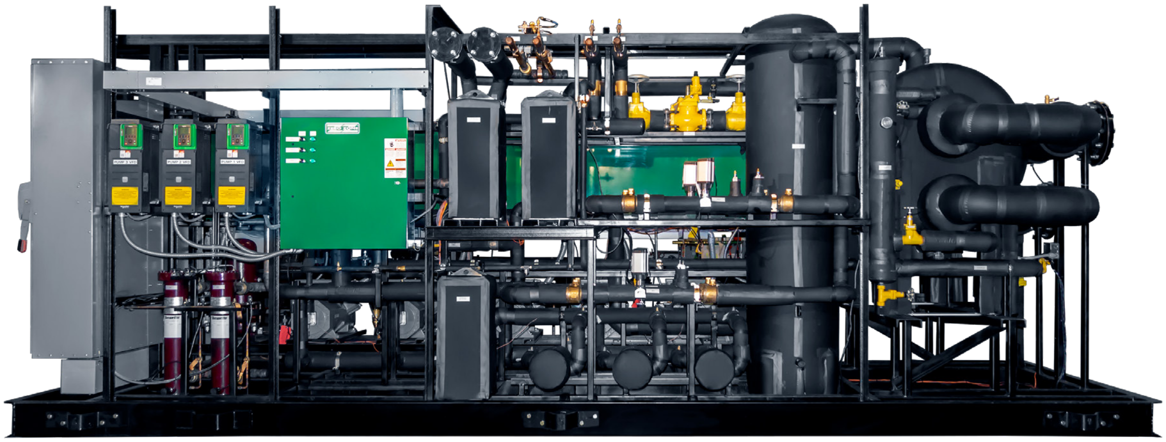

Natural Refrigeration Solutions

ZERO ZONE

CO_2 PACKAGED SYSTEMS

INSTALLATION, OPERATION AND MAINTENANCE MANUAL

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Intertek

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1. ZERO ZONE WARRANTY

Limited Warranty

Zero Zone, Inc. (Seller) hereby warrants that any products manufactured by it and sold are warranted to be free from defects in material and workmanship, under normal use and service for its intended purpose, for a period of one (1) year from the date of original installation (not to exceed 15 months from the date of factory shipment). Zero Zone ChillBrite® LED Lighting carries a 5-year parts warranty. Zero Zone CoolView® Doors carry a 10-year glass pack parts warranty. The obligation under this warranty shall be limited to repairing or exchanging any part, or parts, FOB Factory, which is proven to the satisfaction of the Zero Zone Service Department to be defective. Zero Zone reserves the right to inspect the job site, installation, and reason for failure. This limited warranty does not cover labor, freight, or loss of food or product, including refrigerant loss. This warranty does not apply to motors, switches, controls, lamps, driers, fuses, or other parts manufactured by others and purchased by the Seller unless the manufacturer of these items warrants the same to the Seller, and then only to the extent of those manufacturer's warranty to the Seller. Any products sold on an "AS IS" basis shall not be covered by this warranty.

Extended Warranties

In addition to the standard limited warranty, for further consideration, the Seller will extend to the original purchaser prior to shipment, a limited extended warranty on the compressor only, following expiration of the standard warranty. The Seller agrees to repair or exchange, at its option, or provide reimbursement for such exchange as directed, less any credit allowed for return of the original compressor, of a compressor of like or similar design and capacity, if it is shown to the satisfaction of Zero Zone that the compressor is inoperative due to defects in factory workmanship or material under normal use and services as outlined by Zero Zone in its Installation & Operation Manuals and other instructions.

Length of Extended Warranty

Any compressor warranty may be extended for an additional four (4) years, but such extension must be purchased prior to shipment to be effective. This warranty is only for the compressor and not for any other associated parts of the refrigeration system.

Product Not Manufactured by the Seller

The written warranty, if any, provided by the manufacturer of any part of the refrigeration unit sold by Seller to Buyer, but not manufactured by Seller, is hereby assigned to the Buyer. However, Seller makes no representation or warranty regarding the existence, validity, or enforceability of any such written warranty.

Limitation and Exclusion of Warranties

THE WARRANTIES SET FORTH HEREIN ARE EXCLUSIVE AND IN LIEU OF ALL OTHER WARRANTIES AND REMEDIES WHATSOEVER, INCLUDING, BUT NOT LIMITED TO, IMPLIED WARRANTIES OF MERCHANTABILITY AND/OR FITNESS FOR A PARTICULAR PURPOSE.

2. INTRODUCTION

2.1. Forward

This technical manual gives information for the recommended operation and maintenance of the equipment. This technical manual is written for the original design application of the equipment. If the application of the equipment changes, the operation, maintenance information and procedures could change. This technical manual is not a substitute for comprehensive operator and maintenance training. Read and completely understand this technical manual, equipment functions, and equipment safety features before operating or doing maintenance to the equipment.

The manual is to serve as a guide for placing your equipment into service and operating and maintaining it properly. Improper installation can lead to poor equipment performance or severe equipment damage. Failure to follow the installation instructions may result in damage that will not be covered by your warranty. It is extremely important that a qualified refrigeration installation contractor perform all installation line sizing and piping. Please supply these instructions to your authorized refrigeration contractor. This manual is supplemented as required to accommodate any special items that may have been provided for a specific application. The written information contained in this manual, as well as various drawings, are intended to be general in nature. The drawings included in this manual are typical only and may not represent the actual unit purchased. Actual drawings are included with the equipment and should be referred to for troubleshooting and servicing of the unit. Additional copies of drawings are available upon request. We strive to maintain an accurate record of all equipment during its useful life. While every effort is made to standardize the design features of this equipment, the various options may make it necessary to rearrange some of the components; therefore, some of the general drawings in this manual may differ from your specific unit.

Specific references to current applicable codes, ordinances, and other local laws pertaining to the use and operation of this equipment are avoided due to their ever-changing nature. There is no substitute for common sense and good operating practices when placing any mechanical equipment into operation. We encourage all personnel to familiarize themselves with this manual's contents. Failure to do so may unnecessarily prolong equipment down time.

The equipment uses carbon dioxide (CO_2/R744) refrigerant for heat transfer purposes. This chemical is sealed and tested in a pressurized system containing ASME coded vessels; however, refrigerant gas can be released if there is a system failure. A carbon dioxide refrigerant leak can cause a hazardous situation within a closed, not ventilated space. These units must be placed in a well-ventilated area. Check local regulations for required safety features.

Failure to follow these instructions could result in a hazardous condition. Customers are advised to implement a refrigerant management program including a survey of all equipment to document the quantity of refrigerant in each machine. All refrigeration service technicians must be licensed and certified by an approved organization. It is recommended that good piping practices are followed and that the information in this manual is adhered to. We cannot be held responsible for liabilities created by substandard piping methods and installation practices external to the equipment.

We trust your equipment will have a long and useful life. If you should have any questions, please contact our Customer Service Department specifying the serial number and model number of the unit as indicated on the nameplate.

INTRODUCTION

2.2. Important User Information

The information in this manual is subject to change without notice and does not represent a commitment on the part of Zero Zone. Zero Zone does not assume any responsibility for any errors that may appear in this manual. In no event will Zero Zone be liable for technical or editorial omissions made herein, nor for direct, indirect, special, incidental, or consequential damages resulting from the use or defect of this manual.

The information in this document is not intended to cover all possible conditions and situations that might occur. The end user must exercise caution and common sense when installing, using, or maintaining Zero Zone products. Zero Zone products should only be installed by qualified, professional refrigeration technicians. If any questions or problems arise, call Zero Zone at 800-247-4496.

Any change to a Zero Zone product made during the installation, start-up, or at any other time must be submitted in writing to Zero Zone for approval and be approved by Zero Zone in writing prior to commission. The product warranty is voided when any unapproved change is made to a Zero Zone product.

2.3. Manufacturer

Zero Zone, Inc.
Refrigeration Systems Division

6151 140th Avenue NW • Ramsey, MN 55303 • 800-247-4496 • www.zero-zone.com

2.4. Intended Use

Zero Zone products are intended to be installed and used as described in this manual and other related Zero Zone literature, specifications, drawings, and data. All Zero Zone products must be leveled after being installed.

2.5. Notice to Refrigeration Contractor

The Zero Zone Refrigeration Systems Manual includes default settings to allow the contractor to start the equipment. The contractor is responsible for reviewing the operation of equipment following start-up and for making necessary adjustments.

Authorization and approval from Zero Zone, Inc. must be obtained before any warranty rework or repairs are done to any products provided by Zero Zone, Inc. Authorization consists of obtaining a rework number from the Zero Zone Service Department. Labor charged to be at same rate as installation rate and/or rate standards. Zero Zone, Inc. reserves the right to furnish materials necessary to make repairs or authorized changes.

Failure to comply with these requirements may void the warranty and charges for repairs or rework may be denied. Please contact us at 800-247-4496 if you have any questions or concerns.

This manual covers general instructions for Zero Zone refrigeration systems. For more information about individual pieces of equipment, refer to the manufacturer's literature.

The Zero Zone, Inc. order number of the equipment must be given with all communication for correct identification of the equipment.

2.6. Carbon Dioxide - CO_2 (R744)

The atmosphere contains approximately 0.04% (370 ppm) of carbon dioxide, a naturally occurring substance. CO_2 is termed a "Natural Refrigerant" because it exists in the natural environment. The release of CO_2 into the atmosphere from refrigeration systems has a negligible effect compared to other CO_2 sources that are driving the global warming concern. CO_2 refrigeration systems meet the demand for a natural refrigerant with a low global warming impact (GWP rating of 1) but present challenges in both their application and handling. This section outlines the hazards of CO_2 and explains why CO_2 refrigeration systems differ from conventional systems.

2.6.1. CO_2 SAFETY

- It is very important to know that all refrigerant gases could be fatal simply because of a lack of oxygen caused by air displacement.
- Mechanically introducing an asphyxiate gas into a closed environment would immediately displace the air and force it to exit at the same rate as the gas entering the environment.
  - For example, an air conditioning system with an evaporator gas leak would introduce R-744 into the environment. Consequently, the increased pressure would force air to escape through any small openings around the doors, windows, etc.
- One difference regarding CO_2 is that it's not only an asphyxiate gas; it's also a narcotic agent, which reduces awareness of the danger. It is also the most potent brain vasodilator (a substance that increases the size of a human's blood vessels, stretches muscular fibers, and consequently dramatically reduces blood pressure) ever known.
- **See Table 1** compares CO_2 Safety to other refrigerants.
- The main difference among the various refrigerants is related to their boiling temperatures.

TABLE 1: REFRIGERANT ASHRAE SAFETY CLASSIFICATION

Refrigerant	HAZCHEM Code	Boiling Point (°F)	Safety Code ASHRAE	Dangers	TLV/TWA (ppm)
R744	2RE	-173.3	A1	Asphyxiant	5000
R410A	2RE	-126	A1	Asphyxiant in high concentrations	1000
R404A	2RE	-116.2	A1	Asphyxiant in high concentrations	1000
R507	2RE	-116.1	A1	Asphyxiant in high concentrations	1000
R407C	2RE	-109.4	A1	Asphyxiant in high concentrations	1000
R448A	2RE	-105.3	A1	Asphyxiant in high concentrations	1000
R134a	2RE	-79.2	A1	Asphyxiant in high concentrations	1000
R717	2RE	-92.1	B2	Toxic Inhalation	25

- Refrigerants have the potential to suffocate and cause serious burns when they come into contact with skin or eyes as a result of the extremely low temperatures.
- If high concentrations of these gases are inhaled, move the victim into an air with fresh air immediately.
- Proper first aid techniques (such as CPR) must be applied in the case of respiratory or cardiac failure. Arrange for immediate medical treatment of the victim.
- Be aware of the high pressure of the CO_2 refrigerant before working on or around a CO_2 system.

INTRODUCTION

2.6.2. CO_2 PROPERTIES

CO_2 has vast array of properties (**See Table 2**) that are useful in refrigeration, but it also has some notable safety concerns. Below is a list of key features.

- Approximately 50% heavier than air
- Can suffocate in high concentrations
- Nonflammable
- Slightly acidic
- When in contact with water forms carbonic acid
- Higher pressure ranges than typical refrigerants
- Excellent thermodynamic and physical properties for refrigeration

TABLE 2: PHYSICAL PROPERTIES OF CO_2 (R744)	
Appearance	Colorless
Odor	Odorless
Flammability	Nonflammable
Molar Mass	44.01 lbm/lbmol
Triple Point Temperature	-69.804°F
Normal Sublimation Point	-109.24°F
Critical Temperature	87.761°F
Critical Density	29.191 lbm/ft^3
Specific Gravity (Air = 1) at 70°F and 1 atm	1.52
Solubility in Water vol/vol at 68°F and 1 atm	0.90

2.6.3. THERMODYNAMIC PROPERTIES OF CO_2

Below is a selected set of thermodynamic properties for CO_2 (**See Table 3**). **See Table 7** in the appendix for a full list of properties across the refrigeration application range.

TABLE 3: SELECTED THERMODYNAMIC PROPERTIES OF CO_2

Temp	Pressure	Volume	Density	Enthalpy		Entropy	
		Vapor	Liquid	Liquid	Vapor	Liquid	Vapor
°F	psig	ft^3/lbm	lbm/ft^3	Btu/lbm	Btu/lbm	Btu/lbm	Btu/lbm
-40	130.99	0.61325	69.696	48.539	187.15	0.15898	0.48928
-30	163.13	0.50327	68.307	53.39	187.58	0.1702	0.48251
-20	200.22	0.41582	66.862	58.317	187.84	0.18131	0.47589
-10	242.7	0.3455	65.349	63.337	187.9	0.19233	0.46933
0	291.04	0.28835	63.757	68.469	187.74	0.20331	0.46277
10	345.71	0.24144	62.069	73.738	187.32	0.2143	0.45614
20	407.21	0.20254	60.263	79.175	186.6	0.22536	0.44933
30	476.07	0.16993	58.31	84.824	185.52	0.23658	0.44222
40	552.88	0.14229	56.165	90.748	183.97	0.24805	0.43462
50	638.29	0.11852	53.758	97.046	181.81	0.25996	0.42626
60	733.05	0.097683	50.964	103.89	178.77	0.27261	0.41669
70	838.13	0.078809	47.517	111.66	174.29	0.28666	0.40491
80	954.88	0.060289	42.618	121.44	166.77	0.30404	0.38804

INTRODUCTION

2.7. System Definitions

Sub-Critical CO_2: A CO_2 refrigeration cycle that is intended to operate below the critical point of CO_2. This allows for more traditional working pressure ranges for materials and components. Sub-Critical CO_2 systems have a traditional condenser and optional receiver. THis system does not require a high-pressure expansion valve or flash gas bypass valve.

Trans-Critical CO_2: A CO_2 refrigeration cycle that is intended to operate above the critical point of CO_2. This system will experience pressures in excess of typical refrigeration design and must take appropriate measures to accommodate the high pressures.

Critical Point: The critical point of CO_2 is at a temperature of 31°C (87.8°F) and a pressure of 1071 psig (73.8 bar). Above this critical point, CO_2 exists in a supercritical fluid state, which exhibits the properties of both a gas and a liquid.

Triple Point: The triple point of CO_2 occurs at a temperature of -56.6°C (-69.8°F) and a pressure of 61 psig (4.17 bar). At this point, CO_2 exists as a mixture of solid, liquid, and gas, with the solid form of CO_2 (dry ice) in equilibrium with its liquid and gaseous phases.

Liquid Overfeed: Liquid Overfeed: This system pumps a mixture of liquid and vapor from the evaporaters back to the liquid CO_2 vessel, where it cools to 100% liquid.

Receiver / Flash Tank: Similar to a Liquid Receiver in a traditional DX system. The Separator primarily stores and receives liquid CO_2 for the system. It also has another role, as it serves to separate entrained vapor (flash gas) from liquid CO_2. This flash gas vapor is returned to the compressors and has no refrigeration effect. The evaporators receive the liquid CO_2 and produce the desired refrigeration effect.

Cascade Refrigeration System: A refrigeration system having at least two independent refrigeration circuits, each with its own refrigerant. The lower-temperature circuit uses the higher-temperature circuit's evaporator as a condenser/gas cooler. When applied with CO_2, a cascade system would typically have a traditional HFC, ammonia, or hydrocarbon as the higher temperature refrigerant and a subcritical CO_2 system as the lower temperature refrigerant. A CO_2 cascade system enables the CO_2 refrigeration system to operate at lower pressures while still using traditional HFC system construction materials.

High-Side Cascade (Primary): This is the high-temperature side of a cascade system. Typically, this is a traditional refrigerant that can operate at lower working pressures under normal atmospheric conditions. This will energize the evaporative side of the cascade condenser/gas cooler.

Low-Side Cascade: This is the medium- and low-temperature side of a cascade system. Typically, this is the CO_2 component of the system. The high side of the cascade allows the low side to stay within acceptable working pressures and below relief valve opening pressure.

Condenser/gas cooler: In transcritical CO_2 refrigeration systems, people often refer to the condenser/gas cooler as a gas cooler. If it is a water-cooled condenser/gas cooler, it exchanges the heat of rejection with ambient air or a water stream. Depending on whether the CO_2 refrigeration system operates below the critical point using a condenser/gas cooler, or above the critical point using a gas cooler, the condenser/gas cooler and/or gas cooler are the same component and are commonly used interchangeably when describing this heat exchanger. When the ambient temperature cools the CO_2 discharge vapor sufficiently for the CO_2 refrigeration cycle to operate below the critical point or within the subcritical zone, the gas cooler functions as a condenser/gas cooler.

Gas Cooler: The gas cooler takes over the role of a traditional condenser/gas cooler when the CO_2 discharge pressure and/or temperature are above the critical point of CO_2. It is known as a gas cooler rather than a condenser/gas cooler because the CO_2 discharge vapor only cools and does not condense in the gas cooler while the CO_2 is operating in the transcritical zone. When the ambient temperature cools the CO_2 discharge vapor sufficiently for the CO_2 refrigeration cycle to operate below the critical point or within the subcritical zone, the gas cooler functions as a condenser/gas cooler.

High Pressure Expansion Valve: Regulates the refrigerant pressure leaving the gas cooler.

Flash Gas Bypass Valve: Sends gas to the suction lines to regulate and maintain pressure in the receiver/flash tank.

Desuperheat: Removes heat from the compressor discharge gas. The heat is typically reclaimed for use elsewhere.

Parallel Compression: Uses multiple compressors that are piped and work together to provide a sufficient refrigerant load.

3. SAFETY

3.1. General Safety Information

It is the responsibility of the owner and user of this equipment to know the safety codes, insurance requirements, and national, federal, provincial, state, and local laws and regulations affecting all uses of the equipment. This technical manual does not provide regulatory information because regulations are subject to change and are different from location to location. Not using the equipment according to these regulations can result in damage to the equipment and death or injury to personnel.

Zero Zone, Inc. provides technical manuals for the different types of equipment it manufactures and sells. The owner and user must use these technical manuals to give the correct information and training to the people who will operate, maintain, or supervise the use of the equipment.

The owner and user must establish a regularly scheduled inspection and maintenance program based on the information in the Zero Zone, Inc. technical manual, in addition to other sources. See the manufacturer's operational manual for safety information regarding Zero Zone vendor components. Inspection and maintenance programs help prevent accidents and keep the equipment operating efficiently. Correct training, inspection, and maintenance programs are important to avoid personal injury, damage to equipment, high maintenance costs, and lost production.

Read and understand the technical manuals provided with this equipment before operating or doing maintenance on the equipment. Assistance is available from the Zero Zone, Inc. Service Department.

Throughout this technical manual are steps and procedures that, if not followed, can result in a hazard. The following signal words are used to identify the level of a hazard:

3.1.1. CONVENTIONS

⚠ THIS ICON SIGNIFIES INFORMATION THAT DESCRIBES AN UNSAFE CONDITION THAT MAY RESULT IN DEATH, INJURY, OR DAMAGE TO THE EQUIPMENT. WARNING LEVELS ARE DEFINED BELOW.

⚠ **DANGER!** A CONDITION THAT CAN RESULT IN DEATH OR SERIOUS INJURY.

⚠ **WARNING!** A CONDITION THAT CAN RESULT IN SERIOUS INJURY OR DAMAGE TO EQUIPMENT.

⚠ **CAUTION!** A CONDITION THAT CAN RESULT IN INJURY OR DAMAGE TO EQUIPMENT OR PRODUCT.

3.1.2. SAFETY DURING MAINTENANCE AND OPERATION

Do not work on or operate the system without reading and understanding this section, which contains important information and warnings. Ignoring these warnings can result in death, serious injury, or damage to the system and product.

Under all circumstances, one must follow all applicable safety guidelines. This includes, but is not limited to, NEC, ASHRAE, OSHA, and National/State/Local Authorities.

Do not operate the equipment under any conditions or in any manner other than those for which the equipment has been specified, sold, and described in this technical manual.

The operator must know all the main parts, controls, and safety features of the equipment before operating it. The operator must know the correct operation and inspection procedures of the equipment before operating it. "Administrative controls" refers to the technician or operator. No engineered solution exists for procedures that use administrative controls. It is the technician's or operator's responsibility to ensure safety.

Do not bypass, disconnect, or ignore safety and warning devices of the system.

The refrigeration system contains electrical, electronic, and mechanical parts. Only qualified, trained maintenance personnel must perform maintenance, calibration, and inspection procedures in accordance with the technical manual. Maintenance personnel must have a strong electronics background.

SAFETY

Do not operate the equipment after an inspection reveals a possible safety hazard or if any equipment parts require maintenance or replacement. Always look for equipment damage during operation. If damage is found, safely shut down the equipment and correct the damage before continuing operation.

Shut off the electric power when doing maintenance on or near the electrical equipment parts.

Do not make modifications to the equipment unless approved in writing by Zero Zone, Inc.

3.1.3. FIRE SAFETY

Install fire detection, smoke detection, and fire suppression systems in accordance with NFPA and local code requirements. Fire extinguishers should be clearly marked and located in easily accessible areas near the unit. Exits must be clearly marked to enable easy evacuation in cases where the fire cannot safely be suppressed.

Keep the unit clean and free of scrap materials, oils, or solvents to prevent the possibility of fire.

⚠ **DANGER!** IN THE EVENT OF A FIRE, DE-ENERGIZE THE UNIT IMMEDIATELY BY DISCONNECTING THE POWER. ALWAYS DISCONNECT ALL POWER UPSTREAM OF THE UNIT AND SAFELY MOVE AWAY FROM THE FIRE BEFORE EXTINGUISHING THE FIRE. USE AN APPROPRIATE FIRE EXTINGUISHER WHILE ATTEMPTING TO EXTINGUISH THE FIRE. A MACHINE CONNECTED TO ELECTRICAL POWER CAN RESULT IN SERIOUS INJURY OR DEATH.

3.1.4. REQUIREMENTS FOR PERSONAL PROTECTION EQUIPMENT (PPE)

- Low Risk Operations: Standard operations such as making adjustments and using standard diagnostic equipment
  - Safety glasses with side shields
  - Long sleeve shirt or jacket
  - Safety shoes
- High Risk Operations: Charging the system or opening pipes with refrigerant present.
  - Face shield
  - Protective insulated gloves (leather or mechanical gloves)
  - Insulated Apron

3.1.5. REFRIGERANT LINE SAFETY

- Know if refrigerant lines are pressurized before cutting lines or opening and closing valves.
- **Pressures can cause lines to burst if improperly isolated and allowed to absorb heat.**
  - It is important to be trained and familiar with CO_2 refrigeration systems. Study the system piping and understand the necessary standard operating procedures prior to servicing.
- Ensure that proper ventilation is provided.

⚠ **DANGER!** NEVER APPLY HEAT DIRECTLY TO A REFRIGERANT PIPE CONTAINING CO_2. RAPID THERMAL EXPANSION OF LIQUID CO_2 CAN CAUSE THE PIPE TO BURST.

⚠ **DANGER!** EQUIPMENT BEING USED TO SERVICE THE CO_2 SYSTEM SHOULD HAVE AN OPERATING PRESSURE GREATER THAN THE SECTION OF THE SYSTEM BEING SERVICED.

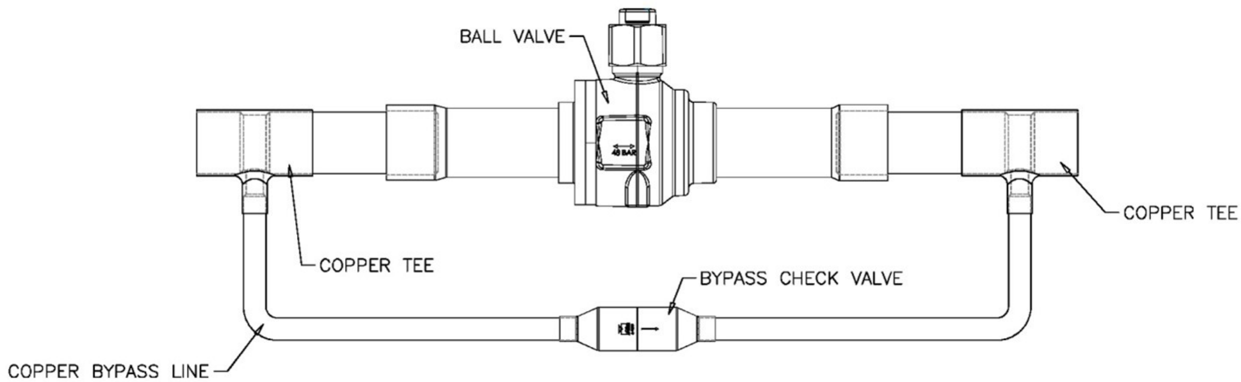
SAFETY

3.1.6. RELIEF VALVES, BYPASS CHECK VALVES, AND VENTS

Any line that may be manually isolated in a CO_2 system must be either protected by a safety relief valve, relieved back to a point that can handle the pressure by use of a bypass check valve, or relieved by manually venting by use of administrative controls. Typical relief points include the low-pressure side of DX compressors and the Receiver / Separator. In the event that one would like to bypass CO_2 back to the Receiver / Separator, one would install a bypass check valve (**See Figure 1**) around the component. Evaporator isolation valves and non-pilot-operated solenoids are examples of typical applications. See the ball valve piping example in **Figure 1**.

