through the vent line back to the suction accumulator where it will then be taken back to the compressor. Above this temperature, water vapor will begin to leave the Ammonium Hydroxide solution and exit the still vent line where it will go back into solution with any ammonia liquid present in the suction accumulator. Based on this, the heating element in the still must be controlled to bring the solution temperature up to a maximum of 100 to 120 deg F, at which point it is ready to be removed safely to a storage container for further processing and/or disposal.

FIGURE 16

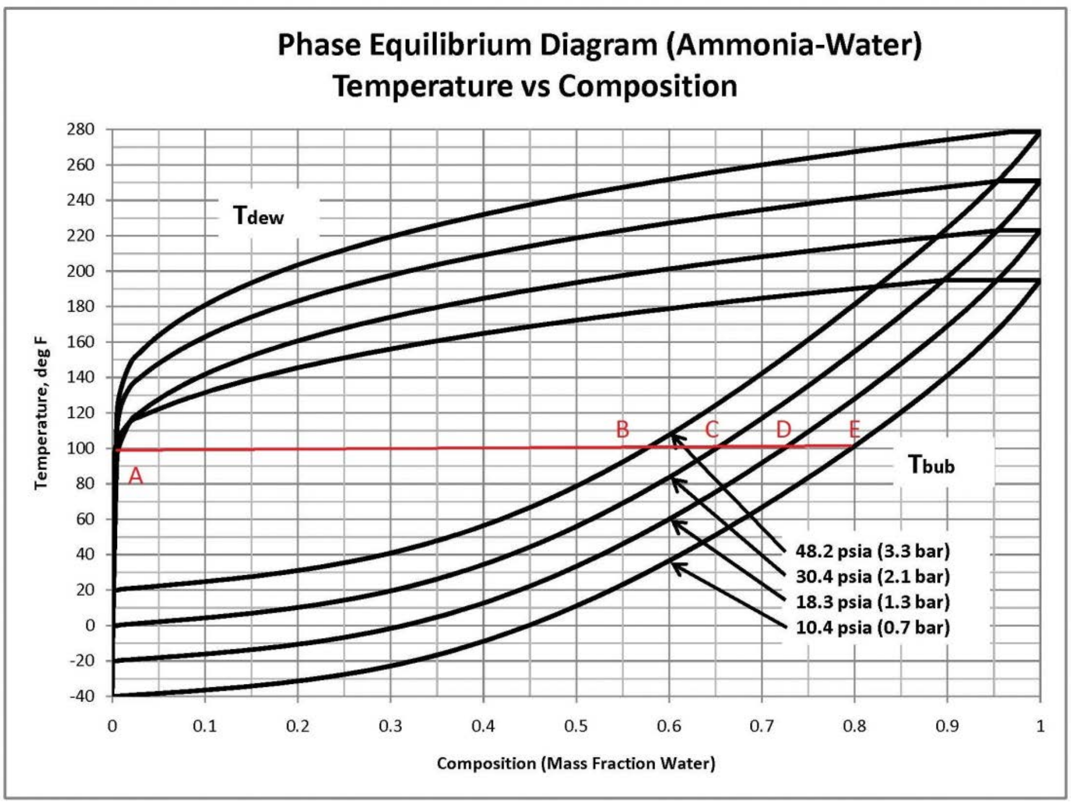

Figure 16 also shows that the maximum water concentration in the Ammonium Hydroxide solution heated to 100 deg F varies with suction pressure. The maximum water concentrations possible are shown as Points B, C, D, and E, in Figure 16, and are listed in Table 7 below. It is apparent from the figure and the table that the still is able to achieve higher water concentrations at lower suction pressures.

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TABLE 7
AMMONIA-WATER CONCENTRATIONS @ 100 deg F vs SUCTION PRESSURE

Suction Pressure, psia (Saturation Temp, F)	Water Concentration, % by mass	Ammonia Concentration, % by mass
48.2 (+20 F)	57.5	42.5
30.4 (0 F)	65.0	35.0
18.3 (-20 F)	72.5	27.5
10.4 (-40 F)	80.0	20.0

Using the above information, an estimate can now be made of the volume of Ammonium Hydroxide solution that will be generated by the still for a given system ammonia charge having a given initial water content. Table 8 below shows the expected volume of Ammonium Hydroxide solution per pound of initial ammonia charge that will have to be removed by the still (and disposed of) in order to completely remove the water from refrigeration system.

TABLE 8
EXPECTED VOLUME OF DISTILLED SOLUTION AMMONIUM HYDROXIDE @ 100F
(GALLONS per POUND INITIAL AMMONIA CHARGE)

Initial Water	Saturated Suction Pressure, psia (Saturated Temp, F)			
Content, %	48.2 (+20 F)	30.4 (0 F)	18.3 (-20 F)	10.4 (-40 F)
0	0.00000	0.00000	0.00000	0.00000
1	0.00246	0.00211	0.00183	0.00161
3	0.00738	0.00633	0.00550	0.00484
5	0.01230	0.01055	0.00917	0.00807
10	0.02460	0.02109	0.01835	0.01614
20	0.04920	0.04218	0.03669	0.03229

EXAMPLE:
A system has an initial ammonia charge of 5,000 lbs with 3% water content. The still is installed on the -20 deg F suction accumulator. What will be the total volume of distilled Ammonium Hydroxide solution drained from the still?

Answer:
Final Distilled Solution Ammonia Concentration for Disposal (from Table 7): 27.5%
Expected Volume of Distilled Solution per Pound (from Table 8): 0.0055 gal/lbs

Total Expected Volume of 27.5% Ammonium Hydroxide for Disposal:
5,000 lbs x 0.0055 gal/lbs = 27.5 gallons

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Storage and Disposal:

Ammonium Hydroxide is listed as a hazardous substance under CWA (40 CFR 1164.40 CFR 117.3 Reportable Quantity Category C. 1000lbs/454 kg). As such, it is important to comply with all local and national regulations for safe handling and disposal of the solution removed from the system still (Smith 2010).

It is interesting to note that suitably diluted Ammonium Hydroxide may be disposed of on agricultural land as fertilizer. However, the material should be kept from entering streams and lakes as it is harmful to aquatic life and can cause environmental damage.

Ammonium Hydroxide will react exothermically (heat is generated) with acids, and so neutralizing of the solution by unqualified personnel is not recommended.

It is important to prevent contact of the Ammonium Hydroxide solution with chemicals such as mercury, chlorine, iodine, bromine, silver oxide, and hypochlorites, as they can form explosive compounds. Contact with chlorine forms chloramine gas which is a primary skin irritant and sensitizer.

Figure 16 in combination with Table 7 can be used to predict the temperature above which ammonia vapor will be generated when the distilled solution is stored in an open container. This “vapor neutral” temperature is found using the ammonia concentrations shown in Table 7 for various suction pressures, intersecting a line of constant bubble point temperature (Tbub) at atmospheric pressure (14.7 psia) on Figure 16. Table 9 below shows the ambient (storage) temperatures below which ammonia vapor will not be generated from the Ammonium Hydroxide solution discharged from the still.

TABLE 9
RECOMMENDED MAXIMUM AMMONIUM HYDROXIDE STORAGE TEMPERATURES

Suction Pressure, psia (Suction Temp, F)	Ammonia Concentration, % by mass	Storage Temperature, Deg F
48.2 (+20 F)	42.5	42
30.4 (0 F)	35.0	64
18.3 (-20 F)	27.5	90
10.4 (-40 F)	20.0	108

Ammonium Hydroxide solution has a corrosive reaction with the following materials which should not be used to store the distilled Ammonium Hydroxide solution (LaRoche Industries 1987):

- Galvanized (zinc coated) surfaces
- Copper
- Brass and bronze alloys
- Certain types of elastomers

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The distilled Ammonium Hydroxide solution can be safely stored in containers made of the following materials:

- Carbon steel
- Stainless steel
- Aluminum
- Cast Iron

Generally speaking, aluminum alloys are not recommended for exposure to aqueous solutions having a pH greater than 9.0 due to accelerated corrosion and metal loss. Ammonium Hydroxide however, even in high concentrations, is an exception to this rule. (Davis 1999).

In conclusion, Ammonium Hydroxide solution collected from the still should be stored in an appropriately constructed container located in a cool space out of direct sunlight. It is recommended that the distilled solution be disposed of using a local qualified waste disposal vendor.

More detailed handling and safety information can be found on MSDS sheets published by suppliers of Ammonium Hydroxide (Tanner Industries 2000, LaRoche Industries 1998).

3. Liquid Transfer

Liquid refrigerant will leave the evaporator(s) and accumulate in the suction accumulator vessel during operation for a number of reasons:

a. Liquid floodback due to water in the ammonia (see above explanation),
b. Liquid floodback due to a rapid change in system pressure and/or load,
c. Liquid condensate from hot gas defrost.

The total anticipated volume of liquid refrigerant reaching the suction accumulator vessel must be calculated by the system designer in order to determine whether or not a liquid transfer system will be needed. As mentioned above, the amount of heat available from subcooling and/or booster discharge gas desuperheating must be equal to or greater than the heat required to vaporize the liquid reaching the suction accumulator. If this is not the case, a liquid transfer system must be added to the design. In order to properly size the transfer system, estimates of the amount of liquid returning from evaporators for the reasons stated above must be made.

i. Liquid Floodback Due to Water in Ammonia

The anticipated volume of ammonia-water liquid leaving the evaporator(s) based on an average 20% water concentration at the evaporator exit has been calculated and shown in Table 10 below. Multiply the value shown in the table by the total capacity

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of the system in tons (TR) to determine the volume of ammonia-water liquid returning to the suction accumulator.

TABLE 10
VOLUME OF AMMONIA-WATER LIQUID LEAVING DX EVAPORATORS

Water Content in Ammonia, %	Volumetric Flowrate of Ammonia-Water (20% water concentration) Leaving DX Evaporators, ft3/h/TR
0.5	0.01
1.0	0.02
3.0	0.07
5.0	0.12
10.0	0.24

Example:
It has been determined that the ammonia fed to evaporators with total capacity of 200 tons (TR) has a water content of 3%. If the evaporators are operated as direct expansion (DX), how much ammonia-water liquid is expected to return from the evaporators to the suction accumulator?

Answer:
Volume of Floodback Due to Water = 200 TR x 0.07 ft3/h/TR = 14 ft3/h = 1.8 gal/min

In a properly designed and operated system, this type of liquid floodback should only occur initially during startup since water in the system will be captured in the still and then removed.

ii. Liquid Floodback Due to Rapid Changes in Pressure or Load

This type of floodback is difficult to predict, but fortunately is (or should be) relatively small. A ‘worst-case’ rule of thumb might be to assume that an average 10% of the mass of refrigerant leaves as liquid from 25% of the evaporators. In that case, the transfer system would need to handle a volume of liquid approximated by the following formula:

$$Volume\ of\ Floodback, ft3/h = \frac{\dot{q} \cdot 12{,}000}{h_{fg} \cdot dx} \cdot v \cdot 0.10 \cdot 0.25 \tag{8}$$

Where:
$\dot{q} = Total\ Evaporator\ Capacity, TR$
$h_{fg} = Latent\ Heat\ of\ Vaporization, Btu/lbm$
$dx = Change\ in\ Vapor\ Quality\ Through\ the\ Evaporator$
$v = Specific\ Volume\ (liquid), ft3/lbm$

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Example:
200 TR of ammonia evaporator capacity at -25 deg F suction temperature is connected to the suction accumulator. What is the expected average volume of liquid returning to the accumulator due to liquid floodback?
Answer:
Latent Heat of Vaporization, hfg = 550 Btu/lbm
Change in Vapor Quality through the Evaporator, dx = 0.8
Specific Volume (liquid), v = 0.024 ft3/lbm

$$Volume\ of\ Floodback = \frac{200 \cdot 12{,}000}{550 \cdot 0.8} \cdot 0.024 \cdot 0.10 \cdot 0.25 = 3.3 ft3/h = 0.4\ gal/min$$

iii. Defrost Condensate from Hot Gas Defrost

If there is any water present in the ammonia entering the evaporator during low temperature operation, it will be held and distilled in the pores of the proprietary wicking structure on the ID of the Colmac evaporator tubes. This local distillation process degrades the performance of the evaporator by reducing the local mean temperature difference (MTD). Hot gas defrost is critical to removing this "water-rich" liquid from the wicking structure. The ammonia hot gas coming from the high pressure receiver (see Figures A1 thru A4) is essentially water-free and oil-free ammonia. This pure ammonia vapor condenses on the tube ID, dilutes the "water-rich" liquid, and sends it to either the intercooler vessel or the low pressure suction accumulator where it can be distilled in the ammonia still and removed from the system.

This process of "flushing" the evaporators and the system of water during hot gas defrosting should only happen initially during the startup phase for systems which operate with a low suction pressure above one atmosphere (0 psig) and then only periodically for systems with a low suction pressure operating in a vacuum (blast freezing). In the accumulator the water-laden ammonia is captured in the water still, distilled, and removed from the system.

Defrost condensate from hot gas defrosting units is returned to the high pressure suction accumulator. This effectively captures any water in the ammonia in this vessel where it can be distilled and removed. Defrost condensate returning from hot gas defrosting units is utilized in the flooded plate heat exchanger piped to the high pressure suction accumulator to subcool the high pressure liquid. When there is insufficient condensate to keep the subcooler flooded, makeup liquid is added via a makeup line to maintain a liquid level in the accumulator sufficient to achieve the required amount of subcooling. Normally, the heat generated by subcooling equals or exceeds the amount of heat needed to vaporize all of the defrost condensate returning from hot gas defrosting evaporators. If the subcooling load is not high enough to vaporize all the defrost condensate, then the excess liquid must be removed by installing a liquid transfer system to return the liquid to the high pressure receiver. A liquid transfer line to the low pressure

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suction accumulator is shown in the P&ID, intended to allow excess liquid to be moved from the high pressure suction accumulator to the low pressure suction accumulator only in the event of an upset condition, power failure, restart, etc.

XIII. Effects of Oil on Evaporator Performance and Oil Separation

Immiscible lubricants are recommended over miscible lubricants for large industrial DX ammonia refrigeration systems for a number of reasons:

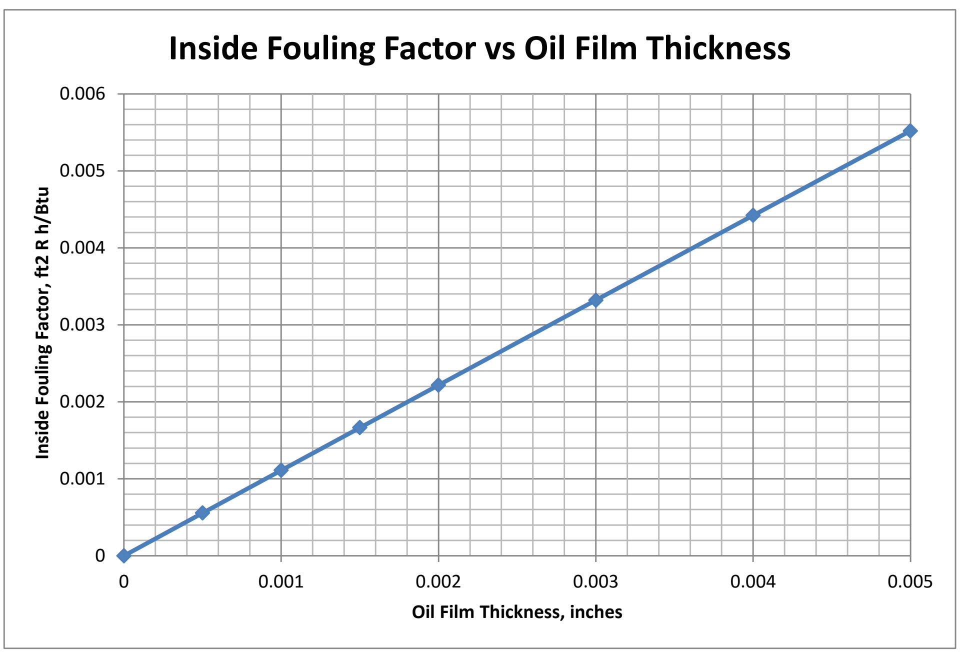
- Lower cost
- Ease of separation
- Relative insensitivity to contaminants (water, dirt)

Even though immiscible oils are preferred over miscible types for the reasons stated above, any oil reaching the evaporator can potentially coat the inside of the tubes and severely degrade heat transfer performance due to:

1. Added resistance to heat transfer as explained below and shown in Figure 17, and
2. Fouling of the proprietary wicking structure preventing liquid ammonia from coating the inside of the tubes by capillary action.

Even a thin layer of oil coating the inside of evaporator tubes adds resistance to heat flow as shown below.

FIGURE 17



In a typical DX ammonia evaporator, this fouling factor causes a significant reduction in cooling capacity as is shown below in Figure 18.

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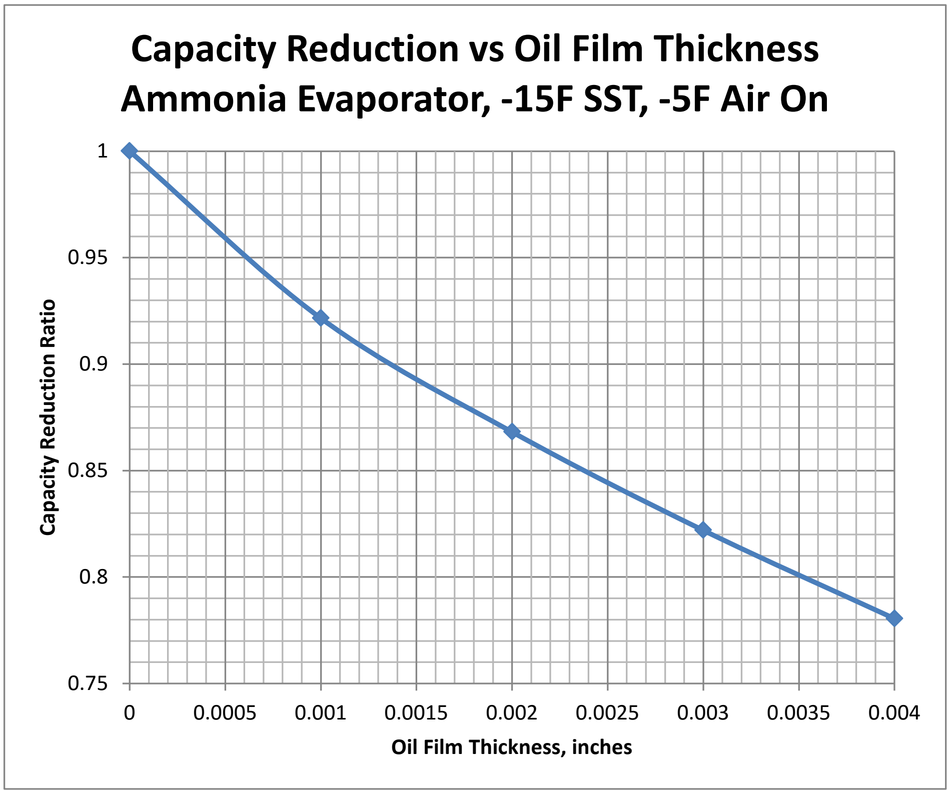
FIGURE 18



It is apparent from Figures 17 and 18 above that it is highly desirable from an energy efficiency standpoint to prevent compressor lubricating oil from reaching the evaporators. To achieve this, the following should be carefully considered and specified in the system design:

a. Type of compressor lubricating oil
b. Compressor oil separator design and efficiency
c. Oil capture and management at the outlet of the condenser
d. Oil capture in the suction accumulator(s)
e. Oil capture at the evaporator

Type of Oil:

Depending on the type of compressor used (reciprocating or rotary screw), varying amounts of lubricating oil will unavoidably be discharged with the ammonia vapor. Oil will leave the compressor both in liquid droplet form and as oil vapor. The liquid droplets can be captured mechanically in the oil separator vessel by controlling velocity and by incorporating coalescing elements. The oil which is combined with the ammonia in vapor form is more difficult to capture. Generally speaking, as volatility and solubility of the oil increase, separation becomes more difficult. The amount of oil which is not captured in the separator and returned to the compressor is referred to as “oil carryover”.

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All lubricating oils used in the ammonia refrigeration industry are blends of a base fluid(s) with additives (Wierbosch 2010). The base fluid controls volatility and solubility of the oil. Today, commonly used base fluids include:

- Naphthenic
- Solvent Refined Paraffinic
- Alkyl Benzene
- 2-Stage Hydrocracked
- PAO/AB

The aromatic content of the base fluid has a large effect on vapor pressure (volatility) and solubility. The higher the vapor pressure of the oil, the more oil vapor will leave the compressor with the ammonia in the discharge gas (Briley 1984). Since this oil vapor is difficult to capture in the separator, it is desirable to select an oil which has the lowest vapor pressure possible. Alkyl Benzene and Naphthenic bases have the highest aromatic content, vapor pressure, and solubility. 2-Stage Hydrocracked bases have lowest aromatic content, vapor pressure, and the lowest solubility.

It is therefore recommended that ammonia refrigeration oil having a 2-Stage Hydrocracked base fluid be used in the DX ammonia compression system design. 2-Stage Hydrocracked mineral oil manufactured by CPI ("CPI-1009-68") is recommended for application in reciprocating and screw type ammonia compressors for temperatures above -40.

Another factor affecting oil vapor pressure is the oil temperature. The higher the oil temperature, the higher the vapor pressure. Reducing the discharge gas (and oil vapor) temperature before it enters the separator will therefore reduce overall oil carryover and increase the efficiency of the separator. For example, desuperheating the discharge gas from 80 deg C to 35 deg C reduces the oil vapor pressure, and therefore carryover of oil vapor, by approximately 85% (Wiencke 2012).

Oil Separator:

For successful DX ammonia system operation, an oil separator with coalescing elements capable of guaranteeing 5-7 ppm carryover should be specified and installed.

For reasons mentioned above, it is also recommended that the discharge gas be desuperheated as much as practical prior to entering the oil separator.

NOTE: "Mesh Pad" oil separators as found on older screw compressor packages and reciprocating compressors will not have the required separation efficiency and are not recommended!

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Oil capture and management at the outlet of the condenser:

As mentioned above, reducing the temperature of the discharge gas down to the saturated condensing temperature (i.e. fully desuperheating) significantly reduces the vapor pressure of the oil in the discharge gas. This reduction of the oil vapor pressure increases the amount of oil available for capture.

Consequently, most of the oil vapor which has escaped the oil separator vessel will be condensed and held in the liquid ammonia leaving the condenser. It is possible to design the high pressure receiver to collect and separate this oil, now in the liquid phase, and then automatically return it to the compressors. It is also desirable to take the "de-oiled" ammonia vapor from the top of the high pressure receiver rather than using oil-laden discharge gas for hot gas defrost. These features are shown in Figures A1 thru A3 in the appendix.

Oil capture in the suction accumulator(s):

Properly designed suction accumulators should include accompanying oil pots to collect and remove any small amount of oil that has made it as far as the evaporators. See Figures A1 thru A3 in the appendix.

Oil Capture at the Evaporator:

As explained above, it is important to prevent fouling of evaporator tubes with oil particularly at low temperatures. To this end, Colmac has developed a proprietary DX ammonia distributor which effectively separates any oil which has escaped the oil separator and high pressure receiver and prevents it from entering the evaporator. The Colmac Tank Distributor (patented) incorporates a drop leg into the body of the distributor tank which serves to collect oil and debris where it can be periodically drained and removed from the system at the evaporator.

Figure 19 below shows a cross section of the Colmac Tank Distributor with its integral drop leg feature for capturing and removing oil.

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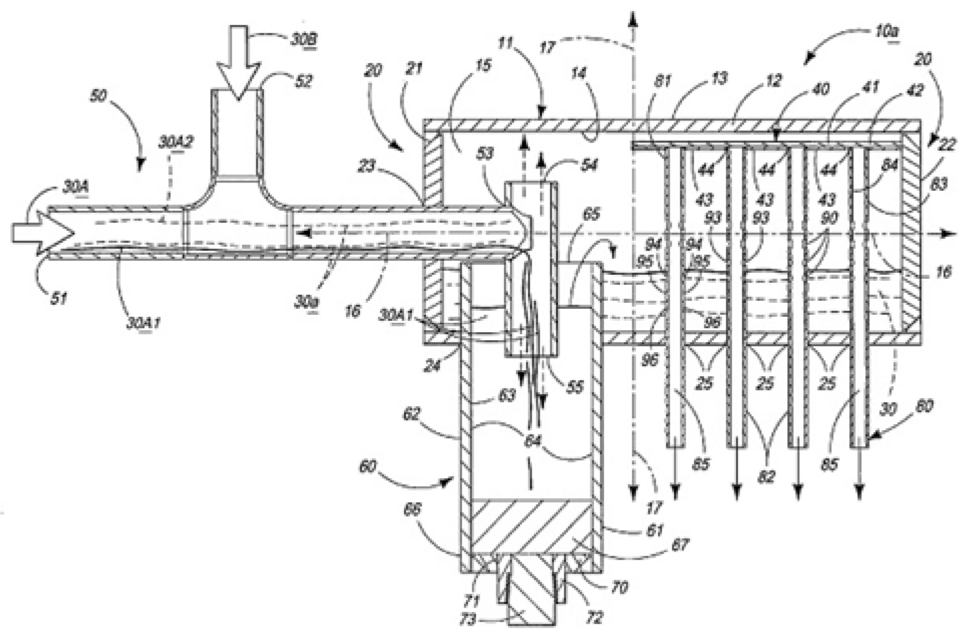
FIGURE 19
COLMAC TANK DISTRIBUTOR (CROSS SECTION)



Unlike conventional orifice plate type distributors, the Colmac Tank Distributor operates with very low pressure drop and is well suited to the following applications:

- DX ammonia utilizing motorized expansion valves
- Floating head pressure systems
- Evaporators designed for operation with more than one refrigerant

XIV. Estimating DX Evaporator Refrigerant Charge Inventory

In order to properly size the volume of the system vessels (high pressure receiver and low pressure accumulator), an estimate of the refrigerant charge held in the evaporators must be made. Designers normally calculate the evaporator charge as a percentage of the evaporator internal volume times the liquid density of ammonia.

One of the main advantages of DX operation is the significantly reduced evaporator ammonia charge compared to pumped ammonia. Many system designers estimate evaporator charge for bottom feed pumped ammonia evaporators to be as much as 80% of the internal volume times the liquid density to account for low load and idle conditions. DX ammonia evaporator charge can be estimated using two phase void fraction equations. Table 11 below shows DX ammonia evaporator charge as a percentage of internal volume.

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TABLE 11
COLMAC DX AMMONIA CHARGE INVENTORY

Suction Pressure, psia (Saturation Temp, F)	Colmac DX Ammonia Evaporator Charge Inventory, lbs/ft3 of Internal Volume
48.2 (+20 F)	1.01
30.4 (0 F)	0.83
18.3 (-20 F)	0.63
10.4 (-40 F)	0.52

This significantly reduced system charge not only reduces the required size of the receiver (and/or other system vessels), it also greatly reduces pump out time for the evaporators prior to defrosting. This serves to shorten total defrost time and increase the effectiveness of hot gas defrosting, reducing energy consumption and operating costs.

EXAMPLE:
A Colmac DX ammonia evaporator operating at a suction temperature of -20 deg F has an internal volume of 12 ft3. What is the expected DX ammonia operating charge? What would the operating charge be for pumped ammonia operation using the "80%" rule?

Answer:
Colmac DX ammonia charge = 12 ft3 x 0.63 = 7.6 lbs
Pumped ammonia charge = 12 ft3 x 0.8 x 42.2 lbs/ft3 = 405 lbs

XV. Optimizing Hot Gas Defrost

The energy efficiency of hot gas defrosting evaporators depends on the following (Nelson 2011(1)):

1. Minimizing convective heat loss.
    - Use lowest practical defrost regulator setting. 75 to 90 psig (50 to 60F) should be adequate. Note: If higher pressures are needed, look for problems elsewhere.
2. Shorten defrost duration.
    - Use top feed or DX (direct expansion) evaporator feed to reduce time required for pump out.
    - Open the hot gas solenoid only long enough to clear coil (6-8 minutes).
    - Install a separate hot gas solenoid and defrost regulator for pre and post-heating of the pan loop. Alternately, install electric resistance drainpan heating.
3. Reduce the number of defrosts per day.
    - Reduce the number of defrosts per day to match the frost load.
    - Choose evaporators with wide fin spacing (3 fpi instead of 4 fpi) to maximize frost carrying capacity.

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- Mitigate infiltration of humid air into the refrigerated space by:
    - Proper design and operation of doorways, and
    - Keep loading docks at the lowest practical dewpoint temperature.

Calculating the Cost of Defrost

As mentioned above defrost efficiency can be significantly improved by reducing the amount of energy lost to the room by convection during defrost. The operating cost savings due to a reduction in defrost duration has been calculated and presented below based on:

1. Reducing defrost duration from 30 minutes to 10 minutes, and
2. Increasing frost thickness from 1mm to 2mm (reducing the number of defrosts per day by half).

The calculations assume:

- Evaporator capacity: 100 TR
- Compressor runtime: 16 h/day
- Cost of Electricity: $0.10/kWh

Table 12 shows calculated cost savings for four different room temperatures.

TABLE 12
CALCULATED COST SAVINGS ($/y/100 TR) FOR OPTIMIZED VS CONVENTIONAL DEFROST

	Room Temp, C (F)			
	0 (+32)	-18 (0)	-23 (-10)	-34 (-30)
SHR	0.66	0.89	0.93	0.97
System COP:	3.2	2.5	2.2	2
Frost Removed, kg/day:	2,778	899	572	245
Frost Removed, kg/y:	1,014,096	328,090	208,784	89,479
I. Baseline (30 min, 1 mm)				
Defrost Efficiency, %	32%	18%	17%	14%
Defrost Convective Losses, %:	46%	61%	63%	65%
Defrost Convective Losses, kWh/y:	1,012,438	753,334	545,922	283,071
Baseline Cost of Defrost (Convective), $/y:	**$31,639**	**$30,133**	**$24,815**	**$14,154**
II. Optimized (10 min, 2 mm)				
Defrost Efficiency, %	61%	46%	43%	40%
Defrost Convective Losses, %:	15%	26%	27%	30%
Defrost Convective Losses, kWh/y:	168,740	125,556	90,987	47,178
Optimized Cost of Defrost (Convective), $/y:	**$5,273**	**$5,022**	**$4,136**	**$2,359**
Savings Optimized vs Baseline, $/y:	**$26,366**	**$25,111**	**$20,679**	**$11,795**

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Conventional ammonia evaporators are typically arranged for bottom feed with the hot gas pan loop piped in series with the coil. The highest possible defrost efficiency and lowest operating cost can be achieved by utilizing top feed DX circuiting with the hot gas pan loop piped separately from the coil. This results in:

- Shorter pump out period
- Defrost duration (time coil hot gas solenoid is open) of only 6-8 minutes

With a conventional bottom feed and hot gas defrost piping arrangement, hot gas is first sent through the drainpan loop and then in series through the coil block. This commonly used arrangement is effective and simple, however, it requires that the hot gas solenoid remains open to keep the drainpan heated long enough for all water to completely drain and exit through the drain piping. Convective heat loss to the room continues after the coil is clear of frost while the pan is draining.

A more efficient arrangement is to control hot gas to the coil block and to the drainpan loop separately through two separately timed hot gas solenoid valves. This arrangement shortens the amount of time hot gas is flowing through the coil block, minimizing the convective heat loss and maximizing defrost efficiency.

Diversity and Defrost Timing

As with all hot gas defrost systems, the “two to one” rule must be observed in the execution of defrosts. That is, a minimum of two evaporators in the same temperature zone must be running (liquid line solenoids open) at the same time one evaporator is defrosting. This strategy is needed to provide enough load to balance evaporating to condensing (defrosting) capacity in the refrigeration system.

XVI. Defrost Water Volume and Drain Line Sizing

Following is a simple method to calculate the amount of moisture removed by the air coolers from air in the refrigerated spaces in order to determine:

A) Total sewerage requirements for the facility, and
B) Proper drain piping sizes to handle peak flowrates during defrost.

This section will present two simple calculation methods for determining these important design parameters (Nelson 2008).

Determining Total Volume of Moisture Removed:

In order to estimate the volume of water generated from defrosting (or wet fin) air coolers, the hours per day the cooler(s) operate along with the Sensible Heat Ratio (SHR) must be known. Assuming a room relative humidity of 90%, the SHR for an air cooler operating at various temperatures will be as shown in Table 13 below.

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TABLE 13
SHR FOR 90%RH AIR AT VARIOUS TEMPERATURES

Room Temp, F	Air SHR
45	0.59
32	0.70
10	0.85
-10	0.93
-30	0.98

The amount of moisture accumulated on the surfaces of the air cooler(s) that will be drained as condensed water in high temp rooms or as melted frost in medium and low temp rooms, can be estimated using the following formula:

$$Gal/day = 1.35t(1 - SHR)Q \tag{9}$$

where:
t = Operating Time, hours/day
SHR = Air Sensible Heat Ratio
Q = System Cooling Capacity, tons (note: 1 ton = 12,000 Btuh)
1.35 (constant) = 12,000 Btuh/ton / (8.33 lbs/gal x 1,068 Btu/lbs)
8.33 lbs/gal = liquid density of water
1,068 Btu/lbs = latent heat of vaporization of water

Example 1:
Room Temp: 45F
Operating Time: 12 hours/day
Room SHR (from Table 1): 0.59
System Cooling Capacity: 50 tons
Condensed Water Volume = 1.35 x 12 x (1-.59) x 50 = 332 gal/day

Example 2:
Room Temp: -10F
Operating Time: 16 hours/day
Room SHR (from Table 1): 0.93
System Cooling Capacity: 100 tons
Defrost Water Volume = 1.35 x 16 x (1 - 0.93) x 100 = 151 gal/day

Determining Peak Defrost Water Flowrate

To determine the peak defrost water flowrate leaving a frosted coil surface, first calculate the volume of water yielded by a cooling coil during defrost using the following equation:

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$$V_{def} = 0.0937 \times A_{surf} \times \left[\frac{\left(\frac{1}{S_{fin}} - t_{fin} \right)}{2} \right] \times \varepsilon \qquad (10)$$

where:

$V_{def} =$ *Volume of Defrost Water, gallons*

$A_{surf} =$ *Total Frosted Surface Area, sq ft*

$S_{fin} =$ *Fin Spacing, fins per inch*

$t_{fin} =$ *Fin Thickness, inches*

$\varepsilon =$ *Fraction of Frost Blockage (50% = 1.5)*

Note: This equation assumes frost has average density of 150 kg/m3 (Besant 1999), approx. 1/6th that of liquid water.

Example 1:

Total Surface Area = 4,500 sq ft
Fin Spacing = 4 fins per inch
Fin Thickness = 0.012 inches
Fraction of Frost Blockage = 0.5
Volume of Defrost Water = 0.0937 x 4,500 x (1/4-0.012)/2 x 0.5 = 25 gallons

In order to then determine the peak flowrate, an estimate of the length of defrost time must be made. For hot gas defrosting, the majority of defrost water flows to the drain in a relatively short period of time. To estimate peak flow rate of defrost water an estimated duration of defrost of 5 minutes can reasonably be made (Stoecker 1983).

To calculate peak flowrate, simply divide the volume of defrost water by the estimated duration of defrost. For the example:

Estimated peak defrost flowrate = 25 gal/ 5 min = 5 gpm

Drain lines can now be sized based on the calculated peak defrost flowrate. The maximum peak flowrate for a facility will be the combined flowrates for the maximum number of cooling coils expected to defrost simultaneously.

Colmac provides to its representatives and selected customers a calculation tool for estimating defrost flow rate given operating temperatures and evaporator dimensional data.

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Sizing Sloping Drain Lines

The American Society of Plumbing Engineers (ASPE) publishes sizing methods for vertical and sloping drains (ASPE 1999). The following table is taken from the ASPE Data Book Volume 2, page 8.

TABLE 14
APPROXIMATE DISCHARGE RATES AND VELOCITIES IN SLOPING DRAINS, N = 0.015*

Actual Inside Diameter of Pipe, inches	½-Full Flow Discharge Rate and Velocity Based on ¼ inch/ft Slope	
	Discharge, gpm	Velocity, fps
1 3/8	3.13	1.34
1 ½	3.91	1.42
1 5/8	4.81	1.50
2	8.42	1.72
2 ½	15.3	1.99
3	24.8	2.25
4	53.4	2.73
5	96.6	3.16
6	157	3.57
8	340	4.34
10	616	5.04
12	999	5.67

* n = Manning coefficient, which varies with the roughness of the pipe.

Horizontal drain lines must be pitched at least ¼” per foot to ensure positive drainage.

Drain lines running through freezing spaces should be actively heated with heat trace cable and then well insulated.

Drain lines should also have p-traps installed just outside the refrigerated space to prevent back flow of warm humid ambient air through the drain line into the refrigerated space.

