ECO2Large
I & O MANUAL
75A10837

CO_2 TRANSCRITICAL

ECO_2 Large

INSTALLATION AND OPERATION MANUAL

KYSOR WARREN
eptarefrigeration

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01 MANUAL DISCLAIMER

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MANUAL DISCLAIMER

1.1. MANUAL DISCLAIMER

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- to the extent that this Manual is provided free-of-charge, for any direct loss;
- for any indirect, special or consequential loss; or
- for any business losses, loss of revenue, income, profits or anticipated savings, loss of contracts or business relationships, or loss of reputation or goodwill.

These limitations of liability apply even if Kysor Warren Epta US has been expressly advised of the potential loss.

NOTE

Installation and maintenance to be performed only by qualified personnel who are familiar with local codes and regulations, and experienced with this type of equipment. Sharp edges and coil surfaces are a potential injury hazard. Avoid contact with them.

WARNING

There may be more than one source of electrical current in this unit. Do not service before disconnecting all power supplies.

WARNING

All pertinent electrical codes and regulations must be strictly followed any deviations from these requirements will be strictly the responsibility of the installer.

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02 ECO_2 LARGE SYSTEM

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ECO_2 LARGE TRANSCRITICAL BOOSTER SYSTEM

2.1. INTRODUCTION

This manual provides information on the ECO2 Large pack including installation, inspection, start-up and service of the system. Additional specifications may include:

- Schedule / Legend of Equipment Load and Electrical Requirements
- Configuration Overview and List of Options ordered
- Sequence of Operations
- Specifications of Components
- Specific Piping Diagram

The manual disclaimer located on Page 4 is also posted on the Kysor Warren Epta website.



Figure 2-1. Example of schedule/legend of equipment load

NOTE

Customer specifications and local codes take precedence over directions contained in this document. Installation and service that do not comply with this manual may lead to poor performance or reliability, and will void the equipment warranty. Changes to the additional specifications (above) that are not approved by KWE will void the warranty of the system. Contact your KWE representative to verify the most current version of this manual.

2.2. SYSTEM OVERVIEW

The ECO_2 Large System provides customers with a cost effective solution for supermarket refrigeration. These systems use naturally occurring, environmentally friendly, and energy efficient CO_2 refrigerant. CO_2 has a Global Warming Potential (GWP) of 1, zero Ozone Depletion Potential (ODP), and therefore is environmentally friendly and is in compliance with federal environmental regulations



Figure 2-2. Front of an ECO2Large Refrigeration System

This system utilizes CO_2 as a refrigerant in a direct expansion (DX) mode on the evaporators to achieve cooling both for medium temperature (MT) and low temperature (LT) loads.

A transcritical refrigeration system uses two-stage compression. The first-stage compression discharge is connected to the second stage suction in order to boost the second stage suction pressure.

The system cycle is transcritical because in high ambient temperatures, the heat rejection occurs at pressures and temperatures above the refrigerant's critical point. For CO_2, the critical point is 87.8°F (31.0°C) and 1070 psig (73.8 bar). The high side operating pressure in CO_2 transcritical systems is higher than conventional CO_2 systems - typically, up to 103 bar (1500 psig).

Liquid CO_2 at temperatures around 36.0°F (2.2°C) is distributed throughout the store with insulated piping to provide cooling for each refrigerated case or walk-in box.

- Electronic expansion valves (EEV) control temperatures by metering refrigerant flow into evaporator coils.
- Suction gas from the LT loads returns to the LT compressors on the CO_2 parallel rack.
- The gas is compressed to the same pressure as the suction line coming from the MT cases. It is then combined with the medium temperature suction gas and any gas coming from the flash tank.
- The mixture then enters the medium temperature compressors where it is compressed and routed to the Gas Cooler for heat rejection (gas cooling or condensation).
- Upon exiting the Gas Cooler, the refrigerant passes through a high pressure electronic expansion valve (EEV) where the pressure and temperature are reduced to enter the Flash Tank.
- In the flash tank, the gas that is generated during the pressure reducing process is separated from the liquid.
- The residual gas is routed through a Flash Gas Bypass Valve back to the MT compressors.
- The liquid refrigerant is piped to the MT and LT electronic expansion valves.
- The cycle is then repeated. Figure 2-3 displays a schematic of this cycle.

2.2.2. EXPLANATION OF CO_2 TRANSCRITICAL BOOSTER REFRIGERATION CYCLE

Using the numbers in Table 2-2, the pressures are shown for each step in Figure 2-3 explains each step.

WORKING AND DESIGN PRESSURES FOR A CO2 TRANSCRITICAL REFRIGERATION SYSTEM

	Description	Working Pressure	Components	Design Pressure
	Low side	188 to 218 psig (13 to 15 bar)	LT Cases, LT Suction Piping	435 psig (30 bar, 28 bar for scroll compressors)
	IM Press Stage – MT Suction	377 to 435 psig (26 to 30 bar)	MT Cases, LT Compressors, MT Suction Piping, LT Discharge Piping	652 psig (45 bar, 43 bar for scroll compressors)
	IM Press Stage – Liquid Line	493 to 551 psig (34 to 38 bar)	Flash Tank, FGBV, FG EEV, Case EEVs, Liquid Supply Piping	652 psig (45 bar)
	High side	652 to 1495 psig (45 to 103 bar)	Gas Cooler, HPEV, MT Compressors, MT Discharge Piping	1740 psig (120 bar)

Table 2-2. Working and Design Pressures for a CO2 Transcritical Refrigeration System

