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LMP

INDUSTRIAL
REFRIGERATION



CO_2 REFRIGERANT PIPING MANUAL

DESIGN AND INSTALLATION GUIDELINES FOR CO_2 REFRIGERATION SYSTEMS

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This document serves as EVAPCO's guideline for the design and installation of CO_2 refrigeration systems by the client/contractor. Included are guidelines and recommendations regarding piping, equipment, and insulation with reference to a variety of official regulations (see **Table 1**).

GUIDELINES ARE SUPERSEDED BY OFFICIAL REGULATIONS AND LOCAL CODES.

THIS DOCUMENT DOES NOT CONSTITUTE AN OFFICIAL REGULATION AND IS NOT INTENDED TO BE USED AS A REPLACEMENT FOR OFFICIAL REGULATIONS AND LOCAL CODES.

THE CLIENT/CONTRACTOR IS STILL SUBJECT TO ALL CURRENT STANDARDS REGARDING THE DESIGN AND INSTALLATION OF CO_2 REFRIGERATION SYSTEMS.

Source	Section	Application
ANSI SP-69-2003	-	Pipe Hangers and Supports
ASME B31.5	-	Piping and Heat Transfer Components
	504.1.2	Minimum piping thickness requirements from allowable stress
ASHRAE 15	-	Safety Standards - Design and Safety Classification of Refrigerants
	9.2.6	Minimum design pressures for CO_2 systems
	9.7	Pressure Vessel Protection
ASME BPVC II	-	Material Tables, Properties
ASME BPVC IX	-	Welding, Brazing, and Fusing
ASME BPVC XIII	-	Rules for Overpressure Protection
CSA B51	-	Boiler, Pressure Vessel, and Pressure Piping Code
CSA B52	-	Mechanical Refrigeration Code
	5.5.1	Minimum design pressures for CO_2 systems
CSA B52 HB	-	Handbook for Practical Application of Mechanical Refrigeration Code
IIAR CO_2	-	Safety Standard for Closed-Circuit Carbon Dioxide Refrigeration Systems
INDUSTRIAL REFRIGERATION HANDBOOK	-	Industrial Refrigeration Handbook
	8.11 – 8.12	Guidelines for recirculated liquid system design
IIAR REFRIGERATION PIPING HANDBOOK	-	Refrigerant Piping Reference
	Ch. 2	Pipe Installation Guidelines
	Ch. 3	Evaporator Piping
	Ch. 7	Insulation for Refrigeration Systems

Table 1: Typical Applicable Codes & Regulations

1.0 - Background and Scope

This document provides EVAPCO's guidelines regarding industrial piping in CO_2 refrigeration systems. It is intended for contractors and system designers to use as a reference for proper design and installation practices when using CO_2 as a refrigerant, specifically with regard to:

- Piping design and materials
- Service-specific recommendations
- Equipment and valve connection (tie-ins)
- Insulation, supports, and anchoring

1.1 - Piping Design

The refrigeration system and all field-installed piping must be safe for operation at the maximum allowable working pressure (MAWP). The designer should consider not only the relevant standards but also the practical aspect of manufacturing/installation. Calculating the minimum pipe thickness can be accomplished via the formulas given in ASME B31.5 (see **Table 1**), using the MAWP and maximum operating temperature. **Table 2** (below) lists some common pipe materials and associated working pressures coupled with a corresponding size range. Refer to the IIAR Refrigerant Piping Handbook Chapter 2 for additional details on piping thickness and related topics.

Practical considerations/suggestions:

- Pipe thickness greater than the minimum calculated value is typically used to facilitate assembly (welding processes) or to increase the safety factor.
    - Example: Schedule 10 stainless steel pipe may be allowable; however, Schedule 40 is widely accepted for welding/installation.
- Pipe sizes as small as 1/4" NPS are available but not typically utilized for field use due to their high flexibility which leads to bending/breaking.
    - Pipe that is 1/2" NPS or smaller is typically reserved only for low capacity (≤ 2 tons) suction risers.

Material	Type/Schedule	Pipe Diameter
Very Low Pressure ≤ 435 PSIG (30 bar), 100°F		
Copper	Type K/Type L	3/8" to 2-1/8"
Copper-Iron	K65/XHP	3/8" to 2-1/8"
Stainless Steel	Schedule 40	3/8" to 12"
Low Pressure ≤ 650 PSIG (45 bar), 100°F		
Copper	Type K/Type L	3/8" to 1-1/8"
Copper-Iron	K65/XHP	3/8" to 2-1/8"
Stainless Steel	Schedule 40	3/8" to 12"
Low Pressure ≤ 650 PSIG (45 bar), 200°F		
Copper	Type K/Type L	3/8" to 7/8"
Copper-Iron	K65/XHP	3/8" to 2-1/8"
Stainless Steel	Schedule 40	3/8" to 12"
Medium Pressure 1,160 PSIG (80 bar), 200°F		
Copper-Iron	K65/XHP	3/8" to 2-1/8"
Stainless Steel	Schedule 40	3/8" to 12"
High Pressure 1,740 PSIG (120 bar), 250°F		
Stainless Steel	Schedule 40	3/8" to 4"
Stainless Steel	Schedule 80	3/8" to 8"

Table 2: Typical Piping Size Range – By Material and Operating Conditions
Reference to ASME B31.5 Sec. 504.1.2

NOTES:

1. The above table represents typical pipe size ranges utilized in CO_2 refrigeration systems. Clients/contractors are responsible for appropriate pipe sizing and consideration for applicable standards and codes.
2. The outside pipe surface is prone to corrosion where improper surface preparation and insulation installation occurs, especially when carbon steel is used instead of the materials listed in **Table 2**.

1.2 - General Suggestions

To aid in proper system operation, key guidelines are provided when installing field piping and other components. The following subsections detail EVAPCO's reasoning and consequences regarding piping and component geometry.

1.2.1 - Oil Management

The refrigeration system requires the appropriate oil to enable the compressor(s) on the rack to operate correctly. The oil mixes with the refrigerant, and the resultant mixture flows through the refrigerant piping. It is important to ensure that the refrigerant/oil mixture circulates through the refrigerant piping/system properly. Failure to observe these guidelines may result in oil becoming trapped within the field piping/components which in turn can adversely affect system efficiency (or even basic operation). Below are some suggestions regarding oil management:

- Sizing the suction lines appropriately to ensure a minimum refrigerant/oil mixture velocity is achieved, which in turn provides oil circulation during operation (see **Table 3**).
- Sloping downward all piping towards the rack at approximately 1" per 20' of pipe run which aids in oil draining after a refrigeration system shutdown.
- Connecting header branches to enable oil flow; underneath the liquid header, on top of the suction header.
- Ensure the installation of oil traps at all vertical height changes. P-traps on the lower suction line, inverted P-traps on the top are suggested.

1.2.2 - Refrigerant Pipe Pressure Drop

An appropriate overall pressure differential for the refrigerant piping system is needed to establish minimum refrigerant/oil mixture velocities. Optimizing the refrigerant system's overall pressure drop improves system efficiency and helps prevent compressor performance issues. Suggested pressure drop ranges are provided in **Table 3** and discussed in more detail in the applicable subsections, such as the High-Stage Discharge guidelines in section 1.3.1.

1.3 - Service-Specific Guidelines

This section provides the designer/contractor information regarding CO_2 line types including target pressure drop and fluid velocity values. Typically, an industrial refrigeration system pipe zone is dedicated to a single purpose, referred to as a "service" as indicated in the table below. Each service type (e.g. High-Pressure Liquid) is associated with a refrigerant state (i.e. liquid, vapor, liquid-vapor mixture) and associated pressure loss/fluid velocity guidelines. The following table **(Table 3)** provides several service types frequently found in CO_2 systems.

Service	Role	State of Refrigerant	Typical Pressure Drop/Fluid Velocity Targets
HSD	Compressor discharge to the gas cooler	Vapor	≤50 FPS ΔP ≤ 15 PSI
HPL	From gas cooler to flash tank	Liquid/Vapor	<13 FPS ΔP ≤ 10 PSI
IPL	Liquid from flash tank to DX evaporator or LPR	Liquid	≤4 FPS ΔP ≤ 1°F
MTS/LTS	Suction from DX evaporator to compressor	Vapor	>30 FPS and <55 FPS ΔP ≤ 1°F
HGD	Hot-gas line for defrost	Vapor	≤33 FPS ΔP ≤ 10 PSI
DC	Defrost condensate to flash tank	Liquid	<13 FPS ΔP ≤ 10 PSI
MTRL/LTRL	Pumped liquid to overfeed evaporator	Liquid	2 to 3 FPS **See Section (1.3.6)**
MTRS/LTRS	Wet suction from overfeed evaporator to low-pressure receiver	Liquid/Vapor	>15 FPS and < 20 FPS
RGS	Reheat gas for reheat coil	Vapor	≤50 FPS
RGC	Reheat condensate back to flash tank	Liquid	ΔP ~ 1°F

Table 3: Service Types and Pressure Drop/Fluid Velocity Targets

1.3.1 - High-Stage Discharge (HSD) and High-Pressure Liquid (HPL)

The HSD and HPL lines connect the rack to the gas cooler via the compressor discharge and return lines, respectively. The HSD carries high-temperature/pressure CO_2 to the gas cooler, and the HPL returns high-pressure liquid to the rack. Some general guidelines/suggestions are indicated below for HSD/HPL line installation:

- Design for oil management (see section 1.2.1)
- Stainless steel ASTM A312/A304 Schedule 40. This is due to high pressure/temperature and for welding accommodation.
- Utilize butt-welded pipe joints
- Utilize long-radius elbows

1.3.1.1 - Gas Cooler Piping

Below are some guidelines specific to the piping directly connected to the gas cooler.