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XVIII. APPENDIX A

Four P&ID diagrams are shown representing:

Figure A1 – Single Stage Single (or Multiple) Temperatures
Figure A2 – Single Stage Multiple Temperatures
Figure A3 – Single Stage Low Temp < -20 deg F
Figure A4 – Single Stage Glycol Med Temp / DX Low Temp
Figure A5 - Two Stage (Screw Compressors) with Intercooling
Figure A6 - Two Stage (Recip Compressors) with Intercooling

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FIGURE A1
SINGLE STAGE SCREW COMPRESSOR(S) W/LIQUID INJECTION OIL COOLING
SINGLE (OR MULTIPLE) TEMPERATURE LEVELS
MAX NO. OF HG DEFROSTS PER DAY = 6

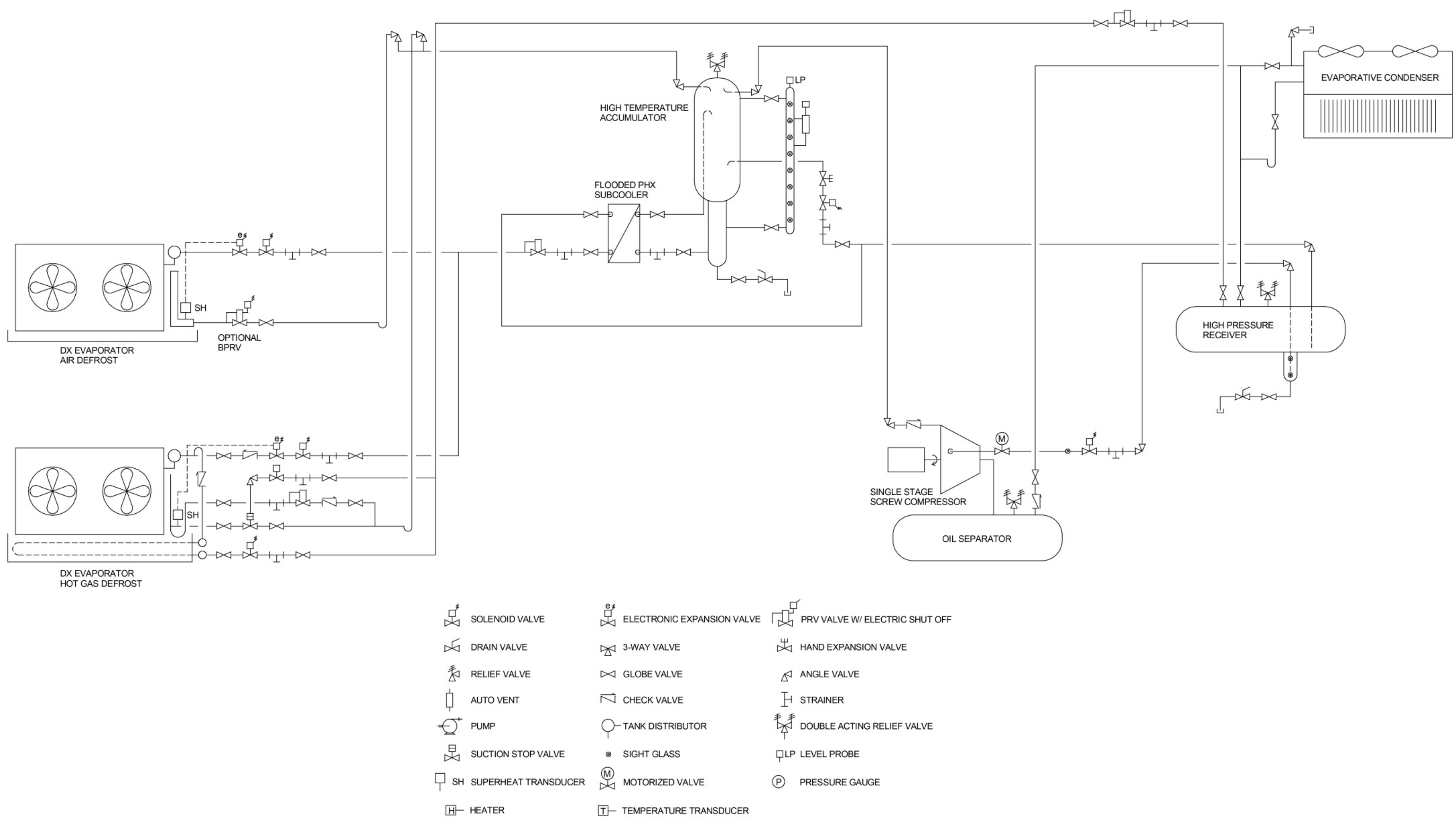

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FIGURE A2

SINGLE STAGE ECONOMIZED SCREW COMPRESSOR(S) W/LIQUID INJECTION OIL COOLING

MULTIPLE TEMPERATURE LEVELS (Te > - 20 F)

MAX NO. OF MED TEMP HG DEFROSTS PER DAY = 6

MAX NO. OF LOW TEMP HG DEFROSTS PER DAY = 2

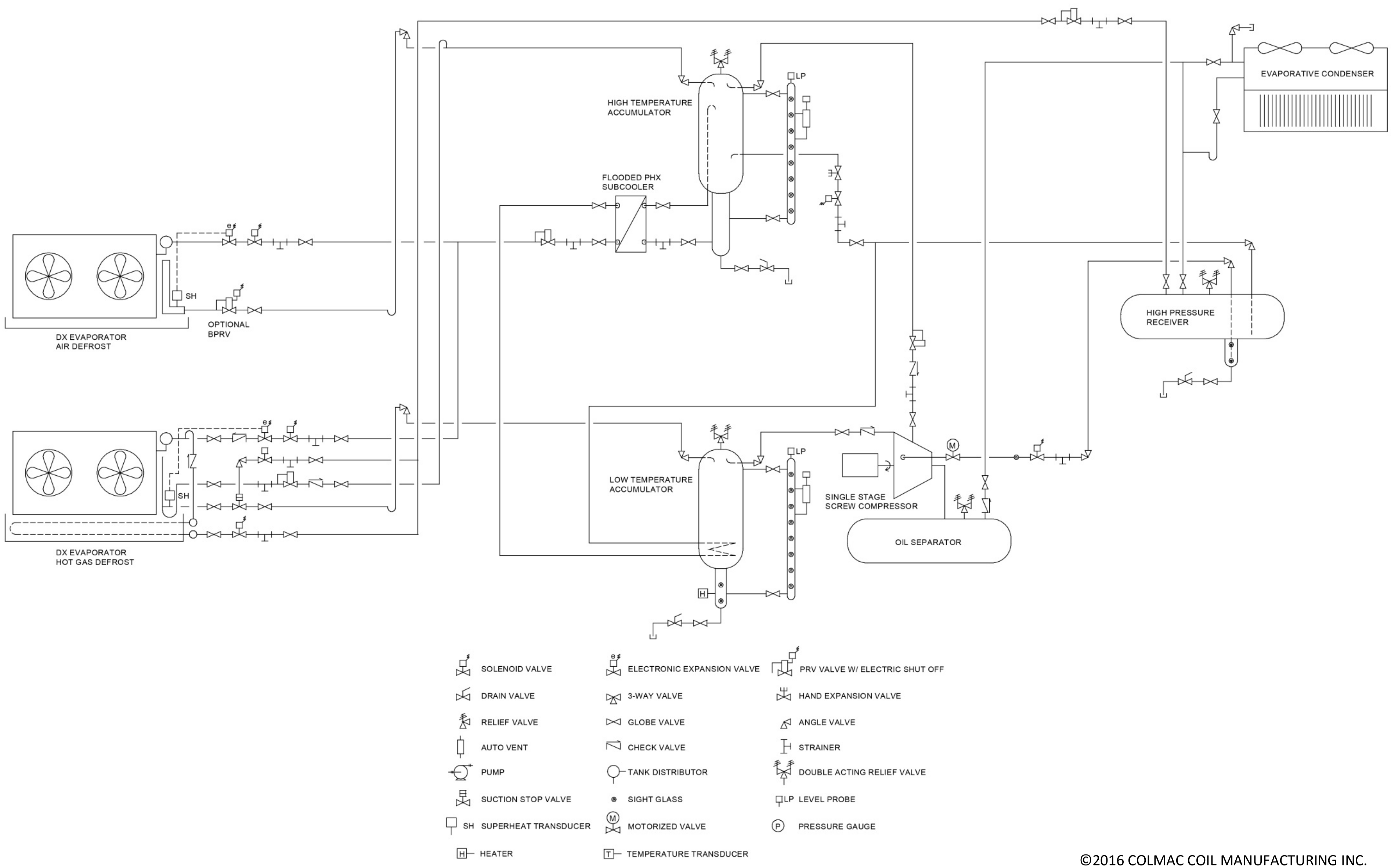

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FIGURE A3

SINGLE STAGE ECONOMIZED SCREW COMPRESSOR(S) W/LIQUID INJECTION OIL COOLING
MULTIPLE TEMPERATURE LEVELS

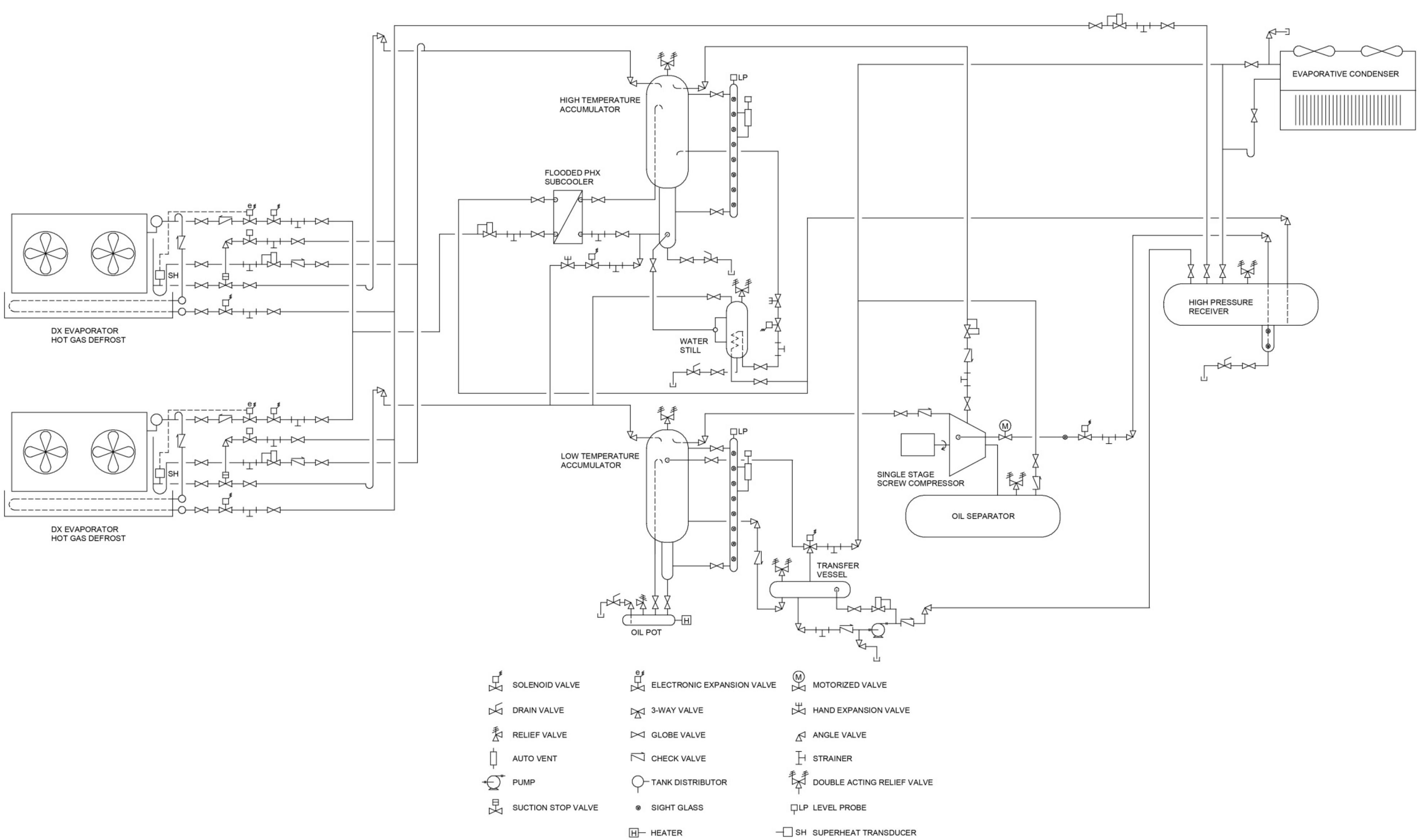

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FIGURE A4

SINGLE STAGE ECONOMIZED SCREW COMPRESSOR(S) W/GLYCOL OIL COOLING
WATER COOLED CONDENSING
GLYCOL MEDIUM TEMPERATURE/DX LOW TEMPERATURE

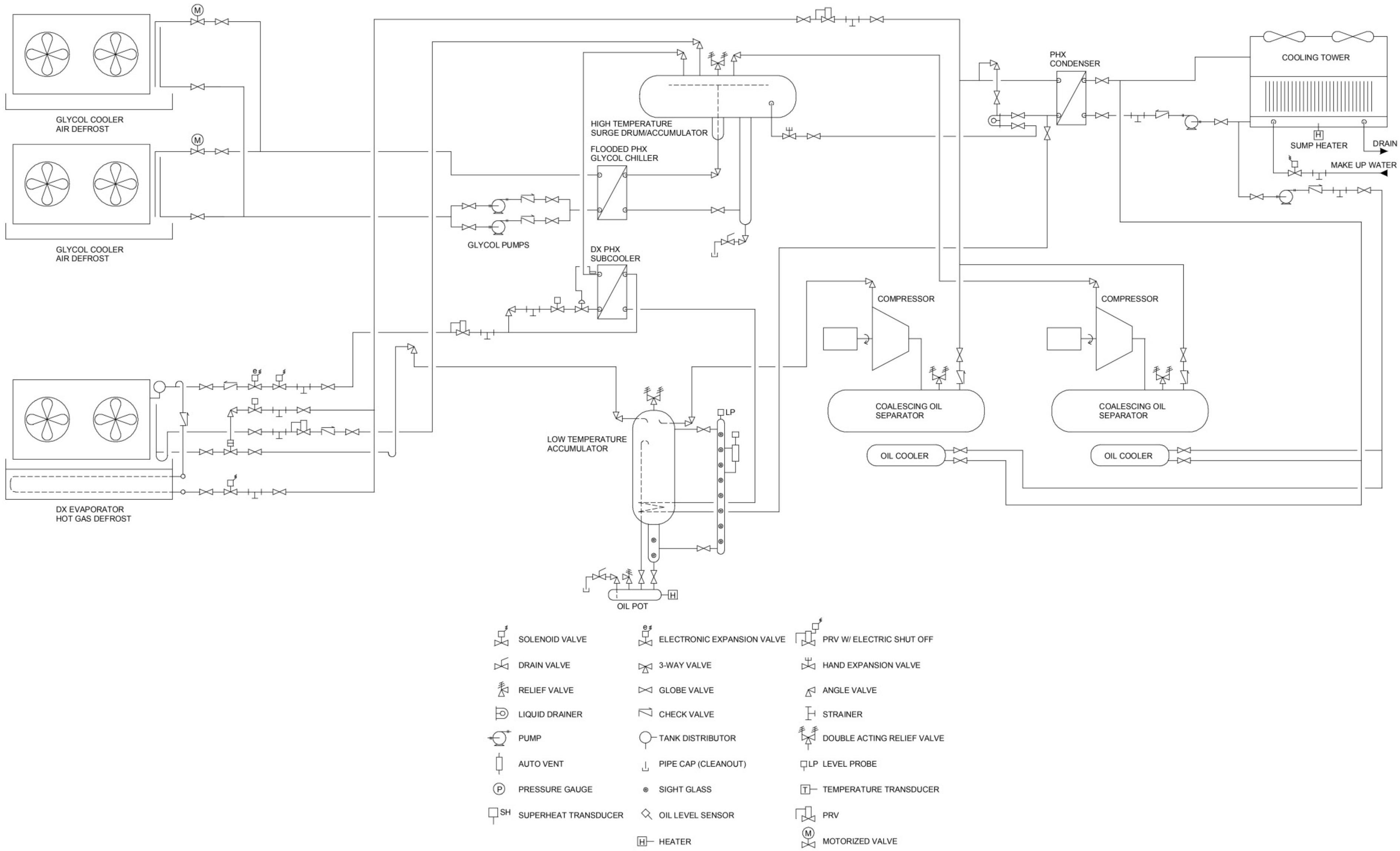

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FIGURE A5

TWO STAGE SCREW COMPRESSOR(S) W/GLYCOL OIL COOLING
HIGH TEMP ACCUMULATOR/FLASH INTERCOOLER
PILOT HP RECEIVER W/HIGH SIDE FLOAT VALVE

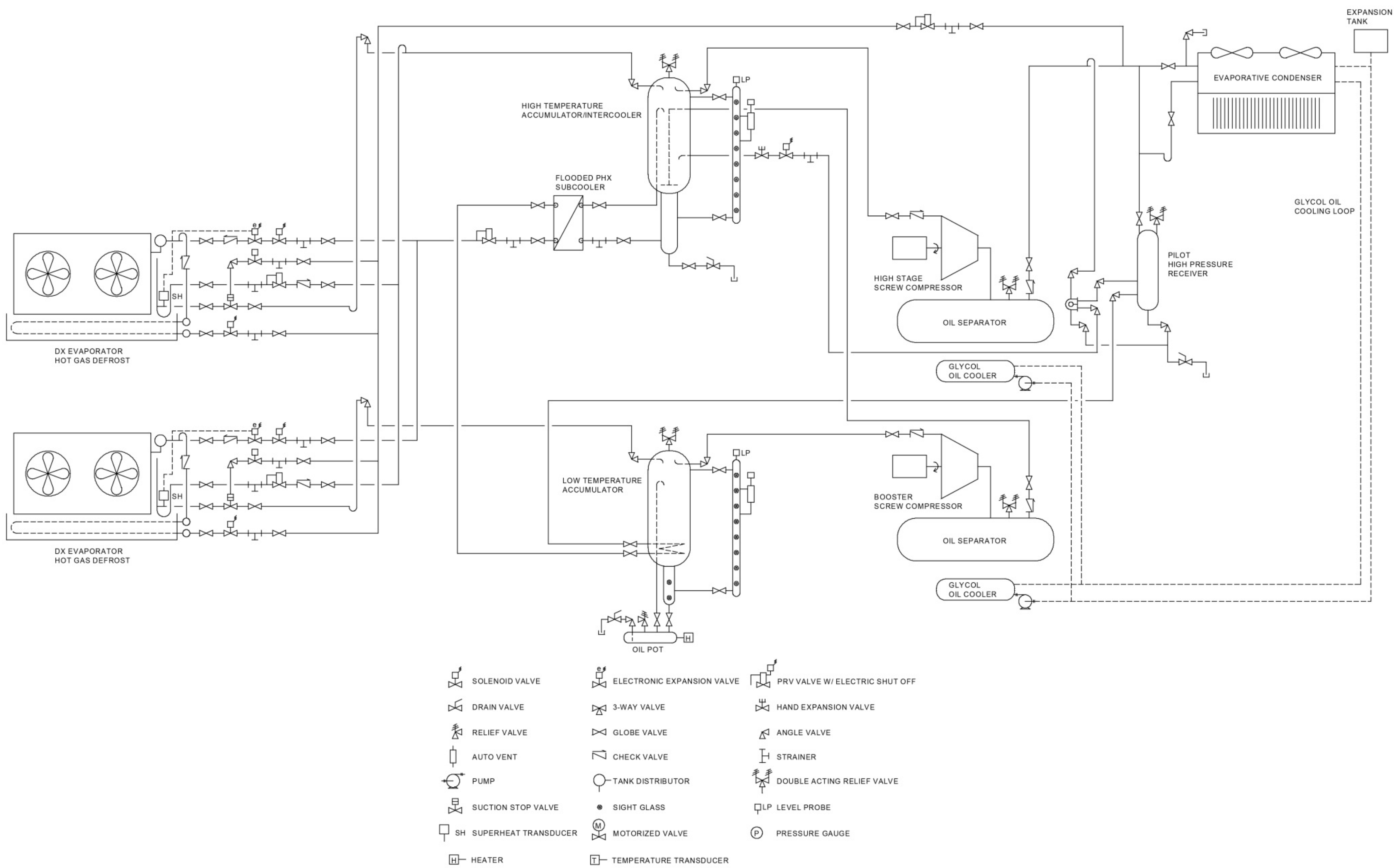

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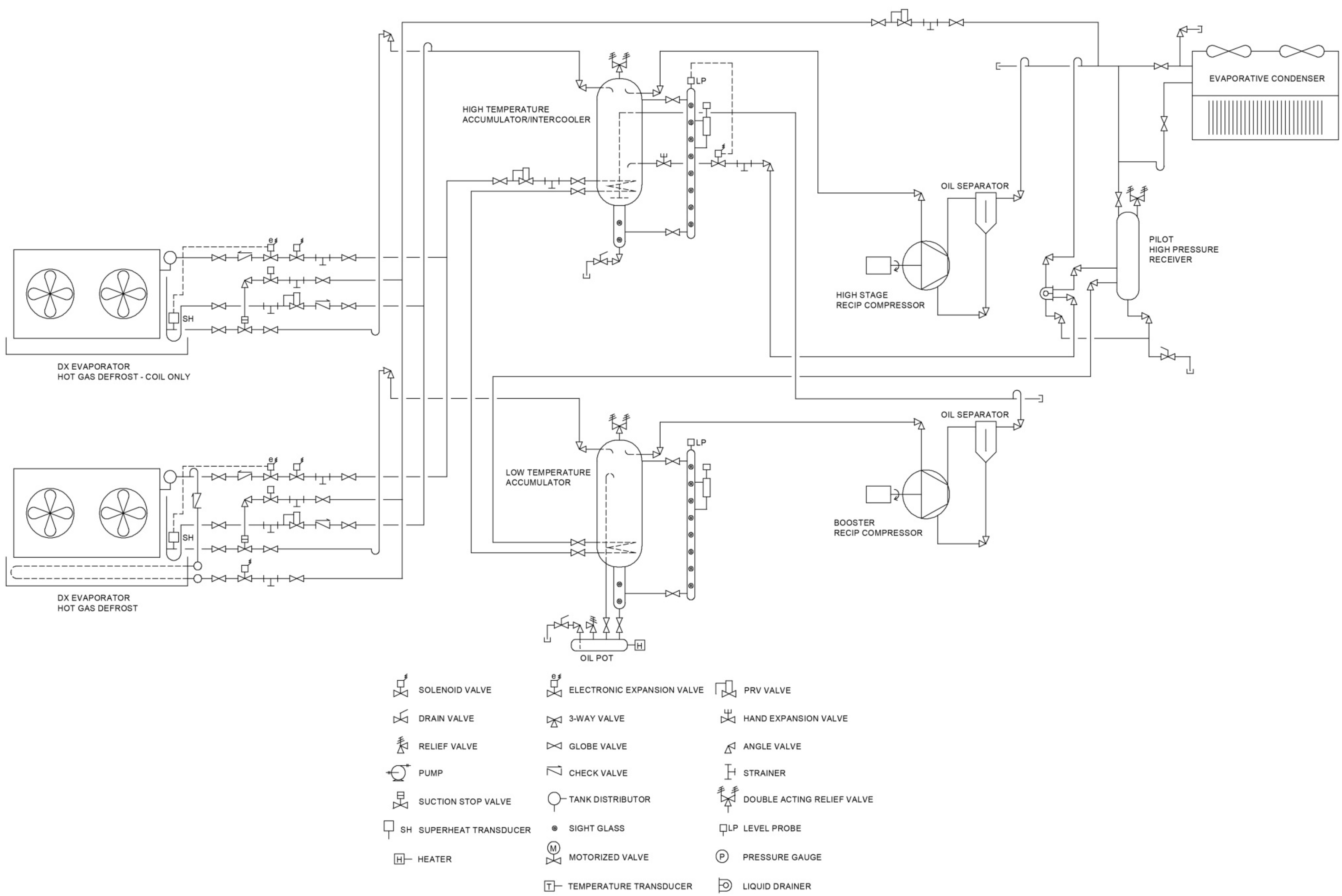
FIGURE A6

TWO STAGE W/RECIP COMPRESSORS
HIGH TEMP ACCUMULATOR/FLASH INTERCOOLER
PILOT HP RECEIVER W/HIGH SIDE FLOAT VALVE



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Hot Gas Defrost Piping Diagrams

ENG00019689 Rev A

Contents

1. INTRODUCTION

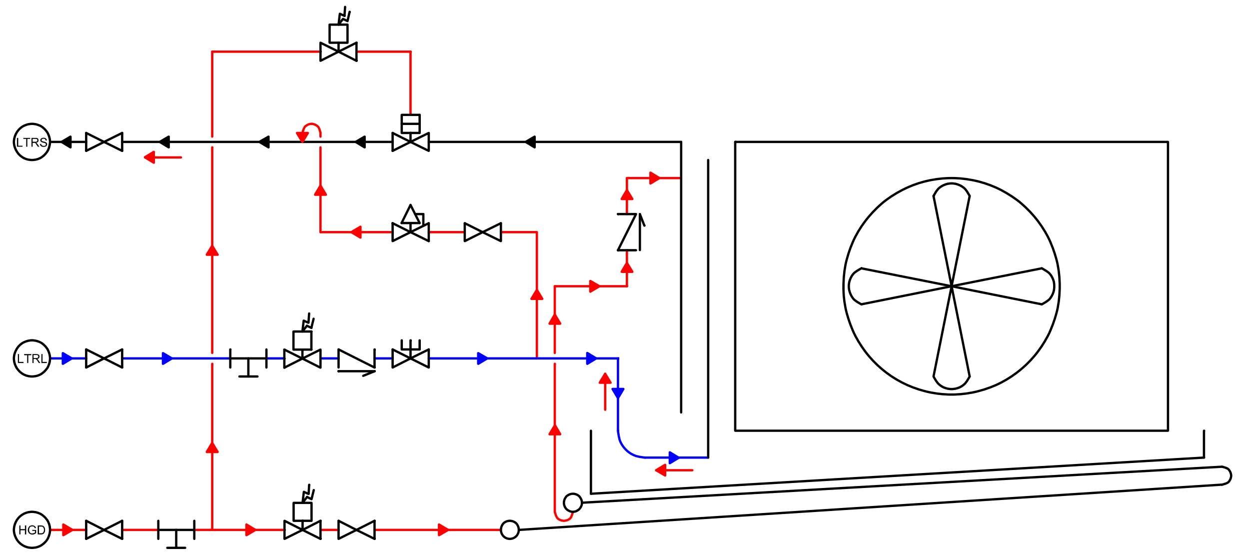
1.1. This document reviews standard hot gas defrost piping diagrams for recirculated, controlled pressure receiver (CPR), direct expansion and gravity flooded evaporator systems.

2. RECIRCULATED SYSTEMS

2.1. Figure 1: Bottom Feed, 3-Pipe, Vertical Headers

FIGURE 1

RECIRCULATED BOTTOM FEED
3-PIPE HOT GAS DEFROST
VERTICAL HEADERS
2-PASS PAN LOOP



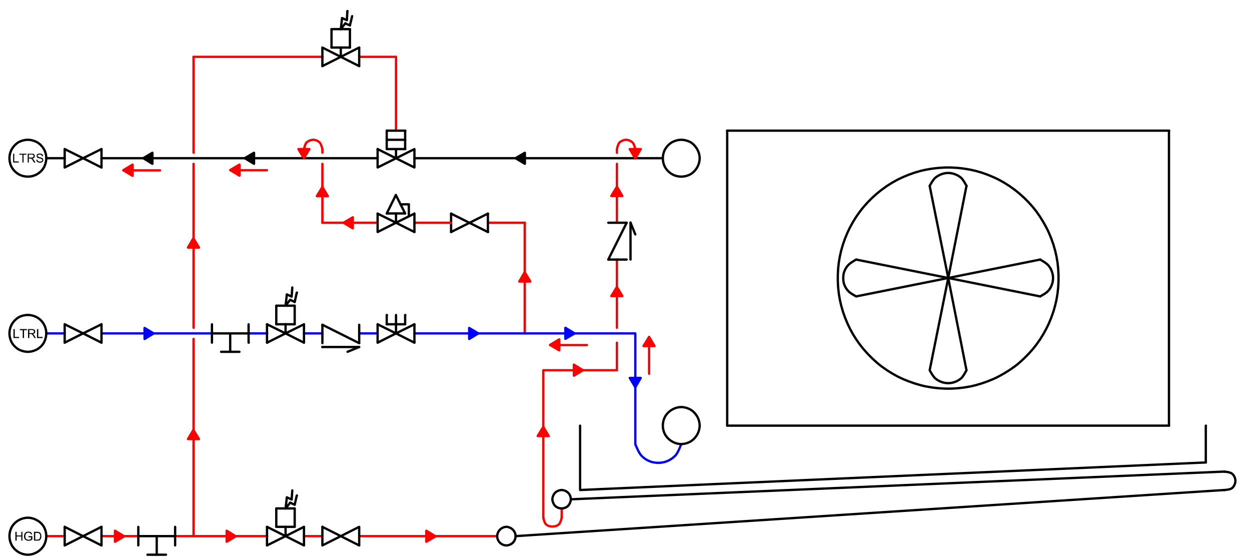
STRAINER	
CHECK VALVE	
GLOBE VALVE	
SOLENOID VALVE	
DEFROST PRESSURE REGULATOR	
GAS POWERED SUCTION STOP VALVE	
HAND EXPANSION VALVE	

HGD	HOT GAS DEFROST SUPPLY
LTRS	LOW-TEMP RECIRCULATED SUCTION
LTRL	LOW-TEMP RECIRCULATED LIQUID
(red arrow)	HOT GAS FLOW
(blue arrow)	SATURATED LIQUID FLOW
(black arrow)	SATURATED LIQUID & VAPOR FLOW

2.2. Figure 2: Bottom Feed, 3-Pipe, Horizontal Headers

FIGURE 2

RECIRCULATED BOTTOM FEED
3-PIPE HOT GAS DEFROST
HORIZONTAL HEADERS
2-PASS PAN LOOP

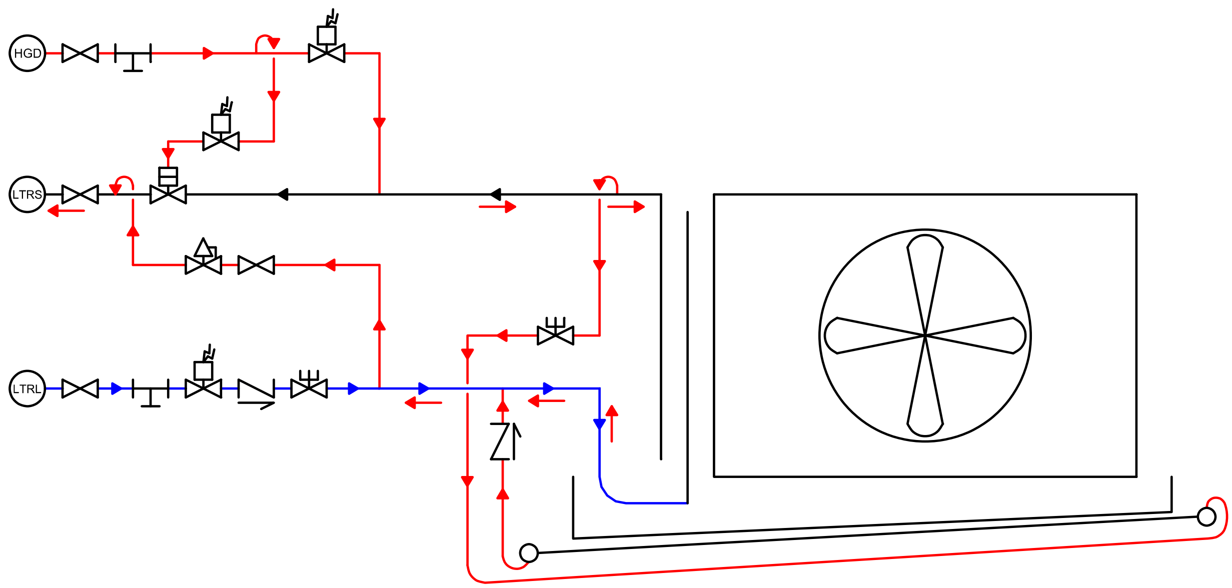


	STRAINER	HGD	HOT GAS DEFROST SUPPLY
	CHECK VALVE	LTRS	LOW-TEMP RECIRCULATED SUCTION
	GLOBE VALVE	LTRL	LOW-TEMP RECIRCULATED LIQUID
	SOLENOID VALVE	(red arrow)	HOT GAS FLOW
	DEFROST PRESSURE REGULATOR	(blue arrow)	SATURATED LIQUID FLOW
	GAS POWERED SUCTION STOP VALVE	(black arrow)	SATURATED LIQUID & VAPOR FLOW
	HAND EXPANSION VALVE		

2.3. Figure 3: Bottom Feed, 2-Pipe, Vertical Headers

FIGURE 3

RECIRCULATED BOTTOM FEED
2-PIPE HOT GAS DEFROST
VERTICAL HEADERS
1-PASS PAN LOOP

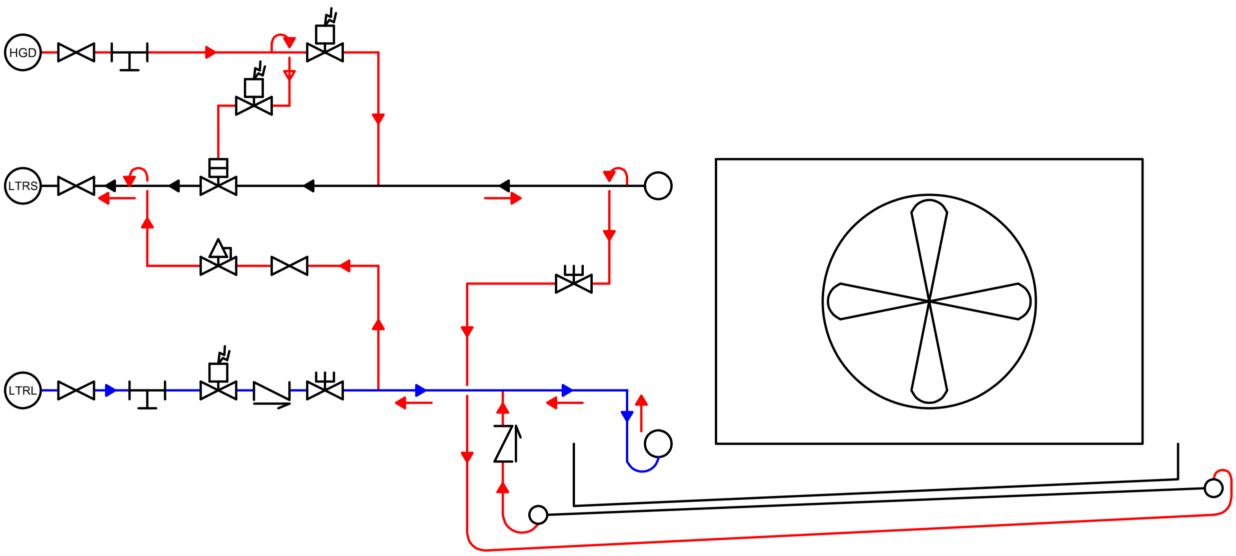


	STRAINER	HGD	HOT GAS DEFROST SUPPLY
	CHECK VALVE	LTRS	LOW-TEMP RECIRCULATED SUCTION
	GLOBE VALVE	LTRL	LOW-TEMP RECIRCULATED LIQUID
	SOLENOID VALVE	→	HOT GAS FLOW
	DEFROST PRESSURE REGULATOR	→	SATURATED LIQUID FLOW
	GAS POWERED SUCTION STOP VALVE	→	SATURATED LIQUID & VAPOR FLOW
	HAND EXPANSION VALVE		

2.4. Figure 4: Bottom Feed, 2-Pipe, Horizontal Headers

FIGURE 4

RECIRCULATED BOTTOM FEED
2-PIPE HOT GAS DEFROST
HORIZONTAL HEADERS
1-PASS PAN LOOP



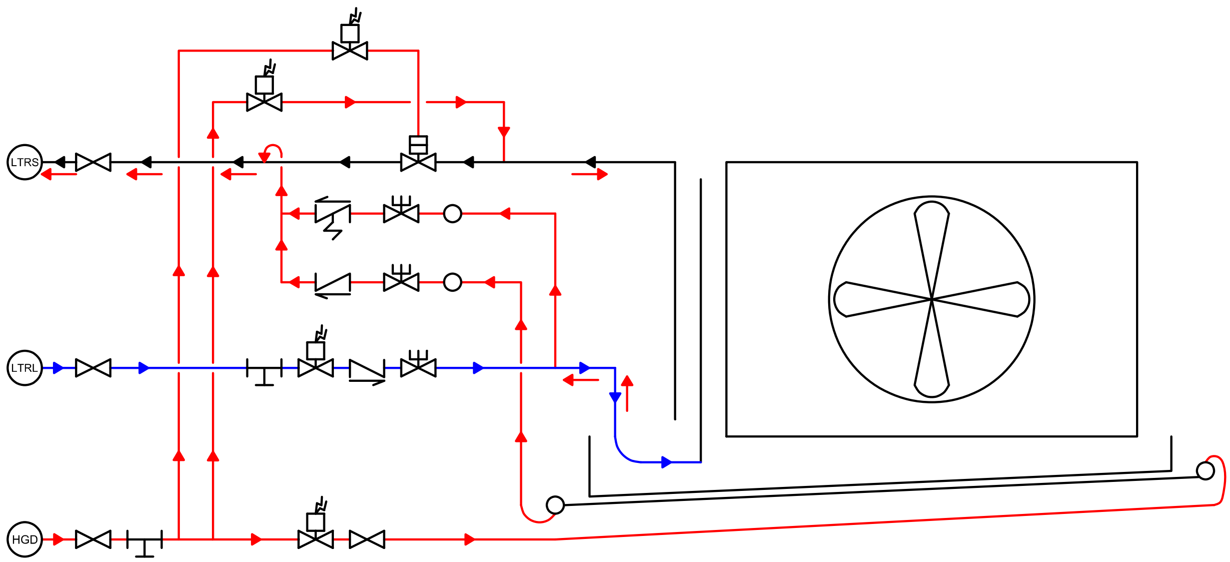
STRAINER		HGD	HOT GAS DEFROST SUPPLY
CHECK VALVE		LTRS	LOW-TEMP RECIRCULATED SUCTION
GLOBE VALVE		LTRL	LOW-TEMP RECIRCULATED LIQUID
SOLENOID VALVE			HOT GAS FLOW
DEFROST PRESSURE REGULATOR			SATURATED LIQUID FLOW
GAS POWERED SUCTION STOP VALVE			SATURATED LIQUID & VAPOR FLOW
HAND EXPANSION VALVE			

NOTE: LIQUID OVERFEED ORIFICES ARE REQUIRED!

2.5. Figure 5: Bottom Feed, 4-Pipe, Vertical Headers

FIGURE 5

RECIRCULATED BOTTOM FEED
4-PIPE HOT GAS DEFROST
VERTICAL HEADERS
1-PASS PAN LOOP

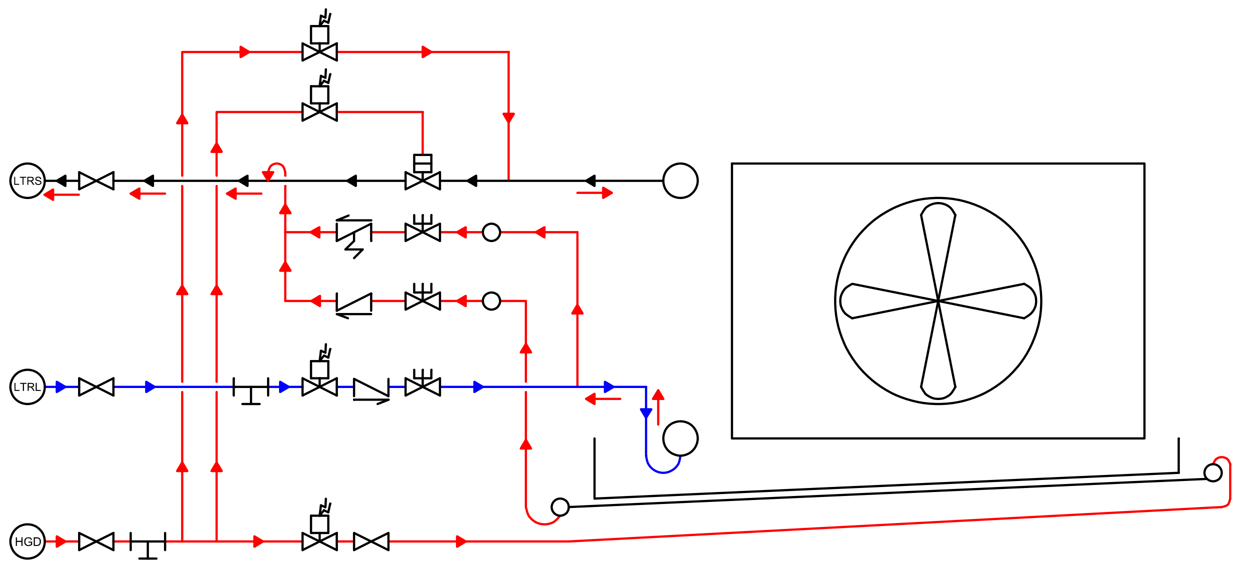


	STRAINER	HGD	HOT GAS DEFROST SUPPLY
	CHECK VALVE	LTRS	LOW-TEMP RECIRCULATED SUCTION
	GLOBE VALVE	LTRL	LOW-TEMP RECIRCULATED LIQUID
	SOLENOID VALVE		HOT GAS FLOW
	SPRING LOADED CHECK VALVE		SATURATED LIQUID FLOW
	GAS POWERED SUCTION STOP VALVE		SATURATED LIQUID & VAPOR FLOW
	HAND EXPANSION VALVE		
	SIGHT GLASS		

2.6. Figure 6: Bottom Feed, 4-Pipe, Horizontal Headers

FIGURE 6

RECIRCULATED BOTTOM FEED
4-PIPE HOT GAS DEFROST
HORIZONTAL HEADERS
1-PASS PAN LOOP

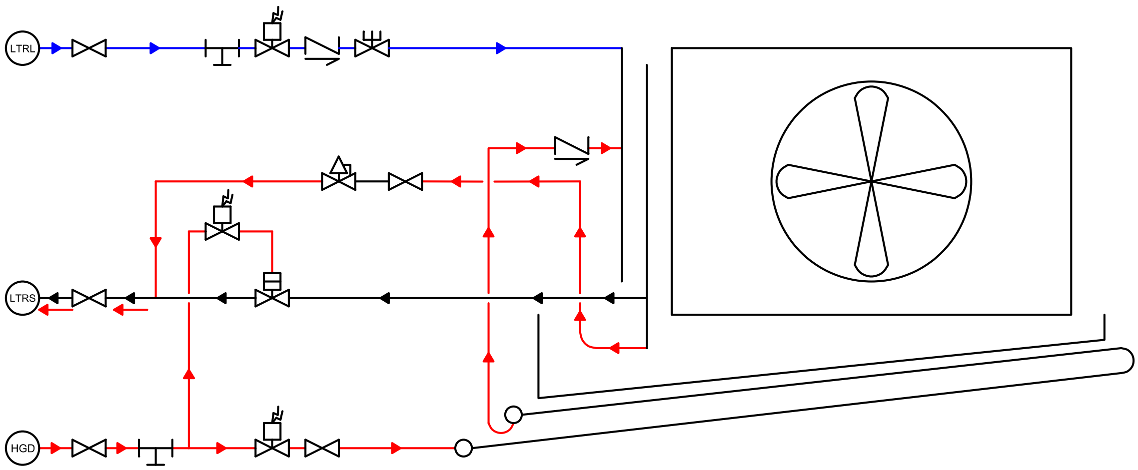


	STRAINER	HGD	HOT GAS DEFROST SUPPLY
	CHECK VALVE	LTRS	LOW-TEMP RECIRCULATED SUCTION
	GLOBE VALVE	LTRL	LOW-TEMP RECIRCULATED LIQUID
	SOLENOID VALVE	→ (red)	HOT GAS FLOW
	SPRING LOADED CHECK VALVE	→ (blue)	SATURATED LIQUID FLOW
	GAS POWERED SUCTION STOP VALVE	→ (black)	SATURATED LIQUID & VAPOR FLOW
	HAND EXPANSION VALVE		
	SIGHT GLASS		

2.7. Figure 7: Top Feed, 3-Pipe, Vertical Headers

FIGURE 7

RECIRCULATED TOP FEED
3-PIPE HOT GAS DEFROST
VERTICAL HEADERS
2-PASS PAN LOOP

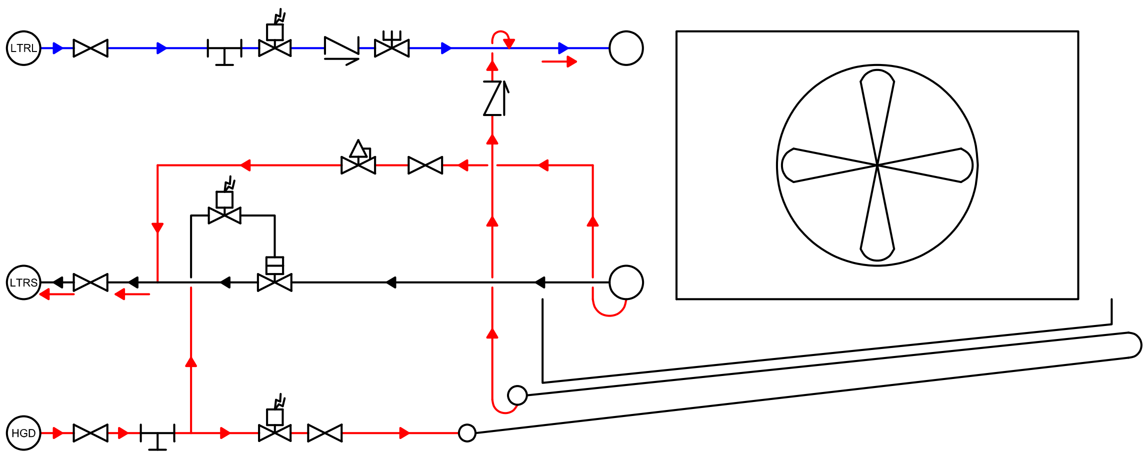


STRAINER	HGD HOT GAS DEFROST SUPPLY
CHECK VALVE	LTRS LOW-TEMP RECIRCULATED SUCTION
GLOBE VALVE	LTRL LOW-TEMP RECIRCULATED LIQUID
SOLENOID VALVE	HOT GAS FLOW
DEFROST PRESSURE REGULATOR	SATURATED LIQUID FLOW
GAS POWERED SUCTION STOP VALVE	SATURATED LIQUID & VAPOR FLOW
HAND EXPANSION VALVE	

2.8. Figure 8: Top Feed, 3-Pipe, Horizontal Headers

FIGURE 8

RECIRCULATED TOP FEED
3-PIPE HOT GAS DEFROST
HORIZONTAL HEADERS
2-PASS PAN LOOP

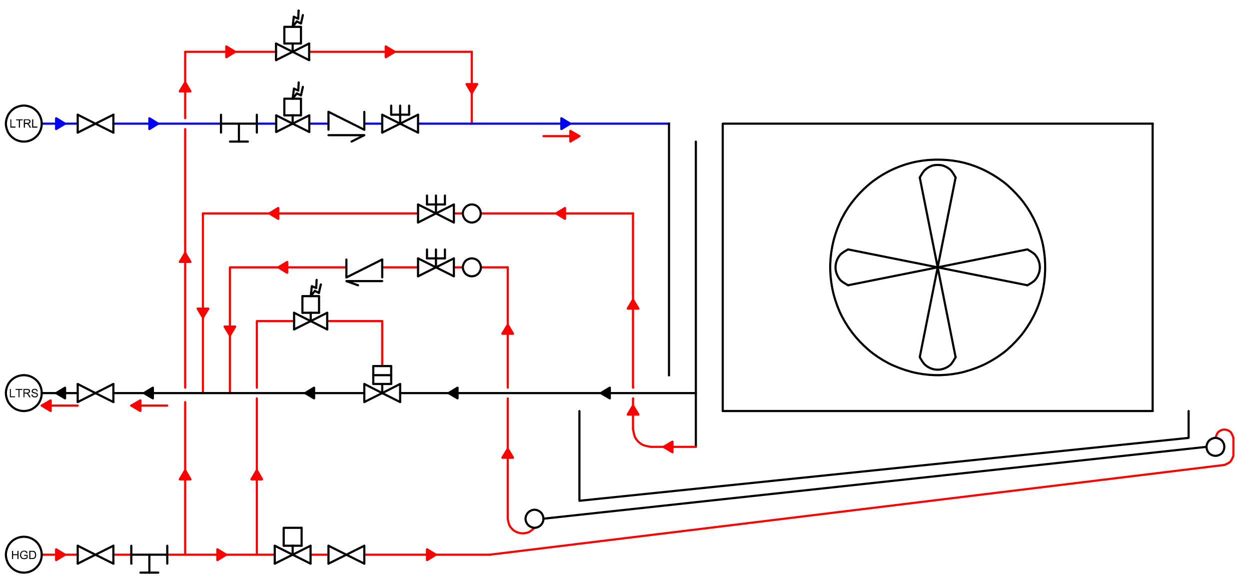


	STRAINER	HGD	HOT GAS DEFROST SUPPLY
	CHECK VALVE	LTRS	LOW-TEMP RECIRCULATED SUCTION
	GLOBE VALVE	LTRL	LOW-TEMP RECIRCULATED LIQUID
	SOLENOID VALVE	(red arrow)	HOT GAS FLOW
	DEFROST PRESSURE REGULATOR	(blue arrow)	SATURATED LIQUID FLOW
	GAS POWERED SUCTION STOP VALVE	(black arrow)	SATURATED LIQUID & VAPOR FLOW
	HAND EXPANSION VALVE		