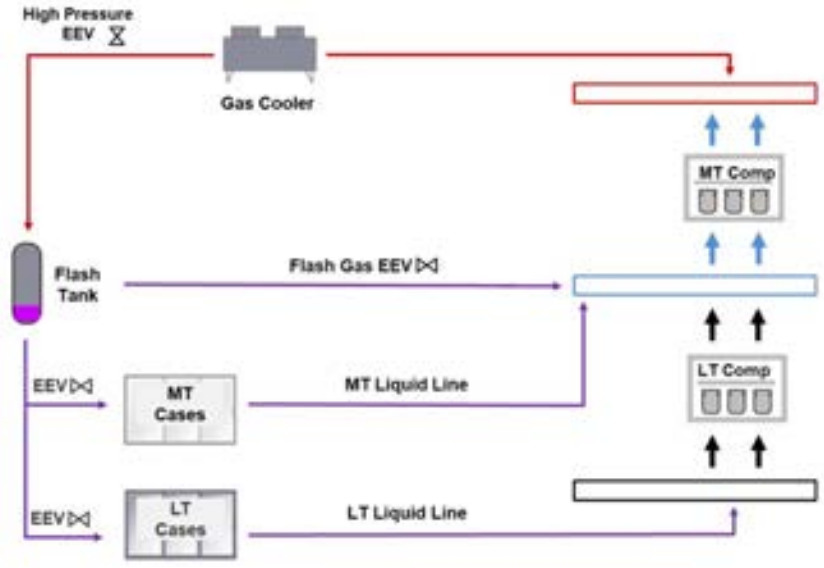

Figure 2-3. Schematic of a CO_2 Transcritical Refrigeration System

2.2.1. REFRIGERATION CYCLE

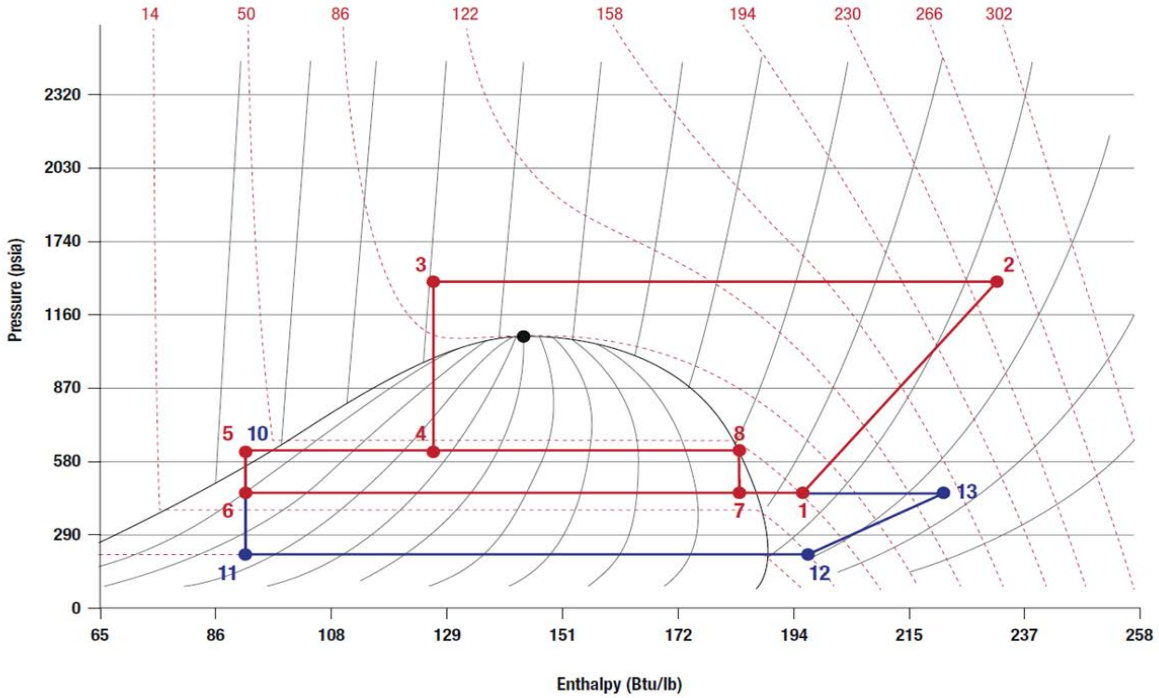

Figure 2.4. CO_2 Pressure – Enthalpy Chart with an Example Refrigeration Cycle

Figure 2.3, Figure 2.4, and Table 2.1 show the CO_2 transcritical system refrigeration cycle. Figure 2.4 superimposes the state of the CO_2 refrigerant on a pressure-enthalpy (p-h) diagram as it cycles through the system. The numbers on the diagram correspond to the numbers in Figure W-5.

Sequence	
1 to 2	The vapor refrigerant is compressed by the MT compressors and discharged to the gas cooler. Some residual heat is added by the compressor as is performs work on the gas.
2 to 3	The vapor refrigerant flows through the gas cooler rejecting heat to the environment.
3 to 4	Expansion across the high-pressure valve (HPV) (stepper expansion valve). The HPV holds back pressure on the gas cooler and maintains a lower pressure in the flash gas tank.
Flash Gas Tank (FGT)	The refrigerant received into the FGT is a liquid-vapor mixture. The liquid settles to the bottom to feed the evaporators. The vapor is directed to the MT suction group and recompressed.
4 to 5	This line represents the enthalpy difference between the refrigerant mixture and the portion that settles out remaining a liquid.
4 to 8	This line represents the enthalpy difference between the refrigerant mixture and the part that settles out into a vapor.
5 to 6	The liquid refrigerant is metered by the electronic expansion valve (EEV) into the MT evaporators, subjecting it to the MT suction pressure.
6 to 7	The liquid expands in the MT evaporator boiling it into a vapor gaining heat.
7 to 1	The super heat region ensuring all liquid is boiled off protecting the MT compressors form liquid slugging.
8 to 7	The flash refrigerant vapor from the top of the flash gas is metered into the MT suction via the flash gas bypass valve (FGBV)
10 to 11	The liquid refrigerant is metered by the EEV into the LT evaporators, subjecting it to the LT suction pressure.
11 to 12	The liquid expands in the LT evaporators boiling into a vapor gaining heat.
12 to 13	The vapor refrigerant is compressed by the LT compressors and discharged to the MT suction. The MT suction will then finish the compression needed to reach the required gas cooler pressures. The LT compressors also add residual heat from doing work on the refrigerant.
13 to 1	This line represents the mixing of gases resulting in a lower enthalpy point. Note that the volume of LT gas is grossly smaller than that of the MT gas.

Table 2-1. The Cycle of the CO_2 Transcritical Refrigeration System

2.3. PRIMARY COMPONENTS AND SUBCOMPONENTS

The ECO_2 Large Transcritical Rack is comprised of the following subsystems:

- LT compressor module
- MT compressor module
- Refrigerant management module
- Oil management module



Figure 2-7. Primary Modules and Components for a CO_2 Transcritical Refrigeration System













This series of pictures represents the journey of an ECO2Large Refrigeration System from being assembled in our Systems Plant to being delivered and installed in the field.

2.3.1. LT COMPRESSOR MODULE

The low temperature (LT) compressor group:

- Compresses the return gas to the same pressure as the MT compressor suction.
- The compressors can be either semi-hermetic reciprocating or hermetic scroll type compressors
- This compressor group is controlled to a pre-defined suction pressure set point.
- A variable frequency drive (VFD) is included on the lead LT compressors for a smoother capacity control when semi-hermetic compressors are used. When using hermetic scrolls, a digital compressor can be used for capacity modulation.

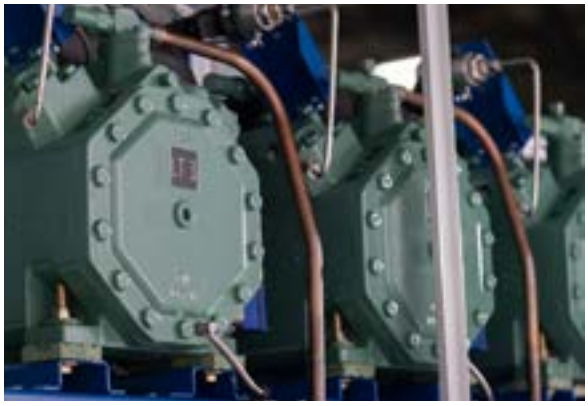

Figure 2-8. Low temperature compressor (LT)

2.3.2. MT COMPRESSOR MODULE

- The medium temperature (MT) compressor group elevates the pressure of the combined flows coming from the MT loads, LT compressor group discharge, and Flash Gas Bypass line up to the gas cooler pressure level.
- The type of compressor used in all designs for KWE products are semi-hermetic reciprocating compressors.



Figure 2-9. Medium temperature compressor (MT)

These compressors are typically designed to withstand pressures exceeding the system design pressures of **1740 psig (120 bar)** on the high side, and **652 psig (45 bar)** for the Intermediate Pressure Stage.

- Capacity control of this compressor group is attained by maintaining a pre-defined suction pressure set point according to design conditions and by staging compressor capacity.
- Depending on compressor model digital capacity control is employed.
- Either a VFD or digital control is offered for capacity control.

2.3.3. REFRIGERANT MANAGEMENT MODULE

This module manages the high side pressure, the flash tank pressure, the refrigerant storage, and liquid-vapor separation. It is made up of a High Pressure Expansion Valve (HPEV), Flash Tank, Flash Gas Bypass Valve (FGBV), and interconnecting piping.

HIGH PRESSURE EXPANSION VALVE (HPEV)

The HPEV is an electronic expansion valve responsible for controlling the gas cooler outlet pressure in transcritical operation mode for optimum energy efficiency.

This valve also is responsible for reducing the pressure of the CO_2 coming out of the gas cooler to the flash tank pressure levels. During this pressure reducing process, a colder vapor-liquid mixture is encountered at the outlet of the valve.

Depending on ambient temperatures the vapor fraction in this mixture can be as high as 45-55%.



Figure 2-10. High Pressure Expansion Valve (HPEV)

FLASH TANKS

Flash tanks are pressure vessels like a receiver in a standard HFC refrigeration system. They:

- Hold the refrigerant charge to 3 to guarantee proper operation of the system throughout the entire change of seasons in a year.
- Physically separate the refrigerant liquid and gas phases so that only the liquid is sent to the loads and the vapor can be redirected to the MT compressor suction through FGBV.
- A vertical flash tank is the standard design due to its effectiveness in phase separation.



Figure 2-11. Flash tank

FLASH GAS BYPASS VALVE (FGBV)

A flash gas bypass valve (FGBV) is an expansion valve that controls the flash tank pressure.

- It opens or closes according to a set point.
- If the amount of flash gas increases or decreases due to ambient conditions, the pressure in the tank will fluctuate around the set-point.