Note: Ball valves with integrated bypass check valves may have a different appearance than the vale displayed in Figure 1.

FIGURE 1: Bypass Check Valves



ELECTRICAL SAFETY

- Know the location of disconnects or circuit breakers
- Know if the circuits are powered before opening panels
- Disconnect power supply before connecting or disconnecting electrical wires or doing work that could create risk of electrical shock.
- Use proper safety precautions when handling powered circuits. Use proper personal protective equipment when necessary.

4. SYSTEM INSTALLATION

4.1. General

- Installation of refrigeration system shall comply with the following guidelines:
  - UL 1995/CSA C22.2 Standard for Heating and Cooling Equipment
  - UL 508A Standard for Industrial Control Panels
  - NFPA 70 National Electric Code (NEC)
  - ANSI/ASHRAE Standard 15: Safety Standards for Refrigeration Systems
  - ASME B31.5 Refrigeration Piping Standard
  - ANSI/IIAR CO2-2021 Safety Standard for Closed-Circuit Carbon Dioxide Refrigeration Systems
  - All local building, mechanical, electrical, plumbing, fire and energy codes.
- Equipment must be installed per any special notes or instructions provided with the system by Zero Zone.
- It is the contractor/installers responsibility to ensure that any field installed materials are compatible with CO_2.
  - Examples include: Pipes, valves, fittings, oil, gaskets, or any other materials that come into contact with CO_2 refrigerant.

4.2. Receiving Inspection

Before accepting delivery, check the overall equipment condition for any visible damage. If damage is evident, it should be properly documented on the delivery receipt. Shipping damage is the responsibility of the carrier. In order to expedite payment for damages, it is important that proper procedures are followed, and records kept. Photographs of damaged equipment are excellent documentation for your records.

The unit should be inspected for hidden damage. Refrigerant lines can be susceptible to damage in transit. Check for broken lines, oil leaks, damaged controls, or any other major component torn loose from its mounting point.

Any sign of damage should be recorded, and a claim filed immediately with the shipping company. Our Customer Service Department will provide assistance in preparation and filing of your claims, including arranging for an estimate and quotation on repairs; however, filing the claim is the responsibility of the receiving party.

Each unit will be equipped with a tag specifying a holding charge of dry Nitrogen or Carbon Dioxide that was installed at the factory. The system pressure should be checked in multiple places to confirm that the entire system pressure is equalized and is equal to the factory pressure applied prior to shipment. Ambient temperature change will affect system pressure and shall be considered. Any loss of pressure will need to be thoroughly investigated and the leak repaired or eliminated. It is extremely important to confirm the system is leak free before the evacuation and charging process commences.

4.3. Rigging, Handling, and Locating Equipment

Proper rigging methods must be followed to prevent damage to components. Please refer to the lifting diagram included with the unit. Avoid impact loading caused by sudden jerking when lifting or lowering the unit. Use pads where abrasive surface contact is anticipated. The frame supporting the unit can be used for positioning the unit with a crane. Please refer to the drawings provided with the unit for rigging details.

⚠ **CAUTION!** SPREADER BARS ARE REQUIRED TO BE USED WHEN LIFTING THE EQUIPMENT TO PREVENT DAMAGE TO THE UNIT, ELECTRICAL PANELS, AND PIPING. ALL LIFTING POINTS MUST BE USED TO DISTRIBUTE WEIGHT EVENLY TO PREVENT THE UNIT FROM DEFORMATION DURING LIFTING.

These units may be designed for either indoor or outdoor use. Please reference the documentation supplied with the unit to determine if the unit is to be indoor or outdoor mounted. The outdoor unit can be stored in environments between -22°F (-30°C) and 122°F (50°C). If the unit is designed for indoor duty, the allowable operating ambient temperature is between 40F (4.4°C) and 86°F (30°C). If the unit is designed for outdoor duty, the allowable operating ambient temperature is between -20°F (-30.2°C) and 105°F (40.5°C), unless the unit is specifically designed for extreme temperature conditions outside of this specified temperature range.

SYSTEM INSTALLATION

⚠ **CAUTION!** UNDER NO CIRCUMSTANCES SHALL A UNIT DESIGNED FOR INDOOR DUTY, BE STORED OR INSTALLED OUTDOORS WITHOUT PROPER PROTECTION FROM THE AMBIENT WEATHER CONDITIONS. INDOOR UNITS ARE NOT DESIGNED TO BE EXPOSED TO OUTDOOR WEATHER CONDITIONS.

⚠ **CAUTION!** TO PREVENT DAMAGE TO THE EQUIPMENT CAUSED BY FREEZING, DO NOT STORE OR OPERATE THE UNIT IN AN AMBIENT CLIMATE WHICH MAY CAUSE FREEZING WITHOUT ADEQUATE FREEZE PROTECTION.

4.3.1. SERVICE SPACE REQUIREMENTS

Serviceability was a primary concern when designing this equipment. Do not compromise this feature by locating the equipment in an inaccessible area. Please allow a minimum of 3 feet around the perimeter of the unit, and 4 feet in front of the electrical enclosures for required clearance, or as specified per local and national electrical code. If it is necessary to store the unit in an unheated area (below 40°F) when not in use, be sure that all water is drained or that an adequate amount of antifreeze is added to prevent freeze-up of the unit.

Locate this equipment in a well-ventilated area. Inhalation of refrigerant can be hazardous to your health and the accumulation of refrigerant within an enclosed space can displace oxygen and cause suffocation.

The gas cooled condenser/gas cooler must be located to ensure an adequate supply of fresh air to the coils. The axial fan(s) are not equipped to overcome external static pressure. When units are located adjacent to walls or in enclosures, care must be taken to ensure the discharge air is not deflected and recirculationulated back to the air intakes.

Each unit must be located and positioned to prevent the introduction of discharge air into the ventilation systems of the building on which the unit is located and of adjacent buildings.

4.3.2. FOUNDATION

Provide a rigid, non-warping mounting surface for the equipment of adequate strength to support the operating weight of the unit. It is imperative that the entire operating weight be considered, including the completed piping and full operating weight of the refrigerant and water. The equipment once mounted should be level within a ¼" over the length and width of the unit.

Mounting information and instructions have been provided in the drawings and documents provided with your system.

SYSTEM INSTALLATION

4.4. Electrical Power

All wiring must comply with local codes and the National Electric Code. The unit nameplate contains information about minimum circuit ampacities, maximum overcurrent protection, and other unit electrical data. This information can also be found in the drawing package provided with the unit.

A specific electrical schematic is shipped with the unit. Measure each leg of the main power supply voltage at the main power source. The voltage must be within the voltage utilization range of +/-10% of the units' rated nominal voltage. If the measured voltage on any leg is not within the specified range, notify the supplier and correct it before operating the unit. The voltage imbalance must not exceed two percent. An excessive voltage imbalance between the phases of a three-phase system can cause motors to overheat and eventually fail. The voltage imbalance is determined using the following calculations:%Imbalance = (Vavg – Vx) x 100 / Vavg

Vavg = (V1 + V2 + V3) / 3

Vx = phase with greatest difference from Vavg

For example, if the three measured voltages are 442, 460, and 454 volts, the average would be:

(442 + 460 + 454) / 3 = 452

The percentage of imbalance is then:

(452 – 442) x 100 / 452 = 2.2 %

This exceeds the maximum allowable of 2%.

A power distribution block (PDB) is provided for main power connection to the main power source. A separate PDB is provided for control power. The main power source should be connected to the PDB through an appropriate disconnect switch. A separate lug for grounding the unit is also provided in the main control panel. ***Note: Tighten connections on arrival after operation.***

⚠ **CAUTION!** THE UNIT REQUIRES THE MAIN POWER TO REMAIN CONNECTED DURING OFF-HOURS TO ENERGIZE THE COMPRESSOR'S CRAKCASE HEATER. DISCONNECT MAIN POWER ONLY WHEN SERVICING THE UNIT. THE CRANKCASE HEATER SHOULD REMAIN ON WHEN THE COMPRESSOR IS OFF TO ENSURE LIQUID REFRIGERANT DOES NOT ACCUMULATE IN THE COMPRESSOR CRANKCASE. ELECTRIC POWER AT THE MAIN DISCONNECT SHOULD BE SHUT OFF BEFORE OPENING ACCESS PANELS FOR REPAIR OR MAINTENANCE. ALLOW A MINIMUM OF 12 HOURS BEFORE ENERGIZING THE COMPRESSOR'S CRANKCASE HEATER.

⚠ **DANGER!** THE CONTROL PANEL AND SAFETIES ARE WIRED SUCH THAT CONNECTING THE APPROPRIATE CONTROL POWER SOURCE TO THE CONTROL ENCLOSURE PDB ENERGIZES THE CONTROL CIRCUITRY OF THE UNIT. A CONTROL TRANSFORMER AND POWER SUPPLY HAS BEEN FACTORY WIRED TO STEP DOWN THE INCOMING POWER FROM 115VAC TO 24V AND DC CONTROL POWER. THE UNIT MUST BE PROPERLY GROUNDED IN COMPLIANCE WITH LOCAL AND NATIONAL CODES.

TABLE 4: ELECTRICAL POWER ACRONYMS

Acronym	Definition
RLA	Rated Load Amps
LRA	Locked Rotor Amps
MCA	Minimum Circuit Ampacity (for wire sizing)
MOCP	Maximum Overcurrent Protection
SCCR	Short Circuit Current Rating

Note: Check the green folder for more information.

SYSTEM INSTALLATION

4.5. Piping Guidelines

The installer should be a trained, experienced technician knowledgeable of good piping practices. The following guidelines are extremely important. These recommendations will enhance the efficiency, overall performance, and longevity of the compressor systems. Not all guidelines listed in this section may be appropriate for all equipment types, as field installation may not be required depending on the particular equipment specification.

TABLE 5: CO_2 PIPING SIZING RECOMMENDATIONS				
	Horizontal or Downflow Line Velocity	Vertical Riser Line Velocity	Saturation Temperature Change [1]	Pressure Drop [1]
Liquid Line	360 ft/min max	200 ft/min max [3]	1 °F max	5 psi max
Gas Cooler Return Line	480 ft/min max [4]	480 ft/min max [4]	1 °F max	10 psi max
Discharge Line	1000-4000 ft/min	1000-1500 ft/min [2]	1 °F max	10 psi max
Suction Line Circuits	1000-4000 ft/min	1000-1500 ft/min [2]	1 °F max	5 psi max
Suction Line	1000-4000 ft/min	1000-1500 ft/min [2]	2 °F max	10 psi max
Discharge Header	1000-3500 ft/min	Not Applicable	½ °F max	5 psi max
Liquid Header	360 ft/min max	Not Applicable	½ °F max	3 psi max
Suction Header	1000-3000 ft/min	Not Applicable	½ °F max	3 psi max

Relief Valve Lines

Relief valve piping material, sizing, and allowable lengths shall be carefully selected and calculated to meet the particular application requirements of the equipment installation. Vent all refrigerant relief valves in accordance with ANSI/ASHRAE Standard 15, Safety Code for Mechanical Refrigeration.

⚠ **DANGER!** LOCATE THIS EQUIPMENT IN A WELL-VENTILATED AREA. INHALATION OF REFRIGERANT CAN BE HAZARDOUS TO YOUR HEALTH AND THE ACCUMULATION OF REFRIGERANT WITHIN AN ENCLOSED SPACE CAN DISPLACE OXYGEN AND CAUSE SUFFOCATION.

Notes:

These are listed as general guidelines for a typical parallel rack refrigeration system with split suction (remote evaporators). The overall pressure drop, including line lengths, valves, and fittings, should always be taken into consideration when selecting line sizing. There are situations where these listed general guidelines must be exceeded based on the application and the requirements. The Gas Cooler Return line should be checked for both vapor and liquid conditions if transcritical operation is considered.

Pressure drop should be based on the approximate actual line length, not an assumed ΔP/100ft.

Adequate velocity must be maintained in vapor lines at all load conditions to ensure oil entrainment. This is always more important than minimizing pressure drop.

1. ***Allowable Pressure drop varies with refrigerant based on saturated temperature change, but the values listed are generally acceptable for CO_2 refrigeration systems.***
2. ***The minimum allowable vertical riser line velocity is the lowest possible load. This is a general recommendation. If this is not appropriate based on a specific design, then reference the ASHRAE Refrigeration Handbook to calculate the absolute minimum line size to ensure oil entrainment. The pressure drop must be greater than: line size <= 2", 0.35 psi/100 ft; line size > 2", 0.2 psi/100 ft.***
3. ***Careful consideration is required for liquid vertical risers to prevent flash gas formation due to excessive pressure drop and lack of proper subcooling.***
4. ***Gas Cooler Return line should be checked for both vapor and liquid conditions if transcritical operation is considered.***

SYSTEM INSTALLATION

4.5.1. PIPING TYPE

All piping installed on the refrigeration equipment from the factory or installed in the field should be selected to meet the specified Zero Zone engineering requirements according to material type, diameter, and the rated maximum working pressure. All piping and fittings shall be joined by an approved method so that the maximum working pressure of the pipe is not derated.

Steel piping and pressure vessels are likely to condense moisture when in operation. Use adequate insulation and vapor barriers to eliminate voids or gaps that would allow moisture to condense on the metal and prevent corrosion.

4.5.2. CO_2 PIPING MATERIAL

Note: See Mueller's spec sheets for current data.

1. Design pressure greater than 700 psig: Mueller Streamline XHP 130 (C19400 ASTM B465).
2. Use Mueller 700 psig copper tube and fittings for design pressures less than 700 psig. This will be ACR copper Type K or L based on size (Type L up to 1 ⅜", Type K greater than 2 ⅝" OD).
3. Copper piping must be brazed using SILVERPHOS 15 (SP15) AWS A5.8 BCuP-5 or equivalent (15% Silver).
4. Stainless steel piping shall be welded. Use 40% silver solder to braze different metal types together.
5. Mechanical joints such as flare, swagelock, and compression fittings should be avoided where possible.

4.5.3. WATER AND PIPING MATERIAL

1. ACR copper tube, and Type K, L, and M shall be used unless otherwise specified. All joints shall be brazed or soldered.
2. Piping material other than copper may be used for water or water lines as specified and which meets the working duty requirements.

4.5.4. REFRIGERANT AND WATER PIPE SUPPORTS

Pipe supports should be designed to adequately bear the entire weight of the media and the pipe. The supports should be spaced at a reasonable distance to eliminate any refrigerant line sagging to minimize the potential of pooling refrigerant oil in any vapor line. Refrigerant vapor lines should be pitched a minimum of ½" per ten feet in the direction of refrigerant flow. Hydra-Zorb-style clamps or Klo-Shure insulation couplings are the recommended clamps to use. Elimination of pipe vibration is also a primary focus when supporting the piping. Inspection of the pipe after startup should be conducted under all loads to ensure there is no vibration present. Install additional pipe supports as needed to eliminate pipe vibration.

4.5.5. NITROGEN PURGING

Purging is required to eliminate oxidation formation within the refrigeration lines during brazing or welding. Oxidation and residue will eventually be swept clean from the pipe walls by the refrigerant and POE oil if nitrogen purging is not utilized. The refrigerant oil will become dirty and discolored from oxidation. This residue will also collect in the filters, TXV screens, and other components to the degree that loss of refrigeration is possible. It is extremely important to keep internal components and piping clean during installation.

4.5.6. ARGON PURGING

Stainless steel requires argon when purging a system in the case of open root welds. Performing socket welds or systems with backing rings do not require purging.

4.5.7. CO_2 PIPE SIZING AND DESIGN CRITERIA

Suction Lines

Suction line sizing is the most crucial of all the refrigeration system lines. The overall pressure drop in suction lines must be kept to a minimum, typically a 2°F maximum change in saturation temperature. An excessive pressure drop in the suction line will lead to poor system performance, higher energy costs, and possible system damage. Length of run, elbows, suction control valves, suction line filters, and accumulators all contribute to the overall pressure drop, which needs to be considered in the design of the suction line sizing. Suction lines must be sized based on the total equivalent length of run from the evaporator to the compressors, with minimal use of 90° elbows.

Refrigerant oil in medium- and low-temperature systems is more viscous, so extreme care must be taken in the overall design of the suction lines to assure oil return. Minimum velocities must be considered based on the minimum expected capacity for proper oil return. Horizontal suction lines should be sized to maintain approximately 700 fpm at minimum capacity to ensure proper oil return and pitched in the direction of flow.

All branch connections should always tie into the top of the main horizontal suction lines. This will eliminate the possibility of oil draining from the main suction line into the branch line during an off-cycle or shutdown of the branch circuit.

Vertical suction risers should be sized to maintain a velocity of 1,000 fpm at minimum capacity. Vertical suction risers will require a P trap at the base to facilitate oil return up the riser. Vertical risers greater than 20’ require an additional P trap every 20’.

Oil traps should be of minimum depth, and the horizontal section should be as short as possible to avoid excess oil accumulation. Oil traps can be of the preformed type or typically configured with long-radius 90° elbows with long-radius 90° street elbows. Oil traps should always have the same pipe size as the vertical line riser.

If large capacity reductions are expected within the system, double risers should be considered. Double risers should be sized so both lines equal the total cross-sectional area of a single, appropriately sized riser for the maximum load at design conditions.

Liquid Lines

Sizing liquid lines is not as dependent on velocity as vapor lines since the oils tend to mix and flow easily with liquid refrigerants. It is very important to ensure that a solid column of liquid is delivered to the expansion valve at all times with minimal pressure drop. If the liquid line pressure is allowed to drop below its saturation temperature, the liquid will begin to flash off into vapor. Vapor has a detrimental effect on system performance when delivered to the expansion valves. Use careful consideration when designing and sizing liquid lines. Sub-cooling the liquid a few degrees below the saturation temperature is recommended to avoid the possibility of flash gas at the expansion valve.

Velocities greater than 300 fpm should be avoided to lessen the chance of liquid hammer from the cycling of the liquid line solenoid when liquid line solenoids are used.

All liquid branch tee connections should be pulled from the bottom of the horizontal liquid lines or liquid loops to ensure a solid column of liquid is supplied to the expansion valve. Never pull liquid branch circuits from a vertical-rise liquid line.

Liquid velocities should always be kept under 360 fpm to avoid excessive noise and piping erosion.

CO_2 liquid for Subcritical or Transcritical systems is normally cooler than traditional HFC refrigerant systems, and it is important to properly insulate these lines to prevent condensation and heat absorption. Poor liquid line insulation can lead to poor system performance and reduced cooling capacity.

Discharge Lines

The discharge line should also be sized based on the maximum pressure drop. Although discharge lines are not as critical as other parts of the system, excessively high pressure drops will decrease compressor capacity.

It is common practice to drop 5 to 10 psi of pressure from the compressor to the condenser/gas cooler. Discharge lines should always be pitched in the direction of flow. Oil flows more freely with the high temperature of vapor in the discharge lines, so line sizing is less dependent on velocity. Vapor velocities should always be kept under 4,000 fpm to avoid excessive noise.

Oil traps must be installed at the base of all vertical risers to prevent excess oil accumulation. Traps must be the full line size of the all vertical risers greater than 6 feet.

Gas Cooler CO_2 Return Lines

For systems designed for Transcritical CO_2 operation, the gas cooler return lines, sometimes referred to as drop legs, should be sized similarly to liquid lines. The CO_2 leaving the gas cooler will not be a condensed liquid but will be a supercritical fluid during transcritical operation. The supercritical fluid is often thought of as a vapor. This high-pressure supercritical fluid is very dense and corresponds more closely to the density of CO_2 liquid than CO_2 vapor. Therefore, follow the same pipe sizing guidelines for a liquid. Sizing the gas cooler return lines similar to those of the discharge lines will result in excessive pipe erosion and premature failure of the piping.

Hot Gas Defrost Lines

Hot gas defrost supply (vapor) lines shall be sized with the same criteria as discharge lines. Hot gas defrost return (condensate) lines may be vapor, liquid, or a refrigerant mixture, depending on the particular time in the defrost cycle. Therefore, it is recommended to use the same criteria as discharge lines when sizing the condensate return line. The return line is significantly cooler than the supply line, so the vapor velocity will decrease in the return line, which may result in a smaller line size as compared to the supply line.

Liquid Recirculation Supply Lines

For systems equipped with pumped CO_2 liquid overfeed, the liquid recirculation supply lines should be generally sized with similar criteria as liquid lines. It is important to note that CO_2-pumped liquid is more tolerant of pressure drop as compared to normal liquid lines. The CO_2 pump adds mechanical subcooling to the CO_2 liquid and therefore allows a much greater pressure drop before the liquid will begin to flash. A system analysis is required to determine the maximum allowable pressure drop in the liquid recirculation supply and return lines. The sum of the pressure drop of recirculation lines, the pressure drop of all components, and the change in pressure due to an elevation change shall not exceed the rated performance of the pump pressure differential.

Liquid velocities should always be kept under 360 fpm to avoid excessive noise and piping erosion.

CO_2 liquid overfeed systems will contain liquid with temperatures often below 30°F, and it is important to properly insulate these lines to prevent condensation and heat absorption. A reduction in cooling capacity due to poor liquid line insulation can result in poor system performance.

Liquid Recirculation Return Lines

The liquid recirculation return lines will be a mixture of both liquid and vapor in systems equipped with pumped CO_2. The design of the liquid overfeed rate will determine the exact ratio. These lines are typically one pipe size larger than the liquid recirculation supply lines to accommodate the significantly higher volume of vapor compared to liquid. A system analysis is required to determine the maximum allowable pressure drop allowed in the liquid recirculation supply and return lines. The sum of the pressure drop of recirculation lines, the pressure drop of all components, and the change in pressure due to an elevation change shall not exceed the rated performance of the pump pressure differential.

It is critical to avoid oversizing the liquid recirculation return riser lines. A separation of liquid and vapor phases can occur if the velocity becomes too low and the pressure drop substantially increases due to liquid stacking up in the vertical riser line.

CO_2 liquid overfeed systems will contain liquid with temperatures often below 30°F, and it is important to properly insulate these lines to prevent condensation and heat absorption. Poor liquid line insulation can lead to poor system performance and reduced cooling capacity.

4.6. Chilled Water/Glycol Piping

All chilled water or chilled glycol piping should be adequately insulated to prevent condensation. The state change of the water from gas to liquid will result in a substantial heat load that becomes an additional burden for the refrigeration system if water is allowed to condense on the piping.

The importance of properly sized piping between the chiller and process cannot be overemphasized. Refer to the ASHRAE Handbook or other suitable design guide for proper pipe sizing. In general, run full-size piping out to the process and then reduce the pipe size to match the connections on the process equipment. One of the most common causes of unsatisfactory chiller performance is poorly designed piping. Avoid unnecessarily long lengths of hoses or quick-disconnect fittings that offer high resistance to water flow. Manifolds should be installed as close to the use point as possible when required for water distribution. Provide flow-balancing valves at each chilled water use point to assure adequate water distribution in the entire system. The nominal chilled water flow rate is usually based on a 10°F range across the evaporator. Reference the specific information and drawings provided with the chiller unit to see the exact design specifications for the chilled water flow rate and temperature range.

The minimum chilled water flow rate is 50% of the specified nominal flow rate, unless it is specified. This is required to prevent fouling and ensure the chiller stays within normal refrigerant operating conditions. Providing less or more than nominal flow may affect the evaporator performance and the chiller's overall rated cooling capacity.

Varying the flow of water through the evaporator is often practiced. The controls of the chiller can adjust to variations in the flow of water through the system and will load and unload compressor(s) as needed to maintain tight control of the supply water temperature of the system. If the water flow is varied, the minimum fluid loop volume must be in excess of 3 gallons of coolant per ton of cooling, and the flow rate must change at a rate no greater than 10% per minute in order to maintain an acceptable level of temperature control. This flow rate will buffer fluctuations, and the chiller will experience gradual rates of change in the inlet water temperature. A gradual rate of change in the inlet water temperature allows for accurate loading or unloading of the compressor(s). The accurate load and unload to the compressor(s) will provide consistent and stable return and supply temperatures.

4.7. Condenser/Gas Cooler Water Piping

The performance of a water-cooled condenser/gas cooler is dependent on maintaining the proper flow and temperature of water through the condenser/gas cooler heat exchanger. Insufficient water flow or a high condenser/gas cooler water supply temperature will reduce the unit's cooling capacity. Extreme conditions will eventually cause the unit to shut down due to high refrigerant pressure. Performance can also be affected if the condenser/gas cooler becomes blocked by contaminants in the condenser/gas cooler water stream. A water treatment program is highly recommended for the condenser/gas cooler cooling water to reduce maintenance costs and unit downtime.