- The gas cooler connections (inlet and outlet) should be split via a centered tee to allow for balanced flow and prevent uneven pressure drop across the unit.
- If multiple gas coolers are used for a single rack, a reverse return at the HPL line (outlet connection) should be installed to ensure even pressure drop across all units.
- Establish an elevation difference between the gas cooler and the liquid receiver to support refrigerant return during subcritical/low-load operation.
- A maximum of 25 PSI pressure loss through the gas cooler section (including through the cooling unit itself) is recommended by EVAPCO.

Gas cooler installation equal or lower than compressor rack

The gas cooler is typically installed on the roof, elevated above the rack. Typically, an inverted P-trap is installed on the outlet piping to ensure oil flow to the flash tank and prevent oil accumulation during trans-critical operation for installations where the gas cooler is not elevated above the rack.

NOTE: EVAPCO LMP strongly suggests avoiding the installation of a gas cooler where the liquid outlet connection is positioned more than 10 feet below the throttle valve. Excessive rise in the return line from the gas cooler may prevent proper oil return. A drawing is included below **(Figure 1)** for illustrative purposes.

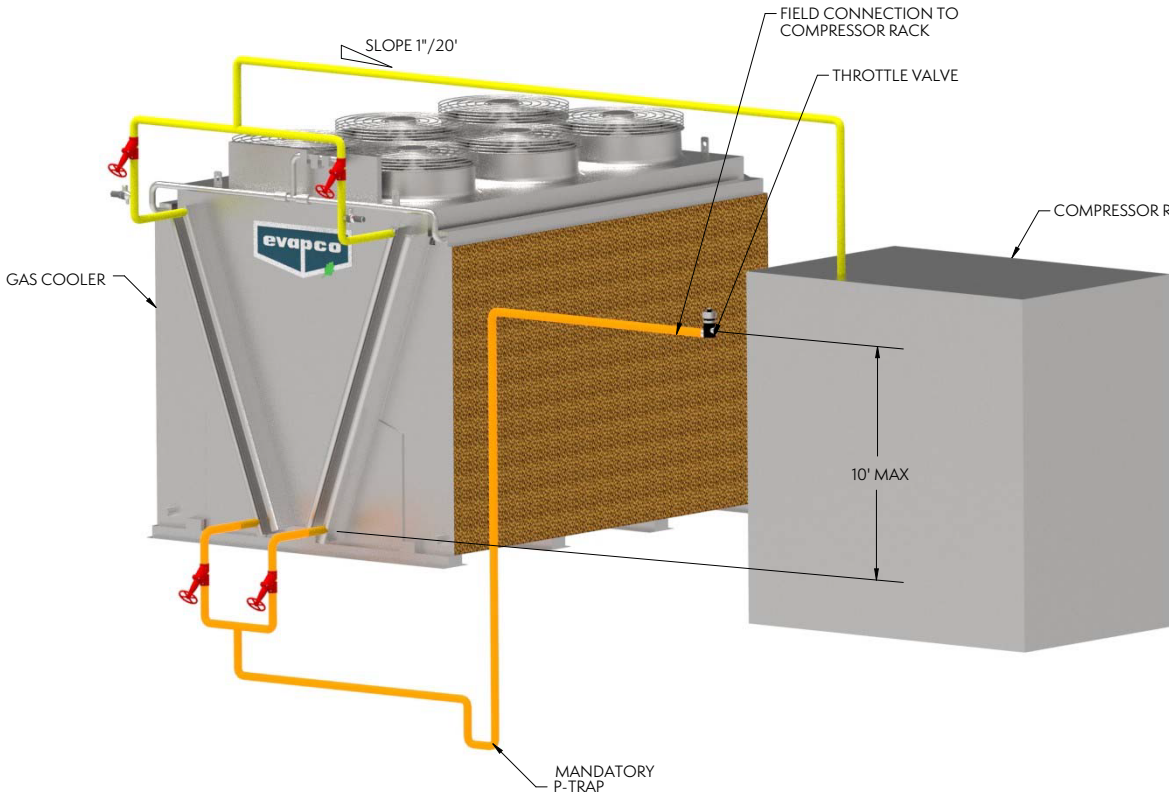


Figure 1: Gas Cooler Level Installation Detail

1.3.2 - Intermediate Pressure Liquid (IPL)

The IPL line supplies liquid refrigerant to a direct expansion (DX) evaporator in the CO_2 system. It connects the flash tank, which is used to separate liquid and vapor CO_2 returning from the gas cooler. Refrigerant in a DX evaporator is in the liquid phase at the inlet and vapor phase at the outlet, with a specific suction temperature listed as a design condition. The temperature in the IPL line is therefore governed by that of the medium temperature evaporators, with a minimum difference of 15°F. The temperature difference exists to ensure sufficient pressure difference (equivalent to ~100 PSI ΔP) between the inlet and outlet, which facilitates proper fluid flow.

Regarding pressure losses, a number of components must be considered by the designer. The piping, expansion valves, distributors, evaporator coils, and any other component between the liquid feed and the suction return line must have its pressure losses accounted for; the total of which must not exceed the ~100 PSI limit. If this guideline is not observed, the excessive pressure drop will result in lower suction temperatures, and in turn the loss of efficiency at the compressors. In extreme cases, the cooling capacity of the system lowers such that it is insufficient for the client's requirements.

For standard CO_2 refrigeration systems, the low side typically operates at 650 PSIG (MAWP). With a safety margin of 20% as specified in CSA B52/ASHRAE 15 **(Table 1)**, this allows a 37°F (at 543.7 PSIA) maximum flash tank temperature, which in turn is associated with a 23°F (441.8 PSIA) maximum evaporator suction temperature. In the case of warmer evaporators, the system pressure can be increased to allow higher temperature IPL lines (typically up to 1160 PSIG). It is important to communicate with EVAPCO LMP regarding the intended design operating temperatures and pressures.

Both the low and medium temperature evaporators are fed liquid via the IPL line. Should the designer require it, separate low and medium temperature liquid lines can be installed. In either case, the liquid line taps should be placed below the main header **(Figure 2)** to facilitate oil evacuation, as described in section 1.2.1.

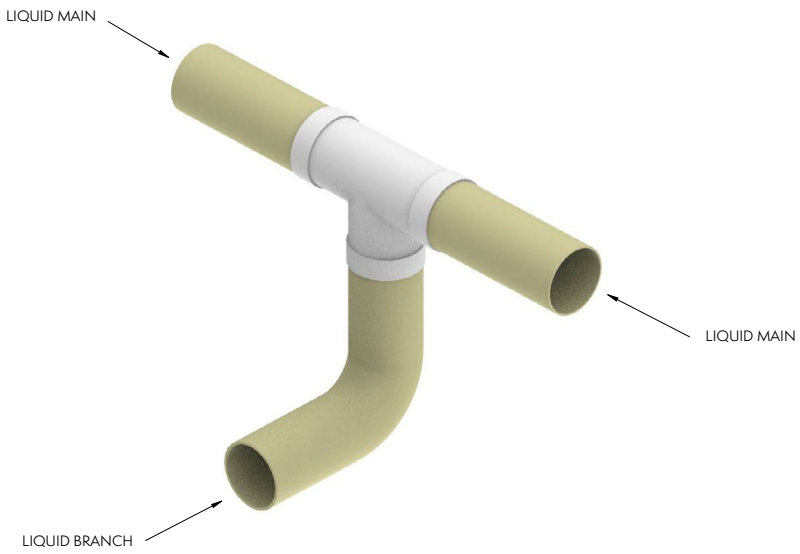


Figure 2: Liquid Line Take-Off

Liquid hammering, hydraulic shock, and refrigerant flashing are important topics for the system piping designer to consider. Properly designed system piping can avoid all three situations during operation. Refer to the IIAR Refrigerant Piping Handbook, Chapter 3 for additional details on these topics.

Flashing, in the case of a refrigerant line, refers to the rapid evaporation of a liquid into its gaseous state usually by means of a pressure decrease. In the CO_2 system, refrigerant exists in the flash tank as both liquid and gas and is therefore drawn from the tank at approximately the saturation temperature/pressure. Should the pressure decrease in the liquid line, the CO_2 can flash before reaching the expansion valves/evaporators. The displacement of liquid refrigerant by vapor causes uneven refrigerant distribution, improper expansion valve operation, 'starved' (under-supplied) evaporators, and reduced cooling capacity.

- To prevent flashing, the liquid line pressure drop is limited (see **Table 3**).
- Attention should be given to the placement of the evaporators relative to the rack, as elevation gain may encourage flashing due to pressure drop in the IPL line.

1.3.3 - Suction (MTS/LTS)

The design of the suction lines is especially critical, the quality thereof determining the operational efficiency of the system. The MTS and LTS lines connect the evaporator(s) outlet to the compressor(s) inlet. Typically, a main header line supplies either a group or the totality of the evaporator mass flow to the associated compressor group.

Physical installation permitting, it is good engineering practice to appropriately slope downward the MTS/LTS (towards the compressor(s)) to prevent the refrigerant mixture from draining back towards the evaporator(s) (see 1.2.1). This preventative design is important not only for normal operation, but especially so for defrost cycles and power outages. If this provision is not observed, accumulation of oil in the evaporators could require a shut-off and maintenance to restore them to operational readiness. As a reciprocal to the liquid line, the suction line branches should be connected on top of the header to allow for oil evacuation **(Figure 3)** and include inverted P-traps at the top of any piping risers.