2.9. Figure 9: Top Feed, 4-Pipe, Vertical Headers

FIGURE 9

RECIRCULATED TOP FEED
4-PIPE HOT GAS DEFROST
VERTICAL HEADERS
1-PASS PAN LOOP

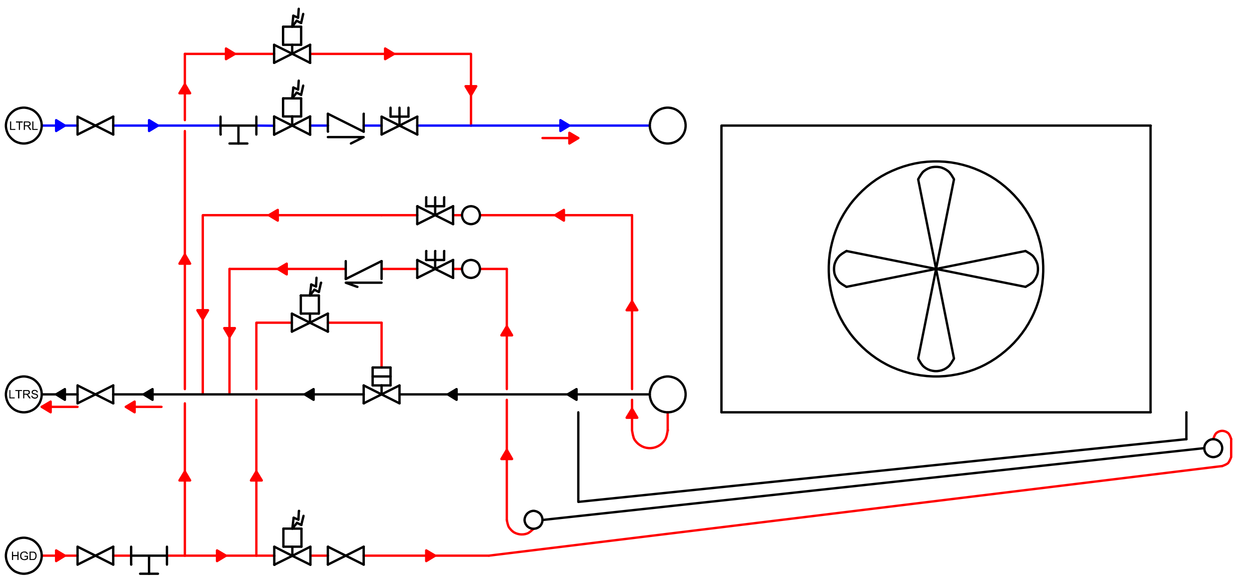


	STRAINER	HGD	HOT GAS DEFROST SUPPLY
	CHECK VALVE	LTRS	LOW-TEMP RECIRCULATED SUCTION
	GLOBE VALVE	LTRL	LOW-TEMP RECIRCULATED LIQUID
	SOLENOID VALVE		HOT GAS FLOW
	GAS POWERED SUCTION STOP VALVE		SATURATED LIQUID FLOW
	HAND EXPANSION VALVE		SATURATED LIQUID & VAPOR FLOW
	SIGHT GLASS		

2.10. Figure 10: Top Feed, 4-Pipe, Horizontal Headers

FIGURE 10

RECIRCULATED TOP FEED
4-PIPE HOT GAS DEFROST
HORIZONTAL HEADERS
1-PASS PAN LOOP



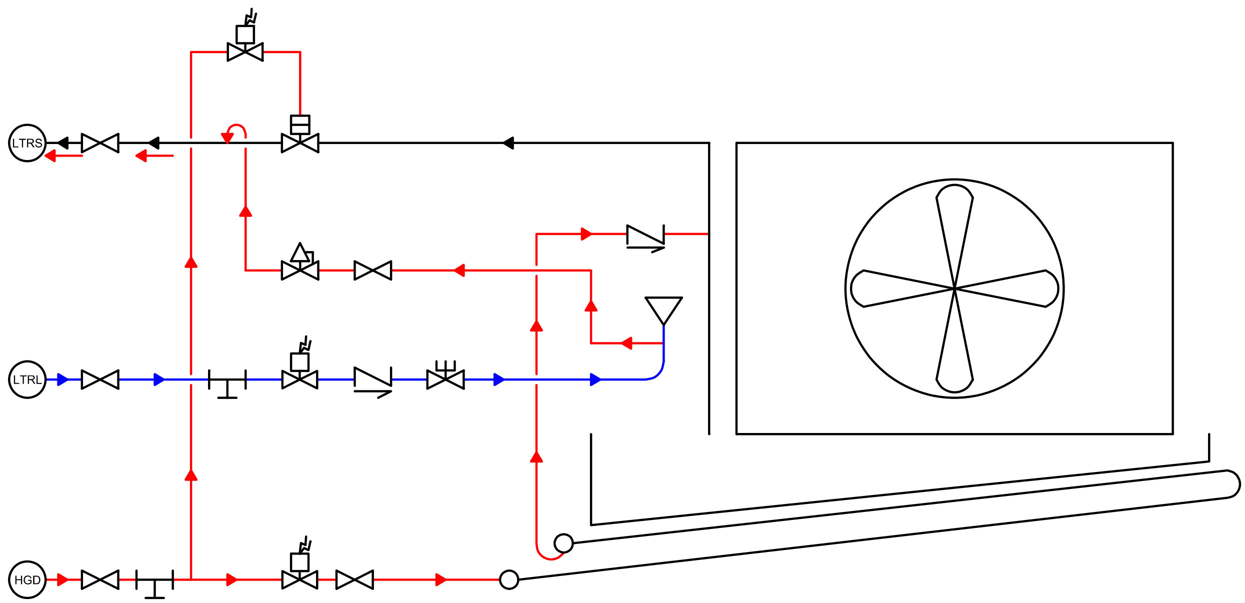
STRAINER	HGD — HOT GAS DEFROST SUPPLY
CHECK VALVE	LTRS — LOW-TEMP RECIRCULATED SUCTION
GLOBE VALVE	LTRL — LOW-TEMP RECIRCULATED LIQUID
SOLENOID VALVE	HOT GAS FLOW
GAS POWERED SUCTION STOP VALVE	SATURATED LIQUID FLOW
HAND EXPANSION VALVE	SATURATED LIQUID & VAPOR FLOW
SIGHT GLASS	

3. CONTROLLED PRESSURE RECEIVER (CPR)

3.1. Figure 11: Bottom Feed, 3-Pipe, Vertical Headers

FIGURE 11

CONTROLLED PRESSURE RECEIVER (CPR) BOTTOM FEED
3-PIPE HOT GAS DEFROST
VERTICAL HEADERS
2-PASS PAN LOOP

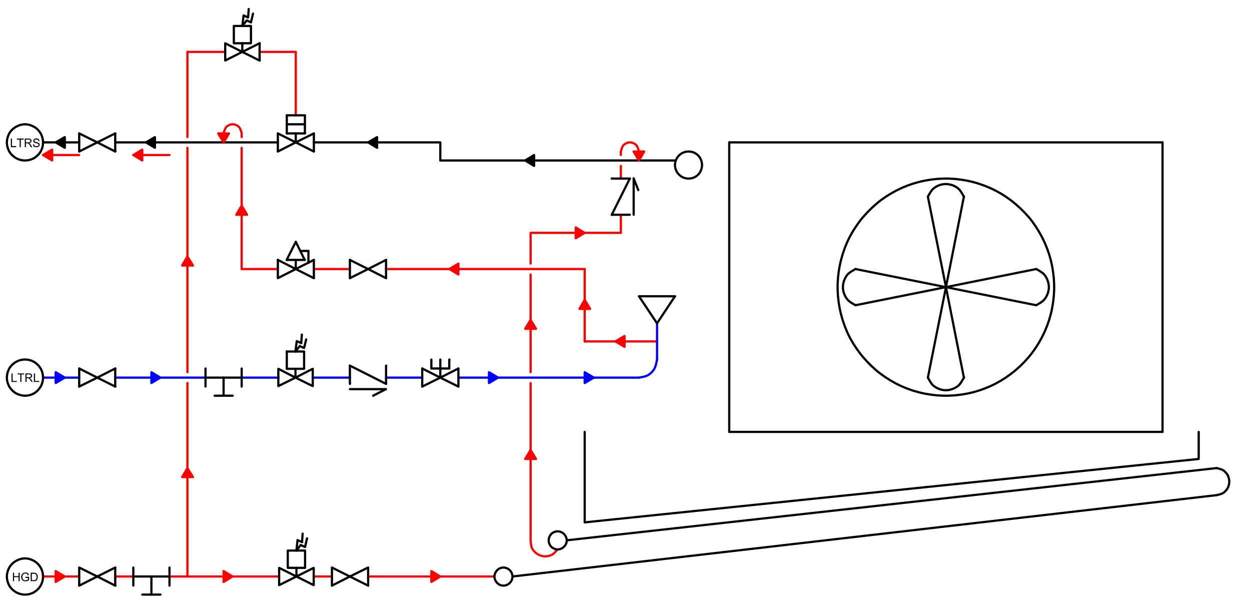


	STRAINER	HGD	HOT GAS DEFROST SUPPLY
	CHECK VALVE	LTRS	LOW-TEMP RECIRCULATED SUCTION
	GLOBE VALVE	LTRL	LOW-TEMP RECIRCULATED LIQUID
	SOLENOID VALVE	(red arrow)	HOT GAS FLOW
	DEFROST PRESSURE REGULATOR	(blue arrow)	SATURATED LIQUID FLOW
	GAS POWERED SUCTION STOP VALVE	(black arrow)	SATURATED LIQUID & VAPOR FLOW
	HAND EXPANSION VALVE		

3.2. Figure 12: Bottom Feed, 3-Pipe, Horizontal Headers

FIGURE 12

CONTROLLED PRESSURE RECEIVER (CPR) BOTTOM FEED
3-PIPE HOT GAS DEFROST
HORIZONTAL HEADERS
2-PASS PAN LOOP



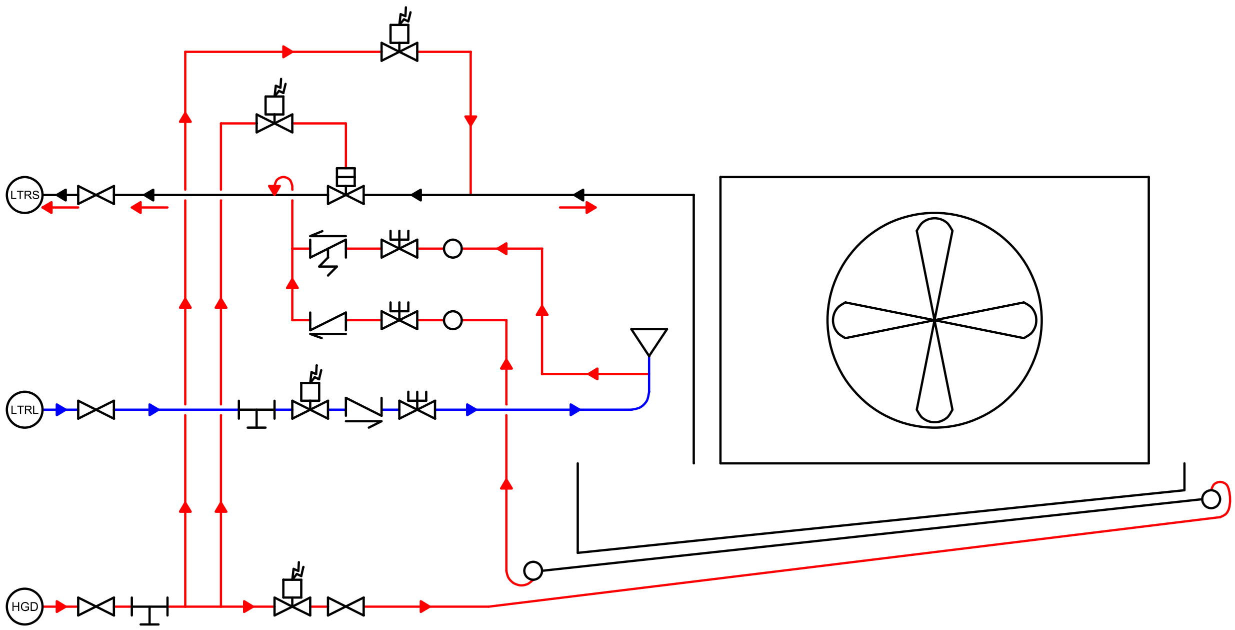
STRAINER
CHECK VALVE
GLOBE VALVE
SOLENOID VALVE
DEFROST PRESSURE REGULATOR
GAS POWERED SUCTION STOP VALVE
HAND EXPANSION VALVE

HGD HOT GAS DEFROST SUPPLY
LTRS LOW-TEMP RECIRCULATED SUCTION
LTRL LOW-TEMP RECIRCULATED LIQUID
HOT GAS FLOW
SATURATED LIQUID FLOW
SATURATED LIQUID & VAPOR FLOW

3.3. Figure 13: Bottom Feed, 4-Pipe, Vertical Headers

FIGURE 13

CONTROLLED PRESSURE RECEIVER (CPR) BOTTOM FEED
4-PIPE HOT GAS DEFROST
VERTICAL HEADERS
1-PASS PAN LOOP



STRAINER

CHECK VALVE

GLOBE VALVE

SOLENOID VALVE

SPRING LOADED CHECK VALVE

GAS POWERED SUCTION STOP VALVE

HAND EXPANSION VALVE

SIGHT GLASS

HGD HOT GAS DEFROST SUPPLY

LTRS LOW-TEMP RECIRCULATED SUCTION

LTRL LOW-TEMP RECIRCULATED LIQUID

HOT GAS FLOW

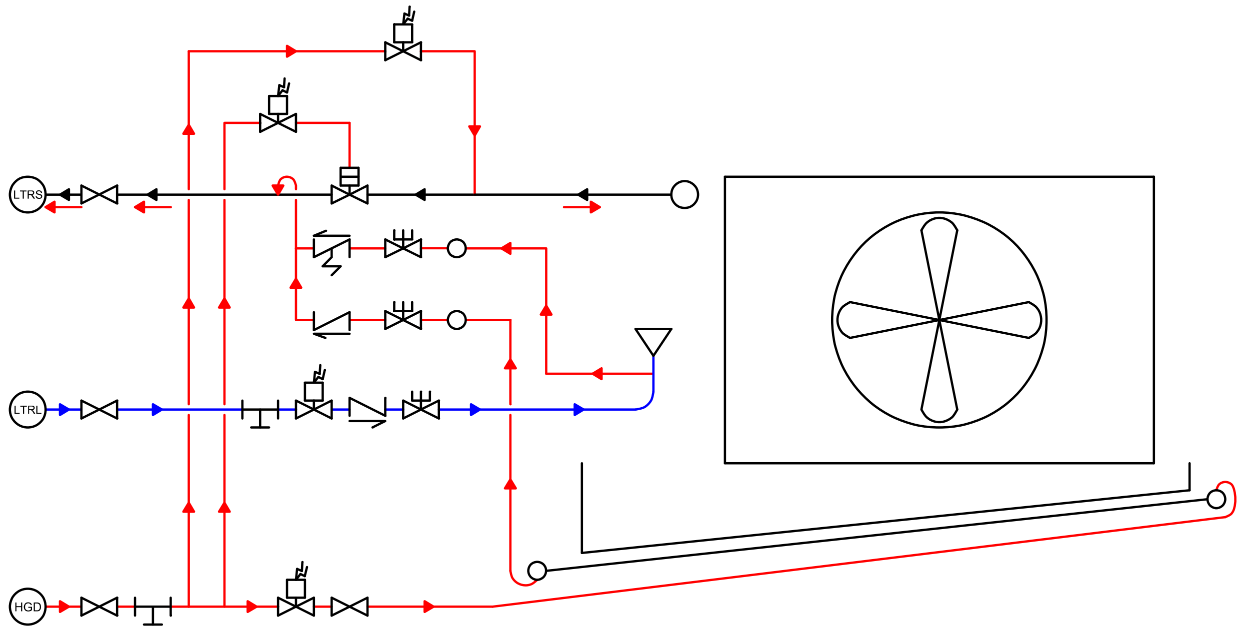
SATURATED LIQUID FLOW

SATURATED LIQUID & VAPOR FLOW

3.4. Figure 14: Bottom Feed, 4-Pipe, Horizontal Headers

FIGURE 14

CONTROLLED PRESSURE RECEIVER (CPR) BOTTOM FEED
4-PIPE HOT GAS DEFROST
HORIZONTAL HEADERS
1-PASS PAN LOOP

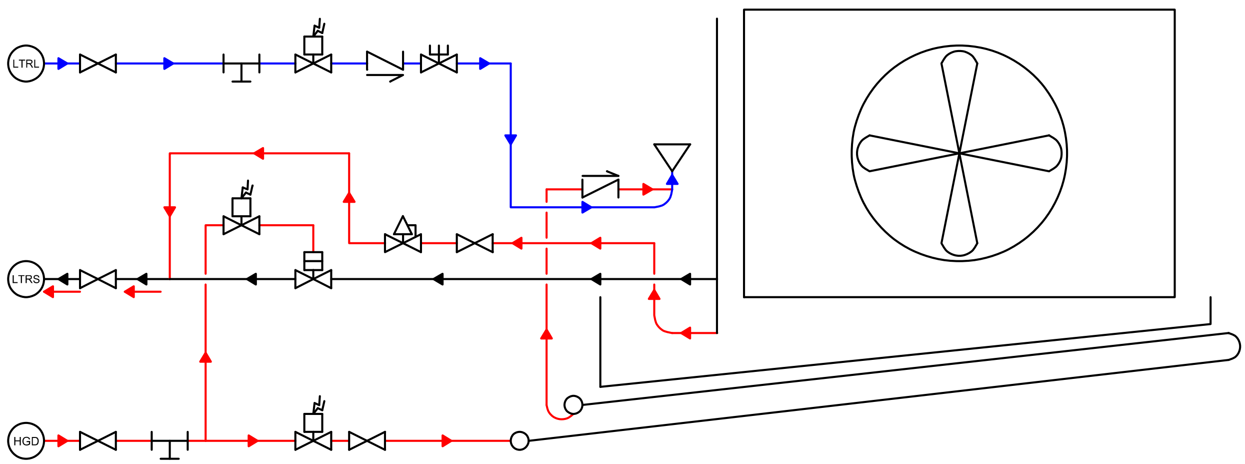


	STRAINER	HGD	HOT GAS DEFROST SUPPLY
	CHECK VALVE	LTRS	LOW-TEMP RECIRCULATED SUCTION
	GLOBE VALVE	LTRL	LOW-TEMP RECIRCULATED LIQUID
	SOLENOID VALVE		HOT GAS FLOW
	SPRING LOADED CHECK VALVE		SATURATED LIQUID FLOW
	GAS POWERED SUCTION STOP VALVE		SATURATED LIQUID & VAPOR FLOW
	HAND EXPANSION VALVE		
	SIGHT GLASS		

3.5. Figure 15: Top Feed, 3-Pipe, Vertical Headers

FIGURE 15

CONTROLLED PRESSURE RECEIVER (CPR) TOP FEED
3-PIPE HOT GAS DEFROST
VERTICAL HEADERS
2-PASS PAN LOOP



STRAINER

CHECK VALVE

GLOBE VALVE

SOLENOID VALVE

DEFROST PRESSURE REGULATOR

GAS POWERED SUCTION STOP VALVE

HAND EXPANSION VALVE

HGD HOT GAS DEFROST SUPPLY

LTRS LOW-TEMP RECIRCULATED SUCTION

LTRL LOW-TEMP RECIRCULATED LIQUID

→ HOT GAS FLOW

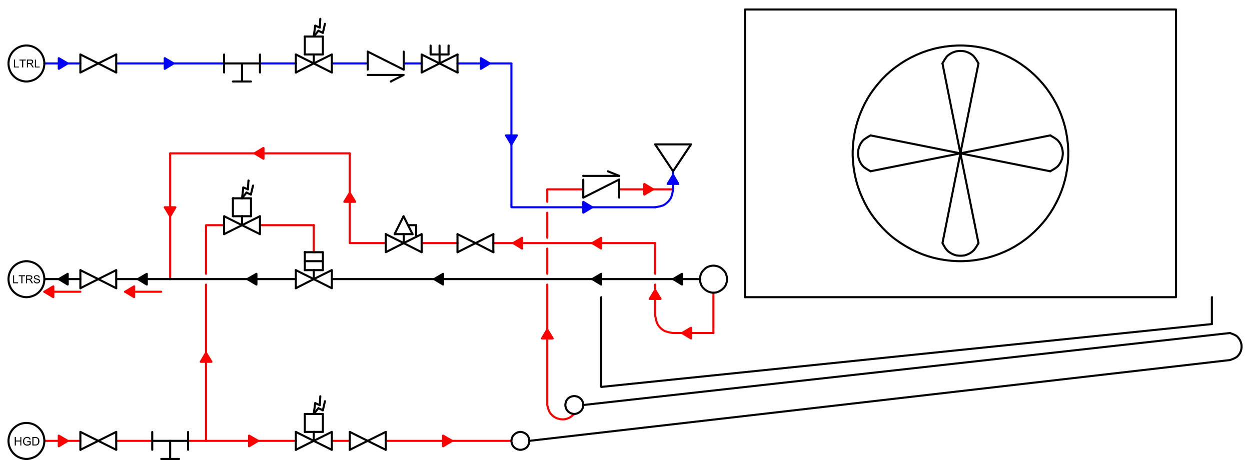
→ SATURATED LIQUID FLOW

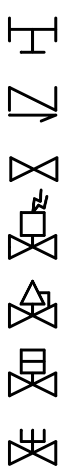
→ SATURATED LIQUID & VAPOR FLOW

3.6. Figure 16: Top Feed, 3-Pipe, Horizontal Headers

FIGURE 16

CONTROLLED PRESSURE RECEIVER (CPR) TOP FEED
3-PIPE HOT GAS DEFROST
HORIZONTAL HEADERS
2-PASS PAN LOOP





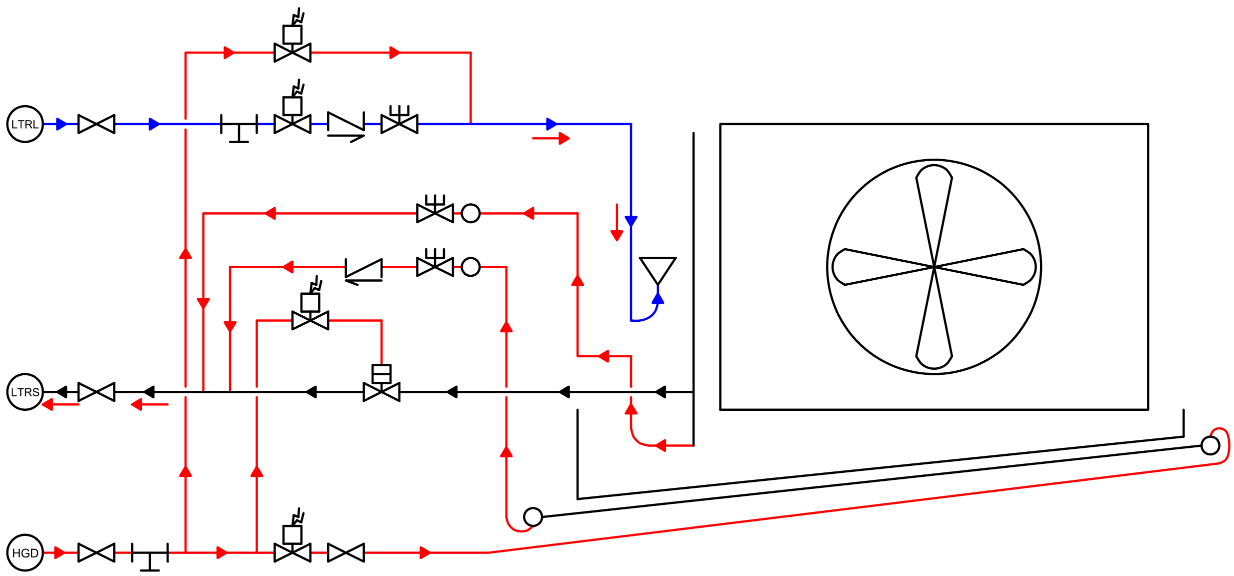
STRAINER	
CHECK VALVE	
GLOBE VALVE	
SOLENOID VALVE	
DEFROST PRESSURE REGULATOR	
GAS POWERED SUCTION STOP VALVE	
HAND EXPANSION VALVE	

HGD	HOT GAS DEFROST SUPPLY
LTRS	LOW-TEMP RECIRCULATED SUCTION
LTRL	LOW-TEMP RECIRCULATED LIQUID
(red arrow)	HOT GAS FLOW
(blue arrow)	SATURATED LIQUID FLOW
(black arrow)	SATURATED LIQUID & VAPOR FLOW

3.7. Figure 17: Top Feed, 4-Pipe, Vertical Headers

FIGURE 17

CONTROLLED PRESSURE RECEIVER (CPR) TOP FEED
4-PIPE HOT GAS DEFROST
VERTICAL HEADERS
1-PASS PAN LOOP

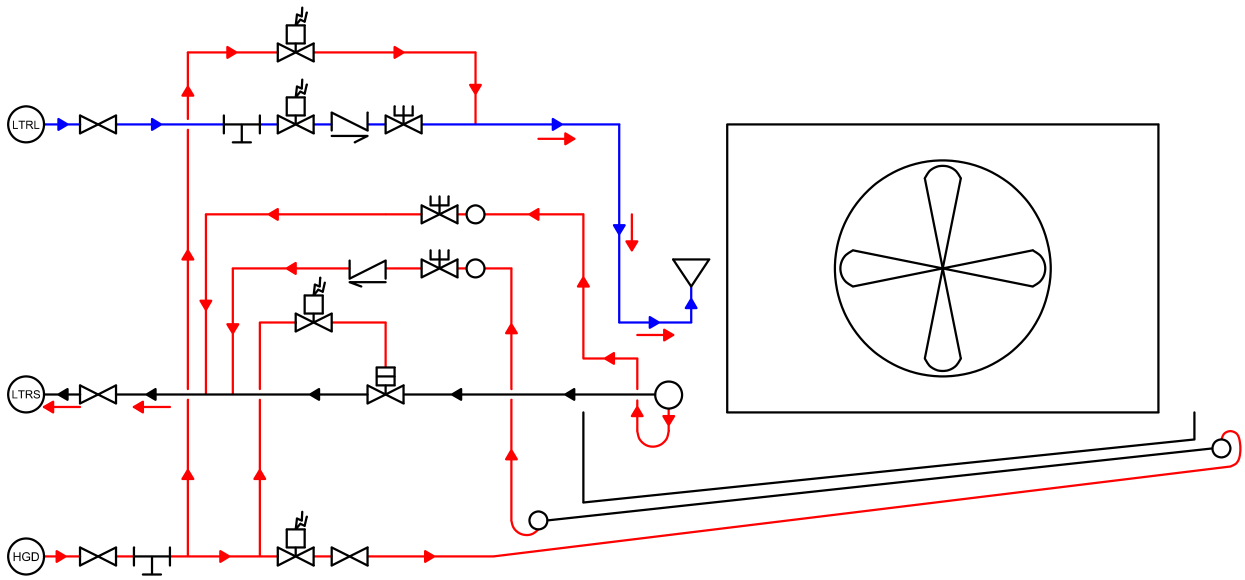


STRAINER	HGD — HOT GAS DEFROST SUPPLY
CHECK VALVE	LTRS — LOW-TEMP RECIRCULATED SUCTION
GLOBE VALVE	LTRL — LOW-TEMP RECIRCULATED LIQUID
SOLENOID VALVE	HOT GAS FLOW
GAS POWERED SUCTION STOP VALVE	SATURATED LIQUID FLOW
HAND EXPANSION VALVE	SATURATED LIQUID & VAPOR FLOW
SIGHT GLASS	

3.8. Figure 18: Top Feed, 4-Pipe, Horizontal Headers

FIGURE 18

CONTROLLED PRESSURE RECEIVER (CPR) TOP FEED
4-PIPE HOT GAS DEFROST
HORIZONTAL HEADERS
1-PASS PAN LOOP



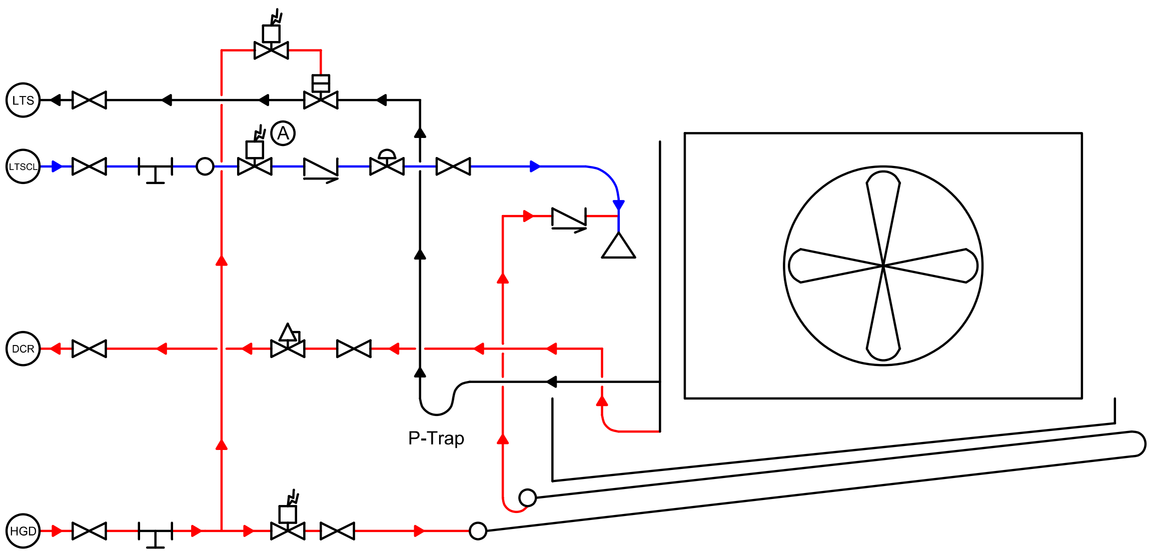
STRAINER		HGD	HOT GAS DEFROST SUPPLY
CHECK VALVE		LTRS	LOW-TEMP RECIRCULATED SUCTION
GLOBE VALVE		LTRL	LOW-TEMP RECIRCULATED LIQUID
SOLENOID VALVE			HOT GAS FLOW
GAS POWERED SUCTION STOP VALVE			SATURATED LIQUID FLOW
HAND EXPANSION VALVE			SATURATED LIQUID & VAPOR FLOW
SIGHT GLASS			

4. DIRECT EXPANSION (DX)

4.1. Figure 19: 3-Pipe, Separate Condensate Return, Vertical Header

FIGURE 19

DIRECT EXPANSION (DX)
3-PIPE HOT GAS DEFROST
SEPARATE CONDENSATE RETURN
VERTICAL HEADER
2-PASS PAN LOOP

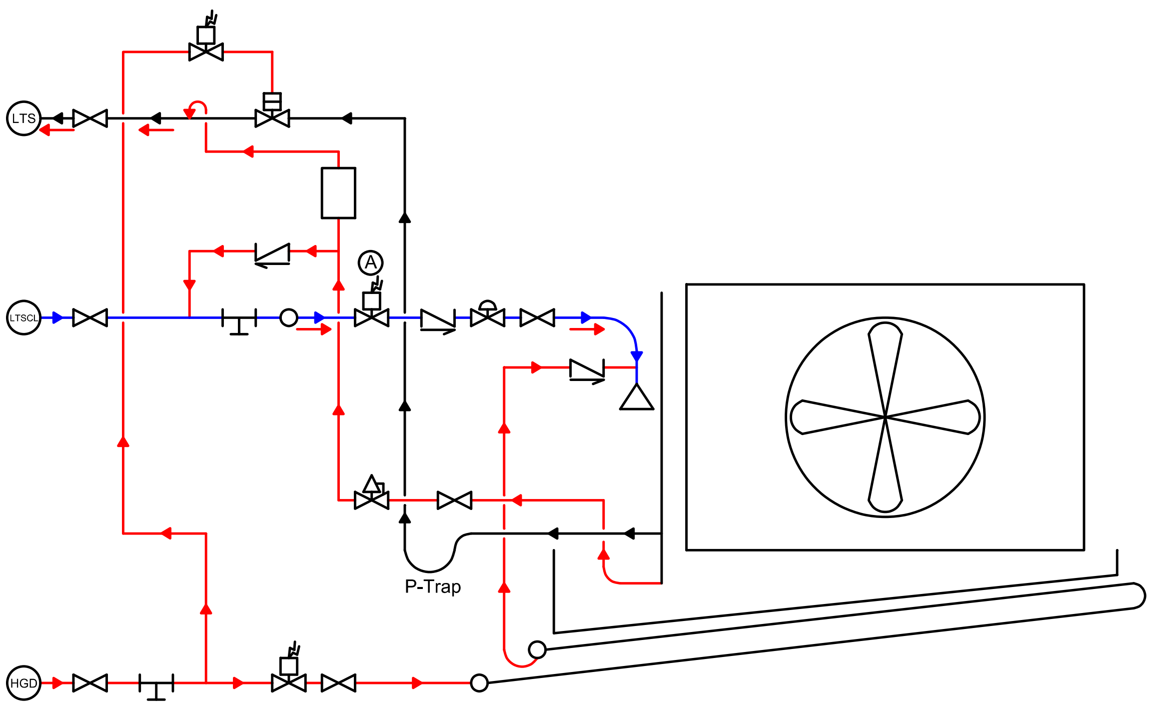


	STRAINER	HGD	HOT GAS DEFROST SUPPLY
	CHECK VALVE	LTS	LOW-TEMP SUCTION
	GLOBE VALVE	LTSCL	LOW-TEMP SUB-COOLED LIQUID
	SOLENOID VALVE	DCR	DEFROST CONDENSATE RETURN
	DEFROST PRESSURE REGULATOR		HOT GAS FLOW
	GAS POWERED SUCTION STOP VALVE		SATURATED LIQUID FLOW
	HAND EXPANSION VALVE		SATURATED LIQUID & VAPOR FLOW
	ELECTRONIC EXPANSION VALVE	Ⓐ	LIQUID LINE SOLENOID
	SIGHT GLASS		

4.2. Figure 20: 3-Pipe, Liquid Line Condensate Return, Vertical Headers

FIGURE 20

DIRECT EXPANSION (DX)
3-PIPE HOT GAS DEFROST
LIQUID LINE CONDENSATE RETURN
VERTICAL HEADER
2-PASS PAN LOOP



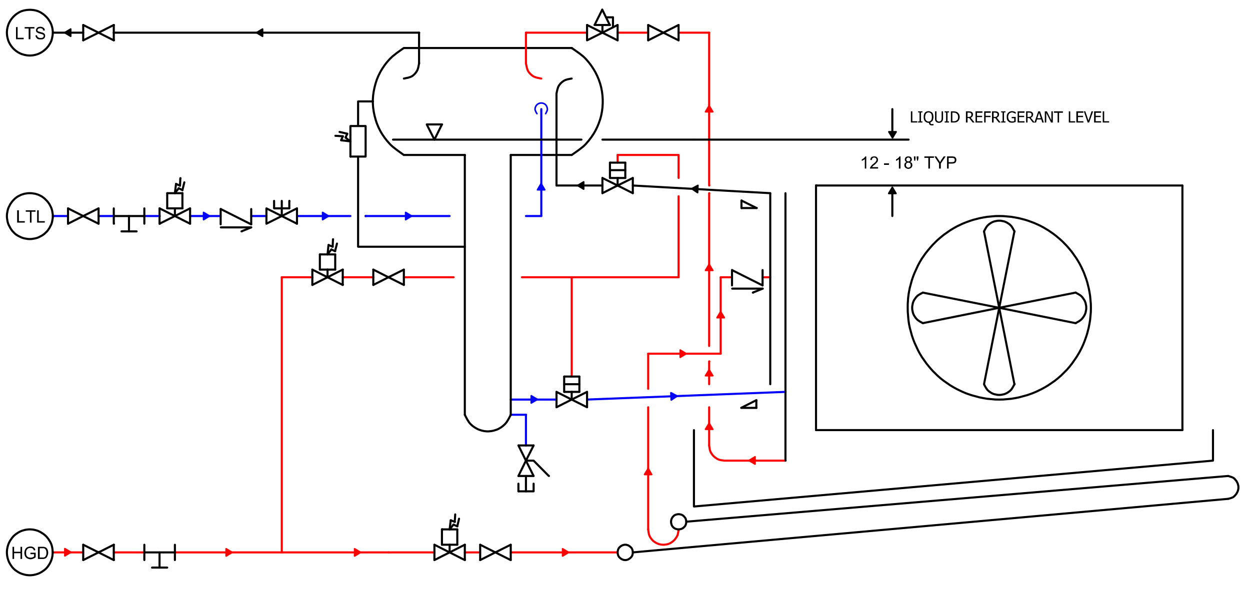
STRAINER	HGD — HOT GAS DEFROST SUPPLY
CHECK VALVE	LTS — LOW-TEMP SUCTION
GLOBE VALVE	LTSCL — LOW-TEMP SUB-COOLED LIQUID
SOLENOID VALVE	HOT GAS FLOW
DEFROST PRESSURE REGULATOR	SATURATED LIQUID FLOW
GAS POWERED SUCTION STOP VALVE	SATURATED LIQUID & VAPOR FLOW
HAND EXPANSION VALVE	(A) LIQUID LINE SOLENOID
ELECTRONIC EXPANSION VALVE	
SIGHT GLASS	
AUTO GAS VENT	

5. GRAVITY FLOODED

5.1. Figure 21: 3-Pipe, Vertical Headers

FIGURE 21

GRAVITY FLOODED
3-PIPE HOT GAS DEFROST
VERTICAL HEADER
2-PASS PAN LOOP



STRAINER	HGD — HOT GAS DEFROST SUPPLY
CHECK VALVE	LTS — LOW-TEMP SUCTION
GLOBE VALVE	LTL — LOW-TEMP LIQUID
SOLENOID VALVE	HOT GAS FLOW
DEFROST PRESSURE REGULATOR	SATURATED LIQUID FLOW
GAS POWERED SUCTION STOP VALVE	SATURATED LIQUID & VAPOR FLOW
HAND EXPANSION VALVE	
DRAINER	
LIQUID LEVEL SWITCH	

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COLMAC COIL Manufacturing Inc.

Technical Bulletin

By Bruce I. Nelson, P.E., President, Colmac Coil Manufacturing, Inc.

EVAPORATORS FOR CO2 REFRIGERATION

BACKGROUND

Carbon Dioxide was first proposed as a refrigerant by the British inventor, Alexander Twining, in his 1850 patent. Its use in refrigeration systems gradually increased and peaked in the mid-1920's. After the introduction of the synthetic chloroflorocarbon "CFC" refrigerants (i.e. R12) in the 1930's, the use of CO2 as a refrigerant declined and finally disappeared almost completely by about 1960.

In 1974 the researchers Molina and Rowland published a laboratory study demonstrating the ability of CFC's to catalytically breakdown Ozone in the presence of high frequency UV light. Further studies estimated that the ozone layer would be depleted by CFC's by about 7% within 60 yrs and based on such studies the US banned CFC's in aerosol sprays in 1978. In 1984 British Antarctic Survey scientists Farman, Gardiner, and Shanklin, discovered a recurring springtime Antarctic ozone hole. In the 1980's the first measurements of this loss were actually documented and in 1984, when the British first reported their findings, October ozone levels were about 35 percent lower than the average for the 1960s. The U.S. satellite Nimbus-7 confirmed these results, and the term Antarctic ozone hole entered our popular language.

Ultimately this research led to the Montreal Protocol on Substances that Deplete the Ozone Layer, an international agreement to phase out the production of numerous substances that are believed to be responsible for ozone depletion. The Montreal Protocol was agreed to in September 1987, and entered into force on January 1, 1989.

All of these events triggered intense research activity throughout the 1980's to find alternate refrigerants with lower Ozone Depletion Potential (ODP) and resulted in the development of various HCFC and HFC type refrigerants. At the same time a group of engineers and academics, mostly Europeans, began to promote the use of "natural refrigerants" as being the only truly environmentally friendly fluids to use in refrigeration and air-conditioning machines. It was in 1993 that Professor Gustav Lorentzen at the University of Trondheim in Norway demonstrated that CO2 could be a viable refrigerant, and a number of patents were issued to him relating to the use of CO2 in vapor compression machines. Interest in applying CO2 in various air-conditioning and refrigeration applications has grown steadily since that time.

In the industrial refrigeration world we are accustomed to using ammonia as the only refrigerant in the system. All of us know and appreciate the benefits of ammonia - it is a great refrigerant! However, because of its toxicity there is interest in using ammonia and CO2 in combination to remove the ammonia from occupied spaces in our refrigerated facilities. Ammonia and CO2 have very different operating characteristics which must be accounted for when designing and operating industrial refrigeration systems. These differences will be highlighted below with an emphasis on the design and operation of air-cooling evaporators.

CO2 BENEFITS AND CHALLENGES

Health and Safety

All of us in the industrial refrigeration industry know and love ammonia for its low cost, high efficiency, and ease of application. On the other hand, ammonia's toxicity and flammability characteristics must be carefully addressed with good safety practices including proper maintenance, training, and coordination with local first responders. Depending on the amount of ammonia on the site, various Federal and local agencies (OSHA, EPA, DHS) will begin to take an interest in Process Safety Management (PSM and RMP) systems in place and other regulatory requirements. Even a small release of ammonia from the refrigeration system can create big problems including plant evacuations, required reporting to various governmental agencies, interaction with surrounding populations and local first responders, unwanted media attention, etc. The comment I hear repeatedly from refrigerated facility end users is "I love ammonia and understand its benefits, just don't put it next to my products or people."

Carbon dioxide on the other hand is referred to as being both non-toxic and non-flammable and has a safety classification of A1 according to ASHRAE Std 34 (ASHRAE 2013). Actually, CO2 is toxic to humans in high enough concentrations. Our bodies continually expel CO2 as a normal physiological process for a reason, too much CO2 is bad for us. The AGA gas handbook presents the following data for adults in good health:

- 0.04%: Normal concentration of CO2 in air.
- 2%: 50% increase in breathing rate.
- 3%: 10 minute short term exposure limit; 100% increase in breathing rate.
- 5%: 300% increase in breathing rate, headache and sweating may begin after about an hour (tolerable — but physically draining).
- 8-10%: Headache after 10-15 minutes. Dizzyness, buzzing in the ears, increase in blood pressure, increased pulse rate, anxiety and nausea.
- 10-18%: After a few minutes, cramps similar to epileptic fits, loss of consciousness and shock (sharp drop in blood pressure). A quick recovery in fresh air is possible.
- 18-20%: Symptoms similar to those of a stroke followed by death.