⚠ **CAUTION!** THE USE OF UNTREATED OR IMPROPERLY TREATED CONDENSER/GAS COOLER WATER CAN RESULT IN SCALING, EROSION, ALGAE, OR SLIME BUILDUP. THIS CAN LEAD TO POOR SYSTEM PERFORMANCE OR PREMATURE FAILURE.

Refer to the unit's specific information and drawings to see the exact design specifications for the condenser/gas cooler water flow rate and temperature range. There will be a rise of approximately 10°F (5.5°C) through the condenser/gas cooler under normal operating conditions. The condenser/gas cooler water pump must be able to supply a pressure drop of at least that listed in the unit’s performance specification across the unit and at the required nominal condenser/gas cooler water flow rate to ensure proper water flow through the condenser/gas cooler.

The importance of properly sized piping between the unit and condenser/gas cooler water supply cannot be overemphasized. Refer to the ASHRAE Handbook or other suitable design guide for proper pipe sizing. In general, run full-size piping out to the unit and then reduce the pipe size to match the connections on the unit. Poorly designed piping is a common cause of unsatisfactory unit performance. Avoid unnecessarily long lengths of hoses or quick-disconnect fittings that offer high resistance to water flow. Manifolds should be installed as close to the use point as possible when they are required for water distribution. Provide flow-balancing valves at each unit to assure adequate water distribution in the entire system.

All condenser/gas cooler water piping should be adequately insulated to prevent condensation. The state change of the water from gas to liquid will result in a substantial heat load that becomes an additional burden for the unit if water is allowed to condense on the piping.

Minimum and maximum condenser/gas cooler water flow limits are generally 50% and 200% of the nominal flow rate and should not be exceeded. Flow rates greater than the maximum will cause excessive heat exchanger erosion and may lead to premature failure. Flow rates that are lower than the minimum will cause excessive fouling and reduced heat transfer.

SYSTEM INSTALLATION

4.8. Heat Reclaim Water Piping

CO_2 refrigeration systems can provide an abundance of hot water produced by transferring heat from the hot CO_2 discharge gas into the water. See the ASHRAE Handbook or other suitable design guides for proper pipe sizing. Water pipe sizing should be based on the specified design operating temperature, water flow, and available water pressure differential for the specific unit performance. In general, run full-size piping out to the unit and then reduce the pipe size to match the connections on the unit. Poorly designed piping is one of the most common causes of subpar unit performance. Avoid unnecessarily long lengths of hoses or quick-disconnect fittings that offer high resistance to water flow. When manifolds are required for water distribution, they should be installed as close to the use point as possible. Provide flow-balancing valves at each unit to assure adequate water distribution in the entire system.

All heat reclaim water piping should be adequately insulated to prevent loss of heat and the possibility of injury caused by burns. Hot water piping has the potential to reach temperatures as high as 160° to 180°.

⚠ **DANGER!** LOCATE THIS EQUIPMENT IN A WELL-VENTILATED AREA. INHALATION OF REFRIGERANT CAN BE HAZARDOUS TO YOUR HEALTH, AND THE ACCUMULATION OF REFRIGERANT WITHIN AN ENCLOSED SPACE CAN DISPLACE OXYGEN AND CAUSE SUFFOCATION.

4.9. Adiabatic and Evaporative Condenser/Gas Cooler Water Inlet

The adiabatic condenser/gas cooler is equipped with a modulating valve located at the water inlet. This valve will begin to open once the ambient air temperature exceeds the adiabatic setpoint. The water valve modulates to supply the condenser/gas cooler with an adequate volume of water and will supply enough makeup water to equal the water that is evaporated. The design water flow rate will be specified on the specification data sheets supplied with the condenser/gas cooler. The valve is controlled by the onboard controller located in the condenser/gas cooler electrical panel. An external water supply is required to be connected to the unit at the unit's inlet. The adiabatic condenser/gas cooler may have an integral pump and water sump, depending on the manufacturer and model. This pump recirculates water across the adiabatic pads.

4.10. Condenser/Gas Cooler Water Drain

The adiabatic condenser/gas cooler is equipped with a water drain solenoid valve. This valve will drain all water from the condenser/gas cooler based on the ambient temperature. The system must be drained once the ambient temperature drops to 40°F. Lowering the setpoint will cause the condenser/gas cooler to freeze and suffer severe damage. The water drain setpoint is controlled by the controller located in the condenser/gas cooler electrical control panel.

4.11. Water Pressure Gauges

It is highly recommended to install pressure gauges or taps (field-supplied) in the inlet and outlet of the water piping. The ability to read the pressure drop across the unit is important and will aid in preventative maintenance and troubleshooting unit performance.

4.12. System Fluid Freeze Protection

The water piping must be protected against freezing. Freeze protection is required for water piping exposed to ambient temperatures less than 40°F. It is recommended to ensure the water is mixed with the proper glycol percentage to protect against freezing at the coldest ambient temperatures expected. As an alternative, add heat trace to all external piping or ensure that all external piping is drained of water when the system is not in use.

5. SYSTEM START-UP

5.1. System Preparation

The success of a quality startup begins with leak testing and the evacuation of the system. Do not start any compressors until the appropriate steps have been executed. Check that the main power and control power are turned off at the main power distribution panel. Assure that all compressor breakers and compressor switches are indeed OFF in the unit system. A premature operation could result in serious damage to the compressor.

5.1.1. SYSTEM VERIFICATION

Verify system integrity prior to pressure testing and evacuation:

- The refrigeration unit shall be set and anchored securely in place.
- All refrigeration components specific to the system design requirements shall be installed, including evaporators, condenser/gas coolers, auxiliary heat exchangers, valves, and sensors.
- Field piping must be installed, properly supported, and all joints connected with approved methods.
- All isolation valves and ball valves should be opened to the system.
- If solenoids with manual opening stems are provided, the stem can be turned in to lift the solenoid disc off the valve seat. Energizing the solenoid circuits will also assist in leak testing and evacuation.
- The proper equipment required to perform pressure tests and evacuation must be in good repair and have undergone recent calibrations.

5.2. Pressure/Leak Test

The factory assembled unit is pressure tested in the factory prior to shipping but must be checked again in the field to ensure the system and any field-erected piping are tight and leak-free. After all the field refrigeration piping is complete, ensure that all isolation refrigeration valves are open, including solenoid valves. Nitrogen should be used to pressure-check the system. The system should be pressurized to not more than 90% of the low-side design pressure and left pressurized for a minimum of 24 hours to confirm the entire system piping is tight and leak-free. The system pressure should be checked in multiple places to confirm that the entire system pressure is equalized. A gauge shall be installed and marked with a red line to ensure accurate recording of pressure. Changes in ambient temperature will affect system pressure and must be considered. Any loss of pressure will need to be thoroughly investigated and the leak repaired or eliminated. It is extremely important to confirm the system is leak-free before the evacuation and charging processes commence. Be aware of your local codes, ASHRAE B31.5 requirements, and Green Chill Best in Class Guidelines.

⚠ **CAUTION!** THE PRESSURE PLACED ON THE UNIT DURING THE PRESSURE TEST SHALL NOT EXCEED GREATER THAN 90% OF THE LOW-SIDE DESIGN PRESSURE TO PREVENT ACCIDENTAL PRESSURE RELEASE THROUGH THE LOW-SIDE RELIEF VALVE.

5.3. Evacuation

The unit system must have passed the pressure/leak test prior to evacuation. When the system has been confirmed to be leak-free, the evacuation process can begin. Do not install liquid filter driers at this time. All compressor suction filters and replaceable oil filters have been factory installed prior to shipment. The unit should be blown down to atmosphere pressure after the leak test is passed.

Begin the evacuation process with a quality vacuum pump(s) containing fresh, clean oil. It is recommended to use copper tubing between the unit connections and the vacuum pump(s) over the typical manifold gauge hoses. Continue to monitor the level and quality of oil in the vacuum pump(s). Evacuate the system down to 1,500 microns, and break the vacuum with dry nitrogen. Refrigerant grade CO_2 may be used as an alternative to nitrogen. Repeat this process a second time, evacuating to 1,500 microns. Before beginning the third and final evacuation, install the liquid filter driers and evacuate the system to below 500 microns. Allow adequate time for the system to stand at 500 microns to verify that it is indeed tight and leak-free. Clean and dry refrigeration oil should be pumped into the unit system at this time. See the oil charging procedure. The system pressure may rise once oil is added, but it will continue to evacuate until the system pressure falls below 500 microns. The system should be isolated from the vacuum pump, and the pump should be turned off. The system pressure must not rise above 500 microns in 30 minutes. If a rise in pressure does occur, then moisture may still be present in the system, and continued evacuation is required. The system is ready to charge with CO_2 after it passes the vacuum decay test.

SYSTEM START-UP

⚠ **CAUTION!** EVACUATION IS PARTICULARLY CRITICAL IN CO_2 SYSTEMS BECAUSE IT DOES NOT TOLERATE WATER.

ITEMS TO TAKE INTO CONSIDERATION TO ENSURE A QUICK AND EFFECTIVE EVACUATION ARE:

- ENSURE THE REMOVAL OF SCHRADER VALVES PRIOR TO HOOKING UP IF YOU MUST USE A ¼" LINE.
- HAVE AS MANY LINES RUNNING TO THE UNIT AS POSSIBLE.
- ENSURE THE SYSTEM IS OPEN AND BEING PULLED DOWN ON ALL SIDES. BE AWARE OF THE VALVE DIRECTIONS.
- ALL BALL VALVE, SCHRADER VALVE, AND SERVICE VALVE CAPS ARE TIGHT.
- MAKE SURE ALL VALVES ARE BACKSEATED AND THAT THE RUBBER PACKING AND CAPS ARE TIGHT AFTER ALL LINES ARE HOOKED UP.
- ENERGIZE THE CO_2 COMPRESSORS CONTAINING OIL.
- ISOLATE TRANSDUCERS DURING EVACUATION. TRANSDUCERS NOT RATED FOR VACUUM CAN BE DAMAGED WHEN EXPOSED.

⚠ **CAUTION!** THE UNIT IS SHIPPED FROM THE FACTORY WITH A DRY VAPOR CHARGE OF NITROGEN AND IS EQUIPPED WITH A TAG SPECIFYING THE STATIC PRESSURE THAT WAS INSTALLED AT THE FACTORY. THE SYSTEM PRESSURE SHOULD BE CHECKED IN MULTIPLE PLACES TO CONFIRM THAT THE ENTIRE SYSTEM PRESSURE IS EQUALIZED AND IS EQUAL TO THE FACTORY PRESSURE APPLIED PRIOR TO SHIPMENT.

5.4. Charging CO_2

5.4.1. REFRIGERANT TYPE

Only one of these specified carbon dioxide refrigerant grades or better is required. The purity must be equal to or better than 99.99%, and the water content must be less than 10 ppm.

1. Instrument Grade
2. Coleman Grade
3. Refrigeration Grade

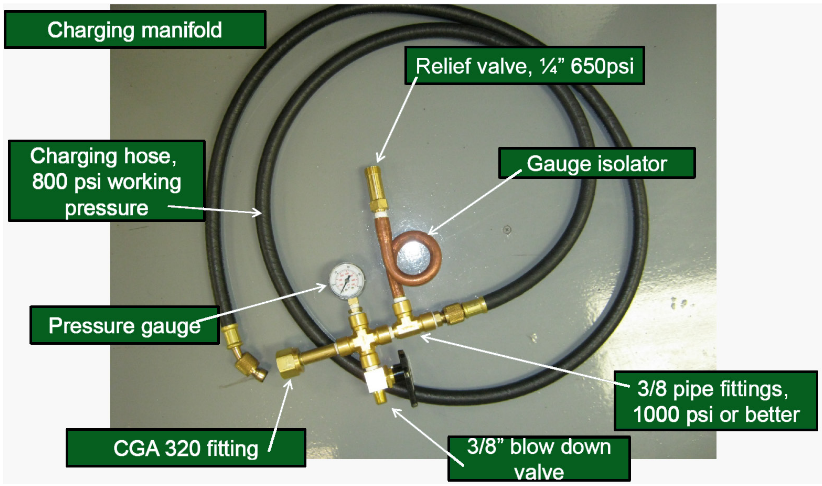
5.4.2. SAFETY AND EQUIPMENT

- A CO_2 charging manifold with a minimum charge of 2000 psig is required.
- Properly rated charging equipment is required for safety. If a charging manifold rated for at least 2000 psig is not available, then the following can be assembled: Using a gauge and a 650 psi relief valve, an assembly should be assembled as shown in the illustration. All hoses and fittings must be properly rated. In addition, the charging procedures must be carefully observed. CO_2 bottles, as received, will be pressurized to over 1000 psi. Because the bottle pressure is higher than the relief setting, the system charging valve must always be opened prior to the bottle valve and closed after the bottle valve. Perform a purge operation after connecting the bottle to the line.

SYSTEM START-UP

FIGURE 2: CO_2 Charging Equipment

Historical



Current

5.4.3. PROCEDURE

1. Charging CO_2 is different from normal HFCs in that the initial charge must be done with vapor until reaching a minimum pressure above 100 psi throughout the system. This is to ensure that the pressure is above the CO_2 triple point of 61 psig, where dry ice might plug lines. It is further recommended that a pressure of 200 psi be achieved if charging into steel pipes where thermal shock might be a problem. After the initial vapor charge, liquid can be used for the remaining fill.
2. Connect a bottle of CO_2 using the charge manifold
3. If the system is under vacuum, purge the hose by cracking the bottle vapor valve. After the system is above atmospheric pressure, purge by opening the charge port and bleeding through the manifold bleed-off valve.
4. CO_2 bottles are available with and without dip tubes. Bottles without dip tubes can be carefully laid over to charge the liquid.
5. With the charging valve open, slowly open the bottle valve while watching the manifold pressure gauge. Do not exceed the pressure relief setting. The pressure will rapidly drop as the bottle cools. When the bottle is finished, close the bottle valve first. This prevents increasing pressure in the charging hose as the bottle warms. Never leave a manifold connected with the charge valve shut off and the bottle open.
6. Open the hose bleed valve to depressurize the hose.

Note: The pressure will decrease until no more refrigerant can be charged into the system as the bottle cools. As much as 25% of the contents may remain.

Note: Never charge liquid CO_2 on suction side.

Note: The approximate amount of the CO_2 refrigerant charge is listed on the unit's documentation. Refer to the circuit schedule to obtain this information. To verify the actual system charge, run the system, check the liquid line sight glass, and verify proper superheating and sub-cooling.

Note: Using a regulated blanket heater or warm water bath to warm the cylinder will accelerate CO_2 charging.

⚠ **WARNING!** DO NOT USE AN OPEN FLAME TO WARM THE CYLINDER.

5.5. Charging Oil

5.5.1. OIL TYPE

- CO_2 systems require POE or PAG type oil as recommended by the compressor manufacturer.

⚠ **CAUTION!** ONLY NEW REFRIGERATION OIL CONTAINED WITHIN A SEALED AND CLOSED CONTAINER SHALL BE USED. POE AND PAG OILS ARE EXTREMELY HYGROSCOPIC AND WILL ABSORB WATER VAPOR QUICKLY. LIMIT THE LENGTH OF TIME THE OIL IS EXPOSED TO THE ATMOSPHERE.

5.5.2. OIL CHARGING NOTES

- OIL CHARGING IS EASIER IF COMPLETED BEFORE CHARGING WITH REFRIGERANT WHILE THE SYSTEM IS UNDER EVACUATION.
- AFTER REFRIGERANT CHARGE, CO_2 SYSTEMS ARE GENERALLY UNDER PRESSURES GREATER THAN 400 PSI. THERE ARE GENERALLY NO AVAILABLE OIL CHARGING PUMPS THAT CAN WITHSTAND THESE PRESSURES. ADDING OIL TO THE RESERVOIR AND/OR COMPRESSORS REQUIRES ISOLATING AND DEPRESSURIZING TO ABOUT 50 PSI. STANDARD REFRIGERANT OIL HAND PUMPS CAN THEN BE USED.
- THE INITIAL OIL CHARGE SHOULD FILL THE COMPRESSORS TO THE ½ SIGHT GLASS LEVEL AND A ½ TO ¾ RESERVOIR LEVEL. THE OIL LEVEL IN THE RESERVOIR WILL DROP AS OIL LINES AND FILTERS FILL, AND SOME OIL WILL BEGIN TO CIRCULATE IN THE SYSTEM. THE LEVEL SHOULD STABILIZE AS THE TEMPERATURE OF THE CONNECTED LOADS BECOMES STABLE.

NOTE: THE UNIT MAY HAVE SHIPPED FROM THE FACTORY WITH A CHARGE. IF THE UNIT HAS BEEN RUN-TESTED IN THE FACTORY PRIOR TO SHIPMENT, IT WILL BE EQUIPPED WITH THE INITIAL OIL CHARGE. UNITS WITHOUT OIL WILL BE TAGGED.

SYSTEM START-UP

5.6. PLANNING THE STARTUP

CO_2 refrigeration systems require a systematic and detailed startup plan to ensure successful system startup and commissioning. There are many different aspects of these systems that are different from those of a traditional HFC system. The control system has been developed and programmed to handle the increased level of control sequences necessary to safely and satisfactorily control the system to maintain the desired load temperatures. The compressors likely have VFD's on the lead compressor, and the many electronic regulating valves provide an increased level of system stability, but all require sophisticated Proportional-Integral-Derivative (PID) regulating control loops. It is very important to study the system design in detail ahead of startup to ensure a proper understanding of the system is developed by all startup personnel.

5.6.1. PRE-PLAN CHECKS

Check the sensors for proper installation and calibration before startup. Sensors should be installed and fastened in their correct locations. Check sensor calibration according to the manufacturer. Confirm the valves operate correctly and close before system startup.

5.6.2. SYSTEM OPERATING PRESSURES

⚠ **CAUTION!** A FULL STARTUP PROCEDURE SHOULD BE FOLLOWED BEFORE ADDING CO_2 TO THE SYSTEM.

CO_2 refrigeration systems operate at much higher pressures than traditional HFC refrigerants, and the saturated pressures associated with CO_2 can exceed the system design pressure if the system is allowed to be exposed to warm ambient temperatures when the system is not operating. It is important to know what the rated design operating pressures are for the CO_2 system, and to understand that saturated temperatures will create a system pressure greater than the design working pressure. For example, the suction side of a low-temperature system may likely be rated at 450 psig, and the system once charged with liquid CO_2 refrigerant will produce a saturated pressure of 450 psig at only 26.3°F ambient temperature. The suction side of a medium-temperature system and the liquid receiver may likely be rated at 650 psig. The system will produce a saturated pressure of 650 psig at only 51.3°F ambient temperature after being charged with liquid CO_2. The system cannot be shut down without exceeding the design pressure and relieving CO_2 through the relief valves unless special preparation is in place to keep the system pressures below their design limits after the system is charged with CO_2. Be prepared to keep the system running after it is started and ensure the necessary personnel are available to focus on startup and commissioning. Do not start the system on Friday afternoon with no site coverage for the weekend, and expect it to be operating Monday morning. In this scenario, it is highly likely that the system could fault, shut down, and then lose its entire charge of CO_2 refrigerant shortly thereafter.

5.6.3. SYSTEM STARTUP SEQUENCE

1. Ensure the system controller, the compressor VFD's, the high pressure expansion valve and flash gas controller for transcritical systems, case controllers, electronic valve drivers, and any other essential components of the main system are properly programmed and the parameter setpoints have been reviewed. Essential components include oil separator and accumulator drain solenoids, liquid and suction line stop valves, and other valves that must function to support the operation of the compressors, gas cooler, condenser/gas cooler, and evaporators.
2. Physically verify that all field-wired I/O signals are properly wired to the correct sensors and components, and they are reading and/or operating correctly by calibrating and documenting.
3. It is extremely important to check the functionality of all field-mounted EEV expansion valves at the evaporators. Ensure that each and every valve is individually driven open and fully closes when commanded to do so. Leaky expansion valves are a common source of system malfunction, so attention to detail is important.
4. Check the gas cooler or condenser/gas cooler controller setpoints, control sensors, fan operation if air is cooled, water wetting if adiabatic, and water-regulating control valve if the compressors are water-cooled. Ensure the gas cooler or condenser/gas cooler is responding to the proper analog control signals from the main system controller.
5. Start and commission the glycol and/or water pumps if the primary function of the CO_2 system is to produce chilled water or glycol. The same thing applies if the equipment contains a water-cooled condenser/gas cooler or gas cooler. Ensure that the design flow across the chiller and/or condenser/gas cooler is stable and correct per the equipment specifications.

SYSTEM START-UP

6. Plan to start up the medium-temperature suction group first. Have just enough medium-temperature load available that is greater than the minimum turn-down percentage of the medium-temperature suction group. Likely, 20–30% of the entire medium temperature load is necessary, but study the specific circuit schedule to determine what this exact value is. Before continuing and bringing more medium-temperature load on, make sure all medium-temperature loads are controlling superheat properly and the system operation is stable. If necessary, make control adjustments now when focus can be given to a smaller subset of loads and components. Allow adequate time to run each compressor to verify that the oil management system is working and that each compressor is capable of filling and controlling the crankcase oil level. It can take hours, if not days, on large systems to wet the system piping with oil, so it is not abnormal to have to charge the system reservoir with oil a couple of times during startup.If the temperature load being the cascade condenser/gas coolers, then it will be necessary to start up both the low temperature and medium temperature compressor groups simultaneously.

Note: Cascade systems require the primary refrigeration system to be prepared and available for operation before the low-pressure side of a CO_2 system is started. The primary refrigeration system loads should be operating and stable before the Cascade ssytem to reduce unpredictable system behavior.

7. It is likely that even with a small percentage of medium-temperature loads, the load created during pulldown is large enough to create demand for all compressors. Make sure to properly test all compressors manually before allowing them to run in automatic mode. It is best to allow the compressors to run near their designed saturated suction pressures. Make sure the evaporator controller MOP (maximum operation pressure) setpoint is properly adjusted to keep the suction pressure low and close to the design suction setpoint.
8. Match the percentage evaporator load with the appropriate compressor capacity during pulldown. Do not allow all evaporators to run with reduced compressor capacity. With reduced compressor capacity, the reduced mass flow will result in reduced refrigerant velocities when divided up between all evaporator piping. This can lead to oil logging, a lack of oil return, and increased oil charges. Monitor oil levels during the startup procedure.
9. Start the low-temperature loads after the medium-temperature suction group is running and all medium-temperature compressors have been tested. Have just enough low-temperature load available that is greater than the minimum turn-down percentage of the low-temperature suction group. Likely, 20–30% of the entire low-temperature load is necessary, but study the specific circuit schedule to determine what this exact value is. Before continuing and bringing more low-temperature load on, make sure all low-temperature loads are controlling superheat properly and the system operation is stable. Make necessary control adjustments now when focus can be given to a smaller subset of loads and components.
10. If the system is a cascade system with a mixture of medium-temperature loads being glycol or direct expansion and CO_2 cascade condenser/gas coolers, it is a good approach to have as much other medium-temperature load active before starting up the cascade condenser/gas coolers and low-temperature CO_2 compressors. This will provide greater stability to the system and prevent unpredictable system behavior.
11. Start and commission the desuperheater if the low-temperature compressors are equipped with a desuperheater. It is acceptable to initially manually override the desuperheater operation to create a stable operating environment for the medium-temperature suction group. The low-temperature compressors discharge into the medium-temperature compressor suction in a booster system. It is necessary to cool the low-temperature compressor discharge before entering the medium-temperature compressor suction if the system has a desuperheater. This prevents overloading and overheating the medium-temperature suction group.
12. Repeat steps 7 and 8 for the low-temperature compressor group and loads.
13. Review the operation of the gas cooler control during steps 5 through 9 if the system is a transcritical CO_2 system. Stable control of the gas cooler is critical for overall system stability. The gas cooler outlet temperature should maintain the setpoint of +/- 5°F. However, it is more important for the gas cooler outlet temperature to be stable and not cycling, even if this means the setpoint is not maintained perfectly. This allows the gas cooler control to respond slowly rather than rapidly chasing a setpoint.
14. After the compressor groups and all loads have been started and properly commissioned, it is now acceptable to enable the operation of any other auxiliary control functions, including but not limited to heat reclaim, mechanical subcooling, gas cooler bypass, hot gas bypass, and liquid injection. It is acceptable to enable this control earlier in the sequence if the system is not able to run without support from one of these axiliary control functions. For example, it is likely to have high return gas temperatures, resulting in high compressor discharge temperature faults during pulldown. It is then necessary to enable liquid injections to cool the compressor return gas.

6. DESCRIPTION OF SYSTEM

6.1. Background

The cooling system consists of a CO_2-based refrigeration system and may contain one or more compressors, a condenser/gas cooler or gas cooler, an evaporator(s), a receiver or flash tank, heat exchangers, suction accumulators, control valves, sensors, piping, and an electrical control system. The exact design of the refrigeration system is dependent on the application, geographic area, and intended use of the system. Refer to the system documentation supplied with the refrigeration system to see the exact system details. The refrigeration may be self-contained or may require field piping installation to connect a condenser/gas cooler and evaporators to the compressor skid.