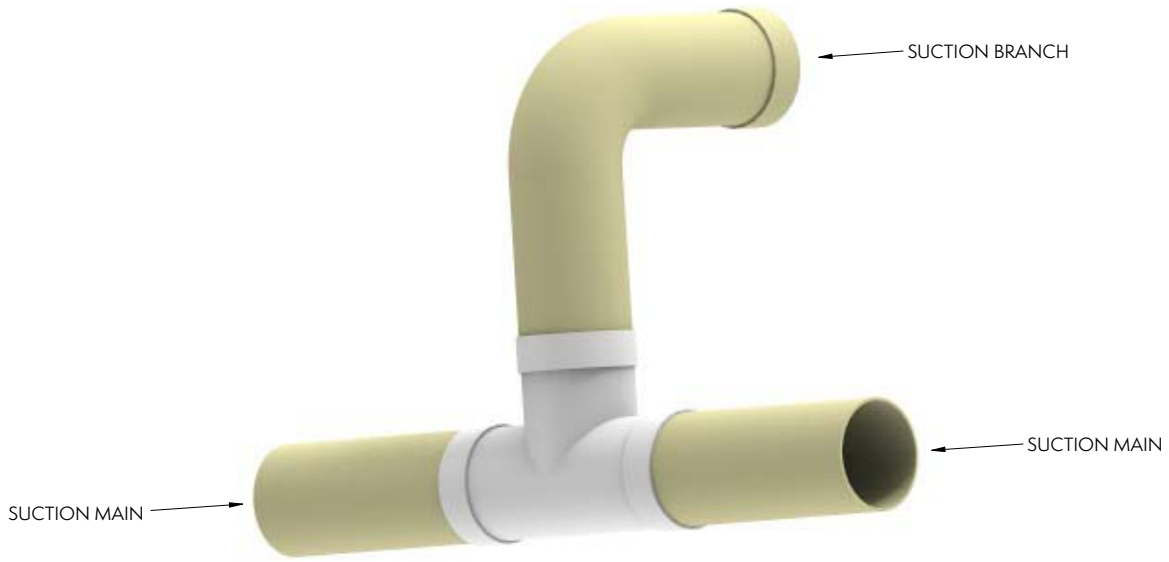


Figure 3: Suction Line Main Tie-In

The outlets of the evaporators should also include a P-trap to ensure safe oil return to the rack. In the event of longer suction risers (>20'), suction traps must be placed every ~10' through the pipe length.

Refrigerant velocity should observe a few guidelines:

- At half load, >15 FPS
- At peak load, >30 FPS

High fluid speeds within the piping of a refrigeration system may lead to vibration. Pipe vibration causes excessive strain on fittings and mounting brackets, significantly reducing the lifetime of piping components. Due to the higher speeds experienced in the suction lines, vibration is a key issue in these sections. A maximum fluid speed guideline is therefore established to mitigate the possibility (see **Table 3**).

1.3.4 - Hot-Gas Defrost and Condensate (HGD/DC)

The hot-gas defrost system uses gas from the HSD to heat (and therefore defrost) the evaporators. Two types of hot-gas defrost methods are available for use on the CO_2 refrigeration systems provided by EVAPCO LMP. Each type, as well as considerations for design, are listed below.

2-Pipe Defrost

The 2-pipe defrost method re-uses the existing liquid/suction to perform the defrost operation. When a defrost cycle is initiated by the control system:

1. The suction stop valve for the circuit is closed at the compressor rack.
2. The hot gas solenoid is then energized.
3. This allows high-pressure hot gas to flow through the suction line to the evaporator, where it condenses and drives the liquid refrigerant back through a dedicated line to the flash tank.
4. The defrost sequence is terminated once the hot gas no longer condenses within the evaporator.

One main advantage of this system is that the hot gas defrost piping is entirely on the rack, in contrast with the 4-pipe method detailed below.

One drawback of the 2-pipe method is that all evaporators on a given circuit will be defrosted simultaneously. It is therefore not a preferred method for systems with multiple evaporators on a single circuit. Another consideration is that the piping is sized based on normal operating conditions only. As a result, the same liquid and suction lines are used during hot-gas defrost, and these lines are not specifically sized to accommodate defrost flow conditions, which may differ significantly from standard operation.

4-Pipe Defrost

In contrast to the 2-pipe method, the 4-pipe method does not introduce additional piping runs but instead makes use of the existing rack headers by adding dedicated hot gas defrost (HGD) and defrost condensate (DC) headers in parallel with the standard liquid and suction headers. All four headers are available at rack level. This arrangement allows HGD and DC distribution through shared main headers rather than individual runs per evaporator, which can reduce field piping complexity on larger projects.

The required mass flow of defrost gas is approximately twice that of the liquid line during normal operation. The main HGD line should be sized according to the maximum capacity of evaporators meant to be defrosted simultaneously. This means that two main factors are required for sizing: the IPL mass flow, and the quantity of evaporators to be defrosted simultaneously.

Defrost System Considerations and Limits

Due to the use of hot gas from the compressor discharge, the capacity of any defrost operation affects the performance of the rack during normal operation. Limits for the defrost capacity should therefore be enforced to prevent adverse effects on the rack's performance during the defrost cycle. These limits are based on the pressure of the rack, which is generally 650 PSIG (45 bar) for "low pressure" systems and 1160 PSIG (80 bar) for "high pressure" systems. The designer should note that all on-site piping to the evaporators must be rated at minimum to the design pressure listed for the rack and/or evaporators (pressure relief must be set to the 'weakest link', the lowest-pressure-rated component in a service protected by a pressure relief valve) – designers MUST follow all national, provincial, state and local codes on pressure design and relief design and sizing.

- For Low-pressure 2-pipe defrost: Maximum of 150 MBH (12.5 tons) @ 650 PSIG
- For High-pressure 2-pipe defrost: Maximum of 600 MBH (50 tons) @ 1160 PSIG

Additionally, it is recommended for the designer to observe the following limits and considerations for the defrost system:

- A maximum hot gas capacity no greater than 25% of the total system capacity
- A maximum hot gas velocity respecting guidelines from **Table 3**
- Piping where liquid can exist (DC lines) sloped towards the rack for liquid evacuation in the event of power failure

1.3.5 - Reheat Line and Condensate (RGS/RGC)

The reheat system follows similar guidelines to the 4-pipe defrost setup, with a few differences. Firstly, the hot gas in the reheat system is taken from the HSD without pressure regulation, meaning the design pressure is now 1740 PSIG (120 bar). All reheat piping must be rated at **minimum** to this level, typically resulting in stainless steel piping. The mass flow in the RGS/RGC lines is also no longer dictated by any other capacity or mass flow in the system. This must be decided upon by the designer, with consideration to the fact that the reheat capacity cannot exceed that of the refrigeration system itself. If reheat functionality is required, this must be communicated with EVAPCO LMP for proper system specification. It should be noted that the reheat function is auxiliary to that of the refrigeration and should be considered as a byproduct rather than the primary design point.

1.3.6 - Pumped Liquid and Wet Suction (MTRL/LTRL/MTRS/LTRS)

Pumped (recirculated) liquid CO_2 lines are installed between the low-pressure receiver (LPR) pump outlet and the overfeed evaporator. Any of these lines must be sized with regard to the sum of all pressure drops across piping, valves, and flow elevation so as to maintain a specific pressure at the expansion valve(s). Coordination with EVAPCO LMP is necessary for pump sizing. Each line has a few requirements for fluid targets:

- MTRL/LTRL lines sized for a pressure drop of:
  - Between 30 PSI and 50 PSI at full flow (for the furthest user)
- MTRS/LTRS lines sized for a fluid velocity of:
  - Between 15-20 FPS flow in horizontal lines
  - 30 FPS flow in 2-phase risers

An appropriate pipe diameter can be calculated using equations provided by Stoecker's Industrial Refrigeration Handbook, Section 8.12. The designer must go through an iterative process in order to properly size the pump. With the previous guidelines, the pump total pressure loss can be calculated and given to EVAPCO LMP for final sizing.

2.0 - Equipment Tie-In and Valve Groups

2.1 - Gas Cooler (Air-Cooled)

It is good engineering practice for the gas cooler to be installed with the appropriate tie-in, take-off, and valves. **Figure 4** (below) shows the typical installed arrangement for smaller systems utilizing a single gas cooler.

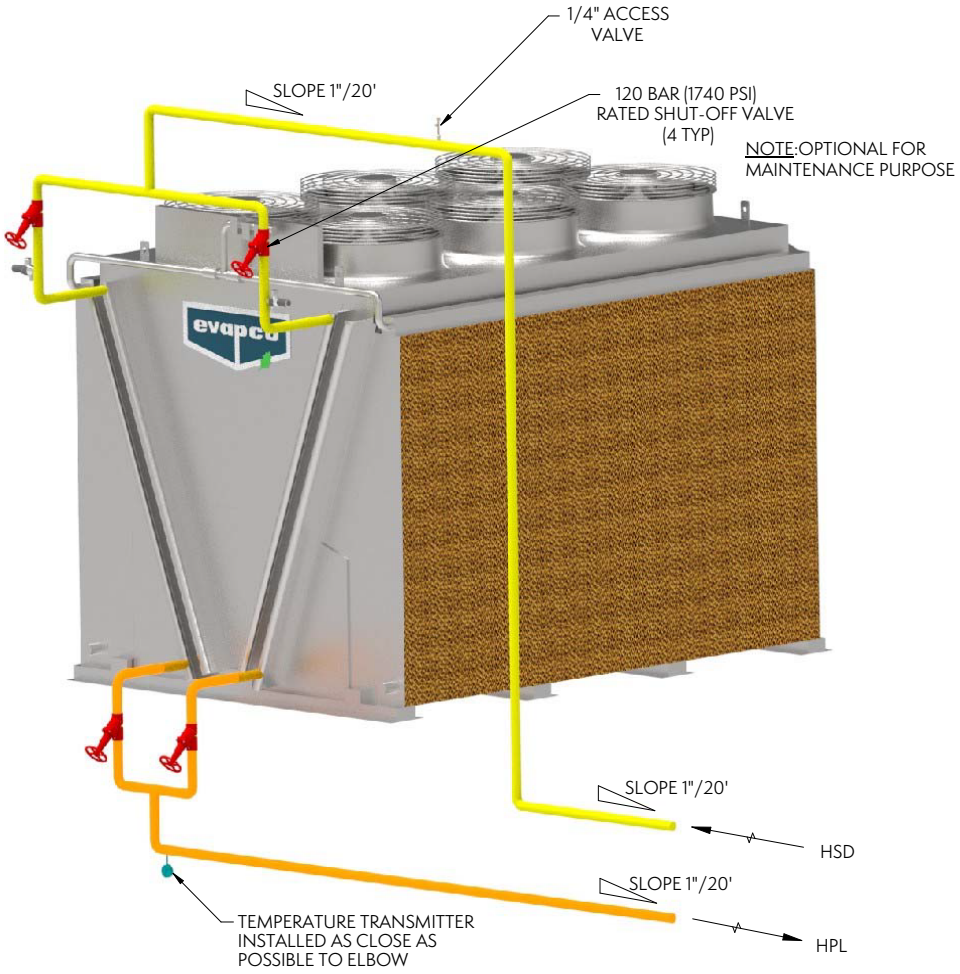


Figure 4: Single Gas Cooler Installation

For larger systems, additional gas cooler units may be required. In this case, supplemental components and piping are typically needed as shown in **Figure 5** (below). The total pressure drop associated with the additions to the gas cooler piping must be considered by the designer. Refer to Section 1.3.1.1 for pressure drop targets.