Figure 2-12. Flash Gas Bypass Valve

2.3.4. OIL MANAGEMENT

Oil is essential for the reliability of the compressors in a refrigeration system as well as lubricating seals. As compressors pump refrigerant they also pump a small amount of oil with it. The volume of oil in refrigerant lines and heat exchangers displaces refrigerant volume, and reduces the efficiency of the system. To avoid trapping oil in other parts of the system and depleting the oil level in the compressors, it is important to recover it and properly return it to the compressor crankcase. However, we do not want to remove all of the oil as it is still needed to lubricate the various valves and other components throughout the system.

The oil management system of Kysor Warren ECO2 racks includes an oil separator with electronic oil management at the discharge side of the MT compressors group. Also included in this module are: an oil reservoir, an oil filter and electronic oil level regulators for replenishing the oil according to the demand by each individual compressor.

A coalescing type oil separator is used to provide very high efficiency oil recovery. The oil reservoir is a standard pressure vessel for oil storage and supply to the compressor crankcase. The electronic oil level regulators use a level switch mounted at the sight glass port of the compressor to detect the oil level inside of the compressor. When the oil level falls below the sensor, a solenoid valve opens allowing oil flow to the compressor crankcase.



Figure 2-13. Oil reservoir



Figure 2-14. Coalescing oil separator

The oil separator are rated for **1740 psig (120 bar)**.

REMOTE GAS COOLER/CONDENSER

The gas cooler cools the refrigerant, which is above the critical point of 88 F degrees, to near ambient temperature. Above the critical point, CO_2 gas does not condense, so there is no phase change. The CO_2 remains as a single phase gas from the inlet to the outlet as the temperature is reduced. Gas coolers come in different forms and functions. The most commonly used are air cooled gas coolers. Systems in dry climates could benefit by adding evaporative assisted cooling. The efficiency of any gas cooler varies with the climate. At lower ambient temperatures, when CO_2 is below the critical point, a gas cooler operates as a conventional condenser and phase change occurs from vapor to liquid.



Figure 2-15. Remote gas cooler/condenser

2.4. OPTIONAL COMPONENTS

CO2 CHARGE PROTECTOR (TM)

The optional CO_2 Charge Protector (CCP) Unit (TM) functions as auxiliary pressure control device for the flash tank in case of main power outage. It runs off of the main electrical power and backup power (generator) during power outages. Although the flash tank is properly insulated, heat transfer will occur from the surrounding atmosphere and into the flash tank. When the CO_2 inside the flash tank absorbs heat, vapor is generated causing pressure to rise. The purpose of CCP is to keep the pressure inside the flash tank below the relief valve setting(s).



Figure 2-16 CO_2 Charge Protector™

FULL TRANSCRITICAL EFFICIENCY (FTE) UNIT (™) (OPTIONAL)

The Full Transcritical Efficiency (FTE TM) energy efficiency module creates more useful work on the cases, reduces the MT compression ratio, and can serve as an additional reservoir for refrigerant during system pump down. The FTE tank operates on the low pressure side and allows the elimination of superheat (SH) on the MT cases. The additional liquid generated from the flooded MT coils will be separated in the FTE tank and used to feed the LT case evaporators. Specific FTE I&O materials are available for this optional module. FTE 1.0 is a separate module from the rack.



Figure 2-17 Full Transcritical Efficiency (FTE) UNIT™

EXTREME TEMPERATURE EFFICIENCY (ETE) UNIT (™) (OPTIONAL)

The XTE Unit (™) energy efficiency module employs a pressure exchanger, subcooler, pressure reducing valve, and extra circuit in the gas cooler to lower the vapor's pressure and temperature entering the flash tank, increasing liquid production with less compression work, thus reducing the system's energy needs



Figure 2-18 Extreme Temperature Efficiency (ETE) UNIT™

NOTES:

03 SAFETY

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SAFETY

KWE highly recommends that clients using these products have a strong safety program. The keys to the safe operation of a refrigeration system are:

- A visible and vigorous safety program
- The installation and operation of the system with all safety concerns recognized, evaluated and incorporated.
- Well trained and competent operators.

3.1. GENERAL SAFETY CONSIDERATIONS

- The installation, commissioning, maintenance and disassembly must be carried out by trained and qualified personnel with sufficient knowledge of this type of equipment.
- When maintenance is performed, equipment is pressurized with dry air or inert gas.
- All equipment piping must be evacuated before charging the system with refrigerant.
- Make sure that all field wiring conforms to the requirements of the equipment and all applicable national and local codes.
- Avoid contact with sharp edges and coil surfaces. They are a potential injury hazard.
- Before working on the system, make sure all power sources are disconnected.

3.2. ON SITE WARNING SIGNAGE

Owners are responsible for display of cautionary / safety signage. Caution signage should be installed on the premise at entrances to the equipment room or areas near installed equipment.



Figure 3-1. Examples of cautionary and safety signage

3.3. PERSONAL PROTECTIVE GEAR

Technicians and support staff are responsible for using proper protective gear. It is recommended that all staff working on this type of installation to use the personal protective equipment (gloves, glasses and safety shoes).



Figure 3-2. Examples of types of protective equipment

3.4. CO_2 SAFETY AND ENVIRONMENTAL CHARACTERISTICS

CO_2 is unique among natural refrigerants for having good safety characteristics. It is non-flammable, non-explosive, and relatively non-toxic. It exists naturally in the atmosphere at concentrations around 400 ppm. These characteristics make it an ideal fluid, especially for applications where relatively large quantities of refrigerant are needed. As a natural substance, CO_2 has no Ozone Depletion Potential (ODP) and a GWP of 1. It is classified in safety group A1, according to ASHRAE Handbook-Fundamentals. This group contains the refrigerants that are least hazardous and least toxic.

3.4.1. CO_2 CONCENTRATIONS

According to ASHRAE 34, a CO_2 concentration of 1000 ppm is the recommended limit to ensure the comfort for the occupants (the higher concentration than found naturally, 400 ppm, may be the result of human activities or the use of machinery). In a CO_2 controlled ventilation system therefore, fresh air should be supplied so that the CO_2 concentration level does not exceed 1000 ppm. A very high leakage rate in indoor supermarket spaces or in the machine room however, could result in hazardous health conditions and additional safety measures are required.

OSHA lists 5000 ppm as the TLV-TWA (Threshold Limit Value – Time Weighted Average). Table 3-1 is a list of selected concentration levels of CO_2 and the expected effects on human health.

CO2 Concentration		Symptoms and Effects on Humans
%	ppm	
0.04%	400	Normal concentration in the atmosphere
0.1%	1000	Recommended upper limit for comfortable indoor air quality
0.5%	5000	8 hours – long term exposure limit TLV-TWA (OSHA)
1%	10,000	Drowsiness
1.5%	15,000	10 minutes – short term exposure limit TLV-TWA
2%	20,000	50% increase of breathing
3%	30,000	OSHA STEL 10 minute TWA exposure, 100% increase of breathing
5%	50,000	IDLH – Immediate Danger to Life or Health
10%	100,000	Lowest lethal concentration, few minutes' exposure causes unconsciousness
30%	300,000	Brief exposure causes unconsciousness and death

Table 3-1. CO_2 concentrations and Their Effect on Humans

3.4.2. SAFETY CONCERNS RELATED TO OTHER CO_2 PROPERTIES

CO_2 has certain unique physical properties that require additional specific safety considerations. Solid CO_2 is commercially available in the form of dry ice or snow and can cause severe frost burn if not handled with care and the use of suitable personal protective equipment. Liquid CO_2 has a very high coefficient of thermal expansion. Care must be taken to ensure that liquid CO_2 is not trapped in pipelines between shut off devices. An increase in the temperature of trapped liquid will cause hydrostatic expansion that can generate sufficient pressure to rupture pipes and components.