When looking at the concentration amounts shown above for CO2, bear in mind that even 5% concentration in air is very high compared to the 50 ppm ammonia concentration that has us all looking for the door to get out. 5% concentration is equal to 50,000 ppm, so it takes a relatively large leak of CO2 to produce the serious reactions listed above. One of the problems with CO2 leaking in confined spaces is its absence of odor - you can't smell it. Everybody knows when there is even a small ammonia leak, but unless you are trained to recognize the physical symptoms related to the presence of high CO2 concentrations you won't know there has been a leak and you may be in trouble.

Carbon dioxide is also different from ammonia in that it is heavier than air and so will tend to collect in higher concentrations at low points in confined spaces like engine rooms.

Carbon dioxide is absolutely non-flammable which is beneficial. Ammonia, while it is flammable only in a narrow range of concentration in air (approx. 16%) is nonetheless classified as B2L according to ASHRAE Std 34. CO2 is good at displacing oxygen and is actually used as an effective fire extinguishing agent. However, what is good for fire-fighting is bad for us humans who need oxygen to breath and avoid asphyxiation.

Because of the above risks, having properly placed and maintained CO2 detectors is absolutely critical to health and safety in industrial refrigeration systems running with CO2.

Cost

Carbon dioxide is abundant in nature and is widely used in many industries, including the beverage business. This tends to keep the cost of CO2 extremely low compared to the synthetic HFC and HFO refrigerants. Similarly, the cost of ammonia is also very low because it is produced in huge quantities for use as fertilizer and in other industrial processes. Natural refrigerants are cheap!

Thermodynamic Properties

Two thermodynamic properties of carbon dioxide make it somewhat more challenging to use as a refrigerant compared to ammonia, its pressure and its critical temperature.

The higher operating pressures of CO2 effect all of the pressure bearing components in the system, compressors, piping, vessels, control valves, and heat exchangers. Fortunately, all of the components needed to design for these higher pressures are now widely available in the market.

We are all used to designing refrigeration systems to operate well below the critical point of the refrigerant. Ammonia has a particularly high critical temperature of 270 deg F (132 deg C) and so can easily operate 'subcritically'. The high critical temperature of ammonia also produces low throttling losses and inherently high COP under most conditions. On the other hand, the low critical temperature of 88 deg F (31 deg C) of CO2 limits efficient subcritical operation to very low condensing temperatures, around 32 deg F (0 deg C). Operation with high side temperatures above 88 deg F is possible but becomes 'transcritical'. Operation of a transcritical machine is more complicated than a traditional subcritical machine and is always less energy efficient (IIAR 2014).

In the subcritical operating range typical for carbon dioxide, gas densities are very high and the resulting refrigerating capacity (in TR/ft3 of displacement) is relatively high. This translates to compressor displacements which are much smaller than those required for an ammonia compressor having similar refrigeration capacity. The high suction and discharge pressures for CO2 also result in compression ratios that are significantly lower compared to ammonia.

Ammonia and CO2 Together - A Perfect Marriage

Finding ways to cost effectively use ammonia and carbon dioxide together in cascade refrigeration systems would seem to be the perfect solution for a facility operator:

- Both fluids are 'natural refrigerants' and ultimately make industrial refrigeration safe for the environment.
- Ammonia/CO2 cascade refrigeration systems are at least as energy efficient as a traditional ammonia refrigeration system (Christensen 2006).
- Ammonia has high operating efficiencies even at high temperatures and so can efficiently reject heat even in high ambient environments. Using ammonia on the high side of a cascade system reduces the amount of ammonia in the system and allows it to be managed in ways that minimize or eliminate the negative effects of an ammonia leak on products or people. NH3/CO2 cascade systems are safer for workers in refrigerated facilities.
- Carbon dioxide is non-toxic and is highly efficient at low temperatures, which is the part of the refrigeration system that is closest to products and people. Using CO2 on the low side of a cascade system is safer for people and eliminates the risk of damage to products in the event of a leak.

AMMONIA / CO2 CASCADE SYSTEMS

Ammonia and carbon dioxide can be used effectively in combination in two main configurations:

a. Ammonia / CO2 Cascade with low-side compression
b. Ammonia / CO2 Cascade with low-side pumped as a volatile brine

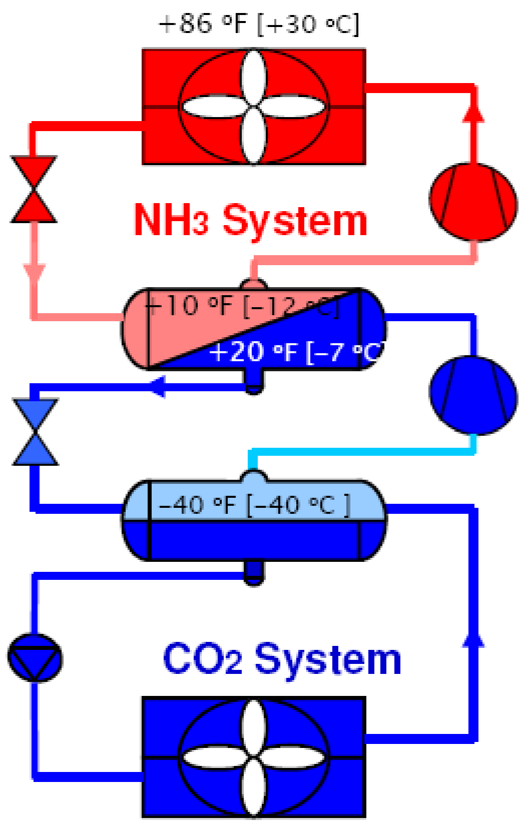
Ammonia / CO2 Cascade with low-side compression

In this type of system carbon dioxide is used with compression on the low side to absorb heat from the load being refrigerated. Heat is transferred at an intermediate temperature level to the ammonia through a heat exchanger ('cascade heat exchanger'). In the heat exchanger the CO2 is condensed while the ammonia is evaporated. The ammonia evaporated in the cascade heat exchanger is compressed to a pressure and temperature high enough to reject the heat to ambient.

Figure 1 below shows a typical Ammonia / CO2 Cascade system with compression and pumped liquid on the low-side (Danfoss 2014).

FIGURE 1

Ammonia / CO2 Cascade with Compression and Pumped Liquid on Low-Side



The compressor oil typically used in this type of system is fully miscible POE (Polyol Ester) which will become concentrated in the recirculator vessel. This requires an oil rectifier to distill the recirculator liquid and return the oil-rich liquid back to the crankcase of the compressor(s), and is similar in this regard to a pumped halocarbon system.

Various examples of this type of system are shown in the Appendix:

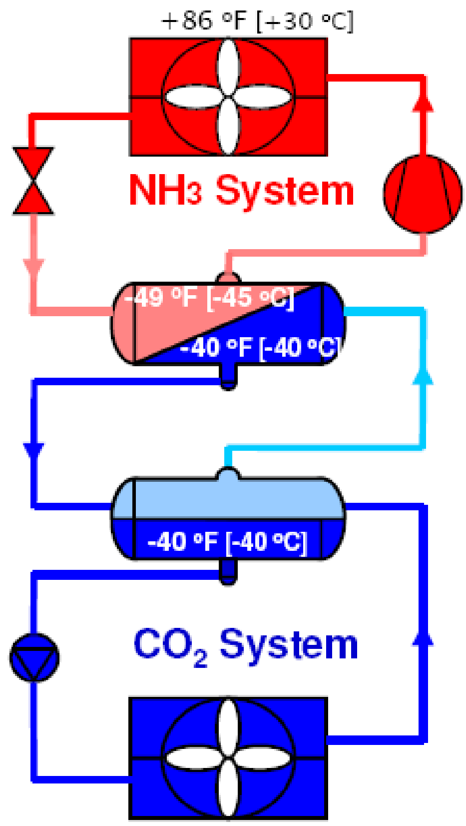
- Figure A1: NH3/CO2 with low side compression. CO2 pumped to (3) x temperature levels. Electric or water defrosting. CO2 reciprocating compressors with oil rectification.
- Figure A2: NH3/CO2 with low side compression. CO2 pumped to (2) x temperature levels. Hot gas defrosting. CO2 reciprocating compressors with oil rectification.

- Figure A3: NH3/CO2 with low side compression. CO2 pumped to medium temperature level, CO2 DX to (2) x low temperature levels. Electric or water defrosting. CO2 reciprocating compressors with oil rectification.
- Figure A4: NH3/CO2 with low side compression. CO2 pumped to medium temperature level, CO2 DX to (1) x low temperature level. Electric or water defrosting. CO2 screw compressors without oil rectification.

Figure 2 below shows a typical Ammonia / CO2 Cascade system with pumped liquid on the low-side but no CO2 compression (Danfoss 2014). The CO2 in type of system is often referred to as pumped "volatile brine".

FIGURE 2

Ammonia / CO2 Cascade with Pumped Liquid and No Compression on Low-Side



In the system shown in Figure 2 above, since there is no compression taking place on the CO_2 side of the system, the CO_2 "brine" is kept oil-less and oil rectification in the CO_2 recirculator vessel is not needed.

An example of this type of system is shown in the Appendix:

- Figure A5: NH_3/CO_2 without low side compression. CO_2 pumped to (2) x temperature levels. Electric or water defrosting.

Note that in these types of systems, hot gas defrosting is possible but requires that liquid CO_2 be pressurized and then fed to a heat driven boiler to generate hot gas for defrosting. This type of hot gas defrost system will not be covered in this paper. Also, because of the relatively low difference between CO_2 supply liquid pressure and suction pressure, direct expansion of the evaporators would be difficult (not enough pressure difference for stable expansion valve operation) and pumped CO_2 is recommended. Evaporators for these types of systems are selected in the same way as you would for any pumped CO_2 system. i.e. Evaporators shown in Figure A5 are selected the same way as evaporators shown in Figure A1. These evaporators can be arranged for either top feed or bottom feed.

Effects of Oil on Evaporator Performance

Even though the oil used in CO_2 compressors is miscible (typically POE) and is in solution with the CO_2, there is a slight penalty to the boiling heat transfer coefficient (Kim and Hrnjak 2012). This penalty is very small (on the order of 1-3%), however, for normal operating conditions found with refrigeration evaporators and is typically neglected in ratings and selection.

Theoretically there is a very slight increase in evaporator performance in the oil-less volatile brine type system compared to the system with CO_2 compression, however, the bigger benefit is the elimination of oil rectification and problems associated with oil return.

Effects of Water on Evaporator Performance

As is pointed out elsewhere (Vestergaard 2004), the solubility of water in CO_2 particularly at low temperatures is very low in the vapor phase. This means that even small concentrations of water in CO_2 will form free water and freeze to ice when liquid CO_2 flashes at expansion valves. This will obviously cause plugging of the expansion valves and starving the coils, and must be avoided by: a) very thorough evacuation on startup, b) charging the system with dry CO_2, and c) installation and servicing of generously sized desiccant type filter-driers in the liquid line(s).

CO_2 WORKING PRESSURE

Table 1 below compares the saturation pressures for CO_2 and ammonia and illustrates the significantly higher pressures (and consequently higher strength requirements) for CO_2. Both copper and stainless steel are completely compatible with CO_2 (Nelson 2014) and so are chosen as the tubing materials shown below.

TABLE 1					
Saturation Pressure vs Temperature					
CO2 vs Ammonia					
		Ammonia		CO2	
Temperature		Pressure		Pressure	
deg F	deg C	psia	bar	psia	bar
-60	-51.1	6	0.4	95	6.5
-40	-40.0	10	0.7	146	10.0
-20	-28.9	18	1.3	215	14.8
0	-17.8	30	2.1	306	21.1
20	-6.7	48	3.3	422	29.1
40	4.4	73	5.1	568	39.1
60	15.6	108	7.4	748	51.6
80	26.7	153	10.6	970	66.8

ASHRAE Standard 15 “Safety Standard for Refrigeration Systems” (ASHRAE 2013), sets the minimum design pressure for system components (including evaporators) in Section 9.2. This section of the standard also refers to the ASME Boiler and Pressure Vessel Code, Section VIII, as the appropriate method of determining the design (or ‘working’) pressure given evaporator dimensions and materials of construction.

Table 2 below shows the calculated minimum required design pressure for CO_2 piping and equipment, including evaporators, according to Section 9.2 of the standard. The temperature shown in Table 2 is defined as the "warmest location in the circuit" and can be considered the same as the room temperature.

TABLE 2				
Minimum Design Pressure vs Temperature				
CO2 Evaporators				
		Minimum Design		
Temperature		Pressure		
deg F	deg C	psia	psig	bar
-60	-51.1	113	99	7.8
-40	-40.0	175	160	12.1
-20	-28.9	258	243	17.8
0	-17.8	367	352	25.3
20	-6.7	506	492	34.9
40	4.4	681	666	47.0
60	15.6	897	883	61.9
80	26.7	1070*	1055*	73.8*
* Exceeds the critical pressure of CO2 so design pressure				
is set equal to the critical pressure.				

Since copper and stainless steel are both recommended for use in carbon dioxide evaporators (Nelson 2014), Table 3 below has been constructed to show the minimum tube wall thickness needed to meet the requirements of ASHRAE Standard 15 in a CO2 evaporator operating at various room temperatures.

TABLE 3							
Minimum Tube Wall Thickness vs Room Temperature (ASHRAE Std 15)							
CO2 Evaporators							
		Minimum Tube Wall Thickness, in					
Room Temperature		SB-75 Cu Tube Diameter			SA-249 304 SS Tube Diameter		
deg F	deg C	3/8"	1/2"	5/8"	5/8"	7/8"	1"
-60	-51.1	0.010	0.010	0.010	0.010	0.010	0.010
-40	-40.0	0.010	0.011	0.013	0.010	0.010	0.010
-20	-28.9	0.012	0.015	0.018	0.010	0.010	0.012
0	-17.8	0.016	0.020	0.025	0.011	0.015	0.017
20	-6.7	0.022	0.028	0.034	0.015	0.021	0.024
40	4.4	0.027	0.035	0.043	0.020	0.027	0.032
60	15.6	0.036	0.046	NR	0.026	0.036	0.041
80	26.7	NR	NR	NR	0.031*	0.042*	0.048*
* Critical pressure used to determine MAWP.							

Note that the minimum tube wall thicknesses shown in Table 3 are theoretical calculated values. In normal manufacturing practice, copper tubing with wall thickness less than about 0.016” is difficult to produce and to handle. With stainless steel tubing the practical minimum wall thickness is around 0.020”. While lower temperatures may allow the use of light wall tubing and relatively low design pressures during normal operation, remember that the appropriate design pressure may be higher than the design room temperature in some cases. When specifying evaporator construction (tube material and wall thickness) all potential temperature/pressure conditions need to be considered, including (but not limited to):

- Startup conditions
- Peak load operation
- Abnormal loads (process temperature excursions)
- Standby conditions that occur frequently
  - Power outages limited in time duration but which may happen with some frequency
  - Shutdown during cleanup

Control Valve Groups for Convertible Rooms

In many cases, cold storage facilities are designed with convertible rooms. That is, with rooms which can be operated at different temperatures depending on the product being stored. Because of the high pressure of CO_2, transferring a convertible room from high temperature to low temperature operation can involve a very large change in pressure. To manage this large pressure change in both liquid and suction lines, motorized valves should be used with additional equalizing bleed valves. Piping diagrams for this type of convertible room unit(s) are shown in Figures A8 and A9.

OPTIMUM OVERFEED RATE FOR PUMPED CO2

Reducing the overfeed rate in pumped refrigerant systems is desirable because pumping power will be reduced by the cube of the ratio of the reduction in flowrate. As the liquid overfeed rate is reduced, however, the risk of operating evaporators with the refrigerant in separated flow patterns (stratified/wavy) increases. Cooling capacity of the evaporator falls off dramatically when this occurs. With CO_2 in an evaporator having 5/8" tubes, a minimum mass flux of 41 lbm/ft2-s (approx. 1.5 TR/feed for 2:1 overfeed) is required to avoid stratified/wavy flow.

The thermodynamic properties of CO_2 differ significantly from ammonia:

- Latent heat of vaporization is much lower resulting in higher mass flow rates for a given cooling capacity.
- The ratio of liquid to vapor density is much lower which results in lower void fractions (less tube volume occupied by vapor).
- Higher mass flux for reasons explained above (see Heat Transfer section).

These characteristics allow pumped CO_2 evaporators to be designed for lower overfeed rates compared to ammonia. Recommended overfeed rates for pumped CO_2 evaporators are 1.5:1 for coolers and 2:1 for freezers.

In comparison, to avoid separated flow in pumped ammonia evaporators, recommended overfeed rates are 3:1 for coolers and 4:1 for freezers.

DEFROST

CO_2 evaporators can be defrosted using the following methods:

- Electric
- Water
- Hot Gas
- Interlaced Warm Glycol

Electric Defrost

This method is simple and results in simplified control valves and piping. Control valve groups for this type of defrost are shown in Figures A6 through A9. There are added first costs associated with the required power cabling in addition to the operating costs from power consumed by the heating elements during defrost. The addition of return air defrost hoods shown below in Figure 3 can significantly reduce the amount of power consumed during defrosting (less heat lost to the room), reduce defrost duration, and improve the effectiveness of defrosting (coils get cleaner).

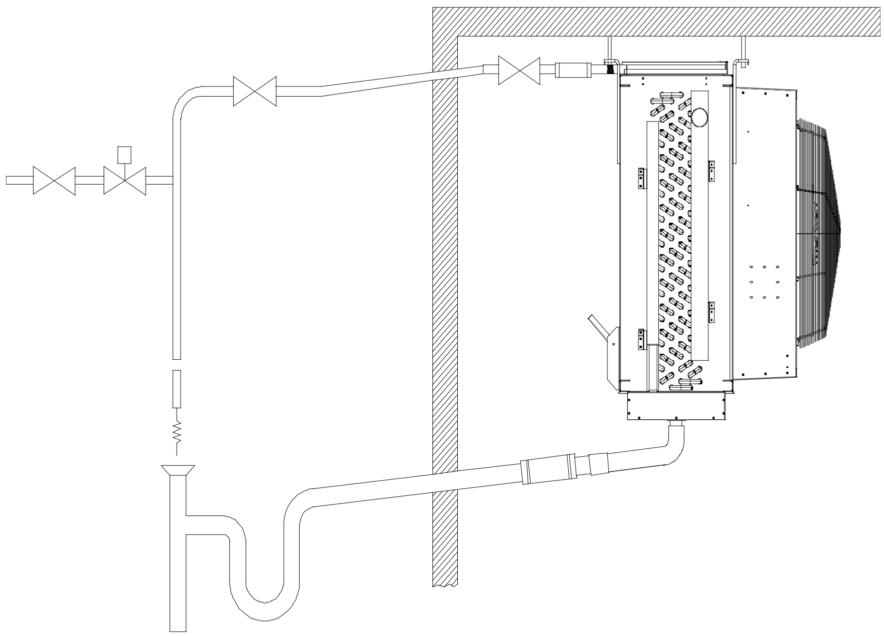
FIGURE 3
Return Air Defrost Hood

The evaporator manufacturer must insure proper placement and number of heating elements to insure a complete defrost. Also, provisions need to be made to prevent heating elements from "creeping" (moving out of the coil block over time) which can result in damage to the elements themselves and to electrical wiring.

Water Defrost

This method produces a very fast and complete defrost. Waste heat from the high side of the system can be used to heat the defrost water for reduced power consumption. Care must be taken to provide for complete drainage of water lines at the end of defrost as well as specifying and using high quality water supply valves. Use of high quality motorized ball valves is recommended for controlling water flow.

FIGURE 4
Evaporator Arranged for Water Defrost



The trick to making this type of defrost work in low temperatures is to design the evaporator cabinet and drainpan properly to manage and minimize overspray of water during defrost. Design guidelines and sequence of operation for water defrosting can be found elsewhere (Colmac Coil 2012). As with electric defrosting, the evaporator control valve group is very simple - see Figures A6 through A9.

Hot Gas Defrost

This method is very familiar to all of us in the industrial refrigeration business. The control valve groups are arranged the same as for ammonia and are shown in Figures A10 and A11. The main difference between CO2 and ammonia of course is the pressure required to reach defrosting temperature with CO2. Typically CO2 hot gas provided for defrost must be at around 710 psig (50 bar) which translates to 60 deg F. The challenge with CO2 hot gas defrost is having to add a separate compressor to provide the defrost gas. Figure A2 shows a hot gas defrost system with a swing compressor able to provide 710 psig gas during defrost and then go back to running with discharge pressure of 407 psig during normal cooling.

As with any hot gas defrost system, there must be a sufficient supply of gas coming from evaporators operating in the cooling mode to fund the amount of gas needed for defrosting (think "2 to 1 rule"). Oil return to the hot gas compressor is also something to carefully consider and manage.

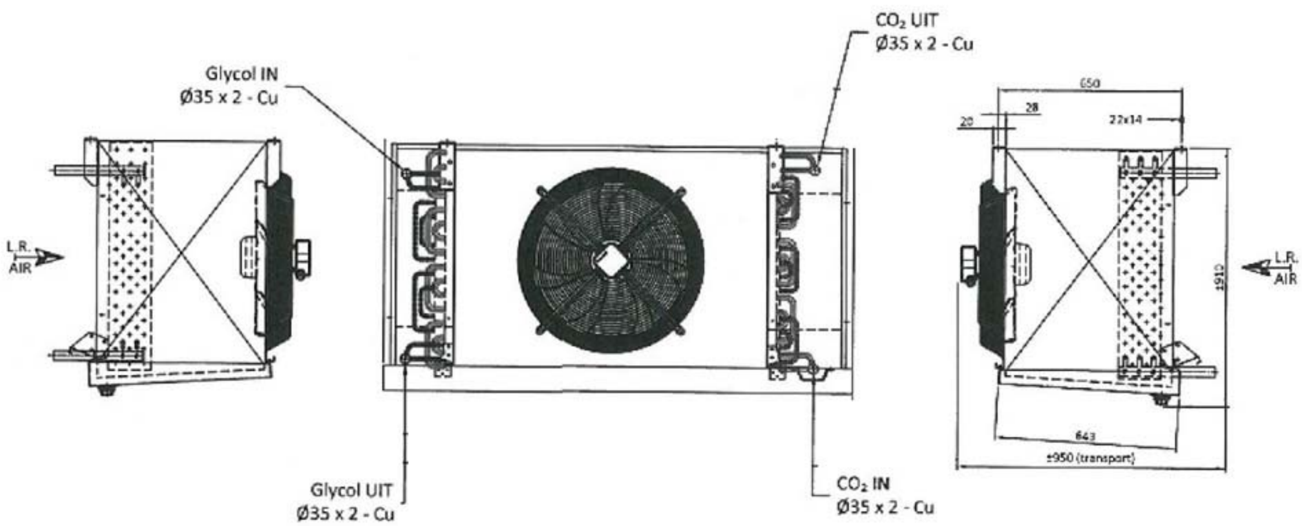
Compared to electric and water defrosting, the more complex control valve groups as well as additional piping and the hot gas compressor may add cost to the point that this method is not financially attractive.

Interlaced Warm Glycol Defrost

In this method, heated Propylene Glycol is circulated through tubes evenly spaced throughout the coil block to warm the coil and melt frost. Figure 5 below shows an evaporator arranged for pumped CO_2 with an interlaced glycol defrost circuit.

FIGURE 5

CO_2 Evaporator with Interlaced Glycol Defrost Circuit



Glycol for defrosting is typically provided at the coil at 60 to 70 deg F (15 to 20 deg C) for 20 minutes at a heating duty that is approximately 150% of the cooling capacity (Pearson 2015). Glycol flowrate is supplied to the coil to produce this heating duty with a glycol temperature change of 10 to 12 deg F (5 to 7 deg C) at a glycol circuit pressure drop of around 10 to 15 psi (80 kPa).

While this defrosting method does offer the benefit of being able to use waste heat from the high side of the system to heat the glycol, it is quite limited in its application.

Room temperatures with this type of defrost should not be lower than 25 to 28 deg F (-2 to -3 deg C). Below these temperatures, a number of problems arise:

1. Glycol pumping power becomes excessive,
2. The pumping pressure required to move the cold glycol out of the coil at the start of defrost will be quite high,
3. The amount of energy required to heat the mass of cold glycol coming from the coil at the start of defrost and the energy needed to cool it back down again at the end of defrost, becomes excessive,
4. Heat loss from the glycol circulating loop could become very high depending on how well insulated the piping loop is,
5. The risk of freezing glycol and bursting coil tubes due to poor mixing, improper preparation, or diluted glycol.

While the evaporator control valve groups are quite simple for this type of defrost system (see Figures A6 through A9), the added glycol heating system, piping, insulation, and control valves, add significant cost and may make interlaced glycol defrosting economically unfeasible.

CONCLUSION

The combined use of ammonia and carbon dioxide in industrial refrigeration systems offers end-users a solution which is both safe for the environment and safe for workers, products, and the public.
The paper has described several possible arrangements for cascade NH3/CO2 refrigeration systems and has highlighted special concerns and considerations for CO2 evaporators used in these systems.

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APPENDIX

1. Figure A1: P&ID NH3/CO2 with low side compression. CO2 pumped. Electric or water defrosting. CO2 recip compressors.
2. Figure A2: NH3/CO2 with low side compression. CO2 pumped med and low temps. Hot Gas defrosting. CO2 recip compressors.
3. Figure A3: NH3/CO2 with low side compression. CO2 pumped med temp, DX low temp. Elec or Water defrosting. CO2 recip compressors.
4. Figure A4: NH3/CO2 with low side compression. CO2 pumped med temp, DX low temp. Elec or Water defrosting. CO2 screw compressors.
5. Figure A5: NH3/CO2 without low side compression. CO2 pumped. Elec or Water defrosting. CO2 recip compressors.
6. Figure A6: Control Valve Group for Top Feed Pumped CO2 Evaporator. Single Temperature Level. Electric Defrost.
7. Figure A7: Control Valve Group for Top Feed Pumped CO2 Evaporator. Multi-Temperature Levels. Electric Defrost.
8. Figure A8: Control Valve Group for Bottom Feed Pumped CO2 Evaporator. Single Temperature Level. Electric Defrost.
9. Figure A9: Control Valve Group for Bottom Feed Pumped CO2 Evaporator. Multi-Temperature Levels. Electric Defrost.
10. Figure A10: Control Valve Group for Bottom Feed Pumped CO2 Evaporator. Single Temperature Level. Hot Gas Defrost.

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FIGURE A1

NH3/CO2 with low side compression. CO2 pumped. Electric or water defrosting. CO2 recip compressors.

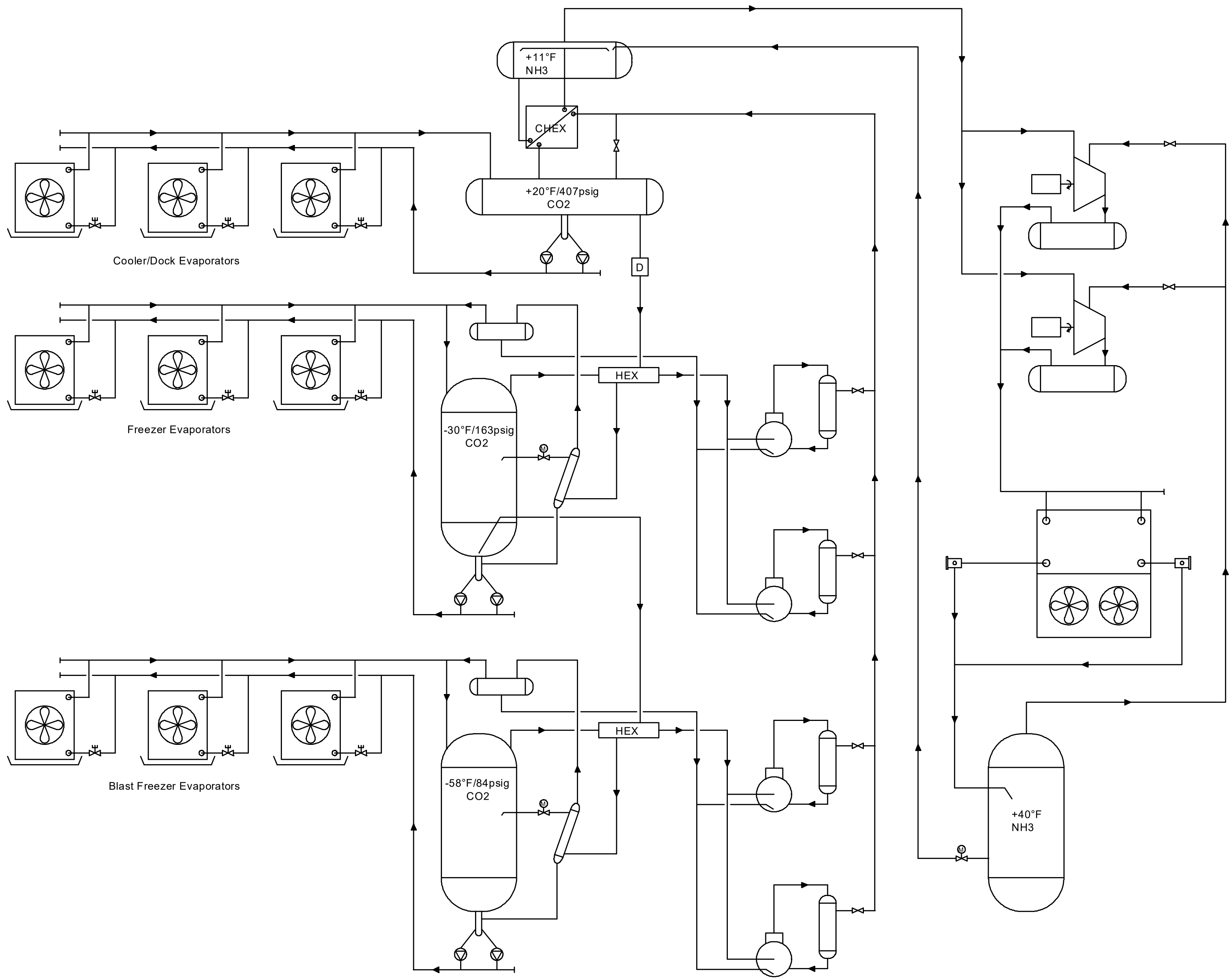


FIGURE A2

NH3/CO2 with low side compression. CO2 pumped med and low temps. Hot Gas defrosting. CO2 recip compressors.

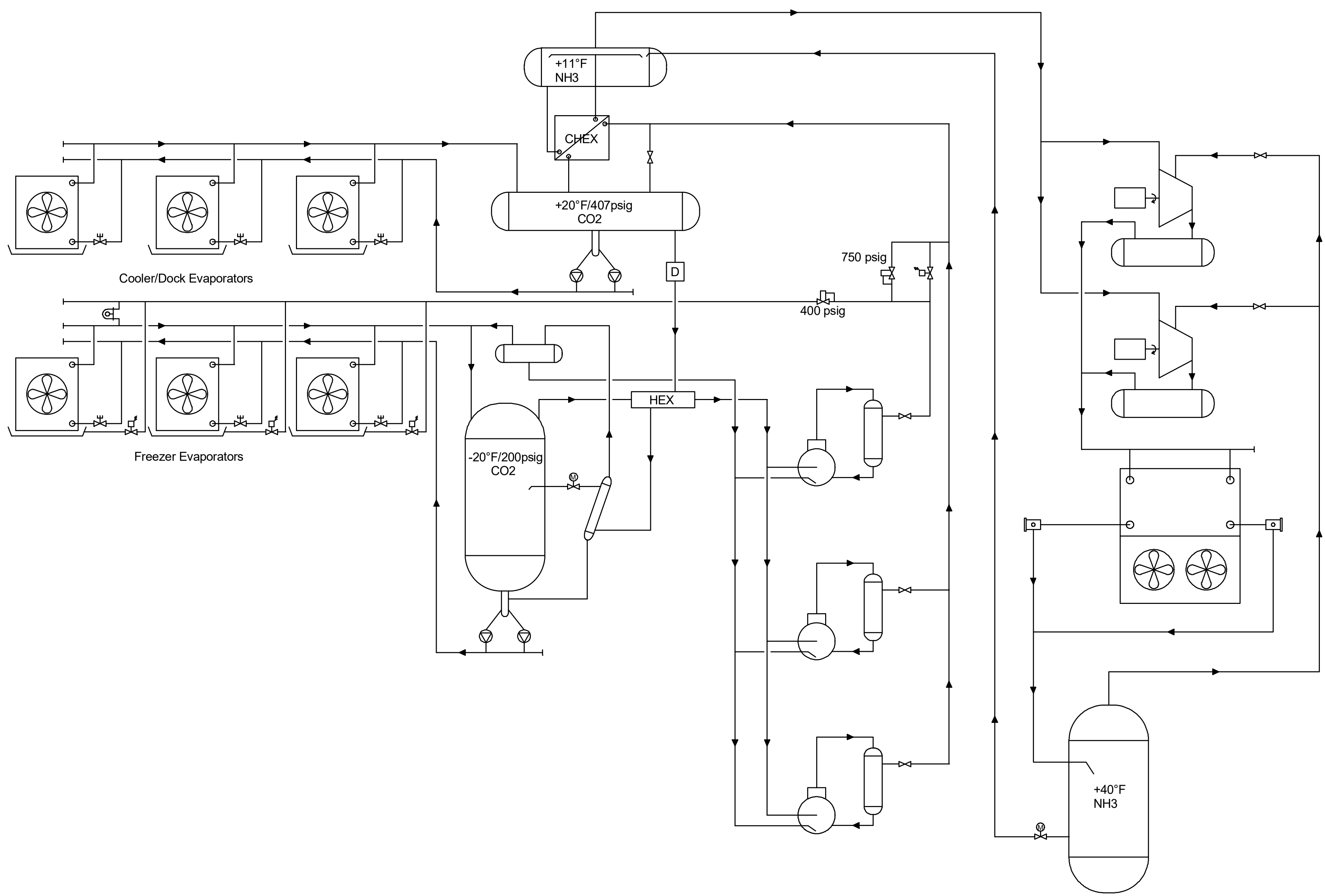


FIGURE A3

NH3/CO2 with low side compression. CO2 pumped med temp. DX low temp. Elec or Water defrosting. CO2 recip compressors.

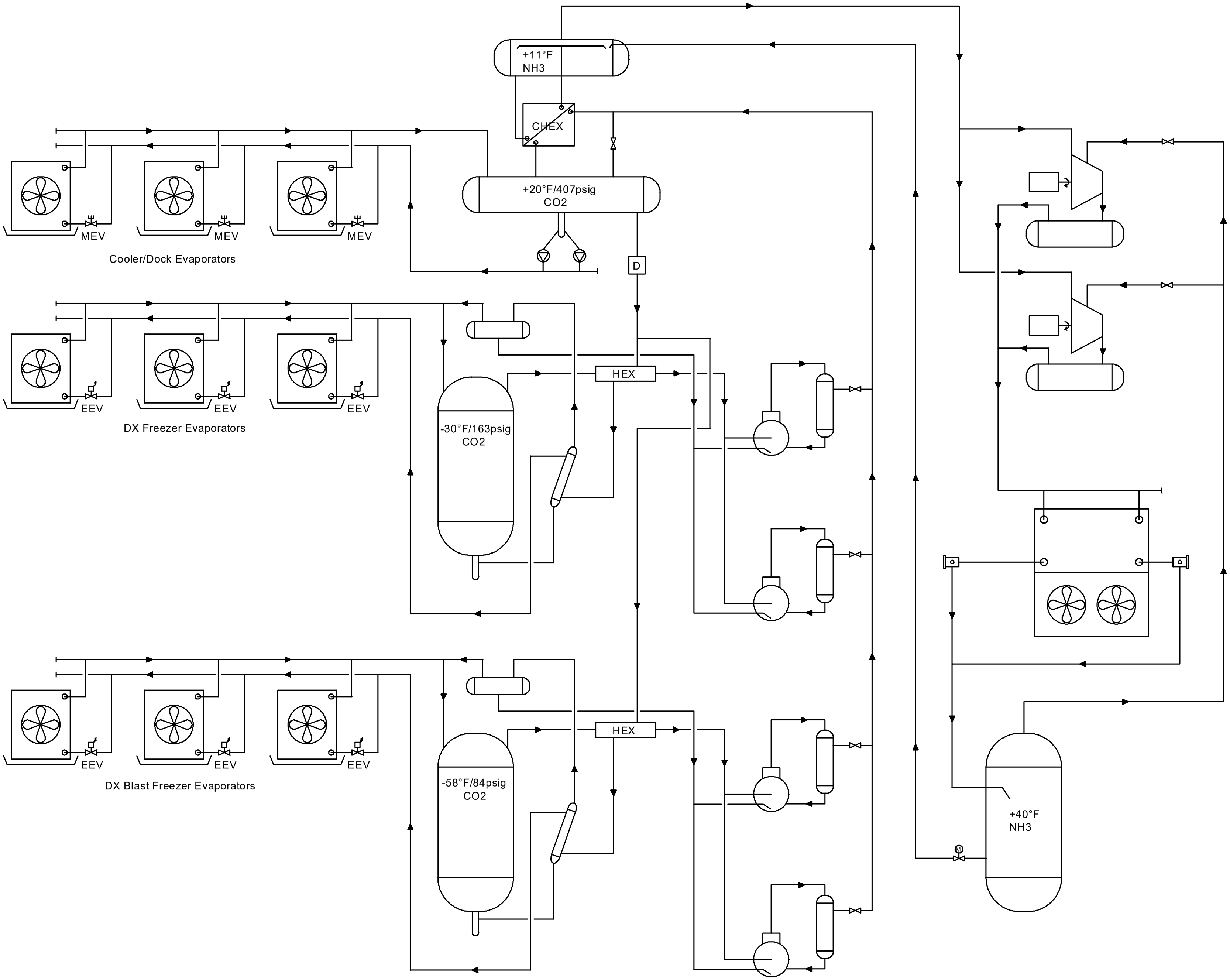


FIGURE A4

NH3/CO2 with low side compression. CO2 pumped med temp, DX low temp. Elec or Water defrosting. CO2 screw compressors.

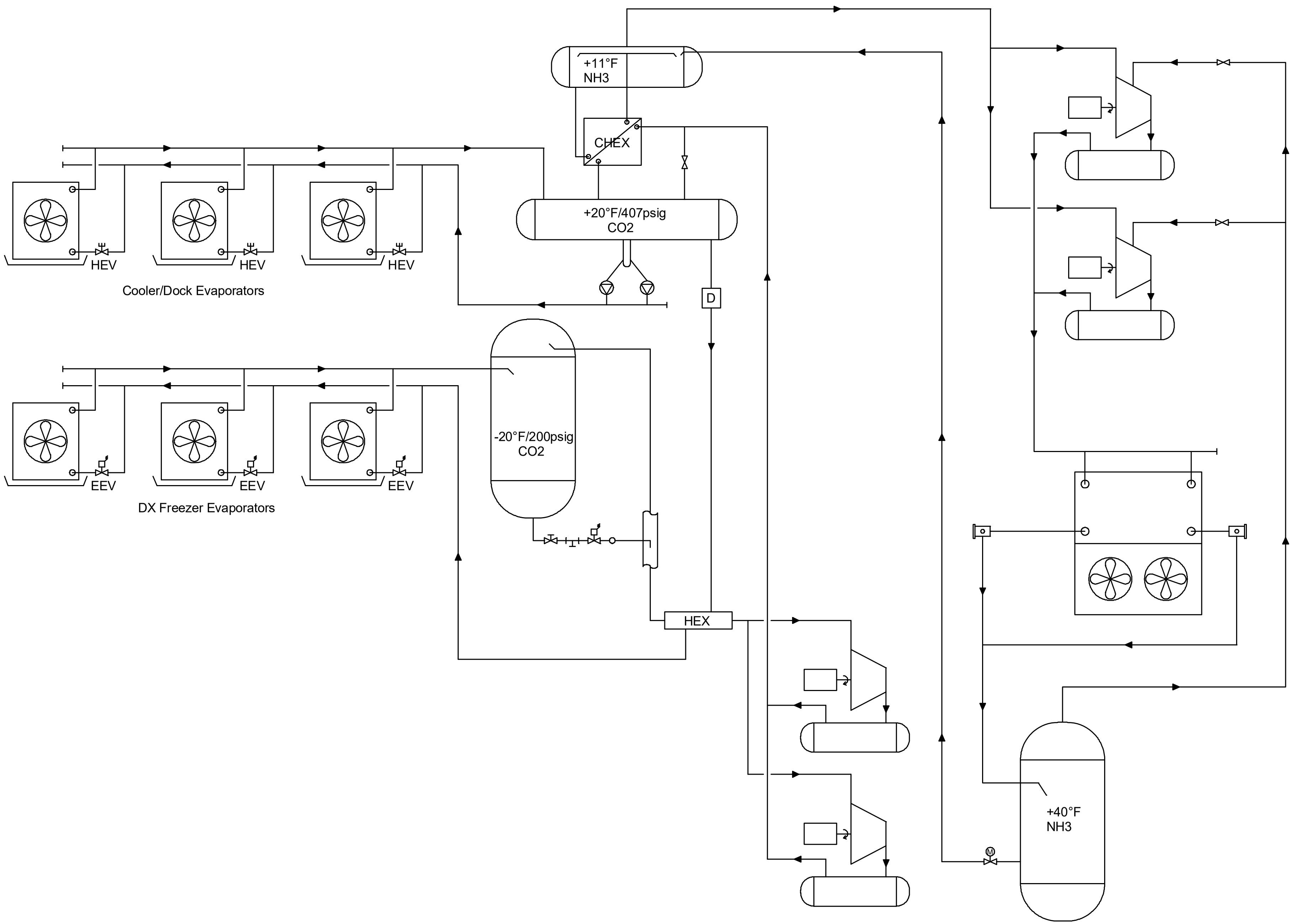


FIGURE A5

NH3/CO2 without low side compression. CO2 pumped. Elec or Water defrosting. CO2 recip compressors.