1. Install shut-off valve at each coil inlet and outlet (optional – for control purposes).
2. Install purge/access valve at each coil inlet (if shutoff valves are installed).
3. Ensure that the piping lengths are equal for all gas cooler units to promote equal pressure drop through each coil, and to balance the refrigerant flow.

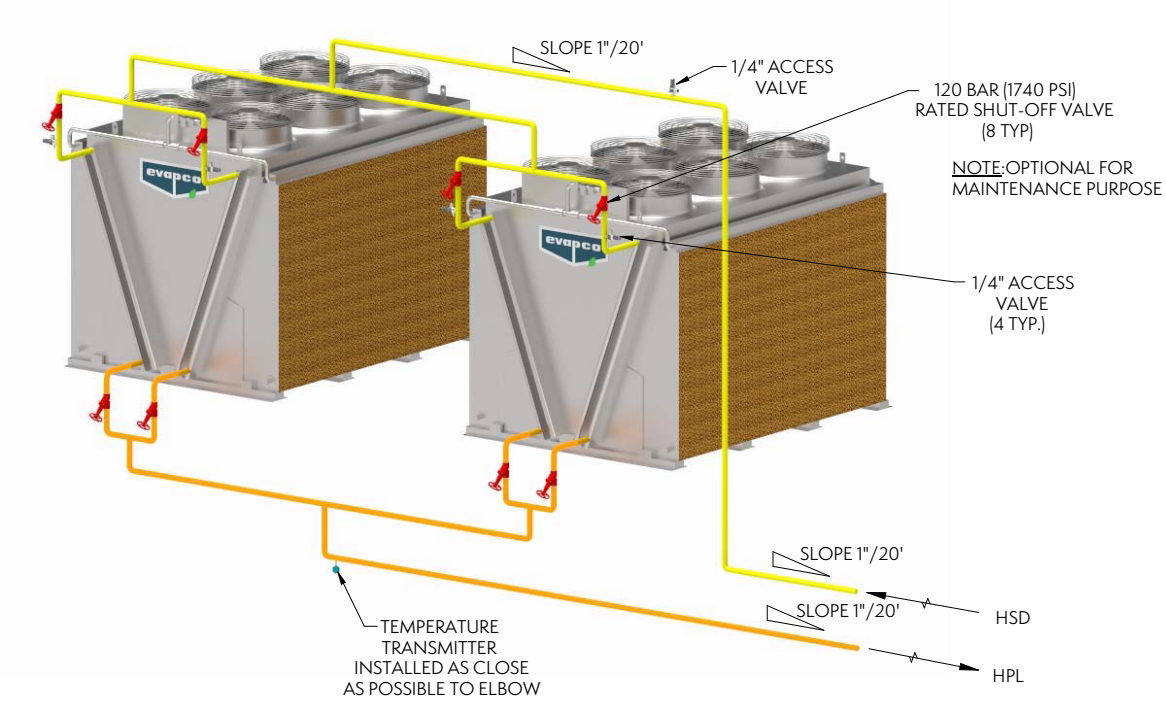


Figure 5: Two Parallel Gas Coolers Installation Detail

Insulation is not necessary for HSD and HPL lines, but some clients will require insulation for safety only. If insulation is installed, never use elastomeric (Armaflex) insulation, as it has a relatively short lifespan (only a few years). Instead, the industry standard is to use polyisocyanurate insulation with embossed aluminum jacketing when installed outside, and PVC jacketing when installed inside, or as per the client standards.

2.1.1 - Adiabatic System

On industrial trans-critical CO_2 systems, it is almost always recommended to install an adiabatic gas cooler as it reduces the compressor head pressure and thereby increases efficiency during high temperature operation (above +/- 70°F).

EVAPCO gas coolers utilize a 1" NPS connection size for the water supply lines. The EVAPCO CO_2 gas cooler technical data sheet provides the water supply flow rate and inlet pressure required. The EVAPCO submittal drawing indicates 2-1/2" NPS, MPT water drain connections.

2.2 - Direct Expansion Evaporators

2.2.1 - Air/Electric Defrost

The direct expansion (DX) evaporator with air and electric defrost is the most common technology used on smaller capacity (≤ 10 tons) evaporators. Therefore, the fundamentals of installation design are important to understand in order to ensure a safe, reliable, and efficient CO_2 refrigeration system. For proper air and electric defrost, the following components are recommended for the installation:

1. Shut-off valve (quarter-turn ball valve)
2. Strainer
3. Expansion valve
4. Purge/access valve
5. Pressure sensor with access valve
6. Superheat temperature sensor
7. Room air sensor
8. End defrost temperature sensor (for electric defrost only)

Refer to the detail below for valve installation, P-trap, and sensor requirements.

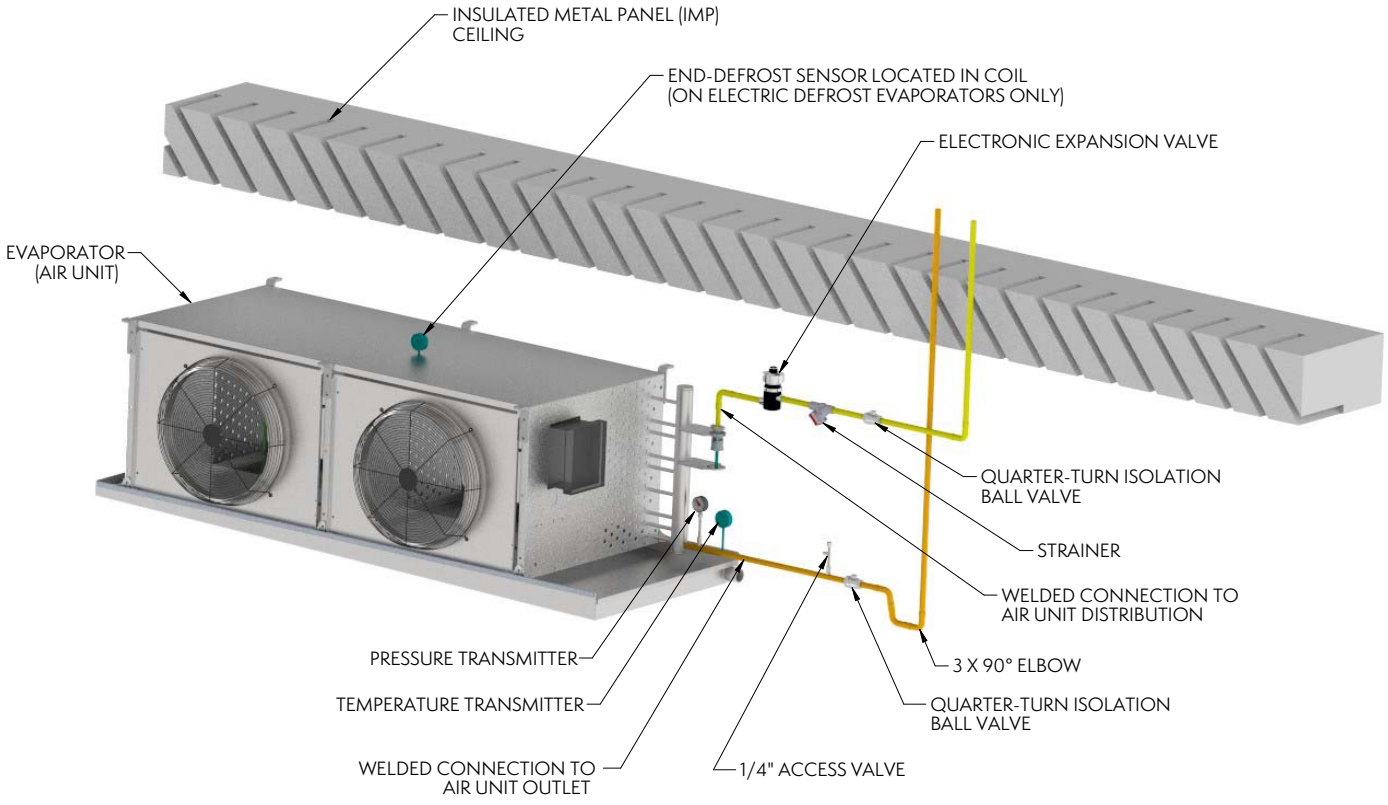


Figure 6: Direct Expansion Air Defrost Evaporator Installation Detail

2.2.2 - Air/Electric Defrost with EPR Valve

In systems using electronic pressure regulating (EPR) valves where two automatic control valves could shut off and trap liquid within the air units, an unsafe condition potentially exists. The simplest way to mitigate this risk is to install a 3/8" check valve to bypass the electronic expansion valve. This design adds the following components:

1. Electronic pressure regulator (EPR) valve
2. Check valve (3/8")
3. Shut-off valve (3/8")

Furthermore, the purge/access valve must be moved to this bypass, between the check valve and shut-off valve. Follow the detail below for installation requirements.