3.4.3. CO2 SUPPLIERS – NORTH AMERICA

Molecular Weight	44.01 g/mol
Boiling Point (sublimation) @ 1 atm.	-109.1°F (-78.5°C)
Triple Point Temperature	-69.8°F (-56.6°C)
Triple Point Pressure	75.2 psia (5.19 bar)
Critical Pressure	1070 psia (73.8 bar)
Critical Temperature	+88°F (+31°C)
Specific Gravity @ 1 atm.	1.53
Saturation Pressure @ +21°F (-6°C)	430 psia (29.632 bar)
Liquid Density @ +21°F (-6°C)	60.04 lb/cf (961.7 kg/m³)
Vapor Density @ +21°F (-6°C)	5.04 lb/cf (80.77 kg/m³)
Saturation Pressure @ -22°F (-30°C)	207 psia (14.278 bar)
Liquid Density @ -22°F (-30°C)	67.15 lb/cf (1075.7 kg/m³)
Vapor Density @ -22°F (-30°C)	2.32 lb/cf (37.098 kg/m³)
Safety Limit of CO2 in air (OSHA TLV-TWA)	5000 ppm (0.5%)

Table 3-2. Selected Properties of CO_2

AIR LIQUIDE AMERICA L.P. 2700 Post Oak Boulevard, Suite 1800 Houston, TX 77056 866-822-5638 Website www.airliquide.com
LINDE GAS 6055 Rockside Woods Blvd Independence, OH 44131 216-642-6600 www.us.lindegas.com
PRAXAIR, INC. 39 Old Ridgebury Road Danbury, CT 06810 203-837-2000 www.praxair.com
AIRGAS 2530 Sever Road, Suite 300 Lawrenceville, GA 30043 800-473-3766 www.airgasrefrigerants.com

Table 3-3. Suppliers of CO_2 Refrigerants in the United States

3.4.4. CO_2 GRADES

Carbon Dioxide is produced as a byproduct of a number of different manufacturing processes including the formation of hydrocarbons and various distillation and fermentation processes. CO_2 also naturally exists in wells. After the CO_2 gas has been isolated, it is purified into different levels through the filtration of impurities and removal of moisture and non-condensable gases that result in different grades of CO_2 for different applications. Examples of various grades of CO_2 are shown in the table 3-4 below.

@	Grade	% Purity	H2O#	THC#	Ar#	CO#	N2#	O2#
**	SFE	99.9995	1	0.5	1	1	5	1
**	SFC	99.999	3	1	1	1	5	1
**	Research Plus	99.999	2	0.5			4	1
**	Research	99.999	3	1	1	1	5	1
**	Semi conductor	99.995	5	5				
**	Laser-PlusTM - Ultra	99.996	5	1				10
**	Laser-PlusTM	99.995	5	5				
**	Pure Clean	99.995	5	5				
*	LaserTM -	99.99	10	10			70	20
*	Refrigerant	99.99	10					
*	Instrument/ Coleman	99.99	10	10			70	20
NO	Anaerobic	99.9			10			10
NO	Bone Dry	99.9	10					
# Concentrations shown in ppm unless otherwise specified. Source – Air Gas								

Table 3-4. CO_2 Grades

Coleman grade * (or higher purity**) CO_2 refrigerant which contains less than 0.01% impurities are recommended by KWE for use in ECO_2 Large refrigeration systems. Carbon Dioxide used in refrigeration systems must be of sufficient purity to prevent accumulation of non-condensable gases and moisture in the condenser-evaporator. A build-up of these impurities can block heat transfer surfaces and cause inefficient operation or malfunction of the system.

3.5. SAFETY RELATED COMPONENTS

CO_2 transcritical booster systems have several safety components installed throughout the systems. Primary ones include:

- Leak detection systems
- Pressure relief valves
- System overpressure protection

3.5.1. LEAK DETECTION SYSTEMS

CO_2 has one main drawback in not being self-alarming: it does not have a distinctive odor or color. This implies that facilities where CO_2 may leak must be equipped with sensors that trigger an alarm when the concentration level exceeds 5000 ppm, to avoid an adverse health condition.



Since CO_2 is heavier than air, the sensors and ventilators in the space where CO_2 might leak should be located close to the floor.

In the event of a detection of high CO_2 concentration levels, the control system may be configured to turn off compressor(s), pump (s) and/or close control valve(s) or run purge ventilation in addition to initiating the personnel alarm system(s).

CO_2 refrigerant is inexpensive and relatively safe. Nevertheless, CO_2 components and lines generally result in lower volume charge when compared to systems using other refrigerants.

Leak detection systems usually require the user to preset the type of gas during installation, to avoid false alarms. The ECO2 Large uses the following leak detection systems:

- Emerson RLDS/MRLDS
- Danfoss GDC IR 10000/40000
- Vaisala CO_2 leak detector

These systems can detect CO_2 concentration as low as 5 to 20 ppm. Other handheld devices for detecting CO_2 leaks are not as accurate. When a leak occurs in the liquid lines of the system, it becomes visible as a cloudy vapor emission. This is due to the condensation of moisture in the air surrounding the leak. **The installed design of leak sensors must comply with local codes and regulations.** Figure 3-3 shows an example.



Figure 3-3. Example of a Leak Detection System

3.5.2. PRESSURE RELIEF VALVES (PRV)

Pressure relief valves provide safety measures during circumstances such as power outages, natural disasters, or system malfunctions that may cause abnormal operation and high pressure in the system. When the pressure exceeds the designed set-point, the valve opens relieving the pressure to a safe level.

The figure below shows a pressure relief valve that is spring loaded to counter the refrigerant flow through the inlet nozzle. The set point pressure can be set within a pressure range (depending on the PRV) with the help of pressure adjusting screw at the top of the valve. When the pressure at the inlet nozzle breaches the set point pressure, the force applied by the refrigerant pushes open the valve seat to allow flow through the PRV, reducing the system pressure, and safeguarding it from damages. PRV are selected to operate in specific locations in the system. Relief valves are sealed by the manufacturer and should never be adjusted in the field. These should only be installed or replaced according to KWE specifications. The installed design must comply with local codes and regulations.

3.5.3. SYSTEM REFRIGERATION PRESSURE PROTECTION

The KWE ECO_2Large Refrigeration system includes some safeguards to ensure that pressures do not exceed design limits. There are a few conditions that could cause high pressure in the system.

- Discharge line blockage – MT or LT
- System shutdown – all low and intermediate pressure affected

The KWE ECO_2Large Refrigeration systems have several layers of protection for each condition.

Discharge Line Blockage

Medium Temperature

- Rack controller set at 1535 psi (99 bar) – shuts down
- High pressure switch at 1570 psi (108 bar)– shuts down
- Pressure relief valve set at 1740 psi (120 bar) – releases refrigerant

Low Temperature

- High pressure switch at 586 psig (33 bar) – shuts down
- Pressure relief valve set at 652 psig (43 or 45 bar) - releases refrigerant

System Shutdown

If the CO_2 refrigeration system is damaged and not operational, the pressure will tend to rise to nearly the saturated pressure corresponding to the warmest ambient exposure. The system design has several features to prevent this.

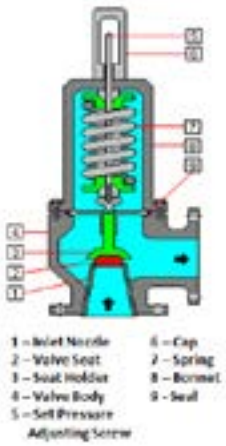

Figure 3-4 . Pressure Relief Valve



Figure 3-5. Pressure Relief Valve Housing

Flash tank

- **Pressure relief valve:** If pressure rises to the limit of the pressure rating of the flash tank, a pressure relief valve will release the refrigerant to the outside.
- **CO_2 Charge Protector (CCP) Unit (TM) (Optional):** KWE offers the addition of a CCP that automatically starts if high pressure is sensed on a mechanical pressure switch installed on the flash tank. The CCP unit will then condense and cool the CO_2 gas in the



Figure 3-6 . CO_2 Charge Protector (CCP) Unit flash tank, to maintain the design pressure.

Discharge lines

- **MT:** same layer of protection as for High Ambient Temperatures
- **LT:** Pressure relief valve shared with the an MT suction piping

NOTE

The installed design must comply with local codes and regulations (reference ASHRAE 15).

04 INSPECTION AND HANDLING

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4. INSPECTION AND PLACEMENT OF MATERIAL

Materials at the construction site should be thoroughly inspected upon unloading for damage, missing parts and serviceability.