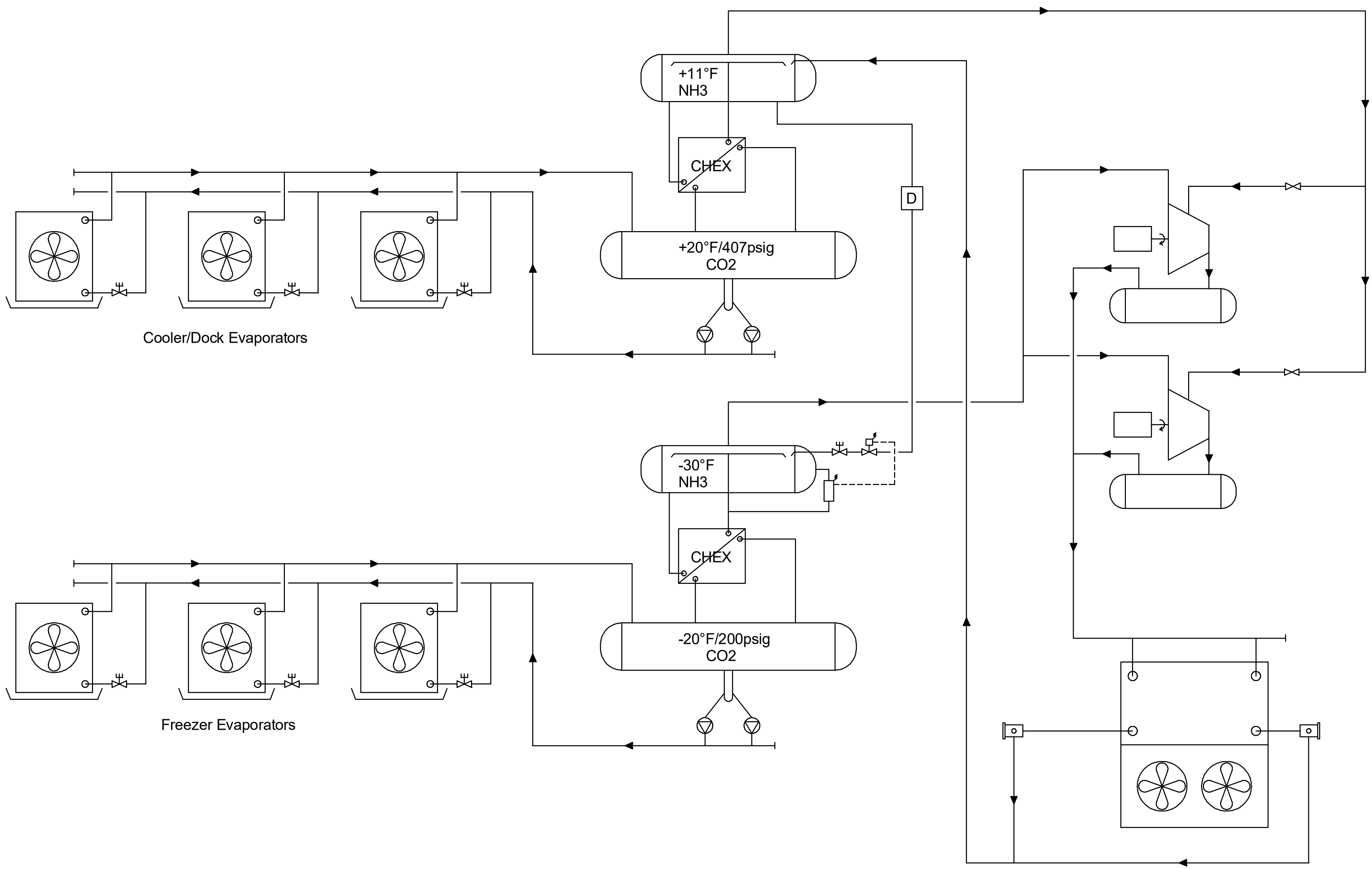


FIGURE A6
Control Valve Group for Top Feed Pumped CO2 Evaporator. Single Temperature Level. Electric Defrost.

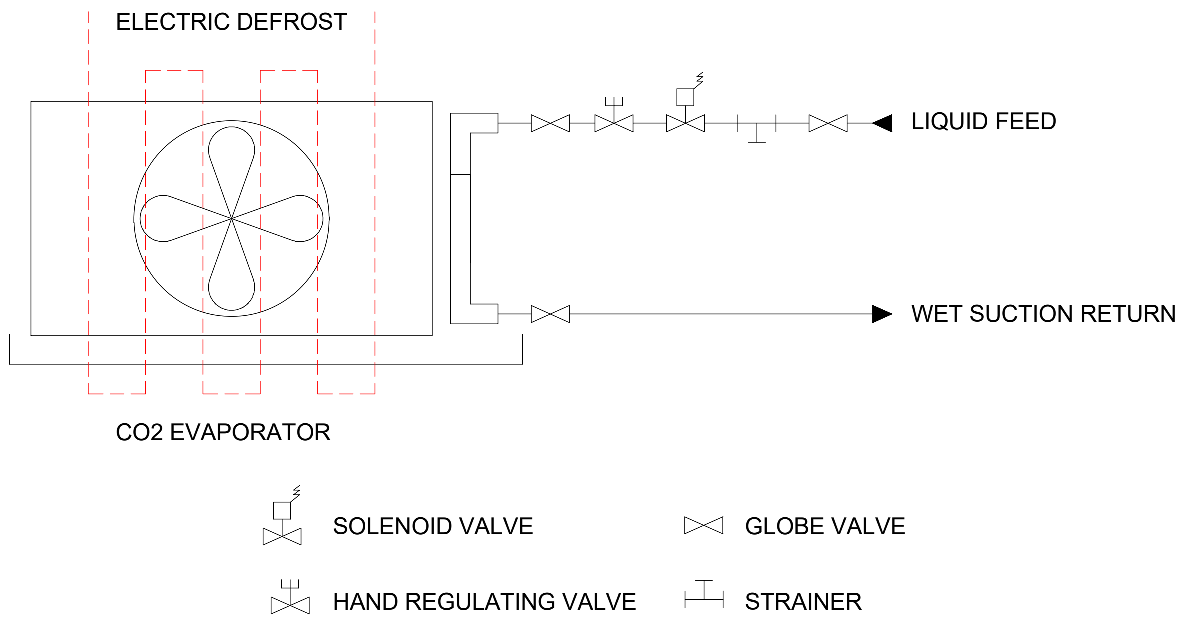


FIGURE A7
Control Valve Group for Top Feed Pumped CO2 Evaporator. Multi-Temperature Levels. Electric Defrost.

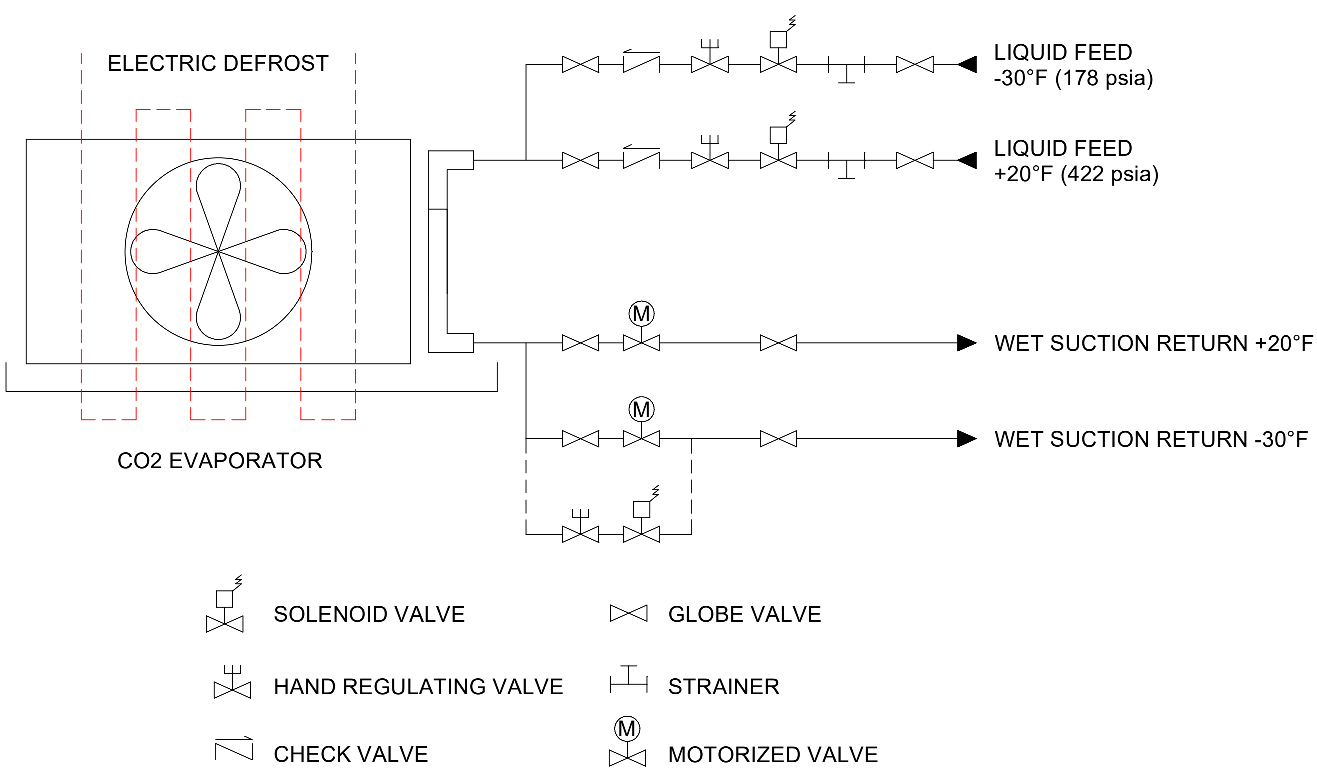


FIGURE A8

Control Valve Group for Bottom Feed Pumped CO2 Evaporator. Single Temperature Level. Electric Defrost.

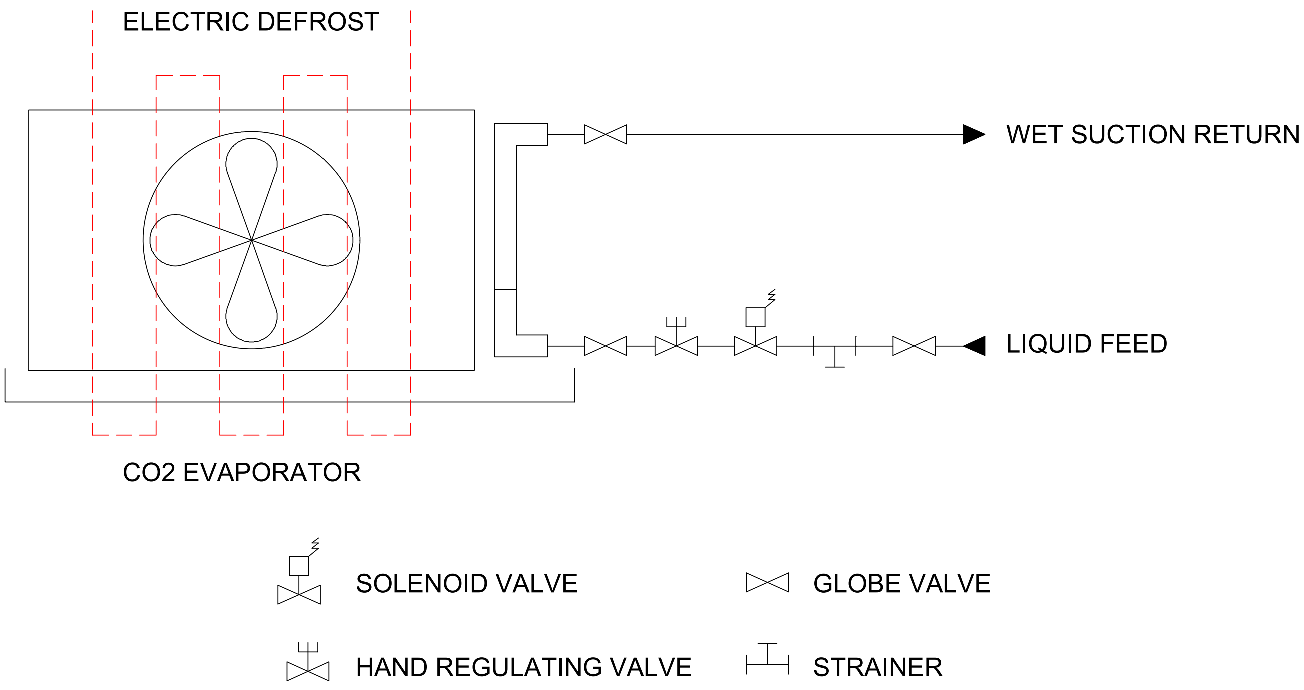


FIGURE A9

Control Valve Group for Bottom Feed Pumped CO2 Evaporator. Multi-Temperature Levels. Electric Defrost.

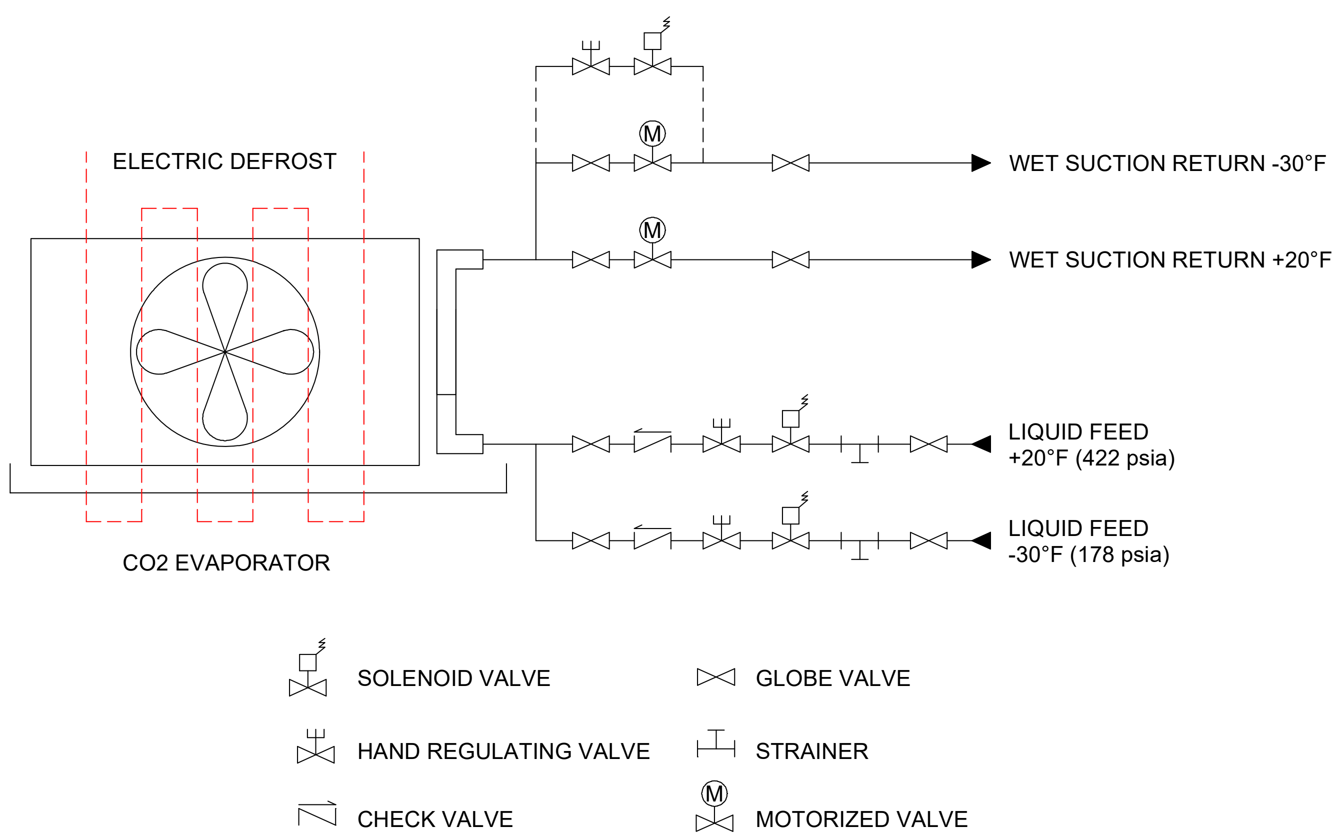
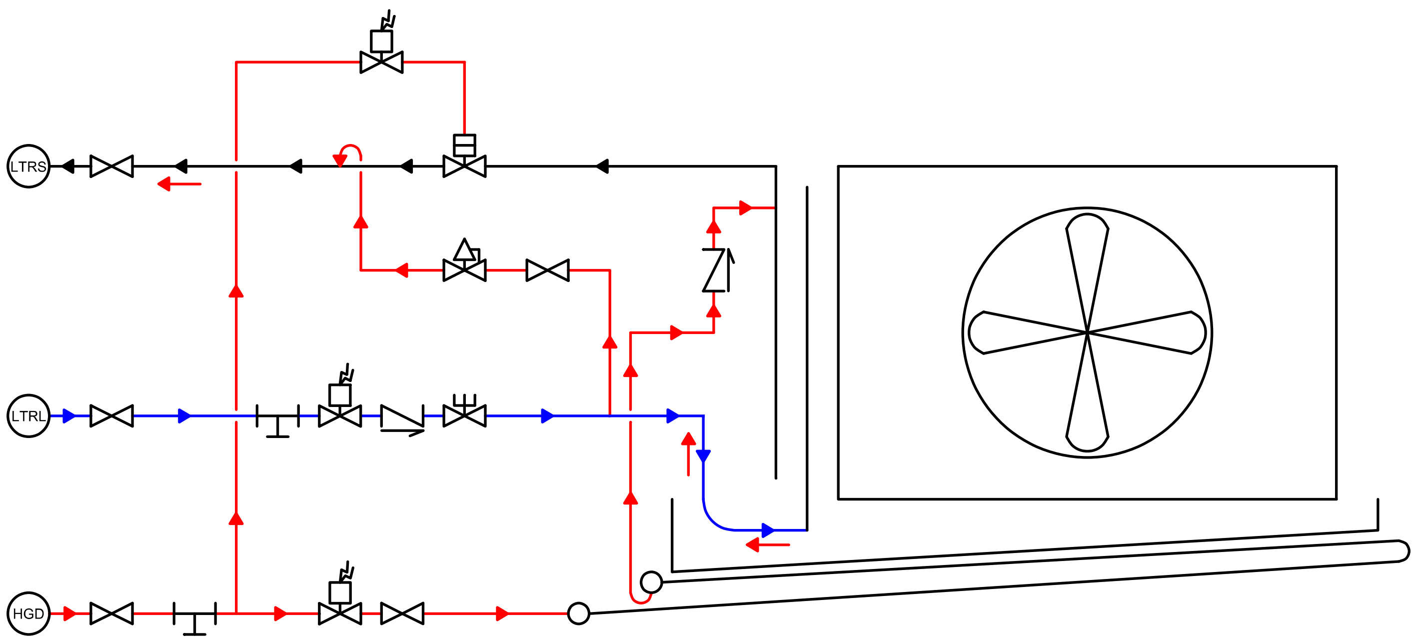


FIGURE A10

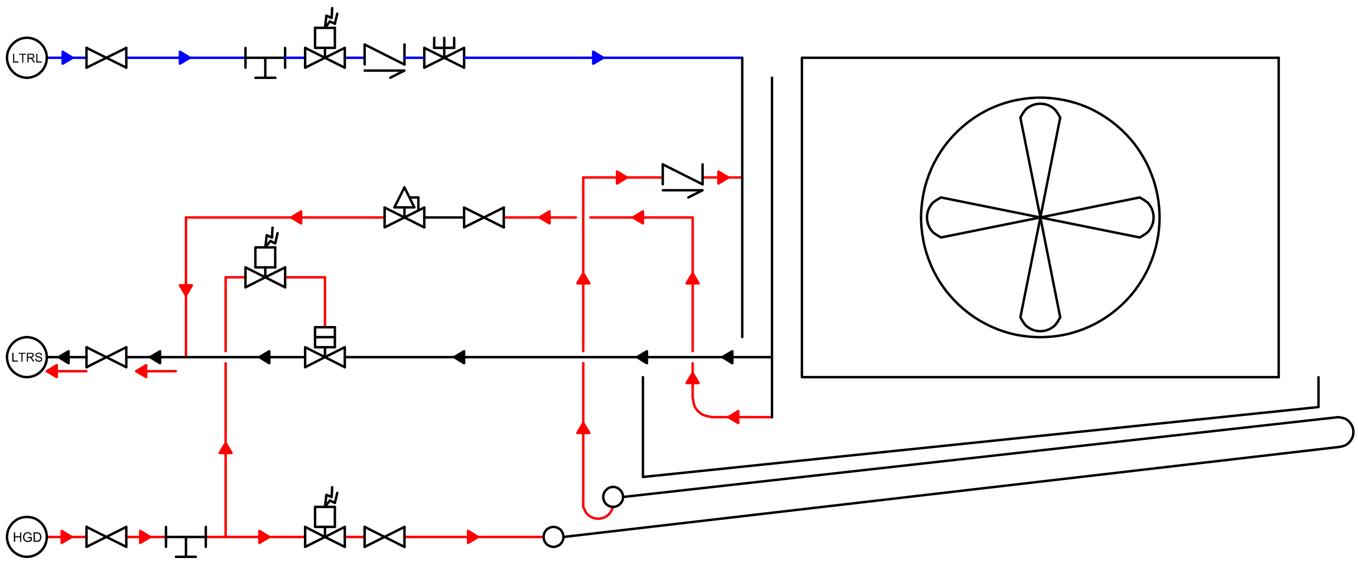
Control Valve Group for Bottom Feed Pumped CO2 Evaporator. Single Temperature Level. Hot Gas Defrost.



STRAINER	HGD — HOT GAS DEFROST SUPPLY
CHECK VALVE	LTRS — LOW-TEMP RECIRCULATED SUCTION
GLOBE VALVE	LTRL — LOW-TEMP RECIRCULATED LIQUID
SOLENOID VALVE	HOT GAS FLOW
DEFROST PRESSURE REGULATOR	SATURATED LIQUID FLOW
GAS POWERED SUCTION STOP VALVE	SATURATED LIQUID & VAPOR FLOW
HAND EXPANSION VALVE	

FIGURE A11

Control Valve Group for Top Feed Pumped CO2 Evaporator. Single Temperature Level. Hot Gas Defrost.



(symbol)	STRAINER	HGD	HOT GAS DEFROST SUPPLY
(symbol)	CHECK VALVE	LTRS	LOW-TEMP RECIRCULATED SUCTION
(symbol)	GLOBE VALVE	LTRL	LOW-TEMP RECIRCULATED LIQUID
(symbol)	SOLENOID VALVE	(red arrow)	HOT GAS FLOW
(symbol)	DEFROST PRESSURE REGULATOR	(blue arrow)	SATURATED LIQUID FLOW
(symbol)	GAS POWERED SUCTION STOP VALVE	(black arrow)	SATURATED LIQUID & VAPOR FLOW
(symbol)	HAND EXPANSION VALVE		

COLMAC COIL Manufacturing Inc.

Technical Bulletin

By Bruce I. Nelson, P.E., President, Colmac Coil Manufacturing, Inc.

SELF-POSITIONING SYSTEM FOR ELECTRIC RESISTANCE DEFROST HEATING ELEMENTS (US PATENT NO. 7,712,327)

Background

Air-cooling heat exchangers operating at temperatures below the freezing point of water (32F) will accumulate frost on fin and tube surfaces which must be removed periodically in order to maintain system cooling capacity. One method of removing frost involves tubular electric resistance heating elements inserted in vacant tube spaces within the heat exchanger fin bundle. These heating elements are energized periodically to warm the frosted fin and tube surfaces sufficiently to melt the frost which is then captured as liquid water and removed from the space being refrigerated. After all of the frost has been melted and removed from the heat exchanger, the heating elements are de-energized and the heat exchanger is cooled back down to refrigerating temperature. This periodic removal of frost is termed a “defrost cycle”.

As the heating elements warm up during a defrost cycle, melted frost in the form of liquid water can make its way into the space(s) occupied by the heating element(s). This liquid water re-freezes at the end of the defrost cycle, attaching itself to the heating element and to the sides of the space occupied by the heating element. As the heating element cools back down to refrigerating temperature its length is reduced by an amount equal to the coefficient of linear expansion of the metal in the heating element sheath times the length of the element times the temperature difference between the freezing point of water (32F) and refrigerating temperature. In the case of long heating elements typically found in commercial and industrial heat exchangers, the amount of expansion and contraction during the defrost cycle can be relatively large (greater than ½” for a 240” long heating element operating in a –30F refrigerated environment).

If the heating element is unrestrained, this repeated heating and cooling with its associated re-freezing of melted frost and contraction of the heating element results in the heating element “creeping” or “walking” out of the heat exchanger. The re-freezing of liquid water onto the surface of the contracting heating element generates extremely powerful forces acting to slowly move the heating element along the length of the vacant space in the heat exchanger. If the heating elements are allowed to creep or walk out of the heat exchanger, damage to electrical wiring and to the element itself will result. Simply restraining the heating element with a rigid clamping system is insufficient to keep the heating element from creeping or walking – a simple clamp cannot be designed that is strong enough to resist these forces!

Colmac Breakthrough Technology

Colmac is proud to introduce a new technology designed and proven to solve this problem. The Colmac Self-Positioning Defrost Element System provides a means of restraining electric resistance heating elements used for defrosting air-cooling heat exchangers in a way which allows limited movement of the heating element during heating and cooling but acts to return the element to its original proper position in the heat exchanger at the beginning of the next defrost cycle.

The newly patented system effectively eliminates the possibility of heating elements creeping or walking out of the heat exchanger thus preventing damage to the element or to electrical wiring attached to the element. The new system has been shown in many field installations to insure proper operation of these heating elements over their normal working life.

The Colmac system also simplifies installation of heating elements compared to current designs by minimizing the number of parts required to securely mount heating elements in the heat exchanger. In addition, the need for a separate ground strap to electrically ground the heating element sheath is eliminated.

How It Works

The Colmac Self-Positioning Defrost Element System is simple!

It works by means of a spring which is attached securely to both the heating element sheath and to the coil tubesheet. The spring allows movement of the heating element in either direction parallel to the axis of the heating element. Movement of the heating element is caused when melted frost in the form of liquid water re-freezes and bonds the heating element sheath to an adjacent heat exchanger surface at a point along the length of the heating element while the element continues to shrink as it cools to refrigerating temperature. During the next defrost cycle the defrost element heats up, ice is melted, and the spring brings the element back to its original position in the coil.

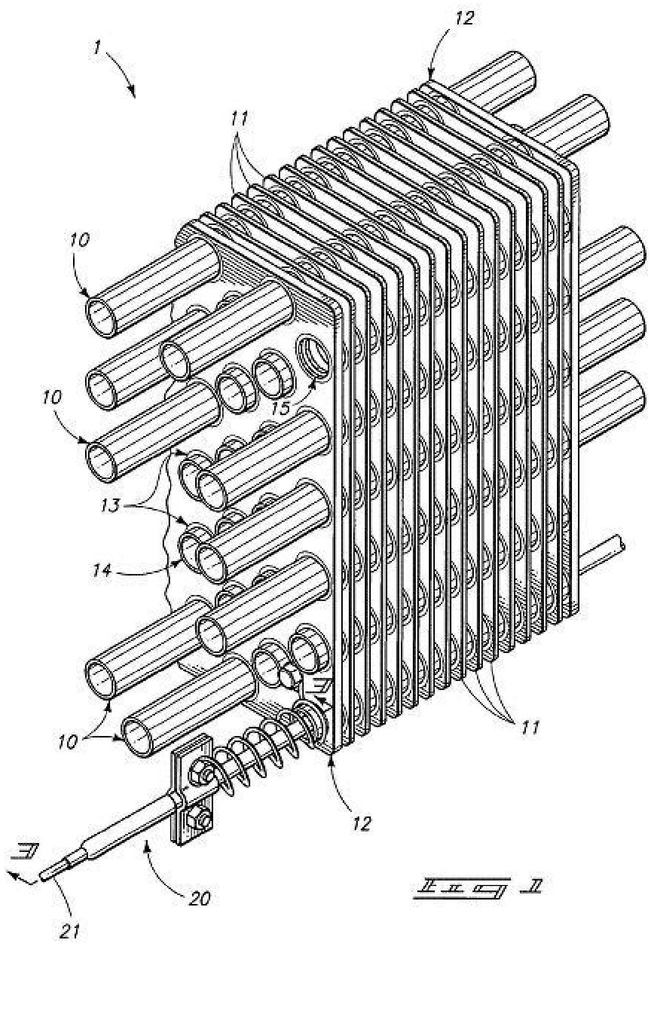
Benefits

The Colmac Self-Positioning Defrost Element system improves the reliability of electric defrost (extends the life of heating elements), and reduces first costs (wiring and installation) by:

- Eliminating damage to the defrost elements and electrical wiring caused by heating elements "creeping" out of the coil,
- Simplifying electrical wiring by eliminating the need for separate grounding of the defrost element

This new design from Colmac is offered as a standard feature on all Colmac electric defrost evaporators, and can even be supplied as a retrofit to existing evaporators. Finally, trouble-free electric defrost is possible! Demand Colmac Self-Positioning Electric Defrost on your next electric defrost evaporator order!

Figure 1 below shows the Colmac Self-Positioning Defrost Element System (item 20) installed in a finned-tube coil (item 12).



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COLMAC COIL Manufacturing Inc.

Technical Bulletin

By Bruce I. Nelson, P.E., President, Colmac Coil Manufacturing, Inc.

"OPTIMIZING HOT GAS DEFROST"

Introduction

Several methods are commonly used to remove accumulated frost from air cooling evaporators which operate below freezing. They include; water, electric, and hot gas defrost. If designed and operated properly, hot gas defrost offers the refrigeration system operator a method which is effective, automatic, reliable, and safe.

Why is using hot gas an effective method of defrosting evaporators?

1. The evaporator becomes a condenser. During the hot gas defrost process, high pressure hot gas from the discharge side of the compressor is introduced into the evaporator in a controlled fashion where it condenses back to its liquid state.
2. The latent heat of the refrigerant is used. The process of condensing releases a large amount of energy, equal to the mass flow rate of the hot gas entering the evaporator times the latent heat of vaporization of the refrigerant. The heat released during condensing is called "latent" heat since there is no change in temperature during the condensing process (the term latent means "hidden"). If the condensing pressure is held constant, the condensing process will take place at a constant temperature. The amount of heat released during the condensing process is much greater than the amount of heat released when superheated gas is cooled without condensing (called "sensible" cooling).
3. The condensed liquid is "recycled" and sent directly back to other evaporators. The condensed liquid from the defrosting evaporator is expanded into the wet suction line and returned to the Low Pressure Receiver (LPR) or Intermediate Pressure Receiver (MPR) where it is "recycled" and pumped directly back out to evaporators.
4. Hot gas defrost acts like a heat pump to "move" heat. A heat pump moves heat "uphill" by gathering energy at a low temperature level in the evaporator, compressing the evaporated refrigerant to a higher pressure, then releasing the energy at a higher temperature level during the condensing process. This process is 7 to 8 times more energy efficient than burning fossil fuel or electricity directly to produce the same heating effect. In the same way the heat used for hot gas defrosting has actually been gathered from the refrigerated space by the operating evaporators, then "moved" to the defrosting evaporators by the compression process at a refrigerant pressure and temperature high enough to melt the frost. Hot gas defrosting is very energy efficient!

Defining Defrost Efficiency

A generally accepted definition of defrost efficiency is shown below:

$$\eta_D = \frac{Q_f}{Q_{total}}$$

where:

$\eta_D =$ *Defrost Efficiency*

$Q_f =$ *Heat to warm and melt frost*

$Q_{total} =$ *Total energy input for defrost*

The absolute minimum amount of heat required for an ideal defrost (100% efficient) would equal just enough to warm and melt the frost itself. Any additional heat applied to the evaporator reduces the defrost efficiency to less than 100%. Unfortunately, heat must be applied at the start of the defrost cycle to heat the metal of the evaporator from the evaporating temperature up to 32F (0C). This heat must then again be removed at the end of defrost when the refrigeration system is restarted. Heat must also be added to the drainpan to keep the melted frost liquid long enough to escape the refrigerated space through the drain. This heating (and cooling) of the coil and drainpan metal is unavoidable and results in a reduction in the ideal maximum defrost efficiency.

Defrost efficiency is also reduced when some of the defrost heat is lost to the room as heated air (convection) and radiation. Finally, hot gas bypassing the defrost regulator at the end of the defrost cycle represents another loss by imposing a false load on the compressor, and further reduces defrost efficiency. Improving defrost efficiency by reducing these last two types of defrost heat losses is the subject of the following discussion.

How efficient is a typical freezer defrost?

Cole (1989) observed that most freezer evaporators operate with ***defrost efficiency of only 15% to 20%***. Of the total defrost energy input he determined that:

- 15 to 20% was utilized to melt the frost,
- 60% was lost to the room via convection and radiation,
- 20% was required to heat and cool the metal in the evaporator, and
- about 5% was lost due to hot gas bypassing the defrost regulator at the end of defrost.

Cole further suggested that the maximum theoretical defrost efficiency was probably in the range of 60% to 70%.

Defrost efficiency will be reduced as energy lost to the room during defrost increases. The amount of heat lost to the room is directly affected by room temperature (a colder room will have larger convective losses), the duration of the defrost (a longer defrost will result in more convective heat loss), and the temperature of the hot gas (higher temperature hot gas will result in more convective losses). The frequency of defrosts and amount of accumulated frost will also affect defrost efficiency, that is, more accumulated frost will directly increase defrost efficiency by the equation shown above.

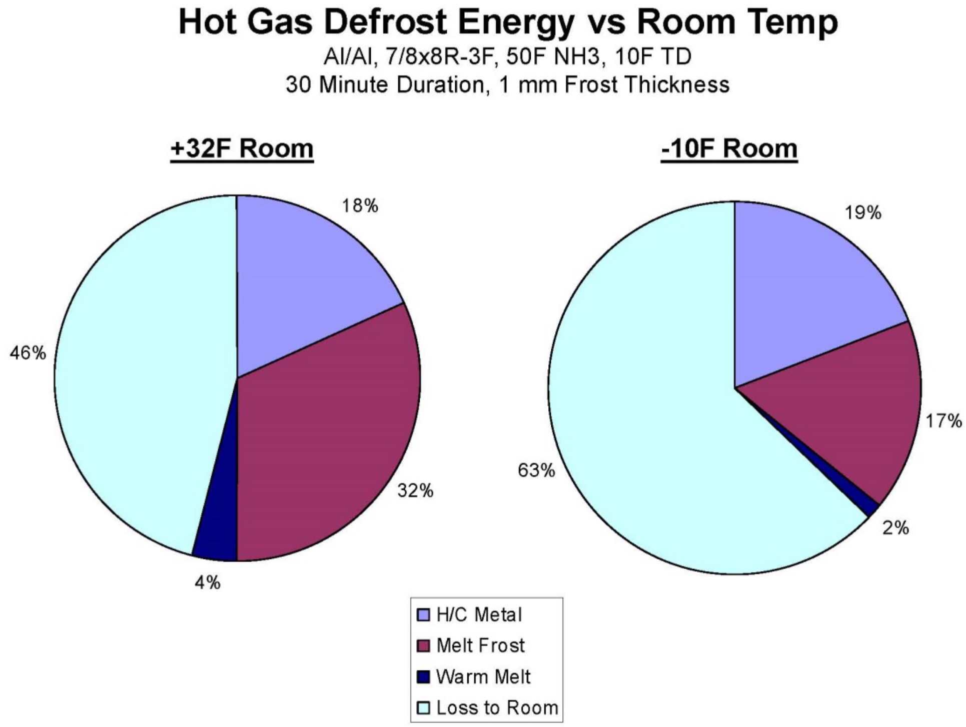
A heat transfer model was written for a typical industrial evaporator to examine how defrost efficiency is affected by:

- Room temperature,
- Hot gas temperature,
- Duration of defrost,
- Frost thickness, and
- Materials of construction

Room Temperature

As room temperature is reduced, the defrost heat lost to the room due to convective heating of air unavoidably becomes greater. This means that defrost efficiency in a freezer room will always be less than defrost efficiency in a medium temperature room. Figure 1 below illustrates the greater convective heat loss in the freezer (63%) compared to the medium temperature room (46%), and the resulting lower defrost efficiency in the freezer (17%) versus the medium temp room (32%). Note that the defrost efficiency is equal to the “Melt Frost” percentages shown in the charts. This highlights the relatively large amount of heat that is lost to the room during defrost due to convective air heating regardless of the room temperature. Reducing this convective heat loss by changing the design of the evaporator cabinet therefore represents an opportunity to significantly improve defrost efficiency and will be discussed later.

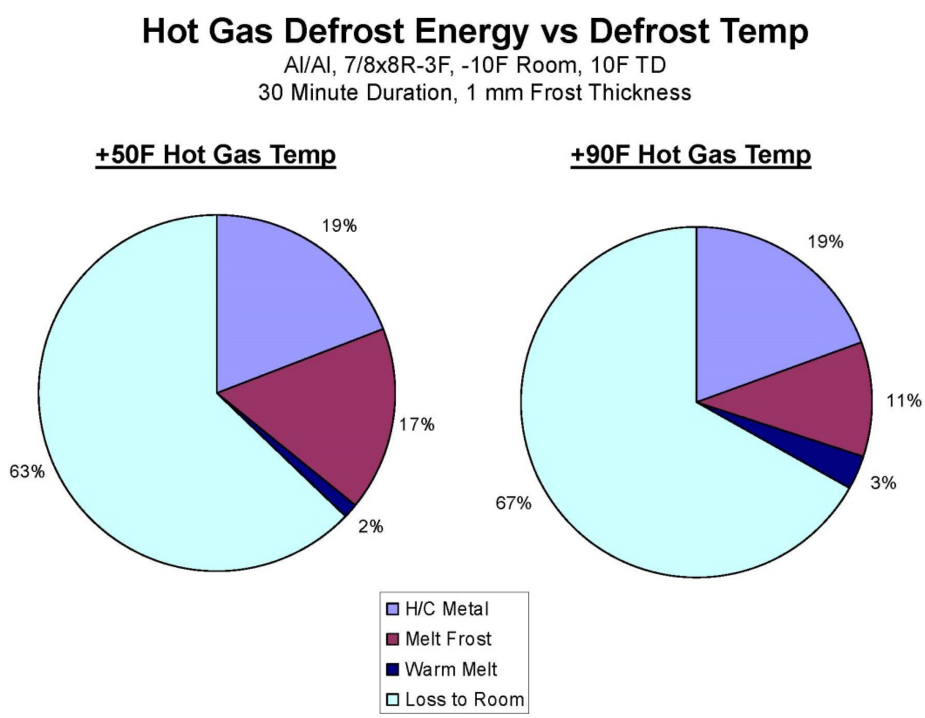
FIGURE 1



Hot Gas Temperature

Since the amount of convective heat loss to the room is directly affected by the temperature difference between hot gas temperature and room temperature, any increase in hot gas temperature above the absolute minimum required to melt the frost results in a proportional increase in the convective loss. It is generally accepted that the practical minimum hot gas temperature for effective defrosting is around 50F (a defrost regulator setting of 75 psig). Figure 2 illustrates how an increase in the hot gas temperature results in an increase in convective heat loss and reduction in defrost efficiency. It is the author's observation that in many facilities, the hot gas temperature is raised above the minimum required 50F in an attempt to clear the coil of ice due to some design related issue(s) such as ice buildup in drainpans, or improper defrost piping.

FIGURE 2



In a conventional hot gas control valve arrangement, hot gas pressure (and therefore defrost temperature) is determined by the defrost regulator setting. It is important to recognize that some minimum pressure difference between hot gas supply pressure and the defrost regulator setting must be maintained in order to provide enough "push" to keep clearing the condensed refrigerant out of the coil. A pressure differential of 15 to 20 psig should be sufficient to keep the coil clear of condensed refrigerant. If this pressure difference becomes too small (either hot gas supply pressure falls too low or the defrost regulator setting is too high) then condensed liquid refrigerant can accumulate in the coil tubes and become subcooled, typically in the bottom rows. Once the refrigerant liquid becomes subcooled it loses its ability to melt the frost and ice will accumulate.

Also, coil manufacturers must properly design evaporators to continuously drain and clear condensed refrigerant from the:

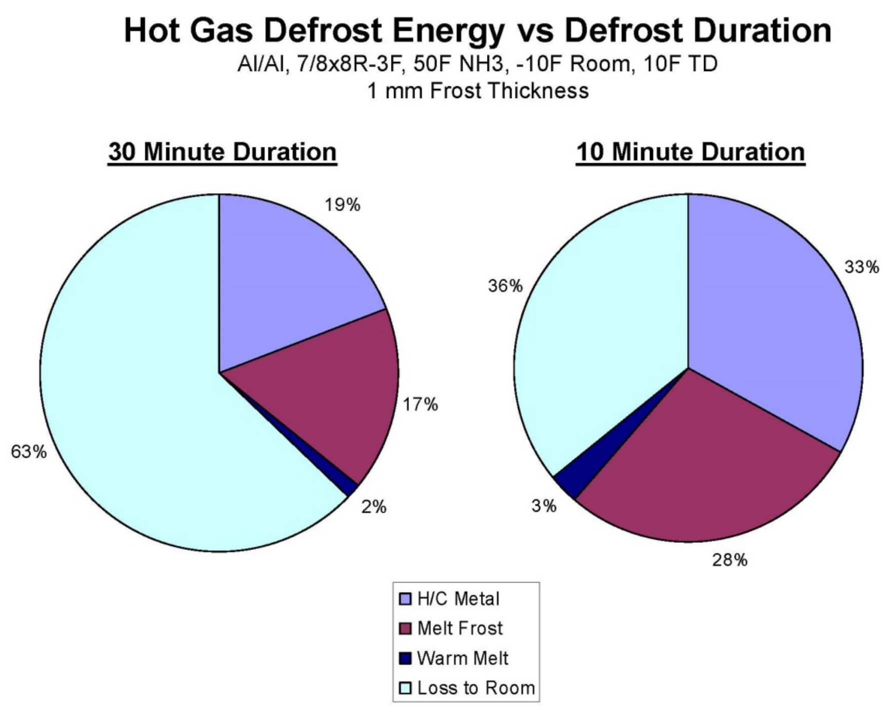
- Hot gas pan loop,
- Coil circuits, and
- Liquid header and connection

Designing the liquid header to effectively trap condensed refrigerant and form a liquid seal below the lowest tube in the coil is particularly important to avoid the problem of accumulating subcooled liquid in the bottom coil tubes mentioned above.

Duration of Defrost

Cole (1989) confirmed by his own measurements, and by the observation of others, that the minimum time required to melt the frost on evaporator tubes and fins is only between 8 and 10 minutes. However, it is the observation of the author that most evaporators in industrial refrigeration facilities have hot gas defrost duration settings in excess of 30 minutes, that is, the period of time the hot gas solenoid is open. Figure 3 shows the significant reduction in convective heat loss, and the increase in defrost efficiency, resulting from shortening the duration of defrost from 30 minutes to 10 minutes.