6.2. Coolant Circuit

If equipped, a coolant pump circulates coolant through the process piping and then back to the chiller. The coolant will pass through a y-strainer (if equipped), which filters the process fluid before entering the evaporator upon entering the chiller. The coolant then passes by a flow switch before entering the evaporator. Heat is transferred from the coolant to the refrigerant in the evaporator. Varying the amount of heat transferred in the evaporator determines the loading of the compressor, which maintains the temperature set point of the coolant delivered to the process.

After leaving the evaporator, the coolant passes by the chilled water supply temperature sensor. The temperature sensor senses the temperature of the coolant being delivered to the process and communicates this temperature to the controller. This temperature sensor also functions as a freezestat. This supply sensor is the control sensor for the control system.

6.3. Refrigerant Circuit

The heat transferred in the evaporator from the coolant to the refrigerant changes the state of the refrigerant from a liquid to a gas. This refrigerant gas then moves from the evaporator to the compressor.

The compressor is the heart of the refrigeration circuit. Cool, low-pressure gas enters the compressor, while hot, high-pressure gas exits. Some extra heat is added to the refrigerant as it is being compressed due to the compressor(s) not being 100% efficient.

The hot, high-pressure gas that exits the compressor is delivered to the gas cooler, condenser, or cascade condenser/gas cooler. In air-cooled gas coolers/condensers, heat is transferred from the refrigerant to the ambient air that is flowing across the finned tubes. In water-cooled condenser/gas cooler units, the heat is transferred from the refrigerant flow through the plates to the water that is flowing through the parallel plates. In a cascade system, the heat is transferred from the CO_2 refrigerant flow through the plates to the high-side refrigerant that is flowing through the parallel plates. As the heat is transferred, the refrigerant changes from a gas to a liquid. The condenser/gas cooler has been sized to remove the heat from the process load and the heat that was added by the compressor.

The transcritical CO_2 refrigeration process starts at the outlet of the condenser/gas cooler. The liquid refrigerant then passes the high-pressure expansion valve of a transcritical system through the flash tank, filter drier, then sight glass. The flash tank maintains a controlled pressure and acts to store excess refrigerant in the system when it is not required for operation. The flash gas in the flash tank passes through the flash gas bypass valve to the medium-temperature compressors. The filter drier filters out any particles and/or moisture from the refrigerant. The sight glass is used to monitor the stream of liquid refrigerant. The liquid refrigerant then passes through the electronic expansion valve, which meters the flow into the evaporator, and the process restarts.

Sub-critical systems, including cascade systems, condense the CO_2 and do not require a high-pressure expansion valve or flash gas bypass valve and use a traditional receiver.

6.4. Oil Circuit

The compressor uses oil to lubricate the compressor's internal components. A small amount of oil leaves each compressor with the discharge gas and is separated from the CO_2 refrigerant by the oil separator. The excess system oil is stored in the oil reservoir, where it is returned to the compressors as required. Each compressor monitors its own oil level and transfers oil to the compressor as needed using the oil level controller attached to the compressor. See Transcritical CO_2 Oil Management System FAQs in the appendix for more information.

7. SEQUENCE OF OPERATION

7.1. Control System

This installation and operation manual does not include information for the control system. There are several different control systems that may be supplied with your refrigeration system, and while they have similar control features, there are many differences as well. If special control sequences of operations were created for the refrigeration system beyond the standard control sequences of the controller, then a separate document will be included in the documentation provided with the unit.

7.2. Startup Sequence

The system will start if there are no critical faults present and there is load demand present when the unit is enabled. The condenser/gas cooler fans will start once the unit is started, and a compressor will start and run at its minimum speed until the demand capacity increases. The compressor VFD will then modulate the compressor speed, and additional compressors will cycle on and off as necessary to maintain the target set point. The lead compressor will always be the first compressor on and the last compressor off. When the load drops below the minimum capacity of the unit, the lead compressor will unload to its minimum speed and will maintain it until the control point drops to the set point minus a cut-out dead band (otherwise known as the pumpdown value).

Note: The compressor(s) will not start until the suction pressure or chilled water temperature rises above the setpoint, depending on the specific purpose of the unit and its control loop process value. This will normally be suction pressure, unless the unit is designed to be a chiller.

7.3. Shutdown Sequence

If a critical fault occurs or the E-stop button is depressed, the unit will shut down immediately without a controlled shutdown procedure while it is running. If the unit is either locally or remotely disabled, the compressor will reduce its speed to the minimum speed via a controlled rampdown and then shut off.

7.3.1. CRITICAL FAULT

When a critical fault occurs, the compressor(s) will shut down immediately. The remote alarm contacts will be activated any time a fault occurs and should be monitored so necessary steps can be taken.

7.3.2. REMOTE ALARM CONTACTS

The remote alarm contacts will be activated any time a fault occurs that results in the unit shutting down. If the fault can reset itself, the unit will automatically restart once the conditions causing the fault have been cleared. After the fault resets, the remote alarm contacts will switch back to their default positions. The fault can be reset at the Human-Machine Interface (HMI) if it requires a manual reset.

7.4. Off Cycle Control

7.4.1. OFF-CYCLE PRESSURE CONTROL

When the refrigeration system has main power connected, the unit is idle (no heat load), and all control devices are enabled, the compressor(s) will cycle to maintain the suction pressure setpoint. When the suction pressure rises, the compressor will start and begin its normal startup sequence and will run until the suction pressure set point is reached.

For transcritical systems, when there is no system load, the high-pressure expansion valve and flash gas bypass valve are still active and will regulate to maintain their respected set points. The flash gas bypass will transfer ambient load to the compressors and maintain system static pressure to acceptable levels. This feature prevents excessive CO_2 pressure from developing and reduces the possibility that a CO_2 release will occur.

SEQUENCE OF OPERATION

7.5. Compressor Control

The refrigeration system is usually equipped with multiple reciprocating or scroll compressors. Each suction group's lead compressors have variable capacity control, either through VFDs or digital unloaders. Each VFD is controlled by the system controller. A PID algorithm is utilized to determine the appropriate compressor speed and number of compressors running necessary to maintain the suction or chilled water set point. The compressor will run at minimum speed until the process variable falls to the setpoint minus the cutout dead band under low load conditions. The compressor will not start until the process variable rises to the set point. When the compressor starts, it will run at the minimum speed until the load increases. The lead compressor will ramp up or down, and other compressors will start or stop based on the demand generated from the PID control loop.

The unit may be equipped with multiple compressors, and all compressors are allowed to run if the required cooling capacity is necessary to satisfy the current heat load. If there are two separate compressor groups intended to control two different suction pressure setpoints, the medium temperature compressors work to control the medium temperature suction pressure at a setpoint, and the low temperature compressors work to control the low temperature suction pressure at a setpoint. The two compressor groups operate independently of each other from a PID control standpoint but are very much affected by the operation of the other compressor group. Whether it's a booster system, where low-temperature compressors discharge into the suction of medium-temperature compressors, or a cascade system, the operation of each compressor group directly influences the other. The low-temperature group cannot run without the medium-temperature group running. The low-temperature group usually places a large cooling load on the medium-temperature group, so when no low-temperature compressors are running, it is common to see the medium-temperature group running at a lower capacity.

7.6. Air Cooled Gas Cooler/Condenser Control

See the operation and maintenance manual (shipped with the component) specific to the gas cooler or condenser/gas cooler for a detailed description of their operation and maintenance. The air-cooled gas cooler may be a dry cooler or an adiabatic cooler. The dry gas cooler operates without evaporative cooling, while the adiabatic gas cooler utilizes evaporative cooling to achieve lower gas cooler outlet temperatures.

7.6.1. DRY OPERATION

The unit runs as a dry cooler to save water and energy when the ambient air is cool and below the water assist setpoint. The ambient air condenses the refrigerant in the coils, which is then returned to the system. Air is moved over the coil using multiple variable-speed axial fans. The fans modulate together to maintain a condenser/gas cooler TD setpoint in both transcritical and subcritical operations. The speed of the fans will modulate the air flow rate necessary to maintain the condenser/gas cooler TD and is determined via a PID algorithm. The condenser/gas cooler TD is defined as the difference between the gas cooler outlet temperature and the ambient air temperature. The TD control will float the condenser/gas cooler pressure down as the ambient temperature decreases until a minimum condenser/gas cooler pressure is reached. At this minimum pressure, the TD control is abandoned, and a fixed condenser/gas cooler pressure control begins. TD control will resume only when the pressure increases above the minimum condenser/gas cooler pressure plus a dead band. The main controller determines the speed of the condenser/gas cooler fans.

7.6.2. WET OPERATION (ADIABATIC GAS COOLER)

Water is evenly sprayed over the highly efficient cooling pads when the ambient air rises to the wet operation temperature setpoint. The air is humidified as it passes through the media, cooling down to 5-10°F above the wet-bulb temperature. Such a substantial depression of the dry bulb temperature results in a major increase in dry cooling capacity. The wet operation temperature setpoint is controlled by the gas cooler controller.

The cooled air passes over the coil and condenses the refrigerant in the coil, which is then returned to the system. Excess water that is not evaporated drains out of the condenser/gas cooler.

SEQUENCE OF OPERATION

7.7. Water Cooled Condenser/gas cooler Control

The water-cooled condenser/gas cooler is equipped with a modulating water-regulating valve. This valve regulates the flow of condenser/gas cooler cooling water to maintain the temperature of the condenser/gas cooler at a fixed condensing pressure set point. The CO_2 condensing pressure will be directly controlled by the amount of condenser/gas cooler cooling supplied to the condenser/gas cooler. The position of the regulating valve will match the necessary volume flow rate to maintain the condensing temperature and is determined via a PID algorithm. It is expected that the supply condenser/gas cooler temperature remains within the specified operation range of the equipment, and the condenser/gas cooler flow rate will vary based on the necessary cooling. The building condenser/gas cooler water loop must be capable of supplying water to the condenser/gas cooler at the design flow rate. The condenser/gas cooler water supply temperature for the condenser/gas cooler must maintain the nominal design supply in order to provide the required cooling capacity. This includes the combined required flow rate for both the condenser/gas cooler and the desuperheater, if equipped. The system will shut down at high pressure, which may result in the opening of a high-pressure relief valve if the flow rate falls too low or the supply temperature rises too high. Excessive water flow through the condenser/gas cooler can cause excessive pressure drop and premature heat exchanger failure due to accelerated erosion. Inlet and outlet condenser/gas cooler water temperature sensors are provided and will be displayed on the HMI for monitoring. The condenser/gas cooler is also supplied with a flow switch, water strainer, and shutoff service valves on the water side. The flow switch will indicate a loss of flow, and the entire unit will shut off immediately if the condenser/gas cooler water flow rate supplied to the condenser/gas cooler drops too low.

Note: A water maintenance program should be employed to preserve the quality of condenser/gas cooler water. Excessive condenser/gas cooler fouling caused by poor condenser/gas cooler water quality will cause poor unit performance and/or unit failure.

7.8. Cascade Condenser/gas cooler Control

The cascade condenser/gas cooler will be controlled by an electronic expansion valve (EEV). The set point of this EEV is to be determined by the superheat of the HFC side of the cascade condenser/gas cooler. A normally closed solenoid is installed upstream of the EEV as a failsafe in the event of power failure to prevent the flow of refrigerant. The outlet temperature of the condensed CO_2 is monitored. This will ensure that the superheat control has the correct setpoint. A thermosyphon is used to induce flow on the CO_2 side of the cascade condenser/gas coolers. See the section on thermosyphon for further information.

The entire cascade condenser/gas cooler cycle is dependent on the thermosyphon principle. Component placement and layout have been designed specifically to ensure that an adequate pressure differential is achieved to make the thermosyphon operate. Engaging the cascade condenser/gas cooler causes this process to run continuously.

7.9. Direct Expansion Evaporator Control - Low Temperature

The medium- and low-temperature evaporators are equipped with evaporators suitable for either coolers or freezers. The amount of refrigerant flow through the evaporator is measured by the Electronic Expansion Valve (EEV) and depends on the superheat exiting the evaporator. The evaporator controller monitors the superheat and modulates the EEV as necessary to control the superheat set point. An alternate control method is the EEV will use the process temperature. If the EEV drops to a certain level, the EEV will close. If the CO_2 system faults and shuts down, the CO_2 system controller will instruct the evaporator controls to disable the EEV's immediately, thus preventing liquid refrigerant from flooding back. The staging of the evaporator circuits allows the evaporator cooling capacity to match the cooling capacity required by the loads.

Evaporator EEVs also have a MOP (maximum operating pressure) setpoint, which prevents operation at unacceptable suction pressures. If the suction pressure rises past the MOP setpoint, the EEV will be closed to limit the suction pressure. A compressor motor can overload if allowed to operate at high pressure. These setpoints can be adjusted via the evaporator controller.

The air flows across the evaporator, and all defrost control is normally provided by the evaporator controller. The medium temperature defrost control is usually off-cycle, so the evaporator fans remain running at all times, even when the evaporator is defrosting.

7.9.1. DIRECT EXPANSION TEMPERATURE CONTROL

The temperature in the cooler(s) and freezer(s) is normally controlled by the evaporator controller but may also be controlled within the main system controller by turning on the evaporator EEV valves while air is moving across the evaporator coils. The EEV valves are cycled off to stop further cooling after the space temperature reaches the setpoint. Closing the EEVs will cause the compressors to cycle off.

7.10. Evaporator Pressure Regulator (EPR)

The medium and/or low-temperature direct expansion evaporators may be supplied with an EPR (Evaporator Pressure regulator). An evaporator pressure regulator (EPR) is installed on the CO_2 system to control and regulate the evaporator pressure above the design Saturation Suction Temperature (SST) for the compressors for certain evaporator loads. The regulation of the EPR valve is controlled by the PID algorithm of the evaporator controller or by the main system controller.

7.11. Chilled Water Evaporator Control

The chiller is equipped with evaporator(s) that are constructed of stainless steel plates and copper brazing. The refrigerant passes between every other set of plates, while the chilled water flows on the other side of the plates in the opposite direction. The amount of refrigerant flow through the evaporators is measured by the Electronic Expansion Valves (EEV) and depends on the superheat exiting the evaporator. The evaporator controller monitors the superheat and modulates the EEV as necessary to control the superheat set point.

Each evaporator is equipped with a flow switch. If an evaporator flow switch senses a lack or loss of chilled water flow, the evaporator will be disabled by closing the EEV, and the compressor(s) will shut off if all evaporators experience a loss of flow.

Note: A water maintenance program should be employed to preserve the quality of chilled water. Excessive evaporator fouling caused by poor chilled water quality will cause poor chiller performance and/or chiller failure.

7.12. Desuperheater Control

The desuperheater is equipped with a modulating water-regulating valve if it is water-cooled and 3-way modulating/stepper valve if it is air-cooled. This valve and/or fan(s) regulate the flow of desuperheater cooling media to maintain the temperature of the CO_2 gas leaving the low-temperature compressors at a design temperature setpoint. The leaving CO_2 gas temperature will be directly controlled by the amount of desuperheater water or air supplied to the desuperheater. The position of the water regulating valve or speed of the fan(s) will match the necessary volume of water or air necessary to maintain the leaving CO_2 gas temperature and is determined via a PID algorithm. For a cascade system, the desuperheater helps reduce the inlet temperature to the cascade condenser/gas coolers, which prolongs the life expectancy by removing unnecessary stress and fatigue. In Booster Transcritical systems, the desuperheater reduces the suction gas temperature of the medium-temperature compressors and helps to keep the discharge temperature within safe operating limits.

7.12.1. AIR COOLED DESUPERHEATER

The desuperheater's air supply temperature must maintain the nominal design supply temperature. If the flow rate falls too low or the supply temperature rises too high, the system will shut down at a high CO_2 gas temperature. Inlet and desuperheater air temperature sensors are provided and will display on the HMI for monitoring.

If the ambient air temperature drops too low and the CO_2 desuperheater outlet temperature drops below the minimum setpoint, the fan speed will reduce to 0 RPM, and a 3-way bypass valve (if equipped) will bypass the desuperheater to prevent the CO_2 vapor from becoming too cold and possibly condensing.

7.12.2. WATER COOLED DESUPERHEATER

It is expected that the supply desuperheater water temperature remains within specified supply temperature limits and that the desuperheater water flow rate will vary based on the necessary cooling. The building condenser/gas cooler water loop must be capable of supplying water to the condenser/gas cooler and desuperheater at the specified design flow rate. This includes the combined required flow rate for both the condenser/gas cooler and the desuperheater. The desuperheater's water supply temperature must maintain the nominal design supply temperature. If the flow rate falls too low or the supply temperature rises too high, the system will shut down at a high CO_2 gas temperature. Inlet and outlet desuperheater water temperature sensors are provided and will display on the HMI for monitoring. The desuperheater is supplied with a flow switch and shutoff service valves on the water side. If the water flow rate supplied to the desuperheater drops too low, the flow switch will indicate a loss of flow and an alarm message will be displayed, but the unit will remain running.

The water temperature leaving the desuperheater is not controlled, and the temperature difference across the desuperheater may be as large as 60 to 80°F. The desuperheater's water flow volume is smaller than that of the condenser/gas cooler, which means that even if the desuperheater's outlet water temperature is high, it will mix with the condenser/gas cooler's water temperature, resulting in a combined leaving water temperature that is typically 65°F or lower. The unit will run at minimum capacity, and the water-regulating valve may reach its minimum close position during very low cooling loads.

7.13. CO_2 Pumps - Liquid Overfeed

The CO_2 pumps are designed to pump the liquid CO_2 to both the direct expansion evaporators and the liquid overfeed evaporators, unless otherwise specified. The design intent is that 100% of the liquid in both low- and medium-temperature suction groups will be pumped. The pump provides mechanical subcooling to the liquid CO_2. This type of system is referred to as a liquid overfeed system. Pressure transducers are installed at the inlet and outlet of each pump to measure the differential pressure across the pump. This differential pressure is used in the pump control algorithm to control the state of the pump. This is also capable of triggering alarms. The liquid CO_2 piping also features the use of a CO_2 flow switch. This will allow detection of a flow state and serve as a safety check to make sure flow is present when the pump is running.

8. SYSTEM CHARGE SAVER

8.1. Overview

- CO_2 refrigeration systems pose unique challenges that are not typically encountered in systems utilizing traditional refrigerants. Refrigerant loss (through relief) can be a more common occurrence in situations where you wouldn't normally see a loss with traditional refrigerant due to the higher operating pressures associated with CO_2 systems and lower system design pressures.
- Some of these scenarios include
    - Power loss
    - Rack emergency shutdown (certain scenarios)
    - Rack controlled shutdown (maintain charge when off).

The "Charge Saver" auxiliary condensing unit is a great addition to a CO_2 refrigeration system, helping to combat an unwanted partial or complete loss of CO_2. It can be applied to subcritical (DX, cascade, and Pumped Overfeed) and transcritical CO_2 refrigeration systems when the design pressure of components is less than the associated saturated pressure of CO_2 at peak ambient conditions. The Charge Saver may not provide complete protection, but it will cover the majority of situations where there is a high risk of complete CO_2 loss.

The Charge Saver condensing unit provides cooling directly to the receiver during times when the refrigeration system is not able to run. In simple terms, it moves the lowest pressure point of the refrigeration system to the receiver, where the CO_2 charge can now migrate to the receiver vessel. The receiver can hold a large volume of refrigerant, and the pressure can be maintained below the maximum design pressure of the receiver, thus preventing the relief valve from relieving due to excessive pressure.

Pressure, like temperature, will move from a higher-pressure area to a lower-pressure area in an effort to equalize. This property is what allows the CO_2 to move through the system, eventually ending up at the receiver. The lowest temperature and lowest pressure point of the system will be the receiver, and this is due to the Charge Saver.

The charge saver works by installing a small auxiliary heat exchanger above the receiver, which is connected to a small, low-capacity condensing unit using any number of refrigerants. The condensing unit cools the evaporator heat exchanger, which drives the thermosyphon cooling effect on the CO_2. The charge saver requires auxiliary power such as a generator or an uninterruptible power supply batteries.

See section 13.5 on page 57 in the appendix of this manual for more information.

9. INITIAL STARTUP

9.1. Overview

The equipment is functionally tested at the factory prior to shipment, but it is not fully run-tested. Therefore, not all components have been fully tested in a real operational state. Proper startup and validation of all components are necessary for proper operation. The majority of units are factory-set to operate in accordance with the standard operating specifications for that particular equipment. Confirm programs are loaded in all controllers. Because of the variables involved with different applications and installations, minor adjustments may be required during the initial start-up to ensure proper operation.

The following start-up procedure should only be performed by a qualified, experienced refrigeration technician and must be followed in sequence. If trouble is encountered in putting a system in operation, the fault can usually be traced to one of the control or safety devices.

This outline can be used as a checklist for the initial start-up and for subsequent start-ups if the system is taken out of service for a prolonged period of time:

1. Ensure that the main power source is properly connected, matches the voltage shown on the unit's nameplate, and is within the voltage utilization range.
2. Check the compressor's oil level. The level should be visible in the sight glass or indicated by the electronic oil level control.

Note: The main power must be on for 24 hours prior to starting the compressor to allow the crankcase heater to sufficiently vaporize any liquid refrigerant that may be present in the compressor.

3. Check to make sure that all of the water and/or glycol field piping connections are complete. Perform a proper pressure test, cleaning, and flush of this piping.
4. If equipped, check that all waterside strainer(s) are clean and free of debris.
5. If the equipment has an adiabatic gas cooler, a water-cooled condenser/gas cooler, or a chiller, fill the water system(s) with the proper water solution.
6. Check the condenser/gas cooler to ensure the coil surface is clean and free of debris.
7. Check the refrigerant lines to make sure all connections are secure and ensure a proper pressure test and evacuation have been completed on the unit and any field-installed refrigeration piping.
8. Charge the unit with refrigerant.
9. Verify that all refrigerant valves are open.

⚠ **CAUTION!** DO NOT OPERATE THE UNIT WITH THE COMPRESSOR OR LIQUID LINE SERVICE VALVES "CLOSED". FAILURE TO HAVE THESE "OPEN" MAY CAUSE SERIOUS COMPRESSOR DAMAGE.

10. Turn on the control power if the control power has been isolated. The panel displays should now be illuminated.
11. Make sure the set points are appropriate for the operating conditions of the unit.
12. Establish flow through the evaporator if it is a chiller.

Note: The compressors will not start as long as the evaporator flow switch is open. A positive flow must be established through the evaporator before the compressor(s) can operate.

13. If equipped, set water flow through the Evaporator and Condenser/gas cooler as indicated in the unit specifications. If a flow meter is not available and when the unit is ready to run fully loaded, balance the flow until a 10°F drop is established or according to the design temperature range. A significant increase in flow beyond the recommended rate may damage the evaporator or condenser/gas cooler and create excessive pressure drops that affect the system's overall efficiency.

14. Start the system. A compressor will not start until its cycle time has expired, its evaporator electronic expansion valve(s) are open, and its safeties are met. Additional compressor(s) will load accordingly if the demand requires additional loading after the compressor starts. See "Planning the Startup" on page 23 to help aid in developing a detailed startup plan.

⚠ **DANGER!** UNDER NO CIRCUMSTANCES SHOULD THE HIGH REFRIGERANT PRESSURE SWITCH BE DEACTIVATED. FAILURE TO HEED THIS WARNING CAN CAUSE SERIOUS COMPRESSOR DAMAGE, SEVERE PERSONAL INJURY, OR DEATH.

15. The control of the unit capacity is determined by either the suction pressure or, in the case of a chiller, the temperature of the chilled water supply. Adjust to the desired operating pressure and temperature. Resetting the pressure and temperature will change the operating conditions of the unit.
16. Operate the system for approximately 30 minutes. Check the liquid line sight glasses. The refrigerant flow past the sight glasses should be clear. Bubbles in the refrigerant indicate either a low refrigerant charge or an excessive pressure drop in the liquid line. A shortage of refrigerant is indicated if operating pressures are low and subcooling is low. Flash gas will be produced if the receiver/flash tank pressure varies. The evaporator(s) superheat should be approximately 10°F (5.5°C). If the refrigerant pressure, sight glass, superheat, and subcooling readings indicate a refrigerant shortage, gas-charge refrigerant into the unit, as required. With the unit running, add refrigerant vapor by connecting the charging line to the suction service valve and slowly charging through the backseat port until operating conditions become normal.

⚠ **CAUTION!** A CLEAR SIGHT GLASS ALONE DOES NOT MEAN THAT THE SYSTEM IS PROPERLY CHARGED. ALSO CHECK THE SYSTEM'S SUPERHEAT, SUBCOOLING, AND UNIT OPERATING PRESSURES. IF BOTH SUCTION AND DISCHARGE PRESSURES ARE LOW, BUT SUBCOOLING IS NORMAL, THERE IS A PROBLEM OTHER THAN A REFRIGERANT SHORTAGE. AVOID ADDING REFRIGERANT, AS THIS MAY CAUSE THE CIRCUIT TO OVERCHARGE.

17. The equipment is now ready for regular service operation.

9.2. Service Procedure

Before servicing the system, follow the procedure listed in this section to pumpdown the receiver/flash tank to service the system in standstill mode.

1. Close the flash tank outlet valve.
2. Pumpdown the evaporators by pumping down the cycle from the compressors. Isolate any high pressure connection points such as hot gas injection.
3. Turn off compressor switches.