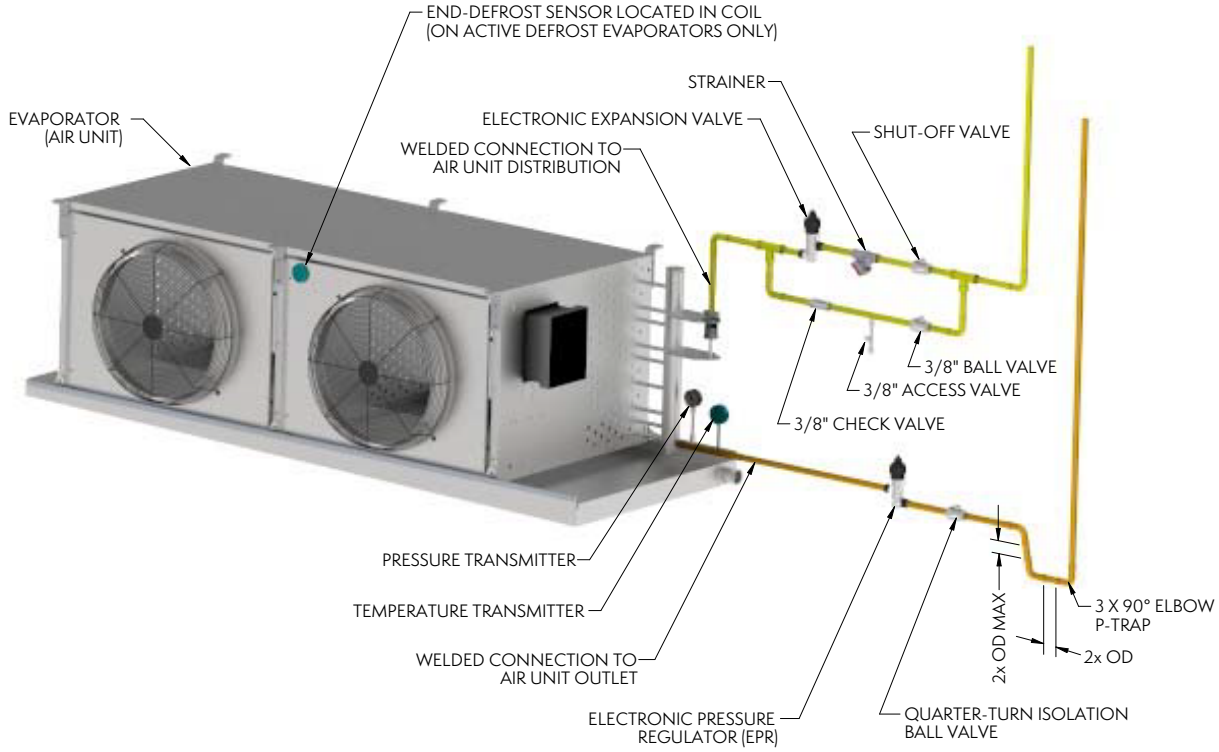


Figure 7: Direct Expansion Air Defrost Evaporator with EPR Valve Installation Detail

2.2.3 - Direct Expansion Evaporator (2-Pipe Hot-Gas Defrost)

On systems using 2-pipe hot gas defrost, CO_2 vapor flows through the suction line from the compressor rack, through the evaporator, and returns to the receiver through the liquid line. In that case, the components are the same as the DX air defrost evaporator system, but with an added check valve at the expansion valve to safely and effectively release the hot gas condensate from the evaporator. A standard installation detail is shown in **Figure 8**.

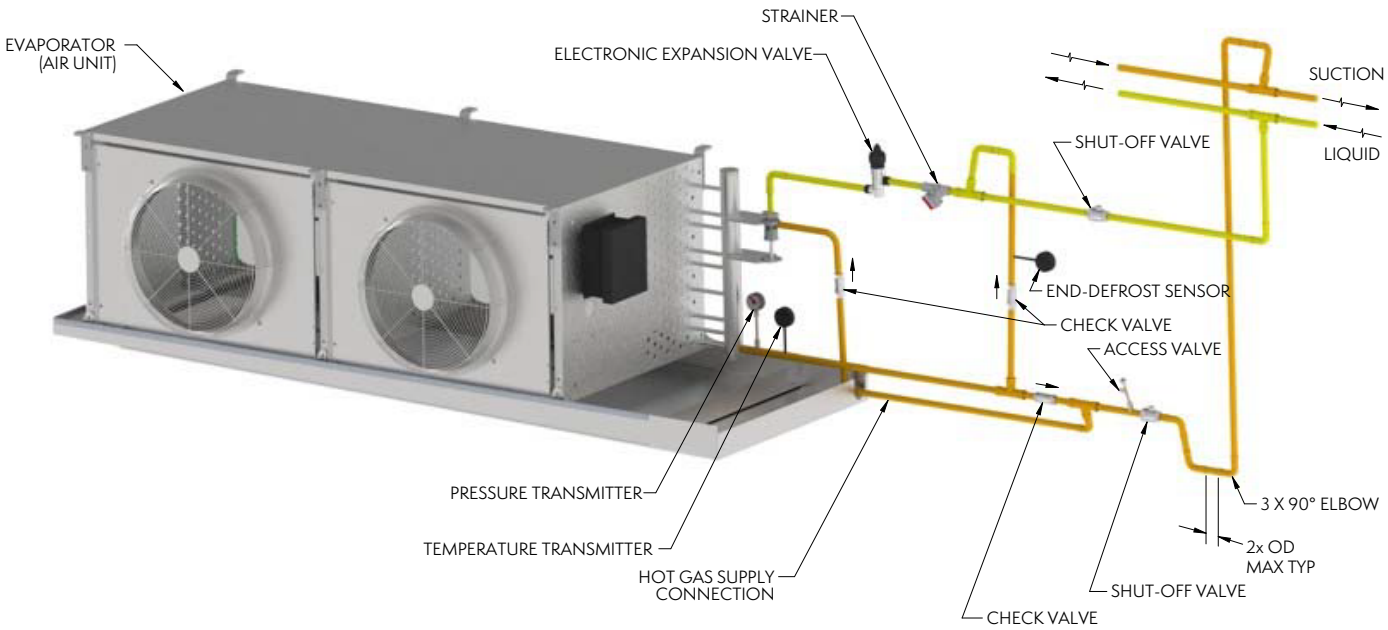


Figure 8: Direct Expansion 2-Pipe Hot Gas Defrost Evaporator Installation Detail

2.2.4 - Direct Expansion Evaporator (4-Pipe Hot-Gas Defrost)

CO_2 direct expansion refrigeration systems employing a 4-pipe hot-gas defrost design utilize more valves that must be controlled differently to maximize energy efficiency while minimizing the risk of overpressure.

The hot gas enters the drain pan first and then is directed to the distributor. The piping and check valve between the drain pan and distributor are factory installed on EVAPCO evaporators. The gas condenses within the coil and is then bled out through the suction line. Since the motorized suction stop valve is closed during defrost, the CO_2 defrost condensate is redirected to the defrost condensate line.

In normal operation, the defrost condensate pressure is higher than the suction pressure. This ensures that suction gas does not flow toward the defrost condensate in normal operation.

A standard installation detail is shown in **Figure 9**.