4.1 INSPECTION OF MATERIALS

Inspect the CO_2 refrigeration system and accessories for damages or shortages before and during unloading.

If there is any damage, notify the carrier immediately and request an inspection. Ensure:

- The delivery receipt is annotated that the equipment was received damaged.
- If damage is not noticeable on receipt, contact the carrier immediately when the damage is discovered.

It is the responsibility of the consignee to file all claims for damage with the transportation company.

4.1.1. ACCESSORIES

Be sure that you receive all items. Accessories may be packaged separately.

Check the packing list against the contents.

☐ All parts are present.

NOTE

If parts are missing, contact the Technical Sales Support (TSS) or the point of contact listed in the packing list.

4.1.2. SYSTEM PRESSURE

☐ Pressure in the system is within specified limits.

NOTE

The system is shipped with a 50 psi holding charge of dry nitrogen. Report lack of or a reduced pressure immediately to the KWE technical sales support.

4.1.3. ELECTRICAL

☐ Specifications on electrical rating plate matches on-site power configuration.

4.1.4. COMPATIBILITY OF FIELD INSTALLED MATERIAL

☐ Field installed material meets manufacturer's specifications.

4.1.5. MATERIALS MEET SPECIFIED PRESSURE RATINGS

☐ Field Installed material meets specified pressure ratings.

4.2 DATA PLATE

The data plate (Figure 4-1) provides information for the model. Verify the information on the data plate corresponds to the model ordered.

☐ The model on data plate is the same as the model ordered.

☐ The supply voltage is the same as required by the unit.

☐ The refrigerant is correct.

☐ The maximum and minimum design pressures match.

☐ The number and specifications for each compressor is correct.

☐ **Set on a flat and level platform.**



Figure 4-1 . Sample Data Plate

NOTE

Each rack has a rating plate and a legend on the front or the inside of the electrical panel

4.3 LIFTING INSTRUCTIONS

Each rack system has lifting lugs built into the structure. Failure to lift the unit properly can cause damage to the unit or bodily harm to people in the area.

☐ Spreader Bar(s) are used for all rigging to avoid damaging the equipment.

☐ Use ALL lifting lugs provided on equipment.

☐ Lifting cables and other lifting equipment should not be in contact with piping or electrical components.

☐ Adjust tension on the lifting straps to equalize the weight of the rack when lifted.

☐ Unpack the unit at the installation site.

4.4 PLACEMENT OF EQUIPMENT

Good positioning at the site of the refrigeration equipment:

- Reduces costs.
- Permits the free flow of air around the system.

NOTE

KWE provides information on the equipment weight and the location of lifting lugs. It does not provide detailed lifting instructions because:

- Of the wide variety of conditions and equipment at the construction site.
- The responsible personnel on site are best qualified to determine the specific materials required to lift the equipment.

4.4.1. RACK SYSTEM

Outdoor Location of Equipment

☐ The mounting platform or base is level and permits free air flow. (also see recommendations for free air flow).

☐ Set on a flat and level platform.

☐ Units are not located near steam, hot air or fume exhausts.

☐ The unit is mounted away from noise sensitive spaces such as offices.

☐ The unit has adequate support to avoid vibration and to reduce noise transmission into the building.

Equipment Mounted on the Ground

The foundation is:

☐ Set on a flat and level foundation

LIFTING EQUIPMENT

KWE provides information on the weight of the equipment and the location of lifting lugs. Being at the site, the contractor is best qualified to determine the specific materials required to lift the equipment. Figure 4-2 shows an example of a shackle attached to a lifting lug. Figures 4-3 and 4-4 show examples with a front and side view, of the lifting arrangement for a refrigeration equipment.



Figure 4-2. Example of a shackle and Lifting Lug



Figure 4-5. Rack system mounted on a roof.

☐ Is designed to support the weight of the equipment

☐ Isolated from the building structure.

☐ Rechecked to ensure it is level prior to tightening the bolts.

Equipment Mounted on the Roof

☐ The structure is strong enough to support the weight of the unit and service personnel.

☐ The structure minimizes deflection and vibration transmission

Ventilation

☐ Ventilation is in the range of 40-100cfm per compressor horsepower depending upon ambient temperatures or as specified by the customer.

☐ The air intake is positioned and sized so that air passes over the units at a maximum velocity of 500ft/ minute velocity.

☐ Check national and local codes and use the larger of the manufacturer's recommendations and national/ local codes.

Reducing Vibration

☐ Vibration isolation pads are used.

☐ Isolation hangers are used when refrigeration lines are suspended from the structure.

☐ If required, special vibration absorbing spring mounts (optional equipment), Figure 4-6 are placed under the base frame of each unit.



Figure 4-6. Example of a Vibration Absorbing Spring Mount



Figure 4-7. Example of Mounting Feet on ECO2Large unit.

ECO$_2$Large
I & O MANUAL
75A10837

05 SYSTEM INSTALLATION

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5. SYSTEM INSTALLATION

5.1. GENERAL

Installation of the refrigeration must comply with the "Safety Standard for Refrigeration Systems" (ANSI/ASHRAE Standard 15), ASME B31.5 Refrigeration Piping Standard, and local building codes.

NOTE

Customer is solely responsible for compliance with local codes and regulations.

- Properly sized refrigeration lines are essential. Suction lines are more critical than liquid or discharge lines. Consult the technical manual or legend sheet for proper line sizes.
- Do not run refrigeration lines from one system through cases on another system.
- Refrigeration lines should never be placed in the ground unless they are protected against moisture and electrolysis attack.
- Main trunk lines should enter a line-up of cases in the center.

5.2. RESPONSIBILITIES

Responsibilities for the installation of the refrigeration systems are divided between KWE, the store owner, and the installer (Table 5-1).

Action	KWE	Store Owner	Installer
Code compliance		X	
Caution Signage per Local Code		X	
Inspection of material			X
Component specifications	X		
System Specifications	X		
Store Layout		X	
Installation of System			X
Interconnection of System			X
Operational Testing			X

Table 5-1. Responsabilities

5.3. FIELD PIPING

5.3.1. PIPE LINE SIZING

☐ Piping lines are installed according to the drawings and customer specifications

☐ Changes to diameters and materials are confirmed and documented

5.3.2. PIPE PRESSURE RATINGS

This specification is used in conjunction with the customer specifications. It is intended to supplement and clarify the scope of work and technical specifications for field refrigerant piping for ECO_2 Large Transcritical systems as well as leak testing, approval of local authorities, charging, start-up and commissioning of the entire system. It includes systems piping between WEM (Weather Enclosure Mechanical) racks and display cases / walk-in coolers / freezers including installation of flow control valves, circuit solenoid valves, full-port ball valves with bypass return check valve, etc.

NOTE

Site specific installation drawings take precedence over these guidelines

CO_2 as a refrigerant has a higher density and pressure compared to other conventional refrigerants. Thus the pipe sizes are smaller compared to other refrigerant systems. Install piping with adequate clearance between pipe and adjacent walls and hangers to allow for service and inspection. Use pipe sleeves through walls, floors, and ceilings, sized to permit installation of pipes with full thickness insulation. Table 5-2 shows sections of the ECO_2 Large rack with related pipe material rated for the operating pressure and temperature. See Section 1 for typical ECO_2 Large operating pressures and temperature. The maximum pressures in this table and the design pressures in table 5.2 are similar but they do not exactly match

NOTE

The installed design must comply with local codes and regulations.