FIGURE 3

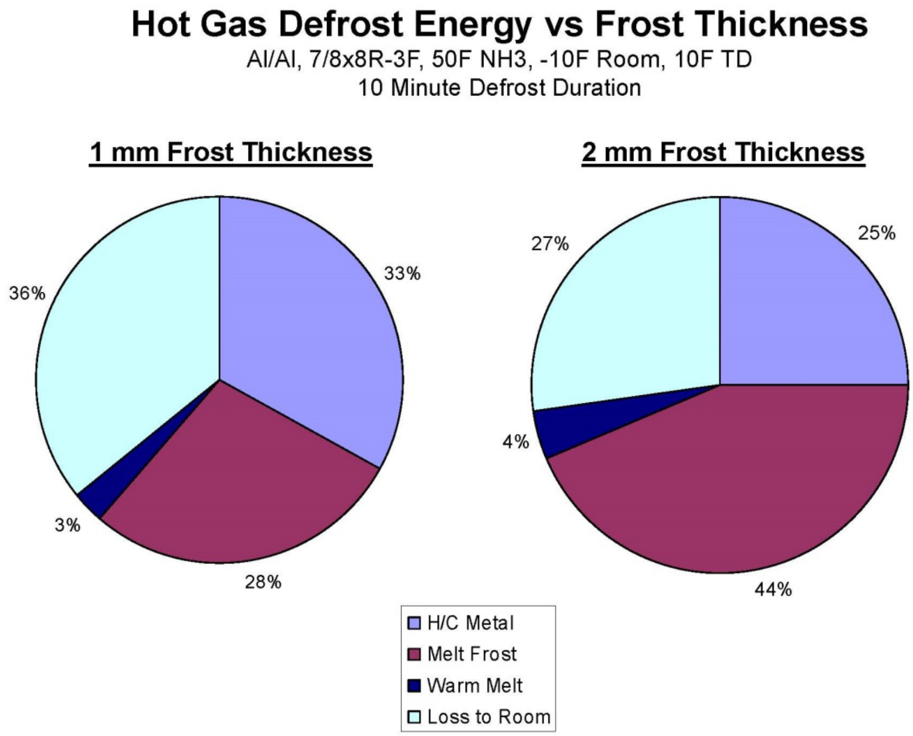


Defrost duration of longer than the minimum 10 minutes should not be needed, however, it is quite common to see defrost durations of 30 minutes or longer. This being a result of deficiencies in either the design of the evaporator (ice in drainpans or improperly trapped coil outlet connection), or in the defrost piping and/or controls.

Frost Thickness

The definition of defrost efficiency implies that increasing the amount of frost melted during defrost will directly increase the efficiency. Reducing the number of defrosts per day will increase frost thickness and increase efficiency of defrosting. Figure 4 shows the effect of increasing frost thickness from 1 mm to 2 mm, and confirms a significant increase in efficiency.

FIGURE 4



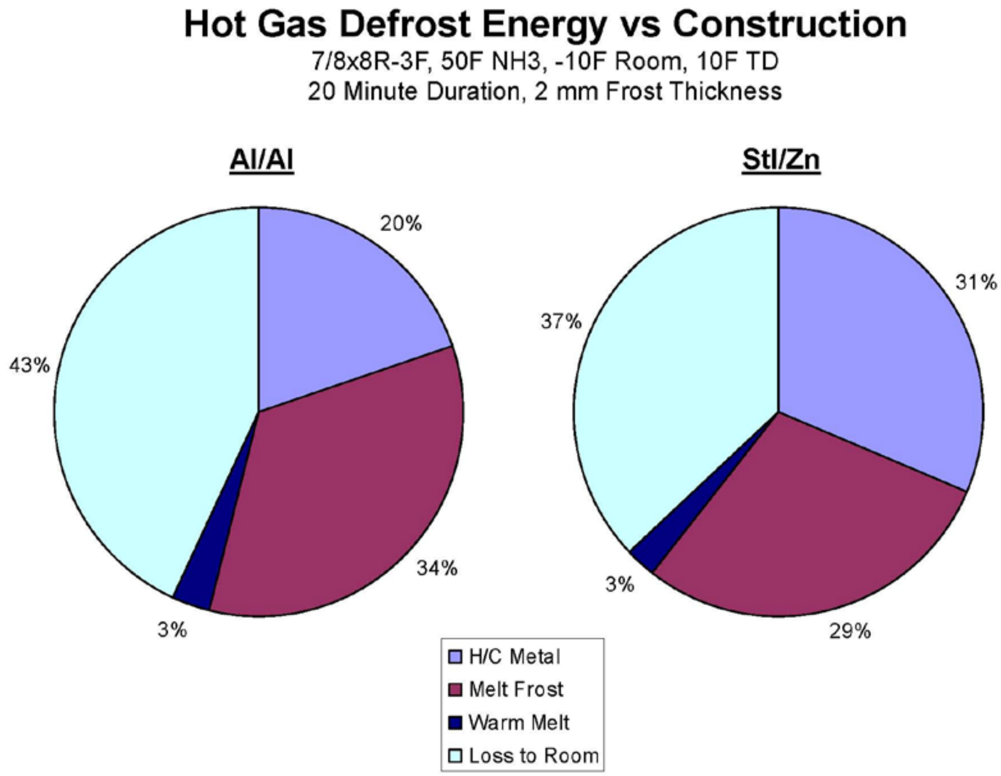
Reducing the number of defrosts per day may or may not be possible with existing installations, depending on the evaporator design. In order for evaporators to carry more frost on fin surfaces between defrosts, two design characteristics are needed:

1. Wide fin spacing. A fin spacing of 3 fpi (8.5 mm/fin) will allow more accumulated frost between defrosts compared to 4 fpi (6.4 mm/fin) with less restriction of airflow and less reduction in evaporator performance.
2. A large ratio of secondary (fin) to primary (tube) surface. Evaporators having very close tube spacing will have reduced total surface area for a given cooling duty and reduced frost carrying capability. Evaporators having tubes spaced farther apart will have greater total surface area and greater frost carrying capability. For example, an evaporator with 50mm tube spacing and 3 fpi will allow longer run time between defrosts than an evaporator with 38mm tube spacing and 4 fpi. More total surface area for a given cooling duty allows fewer defrosts per day.

Materials of Construction

Nelson (2003) showed that more energy is required to heat and cool the metal in a galvanized steel evaporator compared to an aluminum tube/aluminum fin evaporator during a defrost cycle. This is due primarily to the greater mass of metal in the galvanized steel construction. Figure 5 shows the reduction in defrost efficiency for a galvanized evaporator (Stl/Zn) compared to an all aluminum (Al/Al) one.

FIGURE 5



Summary: Defrost Efficiency

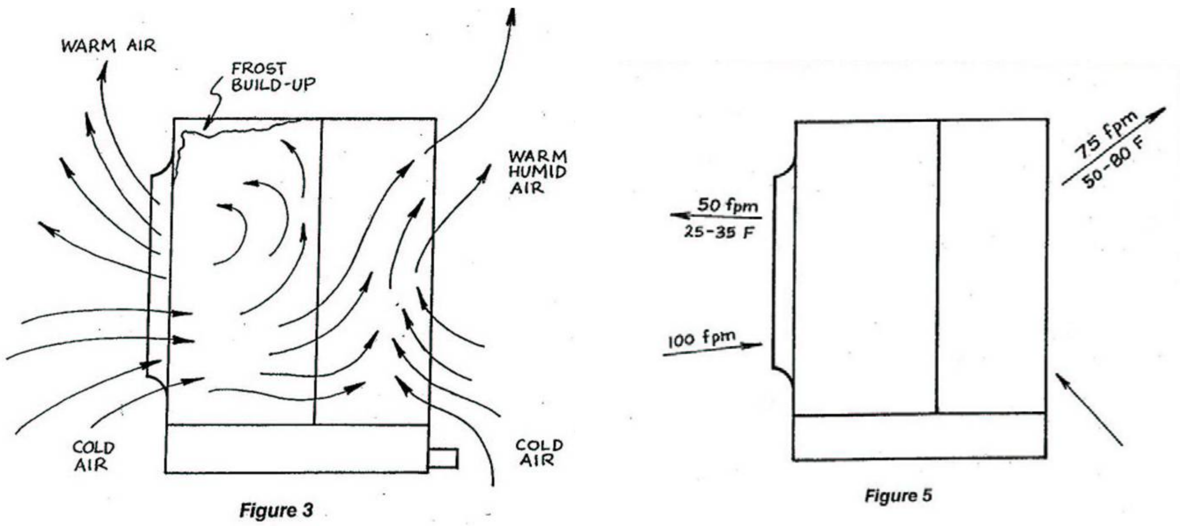
From the preceding discussion we can summarize:

1. Colder room temperatures will unavoidably have lower defrost efficiencies.
2. Defrost efficiency improves as:
   a) Hot gas temp is ***lowered***, and/or
   b) Defrost duration is ***shortened***, and/or
   c) Time between defrosts (frost thickness) is ***increased***.
3. Convective heat loss is a significant penalty in all cases.
4. Reducing *duration* and increasing *frost thickness* improved defrost efficiency from 17% to 44% in the freezer.
5. All aluminum (Al/Al) construction improved defrost efficiency from 29% to 34% in the freezer compared to galvanized steel (Stl/Zn). Note that all aluminum construction will also defrost faster than galvanized steel due to the much higher thermal conductivity of aluminum.

Reducing Convective Heat Loss

As shown above, reducing convective heat losses during defrost represents a significant opportunity to improve the energy efficiency of hot gas defrosts. Figure 6 below from Cole (1989) shows field measured air movement patterns and velocities taken during defrost.

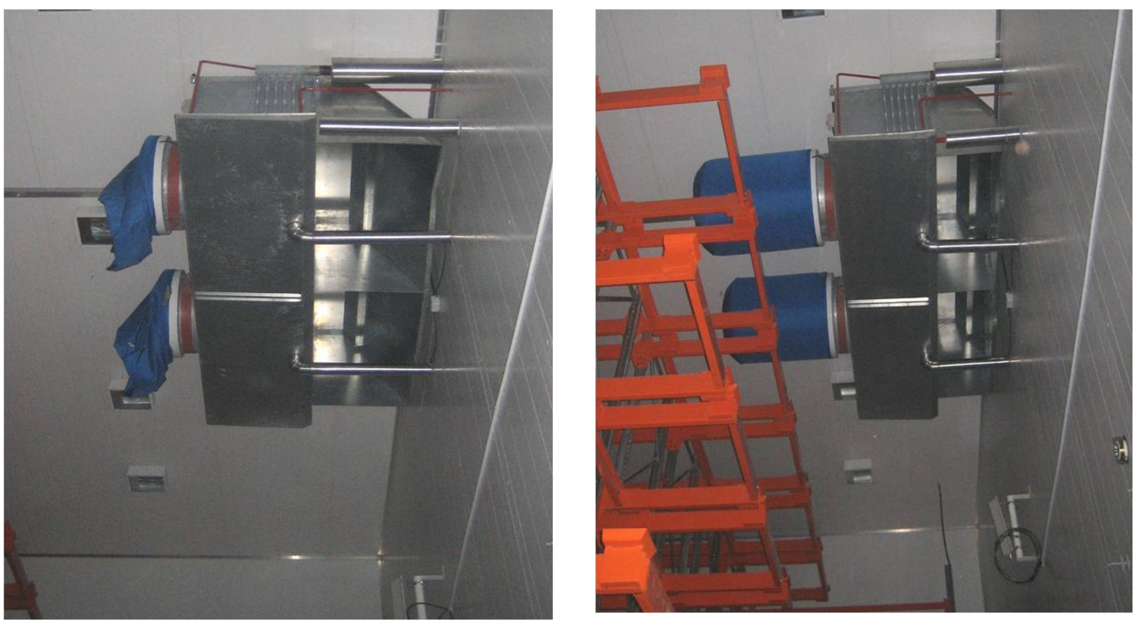
FIGURE 6
CONVECTIVE AIR MOVEMENT DURING DEFROST



Taken from: Cole, R.A. 1989. "Refrigeration Loads in a Freezer Due to Hot Gas Defrost and Their Associated Costs." *ASHRAE Transactions*, V.95, Pt.2.

The use of return air hoods, and fan discharge socks is a recent development now available as an option from several evaporator manufacturers. Return air hoods in combination with fan discharge socks effectively eliminate convective air movement and heat loss during defrost. Figure 7 shows typical return air hoods and fan discharge socks installed on an evaporator.

FIGURE 7
EVAPORATOR WITH RETURN AIR HOOD AND DISCHARGE SOCK INSTALLED



Return air hoods such as those shown are very effective. However, if care is not taken to (a) insulate the hood, and (b) actively heat the inside surfaces of the hood during defrost, then hoar frost and ice can build up on the inside surfaces of the hood and either block airflow or fall to the floor below. Also, fan discharge socks may require periodic removal for cleaning and de-icing.

Optimizing Hot Gas Defrost: Conclusions

From the above discussion, it can be seen that hot gas defrosting of evaporators can be made significantly more efficient by doing the following:

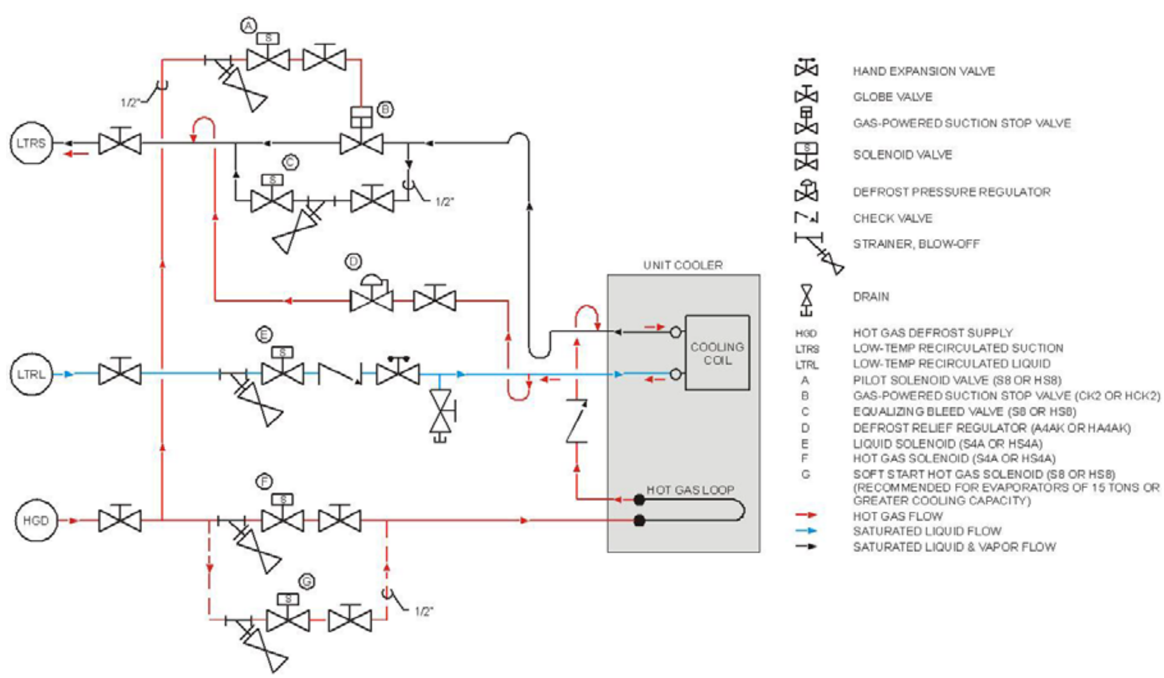
1. Minimize convective heat loss.
   - Use lowest practical defrost regulator setting. 75 to 90 psig (50 to 60F) should be adequate. Note: If higher pressures are needed, look for problems elsewhere.
   - Capture defrost heat (i.e. install Return Air Hoods).
2. Shorten defrost duration.
   - Open the hot gas solenoid only long enough to clear coil (8-10 minutes).
   - Install a separate hot gas solenoid and defrost regulator for pre and post-heating of the pan loop. Alternately, install electric resistance drainpan heating.
3. Reduce the number of defrosts per day.
   - Reduce the number of defrosts per day to match the frost load.
   - Choose evaporators with wide fin spacing (3 fpi instead of 4 fpi) and large secondary (fin) surface area to maximize frost carrying capacity.

Sequence of Operation

Referring to the piping diagram shown in Figure 8 below, a typical sequence of operation for hot gas defrosting is as follows:

1. Close Liquid Solenoid *with fans running*.
2. Pump down for as long as required to remove all liquid. NOTE: DX and top feed evaporators will require less time for pump down.
3. Stop fans.
4. Open Hot Gas Pilot Solenoid to close Suction Stop Valve.
5. On coils >15TR open Soft Start Hot Gas Solenoid to gradually bring coil up to near defrost pressure.
6. Open Hot Gas Solenoid and start defrost.
7. Hot Gas Solenoid stays open long enough to clear the coil of frost and keep the drainpan heated until completely drained.
8. Close Hot Gas Solenoid to end defrost.
9. Open Equalizing Bleed Valve to gradually bring coil down to suction pressure.
10. Close Hot Gas Pilot Solenoid to open Suction Stop Valve.
11. Open Liquid Line Solenoid to start cooling.
12. After delay, restart fans.

FIGURE 8
TRADITIONAL BOTTOM FEED HOT GAS DEFROST PIPING



The control valve arrangement shown in Figure 8 sends hot gas first through the drainpan loop and then in series through the coil block. This commonly used arrangement is effective and simple, however, it requires that the hot gas solenoid remain open to keep the drainpan heated long enough for all water to completely drain and exit through the drain piping. Convective heat loss to the room continues after the coil is clear of frost while the pan is draining. As mentioned above, a more efficient arrangement would control hot gas to the coil block and to the drainpan loop separately through two hot gas solenoids and two defrost regulating valves. This separate control of pan heating can also be accomplished by electrically heating the drainpan. This arrangement shortens the amount of time hot gas is flowing through the coil block, minimizing the convective heat loss and maximizing defrost efficiency.

Design for Reliability

Reliable operation of the hot gas defrost system depends on an adequate supply of hot gas throughout the defrost cycle. Remember to:

1. Correctly size and insulate hot gas lines according to IIAR guidelines (IIAR 2004).
2. Make sure 2 coils are running for every coil that is defrosting. This is because the evaporator has approximately twice the condensing capacity as evaporating capacity during defrost.
3. Control the system head pressure to maintain a minimum hot gas supply pressure that is 15 to 20 psi above the defrost regulator setting. For example, if the defrost regulator is set at 80 psig, then hot gas pressure supplied to the hot gas solenoid at the coil should be maintained (throughout the year) at a minimum of 100 psig.

Reliable hot gas defrost operation also depends on correct selection and sizing of control valves. Control valve manufacturers' literature and guidelines should be consulted. Oversized hot gas control valves will typically "chatter", which can cause excessive noise and premature failure of valves.

Design for Safety

Safety must always be a primary consideration when designing and operating an ammonia hot gas defrost system. Remember, as a minimum, to do the following:

1. Use good piping practice per the IIAR Piping Handbook (2004).
2. Keep hot gas lines clear of liquid by pitching down toward liquid drainers.
3. Always equalize pressure after defrost before opening Suction Stop Valve.
4. On coils >15TR always use a Soft Start Hot Gas Solenoid to gradually come up to defrost pressure.
5. Develop and maintain a complete PSM-RMP (Process Safety Management – Risk Management Program) for your ammonia refrigeration system.
6. Develop and maintain a culture of safety training and preparedness throughout all levels of your organization.

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By Bruce I. Nelson, P.E., President, Colmac Coil Manufacturing, Inc.

WATER DEFROSTING AT FREEZER TEMPERATURES

Introduction

The following guidelines should be used when designing water defrost systems for low temperature freezer applications.

1. Water defrost is fast and effective at medium *and* low temperatures.

2. Coil steaming can be minimized by keeping water temperatures below about 60F. Typically, frost accumulation problems in cold stores are the result of excessive infiltration of humid outside air. Water defrost generally produces less steam over the defrost period compared to hot gas and electric defrost, due to its shorter duration and lower temperatures.

3. Water temperature must be kept above 40F to avoid refreezing problems.

4. Use of cooling tower or evaporative condenser sump water is not recommended because of entrained sediments that will be present. If sump water is used it must be filtered. Also, water temperatures must be controlled to avoid excessive steaming. Normally, tap water can effectively be used for water defrosting if kept within the temperature range mentioned above.

5. In low temperature applications, it is critical that water be allowed to completely drain from water supply lines and control valves when defrost is terminated to avoid freezing. See Installation, Operation & Maintenance manual for instructions.

6. One potential nightmare in low temperature cold stores is a water supply valve that sticks and allows water to continue to flow to the air cooler after defrost has terminated. Water must be filtered, and piping designed to eliminate this possibility.

7. In blast freezer applications, water defrost is desirable for cleanup reasons. A "hot gas assist" system is very effective where the coil is warmed with hot gas to loosen ice and frost, then washed off with water.

8. To avoid water hammer in defrost lines, use motorized water supply valves instead of fast-acting solenoid valves.

9. Pitch drain lines exposed to freezing temperatures approx. 1-1/2” per foot. Heat tracing of drain lines is not necessary if they are properly pitched, even in low temperature rooms.

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Technical Bulletin

By Bruce I. Nelson, P.E., President, Colmac Coil Manufacturing, Inc.

COMPARING AIR COOLER RATINGS – PART 1: Not All Rating Methods are Created Equal

Summary

Refrigeration air coolers (evaporators) are widely used to cool and circulate air in cold storage warehouses and food processing facilities. Manufacturers of air coolers publish cooling capacities based on differing assumptions and rating methods. It is important for refrigeration design professionals to understand these different rating methods and to apply them appropriately. In extreme cases, air coolers can be grossly undersized even though nominal catalog ratings appear to satisfy the calculated refrigeration load. The article illustrates the differences in these rating methods and highlights the importance of selecting air coolers using ratings suited to the operating conditions.

Background

Refrigeration air coolers (evaporators) are widely used to cool and circulate air in cold storage warehouses and food processing facilities. Manufacturers of air coolers publish cooling capacities based on differing assumptions and rating methods (Nelson 2010). In Europe, a number of manufacturers of commercial air coolers (i.e. coolers designed for use with R404a/R507) subscribe to the Eurovent certification program based on the European test standard EN 328 (EN 2002), however, no manufacturer is currently certified for industrial air coolers (i.e. coolers designed for use with ammonia refrigerant). In the U.S. the performance standard AHRI-420 exists (AHRI 2008), but no manufacturers participate in a certification program based on this standard. It is, therefore, important for refrigeration design professionals to understand the different rating methods being used and to apply them appropriately. In extreme cases, air coolers can be grossly undersized even though nominal catalog ratings appear to satisfy the calculated refrigeration load. The smaller size and lower first cost of air coolers which are inadvertently undersized due to misunderstood or misapplied ratings are seductively attractive to contractors and end users, however, the price difference will ultimately be more than paid for by the unsuspecting end user whose undersized air coolers cause lower-than-expected operating suction temperatures with associated increased energy consumption and loss of refrigerating capacity.

Air Temperature Change

As air passes across the fins of an evaporator coil, the temperature is reduced according to the following relationship (ASHRAE 2009):

$$\dot{q} = \dot{m} \cdot C_p \cdot \left(T_{ent} - T_{lvg}\right)$$

where

$\dot{q}$ = cooling capacity (sensible only), Btu/h (kW)
$\dot{m}$ = mass flow rate of air, lbm/h (kg/s)
C_p = specific heat capacity of moist air, Btu/lbm F (kJ/kg C)
T_{ent} = dry bulb air temperature entering the coil (“air on” temperature), F (C)
T_{lvg} = dry bulb air temperature leaving the coil, F (C)

In a room being refrigerated by air cooling evaporators, the change in the temperature of the air (reduction) as it passes through the evaporator coils will equal the change in the temperature of the air (increase) as it circulates throughout the room. This means that in a well designed cold room, the air temperature gradient found in the room will

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be roughly equal to, and will be determined in large part by the air temperature change in the evaporator coils. By Equation (1) the magnitude of the air temperature change (gradient) in the room will be determined by the air mass flow rate through the evaporators. For example, if a relatively small air temperature gradient is desirable in a refrigerated room, then air coolers with relatively high air flow rate (i.e. high CFM/TR) for a given capacity must be selected.

Heat Exchanger Effectiveness

One well known method used to calculate the sensible cooling capacity of evaporators is the effectiveness method (Kays and London 1964). Heat exchanger effectiveness is defined as the ratio of the actual amount of heat transferred to the maximum possible amount of heat that could be transferred with an infinite area. This method is extremely useful because cooling capacity can be calculated directly knowing only the dimensional characteristics of the coil and the initial temperature difference (entering air temperature minus the evaporating temperature). This initial temperature difference is referred to as “DT1” (or “TD”) in the refrigeration industry. Sensible cooling capacity is calculated as follows:

$$\dot{q} = \dot{m} \cdot C_p \cdot \epsilon \cdot \left(T_{ent} - T_{evap}\right) = \dot{m} \cdot C_p \cdot \epsilon \cdot DT1$$

where

$\dot{q}$ = cooling capacity (sensible only), Btu/h (kW)
$\dot{m}$ = mass flow rate of air, lbm/h (kg/s)
C_p = specific heat capacity of moist air, Btu/lbm F (kJ/kg C)
ϵ = effectiveness = $\left(T_{ent} - T_{lvg}\right)/\left(T_{ent} - T_{evap}\right)$
T_{ent} = dry bulb air temperature entering the coil (“air on” temperature), F (C)
T_{lvg} = dry bulb air temperature leaving the coil, F (C)
T_{evap} = average refrigerant evaporating temperature, F (C)

For a given sized coil operating with constant air flow rate, the effectiveness can be considered constant over the small operating temperature ranges typical of refrigeration applications, and therefore, capacity can be considered to be proportional to the ratio of DT1. Hence, if evaporator coil sensible capacity is known for a given DT1, then capacity at a new initial temperature difference, DT1’, can be found simply by multiplying the original capacity by the ratio DT1’/DT1. For example, a refrigeration air cooler has a rating of 10 TR at a DT1 of 10F. The capacity of the same cooler operating with a new DT1 of 12F will be very close to 10 x 12/10 = 10 x 1.2 = 12 TR.

Average Room Temperature and DTM Ratings

Control of the refrigeration system is normally accomplished by maintaining room air temperature, that is, compressors and coolers are cycled on or off depending on whether room temperature is rising or falling. Location of the air temperature sensing device relative to the location of evaporators will affect evaporator performance since a temperature gradient always exists in the room and, as seen above, evaporator performance is determined by the air on temperature (i.e. by DT1). Evaporators located high in the room (mounted on the ceiling, for example), will be exposed to the highest air temperature in the room and operate with the largest DT1. Conversely, floor mounted evaporators will be exposed to the coldest air in the room and operate with the smallest DT1.

For the specific case where; 1) air coolers are ceiling mounted (i.e. operate at the warmest location in the room), and 2) the system control temperature sensor is mounted at a location where it will sense the *average* room temperature (i.e. at the midpoint elevation in the room), manufacturers of air coolers publish ratings based on *mean* (average room) temperature difference. This average temperature difference is termed “DTM”. DTM ratings for the same air cooler will always be higher than DT1 ratings since the effective initial temperature difference seen by the evaporator coil is higher by approximately ½ of the air temperature change. Figure 1 below illustrates how air temperature changes as it passes through an evaporator at two different operating conditions. Note that airflow is held constant for both operating conditions. The first condition with DT1 = 10F is shown as Figure 1(a). The second condition with DTM = 10F is shown as Figure 1(b). Because the DTM = 10F condition has the larger *initial* temperature difference of -6.7 – (-20) = 13.3F, the cooling capacity and air temperature change are significantly larger than for the DT1 = 10F condition. It is interesting how the same evaporator can produce more cooling capacity simply by redefining “temperature difference”!

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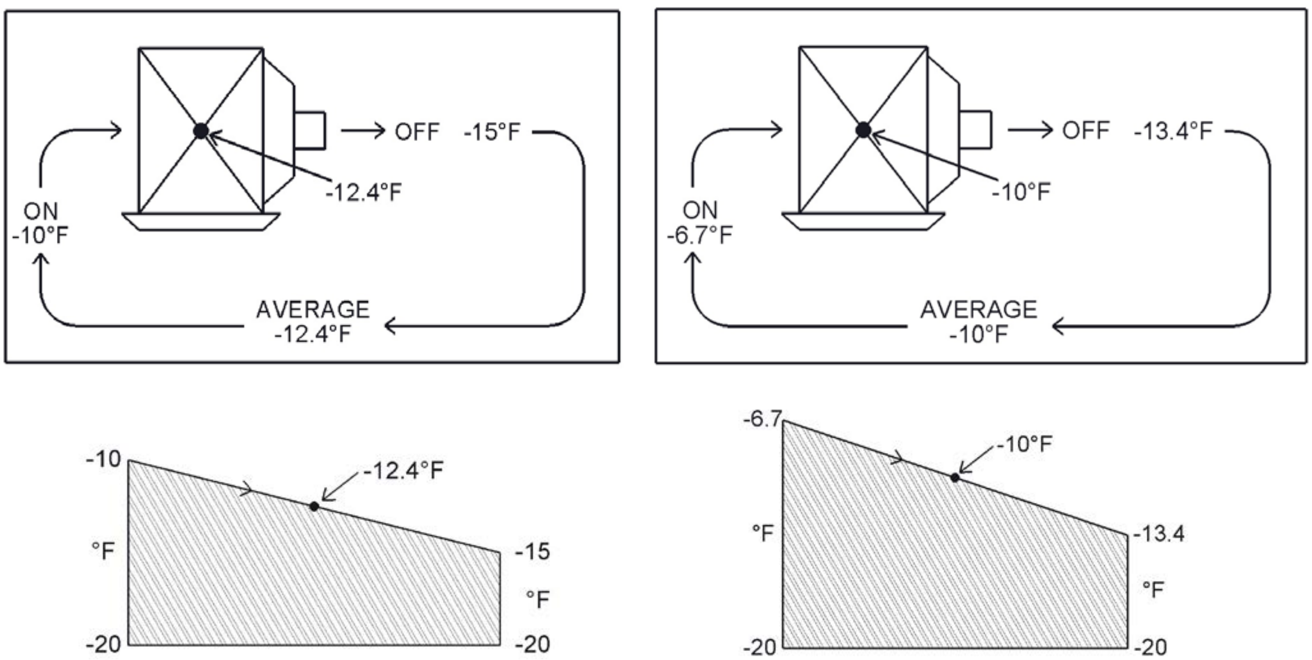
FIGURE 1
Temperature Profiles for DT1 vs DTM

(a) DT1 = 10F (Air On) Temp Difference **(b) DTM = 10F (Average) Temp Difference**



DT1 LMTD = 7.2 F DTM LMTD = 9.6 F

Although DTM ratings may useful in the specific case of ceiling mounted air coolers (equipment size and first cost can be reduced), refrigeration system designers must be careful to recognize the limitations of this rating system and avoid the mistake of misapplying DTM ratings. Whenever air coolers are installed at a location in the room where the air on temperature to the coil is less than the highest temperature in the room, DTM ratings should not be used. This would be the case with cooler inlet air ducted from some lower temperature point in the room, or with floor mounted coolers.

DT1 ratings used with actual anticipated air on temperature will always result in accurate ratings and correct air cooler selections. This method for air cooler selection is conservative and recommended whenever air on temperature to the coil is less than the maximum found in the room or process.

Converting DT1 to DTM Air Cooler Ratings

Equations (1) and (2) above were used to derive the relationships shown in Equations (3) and (4) below which can be used to convert from known a DT1 air cooler rating to a new DTM rating for the same cooler.

$$\dot{q}_{DTM} = \frac{\dot{q}_{DT1} \cdot \frac{DTM}{DT1}}{\left(1 - \frac{\dot{q}_{DT1}}{2 \cdot 60 \cdot C_p \cdot \rho \cdot \dot{V} \cdot DT1}\right)} \quad \text{(IP)} \qquad (3)$$

$$\dot{q}_{DTM} = \frac{\dot{q}_{DT1} \cdot \frac{DTM}{DT1}}{\left(1 - \frac{\dot{q}_{DT1} \cdot 3600}{2 \cdot C_p \cdot \rho \cdot \dot{V} \cdot DT1}\right)} \quad \text{(SI)} \qquad (4)$$

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where

$\dot{q}_{DTM}$ = capacity at mean (room) temperature difference, Btu/h (kW)
$\dot{q}_{DT1}$ = capacity at initial (air on) temperature difference, Btu/h (kW)
DT1 = initial temperature difference = Air On Temp - Evap Temp, F (C)
DTM = mean (room) temperature difference = Ave Room Temp – Evap Temp, F (C)
C_p = air specific heat, Btu/lbm F (kJ/kg C)
ρ = air density, lbm/ft3 (kg/m3)
$\dot{V}$ = actual volumetric air flow rate, ft3/min (m3/h)

Example:

An air cooler has a DT1 rating of 120,000 Btu/h at DT1 = 10F and -10F air on temperature. The cooler has a published airflow rating of 18,850 CFM. Assume the coil is operating with average air density = 0.0883 lbm/ft3, and average air specific heat = 0.24 Btu/lbm F. Note this is the same cooler shown in Figure 1 above.

Find the DTM rating for the same cooler with DTM = 10F.

From Equation (3):

$$\dot{q}_{DTM} = \frac{120{,}000 \cdot \frac{10}{10}}{\left(1 - \frac{120{,}000}{2 \cdot 60 \cdot 0.24 \cdot 0.0883 \cdot 18{,}850 \cdot 10}\right)} = 160{,}050\ Btu/h$$

As is seen from the example, DTM ratings are typically significantly higher than DT1 ratings for the same air cooler operating under the same conditions. In the case of the example, the DTM rating is +33% greater than the DT1 rating!

Note that the above equations apply only to sensible capacity calculations and ratings and do not account of the effects of latent cooling on coil performance and temperature change. The effects of latent load on coil performance and ratings are covered in the following sections.

Latent Load And Sensible Heat Ratio (SHR)

Whenever cooling coil surfaces operate at temperatures below the dewpoint of the air being cooled, water vapor in the airstream is condensed to liquid (at temperatures above 32F (0C)) or deposited to form frost (below 32F (0C)). The cooling effect associated with this dehumidification of the airstream is termed “latent” cooling. The sum of the sensible cooling load and latent cooling load is termed the “total” load. The ratio of the sensible cooling load divided by the total cooling load is called the Sensible Heat Ratio (SHR) and defines the slope of the air process line on a psychrometric chart.

$$SHR = \frac{Sensible\ Cooling\ Load}{Sensible\ Cooling\ Load + Latent\ Cooling\ Load} \qquad (5)$$

Accurate prediction of the refrigeration load, both sensible and latent components, is critical to proper refrigeration system equipment selection and successful operation. Various types of sensible cooling loads must be anticipated and included in the calculation, such as: lighting, electric motors, forklifts, product cooling/freezing, transmission of heat through walls, ceilings, and floors, and cooling of infiltration air. Latent cooling loads are present whenever moisture is added to the air in the refrigerated space. Sources of introduced moisture typically include: infiltration air, respiring food products, surface moisture on products, packaging, and other objects entering the space, human respiration, and humidification equipment (above freezing).

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The SHR determined from the load calculation will come to equilibrium with the SHR of the air passing through the air cooler evaporator coil. In general, as air temperature decreases the amount of water vapor held in air decreases by the law of partial pressures, and the minimum possible SHR increases.

Relative humidity of the refrigerated space can be predicted by plotting the air process line on a psychrometric chart with the end point plotted on the saturation curve at the predicted coil surface temperature, and the air process line extending from left to right at a slope equal to the SHR. The intersection of this line with a vertical line drawn through the entering air dry bulb temperature indicates the relative humidity of the air entering the coil. Table 1 below shows typical Sensible Heat Ratios for various air temperatures at 95% air on relative humidity.

TABLE 1
SHR FOR 95% RH AIR ON AND DT1 = 10F AT VARIOUS TEMPERATURES

Room Temperature, F (C)	SHR
45 (7.2)	0.55
32 (0)	0.66
10 (-12.2)	0.83
0 (-17.8)	0.89
-10 (-23.3)	0.93
-30 (-34.4)	0.97

Impact of Latent Load (SHR) on Air Cooler Ratings

Evaporator coils are typically constructed of plate fins bonded to tubes. Fins are referred to as “secondary” surface while tubes are referred to as “primary” surface. For purposes of calculating evaporator performance, primary surface is considered to be 100% effective in its contribution to the total heat transfer surface area while secondary surface has a surface effectiveness less than 100% due to the change in surface temperature from the root to the tip of the fin.

The capacity of the evaporator surfaces to transfer mass (condense water, or deposit frost, from the airstream) is a function of the difference in water vapor pressure between the coil surface and air stream and the surface mass transfer coefficient. The mass transfer process is much more “thermally effective” than the sensible heat transfer process, that is, the heat flux through the evaporator surfaces during the mass transfer process is extremely high (AHRI 2001). Consequently, if the surface effectiveness of the coil were to remain constant, the increase in the evaporator cooling capacity during combined sensible and latent cooling would be equal to the sensible cooling capacity divided by the SHR, as follows:

$$Total\ Cooling\ Capacity_{Ideal} = \frac{Sensible\ Cooling\ Capacity}{SHR} \quad (6)$$

However, the increase in heat flux through the fin surfaces has the effect of decreasing fin efficiency and overall surface effectiveness due to an increase in the fin surface temperature gradient (Xia & Jacobi 2005). The result is a slightly lower total cooling capacity than that predicted by Equation (6). Using a computer model developed to accurately calculate fin efficiency and surface effectiveness for both sensible and combined sensible and latent heat transfer, a prediction of the increase in evaporator coil performance as a function of SHR was made. Results of the predicted capacity increase as a function of SHR for an ammonia refrigeration evaporator coil operating over a wide range of room temperatures (+35F to -30F) and having typical fin spacing and geometry with DT1 = 10F are shown in Figure 2 below.

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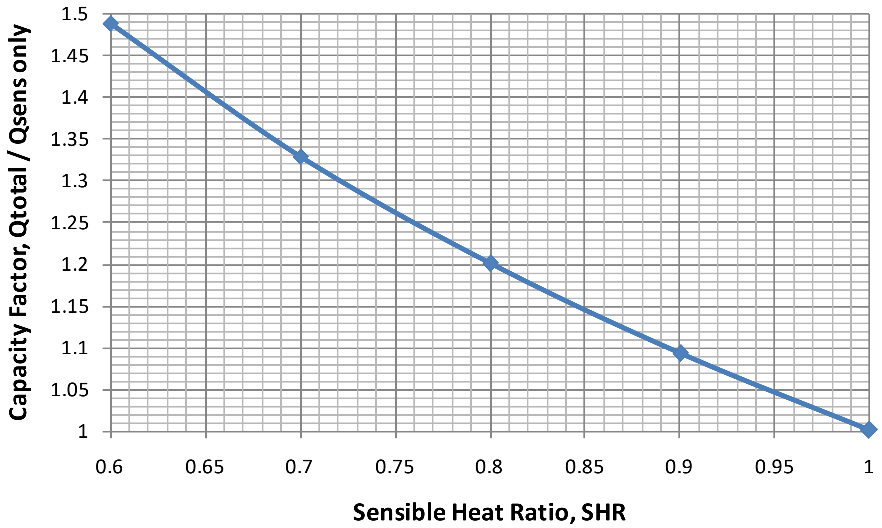
FIGURE 2
Total Cooling Capacity Factor vs SHR



Air cooler ratings which include latent cooling will appear higher (in some cases significantly higher) than all sensible ratings. Care must be taken, therefore, to correctly predict the cooling load SHR and the resulting relative humidity in the refrigerated space. From the above it should be apparent that selecting an air cooler with a rating based on a relatively high room relative humidity (SHR less than 1.0) for a room with an actual SHR equal to or close to 1.0 will result in undersized air coolers.

For example, a long term cold storage warehouse is designed for +0F (-17.8C) room temperature with a calculated SHR nearly equal to 1.0 (i.e. packaged products and minimal infiltration). From Table 1, the SHR for +0F air temperature and 95% relative humidity would be 0.89. From Figure 2, an air cooler rated on a total cooling basis at +0F and 95% air on relative humidity would show a nominal capacity +11% greater (capacity factor = 1.11) than a sensible only rating. In this case, therefore, air coolers selected using ratings based 95%rh air on would be significantly undersized.

Conclusions

U.S. air cooler manufacturers have traditionally published capacity ratings based on SHR = 1.0 (all sensible) and DT1. European manufacturers typically include latent cooling in their air cooler ratings, indicated by an air on relative humidity typically between 85% and 95%. European manufacturers also publish ratings based on either DT1 or DTM, or both. The discussion above illustrates the differences in these rating methods and highlights the importance of selecting air coolers using ratings suited to the operating conditions. Misapplication of DTM and/or total cooling ratings can result in severely undersized air coolers and the consequent failure of the refrigeration system to perform to energy efficiency and cooling capacity expectations.

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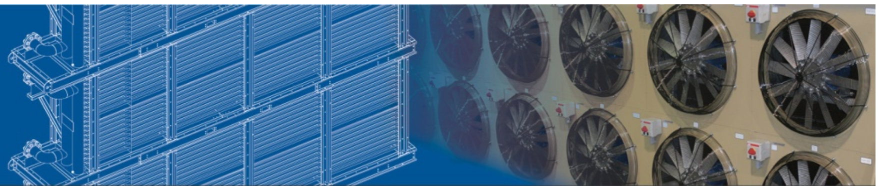

By Bruce I. Nelson, P.E., President, Colmac Coil Manufacturing, Inc.

COMPARING AIR COOLER RATINGS – PART 2: Why DTM Ratings Cost You Money

Summary

As explained in a previous article, manufacturers of refrigeration evaporators publish ratings based on either average "room" temperature difference (DTM), or air on temperature difference (DT1). Compared to DT1 ratings, the DTM rating method results in evaporator selections which are undersized for the cooling load and will cause the system to operate with lower than expected suction temperatures. This article calculates the energy efficiency penalty resulting from selecting evaporators using DTM ratings, and puts the benefit of reduced power consumption when using DT1 ratings in terms of incremental return on investment (IROI). Depending on the room temperature and type of compression system (single or 2-stage) the IROI when using DT1 ratings can be as high as 156%, a simple payback of as short as 8 months!

Background

In a previous article (Nelson 2010), two commonly used methods for rating refrigeration air coolers (evaporators), DT1 and DTM, were defined and quantified. DT1 and DTM refer to two different definitions of the difference between air temperature and evaporating temperature used to select an evaporator for a given cooling load.

DT1 = Air On Temperature – Evaporating Temperature
DTM = Average ("Room") Air Temperature – Evaporating Temperature

The effect of including latent cooling on ratings and evaporator selection was also discussed and explained.

It was shown that using DTM ratings allows the selection of air coolers which have less surface area compared to air coolers selected using DT1 ratings for the same cooling load and temperature difference. As with many things in life, "If something sounds too good to be true, it is too good to be true!". If coolers selected using DTM ratings have less surface area than DT1 coolers, then it follows that DTM rated coolers will operate with a lower suction temperature than DT1 rated coolers for the same cooling load.

This article, as a continuation of the previous discussion, quantifies exactly how much lower the operating suction temperature will be with DTM coolers and how much the system operating costs will increase as a result.

Room Air Temperature Gradient and DTM

DTM evaporator ratings assume a room air temperature gradient which is equal to the air temp change through the evaporator coil. Put another way, DTM assumes there is no (zero) mixing of the air leaving the evaporators with the room air. This is a false assumption which never occurs with ceiling hung air coolers discharging air from fans into the refrigerated space.
The cooled air leaving an evaporator is termed a non-isothermal jet of air. Air distribution in rooms created by jets of various configurations and aspects has been studied for some time (ASHRAE 2009, Li et al 1993). While air change effectiveness is very difficult to predict precisely, the air throw, spread, fall, and entrainment ratio of free air jets can be estimated using various formulas.