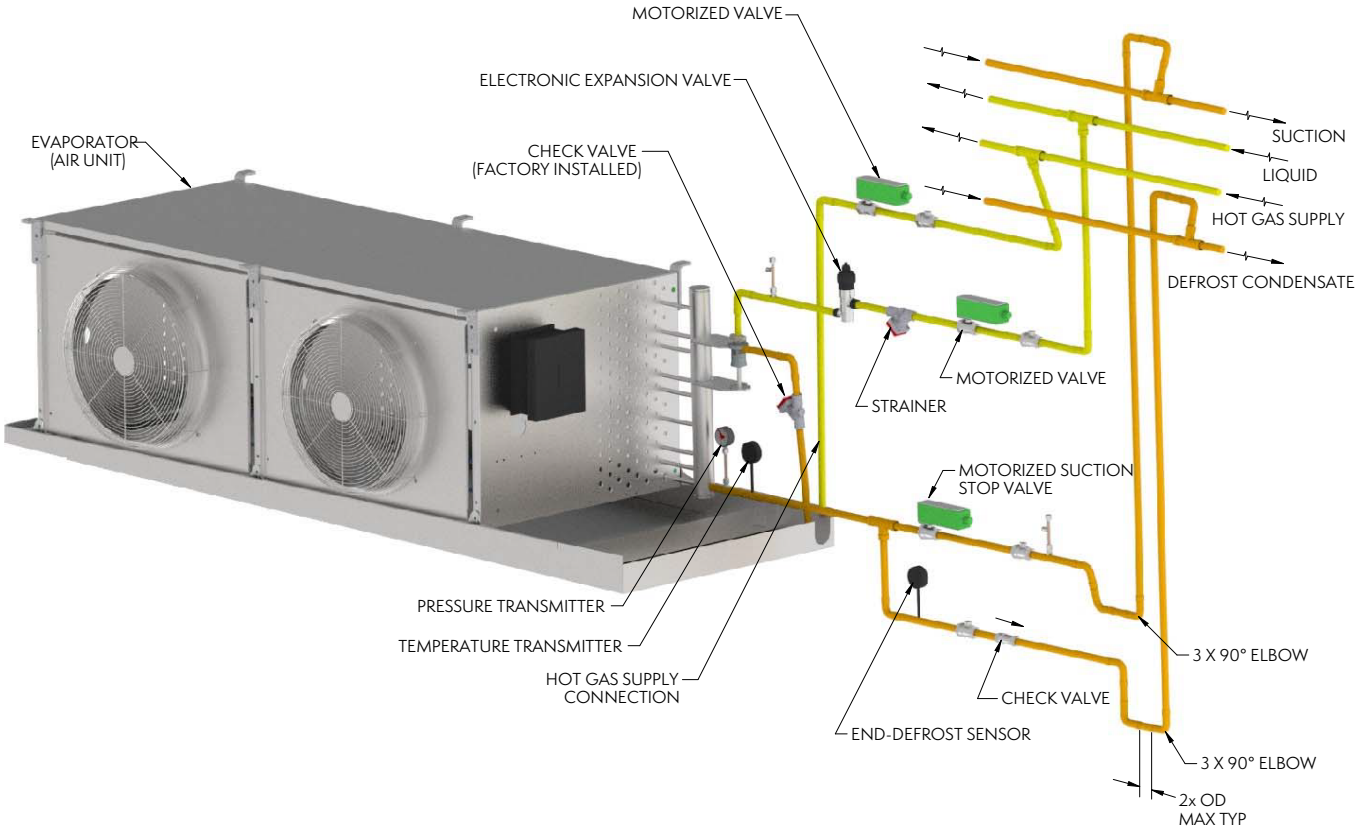


Figure 9: Direct Expansion 4-Pipe Hot Gas Defrost Evaporator Installation Detail

2.2.5 - Direct Expansion Remote Valve Group

Sometimes projects have valves installed remotely, above the ceiling or on the roof for easier maintenance, or to maintain strict food safety guidelines.

In these cases, some important design rules must be followed:

1. Maintain at most one (1) change of direction between the expansion valve and the distributor.
2. Maintain at most 48" of piping between the expansion valve and the distributor.
3. The size of the pipe between the expansion valve and the distributor must match the inlet diameter of the distributor.
4. A P-trap must be installed directly at the outlet of the evaporator, ensuring a velocity of 1,500 ft/min minimum at full capacity.
5. When the valve group is installed between a ceiling and the roof, and the piping runs on the roof, a second P-trap must be installed before the second riser, with the 1,500 ft/min velocity through the riser.

Figure 10 illustrates an example of a direct expansion air handling unit with EPR valve and remote valve train above an IMP ceiling.

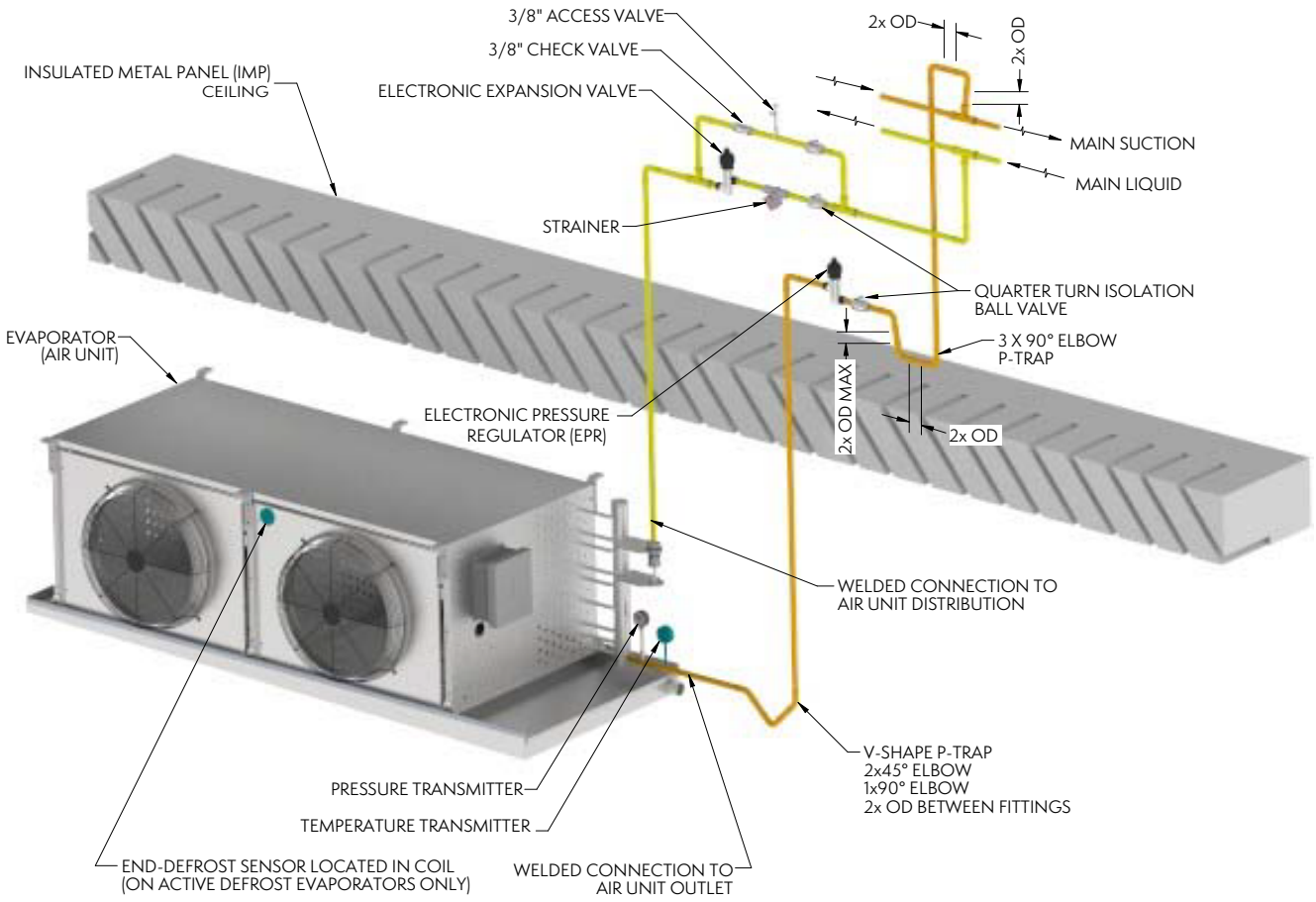


Figure 10: Direct Expansion Remote Valve Train Evaporator Detail

3.0 - Insulation and Pipe Support

3.1 - Insulation

Piping and equipment insulation is a critical part of the refrigeration system, ensuring safe and efficient operation. The insulation type, thickness, and jacketing depend on the physical location where the piping will be installed as well as the CO_2 temperature. As a general rule, the lower the fluid temperature inside the piping, the thicker the insulation must be in order to avoid condensation on the surface of the piping.

Insulation thickness should be determined in accordance with the insulation manufacturer's recommendations for the specified ambient dry-bulb temperature and relative humidity at the specific installation location.

For commercial applications, elastomeric (Armaflex) type insulation is typically used because of its cost, flexibility, and ease of installation. Unfortunately, the major flaw of this installation type is its lifespan. Since industrial facilities are typically designed to operate for more than 20 years, this type of insulation is discouraged for use in industrial refrigeration systems.

A jacketing material is used to protect the insulation against humidity, sun, and physical damage.

Below is a list **(Table 4)** of recommended jacketing types depending on the location.

Location	Requirement	Jacketing type
Outdoor	Sun protection	Embossed aluminum
Machinery room	None	White PVC
Machinery room	Industrial style	Embossed aluminum
Interstitial space	None	White PVC
Non-accessible shaft	None	White PVC
Production space	None	White PVC
Production space	Food safety regulations	Stainless steel
Warehouse	None	White PVC
Acid or caustic area	Sanitation washdown duty	Stainless steel

Table 4: Jacketing Type Table

3.2 - Pipe Support

Physical support throughout the piping system is an element often overlooked, but it can be costly if not designed and implemented correctly. In industrial CO_2 refrigeration systems, there are many locations that require different design and installation methods for pipe supports. In the table below **(Table 5)**, the recommended pipe support type is shown for different locations:

Location	Requirement	Support type
Roof	Roof protection	Roof support, aluminum saddles, roof protection
Outdoor wall	Wall protection	Structural steel I beam (pipe rack)
Under structure	Weight limit	Threaded rods, unistrut and aluminum saddle
IMP ceiling	Weight limit	Threaded rods, unistrut and aluminum saddle
Production space	Food safety	Food safe IMP anchors
Risers	Wall tie-in	Riser clamp, wall anchors

Table 5: Support Type Table

Furthermore, depending on the pipe sizing, there is a distance limit to observe between each support to avoid pipe bending and creating low points in the system. This is especially important for copper piping, as it is more prone to bending than stainless steel. Specific requirements as to pipe spacing and support can be found in ANSI/MSS SP-58, as referenced in ASHRAE 15. Technical drawings are included **(Figure 11, Figure 12, Figure 13)** to illustrate some of the recommended installation guidelines regarding physical supports for on-site piping.