Section	Max Operating Pressure [1] psi (bar)	Max Operating Temp °F (°C)	Material
MT Discharge to HPV Inlet	1740 (120)	+320°F (+160°C)	CuFe2P (C19400 Alloy) 120 Bar rated tubes supplied as Wieland K65™ or Mueller XHP™
HPV Outlet to EEV (Cases & Unit Coolers)	652 (45)	+35°F (+1.7°C)	Mueller Streamline Copper rated to 700 psi (48 Bar) @250°F up to OD1-1/8" - L type Soft OD1-3/8" - L type Hard OD1-5/8" to 2-5/8" - K type Hard
Flash Tank	652 (45)	+35°F (+1.7°C)	
Medium Temperature Suction Line	652 (45)	+25°F (-3.9°C)	
Flash Gas Return Line	652 (45)	+35°F (+1.7°C)	
Liquid Supply	652 (45)	+35°F (+1.7°C)	
Low Temperature Suction Line [2]	435 (30)	-22°F (-30°C)	
[1] Pressure relief valves limit pressure			
[2] For consistency, Mueller Streamline ACR Piping can be used for all store piping; otherwise, the installer must have the following provisions: Pipe and fitting material identification in inventory, Pipe and fitting material identification of installed piping, Callout of pipe and fitting material in store drawings Copper Tube can be rated for 435 psig (30 bar): • up to OD1-3/8" - L type Soft • up to OD2-1/8" - K type Soft			

Table 5-2. CO_2 Piping Requirements

5.3.3. CASE AND UNIT COOLER PIPING

CO_2 Case and Unit Cooler piping & instrumentation is similar to conventional refrigeration systems. For multiple cases, the liquid distribution inside and suction gas pipelines are installed inside but can be externally installed.

Liquid Lines

The CO_2 liquid lines must be rated for 652 psig (45 bar). Since the lubricant is miscible with the liquid refrigerant, these lines do not require special arrangements for oil return. Customer specifications are properly designed in order to achieve the preferred velocity and minimum pressure drop. Increasing pipe sizes results in greater demand of refrigerant and decreasing pipe sizes results in a higher pressure drop. Refer to site-specific p iping i nstallation drawings for liquid piping. Systems without subcooling features require special pipe routing and connections to handle two phase refrigerant.

Suction Lines

Suction lines carry expanded vapor back to the compressor from the evaporators, and should be insulated. The suction lines may travel horizontally or vertically to the refrigeration rack. Any suction line that travels vertically and the direction of refrigerant flow is against gravity, is called a suction riser. Refrigerant flowing through suction risers may be unable to carry the lubrication oil through the pipes to the compressor due to the low flow velocity. Oil traps are therefore designed into the suction risers.

Isolation Valves

If the customer requires isolation valves for individual circuits, they must be a full port ball valves with return check valves and rated for a minimum design pressure of 652 psig. The direction of the check valve should point towards the rack. Contractor should obtain verification (sign-off) from the customer construction manager to confirm the proper direction before proceeding with the insulation. The bypass check valves are required for instances when the isolation valves are closed while the pressure of the refrigerant rises. In these cases the check valves open up and distribute the pressure (towards the rack) avoiding any damage to the pipelines and other equipment. Figure 4-2 illustrates the positioning of check valves

Relief Valve Installation

Relief valves should exhaust to exterior locations to comply with ASHRAE 15. Valves must be located and oriented so that they discharge pressurized refrigerant safely and

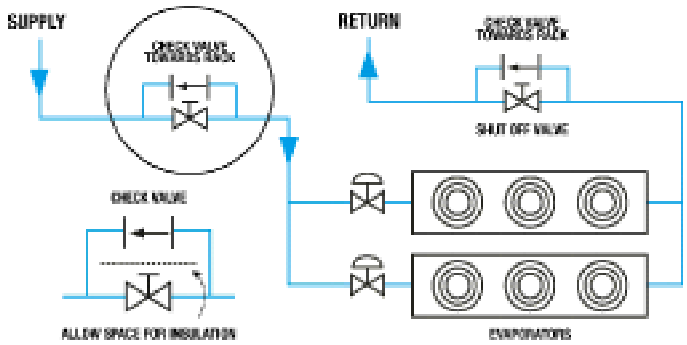


Figure 5-2. Positioning of Check Valves

from personnel.

Sloping Lines

All CO_2 suction return lines must be installed with a slope or pitch downward of 1 inch per 20 feet towards the machine room. If liquid lines are run with suction return lines, they may also be sloped. This is a common practice for conventional CO_2 systems to enable the return of refrigerant oil.

5.3.4. PIPE SUPPORTS

Pipe supports are used for all refrigerant piping. Most of the pipes in the field are insulated, except the gas cooler lines.

☐ Insulated pipes should use saddles to avoid tearing.

☐ The saddle can be metal or PVC (Poly Vinyl Chloride).

☐ The saddle should have a smooth surface and the length of the saddle should be almost three times the diameter of the pipe with its insulation.

☐ The saddle should be in contact with 1/3 of the insulated pipe perimeter.

☐ Air gaps should be maintained between insulated pipes to avoid sweating.

☐ No support should have direct contact with the pipes to avoid heat gain and water seepage due to condensation.

☐ Saddles are also used for underground piping, where insulated pipes are routed through trenches.

☐ Metal clamps are to be avoided as pipe support as they promote heat gain and vapor condensation.

5.3.5. PIPING JOINTS

The following discusses common types of joints commonly found in refrigeration units. It includes brazed, threaded, and flared joints.



Figure 5-3. Piping support

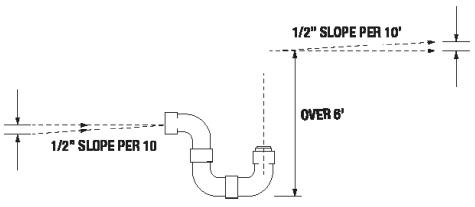


Figure 4-4. Slopes for suction Lines

Brazed Joints

KWE recommends using brazed joints.

Copper joints are brazed with minimum 15% silver brazing alloy (filler) and for dissimilar metals use minimum 45% silver brazing alloy (filler). While brazing, pass nitrogen gas through the pipe or tubing to prevent oxidation as each joint is brazed.

NOTE

Cap the system with a reusable plug after each brazing operation to retain the nitrogen and prevent the entry of air and moisture.

The following are some considerations for brazed joints. When in doubt, consult the technical manual or legend sheet.

☐ There is no flux present on the soldered joint.

☐ P traps are at the bottom of suction line risers that are 4 feet or longer.

☐ Double “P” traps are present for each 20-foot of riser.

☐ Use long radius ells and avoid 45° elbows.

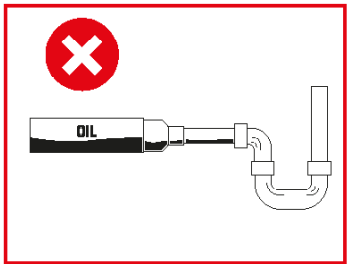
☐ Provide expansion loops in suction lines on systems with hot gas defrost

☐ Flux only the male portion of the connection line never the female portion. Remove the flux after brazing.

NOTE

A suction line trap must be installed at the point where piping changes the direction of refrigerant flow from any horizontal run to an upward vertical run.

Piping should not disrupt or restrict refrigerant flow. Allowing sufficient “play” in the piping system and reducing abrupt changes in refrigerant direction reduces internal stresses and pressure drops. Short radius elbows for example, should be avoided if possible because they increase stress on the piping and cause the refrigerant to lose pressure.



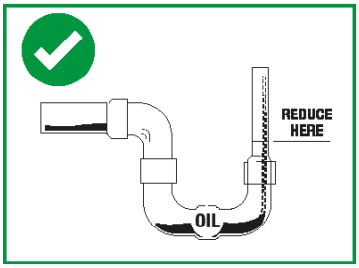


Figure 4-5. Placement of Oil Traps on Suction Lines

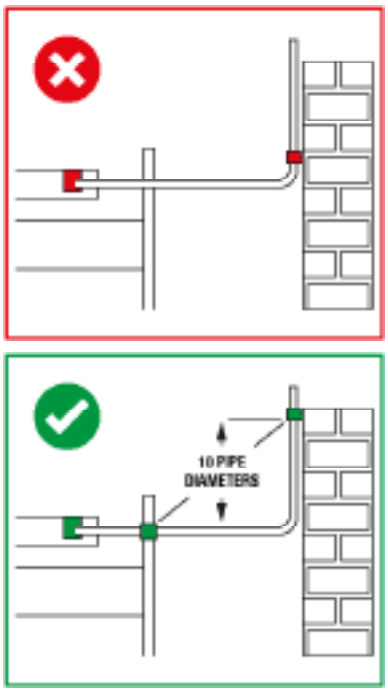


Figure 5-6. Corners support illustration.