Note: Some systems will not have a 3-way valve installed or supplied.

4. Set the flash gas relief valve to service mode using the switching ports on the 3-way valve. The 45-bar relief valves should be in use during standard operation. The system's low-pressure relief valves should be in operation during shutdown.
5. Isolate the oil reservoir vent line to the receiver/flash tank.

Note: A system's low-pressure relief valve can still be used for flash tank protection during shutdown without pumping down the liquid lines. The liquid line pressure needs to be monitored and vented should it rise to the system's design pressure.

Note: Reverse steps 1 through 5 in this section to return the system to service.

10. PREVENTATIVE MAINTENANCE

10.1. Overview

The following maintenance procedures are recommended and should be adhered to as closely as possible after your refrigeration equipment has been placed into service. Specific sight conditions may require certain tasks to be repeated more or less frequently. The importance of a properly established preventative maintenance program cannot be overemphasized. Taking the time to follow these simple procedures will result in substantially reduced downtime, lower repair costs, and a longer useful life for the equipment. Any monetary costs of implementing these procedures will usually more than pay for themselves.

To make this as simple as possible, a checklist should be prepared that lists the recommended service operations and the times at which they are to be performed. You will find a checklist for this purpose at the end of this manual, but please note that it serves only as a guide. A detailed checklist should be prepared for your specific unit. Take note of the locations designated for voltage readings, amperages, and so on, to ensure continuous monitoring. With this information, maintenance personnel may be able to correct a potential problem before it causes any downtime. For best results, these readings should be taken with a full heat load from the process, or preferably with similar operating conditions each time. The following is a list of suggested periodic maintenance.

10.1.1. ONCE A WEEK

1. Check to make sure that the suction pressure or chilled water supply is maintained reasonably close to the setpoint. If the pressure stays more than 10 psi or if the temperature (applicable to a chiller) stays more than 2°F away from the set point, there may be a problem with the unit. If this is the case, refer to the Troubleshooting Chart or contact our Customer Service Department.
2. Check the temperature and pressure of the suction and discharge refrigerant at every compressor, inlet, and outlet.
3. Check the system superheat and subcooling. Normal evaporator superheat is approximately 10°F (5.5°C) and should not exceed 40°F (22.2°C). Normal superheat at the compressors is 20-30°F (11°C to 17°C). Normal subcooling ranges from 3°F (1.6°C) to 20°F (11°C). A low temperature system's compressor superheat ranges from 20-60°F (11-33°C).
4. Check the receiver's pressure. The pressure is controlled at a constant pressure and should not vary any greater than 50 psi.
5. Check the air temperatures at the evaporators' inlet and outlet.
6. Check the inlet and outlet temperatures of the evaporator water at the evaporator chiller.
7. Check the refrigerant sight glass for vapor bubbles or moisture indications. Bubbles in the refrigerant indicate either a low refrigerant charge or an excessive pressure drop in the liquid line. If the sight glass indicates that there is a refrigeration problem, have the unit serviced as soon as possible.
8. Check the level of oil in the reservoir. The oil level should be higher than the lower sight glass. The system size and oil movement may cause oil to be visible in the top sight glass.
9. Check the oil level at each compressor. The compressor is equipped with an electronic oil level control and a compressor oil sight glass. The sight glass should show oil from ⅛ to ½ full.
10. Inspect steel components for corrosion.

10.1.2. ONCE A MONTH

1. Repeat items 1 through 8 in "Once a Week" and continue with the following:
2. Shut off the power disconnect. Check the condition of electrical connections at all contactors, starters, and controls. Check for loose or frayed wires.
3. Make sure the incoming voltage is within 10% of the unit's design voltage.
4. Check the amp draws to each leg of the compressor(s) to confirm that they are drawing the proper current.
5. Check the pressure drop across the oil separator. If the pressure drop reaches 12 psid continuously, the filter element must be changed.
6. Check the operation of the compressor crankcase heaters. The heater should be energized when the compressor is off. Taking an amp reading of the heater leads is the best way to determine the correct operation. Localized heat around the crankcase heater can also be felt when the heater is on.

7. If equipped, check the operation of the oil reservoir heater. The heater should be energized when the oil temperature is below the temperature setting and when the compressor is off. Taking an amp reading of the heater leads is the best way to determine the correct operation. Localized heat around the oil reservoir heater can also be felt when the heater is on.
8. Adiabatic Condenser/gas cooler: Check the condition of the condenser/gas cooler adiabatic pads and the condenser/gas cooler coil for dirt and debris. Clean the adiabatic pads and coil if they are dirty or clogged. Use a water source to rinse the contaminants out of the pad and the air coil. This task may need to be repeated more frequently if the site location has a high potential for the unit to accumulate dirt and debris.
9. Check and clean all water strainers. A blow-down valve can be attached and should be opened to flush the screen free of debris. The Y-strainer should be cleaned more regularly if the water contains a heavy concentration of particulates.
10. Check piping clamps for wear/tightness.

10.1.3. ONCE A YEAR

1. Repeat items in "Once a Week" on page 34 and "Once a Month" on page 34, then continue with the following steps:
2. The unit is equipped with strainers in the oil system. The strainer screen shall be removed and cleared of any debris. The strainer should be cleaned more regularly if it contains a high concentration of particulates.
3. Check the water's condition for algae and particulate fouling. Have a qualified laboratory perform a water analysis. Back-flush the condenser/gas cooler and evaporator with water or another suitable cleaning agent if fouling is suspected. This task may need to be repeated more frequently if the site location has a high potential for the unit to accumulate dirt and debris.
4. A qualified laboratory should conduct a compressor oil analysis. Change refrigeration oil as necessary. Zero Zone does not supply oil test kits.
5. Perform a pump down test to check the condition of each compressor. There may be damage associated with the compressor valves if the compressor does not hold the pump down.

PREVENTATIVE MAINTENANCE CHECKLIST

Job Name:	Job Location:
Model No:	Unit S/N:
Design Suction Pressure Set Point:	Nameplate Voltage:
Design Chilled Water Set Point	Unit Nameplate FLA:

MAINTENANCE ACTIVITY	WEEK NUMBER											
	1	2	3	4	5	6	7	8	9	10	11	12
Date												
Suction Pressure Control												
Unit % Loading												
Chiller Temperature Control												
Chilled Water Inlet Temp												
Chilled Water Outlet Temp												
Refrigerant Suction Pressure												
Evaporator Temperature Control												
Evaporator Superheat Control												
Refrigerant Suction Temp												
Refrigerant Discharge Pressure												
Refrigerant Discharge Temp												
Refrigerant Superheat												
Refrigerant Sub-cooling												
Receiver Pressure												
Refrigerant Sight Glass												
Oil Reservoir Level												
Compressor Oil Level												
Electrical Connections												
Incoming Voltage												

PREVENTATIVE MAINTENANCE CHECKLIST

Job Name:	Job Location:
Model No:	Unit S/N:
Design Suction Pressure Set Point:	Nameplate Voltage:
Design Chilled Water Set Point	Unit Nameplate FLA:

MAINTENANCE ACTIVITY	WEEK NUMBER											
	1	2	3	4	5	6	7	8	9	10	11	12
Compressor L2 Amps												
Compressor L1 Amps												
Compressor L2 Amps												
Compressor L3 Amps												
Oil Separator PSID												
Oil Reservoir Heater												
Evaporator PSID												
Compressor Crankcase Heaters												
Condenser/gas cooler Pads & Coil												
Water Y-Strainer												
*Clean Evaporators												
*Water Analysis												
*Clean Refrigerant Side Strainers												
*Clean Condenser/gas coolers												
*Oil Analysis												
*Oil Strainers												
*Inspect Compressor Pump Down												
***Replace ASME relief valves												

Notes:

(*) Every Year

(**) Every 6 months and after the first 50-100 hours of operation

(***) Per ASME requirements

11. TROUBLESHOOTING

The following table provides some symptoms and their potential causes if a problem with the unit has occurred.

TABLE 6: TROUBLESHOOTING CHECKLIST

ERROR	POSSIBLE CAUSE	CORRECTIVE ACTION
Inaccurate sensor reading	Faulty wiring or bad sensor	Check wiring and replace sensor
Faults on ALARM screens	Bad sensor.	Replace sensor.
	Faulty wiring.	Check wiring
	Reference fault message for details to determine root cause.	Correct situation that caused fault.
	Alarm setpoint not properly set.	Review Alarm setpoint and set it properly.
No HMI display update	Display communication not established	Cycle power to display
	Faulty network wiring	Check network wiring
Compressor will not start	Compressor Motor Protection Module	Reset module, cycle power for 5 seconds.
	Loss of Phase	Check incoming power
	High discharge temperature	Check oil level, superheat, liquid injection
	Low Compressor Suction Pressure	Check suction pressure and refrigerant charge.
		Check operating envelope. Review and change setpoints as necessary.
		Review position of expansion and compressor valves
	High Compressor Discharge Pressure	Check for operation of the condenser/gas cooler fans or condenser/gas cooler cooling water
		Check for operation of the high pressure expansion valve.
		Check operating envelope. Review and change setpoints as necessary.
		Review position of system isolation valves and compressor valves
	Low Oil Level, Oil Flow Fault	Add oil as required
		Check condition of oil filter and replace if required
		Check condition of oil level control in oil separator
		Check condition of oil level control on compressor
	Compressor overload	Check supply voltage, amperage of each leg, contactor and wiring, overload set point
		Check operating envelope
	Compressor VFD	Check Settings, supply voltage, replace if faulty
	Output card	Check supply voltage, replace if faulty
	Compressor failure	Contact Customer Service Department for assistance

TROUBLESHOOTING

ERROR	POSSIBLE CAUSE	CORRECTIVE ACTION
Low refrigerant pressure	Low refrigerant charge	Add refrigerant, Contact refrigeration service technician
	Refrigerant leak	Fix leak, add refrigerant, Contact refrigeration service technician
	Clogged Evaporator	Clean evaporator
	Expansion valve	Check start up settings
		Check control power to Evaporator Controller
		Check control signal output from Evaporator Controller
		Replace Evaporator controller if faulty
		Replace expansion valve if faulty
		Check interface relay, replace if faulty
		Check solenoid coil, replace if faulty
	Liquid line service valve	Open Valve
	Compressor suction service valve	Open valve all the way
	Suction pressure transducer	Replace if faulty
	Input card	Replace if faulty
High refrigerant pressure	Plugged condenser/gas cooler	Clean condenser/gas cooler
	Insufficient condenser/gas cooler air or water flow	Make sure air filter and condenser/gas cooler is clean and the unit is installed in accordance with recommendations in this manual
	High condenser/gas cooler air or water temperature	Maximum temperature is 105°F
	Compressor discharge service valve is partially closed	Open valve all the way
	Refrigerant circuit overcharged	Contact refrigeration service technician
	High refrigerant pressure transducer	Check Wiring, Replace if faulty
	High refrigerant pressure switch	Check Wiring, Replace if faulty
	Input card	Check voltage supply, Replace if faulty
High discharge temperature	High Suction Gas Superheat	Check EEV settings, reduce suction temperature
	Hi Differential Pressure	Reduce condensing pressure, increase suction pressure
	Discharge temperature sensor	Replace if faulty
	Input card	Replace if faulty

TROUBLESHOOTING

Insufficient cooling (temperature continues to rise above set point)	Process load too high	Check to make sure evaporator is properly sized for load
	Evaporator is not cooling	Check EEV control, sufficient water flow
	Insufficient condenser/gas cooler cooling	See High refrigerant pressure
	Refrigeration circuit problem	Contact refrigeration service technician
	Temperature sensor	Replace if faulty
	Input card	Replace if faulty

SYMPTOM	POSSIBLE CAUSE	CORRECTIVE ACTION
Erratic temperature control	Low air flow through evaporators	Adjust flow to proper level
	Cooling load is below minimum capacity of evaporator	Adjust compressor set up parameters
	Temperature sensor	Replace if faulty
	Input card	Replace if faulty
Temperature values unsteady or out of range	Loose temperature sensor wire connections	Tighten terminal screw
	Input card	Replace if faulty
No LEDs are illuminated on Controller	Control power not available at power supply	Check for power at power supply, check control transformer

12. GLOSSARY

12.1. Administrative Controls

The use of human action aimed at achieving a safe level of performance from a system or subsystem.

12.2. Air Cooled Gas Cooler/Condenser

The gas cooler/condenser/gas cooler coil is normally constructed of stainless steel or copper tubing, aluminum fins, and galvanized powder coated casing. This heat exchanger can serve as both a gas cooler and/or a condenser/gas cooler, depending on the saturated CO_2 condensing temperature. If the ambient air temperature is approximately 77°F or lower, the CO_2 will operate below the critical temperature of 88°F, and the CO_2 will fully condense into a liquid, thus a condenser/gas cooler. Then the heat exchanger will function as a gas cooler, and the CO_2 vapor will experience sensible cooling only if the ambient air temperature is greater than 77°F.

- Condenser/gas cooler: A sub-critical CO_2 refrigeration cycle that is intended to operate below the critical point of CO_2. This allows for more traditional working pressure ranges for materials and components.
- Gas Cooler: A transcritical CO_2 refrigeration cycle that is intended to operate above the critical point of CO_2. This system will experience pressures in excess of typical refrigeration design and must take appropriate measures to accommodate the high pressures.

12.2.1. CONDENSER/GAS COOLER FANS

The condenser/gas cooler fans are ECM (electrically commutated motors) axial fans, providing variable-speed air volume control across the condenser/gas cooler coil. Regulation of the fan(s) speed is controlled by the system controller to match the required condenser/gas cooler cooling capacity with the total heat of rejection.

12.3. Cascade Condenser/gas cooler

The primary purpose of the Cascade Condenser/gas cooler is to reject heat from the sub-critical CO_2 system into the HFC system. The HFC system will handle the intermediate stage of refrigeration and the rejection of heat from the atmosphere. The reason this intermediate stage is required is that the CO_2 system is designed to operate at sub-critical pressures. If the CO_2 were allowed to reach trans-critical operation, one would see CO_2 pressure well in excess of the maximum operating pressure of the specified components.

12.4. Compressors

12.4.1. OVERVIEW

The CO_2 compressors are specifically designed for either high-pressure trans-critical or low-pressure sub-critical operation. Trans-critical operation refers to CO_2 gas cooling above the critical point of 88°F (1055 psig) condensing temperature. Subcritical operation refers to CO_2 condensation below the critical point of 88°F (1055 psig) condensing temperature. There are multiple compressors controlling the desired cooling capacity of the refrigeration equipment.

12.4.2. CONTROL

Compressor staging and operation will be controlled by the system controller. Proper safeties and controls are implemented to ensure safe and reliable operation. In addition to software programmed safeties and shutdown, each compressor will be protected individually by a high pressure switch, compressor motor module, and oil safety. See additional control and electrical drawings for further information.

12.4.3. COMPRESSOR VFD

The lead compressors of each suction group are normally fitted with a VFD. This will provide precise variable-speed capacity regulation to match the cooling load requirement. The lead compressor may also include digital unloading.

12.4.4. COMPRESSOR PRESSURE RELIEF VALVE

Each compressor is equipped with relief valves on the suction and/or discharge sides of the compressor. They are mounted on the compressor body and are required to protect the compressor in the event that both the suction and discharge service valves are closed and an overpressure condition occurs in the compressor. The system relief valves are intended to protect the compressor when the service valves are open.

12.4.5. CRANKCASE HEATER

The compressor crankcase heater prevents too high refrigerant concentrations in the oil during shutdown. It is in a heater sleeve and is replaceable if necessary, without breaching the refrigeration circuit.

12.4.6. DISCHARGE CHECK VALVE

A check valve is located in the compressor's discharge line to protect against refrigerant migration during the off cycle, if equipped and/or required by design.

12.4.7. DISCHARGE TEMPERATURE SENSOR

This temperature sensor is located on the compressor refrigerant discharge line and provides readings of the refrigerant vapor temperature to the system controller. The discharge temperature is displayed for viewing on the HMI screen.

12.4.8. SUCTION TEMPERATURE SENSOR

This temperature sensor is located on the compressor refrigerant suction line and provides readings of the refrigerant vapor temperature to the system controller. The suction temperature is displayed for viewing on the HMI screen.

12.4.9. HIGH PRESSURE SWITCH

A mechanical high-pressure switch is located on the discharge side of each compressor. This pressure switch protects the compressor and the refrigeration system from a high-pressure situation. The nonadjustable trip point is at 90% of the design working pressure and shuts down the compressor if the refrigerant pressure reaches the pressure switch trip point. The system also contains a pressure transducer in the discharge line and is programmed to shut down the system if the discharge pressure reaches the programmed high set point. This adjustable programmed fault can be adjusted via the main controller HMI, and it should be set for 90% of the high-pressure switch.

12.4.10. COMPRESSOR ELECTRONIC MOTOR MODULE

Each compressor is fitted with an electronic protection device located within the compressor motor terminal box. This device uses a series of temperature sensors mounted in the motor winding to monitor the motor's temperature. The compressor shuts down immediately, the module locks out, and it requires a manual reset at the trip point temperature. The main power must be cycled off for at least five seconds to reset the module. If a temperature fault occurs, the compressor must also cool down before the module will reset.

12.5. CO_2 Oil System

12.5.1. OVERVIEW

Proper oil control is very important in direct expansion CO_2 systems. Miscibility and oil temperature are very important to maintain. If not properly managed; potential degassing effects can be experienced inside the compressor. This can cause issues with the reliability of the compressor and it is very desirable to minimize as much as possible.

12.5.2. LOW PRESSURE OIL SYSTEM

In an effort to minimize degassing effects, a low pressure oil system is normally implemented unless otherwise specified. This will allow vapor to separate from oil more completely. A coalescent style separator and an oil reservoir are implemented to maximize the oil removal efficiency and provide excess oil storage for varying oil demands. To maintain oil temperature in the reservoir, a heater is added to the oil reservoir if the system is designed for outdoor duty. The oil reservoir pressure is maintained at same pressure as the separator/receiver. This will provide adequate oil pressure differential to push oil across the oil solenoid to each compressor. Each separator is equipped with an oil level sensor that directly controls a solenoid valve that returns oil to the oil reservoir when the oil level in the separator rises.

12.5.3. OIL SEPARATOR

The oil separator is provided to ensure a low oil carry over rate. The oil separator is a coalescent type and is serviceable with a replaceable coalescent filter. The pressure drop across the two filters is monitored by two pressure transducers and is relayed to the system controller. If the pressure drop across the oil separators exceeds 12 psi, an alarm message will be generated.

- Oil Separator Oil Level Switch
  - An oil level switch is installed near the bottom of the oil separator and monitors the level of oil that is separated from the CO_2 gas stream and which accumulates in the bottom of the oil separator. When the oil level rises to the level of the switch, a signal is sent to the system controller and an oil drain solenoid is energized to empty the oil separator into the oil reservoir.
- Oil Separator Drain Solenoid
  - The oil separator oil drain solenoid separates the high pressure in the oil separator from the intermediate pressure in the oil reservoir. When the oil separator oil level switch senses an oil level in the oil separator, a signal is sent to the system controller and the oil drain solenoid is activated and opens. This transfers oil from the oil separator to the oil reservoir.

12.5.4. OIL RESERVOIR

The oil separator is provided to ensure a low oil carry-over rate. The oil separator is a coalescent type and is serviceable with a replaceable coalescent filter. The pressure drop across the two filters is monitored by two pressure transducers and relayed to the system controller. If the pressure drop across the oil separators exceeds 12 psi, an alarm message will be generated.

- Oil Reservoir Heater
  - The oil reservoir heater prevents excessive refrigerant concentrations in the oil during shutdown. It is mounted at the bottom of the oil reservoir and is regulated with a temperature thermostat located on the oil reservoir. The heater is energized when the oil temperature is below the setpoint and when the compressors are off.
- Oil Reservoir Level Switch
  - If equipped, a low-level switch is provided on the oil reservoir to signal inadequate oil levels in the reservoir.

12.5.5. COMPRESSOR ELECTRONIC OIL CONTROL

To ensure the best oil quality, the use of electronic oil control is implemented. This will ensure that proper oil level is maintained in the crankcase of the compressors. The electronic oil level control monitors the oil level in the compressor and turns on a solenoid valve to fill the compressor with oil as required.

12.5.6. OIL STRAINER/FILTER

Oil strainers are provided at the outlet of each oil separator to collect any small debris particles in the oil system that may cause blockage of flow in the oil solenoid control valves. An oil filter is provided at the outlet of the reservoir to remove any additional debris and moisture from the oil before it reaches the compressors.

12.5.7. HIGH PRESSURE OIL SYSTEM

Although less common as compared to a low pressure oil system, a high pressure oil system combines the oil separator with the oil reservoir into one vessel and eliminates the oil separator level switch and the oil transfer solenoid valve. As the oil is separated, it collects in the bottom of oil separator. Essentially the oil separator has a larger oil storage volume built into the bottom of the oil separator. The high pressure oil is directly fed to the compressor electronic oil level control. A high pressure oil system is not recommended for all applications and should be applied to a system design carefully.

12.6. High Pressure Expansion Valve/Flash Gas Bypass Valve

12.6.1. OVERVIEW

The high-pressure expansion valve and flash gas bypass valve function together to maintain CO_2 discharge pressure and the separator/receiver pressure. These valves are typically used in a trans-critical CO_2 system but can also be used in subcritical CO_2 systems. Subcritical operation can still reach high pressures above the normal working pressure rating of standard refrigeration components and copper tubes used in refrigeration systems. Using a flash gas bypass can lower the operating pressure of the separator/receiver and make it possible to install parts and copper pipe that are easy to find. The high-pressure expansion valves (HPEV) and flash gas bypass valves (FGBV) are controlled by the main system controller or an independent HPEV/FGBV controller.

12.6.2. HIGH PRESSURE EXPANSION VALVE

The high-pressure expansion valves will operate to control an optimal CO_2 discharge pressure to ensure the highest operating efficiency of the CO_2 refrigeration system during transcritical operation. The high-pressure expansion valves will regulate to maintain constant subcooling leaving through the condenser/gas cooler in subcritical operation. The valves are located in the liquid CO_2 line leaving through the gas cooler/condenser/gas cooler. These valves will be closed as necessary to hold a minimum condensing pressure or a maximum receiver pressure and open to maintain a minimum separator/receiver pressure.

12.6.3. FLASH GAS BYPASS VALVE

The flash gas bypass valve bypasses CO_2 vapor from the top of the separator/receiver into the suction line of the medium temperature compressors. It regulates to maintain a constant separator/receiver pressure.

12.7. CO_2 Receiver/Flash Tank

The CO_2 Receiver/Flash Tank is different than that of a traditional HFC receiver. The vessel is designed to contain both CO_2 liquid and vapor. Liquid and vapor will be supplied to the vessel. Liquid will separate from the vapor and settle on the bottom. This liquid will then feed the evaporator circuits. Liquid will rise to the top of the vessel as the vapor separates. This vapor will be fed to the flash gas bypass valve. The regulating or primary relief of the system will discharge vapor from the top of the receiver vessel when an overpressurization occurs in the system.

- Liquid Level Low Level Switch
  - A liquid level switch is installed in the CO_2 Receiver/Flash Tank to signal inadequate liquid CO_2 levels in the CO_2 Receiver/Flash Tank.
- Liquid Level High Level Switch
  - A liquid level switch is installed in the CO_2 Receiver/Flash Tank to signal high liquid CO_2 levels in the CO_2 Receiver/Flash Tank when equipped. A high liquid level indicates an increased risk of liquid entrainment into the flash gas bypass line.
- Sight Glass
  - To allow a quick reference of the liquid CO_2 level in the CO_2 Receiver/Flash Tank sight glasses can be installed on the Receiver/Flash Tank. Sight glasses are typically located at the CO_2 Receiver/Flash Tank's 25%, 50%, and 75% levels.

12.8. Liquid/Suction Heat Exchanger

The liquid/suction heat exchanger is used to exchange heat between the CO_2 gas cooler outlet or the main liquid and suction line of either medium- or low-temperature loads. The primary function of the liquid/suction heat exchanger is to raise the temperature of the suction gas that returns to the compressors, thereby preventing liquid from flooding back and reducing the solubility of CO_2 gas in the refrigeration oil. A low-suction gas temperature from the CO_2 compressor is undesirable as it can shorten the compressor's operating life.

12.9. Liquid Filter Drier

A replaceable-core filter/dryer is located in the liquid line. It removes any moisture and/or foreign matter that may have gotten into the refrigerant stream. Moisture and foreign matter can cause serious damage to the components of a refrigeration system. It is important that the system be equipped with a clean filter dryer for this reason.

- Replace the filter driers if any of the following conditions occur:
  - Opening the refrigeration system to the atmosphere for repairs or maintenance
  - Indication of moisture in the sight glass (the green ring has changed to yellow)
  - An excessive pressure drop develops across the filter

12.10. Liquid Line Sight Glass

The refrigerant sight glass/moisture indicator is located just downstream of the liquid filter driers. It allows the operator or service technician to observe the flow of liquid refrigerant in the circuit. Prolonged periods of foaming or bubbling in the sight glass may indicate a low refrigerant condition or a restriction in the liquid line.