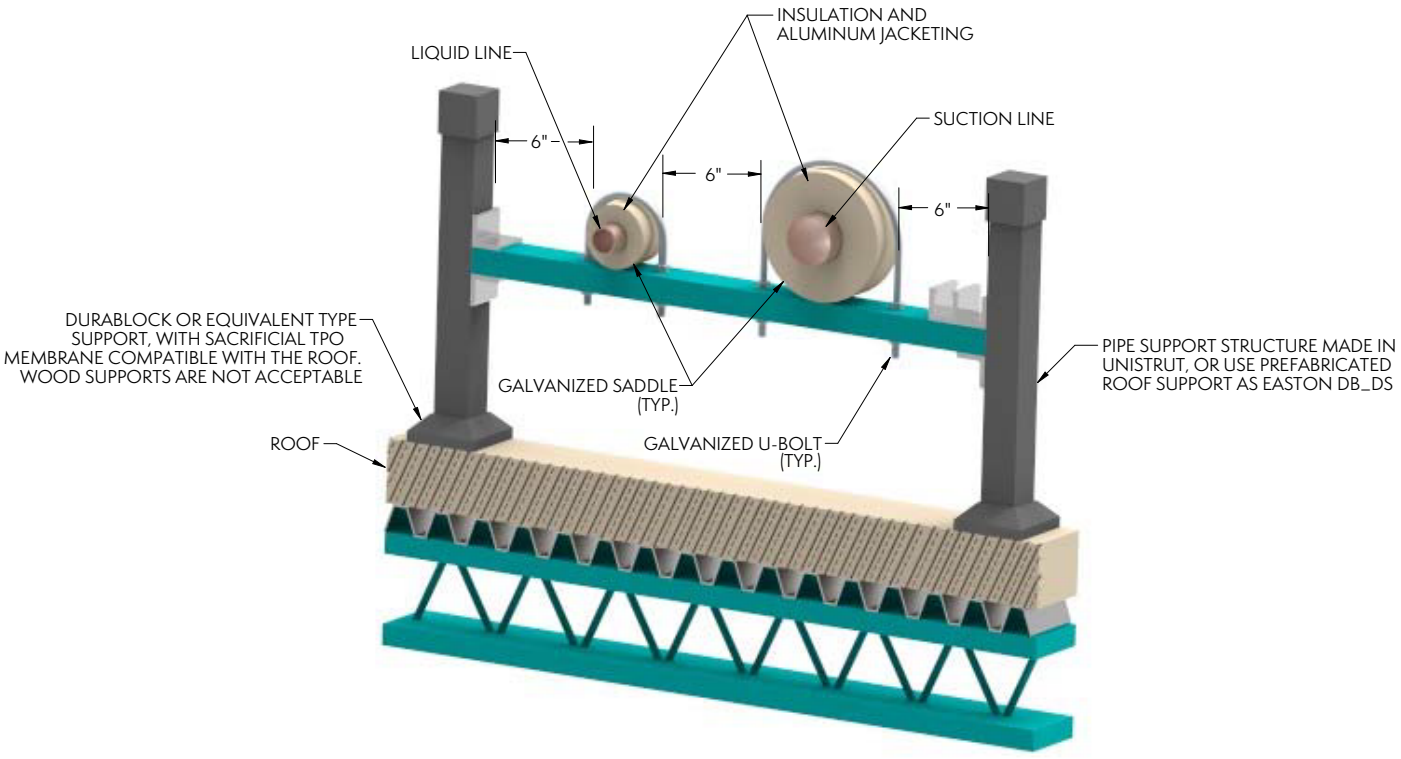


Figure 11: Roof Pipe Support Installation Detail

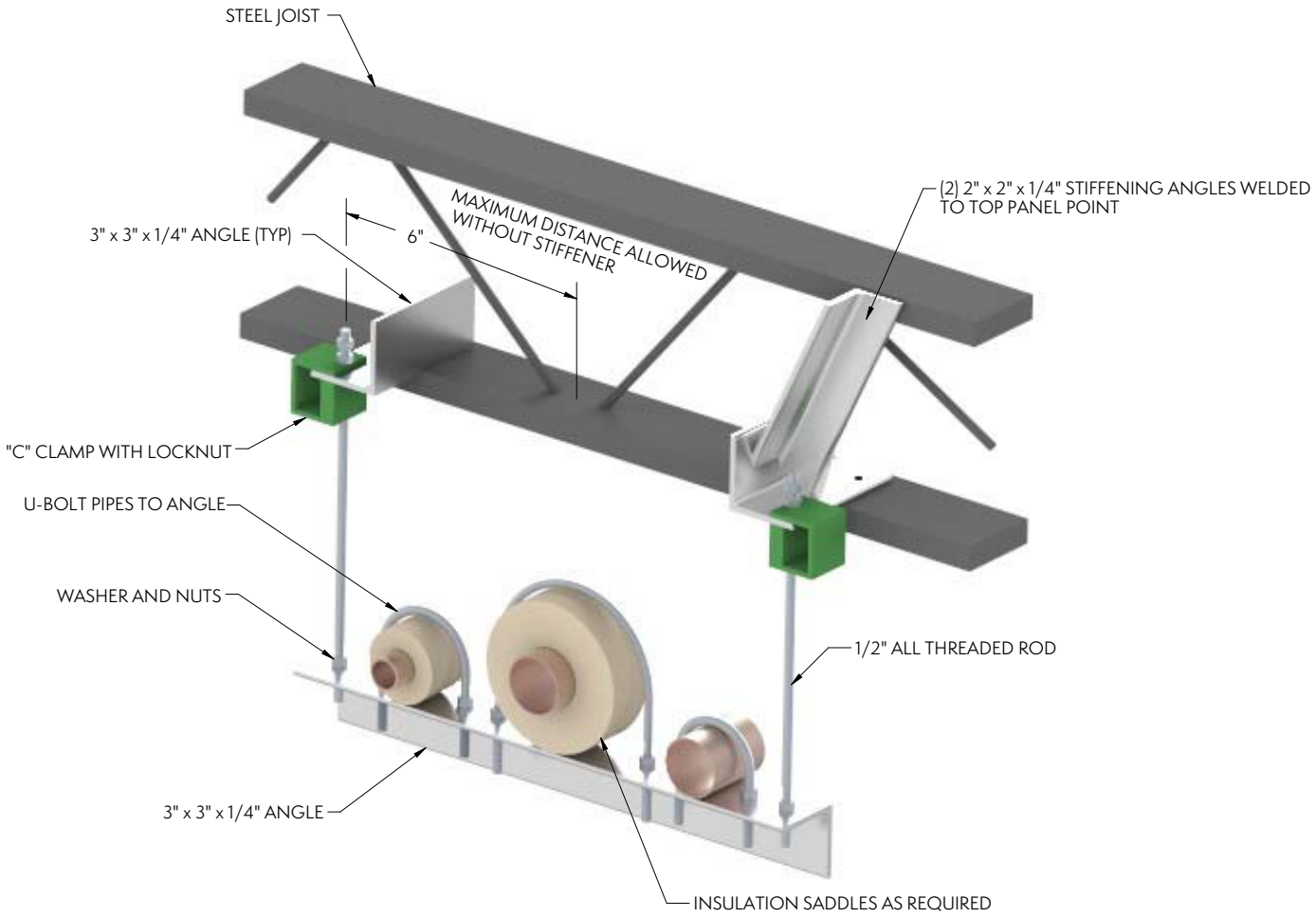


Figure 12: Joist Hanger Pipe Support Detail

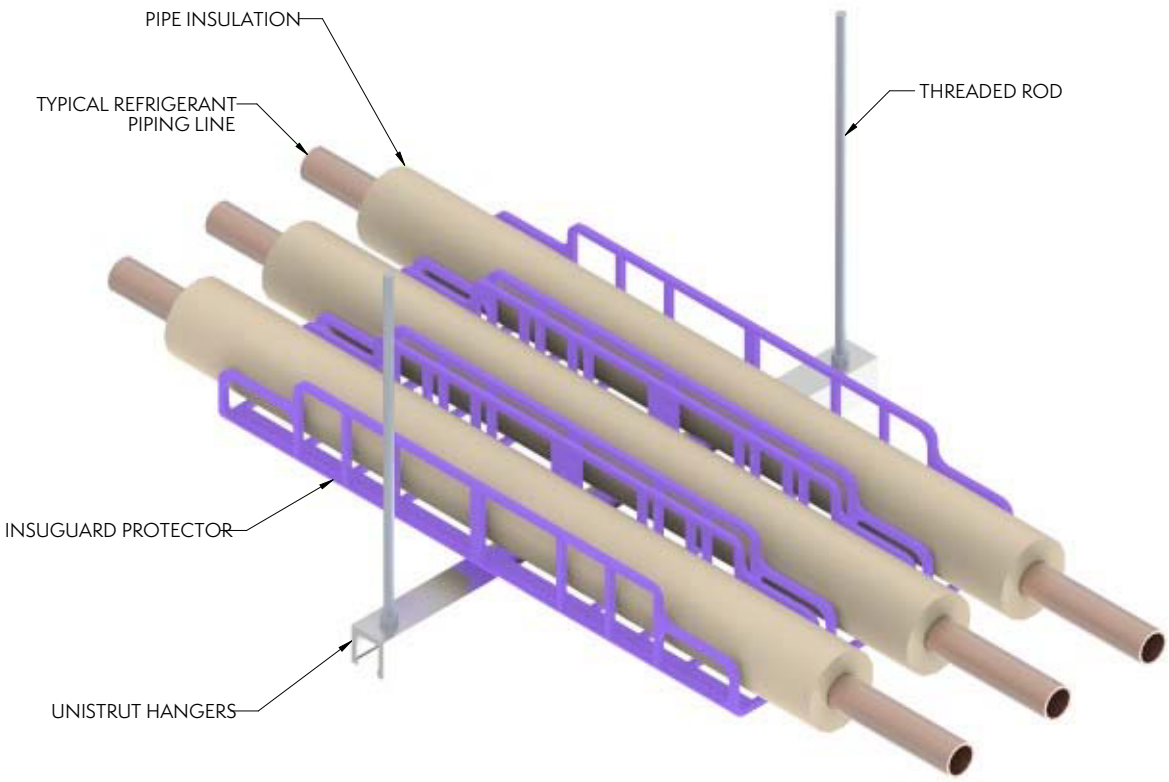


Figure 13: Indoor Pipe Saddle Installation Detail

3.3 - Overpressure Protection

All ASME U-stamped vessels and piping systems must be protected against overpressure to be in compliance with ASME code. Idle CO_2 refrigeration systems at ambient air temperatures exhibit higher pressures in comparison to ammonia. For example, the CO_2 pressure/enthalpy diagram is represented in **Figure 14**, where CO_2 at 72°F has a saturated pressure of 860 PSIG.