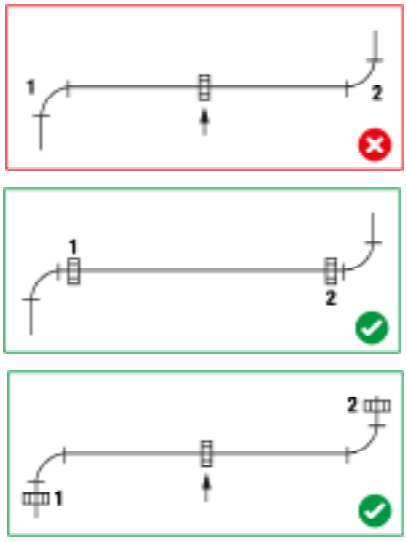


Figure 5-7. Corners support illustration.

Contractors install piping supports based on the plans and industrial standards. Straight lengths of piping for example below, must be supported at each end and have additional supports not more than every 8 feet. Cushioned clamps and pipe supports should be used to prevent contact between pipes.

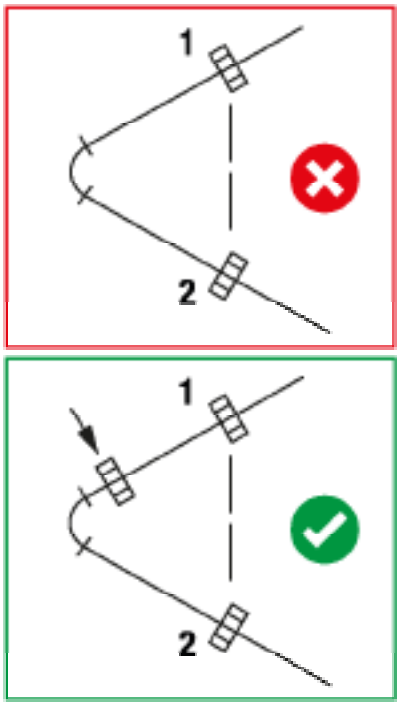


Figure 5-8. Corners must be supported and cannot be left free to pivot around 1-2

Threaded Joints

The threads are wrapped 3-4 times with Teflon tape; then **Loctite 277 or equivalent Threadlocker** is applied over the tape before the threads are engaged.

Flared Joints

KWE does not recommend flare joints.

5.4 TESTING AND EVACUATION

1. PRE-CHECK

☐ Visually inspect refrigerant lines and joints for proper piping assembly and installation
☐ Proper bracing is used throughout
☐ Inspect for any metal to metal contact
☐ Manually verify that all mechanical joints are tight
☐ Ensure all electrical connections are tight.
☐ Check phase monitor for correct polarity

2. ISOLATE COMPONENTS NOT SUITABLE FOR THE PRESSURE LEVELS

3. DISCONNECT OR BYPASS ALL DEFROST HEATERS

4. OPEN VALVES

☐ Ball valves to circuits, branches, satellites, heat reclaim, receiver, etc.
☐ De-energize the solenoid valves (which are normally open).

5. CHECK FOR LEAKS

☐ System pressure is brought to a minimum of 300 psig.
☐ Verify pressurization at multiple system access points.

IF LEAK IS IDENTIFIED:
☐ Leak is isolated from rest of system
☐ Leak is repaired
☐ Area of repair is retested
☐ Area is re-pressurized to a minimum 300 psig
☐ All valves are re-opened
☐ After all leaks are repaired and retested, system stands unaltered for 24 hours with no greater than a +- 1 PSIG change
☐ When system is ready to be evacuated, the nitrogen charge is released.

6. PRE-EVACUATION

☐ System is depressurized
☐ Evacuation pump and sensors working properly
☐ No contaminates are introduced
☐ Evacuation pump is connected to 3 points on rack
☐ Copper lines or approved vacuum hoses are required
☐ Vacuum pump is rated at 8 cfm as a minimum and can reach all parts of the system.
☐ Vacuum pump oil as recommended by manufacturer (use new and clean oil)
☐ Electrical connections are secure and uninterrupted
☐ There are no leaks at the vacuum pump connections.

Lines and Valves
☐ Copper lines or suitable hoses are used.
☐ Packless valves are used
☐ All schrader valve caps are tightened and checked.
☐ All access valve caps are tightened

Micron Vacuum Gauge
☐ Gauge is properly calibrated
☐ Verify with gauge that pump can pull a vacuum of at least 300 microns
☐ Vacuum is measured at a minimum of two points which are at extreme points within the system

7. TRIPLE EVACUATION PROCEDURE

1st Evacuation

☐ Pull a system vacuum down to at least 1,000 microns (+/- 50 microns) and close the vacuum header valves.
☐ If system cannot maintain a vacuum and returns to atmospheric pressure, check and correct leak(s) as previously described
☐ When system maintains a 1,000 micron vacuum for 30 minutes, break the vacuum with dry nitrogen to a pressure of 2 psi

2nd Evacuation

☐ Pull a second vacuum to a minimum of 500 microns.
☐ Close vacuum header valves.
☐ If the 500 micron vacuum holds for a minimum of 30 minutes, then break the vacuum with the refrigerant to be used in the system to a pressure of 2 psig.
☐ Install system suction and liquid drier cores.
☐ Add oil to the compressors, oil separator and oil reservoirs, if equipped before starting compressors

3rd Evacuation

☐ Pull a third vacuum to a minimum of 500 microns.
☐ Close vacuum header valves and allow system to stand for a minimum of 24 hours
☐ System is ready to be charged with refrigerant If the 500 micron vacuum holds for 24 hours with a maximum drift of 100 microns over the 24 hour period.
☐ Break the vacuum: see the process on 5.3 Initial Charging

5.5. INSULATION

Insulation pipes provide:

- Reduces heat transfer to the refrigerant and fluid lines
- Prevents condensation and ice formations on pipe surfaces
- Minimizes pipe corrosion

Insulation should be installed according to local building codes, customer specifications, and manufacturer specifications. ASHRAE 90.1 provides guidelines for insulation for commercial refrigeration.

Warm pipes used for heat rejection usually do not require insulation unless insulation is specified to enhance reclaiming waste heat for use elsewhere (such as hot water and comfort).

Insulation Thickness

Guidelines are shown for insulation thickness. Refer to customer specifications when available.

Normal or Severe Conditions

Insulation material is typically rated for either normal conditions (indoor applications), or severe conditions (outdoor applications). Insulation designed for severe conditions should also be used near exterior openings, non-conditioned areas, or areas with high temperatures and humidity.

Materials

KWE recommends closed-cell elastomeric foam material for insulation. Insulation manufacturers provide detailed guidelines and training programs for installing insulation Table 5-4 lists two suppliers

Armacell LLC 7600 Oakwood St. Ext. - Mebane, NC 27302 919-304-3846 / www.armacell.com
K-Flex 100 Nomaco Drive - Youngsville, NC 27596 800-765-6475 / www.kflexusa.com

Table 5-4. Recommended Elastomeric Insulation Suppliers

Insulation Thickness				
	Pipe Size	**Combined Liquid**	**LT Suction**	**MT Suction**
Normal Ambient Conditions +85°F Dry Bulb 70% RH	Up to 1/2”	3/4"	3/4"	3/4"
	5/8” to 2-1/8”	3/4"	1”	3/4"
Severe Ambient Conditions +90°F Dry Bulb 80% RH	Up to 1-1/8”	1”	1-1/2”	1”
	1-3/8” to 2-1/8”	N/A	1-1/2”	N/A

Installation Notes

- All valves, controls, and fittings on refrigerant fluid lines should be insulated so as to allow easy access for component servicing.
- Components should also be insulated to minimize air pockets or voids, which can collect moisture and

Insulation should be installed according to local building codes, customer specifications, and manufacturer specifications. ASHRAE 90.1 provides guidelines for insulation for commercial refrigeration.

Warm pipes used for heat rejection usually do not require insulation unless insulation is specified to enhance reclaiming waste heat for use elsewhere (such as hot water and comfort).



Figure 5-5 Example labels on piping

Insulation Thickness

Guidelines are shown for insulation thickness. Refer to customer specifications when available.