The final air temperature gradient in a refrigerated room will ultimately be determined by the effective mixing of the cooled air leaving the evaporators with the room air. Over the length of a free air jet, the amount of mixing that takes place can be quantified by calculating the entrainment ratio.

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At a distance of 25 to 100 fan diameters from the point of discharge, the entrainment ratio for a horizontal free air jet can be determined using the following formula:

$$\frac{Q_x}{Q_0} = \frac{2X}{K_c\sqrt{A_0}} \qquad (1)$$

Where

$Q_x = Total\ airflow\ rate\ at\ distance\ X\ from\ face\ of\ the\ outlet$
$Q_0 = Airflow\ rate\ measured\ at\ the\ outlet$
$X = Distance\ from\ face\ of\ the\ outlet$
$K_c = Centerline\ velocity\ constant\ determined\ by\ testing$
$A_0 = Jet\ discharge\ area$

Using equation (1) we can estimate the temperature gradient in a refrigerated space knowing only the air temperature change through the evaporator(s), the length of the room, and the number and diameter of the evaporator fans.

Example:

Two evaporators are ceiling hung in a cold storage room which is 36 m long. Each evaporator has 3 x 762 mm diameter fans.

Given:
Air temperature change through the evaporator(s): 3 deg C
Assume a centerline velocity constant of 4.5, which is typical for fans with wire fan guards

Calculated:
Total fan discharge area per evaporator: 3 x 0.46 sq m per fan = 1.37 sq m

Assuming the average entrainment ratio for the room will be found at half the distance to the back wall, a distance of 36 / 2 = 18 m will be used.

$$Average\ Entrainment\ Ratio = \frac{2\ x\ 18}{4.5\ x\ \sqrt{1.37}} = 6.8$$

Since the entrainment ratio indicates the amount of air mixing that will take place in the room, the average room temperature gradient will be approximately equal to the air temperature change through the evaporator divided by the average entrainment ratio.

$$Average\ Room\ Temp\ Gradient = \frac{Temp\ Change\ Through\ Evaporator}{Average\ Entrainment\ Ratio} = \frac{3}{6.8} = 0.4\ \deg C$$

The above analysis clearly shows that the DTM assumption that room temperature gradient is equal to the air temperature change through the evaporator, is NOT valid.

Because of the mixing effect of the entrainment ratio, evaporators selected using DTM ratings will be undersized for the load and will operate with a suction temperature that is lower than expected in order to achieve the design cooling capacity.

Using the DT1 rating method, on the other hand, assumes there is complete mixing of the air in the refrigerated space. Put another way, DT1 conservatively assumes an infinite entrainment ratio and therefore no room air temperature gradient. While this is not absolutely true, it is much closer to reality and results in operating suction temperatures much closer to design compared to evaporators selected using DTM ratings.

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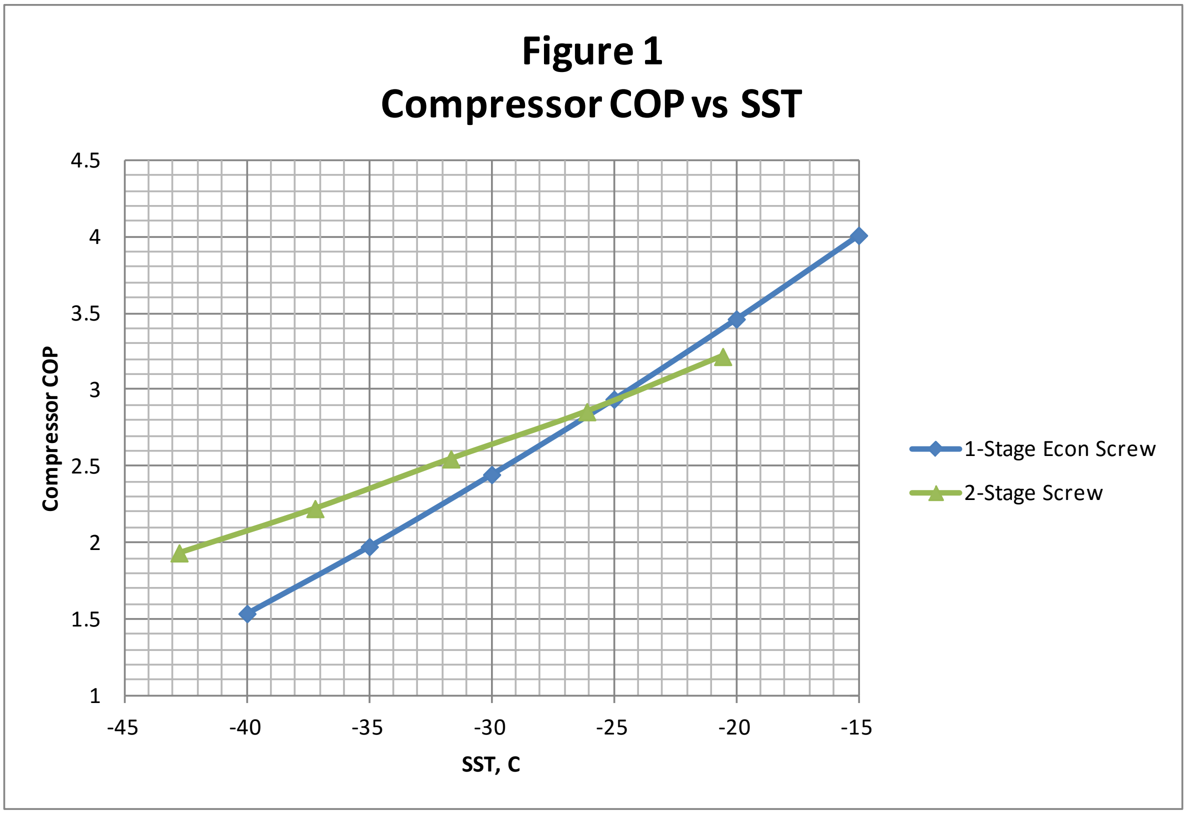
The next sections examine the increase in operating costs resulting from the lower operating suction temperatures required by DTM rated evaporators compared to DT1 rated evaporators.



Effect of Suction Temperature on Energy Consumption

For a given fixed condensing temperature, all compressors lose efficiency as suction pressure falls. With ammonia, the Coefficient of Performance (COP) falls approximately 2.0 to 3.6% for every 1 deg C reduction in suction temperature (Stoecker 1998). Figure 1 shows compressor COP vs suction temperature for typical single stage and 2-stage screw compressor systems at a condensing temperature of 29.4 deg C (85 deg F). Below about -25 deg C (-13 deg F) suction temperature, 2-stage compression systems operate with higher COP compared to single stage compression with economizing (Jekel 2008).

As explained in the previous section, evaporators selected using DTM ratings will cause the system to operate at a lower than expected suction temperature compared to evaporators selected using DT1 ratings. Using the relationships shown in Figure 1 along with fundamental evaporator capacity relationships we can determine how much additional power will be consumed by system compressors when evaporators are selected based on DTM ratings.

Power Consumption Comparison DTM Vs DT1

Two sets of evaporators having the same total airflow rate will be selected for the same cooling load and temperature difference, one on the basis of DTM and the other on the basis of DT1, to answer the questions:

1. What will the difference in actual operating suction temperatures be between DTM and DT1 evaporators?
2. What will be the resulting difference in compressor power consumption?
3. What incremental return on investment benefit will result from selecting evaporators using DT1 ratings instead of DTM ratings?

Assumptions:

- Total Cooling Load: 352 kW (100 TR)
- Temperature Difference, TD: 6.67 deg C (12 deg F)
- Sensible Heat Ratio: 1.0 (all sensible cooling)
- Saturated Condensing Temperature: 29.4 deg C (85 deg F)
- Airflow Rate: 302,308 m3/h (177,930 cfm)

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- Specific Heat of Air: 1.005 kJ/kg K (0.24 Btu/lbm F)
- Cost of Electricity: $0.15/kWh
- Price of DT1 Rated Evaporators: $1,600/kW C
- Air in the room is fully mixed. i.e. Zero or very little room temperature gradient

Based on the above, the following calculations were made for a range of air temperatures and shown in Tables 1 and 2 below:

Air Density:
$$\rho_a = 1.225\ x\ \frac{(273.15 + 15)}{(273.15 + T_0)} \tag{2}$$

Rated DTM Air On Temp:
$$T_{on\ DTM} = T_0 + \frac{\dot{q}}{2\ x\ \frac{Q}{3600}\ x\ \rho_a\ x\ C_p} \tag{3}$$

Rated DTM Air Off Temp:
$$T_{off\ DTM} = T_{on\ DTM} - \frac{\dot{q}}{\frac{Q}{3600}\ x\ \rho_a\ x\ C_p} \tag{4}$$

Rated DTM Suction Temp:
$$T_{evap\ DTM} = T_0 - TD \tag{5}$$

DTM Effectiveness:
$$\varepsilon = \frac{T_{on\ DTM} - T_{off\ DTM}}{T_{on\ DTM} - T_{evap\ DTM}} \tag{6}$$

Actual DTM Air On Temp:
$$T'_{on\ DTM} = T_0 \tag{7}$$

Actual DTM Air Off Temp:
$$T'_{off\ DTM} = T'_{on\ DTM} - \frac{\dot{q}}{\frac{Q}{3600}\ x\ \rho_a\ x\ C_p} \tag{8}$$

Actual DTM Suction Temp:
$$T'_{evap\ DTM} = T'_{on\ DTM} - \frac{T'_{on\ DTM} - T'_{off\ DTM}}{\varepsilon} \tag{9}$$

Actual DT1 Air On Temp:
$$T_{on\ DT1} = T_0 \tag{10}$$

Actual DT1 Air Off Temp:
$$T_{off\ DT1} = T_{on\ DT1} - \frac{\dot{q}}{\frac{Q}{3600}\ x\ \rho_a\ x\ C_p} \tag{11}$$

Actual DT1 Suction Temp:
$$T_{evap\ DT1} = T_{on\ DT1} - TD \tag{12}$$

DTM Power Used:
$$PU_{DTM} = 365\frac{days}{y}x\ 24\frac{h}{day}\ x\ \frac{\dot{q}}{COP_{DTM}} \tag{13}$$

DT1 Power Used:
$$PU_{DT1} = 365\frac{days}{y}x\ 24\frac{h}{day}\ x\ \frac{\dot{q}}{COP_{DT1}} \tag{14}$$

DT1/DTM Price Ratio:
$$PR = \frac{T_{on\ DTM} - T_{evap\ DTM}}{TD} \tag{15}$$

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DT1 Price Premium: $$PP = (PR - 1)\ x\ \frac{\$1600/(kW/C)\ x\ \dot{q}}{TD} \tag{16}$$

DT1 v DTM Simple Payback: $$SPB = \frac{PP}{(PU_{DTM} - PU_{DT1})\ x\ \$0.15/kWh} \tag{17}$$

Incremental Return on Investment: $$IROI = \frac{1}{SPB}\ x\ 100 \tag{18}$$

TABLE 1					
SINGLE STAGE (ECONOMIZED) POWER CONSUMPTION COMPARISON					
Room Temp, C	-12.2	-17.8	-23.3	-28.9	-34.4
Room Temp, F	10	0	-10	-20	-30
Air Density, kg/m3:	1.35	1.38	1.41	1.45	1.48
Rated DTM Air On, C:	-10.7	-16.3	-21.9	-27.4	-33.0
Rated DTM Air Off, C:	-13.8	-19.3	-24.8	-30.3	-35.9
Rated DTM SST, C:	-18.9	-24.4	-30.0	-35.6	-41.1
Rated DTM SST, F:	-2.0	-12.0	-22.0	-32.0	-42.0
DTM Effectiveness:	0.38	0.37	0.36	0.36	0.35
Actual DTM Air On, C:	-12.2	-17.8	-23.3	-28.9	-34.4
Actual DTM Air Off, C:	-15.3	-20.8	-26.3	-31.8	-37.3
Actual DTM SST, C:	-20.4	-26.0	-31.5	-37.0	-42.5
Actual DTM SST, F:	-4.8	-14.7	-24.7	-34.6	-44.5
DTM COP (29.44C SCT):	3.42	2.84	2.30	1.80	1.33
Actual DT1 Air On, C:	-12.2	-17.8	-23.3	-28.9	-34.4
Actual DT1 Air Off, C:	-15.3	-20.8	-26.3	-31.8	-37.3
Actual DT1 SST, C:	-18.9	-24.4	-30.0	-35.6	-41.1
Actual DT1 SST, F:	-2.0	-12.0	-22.0	-32.0	-42.0
DT1 COP (29.44C SCT):	3.58	3.00	2.44	1.93	1.44
DTM Power Used, kWh/y:	901,854	1,083,296	1,337,619	1,714,718	2,319,003
DT1 Power Used, kWh/y:	860,264	1,027,953	1,260,360	1,600,079	2,133,436
Savings/y, $:	$6,239	$8,302	$11,589	$17,196	$27,835
DT1/DTM Price Ratio:	1.23	1.23	1.22	1.22	1.21
DT1 Cooler Cost, $ / (kW/C):	$1,600	$1,600	$1,600	$1,600	$1,600
DT1 Price Premium, $:	$19,482	$19,067	$18,652	$18,238	$17,823
DT1 Simple Payback, y:	3.12	2.30	1.61	1.06	0.64
DT1 Incremental ROI, %/y:	32.0%	43.5%	62.1%	94.3%	156.2%

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TABLE 2 2-STAGE POWER CONSUMPTION COMPARISON					
Room Temp, C	-12.2	-17.8	-23.3	-28.9	-40.0
Room Temp, F	10	0	-10	-20	-40
Air Density, kg/m3:	1.35	1.38	1.41	1.45	1.51
Rated DTM Air On, C:	-10.7	-16.3	-21.9	-27.4	-38.6
Rated DTM Air Off, C:	-13.8	-19.3	-24.8	-30.3	-41.4
Rated DTM SST, C:	-18.9	-24.4	-30.0	-35.6	-46.7
Rated DTM SST, F:	-2.0	-12.0	-22.0	-32.0	-52.0
DTM Effectiveness:	0.38	0.37	0.36	0.36	0.34
Actual DTM Air On, C:	-12.2	-17.8	-23.3	-28.9	-40.0
Actual DTM Air Off, C:	-15.3	-20.8	-26.3	-31.8	-42.8
Actual DTM SST, C:	-20.4	-26.0	-31.5	-37.0	-48.0
Actual DTM SST, F:	-4.8	-14.7	-24.7	-34.6	-54.5
DTM COP (29.44C SCT):	3.42	2.89	2.56	2.24	1.70
Actual DT1 Air On, C:	-12.2	-17.8	-23.3	-28.9	-40.0
Actual DT1 Air Off, C:	-15.3	-20.8	-26.3	-31.8	-42.8
Actual DT1 SST, C:	-18.9	-24.4	-30.0	-35.6	-46.7
Actual DT1 SST, F:	-2.0	-12.0	-22.0	-32.0	-52.0
DT1 COP (29.44C SCT):	3.58	3.00	2.65	2.32	1.75
DTM Power Used, kWh/y:	901,854	1,065,634	1,204,661	1,376,579	1,816,120
DT1 Power Used, kWh/y:	860,264	1,027,953	1,164,475	1,328,353	1,756,369
Savings/y, $:	$6,239	$5,652	$6,028	$7,234	$8,963
DT1/DTM Price Ratio:	1.23	1.23	1.22	1.22	1.21
DT1 Cooler Cost, $ / (kW/C):	$1,600	$1,600	$1,600	$1,600	$1,600
DT1 Price Premium, $:	$19,482	$19,067	$18,652	$18,238	$17,408
DT1 Simple Payback, y:	3.12	3.37	3.09	2.52	1.94
DT1 Incremental ROI, %/y:	32.0%	29.6%	32.3%	39.7%	51.5%

Conclusions

The author has examined two commonly used rating methods for refrigeration evaporators, DTM and DT1. The following conclusions are based on the results of the discussion:

1. The DTM rating method assumes an air entrainment ratio of 1, that is to say, the room air temperature gradient equals to the air temperature change through the evaporator coil. This is a fundamentally flawed assumption and results in an artificially high assumed temperature difference between air on temperature and evaporating temperature.
2. Because of the artificially high assumed temperature difference, evaporators selected using DTM ratings will have less surface area and will cost less than evaporators selected using DT1 ratings.
3. Because DTM ratings result in undersized evaporator selections, the operating system suction temperature will be lower than expected. This results in greater compressor power consumption compared to evaporators selected using DT1 ratings.
4. Selecting evaporators based on DT1 ratings avoids the DTM power consumption penalty and results in significant energy savings due to higher operating suction temperatures. In the examples given, the beneficial DT1 Incremental Return on Investment (IROI) for the single stage compression case ranged from 32% to 156% per year. For the 2-stage compression case, the DT1 IROI ranged from 32% to 52% per year.

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Nomenclature

$A_0 = Jet\ discharge\ area, m^2$
$IROI = Incremental\ return\ on\ investment, \%/y$
$K_c = Centerline\ velocity\ constant\ determined\ by\ testing, dimensionless$
$PP = DT1\ price\ premium, \$$
$PR = \frac{DT1'}{DT1}\ price\ ratio, dimensionless$
$PU_{DT1} = DT1\ power\ consumption, {kWh}/_{y}$
$PU_{DTM} = DTM\ power\ consumption, {kWh}/_{y}$
$\dot{q} = Cooling\ load, kW$
$Q = Evaporator\ airflow\ rate, {m^3}/_{h}$
$Q_0 = Airflow\ rate\ measured\ at\ the\ outlet, {m^3}/_{h}$
$Q_x = Total\ airflow\ rate\ at\ distance\ X\ from\ face\ of\ the\ outlet, {m^3}/_{h}$
$\frac{Q_x}{Q_0} = Entrainment\ ratio$
$SPB = DT1\ vs\ DTM\ simple\ payback, y$
$T_0 = Room\ air\ temperature, C$
$TD = Air\ minus\ evaporating\ temperature\ difference, C$
$T_{on\ DT1} = Actual\ DT1\ air\ temperature\ entering\ the\ evaporator, C$
$T_{off\ DT1} = Actual\ DT1\ air\ temperature\ leaving\ the\ evaporator, C$
$T_{evap\ DT1} = Actual\ DT1\ evaporating\ (suction) temperature, C$
$T_{on\ DTM} = Rated\ DTM\ air\ temperature\ entering\ the\ evaporator, C$
$T_{off\ DTM} = Rated\ DTM\ air\ temperature\ leaving\ the\ evaporator, C$
$T_{evap\ DTM} = Rated\ DTM\ evaporating\ (suction) temperature, C$
$T'_{on\ DTM} = Actual\ DTM\ air\ temperature\ entering\ the\ evaporator, C$
$T'_{off\ DTM} = Actual\ DTM\ air\ temperature\ leaving\ the\ evaporator, C$
$T'_{evap\ DTM} = Actual\ DTM\ evaporating\ (suction) temperature, C$
$X = Distance\ from\ face\ of\ the\ outlet, m$
$C_p = Air\ specific\ heat\ capacity, {kJ}/_{kg\ K}$
$\varepsilon = Evaporator\ effectiveness, dimensionless$
$\rho_a = Air\ density, {kg}/_{m^3}$

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Technical Bulletin

By Bruce I. Nelson, P.E., President, Colmac Coil Manufacturing, Inc.

COMPARING AMMONIA EVAPORATOR CONSTRUCTION: "WHICH ONE IS BEST?"

Abstract

Industrial ammonia evaporator manufacturers offer several types of construction including: galvanized steel, stainless steel tubes with aluminum fins, stainless steel tubes with stainless steel fins, and aluminum tubes with aluminum fins, as well as a number of corrosion resistant coatings. Trying to decide on the right one for a given facility and/or process can be confusing and leads to the question: "Which one is best for my application?" The metals used in each type of construction mentioned above have unique properties which affect the evaporator in terms of thermal performance, weight, defrost energy, corrosion resistance, and cost. Good performance and energy efficiency have a direct positive effect on return on investment for the facility. The weight of the evaporators may affect the roof structure of the building in the case of ceiling or roof mounted units, especially in high seismic zones. In food processing plants where harsh cleaning chemicals are increasingly used on evaporators, appropriate corrosion resistance behavior is critical. The article examines the different types of construction and their characteristics and makes recommendations regarding which type of construction best suits specific applications and operating environments.

Background

Air-cooling evaporators ("air coolers") used in ammonia systems have traditionally been made using galvanized (zinc coated) carbon steel. There are other metals which exhibit excellent compatibility with ammonia, including stainless steel and aluminum.

Designers and installers of industrial ammonia evaporators must be concerned with the cost, weight, performance, and reliability of the equipment being specified. Additionally, there may be requirements for corrosion resistance, cleanability, and defrosting characteristics, which need to be considered.

Aluminum is a good choice for both tubes and fins. The surface of the metal is naturally passivated (the protective oxide layer is stabilized) when directly exposed to ammonia, leading to its widespread use for ammonia-containing vessels, pipe, and tubing. The properties of aluminum also make it an ideal metal to use as fin material. Aluminum is low cost, lightweight, highly conductive, and corrosion resistant.

Some of the properties of stainless steel make it an excellent choice for tubing in ammonia heat exchangers. It has very high tensile strength, which results in high working pressures. Stainless steel is highly corrosion resistant which minimizes the potential for ammonia leaks in hostile environments. It is readily available commercially and is widely used in the food processing industries for piping, vessels, and equipment. It is also easily repaired in the field by welding.

Negative aspects of using stainless steel in heat exchangers are its high relative cost and very low thermal conductivity. These negative characteristics can be mitigated by: a) specifying the wall thickness of the tubing to match the required working pressure of the system, and b) using another more conductive metal, such as aluminum, as the fin material.

Three types of evaporator construction using these metals are in common use and are widely available from a number of manufacturers:

1. Hot Dip Galvanized Steel (Stl/Zn)
2. Stainless Steel Tubes with Aluminum Fins (SST/Al)
3. Aluminum Tubes with Aluminum Fins (Al/Al)

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Trying to decide which of these metals and types of construction are the best choice for a given application and duty can be confusing. In order to answer the question “Which one is best?”, this article will make a comparison of the following characteristics of each type of construction:

- Strength
- Cost/Price
- Weight
- Performance
- Defrosting
- Corrosion Resistance
- Reliability

Comparison of Properties:

Table 1 below compares several properties of stainless steel and aluminum to those of carbon steel and zinc. Galvanized steel is obtained by dipping carbon steel in a bath of molten zinc, hence these two base metals are shown in the table.

TABLE 1
Properties of Various Metals

Metal	Density, lbm/cu ft	Thermal Conductivity, Btu/sq ft h F ft	Specific Heat Capacity, Btu/lbm F	Tensile Strength, ksi
Carbon Steel	490	26	0.107	47
Zinc	445	65	0.094	21
304L Stainless Steel	501	9.4	0.120	70
3003 Aluminum	165	117	0.215	14

The density of the metal directly affects the weight of the heat exchanger, and when multiplied by the specific heat capacity the product indicates the amount of energy required to heat up and cool down the heat exchanger during a defrost cycle.

The thermal conductivity of the metal affects the thermal performance of the heat exchanger, as well as the speed and effectiveness of defrost.

The tensile strength of the metal will determine the burst pressures of the heat exchanger tubes and headers for a given wall thickness. It is interesting to note that various metals behave differently at low temperatures. Carbon steel becomes brittle at temperatures below –20F. Special allowances must be made when designing with carbon steel below –20F such as using special impact tested material, increasing the wall thickness of the pipe, and post-weld heat treating to avoid failures caused by embrittlement of the metal. Table 2 below shows the normal allowable working temperature range for various metals.

TABLE 2
Normal Allowable Working Temperature Range for Various Metals*

Metal	Allowable Working Temperature Range, F
Carbon Steel (SA-179)	-20 to +500
304L Stainless Steel (SA-249)	-320 to +300
3003 Aluminum (SA-210)	-452 to +400

* Taken from ASME Pressure Vessel Code, Section II, Part D.

It is apparent from Table 2 that stainless steel and aluminum offer excellent performance in low temperature freezer applications compared to galvanized steel.

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Comparison: Working Pressure

Maximum Allowable Working Pressure (MAWP) is an important design parameter which must be calculated by the designer (or manufacturer) to insure the pressure bearing parts of the refrigeration system will not fail when exposed to the maximum anticipated operating pressures. Standard ANSI/IIAR 2-2008 (IIAR 2008) states that, for forced air evaporator coils: "Minimum design pressure shall be 150 psig [1030 kPa gage] or in the case where hot gas defrost is utilized, minimum design pressure shall be 250 psig [1720 kPa gage] or the design pressure of the high side source of hot gas, whichever is greater" (Section 8.1.1.1). The standard also states that, for air-cooled ammonia condensers: "Minimum design pressure shall be 300 psig [2070 kPa gage]" (Section 7.1.1.1).

The MAWP for a pressure vessel (i.e. evaporator pipe or tube) can be easily calculated from the ASME Pressure Vessel Code Section VIII when the following parameters are known: diameter, wall thickness, corrosion allowance, maximum allowable stress, and joint efficiency. Table 3 below shows calculated MAWP for 7/8" (22 mm) diameter tubes of various metals and commonly used wall thicknesses.

TABLE 3

MAX. ALLOWABLE WORKING PRESSURE FOR SHELLS UNDER INTERNAL PRESSURE

(CALCULATIONS BASED ON ASME SECTION VIII, 2002 ADDENDA, UG-27)

Pipe/Tube Dia., (in)	Pipe/Tube Wall, (in)	Pipe/Tube Matl	Corrosion Allowance, (in)	Max. allowable Working Press, bar (P)	Max. allowable Working Press, psig (P)	Max. allowable Stress Value (PSI) (S)
7/8	0.028	304L SST	0.002	51	738.2	14200
7/8	0.049	SA-179 CS	0.002	88	1284.7	13400
7/8	0.065	3003 Alum	0.002	31	443.7	3400

As shown in the table, the calculated MAWP for all of the metals being compared easily exceed the 300 psig mentioned above from ANSI/IIAR-2.

Comparison: Cost and Weight

The relative cost (and resulting price) and weight of an evaporator are obviously important considerations when selecting the appropriate type of evaporator construction for a given project. On a per pound basis, carbon steel is lower in cost than both stainless steel and aluminum. This cost differential is offset for aluminum, however, by the metal's low density. Since stainless steel has such a high tensile strength (see Table 1), the wall thickness of the stainless steel tubing can be safely reduced, which reduces the tubing cost per foot accordingly. The expensive process of hot dip galvanizing is not required for stainless tube/aluminum fin construction, which further offsets the higher cost per pound of these metals compared to carbon steel.

In order to make an accurate comparison of the three types of construction (Stl/Zn, SST/Al, and Al/Al) a calculation of relative weight and cost (using current material costs) was made for a typical ammonia evaporator coil block having the following characteristics:

- 7/8" (22 mm) diameter tubes
- 45" FH x 162"FL (1143mm FH x 4115mm FL) – 8 Rows – 4 FPI
- Approximate cooling capacity = 15 TR (53 kW)

Cost:

Figure 1 shows the cost comparison for the three types of construction. As mentioned above, the low density of aluminum combined with its relatively low cost per pound makes Al/Al construction the lowest cost type of construction.

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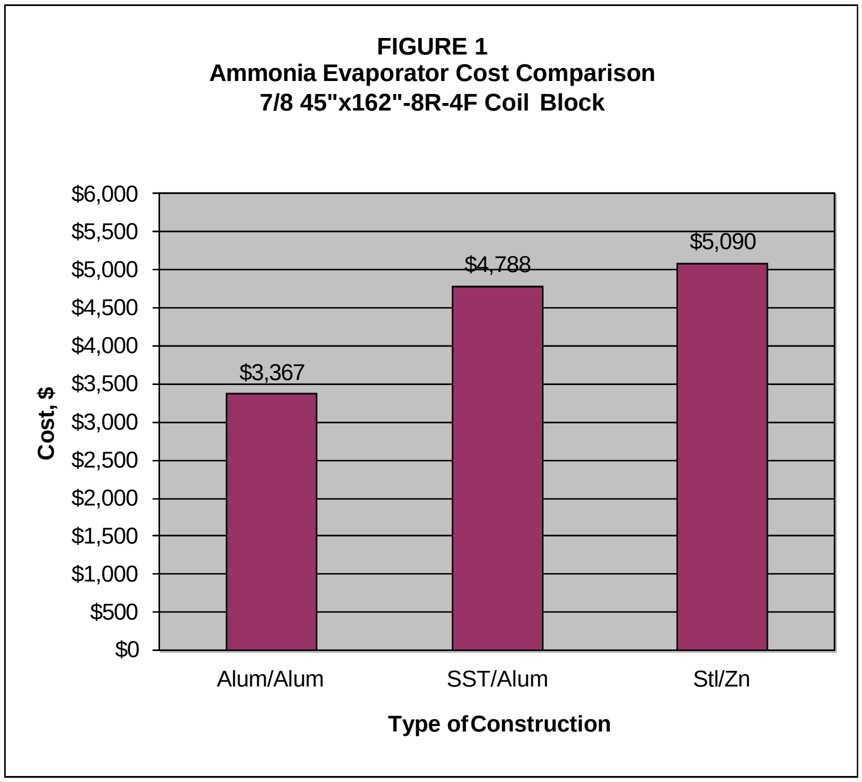
Generally speaking the following conclusions can be made:

1. Stl/Zn construction is most expensive,
2. SST/Al construction costs slightly less than Stl/Zn,
3. Al/Al construction offers lowest cost
   - 25 to 30% lower cost coil block compared to Stl/Zn,
   - 12 to 15% lower cost air cooler compared to Stl/Zn.

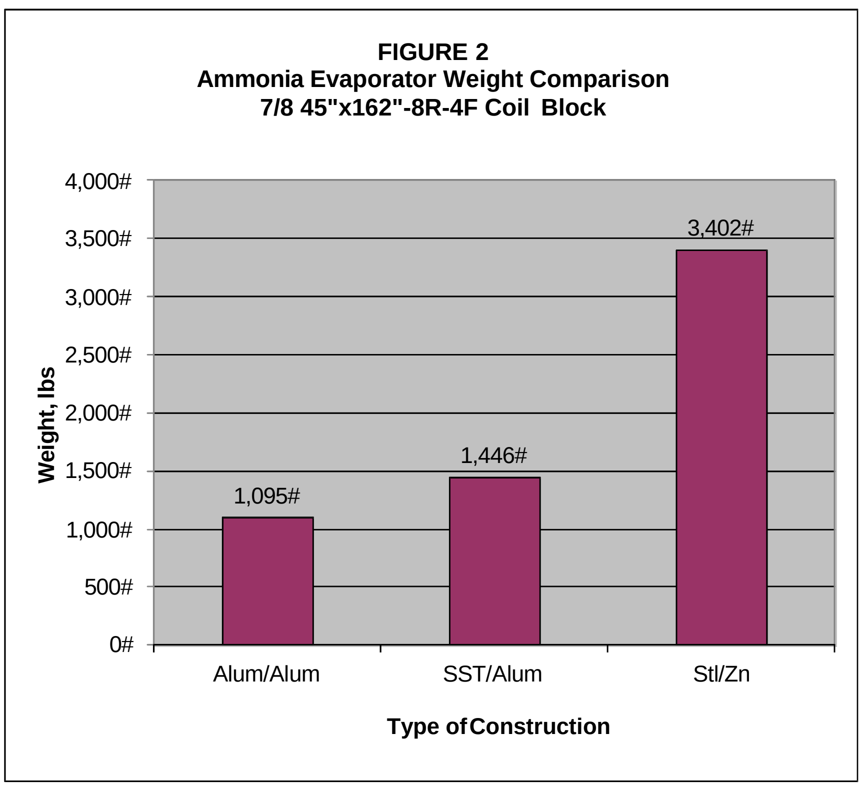


Weight:

The very low density of aluminum makes it an ideal metal to use for heat exchanger fins when weight is a concern. Table 1 shows densities for carbon steel, zinc, and aluminum. The densities of steel and zinc (galvanized steel) are approximately 3 times greater than aluminum. In a refrigeration evaporator, the fins represent approximately ½ the total weight of the coil block. Most of the remaining weight of the coil block is contributed by the tubes and headers.

Tensile and yield strength of the tubing and header metal will affect the wall thickness required for a given working pressure. The higher the tensile strength, the thinner the allowable wall thickness and the lighter the weight of the tubing. From Table 1 it is apparent that tubing made of stainless steel will have a thinner wall thickness and lighter weight when compared to carbon steel tubing for a given calculated working pressure and burst pressure.

Using appropriately selected stainless steel tubing with aluminum fins produces a coil block that is significantly lighter in weight than the same size galvanized steel coil block. A coil block made with both aluminum tubes and fins is even lighter in weight. Figure 2 shows the calculated weights for the three types of construction.



As can be seen in Figure 2, the calculated weight of the galvanized steel (Stl/Zn) coil block (3,402 lbs) is 2.4 times greater than a stainless tube/aluminum fin (SST/Alum) coil block (1,446 lbs), and 3.1 times greater than an aluminum tube and fin (Al/Al) coil block of the same size.

Air coolers are often mounted on the ceiling or roof of the refrigerated building. The weight of the air coolers has a significant impact on the structural design of the building and is of particular importance in high seismic areas. SST/Al and particularly Al/Al air coolers from Colmac offer architects and engineers a new replacement technology to traditional heavy galvanized air coolers. This weight advantage

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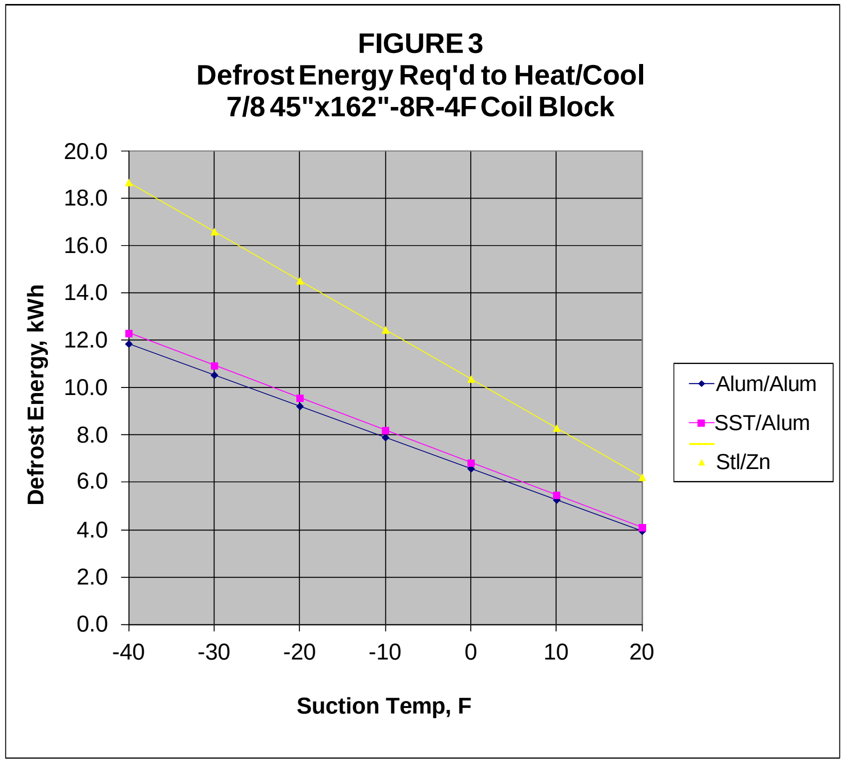
can be used to significantly reduce the cost of building structural members.
The lighter weight of SST/Al and Al/Al air coolers from Colmac also offer installers improved safety for workers when rigging and handling. It is easy to visualize the safety advantages of mounting a cooler weighing only 2,000 lbs in a building with a 25 foot ceiling compared with a heavy galvanized steel cooler of the same capacity weighing 5,000 lbs or more!

Comparison: Performance



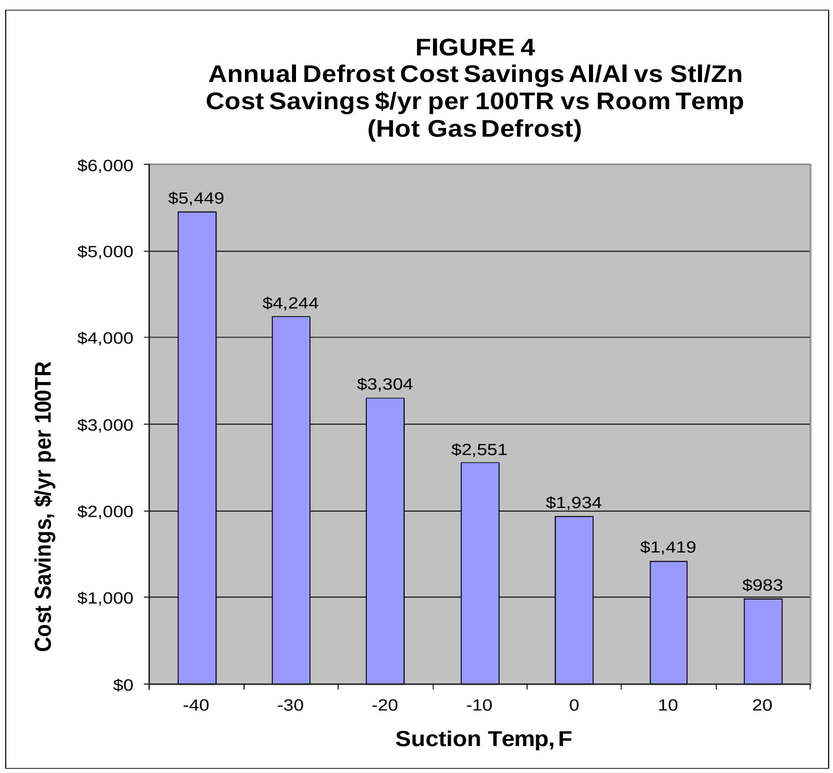
The thermal conductivity of aluminum is 4 ½ times higher than steel, and 2 times higher than zinc. Thermal conductivity of the fin material has a direct effect on heat transfer efficiency, the higher the better. Aluminum is superior to galvanized steel for efficient heat transfer. The measured performance of an Al/Al ammonia evaporator will be approximately 12 to 14% higher than a Stl/Zn evaporator having the same dimensions (Stencel 1992). A SST/Al ammonia evaporator will have slightly lower performance than the Al/Al due to the poor conductivity of the stainless steel tubing, but will still outperform a Stl/Zn evaporator of the same dimensions by 10 to 12%.

The superior cooling capacity of Al/Al and SST/Al construction compared to Stl/Zn allows the designer the choice between (a) selecting an evaporator having fewer rows and/or wider fin spacing for lower first cost, or (b) using the same size unit (same rows and fin spacing) and operating at higher suction pressures with resulting reduced operating costs.

Comparison: Defrost Energy

The high thermal conductivity of aluminum fins also produces faster, more effective defrosts compared to galvanized steel. SST/Al and Al/Al evaporators simply defrost faster and better than Stl/Zn steel coils.

SST/Al and Al/Al evaporators also perform better than Stl/Zn during defrost on an energy basis. A substantial amount of energy is expended during defrost to heat the mass of metal in a refrigeration evaporator up to the defrost temperature, then to cool the metal back down to operating temperature after defrost. When the density of the metal is multiplied by the thermal conductivity the product indicates the amount of energy required to heat (or cool) a heat exchanger of a given volume by one degree.
Based on this analysis, a comparison was made for our example evaporators. Figure 3 shows the total amount of energy required to heat the coil block from suction temperature to 50F and then cool it back to down again. This energy is expended every defrost cycle.



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As shown in Figure 3, the Al/Al and SST/Al coil blocks consume significantly less energy to heat up and cool down during defrost (30 to 35% less) than the Stl/Zn coil block. This reduced amount of energy required for heating and cooling metal results in significant ongoing savings in operating costs compared with traditional energy consuming Stl/Zn evaporators.

Defrost Energy Savings

This difference in energy consumption can be converted to cost savings by making assumptions for number of defrosts per day, days of operation per year, and the electric utility rate. A cost calculation was made for 100TR (350 kW) of evaporator capacity, assuming 6 defrosts per day for 365 days/year, a utility rate of $0.10/kWh, typical screw compressor system COPs (assumed defrost is with hot gas), and a hot defrost pressure regulator setting of 74.3 psig (50F). Calculated cost savings for hot gas defrost are shown in Figure 4.

Comparison: Corrosion Resistance

Corrosion of heat exchangers by contact with, or proximity to foodstuffs is a concern in food processing facilities (Nelson 2007). All foodstuffs are mildly acidic. Aluminum and stainless steel are both more corrosion resistant than galvanized steel when exposed to:

- Acetic and citric acids (dairy products, citrus products)
- Fatty acids (anti-caking agents, lubricants)
- Lactic acids (bread, confections, beverages, fermentation, blood)

Aluminum is also more corrosion resistant than galvanized steel in the presence of:

- Sodium chloride (preservation of meats and vegetables)
- Sulfur dioxide (grape storage)

Neither galvanized steel nor aluminum is recommended for exposure to nitrites (cured and smoked meats). Stainless steel is the suggested material to use in the presence of nitrites.

Generally speaking, aluminum and stainless steel are better metals to use than galvanized steel where there is concern about corrosion due to contact with most foodstuffs.

Cleaning Chemicals

In order to control contamination of food in processing facilities, various chemical compounds are used for cleaning and sanitizing. Cleaning is defined as the removal of organic soils (fats and oils) and/or inorganic soil (mineral scale or stains). Sanitizing is defined as the process of treating cleaned surfaces to effectively kill or remove pathogens.

The USDA requires that these two processes, cleaning and sanitizing, be done separately. Cleaning and sanitizing chemicals used in the food processing industry fall into four categories:

1. Acidic
2. Strongly Alkaline
3. Mildly Alkaline
4. Chlorine Based

Zinc, Aluminum, and Stainless Steel (304L, 316L) react differently to these cleaning chemicals (NACE 1985). In some cases severe corrosion and metal loss can occur. Generally speaking, corrosion and rate of metal loss increases with:

- Increasing temperature
- Increasing concentration
- Longer duration of exposure
- Increased aeration of the solution

Following is a summary of how each of these metals reacts to various environments and recommendations regarding cleaning and sanitizing chemicals appropriate for each.

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Aluminum

General

- The protective oxide layer forms very quickly when the metal is exposed to air and is very stable in the pH range of 4 to 9 (Davis 1999).
- Aluminum corrodes very quickly when exposed to strong alkaline cleaners such as caustic soda (sodium hydroxide) (Alum Assoc 1994) .
- Aluminum is also attacked by strong acids as well as chlorine based cleaners (concentrated sodium hypochlorite).

Cleaning

- Foaming mildly alkaline cleaners are recommended for the removal of animal fats (organic soil). Example: ZEP FS Strike Three, ZEP FS Foamate

- Foaming mildly acidic cleaners (phosphoric acid based with pH >4) are recommended for removal of stains and scale (inorganic soil). Example: ZEP Formula 7961

Sanitizing

- Spray-on quaternary ammonium type sanitizers are recommended. Example: ZEP FS Amine Z, ZEP Amine A
- The use of sodium hypochlorite in high concentrations can cause pitting of aluminum and is NOT recommended for sanitizing.