12.11. Electronic Expansion Valve

The electric expansion valve separates the refrigerant high pressure/temperature on the condenser/gas cooler side from the refrigerant low pressure/temperature on the evaporator side. The EEV can serve two different control functions depending on the system's operating conditions: superheat control and suction pressure control. A constant liquid supply, vapor-free, is required to be fed to the EEV at all times for proper operation. The EEV is driven by the evaporator controller. An alternate control method is the EEV will use the process temperature. If the EEV drops to a certain level, the EEV will close.

- **Superheat Control**
  - The EEV measures the amount of refrigerant entering the evaporator in a precise quantity in order to maintain superheat. The superheat is the difference between the saturated evaporative temperature and the suction line temperature. The superheat is factory-set for 10°F to 12°F (5°C to 6°C) and should never exceed 20°F (8°C) or go below 4°F (2°C). Only a trained refrigeration service technician should adjust this valve.
- **Suction Pressure Control**
  - The EEV behaves as a high-limit suction pressure regulator (MOP) when the suction pressure rises above a preset suction pressure. The valve regulates to maintain suction pressure instead of superheat. The suction pressure set point is factory set to allow the compressor to run at the highest allowable suction pressure. The EEV control reverts back to superheat control if the suction pressure falls below the maximum limit or if the superheat becomes dangerously low. While in suction pressure control, the superheat may float as long as it is within the allowable range.

⚠ **CAUTION!** THE EXPANSION VALVE MOP SHALL BE SET TO PREVENT THE COMPRESSOR(S) FROM OPERATING AT A HIGHER SUCTION PRESSURE THAT WILL RESULT IN OVERLOADING THE COMPRESSOR AND CAUSE IT TO SHUT DOWN. REVIEW THE COMPRESSOR'S ALLOWABLE OPERATING ENVELOPE.

GLOSSARY

12.12. Temperature Sensor

The temperature sensor monitors the temperature in the specific part of the system where it is mounted. Several temperature sensors are used throughout this system. The main controller uses these inputs to control many of the equipment's functions.

12.13. Pressure Transducer

The pressure sensor or transducer monitors the pressure of refrigerant in the specific part of the system where it is mounted. Several pressure transducers are used throughout this system. The main controller uses these inputs to control many of the equipment's functions.

12.14. Suction Accumulator

The suction accumulator is located in the compressor suction line and acts to protect the compressors from liquid back flooding. The accumulator will separate liquid from vapor and allow only refrigerant vapor to return to the compressor. Liquid refrigerant trapped in the accumulator will boil off and return to the compressor. A solenoid is provided as a liquid/oil drain in large horizontal accumulators. When the superheat is high enough, the solenoid valve will open to allow liquid to drain into the suction line. A smaller vertical accumulator will normally entrain small amounts of liquid and/or oil in the return suction gas.

12.14.1.ACCUMULATOR HIGH LEVEL SWITCH

If equipped, a high-level switch is located at the 50% level of the accumulator. A high-level alarm indicates an imminent risk of liquid back flooding into the compressors.

12.15. CO_2 Relief Assembly

The system is provided with a relief valve assembly. The relief assembly contains the main primary relief valves. Working with CO_2 requires extra safety measures. The primary reliefs are designed to open when the system pressure exceeds the designed set points.

12.16. Relief Valves

Relief valves provide a way for refrigerant to be vented. The safety relief valves protect the system from over-pressurization. The 3-Way Service valves provide a way to isolate components on the system for service.

12.16.1. SAFETY RELIEF VALVE

Individual safety relief valves may be installed to protect against hydrostatic expansion caused by manual intervention throughout the system. These valves are designed to relieve pressure only if the piping segment that they are mounted in is capable of being manually isolated and exceeds the maximum working pressure of the system. They are installed to protect the system from over-pressurization. This is the last line of defense to prevent component failure. These safety relief valves should never relieve pressure under normal operation, as these valves are set for higher relief pressures than the main relief valves.

12.16.2. 3-WAY SERVICE VALVE

Manual venting valves are present to provide a means of relieving piping pressure that has been manually isolated by closing service valves when safety relief valves are not installed. Safety relief valves are often provided in pairs. The safety relief valve pairs are mounted to a 3-way valve. The 3-way valve should be positioned for one valve to be exposed to system pressure. The 3-way valve can be changed to connect system pressure to a relief valve that does not need service when another valve is being serviced. Only after the 3-way valve is positioned away from the valve needing service can the valve be removed. The system must always be protected by a safety relief valve.

12.17. Back Check Valves

Individual back check valves may be installed to protect against hydrostatic expansion caused by manual intervention throughout the system. These valves are designed to relieve pressure on another section of piping when the piping segment on which they are mounted is isolated. This is the last line of defense to prevent component failure. It is only when a particular section of pipe is manually isolated from the main relief valves that they are intended to protect the system. The back check valves are positioned to relieve pressure back to the main regulating and pressure relief valves located at the receiver. Then manual venting valves are present to provide a means of relieving piping pressure that has been manually isolated by closing service valves when a back check valve or safety relief valve is not present.

A hybrid ball valve/back check valve is used in each evaporator suction line. It may be used as a service isolation valve. When open, this acts as a ball valve to allow flow in either direction. The valve acts like a check valve to allow flow in one direction only when it is closed.

GLOSSARY

12.18. Heat Reclaim

A heat reclaim system is used to capture heat from the CO_2 discharge line. Heat is transferred using brazed-plate heat exchangers. The CO_2 vapor passes between every other set of plates, while water flows on the other set of plates in the opposite direction. The system is designed to supply heat as required and is controlled by the main controller. Isolation valves are provided to isolate and bypass the heat reclaim circuit if required for service.

12.19. Water Evaporators

The evaporators have stainless steel plates and copper brazing. The CO_2 refrigerant passes between every other set of plates, while the coolant flows on the other side of the plates in the opposite direction. We recommend implementing a proper water maintenance program to ensure that chilled water has the desired quality. Excessive evaporator fouling caused by poor chilled water quality will cause poor chiller performance and/or chiller failure.

12.20. Supply and Return Water Isolation Valves

These valves are to be used to isolate each evaporator from the main water connections. The water supply isolation valve is motorized. This allows the valve to close when staging evaporators.

12.21. Chilled Water Flow Switch

The flow switches are located in the chilled water piping at each evaporator inlet. If the water flow rate drops below the trip point, the evaporator controller will close the EEV valve on the water evaporator. The chiller will shut off, and the EEV valves will close when the evaporator flow switches fault.

12.22. Y Strainer

A Y-strainer with a 1/16" (20 mesh) stainless steel screen is in the entering chilled water line of each evaporator to help protect the evaporator passages from clogging. The Y strainer must be monitored for debris buildup and cleaned as part of regular maintenance.

12.23. Water Supply Temperature Sensor

This sensor is in the water piping leaving the water chiller. The water setpoint will use this sensor for the process value. It will be the control sensor for the chilled water set point and will determine the loading/unloading of all compressors.

12.24. Water Return Temperature Sensor

This sensor is located in the water piping that feeds the water chiller. This sensor will be used for general display purposes and to signal high or low water system temperatures.

12.25. Feezestat

These temperature sensors are located in the water piping leaving each evaporator and provide readings of the chilled water temperature exiting the evaporator. If the leaving water temperature falls below the freezestat set point, the EEV valve on the water evaporator will close in order to protect the chilled water from freezing in the evaporator. If all evaporators experience a freezestat fault, the chiller will shut off immediately.

12.26. Liquid Injection

When equipped, a liquid injection valve is employed to desuperheat the suction gas.

12.27. Hot Gas Injection

When equipped, hot gas injection is used to increase compressor suction superheat when it falls below acceptable range.

13. APPENDIX

13.1. Drawings

We have prepared a custom set of drawings for your unit and placed them inside the control panel prior to shipment. Please refer to these drawings when troubleshooting, servicing, and installing the unit. If you cannot find these drawings or wish to have additional copies sent, please contact our Customer Service Department and reference the serial number of your unit.

13.2. THERMODYNAMIC PROPERTIES OF R-744 (CO_2)

TABLE 7: THERMODYNAMIC PROPERTIES OF R744 (CO_2)

TEMP	PRESSURE	VOLUME	DENSITY	ENTHALPY		ENTROPY	
		VAPOR	LIQUID	LIQUID	VAPOR	LIQUID	VAPOR
°F	psig	ft³/lbm	lmb/ft³	Btu/lbm	Btu/lbm	Btu/ lbm°R	Btu/ lbm°R
-60	79.877	0.9336	72.333	39.014	185.86	0.13606	0.50348
-59	82.055	0.91336	72.205	39.486	185.94	0.13722	0.50275
-58	84.269	0.8365	72.077	39.58	186.02	0.13838	0.50201
-57	86.522	0.87445	71.948	40.431	186.09	0.13954	0.50128
-56	88.813	0.85575	71.819	40.904	186.16	0.1407	0.50055
-55	91.142	0.83754	71.69	41.377	186.24	0.14186	0.49983
-54	93.51	0.81979	81.56	41.851	186.31	014301	0.49911
-53	95.918	0.8025	71.429	42.325	186.38	0.14417	0.49839
-52	98.366	0.78565	71.299	42.8	186.45	0.14532	0.49797
-51	100.85	0.76922	71.167	43.276	186.51	0.14647	0.49696
-50	103.38	0.8532	71.036	43.751	186.58	0.14761	0.49625
-49	105.95	0.73759	70.904	44.228	186.64	0.14876	0.49554
-48	108.56	0.72237	70.772	44.705	186.7	0.1499	0.49484
-47	111.22	0.70752	70.639	45.182	186.77	0.15104	0.49413
-46	113.91	0.69304	70.505	45.66	186.83	0.15218	0.49343
-45	116.65	0.67891	70.372	46.138	186.88	0.15332	0.49274
-44	119.43	0.66513	70.238	46.617	186.94	0.15446	0.49204
-43	122.25	0.65168	70.103	47.097	187	0.15559	0.49135
-42	125.12	0.63856	69.968	47.577	187.05	0.15672	0.49066
-41	128.04	0.62575	69.832	48.058	187.1	0.15785	0.48997
-40	130.99	0.61325	69.696	48.539	187.15	0.15898	0.48928
-39	134	0.60104	69.56	490.251	187.2	0.16011	0.4886
-38	137.05	0.58913	69.423	49.504	187.25	0.16124	0.48791
-37	140.14	0.57749	69.285	49.987	187.3	0.16236	0.48723
-36	143.28	0.56613	69.147	50.471	187.34	0.16349	0.48655
-35	146.47	0.55503	69.008	50.9563	187.39	0.16461	0.48588
-34	149.71	0.54419	68.869	51.441	187.43	0.16573	0.4852
-33	152.99	0.5336	68.73	51.927	184.47	0.16685	0.48453
-32	156.32	0.52326	68.589	52.414	187.51	0.16797	0.48385
-31	159.7	0.51315	68.449	52.902	187.55	0.16909	0.48318
-30	163.13	0.50327	68.307	53.39	187.58	0.1702	0.48251
-29	166.61	0.49361	68.165	53.879	187.61	0.17132	0.48185
-28	170.14	0.48417	68.023	54.369	187.65	0.17243	0.48118
-27	173.72	0.47495	68.88	54.859	187.68	0.17354	0.48051
-26	177.35	0.46592	67.736	55.351	187.7	0.17466	0.47985
-25	181.03	0.4571	67.592	55.843	187.73	0.17577	0.47919
-24	184.76	0.77848	67.447	56.336	187.76	0.17688	0.47852

APPENDIX

TABLE 5: THERMODYNAMIC PROPERTIES OF R-744 (CO_2)							
TEMP	PRESSURE	VOLUME	DENSITY	ENTHALPY		ENTROPY	
		VAPOR	LIQUID	LIQUID	VAPOR	LIQUID	VAPOR
°F	psig	ft^3/lbm	lmb/ft^3	Btu/lbm	Btu/lbm	Btu/ lbm°R	Btu/ lbm°R
-23	188.55	0.44004	67.302	56.83	187.78	0.17799	0.47786
-22	192.38	0.43179	67.156	57.325	87.8	0.17909	0.4772
-21	196.27	0.42371	67.009	57.82	187.82	0.1802	0.47654
-20	200.22	0.41582	66.862	58.317	187.84	0.18131	0.47589
-19	204.22	0.40809	66.714	58.814	187.85	0.18241	0.47523
-18	208.27	0.40053	66.565	59.313	187.86	0.18351	0.47457
-17	212.38	0.39312	66.415	59.812	187.88	0.18462	0.47391
-16	216.54	0.38588	66.265	60.313	187.88	0.18572	0.47326
-15	220.76	0.37879	66.115	60.814	187.89	0.18682	0.4726
-14	225.03	0.37185	65.963	61.316	187.9	0.18792	0.47195
-13	229.36	0.36505	65.811	61.82	187.9	0.18903	0.47129
-12	233.75	0.3584	65.658	62.324	187.9	0.19013	0.47064
-11	238.2	0.35188	65.504	62.83	187.9	0.19123	0.46998
-10	242.7	0.3455	65.349	63.337	187.9	0.19233	0.46933
-9	247.27	0.33925	65.194	63.844	187.89	0.19343	0.46868
-8	251.89	0.33312	65.038	64.353	187.88	0.19452	0.46802
-7	256.57	0.32712	64.881	64.863	187.87	0.19562	0.46737
-6	266.11	0.31548	64.564	65.887	187.85	0.19782	0.46606
-4	270.97	0.30984	64.404	66.401	187.83	0.19892	0.4654
-3	275.9	0.30431	64.244	66.916	187.81	0.20002	0.46475
-2	280.88	0.29888	64.083	67.432	187.79	0.20111	0.46409
-1	285.93	0.29357	63.92	67.95	187.76	0.20221	0.46343
0	291.04	0.28835	63.757	68.469	187.74	0.20331	0.46277
1	296.22	0.28324	63.428	69.511	187.68	0.2055	0.46146
2	301.45	0.27823	63.428	69.511	187.68	0.2055	0.46146
3	306.76	0.27332	63.262	70.034	187.64	0.2066	0.4608
4	312.12	0.2685	63.094	70.558	187.6	0.2077	0.46014
5	317.55	0.26377	62.926	71.084	187.56	0.2088	0.45947
6	323.05	0.25914	62.757	71.612	187.52	0.2099	0.45881
7	328.62	0.25459	62.587	72.141	187.48	0.211	0.45814
8	334.25	0.25012	62.415	72.671	187.43	0.2121	0.45748
9	339.95	0.24574	62.243	73.204	187.38	0.2132	0.45681
10	345.71	0.24144	62.069	73.738	187.32	0.2143	0.45614
11	351.55	0.23722	61.894	74.273	187.26	0.2154	0.45547
12	357.45	0.23308	61.718	74.81	187.2	0.21651	0.4548
13	363.42	0.22902	61.362	75.89	187.07	0.21871	0.45344
14	369.46	0.22503	61.362	75.89	187.07	0.21871	0.45344
13	363.42	0.22902	61.541	75.349	187.14	0.21761	0.45412
14	369.46	0.22503	61.362	75.89	187.07	0.21871	0.45344
15	375.57	0.22111	61.182	76.433	187	0.21982	0.45276
16	381.76	0.21726	61.001	76.977	186.93	0.22093	0.45208
17	388.01	0.21348	60.819	77.524	186.86	0.22203	0.4514
18	394.34	0.20977	60.635	78.623	186.69	0.22425	0.45002
20	407.21	0.20254	60.263	79.175	186.6	0.22536	0.44933
21	413.76	0.19902	60.075	79.73	186.51	0.22648	0.44864

APPENDIX

TABLE 5: THERMODYNAMIC PROPERTIES OF R-744 (CO_2)							
TEMP	PRESSURE	VOLUME	DENSITY	ENTHALPY		ENTROPY	
		VAPOR	LIQUID	LIQUID	VAPOR	LIQUID	VAPOR
°F	psig	ft^3/lbm	lmb/ft^3	Btu/lbm	Btu/lbm	Btu/ lbm°R	Btu/ lbm°R
22	420.38	0.19556	59.885	80.286	186.42	0.22759	0.44794
23	427.07	0.19216	59.694	80.845	186.32	0.22871	0.44724
24	433.84	0.18882	59.501	81.406	186.22	0.22983	0.44653
25	440.69	0.18554	59.307	81.97	186.11	0.23095	0.44582
26	447.61	0.18231	59.111	82.536	186	0.23207	0.44511
27	454.61	0.17914	58.913	83.104	185.89	0.23319	0.44439
28	461.69	0.17602	58.714	83.675	185.77	0.23432	0.44367
29	468.84	0.17295	58.513	84.248	185.65	0.23545	0.44295
30	476.07	0.16993	58.31	84.824	185.52	0.23658	0.44222
31	483.39	0.16696	58.105	85.403	185.39	0.23771	0.44148
32	490.78	0.16404	57.898	85.985	185.25	0.23885	0.44074
31	483.39	0.16696	58.105	85.403	185.39	0.23771	0.44148
32	490.78	0.16404	57.898	85.985	185.25	0.23885	0.44074
33	498.25	0.16117	57.689	86.569	185.11	0.23998	0.44
34	505.81	0.15834	57.478	87.156	184.96	0.24113	0.43925
35	513.45	0.15556	57.265	87.747	184.81	0.24227	0.43849
36	521.17	0.15282	57.049	88.34	184.65	0.24342	0.43773
37	528.97	0.15013	56.832	88.937	184.49	0.24457	0.43696
38	536.86	0.14747	56.612	89.537	184.32	0.24573	0.43619
39	544.83	0.14486	56.389	90.141	184.15	0.24689	0.43541
40	552.88	0.14229	56.165	90.748	183.97	0.24805	0.43462
41	561.03	0.13975	55.937	91.359	183.79	0.24922	0.43382
42	569.26	0.13725	55.707	91.974	183.59	0.25039	0.43302
43	577.57	0.13479	55.474	92.593	183.4	0.25157	0.43221
44	585.98	0.13237	55.239	93.215	183.19	0.25275	0.43139
45	594.47	0.12998	55	93.842	182.98	0.25394	0.43056
46	603.05	0.12762	54.758	94.474	182.76	0.25513	0.42972
47	611.72	0.1253	54.513	95.109	0182.53	0.25633	0.42887
48	620.49	0.12301	54.265	95.75	182.3	0.25753	0.42801
49	629.34	0.12075	54.013	96.396	182.06	0.25874	0.42714
50	638.29	0.11852	53.758	97.046	181.81	0.25996	0.42626
49	629.34	0.12075	54.013	96.396	182.06	0.25874	0.42714
50	638.29	0.11852	53.758	97.046	181.81	0.25996	0.42626
51	647.33	0.11632	53.499	97.702	181.55	0.26118	0.42537
52	656.47	0.11415	53.236	98.364	181.28	0.26242	0.42447
53	665.7	0.112	52.969	99.032	181	0.26366	0.42355
54	675.03	0.10988	52.697	99.705	180.72	0.26491	0.42262
55	684.45	0.10779	52.421	100.39	180.42	0.26616	0.42167
56	693.97	0.10572	52.14	101.07	180.11	0.26743	0.42071
57	703.59	0.10368	51.854	101.77	179.79	0.26871	0.41973
58	713.31	0.10166	51.563	102.47	179.46	0.27	0.41873
59	723.13	0.099661	51.266	103.18	179.12	0.27	0.41873
60	733.05	0.097683	50.964	103.89	178.77	0.27261	0.41669
61	743.08	0.095726	50.655	104.62	178.4	0.27394	0.41563
62	753.21	0.093787	50.339	105.36	178.01	0.27528	0.41455

TABLE 5: THERMODYNAMIC PROPERTIES OF R-744 (CO_2)							
TEMP	PRESSURE	VOLUME	DENSITY	ENTHALPY		ENTROPY	
		VAPOR	LIQUID	LIQUID	VAPOR	LIQUID	VAPOR
°F	psig	ft³/lbm	lmb/ft³	Btu/lbm	Btu/lbm	Btu/ lbm°R	Btu/ lbm°R
63	763.44	0.091866	50.017	106.1	177.61	0.27663	0.41345
64	773.78	0.089961	49.687	106.86	177.2	0.27801	0.41233
65	784.23	0.088072	49.349	107.63	176.77	0.2794	0.41117
66	794.79	0.086197	49.002	108.41	176.31	0.2808	0.40999
67	805.46	0.084335	48.647	109.2	175.84	0.28223	0.40877
68	816.23	0.082484	48.281	110	175.35	0.28368	0.40753
69	827.12	0.080642	47.905	110.82	174.84	0.28516	0.40624
70	838.13	0.078809	47.517	111.66	174.29	0.28666	0.40491
71	849.25	0.076981	47.116	112.52	173.73	0.28819	0.40354
72	860.49	0.075157	46.701	113.39	173.13	0.28975	0.40212
73	871.85	0.073335	46.271	114.29	172.5	0.29135	0.40064
74	883.32	0.071511	45.824	115.2	171.83	0.29299	0.3991
75	894.93	0.069682	45.357	116.15	171.13	0.29467	0.3975
76	906.66	0.067844	44.869	117.13	170.38	0.2964	0.39404
78	930.5	0.064121	43.812	119.19	168.71	0.30006	0.39217
79	942.62	0.06223	43.236	120.28	167.78	0.302	0.39018
80	954.88	0.060289	42.618	121.44	166.77	0.30404	0.38804
81	967.28	0.058305	41.95	122.66	165.66	0.3062	0.38573
82	979.82	0.056253	41.221	123.96	164.42	0.30851	0.3832
83	992.51	0.054105	40.411	125.38	163.03	0.31102	0.38039
84	1005.4	0.051816	39.491	126.95	161.41	0.3138	0.37719
85	1018.4	0.049309	38.406	128.75	159.47	0.31699	0.37339
86	1031.6	0.046417	37.039	130.93	156.98	0.32088	0.36861
87	1044.9	0.042636	35.034	134.01	153.25	0.32638	0.36157
88	1055.3	0.034257	29.191	143	143	0.34267	0.34267
89	1055.3	0.034257	29.191	143.56	143.56	0.34353	0.34353

APPENDIX

13.3. Transcritical CO_2 Oil Management System FAQs

13.3.1. WHAT IS THE PURPOSE OF THE OIL LEVEL MANAGEMENT SYSTEM?

The purpose of the oil management system is to separate oil from the compressor discharge, transfer oil to the oil reservoir through an oil transfer solenoid, filter system oil, and supply oil to the compressors when needed. The compressor oil level control is responsible for maintaining the oil level in the compressors. Details on specific operation can be found in the oil control literature.

13.3.2. WHAT ARE THE BASIC COMPONENTS OF THE OIL LEVEL MANAGEMENT SYSTEM?

1. Oil Separator
2. Oil Reservoir
3. Oil Transfer Solenoid
4. Oil Filter/Strainter
5. Level Eye/Switch

13.3.3. WHAT IS THE SEQUENCE OF EVENTS IN THE OIL LEVEL MANAGEMENT SYSTEM?

- On Demand Operation
  - Oil transfer during normal operation is a demand based system.
  - The oil level is monitored in the oil separator by the oil level eye/switch. The controller sends a command to energize the oil solenoid for 40 seconds when the oil is sensed by the oil level eye/switch and a medium-temperature compressor operation. The pathway is open, and the higher pressure of the discharge gas pushes the oil from the oil separator into the oil reservoir when the oil transfer solenoid is energized. The oil reservoir is maintained at flash gas tank pressure, which is lower than the discharge pressure.
- Timed Operation
  - Newer stores include flex combiner programming that includes both demand operation and times operation.
  - Older stores may only include demand operation.
  - Oil transfer during timed operation is based on a fixed-time interval. The control sequence is programmed to operate in fixed-time intervals when at least one medium temperature compressor is in operation. A fixed-time interval is used to energize the oil transfer solenoid every three minutes for 40 seconds. This fixed time interval can be altered based on system capacity and characteristics as determined in the field and can be lowered to 1 or 2 minutes if the 3-minute duration is not enough.
- Oil Separator
  - The oil separator is a coalescent type that uses an element that the refrigerant gas and oil must pass through before entering the gas cooler. The oil is separated from the gas by the element and returned to the oil reservoir. The element is also effective against contaminants. The contaminants can cause a pressure drop across the element. The pressure drop can increase until there is an alarm. The increase in the pressure drop can cause the gasket to dislodge, creating a path for the discharge gas to bypass the element. The oil level at the rack will fall until it runs out of oil. A clean element will have a 1 - 10 psi pressure drop. The element will need to be changed for a pressure drop reading of higher than 10 psi.

13.3.4. HOW SHOULD NORMAL OPERATION LOOK?

You should see a consistent pattern of oil detection and oil transfer in a functioning system (See Figure 1). If there are extremely large gaps in these functions and the reservoir oil level is low, troubleshoot the detection and transfer devices. The optical sensor has a red light when it is not indicating an oil level in the separator. When the indicator light is off it indicates the oil level is above the optical sensor and the solenoid is energized. The 2 pressure transducers used to measure oil separator pressure should be calibrated at the same time and read identical pressures when the compressors are not operating. CO_2 systems have more oil movement. To account for the oil fluctuations more oil than what is typically used in a similar size HFC system may be required.