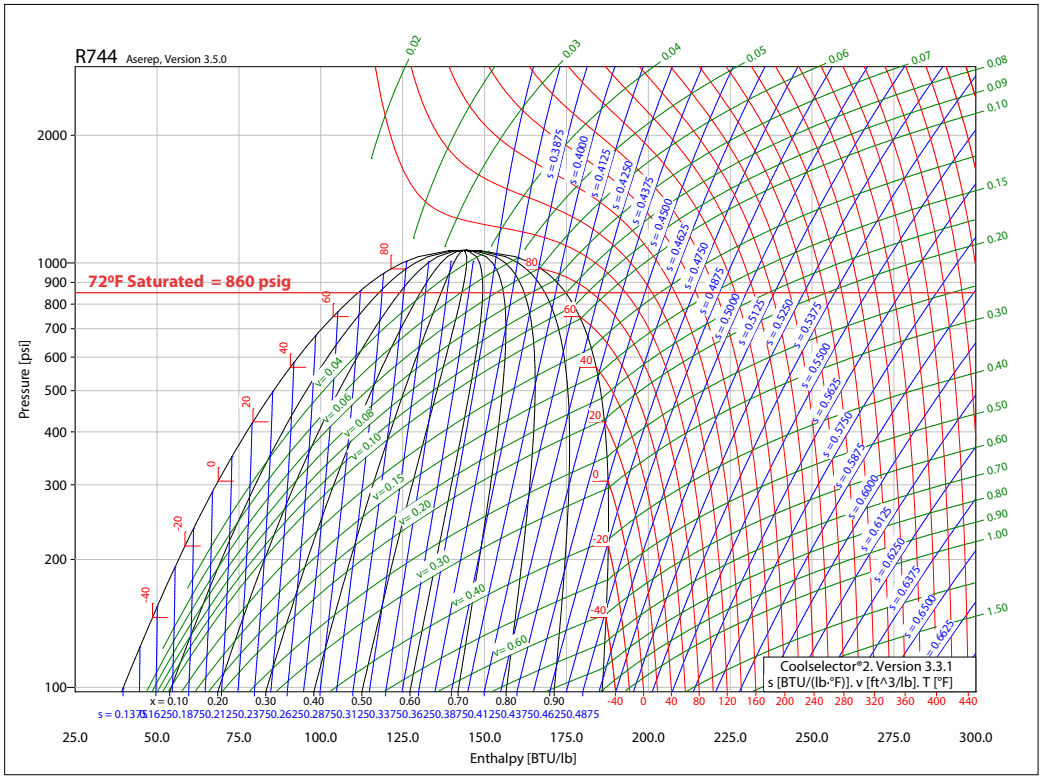


Figure 14: CO_2 P-H Diagram: Ambient Temperature Saturated Pressure

EVAPCO LMP CO_2 systems can be constructed for low side design pressures of 650 PSIG (45 barG) or 1160 PSIG (80 barG). The 650 PSIG design pressure requires the system to operate continuously such that the system's low side pressure remains below the 650 PSIG relief valve setting. This is also true for the low-temperature side suction, since the compressors are rated for 435 PSIG (30 barG). A de-energized system may require auxiliary condensing units to prevent system pressure from exceeding the relief valve setpoint.

3.3.1 - Pressure Relief Valve Location

One particularity of CO_2 is its triple point, at −69.9°F(−56.6°C) and 75.1 psia (517 kPa). At the triple point, CO_2 can exist as a solid, liquid, and gas. Should the triple point pressure be reached, it can cause solid CO_2 (dry ice) to form within the refrigeration system. The triple point pressure is significantly higher than other refrigerants, making it very sensitive to rapid pressure decreases when saturated. Typically, dry ice formation occurs on the outlet of relief valves connected to saturated vessels, such as the flash tank. Below **(Figure 15)** is an annotated P-h diagram for CO_2. The green circle marks a typical condition for CO_2 within a flash tank, with a saturation temperature of approximately 32°F (0°C). If the relief valve is to open, the fluid will begin to evacuate directly to the atmosphere, at ~1 bar (marked with a blue circle). Take note that the fluid will pass below the solid threshold, also known as the solidus line, at the point marked with a red circle.

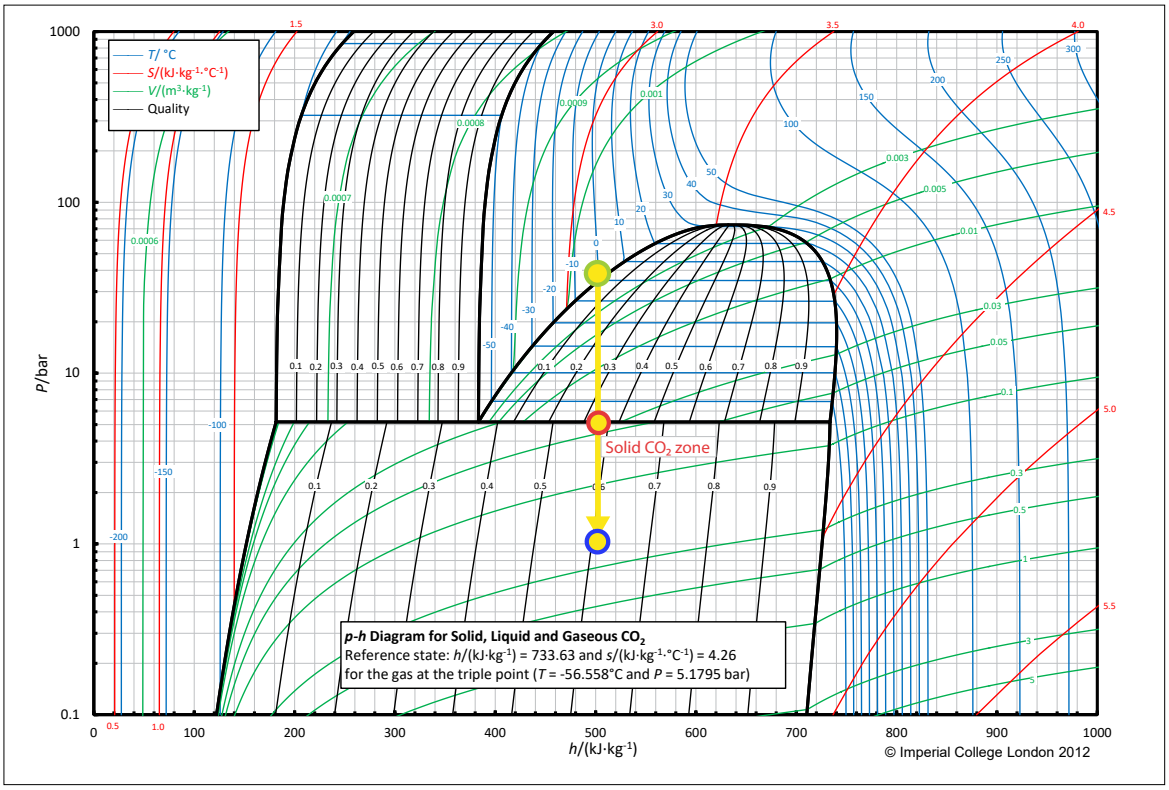


Figure 15: CO_2 P-H Diagram with Triple Point and Solid Zone

Due to the possibility of dry ice formation, it is good engineering practice to avoid piping relief valves through a single manifold. In the event of a saturated vessel relief event, dry ice could form and potentially block the flow of refrigerant through the manifold, creating extremely high pressures (above the MAWP) and potentially a material failure.

To prevent this, EVAPCO recommends that pressure relief valves be installed outdoors and with minimal outlet piping, in a location that meets applicable codes. Please refer to ASHRAE 15, Section 9.7 and the AHJ for further requirements as to the installation of exterior pressure relief valves. EVAPCO also suggests the client/contractor observe the following guidelines in conjunction with local codes/regulations:

- Never install piping at the outlet of the valve
- Secure/brace the relief valve to a permanent structure
- Relief valve outlet cannot face upward
- Refer to local code on installation

The following **(Figure 16)** is an example arrangement that can be used provided it complies with the local code on pressure relief valve installation location.

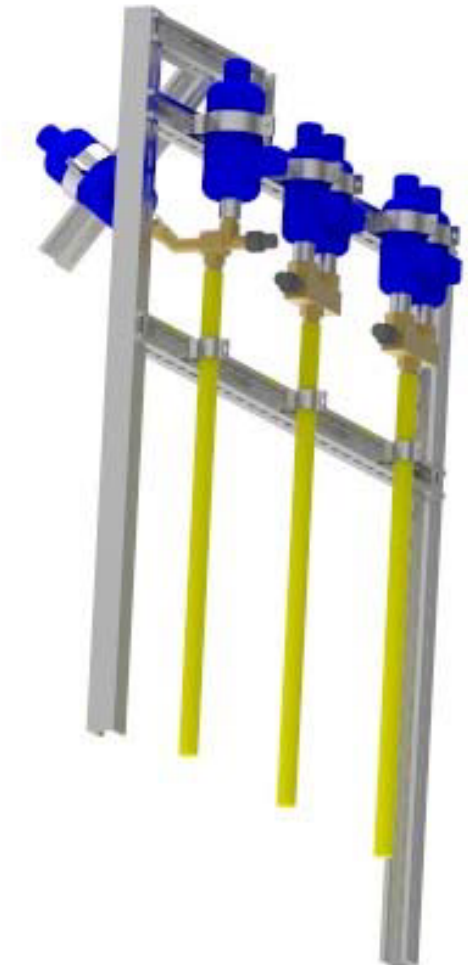


Figure 16: Relief Valve Bracing Example

4.0 - Piping Cleanliness

The refrigeration contractor is solely responsible for ensuring that all field piping is thoroughly cleaned and free of debris during and after installation, including work performed by high-pressure welders. Under no circumstances shall EVAPCO LMP be held liable for any damage, failure, or performance issues resulting from debris present in the system that is attributable to field piping installation.

NOTES

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NOTES

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