Stainless Steel (304L, 316L)

General

- The chromium in stainless steel forms a very dense passive film layer which is generally very stable over a wide pH range (Carpenter 1987).
- These alloys are resistant to strong alkaline cleaners such as caustic soda (sodium hydroxide).
- Halogen salts (primarily chlorides) penetrate the passive layer and can result in pitting and/or stress corrosion cracking.
- Exposure to sodium hypochlorite, or hydrochloric acid solutions, in high concentrations will result in pitting and/or stress corrosion cracking.

Cleaning

- Foaming mildly alkaline cleaners are recommended for the removal of animal fats (organic soil). Example: ZEP FS Strike Three, ZEP FS Foamate
- Foaming mildly acidic cleaners (phosphoric acid based with pH >4) are recommended for removal of stains and scale (inorganic soil). Example: ZEP Formula 7961

Sanitizing

- Spray-on quaternary ammonium type sanitizers are recommended. Example: ZEP FS Amine Z, ZEP Amine A
- The use of sodium hypochlorite in high concentrations will cause pitting and/or stress corrosion cracking and is NOT recommended.

Zinc (galvanized steel)

General

- The oxide layer forms quickly in the presence of air and is stable in the pH range of 7 to 12 (Stencel 1993).
- Zinc corrodes very quickly when exposed to acidic solutions, even mildly acidic.
- The metal is resistant to corrosion by alkaline cleaners such as caustic soda (sodium hydroxide).

Cleaning

- Foaming mildly alkaline cleaners are recommended for the removal of animal fats (organic soil). Example: ZEP FS Strike Three, ZEP FS Foamate
- Acidic cleaners of all types (pH <7) will result in rapid metal loss and are to be avoided. This makes removal of stains and scale (inorganic soil) very difficult and problematic.

Sanitizing

- Spray-on quaternary ammonium type sanitizers are recommended. Example: ZEP FS Amine Z, ZEP Amine A
- The use of sodium hypochlorite is NOT recommended.

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Figure 5
Old Flange Union vs New Colmac BiM Technology

Figure 6
Al/Al Evaporator with Colmac BiM Connections

Comparison: Reliability

In a recent survey of ammonia refrigeration end users, it was found that 95% of all incidental ammonia leaks occur at flange union pipe connections, including coil connections. With Stl/Zn and SST/Al construction the coil connections are typically welded and so the potential for ammonia leaks greatly reduced. Al/Al coil connections traditionally used dielectric type flange unions which are prone to leaks over time. A new technology is now available from Colmac which eliminates the need for flange union coil connections on Al/Al construction. Colmac BiM couplers make the transition from the aluminum coil liquid and suction connections to the system steel (or stainless steel) piping via a proprietary metallurgical bonding process, eliminating the need for bolts, gaskets, and flanges. This new technology is shown below in Figures 5 and 6.

Conclusions:

Three types of ammonia evaporator construction (Al/Al, SST/Al, and Stl/Zn) have been analyzed and compared.

1. Al/Al construction was found to have:
    a. Lowest first cost
    b. Lightest weight
    c. Best performance
    d. Lowest operating cost
2. Unlike Stl/Zn which becomes brittle and requires special design considerations, both SST/Al and Al/Al construction retain full strength and do not become brittle, even at very low temperatures.
3. When Al/Al ammonia evaporators are installed in food processing plants and exposed to cleaning and sanitizing chemicals:
    a. Highly alkaline (pH >10) cleaners should be avoided. Foaming mildly alkaline cleaners are recommended.
    b. Sodium hypochlorite based sanitizers should be avoided. Quaternary ammonium sanitizers are recommended.

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COLMAC COIL Manufacturing Inc.

Technical Bulletin

By Bruce I. Nelson, P.E., President, Colmac Coil Manufacturing, Inc.

SUCCESSFUL REFRIGERATION DEPENDS ON GOOD AIRFLOW

Introduction

Very often we forget that air is the most commonly used heat transfer fluid in air-conditioning and refrigeration systems. We typically remove heat from a refrigerated space by circulating cooled air throughout the room and across the product being refrigerated. A good airflow pattern is critical to the success of any refrigerated space design. A poor airflow pattern will result in poor air cooler and system performance even though the equipment may be adequately sized for the cooling load.

Most refrigeration air coolers use propeller type fans for moving air across the coil and circulating the cooled air throughout the room. Propeller fans are typically low cost, move adequate quantities of air, and use roughly one half the power of centrifugal fans for a given quantity of air at the static pressures normally seen (less than 1 iwg TSP) in refrigeration applications. Proper selection of air cooler configuration and propeller fan design is the topic of this article.

Colmac offers several air cooler configurations to match different airflow requirements. The LP, HP, ICL, and ICH product lines are ceiling-hung with draw through fan/coil arrangement discharging air horizontally. This type of unit is used in relatively large, open rooms where air throw to an opposite wall is desired. Good airflow in the room will depend on a number of factors:

Placement of Air Coolers

Avoid mounting air coolers directly over door openings. Locating the unit(s) opposite door openings reduces infiltration and the amount of warm, humid air drawn into the air cooler. Also, locate air coolers so that the distance to the opposite wall does not exceed the unit's rated air throw distance.

Condition of Ceiling Surface

Smooth ceiling surfaces are always best. The air leaving an air cooler tends to "stick" to and "roll along" the ceiling. A rough ceiling surface will obviously dissipate the momentum in the airstream and reduce air throw. Obstructions on the ceiling, such as beams, piping, ductwork, etc. will also kill air circulation.

Shape of the Room

A wide room (approx. 3X air cooler width) gives the best air circulation. A narrow (2X or less air cooler width), long room is the worst case for air circulation. Here the use of air straighteners is required to promote good air movement.

Straighteners perform three functions:
- a) Increase discharge velocity;
- b) Reduce turbulence of the air stream; and
- c) Increase the amount of entrained air leaving the unit.

Rooms with low ceilings can also create airflow problems. Here, efforts must be made to keep the discharge air stream moving along the ceiling to the opposite wall, such as use of turning vanes in room corners, along with smooth ceiling conditions. Air straighteners may also be used to direct air upwards to the ceiling if needed.

Colmac also offers air coolers suitable for applications where low velocity air movement is required, such as in rooms where workers are in close proximity, or where products are sensitive to high velocity air streams (i.e. flowers). The GF, LV, and AR product lines are designed to provide maximum cooling capacity with low velocity airflow for these types of applications.

Generally, these types of units are ceiling mounted and located throughout the room so air throw distance is not a large concern.

For applications requiring airflow with higher static pressures, such as blast freezing, the Colmac BF line with blow through fan/coil configuration is available. In this case air throw distance is not so critical as: a) even distribution of discharged air, and b) high static pressure capability of the fans.

Depending on fan diameter and speed, the maximum external static pressure that can be generated by a propeller fan typically used on air coolers is approximately 0.25 to 0.50 iwg. Generally speaking, static pressure is generated at the tip of the fan blade. Increasing the tip speed will increase the static pressure for a given blade. Tip speed can be increased by increasing rotational speed and/or increasing fan diameter. Also, as static pressure requirements increase, the clearance between blade tip and venturi becomes more important (the closer the clearance the better the performance). So, if high static pressures are required, the best performance will be gotten from a fan with large diameter and the highest rotational speed practical.

Conclusion

In conclusion, proper air circulation depends on several considerations including: fan design, air cooler configuration, static pressure requirements, as well as shape and size of the room. To design high performance refrigeration systems using Colmac air coolers use the guidelines mentioned above for creating good room airflow patterns.

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REVERSING AIR FLOW EVAPORATORS

Traditionally blast freezing and cooling cells have been designed with airflow moving in one direction only through the product. Research at Colmac Coil using Computational Fluid Dynamics (CFD) software validated by field experience has shown dramatic improvements in both freezing time and product quality when designing for reversing airflow through the product during the freezing (or cooling) cycle. Using recently developed fan blade technology, Colmac offers evaporators with the ability to effectively move air through the product in alternating opposite directions. This new fan technology is cost effective and can be applied to most A+Series™ evaporator configurations.

Using CFD modeling, Colmac engineers can accurately predict airflow patterns and air pressure drop through the product in your facility to optimize the design of your blast freezing or cooling cell. Using reversing airflow evaporator technology has shown freezing times can be reduced by as much as 20% and finished product temperature variations can be reduced to as little as + or - 0.5 deg C.

Reversing Airflow Evaporators designed and manufactured by Colmac offers a number of advantages in the process of cooling and freezing:

- Shorter freezing times
- Reduced evaporator power consumption
- Reduced compressor power consumption
- More uniform temperature and quality of frozen product
- Reduced number of defrost cycles required

Principle of Operation

The design of Reversing Airflow evaporators allows the fan motors to operate fully in two directions of air flow, i.e. forced (blow-through) and induced (draw-through). This allows the rows of products that are initially in the back of the freezer to be switched to the front, reducing freezing time once the direction is reversed.

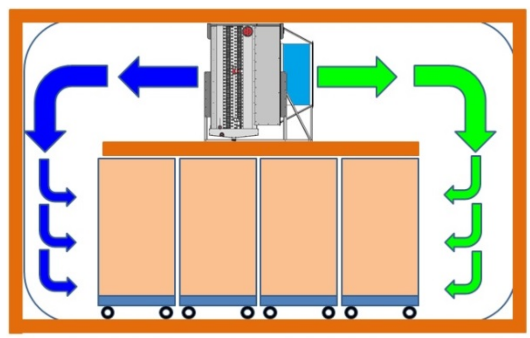
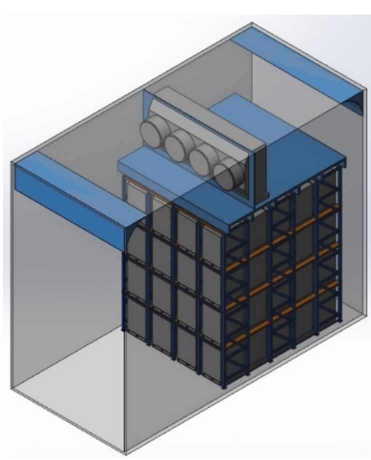
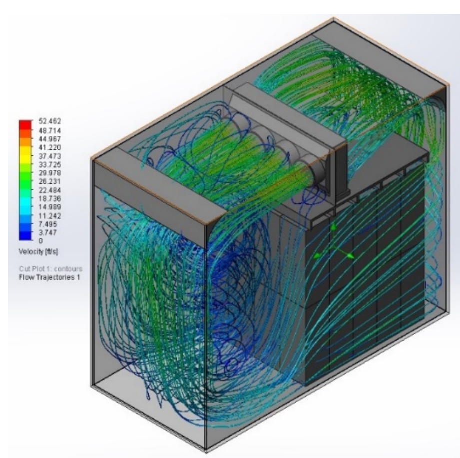


Diagram of Reversing Air Flow Freezer
Blue indicates blow-though air flow
Green indicates draw-though air flow

CFD Analysis

Colmac can assist you with CFD modeling of your blast cell to predict airflow patterns and fan power requirements.





Technical Bulletin

Capacity Expansion Project, Baja Marine Foods - Ensenada, Mexico

Baja Marine Foods is a subsidiary of Tri-Marine Fish Co. of San Pedro, CA. It engages in the production and marketing of sardines, calamari, and other small fish. These products are frozen whole for domestic and international markets, primarily for human consumption. The project added 4 new Reversing Airflow retrofitted 4 existing freezers to this technology. The new Reversible Air Flow freezers have shown a better ability to freeze product, with a decrease in freezing time of 20%. This represents a substantial energy savings, cost reduction and improvement in product quality.

Reversing Airflow Evaporator

Mr. Adrian Gutierrez, General Manager, said: "This technology was chosen based on our many years of experience in freezing our products and we have seen that the design offered by Colmac has resulted in shorter freezing times, operating cost savings, and better quality. We are very pleased with the results and plan to continue using the reversing airflow technology in our upcoming projects. "

Draw-through Air Flow Direction

Blow-through Air Flow Direction

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By Bruce I. Nelson, P.E., President, Colmac Coil Manufacturing, Inc.

ADX™ Ammonia System Evacuation

When water is present in a DX ammonia system, it changes the characteristics of the refrigerant and the operation of the system. Because a DX evaporator coil boils off 100% of the refrigerant prior to the end of the circuit, a small amount of water in the system will create a high water content at the coil exit. This will adversely affect the superheat and refrigerant feed. Recirculated ammonia systems do not utilize 100% evaporation, so any water accumulates on the low side, unnoticed, until the plant efficiency degrades from lower required suction pressures. Please refer to the Colmac DX Ammonia Piping Handbook for a more thorough explanation.

Residual water left over from the construction period is the primary initial source of water in a refrigeration system. Most ASME pressure vessels are pressure tested with water and they are merely drained after testing. Refrigeration pipes are commonly left open to the atmosphere during construction. The normal daily ambient temperature range will cause condensate to form in the pipes overnight. While these quantities of water are small, collectively they can add up to a significant amount. A teaspoon of water at the exit of a coil circuit will falsify the superheat reading by more than the TD of the coil. This completely overwhelms the superheat control, causing the coil to overfeed.

Evacuation Comments

Evacuating a system prior to commissioning accomplishes two things. It removes most of the non-condensables from the system. This allows efficient condenser operation immediately upon start-up. Secondly, it removes water from the system. As the system pressure is reduced, water's boiling temperature will gradually reduce from 212ºF (atmospheric pressure - 760,000 microns) to 32ºF at 4580 microns. The residual heat of the pipe and vessel walls will evaporate this residual water….if, it is spread out in the system. If it collects in a small low spot with little metal volume, it may never absorb enough heat to evaporate, especially if the pipes are insulated. Note: a pound of steel pipe giving up 20ºF will only evaporate ¼ oz of water (2 teaspoons). Also, when that ¼ ounce of water evaporates at 5,000 microns it generates 46 ft^3 of water vapor which significantly slows the rate of evacuation.

Vacuum Pump Selection

The nominal capacity of a vacuum pump is measured at atmospheric pressure. When the vacuum reaches 13,200 (60ºF) to 25,000 (78ºF) microns, the range where water is evaporating, its cfm capacity is only 4% of the nominal rating. Example a 10 cfm vacuum pump will spend most of the evacuation time pumping 0.4 cfm. That is 11 minutes of pumping for the 2 teaspoon example above. A small system may have 150 ft^3 of internal volume and a large system could have 1,500 ft^3 or more internal volume. For a guideline; a 10 cfm vacuum pump will evacuate a 575 ft^3 dry system to 5,000 microns in approximately 24 hours. The presence of water will extend this time.

Evacuation Steps

1. After a successful pressure test, blow off the pressure in stages from all of the valved low points in the system. This will push any pooled liquid out of the system.
2. Re-install any safety relief valves that were removed for pressure testing and ensure that all parts of the system are ready to accept an ammonia charge and are open to the vacuum pump.
3. Connect a digital vacuum gauge to the system such as a "Blu Vac" gauge that is designed to accurately measure and display a deep vacuum in microns.

4. Source a vacuum pump(s) of at least 8 cfm capacity and charge it with fresh vacuum pump oil that is water free. (Water contaminated oil will flash and degrade the pumps vacuum pulling ability)
5. Dead head the suction side of the vacuum pump to the vacuum gauge and prove that it can pump down to 5,000 microns. If not, get a different pump.
6. Connect the system to the vacuum pump through the largest diameter and shortest, deep vacuum rated hoses available and practical.
7. Operate the pump until a vacuum of 5160 microns (35ºF) is achieved. There may be a vacuum level where the vacuum appears to level off rather than drop. This is most likely water evaporating. When all of the water is vaporized, the pressure will resume falling. A wet system may require an intermediate pump oil change to achieve a full vacuum.
8. At this point all of the water should have been evaporated.
9. Break the vacuum with dry nitrogen until the system returns to about 760,000 microns, no vacuum or pressure.
10. Change the oil in the vacuum pump.
11. Pull another vacuum down to 5,160 microns.
12. Valve off the pump and ensure that the vacuum stabilizes and then holds steady for 24 hours. This confirms that there are no leaks or water remaining in the system.
13. Break this vacuum with refrigerant grade (99.98% pure, < 150 PPM H_2O) ammonia.
14. Continue to charge the system with the prescribed amount of liquid ammonia.

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Fin and Tube Specifications

A+ Series™ Air Coolers

COLMAC COIL Manufacturing Inc.

Introduction

Colmac Coil A+Series™ air coolers are available with multiple fin and tube patterns, allowing them to be easily optimized for any operating conditions. Matching the cooler to the application will ensure the best performance and longest runtimes from your A+ Series™ cooler. This bulletin provides an overview of the available options, their effects on cooler performance, and when to use them.

Tube Diameter

The diameter of the tubes in a cooler has a direct effect on the flow pattern of the refrigerant traveling through them. This flow pattern is a major factor in the heat transfer efficiency and refrigerant pressure drop of the cooler. Matching the tube pattern to the refrigerant flow rate will help achieve the best flow pattern.

Because the refrigeration system type provides a general idea of what the flow rate of the refrigerant will be, it can be used as a guideline to select the tube size. A+ Series™ air coolers are available in two tube diameters: 5/8” and 7/8”.

5/8” Tubes

This size is preferred for systems with lower refrigerant mass flow rates, such as DX and glycol coolers. The smaller tube area does, however, create more refrigerant pressure drop, which limits its use in certain applications. Pump recirculated coolers can use 5/8” tubes, as long as an acceptable refrigerant pressure drop can be reached. Colmac’s A+Pro™ software automatically calculates this and will provide notification if it cannot be achieved. CO_2 systems commonly use 5/8” tubes, due to their higher working pressure.

7/8” Tubes

The increased area of this tube allows it to accommodate more refrigerant flow with lower pressure drops. It is the most common choice for pump recirculated coolers and is required for flooded operation. With a Colmac tube enhancement, it can also be used for glycol/brine or Low Temperature DX ammonia coolers.

TABLE 1

Common Tube Diameters Based on System Type*

Refrigeration System	Tube Diameter
Flooded	7/8” (required)
Pump recirculated	5/8 or 7/8”
Single phase liquids, brines	5/8” or 7/8” enhanced
Standard DX	5/8”
CPR	5/8” or 7/8”
Low Temp DX Ammonia	7/8” enhanced (required)

*Always verify design using Colmac’s A+Pro™ software or by contacting your local Colmac representative.

Fin and Tube Specifications

A+ Series™ Air Coolers

COLMAC COIL
Manufacturing Inc.

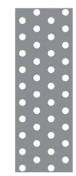
Tube Pattern

The arrangment of the tubes in the cooler determines how the air will flow around them. This affects the air side heat transfer of the cooler as well as the air pressure drop. There are two basic styles of tube patterns, staggered and inline. A staggered pattern causes more air turbulence, which increases heat transfer, but also causes a greater air pressure drop. Inline patterns allow the air to pass more easily for a lower air pressure drop, but more evaporator surface is required with this pattern. The A+ Series™ coolers combine these patterns with the tube diameters for three options: 5/8” staggered, 5/8” inline and 7/8” staggered.

5/8” tubes, 1.5” Staggered Pattern (Fig. 1)

This is a compact pattern for high heat transfer efficiency in a small envelope. This results in the cost effective solutions for warm temperature (>32°F) applications that have low refrigerant flow rates. Because of the compact nature of this pattern, it is more quickly blocked by frost buildup and therefore not recommended for room temperatures below 35°F. Common feed methods for this pattern are DX, single phase liquids/brines, CPR, and low overfeed pump recirculated systems.

Figure 1

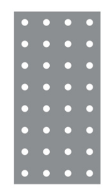


5/8” Tube, 2” (50mm) Inline Pattern (Fig. 2)

This is a wider pattern with the lowest fan power requirement of the three options. With more space between the tubes, it is also well suited for frosted conditions (<32°F) when a 5/8” tube is required. The clear line of sight through the evaporator also increases the cleanability of the inline pattern. The large amount of secondary (fin) surface also helps distribute frost buildup over a large area, allowing for the longest runtime between defrosts of all three patterns.

Electric defrost A+ Series™ coolers are only available in this pattern due to its ability to accommodate heating elements without dropping tubes.

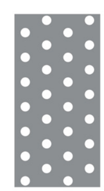
Figure 2



7/8” Tube, 2.25” Staggered (Fig. 3)

This is a widely spaced staggered pattern for high heat transfer efficiency while minimizing the effect on air pressure drop. This pattern has the widest tube spacing and large amounts of secondary surface area for excellent frost carrying capacities and runtimes. The A+ Series™ Engineering Catalog is designed exclusively with this pattern.

Figure 3



Fin Spacing

Fins make up the majority of the heat transfer surface of the cooler and have the greatest effect on its overall heat transfer, air pressure drop and runtime. More closely spaced fins are good for getting the most capacity out of a given envelope, but are more sensitive to blockage by frost and debris. Wider spaced fins provide a lower air pressure drop and more space for frost buildup, but require the cooler to be larger. The most common fin spacing choices are detailed below.

6 FPI (Fins per Inch)

This is the tightest fin spacing available on A+ Series™ coolers. This provides the maximum heat transfer surface area, but can quickly become blocked by debris or frost. It is recommended only for high temp applications (> 35°F) with light condensation and minimal airborne debris. Air velocities must be kept below 600 fpm to prevent water carryover.

Fin and Tube Specifications

A+ Series™ Air Coolers

COLMAC COIL Manufacturing Inc.

4 FPI

By increasing the space between fins, more room is provided for frost to build without blocking the air flow. Because the fins are wider, there are less of them, resulting in slightly less heat transfer surface. This is the standard spacing for medium temperature applications (0°F – 35°F) and is also recommended for high temperature applications (> 35°F) when large amounts of airborne debris are expected. In applications above freezing, air velocities must be kept below 600 fpm to prevent water carryover.

3 FPI

This is the widest standard fin spacing available on A+ Series™ air coolers. It provides extra room for frost buildup, particularly when used with variable fin spacing, as explained below. This spacing is recommended for low temperature applications (< 0°F).

Variable Fin Spacing (Fig. 4)

Variable fin spacing reduces the fin spacing by half on the first two rows of tubes, providing added space for frost buildup where it is needed most. This is recommended in applications with heavy frost accumulation due to airborne ice crystals, such as blast freezers and in cold stores near doorways. Variable fin spacing will provide the longest runtime between defrosts.

Figure 4
Variable Fin Spacing

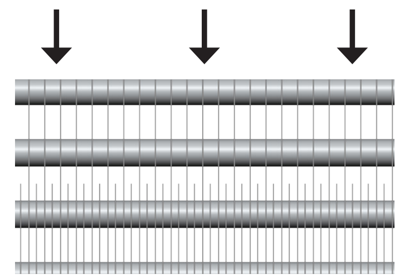


TABLE 2

Recommended Fin Spacing Based on Operating Condition

Room Temp	Conditions	Fin Spacing
> 35°F	Standard	6 FPI
	Fouling/Debris	4 FPI
0°F – 35°F	Standard	4 FPI
	Heavy Frost	Variable: 2/4 FPI or 1.5/3 FPI
< 0°F	Standard	3 FPI
	Heavy Frost	Variable: 1.5/3 FPI

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Nelson

(10) **Patent No.:** **US 6,843,509 B2**
(45) **Date of Patent:** **Jan. 18, 2005**

(54) **COUPLER FOR USE WITH METAL CONDUITS**

(75) Inventor: **Bruce I. Nelson**, Colville, WA (US)

(73) Assignee: **Colmac Coil Manufacturing, Inc.**, Colville, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 61 days.

(21) Appl. No.: **10/308,297**

(22) Filed: **Dec. 2, 2002**

(65) **Prior Publication Data**

US 2004/0104574 A1 Jun. 3, 2004

(51) **Int. Cl.**[7] **F16L 13/02**; B23K 20/08
(52) **U.S. Cl.** **285/288.11**; 285/148.12; 285/329; 228/107; 428/651
(58) **Field of Search** 285/148.11, 148.12, 285/288.1, 288.11, 329; 228/107, 108, 109; 428/651

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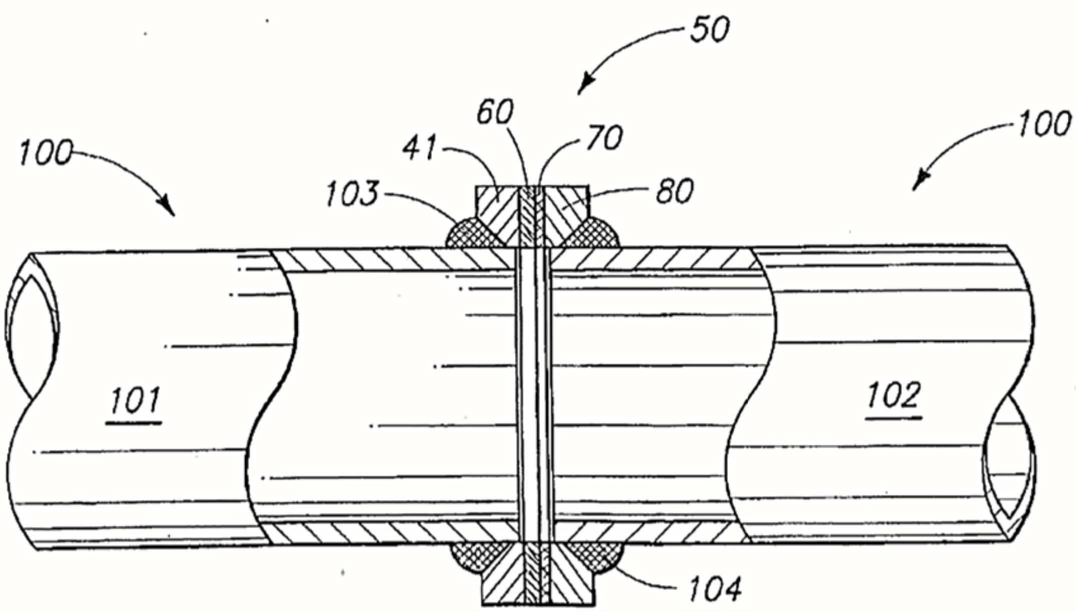
Primary Examiner—James M. Hewitt
(74) *Attorney, Agent, or Firm*—Wells St. John P.S.

(57) **ABSTRACT**

A coupler for joining an aluminum conduit to a steel or stainless steel conduit and which includes a main body which is formed from a first layer of aluminum and a layer of steel or an iron-chromium alloy which are explosively welded together, and wherein the main body has a first aluminum surface, and an opposite, second steel or iron-chromium alloy surface, and wherein the aluminum conduit is welded to the first aluminum surface, and the steel or stainless steel conduit is welded to the second steel or iron-chromium surface.

4 Claims, 3 Drawing Sheets



US007597137B2

(12) **United States Patent**
Nelson et al.

(10) **Patent No.:** **US 7,597,137 B2**
(45) **Date of Patent:** **Oct. 6, 2009**

(54) **HEAT EXCHANGER SYSTEM**

(75) Inventors: **Bruce I. Nelson**, Colville, WA (US); **Delbert A. Morris**, Colville, WA (US)

(73) Assignee: **Colmac Coil Manufacturing, Inc.**, Colville, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 215 days.

(21) Appl. No.: **11/712,847**

(22) Filed: **Feb. 28, 2007**

(65) **Prior Publication Data**

US 2008/0202738 A1 Aug. 28, 2008

(51) **Int. Cl.**
F28F 9/04 (2006.01)

(52) **U.S. Cl.** **165/174**; 165/178; 62/525

(58) **Field of Classification Search** 165/174, 165/178; 62/525

See application file for complete search history.

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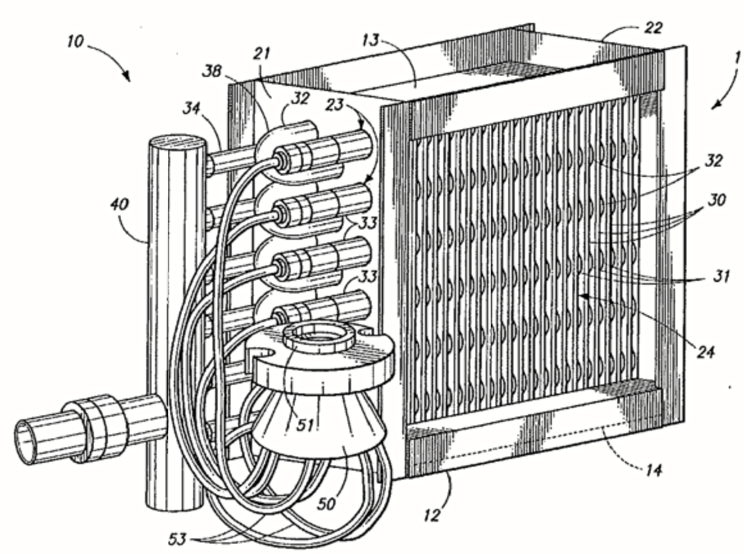
Primary Examiner—Teresa J Walberg
(74) *Attorney, Agent, or Firm*—Wells St. John P.S.

(57) **ABSTRACT**

A heat exchanger system is described and which includes a metal tubular heat exchanger; a fluid distributor conduit fabricated from a metal dissimilar to that of the heat exchanger, and wherein the fluid distributor conduit is connected in fluid flowing relation relative to the metal tubular heat exchanger; and a fluid distributor made of a metal that is similar to that of the fluid distributor conduit, and which is connected in fluid flowing relation relative to the fluid distributor.

8 Claims, 5 Drawing Sheets



US007712327B2

(12) **United States Patent**
Nelson et al.

(10) **Patent No.: US 7,712,327 B2**
(45) **Date of Patent: May 11, 2010**

(54) **HEAT EXCHANGER AND METHOD FOR DEFROSTING A HEAT EXCHANGER**

(75) Inventors: **Bruce I. Nelson**, Colville, WA (US); **John L. Wold**, Springdale, WA (US); **Roger B. Williams**, Colville, WA (US); **Jeremy P. Olberding**, Colville, WA (US)

(73) Assignee: **Colmac Coil Manufacturing, Inc.**, Colville, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 323 days.

(21) Appl. No.: **11/725,689**

(22) Filed: **Mar. 19, 2007**

(65) **Prior Publication Data**

US 2008/0229763 A1 Sep. 25, 2008

(51) **Int. Cl.**
F25D 21/06 (2006.01)
F28F 7/00 (2006.01)

(52) **U.S. Cl.** **62/276**; 62/275; 165/81; 165/82; 219/535

(58) **Field of Classification Search** 62/275, 62/276; 165/81, 82; 219/535, 520, 2, 3, 219/522, 543
See application file for complete search history.

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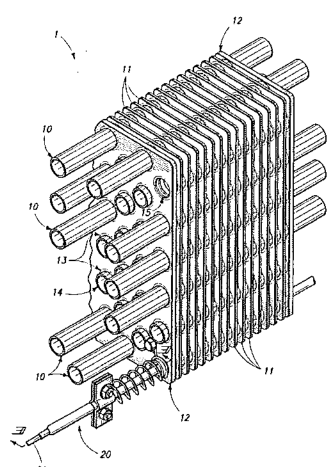
Primary Examiner—Frantz F Jules
Assistant Examiner—Alexis K Cox
(74) *Attorney, Agent, or Firm*—Wells St. John. P.S.

(57) **ABSTRACT**

A heat exchanger and method for defrosting a heat exchanger is disclosed and which includes a heat exchanger having a fluid receiving conduit, and at least one space which is defined, at least in part, by the fluid receiving conduit, an expandable and contractible heating element which is received within the space, and which is located in heat transmitting relation relative to the fluid receiving conduit, and a biasing member mounted on the heat exchanger and the heating element and which longitudinally, and resiliently restrains the movement of the heating element relative to the heat exchanger during the expansion and contraction of the heating element relative to the heat exchanger.

6 Claims, 6 Drawing Sheets



US007958738B2

(12) **United States Patent**
Nelson

(10) **Patent No.: US 7,958,738 B2**
(45) **Date of Patent: Jun. 14, 2011**

(54) **DIRECT EXPANSION AMMONIA REFRIGERATION SYSTEM AND A METHOD OF DIRECT EXPANSION AMMONIA REFRIGERATION**

(75) Inventor: **Bruce Ian Nelson**, Colville, WA (US)

(73) Assignee: **Colmac Coil Mfg., Inc.**, Colville, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 547 days.

(21) Appl. No.: **12/156,980**

(22) Filed: **Jun. 6, 2008**

(65) **Prior Publication Data**

US 2009/0301112 A1 Dec. 10, 2009

(51) **Int. Cl.**
F25B 15/00 (2006.01)

(52) **U.S. Cl.** **62/112**; 62/504; 62/509

(58) **Field of Classification Search** 62/112, 62/498, 504, 509; 165/104.26, 302; 122/366
See application file for complete search history.

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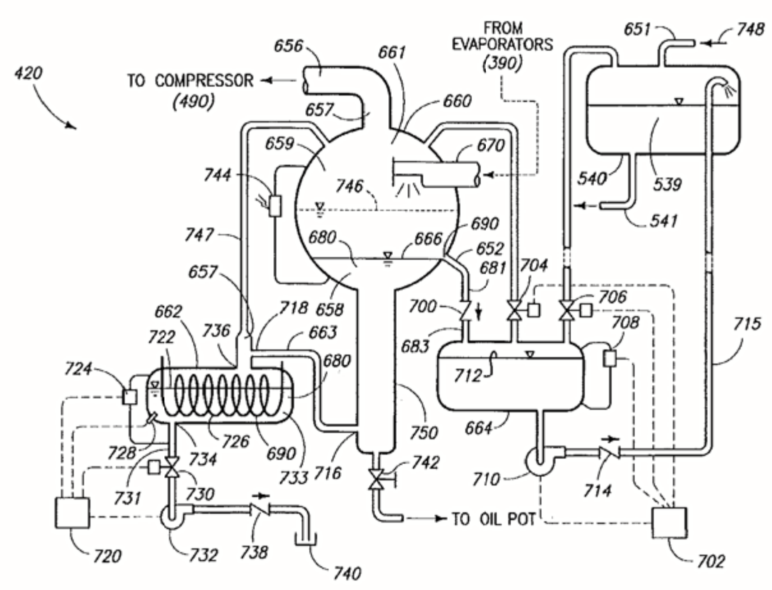
Primary Examiner — Mohammad Ali
(74) *Attorney, Agent, or Firm* — Paine Hamblen, LLP

(57) **ABSTRACT**

A direct expansion ammonia refrigeration system and a method of direct expansion ammonia refrigeration is described and which includes a source of liquid ammonia refrigerant which is delivered in fluid flowing relation to a plurality of evaporator tubes which incorporate wicking structures, and which through capillary action facilitated by the wicking structures are effective for drawing liquid ammonia refrigerant along the inside facing surface of the evaporator tubes so as to substantially reduce any stratified and/or wavy flow patterns of the liquid ammonia refrigerant within the evaporator tubes. The invention further includes a novel accumulator vessel and heat exchanger vessel which are coupled in fluid flowing relation relative to the direct expansion ammonia refrigeration system and which facilitate the removal of water from the ammonia refrigerant in order to enhance the operation of the direct expansion ammonia refrigeration system.

46 Claims, 13 Drawing Sheets



US008474276B2

(12) United States Patent

Nelson

(10) Patent No.: **US 8,474,276 B2**

(45) Date of Patent: ***Jul. 2, 2013**

(54) **DIRECT EXPANSION AMMONIA REFRIGERATION SYSTEM AND A METHOD OF DIRECT EXPANSION AMMONIA REFRIGERATION**

(75) Inventor: **Bruce I. Nelson**, Colville, WA (US)

(73) Assignee: **Colmac Coil Mfg., Inc.**, Colville, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 182 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/064,770**

(22) Filed: **Apr. 13, 2011**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 12/156,980, filed on Jun. 6, 2008, now Pat. No. 7,958,738.

(51) **Int. Cl.**
F25B 15/00 (2006.01)

(52) **U.S. Cl.**
USPC **62/112**; 62/509

(58) **Field of Classification Search**
USPC 62/112, 498, 504, 509, 434; 165/104.26, 165/302; 122/366
See application file for complete search history.

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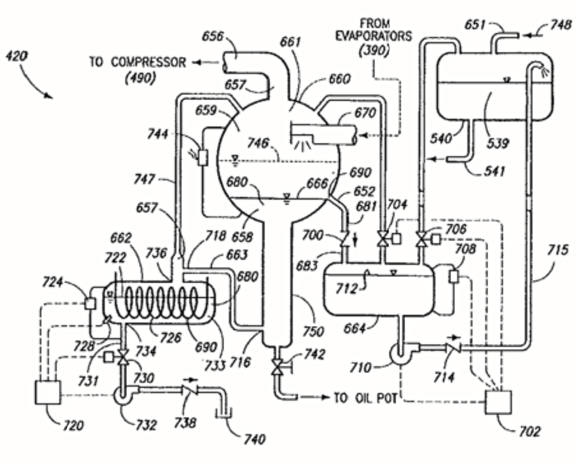
Primary Examiner — Mohammad M Ali

(74) *Attorney, Agent, or Firm* — Paine Hamblen, LLP

(57) **ABSTRACT**

A direct expansion ammonia refrigeration system and a method of direct expansion ammonia refrigeration is described and which includes a source of liquid ammonia refrigerant which is delivered in fluid flowing relation to a plurality of evaporator tubes which incorporate wicking structures, and which through capillary action facilitated by the wicking structures are effective for drawing liquid ammonia refrigerant along the inside facing surface of the evaporator tubes so as to substantially reduce any stratified and/or wavy flow patterns of the liquid ammonia refrigerant within the evaporator tubes. The invention further includes a novel accumulator vessel and heat exchanger vessel which are coupled in fluid flowing relation relative to the direct expansion ammonia refrigeration system and which facilitate the removal of water from the ammonia refrigerant in order to enhance the operation of the direct expansion ammonia refrigeration system.

19 Claims, 13 Drawing Sheets



US008783057B2

(12) **United States Patent**
Nelson

(10) **Patent No.:** **US 8,783,057 B2**
(45) **Date of Patent:** **Jul. 22, 2014**

(54) **REFRIGERANT DISTRIBUTOR**

(75) Inventor: **Bruce I. Nelson**, Colville, WA (US)

(73) Assignee: **Colmac Coil Manufacturing, Inc.**, Colville, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 629 days.

(21) Appl. No.: **12/932,247**

(22) Filed: **Feb. 22, 2011**

(65) **Prior Publication Data**

US 2012/0210744 A1 Aug. 23, 2012

(51) **Int. Cl.**
F25D 11/00 (2006.01)
F25B 39/02 (2006.01)
F28F 9/02 (2006.01)

(52) **U.S. Cl.**
CPC ***F25B 39/028*** (2013.01); *F28F 9/027* (2013.01)
USPC **62/430**; 62/515; 62/527; 62/196.4; 165/110; 165/111; 165/114

(58) **Field of Classification Search**
CPC F23B 39/028; F28F 9/027; F25D 13/00
USPC 62/430, 196.4, 515, 525, 527; 165/174, 165/114, 110–111
See application file for complete search history.

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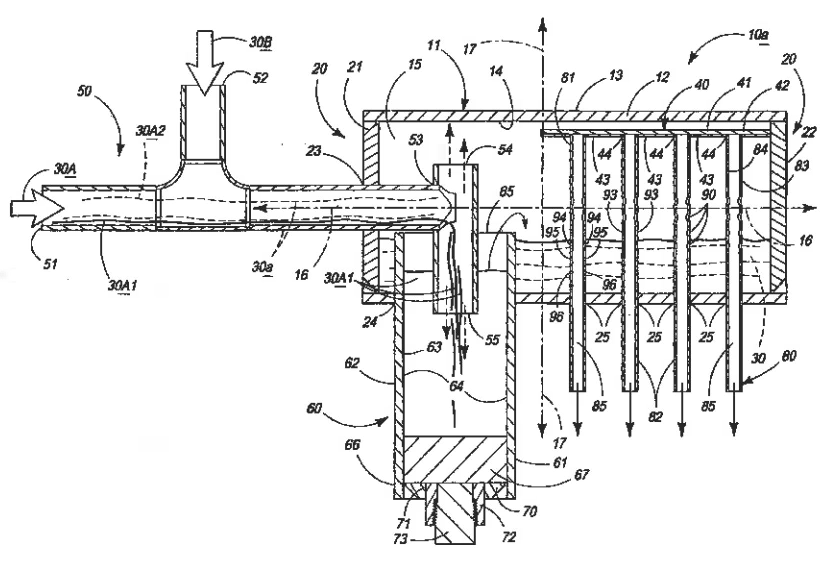
Primary Examiner — Frantz Jules
Assistant Examiner — Martha Tadesse
(74) *Attorney, Agent, or Firm* — Paine Hamblen, LLP

(57) **ABSTRACT**

A refrigerant distributor is described and which includes a tank defining an internal cavity for receiving a source of refrigerant; an inlet conduit for delivering the source of the refrigerant to the internal cavity of the tank; a contaminant collection container coupled in fluid receiving relation relative to the internal cavity of the tank and in disposal fluid receiving relation relative to the inlet conduit; and a plurality of refrigerant distributor conduits coupled in fluid flowing relation relative to the internal cavity of the tank and which have a multiplicity of apertures having variable diametral dimensions and which facilitate a variable flow of the source of refrigerant out through the refrigerant distributor conduits as the volume of the refrigerant in the tank increases.

19 Claims, 6 Drawing Sheets



US009689621B2

(12) United States Patent
Nelson

(10) Patent No.: US 9,689,621 B2
(45) Date of Patent: *Jun. 27, 2017

(54) HEAT EXCHANGER

(71) Applicant: **Colmac Coil Manufacturing, Inc.**, Colville, WA (US)

(72) Inventor: **Bruce I. Nelson**, Colville, WA (US)

(73) Assignee: **Colmac Coil Manufacturing, Inc.**, Colville, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 207 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/594,803**

(22) Filed: **Jan. 12, 2015**

(65) **Prior Publication Data**

US 2015/0122463 A1 May 7, 2015

Related U.S. Application Data

(63) Continuation of application No. 13/527,958, filed on Jun. 20, 2012, now Pat. No. 8,966,935.

(51) **Int. Cl.**

F25B 39/02	(2006.01)
F28D 15/00	(2006.01)
F28F 9/02	(2006.01)
F28D 1/053	(2006.01)
F28D 15/04	(2006.01)
F28F 1/02	(2006.01)
F28D 15/06	(2006.01)

(52) **U.S. Cl.**

CPC ***F28D 15/00*** (2013.01); ***F25B 39/028*** (2013.01); ***F28D 1/05391*** (2013.01); ***F28D 15/046*** (2013.01); ***F28D 15/06*** (2013.01); ***F28F 1/022*** (2013.01); ***F28F 9/026*** (2013.01); ***F28F 9/0256*** (2013.01)

(58) **Field of Classification Search**

CPC F25B 39/028; F25B 39/02; F25B 39/04; F25B 40/02; F28F 9/0212

USPC 62/112, 498, 509, 525; 165/104.26, 174, 165/178

See application file for complete search history.

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Primary Examiner — Melvin Jones
(74) *Attorney, Agent, or Firm* — Randall Danskin, P.S.

(57) **ABSTRACT**

A heat exchanger is described and which includes a heat exchanger portion defining a multiplicity of internal passageways, and wherein at least one of the passageways is defined in part by a wicking structure; and a source of ammonia refrigerant which is supplied to the internal passageways of the heat exchanger portion, and wherein substantial equal amounts of liquid refrigerant are supplied to each of the passageways defined by the heat exchanger portion.

30 Claims, 9 Drawing Sheets