APPENDIX

FIGURE 3: Typical Schematic Diagram

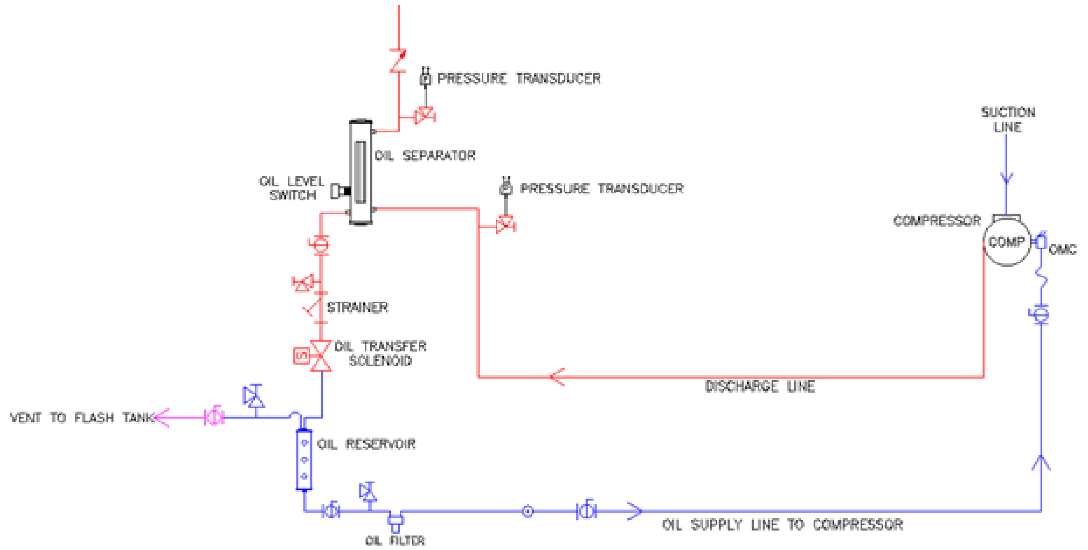


FIGURE 4: Oil Detection and Oil Transfer

Note: The top signal (red) is the oil solenoid output. The bottom signal (yellow) is the oil separator level switch. When the level switch is off (indicated by no illumination) it imitates an oil drain cycle.

TABLE 8: TROUBLESHOOTING TRANSCRITICAL CO_2 OIL SYSTEM		
Error	**Probable Cause**	**Solution**
No oil in reservoir	Gasket on the oil separator element has dislodged, separator no longer separating	Replace element in oil separator with a new element
	Oil leak or logging in other parts of the system	Check for leaks
		Check for logging of oil in evaporators or suction lines
	Restricted oil transfer solenoid or strainer	Investigate for failed components and replace defective components
High or low oil level in compressor	Issue with the compressor oil level control	troubleshoot the compressor oil level control

APPENDIX

Error	Probable Cause	Solution
Oil separator not functioning properly	Clogged or dirty oil separator element	Replace separator element
System is not functioning normally	Oil transfer components inoperable/defective	Investigate for failed components and replace defective components
		Check system programming for proper sequence of operations
Low pressure drop	Gasket/Filter blowout	Replace Gasket/Filter and service system
	Transducers not calibrated	Calibrate/repair transducers

TABLE 9: PREVENTATIVE MAINTENANCE	
Component	**Service Interval**
All Components	Service all components if contamination is present.
Oil	Test once a year for contamination
Oil Separator	Replace element after 10 psi pressure drop is measured or annually, whichever comes first
Oil Filter and Strainer	Service annually

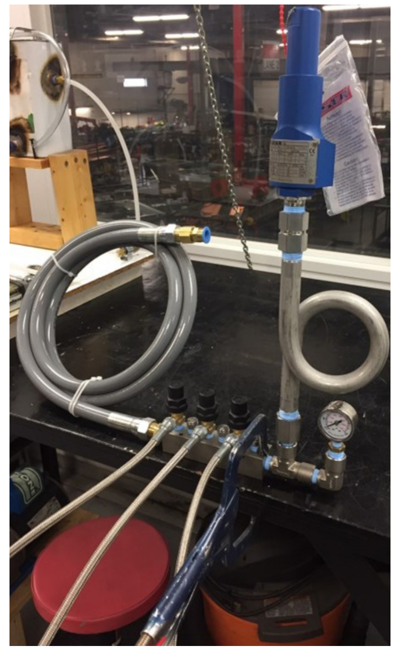
APPENDIX

13.4. CO_2 Rapid Charging Manifold

13.4.1. OVERVIEW

The CO_2 Rapid Charging Manifold is designed to reduce the amount of time required to charge a rack with CO_2 by providing a connection to the rack in which multiple cylinders (up to three) can be utilized for charging. At the same time, the manifold allows empty cylinders to be changed individually while the remaining cylinders continue to feed CO_2 to the refrigeration rack.

FIGURE 5: Rapid Charging Manifold Equipment



13.4.2. COMPONENTS

- Components are rated for 2000 psig or better.
- The relief valve is rated for 90-bar or 1305 psig.
- Typical CO_2 cylinder pressure at room temperature (~70F) is 860 psig. This fluctuates with temperature.
- CO_2 cylinders with dip tubes are preferred to use with the tool. Cylinders should be properly restrained to meet OSHA standards.
- If system pressure is below 100 psig an initial vapor charge must be performed. This prevents dry ice from forming in the refrigeration system.
- Care should be taken to point the relief in a safe direction during use to protect personnel and sensitive equipment

DANGER! TECHNICIANS SHOULD BE USING APPROPRIATE PERSONAL PROTECTION EQUIPMENT DURING USE.

DANGER! VERIFY ADEQUATE VENTILATION BEFORE USE OF THE RAPID CHARGING MANIFOLD. CO_2 CAN DISPLACE OXYGEN RESULTING IN INJURY OR DEATH DUE TO ASPHYXIATION.

APPENDIX

13.4.3. HOW TO CHARGE

1. Locate the charging port to be used on the rack. The large 5/8” hose off the manifold will attach to the charging port (do not open charging port). Provided are adapters that reduce from 5/8” flare on the hose down to 3/8” flare (**See Figure 6**). Verify the angle valves on the manifold are closed. **DO NOT** open any valves.
2. Secure the manifold before use. This will prevent movement in a relief event, and maintain the relief valve in a vertical position. This can be achieved by using a C- channel clamp (**See Figure 7**) or a more permanent solution can be made by utilizing the mounting holes in the manifold block (**See Figure 8**).

FIGURE 6: Rapid Charging ⅜" Adapters

FIGURE 7: Temporary Manifold Installation

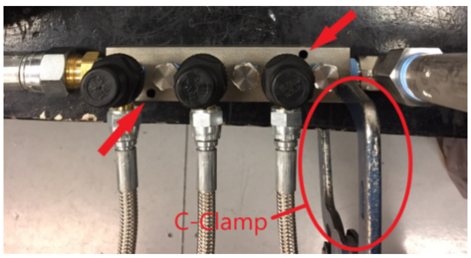
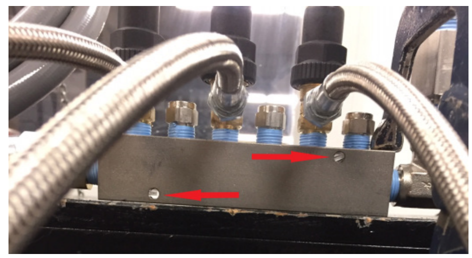


FIGURE 8: Permanent Manifold Installation



3. Gather CO_2 cylinders for charging. Cylinders with dip tubes are recommended. Cylinders should be weighed to record the amount of CO_2 is charged into the system. Connect the cylinder adapters to the bottles; DO NOT open the CO_2 cylinder yet. Verify the cylinder adapter ball valves are closed.
4. Crack open one of the connected CO_2 Cylinders to pressurize the manifold and lines. Open the angle valves on the manifold. Purge CO_2 through the manifold and lines. Once purged, close all charging manifold valves (Angle valves, cylinder adapter ball valves). Check to make sure system pressure is not above the 1305 psi relief setting. Open the charging port on rack. Open the angle valves that have CO_2 cylinders connected. Open the CO_2 cylinders to charge the system.

DANGER! KEEP THE OUTLET OF THE RELIEF VALVE POINTED IN A SAFE DIRECTION. FAILURE TO DO SO MAY CAUSE INJURY.

5. Monitor system pressure and refrigerant level during charging. DO NOT overcharge the system. DO NOT let pressure go over the 1305 psig relief setting. Keep the outlet of the relief valve pointed in a safe direction (**See Figure 9**).

FIGURE 9: Safety Relief Valve

13.4.4. HOW TO CHANGE AN EMPTY CYLINDER DURING CHARGING

1. Close the associated angle valve at the manifold.
2. Close the cylinder valve
3. Bleed off the pressure using the ball valve on the cylinder adapter.
4. Change the empty cylinder
5. Purge the line using the ball valve on the cylinder adapter. Close the ball valve once purged.
6. Open the angle valve and continue charging.

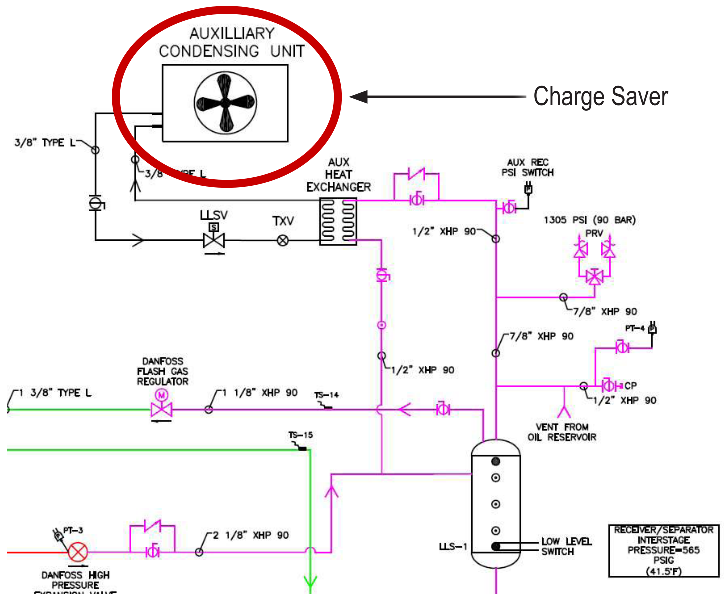
13.4.5. TO REMOVE THE CHARGING MANIFOLD

1. Close the charging port on the rack
2. Close the cylinder valves.
3. Open the angle valves on the manifold.
4. Remove the manifold.

APPENDIX

13.5. CO_2 Charge Save: Application/Best Practices

FIGURE 10: Charge Saver Schematic



13.5.1. OVERVIEW

CO_2 refrigeration systems present unique challenges not typically seen in a system utilizing traditional refrigerants (HFC, HCFC, Etc.). Due to the higher operating pressures associated with CO_2 systems and lower system design pressures, refrigerant loss (through relief) can be a more common occurrence in situations you wouldn't normally see a loss with traditional refrigerant. Some of these scenarios include:

- Power Loss
- Rack emergency shutdown (certain scenarios)
- Rack controlled shutdown (maintain charge when off)

The "Charge Saver" auxiliary condensing unit is a great addition to a CO_2 refrigeration system to help combat an unwanted partial or complete loss of CO_2. It can be applied to subcritical (DX, & Pumped overfeed) and transcritical CO_2 refrigeration systems when the design pressure of components is less than associated saturated pressure of CO_2 at peak ambient conditions. The Charge Saver may not provide complete protection; however, it will cover a majority of situations where there is a high risk of complete CO_2 loss.

13.5.2. HOW THE CHARGE SAVER WORKS

How does the Charge Saver save the CO_2 charge? The Charge Saver condensing unit provides cooling directly to the receiver during times the when the refrigeration system is not able to run. In simple terms, it moves the lowest pressure point of the refrigeration system to the receiver, where the CO_2 charge can now migrate to the receiver vessel. The receiver can hold a large volume of refrigerant and the pressure can be maintained below the maximum design pressure of the receiver, thus preventing the relief valve to rupture due to excessive pressure.

Pressure, like temperature, will move from a higher pressure area to a lower pressure area in an effort to equalize. This property is what allows the CO_2 to move through the system eventually ending up at the receiver (The lowest temperature, lowest pressure point of the system due to the Charge Saver).

APPENDIX

13.5.3. DESIGN TIPS

Typical sizing of the charge saver condensing unit is 3 to 5% of the rack evaporator load, but no more than 10% unless extenuating circumstances exist.

- Medium Temperature Loads - 3%
  - Distributed field piping insulated properly and various loads that can be reduced by nearly 90% at time of main refrigeration system standstill.
  - Adjust capacity up to 10% if loads cannot be isolated. Requires exercise of judgement and analysis of system.
  - Direct expansion or Liquid recirculation applies.
- Low-Temperature Loads - 5%
  - Distributed field piping insulated properly and various loads that can be reduced by nearly 90% at time of main refrigeration system standstill. Adjust capacity up if loads cannot be isolated.
  - Adjust capacity up to 10% if loads cannot be isolated. Requires exercise of judgement and analysis of system.
  - Direct expansion or Liquid recirculation applies.
- Medium Temperature Self Contained (Chiller) - 1%
  - No field piping and chilled water flow is stopped at time of refrigeration system standstill.

13.5.4. REQUIREMENTS FOR SUCCESSFUL APPLICATION

- Power/Emergency power supply (generator).
- Run interlock must be present to prevent parallel run with the refrigeration rack.
- Pressure switch installed on vessel to monitor and control the cut-in/cut-out of charge saver condensing unit.
- Proper set point. The charge saver must be set below the lowest rated part of the system. (Lab example: low side of compressor rated to 410psi, the Charge saver should be set to a maximum of 375psi = cycle on@ 400psi cycle off at 350psi).
- Properly sized receiver. In a shutdown, the Charge Saver will draw CO_2 to the receiver. Receiver size is more critical to systems with long line runs and a large amount of loads. The receiver does not need to hold 100% of the charge. High pressure vapor has a high density and significant refrigerant charge can be held up in the field piping as a vapor.
- In a chiller application, the pumps on the Heat exchanger load must shutdown with the rack. If they stay running, it would cause a rapid pressure increase that the charge saver could not keep up with resulting in a relief.
- In an air coil application, the evaporator fans should shut down with the rack for best results.
- All heat producing items at the loads shut off if possible, including lights and or heaters.
- Isolation of the low side. Could be accomplished by EEV's with battery backup, liquid line solenoids, or manually (isolation valve).
- Loads that are at, or near set point during a shutdown assist the Charge Saver in maintaining CO_2 charge. The load turns into a "cold bank" that assists the CO_2 in a gradual, controlled pressure increase. *NOTE: Some medium temp loads could have operating set points that are above the low side component pressure ratings but would still provide a cold banking effect allowing the Charge Saver to gain control.
- Provide liquid CO_2/pressure a path to the receiver. If a path is not available, but the section could be isolated, a partial loss of refrigerant would occur.
- Pressure will take the path of least resistance back to the receiver. The path would typically be through the back check valves, but has also been confirmed it will push through Bitzer compressor valves.

13.5.5. SYSTEM COMPONENTS THAT AID CHARGE SAVER PERFORMANCE

- Back check valves
  - Back check valves provide a path to get to the charge saver. Having more paths for CO_2 to enter the Charge Saver leads to an increased chance to save CO_2.
- Battery back-up EEVs
  - The battery back-up EEVs allow the EEV to close in a power outage situation. Closing the EEV isolates the low-pressure side of the system and reduces the risk of a safety relief event.
- High stand-still pressure rated compressors and low side piping
  - Higher pressure rated components give the Charge Saver more time to respond and bring the pressure under control (depending on system set points).
- Regulating reliefs
  - Regulating reliefs allow CO_2 to self-refrigerate upon relief. This self-refrigeration action assists the Charge Saver in pressure reduction with minor CO_2 loss.

13.5.6. CHARGE SAVER USE SCENARIOS

TABLE 10: CHARGE SAVER USES [1]		
GOOD [2]	MARGINAL [3]	BAD [4]
Power loss	Fans on during rack shutdown (air coil)	Condenser/gas cooler failure
Maintain charge in off cycle	Pumps on during rack shutdown(chiller, low side is able to be isolated)	Rack failure during startup/ pulldown (high load)
Initial charging of CO_2 at startup	Receiver not sized to handle full system charge	External leak
Emergency rack failure (causing complete shutdown)	System design: Sections are able to be isolated from the Charge Saver and receiver.	Pumps on during rack shutdown (chiller, low side not able to be isolated)

Notes:
1. These are generalized scenarios; each rack should be analyzed for specific issues on a case by case basis.
2. High likelihood of saving and maintaining the CO_2 charge.
3. Will maintain the majority of the charge. Some refrigerant loss is expected.
4. Bad: Results will be poor. There is a high likelihood of losing the majority of the charge.

13.5.7. AFTER A CHARGE SAVER EVENT

Note: Review the system design before the event can occur. Have a good understanding of where liquid CO_2 will be and where it will want to go in a shutdown situation. Each system will be unique, preparedness and planning will be your best defense to prevent catastrophic CO_2 loss.

1. Verify the Charge Saver has power and turns on. A generator is necessary for a power outage.
2. Ensure components that increase and drive the load (Evaporator fans and pumps) are powered off.
3. Refrain from door openings on the load. The exception to this is if the product is sensitive, or a known extended shutdown occurs which requires relocation of the product. Door openings will introduce unnecessary heat and minimize the “cold bank” effect. This will cause a rapid increase of pressure that could overwhelm the Charge Saver and result in a relief of CO_2.
4. Isolate the low side of the system. This could be achieved automatically if equipped with an EEV with battery backup or a liquid line solenoid. If not equipped, manually isolate the low side of the system.
5. Monitor pressures and receiver level until system re start. Because the Charge saver draws CO_2 to the receiver it can achieve a high level during extended shut down periods.
6. Initiate start up sequence once shutdown conditions are corrected and the rack is able to be put back into service.
7. Verify the system charge level once system is up and running.

13.6. Rack Vibration Testing

13.6.1. BACKGROUND

Excess vibration in refrigeration systems, specifically at the compressor, can result in costly failures. Vibration in the system is excited by the motion of the electric motor inside the compressors. The frequency (typically referred to in Hertz (hz) or cycles/second) of vibration caused by the electric motor is dependent on the frequency of the alternating current (AC) voltage applied to the coils of the motor. Systems that use a variable frequency drive (VFD) experience a variety of AC frequencies typically ranging from about 30 hz to 60 hz. This changing frequency results in different levels of vibrational amplitude (measured in mils or thousandths of an inch) throughout the span of the VFD.

The process of limiting excessive motion in refrigeration systems involves two steps: determine the VFD speeds (frequencies) that present excess vibrational amplitude and eliminate the guilty frequencies from the span of the VFD.

13.6.2. CATEGORIZING VIBRATIONAL AMPLITUDES

A standard has been established with discreet thresholds to categorize vibrational amplitude. A standard is necessary to allow comparison between systems and provide concrete data about the behavior of a system.

- Four categories classify the vibration.
  - Excessive vibration: More than 50 mils of peak-to-peak displacement. Imminent failure is pending.
  - Moderate vibration: 25-50 mils of peak-to-peak displacement. Failure is likely to occur.
  - Light vibration: 15-25 mils of peak-to-peak displacement. Failure may or may not occur, but mitigation efforts are required.
  - Minimal vibration: Less than 15 mils of peak-to-peak displacement. Failure is not likely to occur.

13.6.3. DETERMINING THE PROBLEM FREQUENCIES

To determine the frequencies that result in excess vibration, testing, and careful observation must be performed. The general process involves manually setting the speed of the VFD and slowly progressing through the span, noting any frequencies that exhibit excessive vibration.

The exact process for manually setting the VFD speed is dependent on the manufacturer of the VFD. For specific instructions, refer to the attachments to this memo.

The process for measuring the vibration can be found in Appendix 1 and Appendix 2 depending on the type of vibration sticker being used.

APPENDIX

Steps to determine problem frequencies:

1. Set the VFD speed to the minimum frequency
2. Slowly increase the speed (2 hz at a time should be sufficient)
3. Note the vibrational amplitude every 5 hz
4. If any frequency shows Light, Moderate, or Excessive vibration (as detailed in the Categorizing Vibrational Amplitudes section) note the frequency
   A. Continue slowly increasing/decreasing the VFD frequency by 1 hz to identify the complete frequency range that causes undesierable vibration, noting each speed and amplitude
   B. When the vibration amplitude leaves the Light, Moderate, or Excessive range, resume noting the amplitude every 5 hz

Table 11 is an example of how data can be collected.

TABLE 11: VIBRATION DATA COLLECTION	
VFD SPEED (HZ)	**VIBRATIONAL AMPLITUDE**
30	<15
35	<15
36	20
37	25
38	20
39	<15
40	<15
43	25
44	20
45	<15
50	<15
55	<15
60	<15

In the example table, there was excessive vibration that appeared between 36 hz and 38 hz and 43 hz and 44 hz. It can then be said that the problem frequency ranges are 36-38 hz and 43-44 hz

Note: the bounds are inclusive of the "unsafe" frequencies only, the upper and lower limits should not be "safe" frequencies. No "safe" frequencies should be included in the limits.

13.6.4. ELIMINATING THE GUILTY FREQUENCIES

After determining the frequencies that drive vibrational amplitude outside of the acceptable range, the frequencies need to be addressed within the VFD parameters. Again, the specific process is going to differ by VFD manufacturer but the concepts are the same. For specific instructions, refer to the manufacturer's appendix.

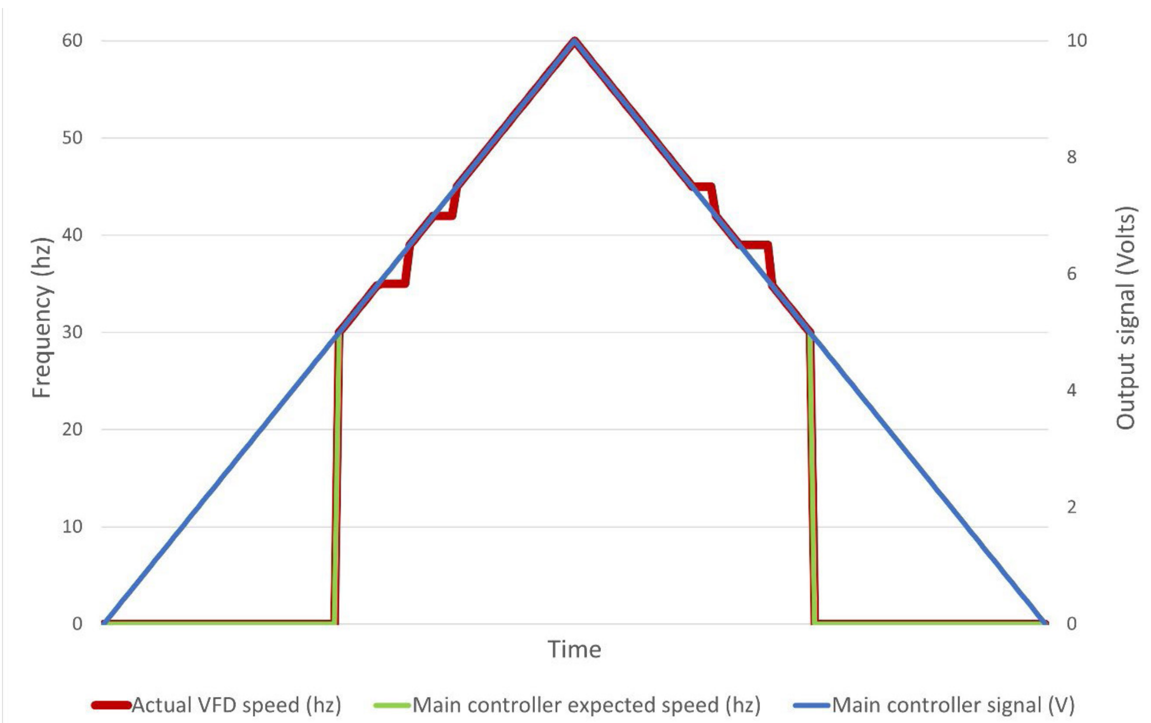
The guilty ranges in the example are 36-38 hz and 43-44 hz.

Once the proper parameters are adjusted on the VFD, the drive should no longer run within those frequencies in either Hand or Auto.

One thing to note is that the main controller (Emerson E2, Danfoss AK-SM 800A, or similar) will still attempt to set the speed to these blocked-off frequencies. The 0-10V signal from the main controller might be 7.2V (corresponding to a 43.2 hz at the drive) but that frequency is blocked off at the drive. If the speed is decreasing (running above 45 hz) the frequency of the drive will continue at 45 hz until the signal from the main controller drops below 7V (corresponding to 42 hz). Once the main controller tells the VFD to run at a speed that is not blocked off by the VFD parameters, the frequency will "jump" to that speed.

Figure 11 below for a visual representation of this behavior.

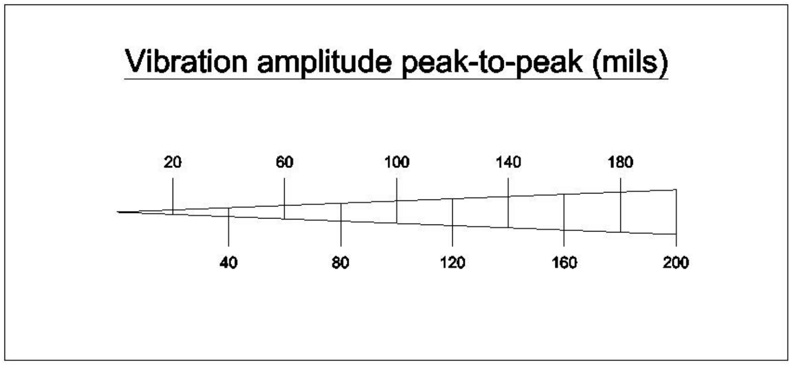
FIGURE 11: VFD Speed Control with Blocked Frequencies
35-39 hz and 42/45 hz skipped by VFD



APPENDIX

13.6.5. MEASURING VIBRATIONAL AMPLITUDE USING STICKER 1

FIGURE 12: Sticker 1

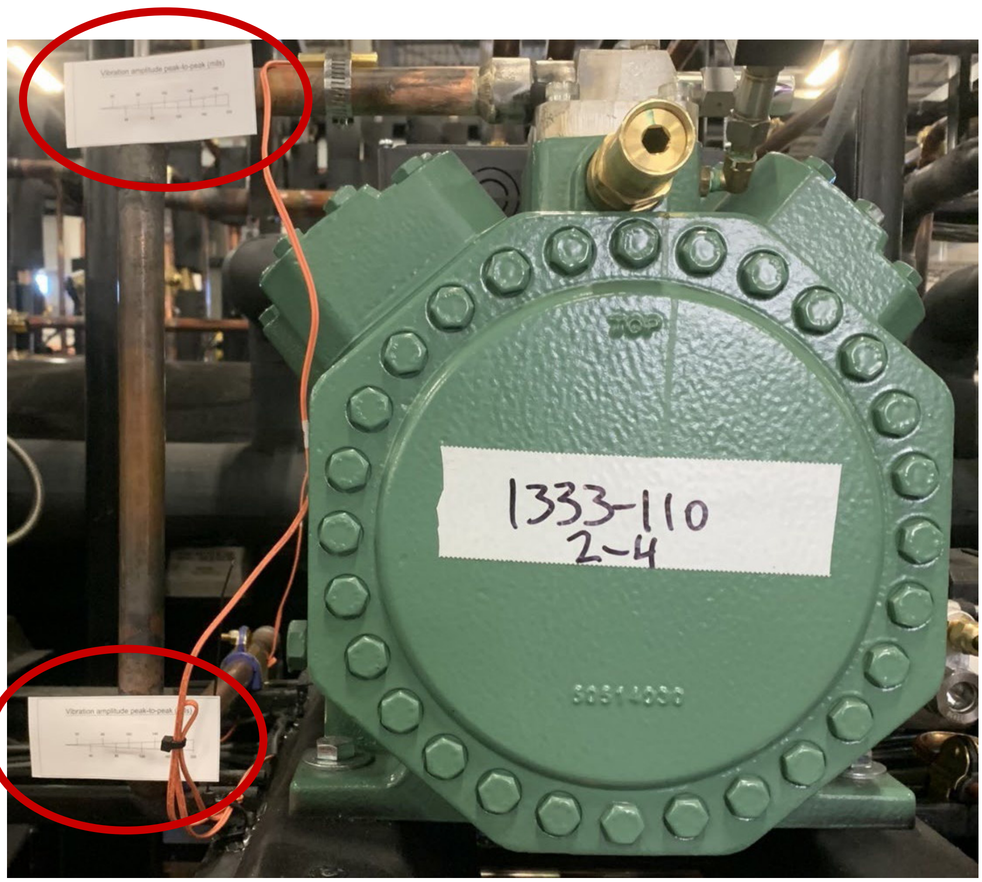


Determining an accurate vibrational amplitude is dependent on two things, proper placement and accurate reading.

Sticker 1 placement:

The compressor discharge line is an area of particular interest. If only one sticker is used, it should go on the discharge of the VFD compressor. More specifically, the sticker should be applied on one of the elbows of the discharge piping.

FIGURE 13: Sticker 1 Placement



APPENDIX

The placement of this sticker is critical. Ultimately the location and orientation of this sticker determine the vibration reading. The sticker can read vibration in one direction and one direction only.

The placement of this sticker is critical. Ultimately the location and orientation of this sticker determine the vibration reading. The sticker can read vibration in one direction and one direction only.

FIGURE 14: Sticker 1 Horizontal Orientation

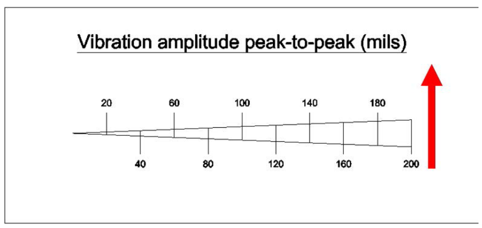
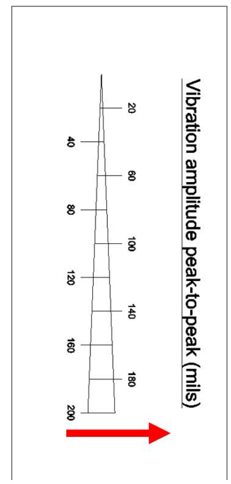


FIGURE 15: Sticker 1 Vertical Orientation

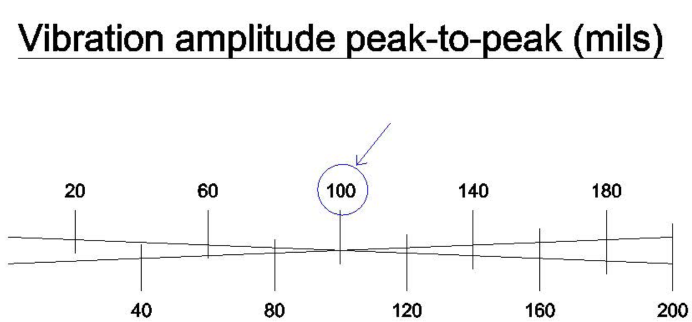


Horizontal vs. Vertical placement will give different readings.

Before placing the sticker, try to determine the direction of the largest motion. Many times it will be approximately vertical or approximately horizontal.

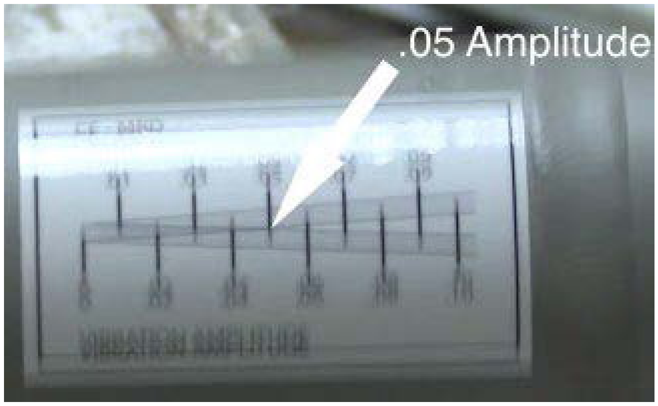
13.6.6. READING STICKER 1

FIGURE 16: Reading Sticker 1



Example reading. As the sticker vibrates, the lines will appear to meet at a point. This is the measurement.

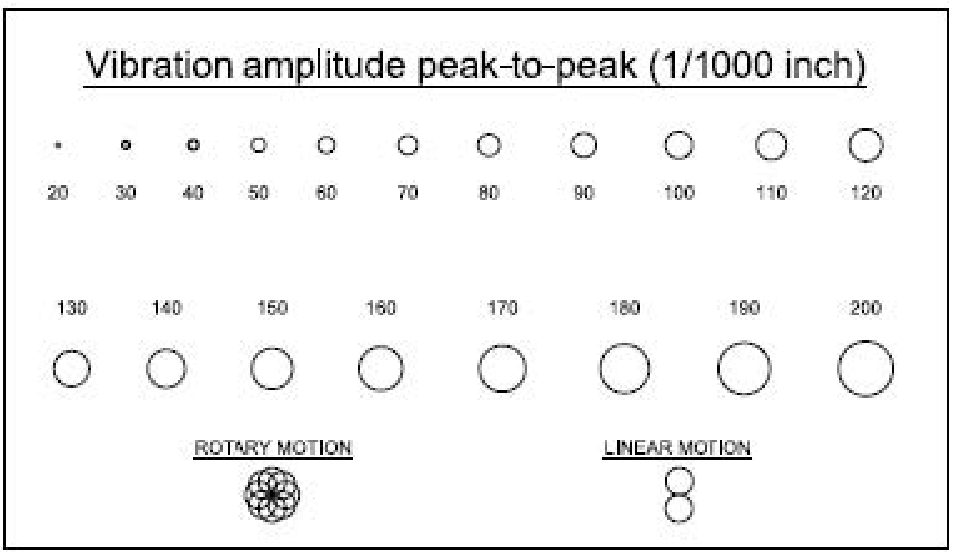
FIGURE 17: Amplitude Sticker 1



In each of these examples, the blurring of the lines gives the illusion that there is a point where the lines meet. The point where the lines appear to meet is the measurement of the sticker.

13.6.7. READING STICKER 2

FIGURE 18: Sticker 2



Determining an accurate vibrational amplitude is dependent on two things, proper placement and accurate reading.

APPENDIX

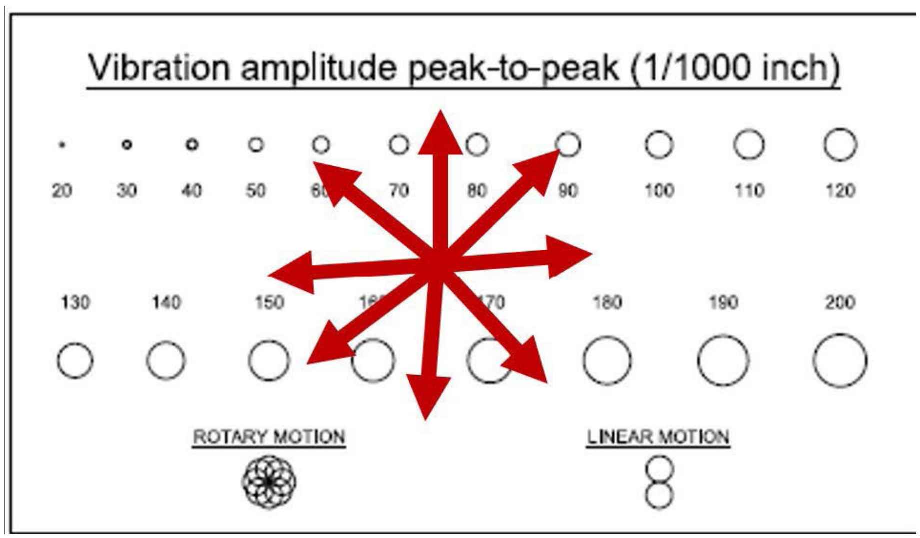
13.6.8. STICKER 2 PLACEMENT

The compressor discharge line is an area of particular interest. If only one sticker is used, it should go on the discharge of the VFD compressor (**See Figure 19**) . More specifically, the sticker should be applied on one of the elbows of the discharge piping.

FIGURE 19: Sticker 2 Placement

The placement of this sticker is critical. Ultimately the location and orientation of this sticker determine the direction of vibration read. The sticker can read vibration in any direction along the plane of the sticker.

FIGURE 20: Sticker 2 Motion



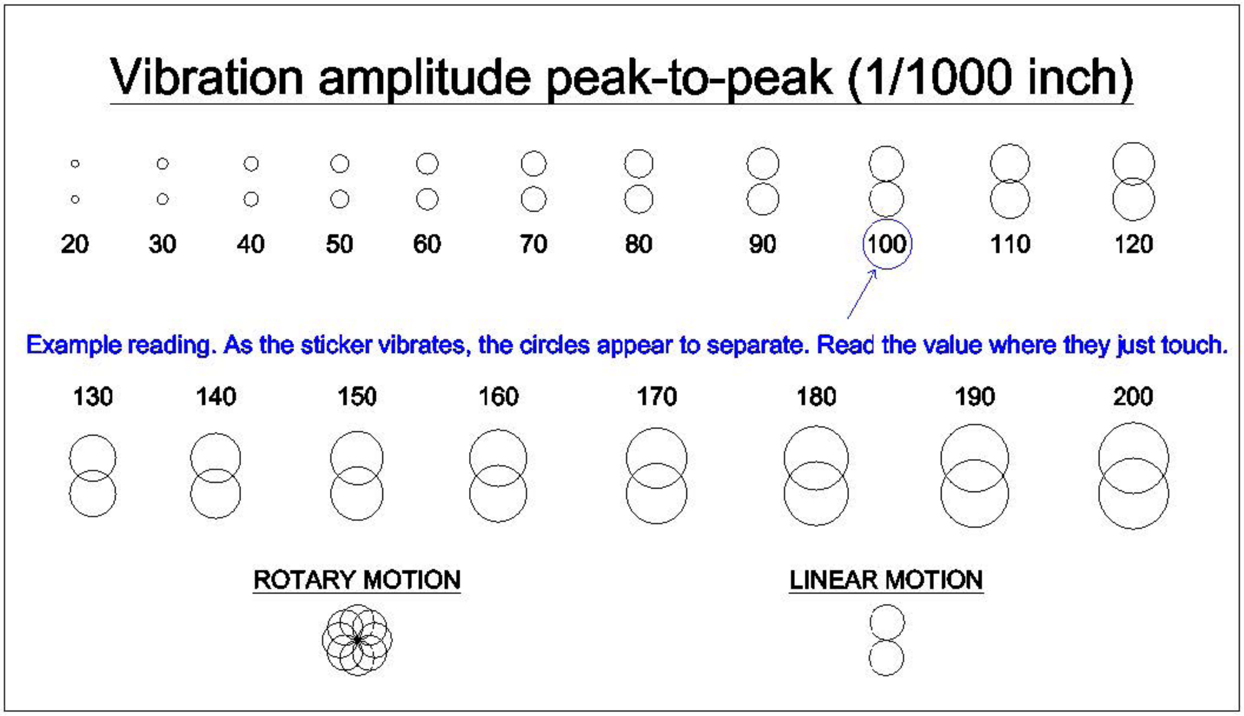
Vibration in the direction of any of the red arrows (or any other direction on the plane of the sticker) can be measured with the sticker in this setup.

APPENDIX

13.6.9. READING THE STICKER

The measurement of the sticker is read where the two circles are perfectly tangent to one another (**See Figure 21**). In other words, where the circles are just touching as shown on the bottom of the sticker.

FIGURE 21: Reading Sticker 2



Notice that the readings lower than the correct value are spaced out further and they do not touch or cross. Additionally, notice that the readings higher than the correct value are intersecting with one another.

The correct measurement, 100 mils, shows circles that are just barely touching but do not intersect.

13.7. Installation Procedure for all Fittings

13.7.1. INSTALLING REFFLEX HOSES

1. Refer to Doc IN-110 Refflex Hose Installation Instructions.
2. Mark a dot on flare nut with a black marker to indicate complete.
3. Perform pressure and leak test on assembly when installation is complete. Refer to Docs QA-017, QA-033, QA-036 and QA-041.

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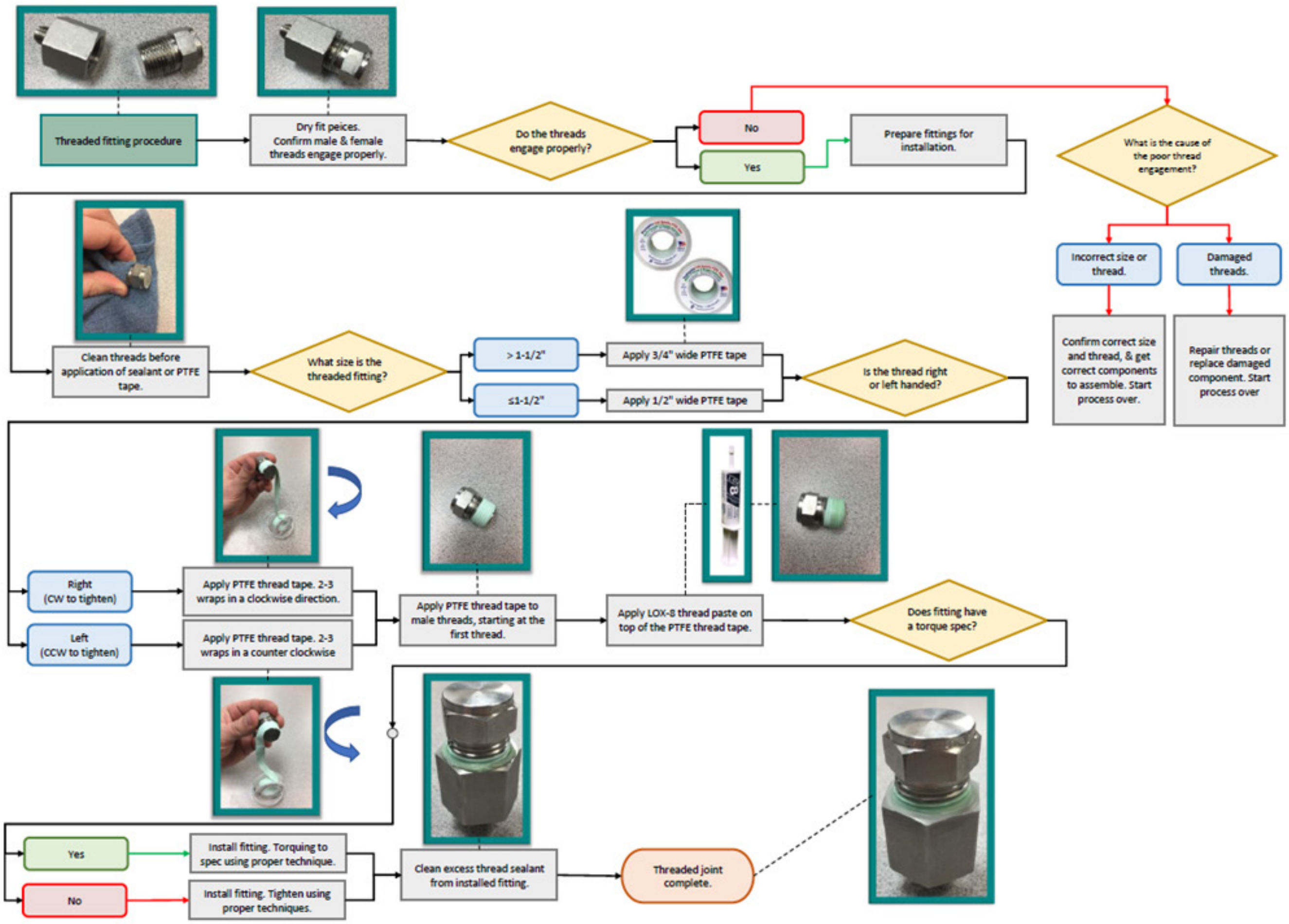
13.7.2. INSTALLING NPT THREADED CONNECTIONS

1. Inspect component part threads and fitting to ensure both are free from contaminants and burrs. Follow reject procedure for defective parts.
2. Proceed with following flow chart diagram (See Figure 23) applying PTFE tape and LOX-8 Thread Paste.

FIGURE 22: NPT Threaded Connections FLow Chart



3. Tighten with torque wrench per document IN-210.
4. Mark a dot on threaded connection with a black marker to indicate complete.

⚠ **CAUTION!** NEVER BACK OFF AN INSTALLED NPT CONNECTION TO ACHIEVE PROPER ALIGNMENT. LOOSENING INSTALLED PIPE FITTINGS WILL CORRUPT THE SEAL AND CONTRIBUTE TO LEAKAGE AND FAILURE. Perform pressure and leak test on assembly when installation is complete. Refer to Docs QA-017, QA-033, QA-036 and QA-041.

13.7.3. INSTALLING FLARE CONNECTIONS

1. Inspect flare fitting and nut for any deformities. Follow reject procedure for defective parts.
2. Apply a small amount of refrigeration oil to flare threads, flare sealing surface and tubing surface to
3. Prevent galling of sealing surface and aid in providing a tight seal.

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4. Screw finger tight, and then tighten with torque wrench per document In-210.
5. Mark a dot on flare nut with a black marker to indicate complete.
6. Perform pressure test and leak test on assembly when installation is complete. Refer to Docs QA-017, QA-033, QA-036 and QA-041.

13.7.4. INSTALLING ROTO LOC CONNECTIONS

1. Inspect male and female connections for cleanliness and any deformities. Follow reject procedure for defective parts.
2. Install Teflon gasket supplied with Roto Loc assembly.
3. Apply a small amount of refrigerant oil to threads and mating surface.
4. Screw finger tight then tighten with torque wrench per the following:
   - 1-1/8” = 40 ft lbs
   - 1-3/8” = 60 ft lbs
   - 2” = 120 ft lbs
   - 2-3/8” = 140 ft lbs
5. Mark a line across both sides of the connection with paint marker to indicate tightening complete.
6. Perform pressure test and leak test on assembly when installation is complete. Refer to Docs QA-017, QA-033, QA-036 and QA-041.

13.7.5. INSTALLING SWAGELOK FITTINGS

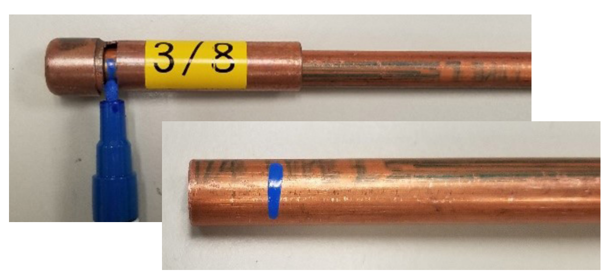
Note: A Swagelok Installation Tool Kit (See Figure 24) is required for Swagelok installation.

FIGURE 23: Swagelok Installation Tool Kit

1. Inspect fittings for any deformities. Follow reject procedure for defective parts.
2. Choose appropriate size pipe marking tool and paint marker from the kit. Place pipe marking tool over the pipe that fitting will be installed on, and mark the pipe through the gauge slot. See **Figure 24** and **Figure 25**.

FIGURE 24: Pipe Marking Tool and Paint Marker

FIGURE 25: Marking Insertion Depth



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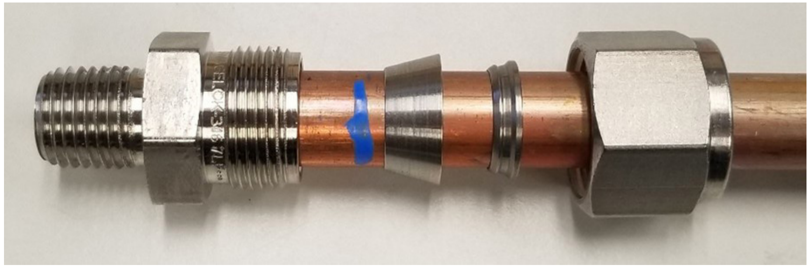
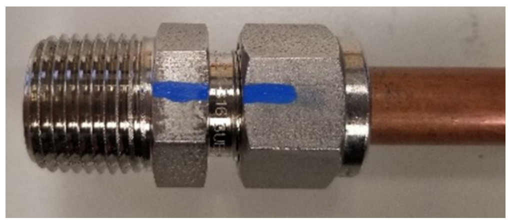
3. Place Swagelok fitting onto pipe and unthread to confirm ferrules are in proper orientation as shown in **Figure 26**.

FIGURE 26: Swagelok Fitting Parts and Assembly Orientation



4. Fully insert the tube into the fitting and against the shoulder. Rotate the nut finger tight. Mark the fitting and compression nut for rotation gauging (See Figure 28) in the next step.

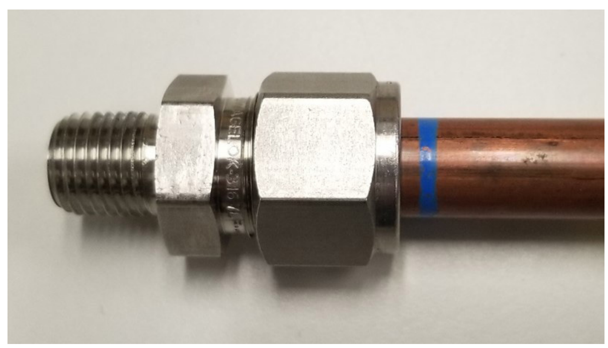
FIGURE 27: Swagelok Marked Rotation



5. While holding the fitting body steady, tighten the nut a full 1 & 1/4 rotations.

FIGURE 28: Swagelok Properly Tightened

FIGURE 29: Swagelok Not Fully Inserted



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6. Position the Swagelok gap inspection gauge next to the gap between the nut and body.
   - If the gauge will not enter the gap, the fitting is sufficiently tightened (**Figure 30**).
   - If the gauge will enter the gap, additional tightening is required (**Figure 31**).
7. Turn nut ¼ turn and check gap
8. Distance with gap gauge. If the gauge will not enter the gap, the fitting is sufficiently tightened.
9. Repeat tightening until gap gauge will not enter the gap.

FIGURE 30: Swagelok Go

FIGURE 31: Swagelok No-Go

10. Perform pressure test and leak test on assembly when installation is complete. Refer to Docs QA-017, QA-033, QA-036 and QA-041.

Note: it is not necessary to remove the compression cap and disassemble the compression fitting for installation. However please inspect the assembly to ensure both ferrules are present.

For other technical support, please refer to
the Technical Resources page at:

WWW.ZERO-ZONE.COM

or contact the Zero Zone Service Department at:

800-708-3735

All specifications subject to change without notice.

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