Brimar Industries 64 Outwater Lane - Garfield, NJ 07026 800-274-6271 / www.brimar.com
Seton 20 Thompson Road - Branford, CT 06405 800-243-6624 / www.seton.com

Table 5-6 Pipe label suppliers

Normal or Severe Conditions

Insulation material is typically rated for either normal conditions (indoor applications), or severe conditions (outdoor applications). Insulation designed for severe conditions should also be used near exterior openings, non-conditioned areas, or areas with high temperatures and humidity.

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Installation Notes

- All valves, controls, and fittings on refrigerant fluid lines should be insulated so as to allow easy access for component servicing.
- Components should also be insulated to minimize air pockets or voids, which can collect moisture and cause corrosion.

- Insulation manufacturers provide detailed guidelines and training programs for installing insulation.

5.6. LABELING REQUIREMENTS

Labelling refrigerant piping assists personnel in the identification and location of parts of the system. Refer to **ANSI/ASME Standard A13.1-81**, "Scheme for the Identification of Piping Systems", for labelling requirements, standards, and placement.

All refrigerant piping should be labeled with arrows indicating direction of flow (see Figure 5-9).

In addition, some piping should provide labels to show (see Figure 5-6):

- Fluid type (i.e., Carbon Dioxide)
- Origin of Flow
- Typical Operating Pressure

Table 5-5 provides information on two label suppliers.



Figure 5-9. Other examples of labels on piping

5.7. ELECTRICAL

Details of the system electrical components and requirements are found in the project Schedule / Legend of Equipment Load and Electrical Requirements. Table 5-7 lists the following power requirements:

Components	VAC Requirement
Compressors	208/60/3, 460/60/3, or 575/60/3
Controls	208/60/1
Electric Defrost	208/60/3, 208/60/1

Table 5-7. Electric Power Requirements

ECO$_2$Large
I & O MANUAL
75A10837

06 SYSTEM OPERATION

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6. SYSTEM OPERATION

Once the system installation is complete, all piping has been evacuated to specification, and all equipment is powered-up and ready to operate; the initial startup of the CO_2 Transcritical System is done with the following steps – the numbers correspond to the subsections:

6.1. INITIATE SYSTEM POWER

6.2. EVAPORATOR TEMPERATURE CONTROL

6.3. CO_2 INITIAL CHARGING

6.3.1. Required Equipment and Material

6.3.2. Oil Charge

6.3.3. Charging CO_2 Vapor

6.4. START COMPRESSORS

6.4.1. Start CCP (optional)

6.4.2. Controls/Instrumentation Check

6.4.3. Liquid CO_2 Charge to Flash Tank

6.4.4. Start MT compressors

6.4.5. Pull Down MT Cases & Walk-ins

6.4.6. Start LT compressors

5.4.7. Pull down LT Cases & Walk-ins

6.5. DEFROST SETUP

6.6. WALK-IN DOOR SWITCHES

6.1. INITIATE SYSTEM POWER

Prior to charging the system or starting compressors, confirm that

☐ Power has been turned on to each subsystem

☐ Control Panel is energized

☐ Panel switches are set with compressor OFF

Check operation of cooling fans

- ☐ Gas Cooler Fans Operating
- ☐ Case Fans Operating

☐ Initial checks for equipment has been completed according to manufacturer's recommendations

☐ Control System is installed and programmed according the System SOO setpoints

☐ Controls, gauges, and thermometers are displaying temperatures and pressures (Check values expected without refrigeration system operating)

6.2. EVAPORATOR TEMPERATURE CONTROL

☐ Verify temperature sensor locations indicated by the controller.

☐ Validate temperature readings on the controller with a known temperature source. This is done using the "ice bath" method, or using a calibrated thermometer.

NOTE

Some adjustment may be required on controller settings.

6.3. CO_2 INITIAL CHARGING

6.3.1. REQUIRED EQUIPMENT AND MATERIALS

The following materials are needed to charge the system. The refrigeration installation contractor is responsible for having these materials. See information on CO_2 grades and suppliers and suppliers discussed in Section 2.

☐ CO_2 Vapor Cylinders

Instrument or Coleman Grade CO_2 vapor to break vacuum and pressurize the system to 150 psig. Tanks are stored at room temperature; dispensing cold refrigerant is limited.

☐ CO_2 Liquid Cylinders (w/dip tube)

Instrument or Coleman Grade CO_2 for remainder of charge – reference refrigeration legend for estimated charge

☐ Charging Hoses

- 3/8" hose recommended for faster charging
- Rated for 1740 psig working pressure

☐ Manifold Gauges

Rated for 900 psig working pressure

☐ CGA-320 Adapter Fitting

CO_2 cylinders (liquid and vapor) have CGA-320 fittings. An adaptor is required to connect the CO_2 cylinder to a flare connection on charging hoses for liquid charging.

☐ Filter/Dryer

Provide filter/dryer in filter charge line. Change filter/dryer about every 500lb. CO_2

☐ Refrigerant Scale

Measures the quantity and rate of CO_2 charging from the cylinders. The scale needs to be rugged enough for the weight and handling of the cylinders.

☐ POE Oil

This is used to fill oil reservoir and compressor crankcases. Oil should be purchased directly from the CO_2 compressor manufacturer.

- BITZER CO_2 compressors use POE oil – BSE85K
- Emerson Copeland CO_2 Compressors use POE Oil – EMKARATE RL68HB

☐ Manual Oil Pump

6.3.2. OIL CHARGE (NEED TO BE DONE BETWEEN 2ND AND 3RD EVACUATION)

Oil Charge to the Oil Separator

- ☐ Confirm that oil is compatible with compressors
- ☐ Close valves to isolate oil separator
- ☐ Open oil separator

Oil Charge to the Oil Reservoir

- ☐ Confirm that oil is compatible with compressors
- ☐ Close valves to isolate oil reservoir
- ☐ Fill reservoir with oil 50%-75%
- ☐ Open valve between oil reservoir and compressors

Oil Charge to Compressors

- ☐ Fill the compressors with oil to the manufacturers' recommended level.
- ☐ Confirm that the compressor crankcase heaters are energized for 24h before start up

NOTE

Crankcase heater must be operating to warm the oil prior to starting the compressor.

6.3.3. CHARGE THE CO_2 VAPOR

The vacuum is broken with a vapor CO_2 charge only. Liquid CO_2 will form into solids potentially causing damage to the equipment.

☐ Break the vacuum with vapor CO_2 to 150 psig

☐ Leave all valves open - complete system and piping distribution network with vapor charge

☐ Continue charging vapor CO_2 to 150 psig

☐ Check that any rack gauges and control pressures read 150 psig

Gauges or sensors that are reading less than 150 psig indicate that some valves might be closed, or faulty pressure transducer

Gauges or sensors reading greater than 150 psig indicate faulty pressure transducer reading

NOTE

For CO2, saturation temperature = -34°F @ 150 psig

6.4. START COMPRESSORS

6.4.1. START CO_2 CHARGE PROTECTION (CCP) UNIT (OPTIONAL)

This applies to systems equipped with an CCP Unit. To prevent loss of CO_2 charge at the relief valves, further charging should only be performed when the operation of the CCP has been confirmed. The CCP is activated by the CCP Pressure Control on the flash tank. When the flash tank pressure rises to the CCP setpoint, this control energizes the liquid line solenoid to the CCP heat exchanger.

VAPOR CHARGING

As vapor is drawn from the CO_2 cylinders, pressure and temperature inside the cylinder will decrease. Frosting on the bottom exterior of the cylinder is evidence that some CO_2 liquid evaporated inside. The reduction in pressure also causes a slower flow rate of vapor into the system. Once the flow from the cylinder has slowed to a low level, the cold cylinder should be disconnected and allowed to warm (see Warming CO_2 Cylinders below). After the cylinder warms, additional CO_2 can be removed. In the meantime, another warm tank can be connected to the system to continue the charging process. A typical full 100 lb. cylinder contains approximately 50 lbs. of useable CO_2 that can be charged into the system. On the first attempt, 20-25 lbs. of CO_2 vapor can typically be obtained from the cylinder before reaching a low-temperature/pressure of the tank.

WARMING CO2 CYLINDERS

CO_2 Cylinders can be warmed by placing them in a warm place, in direct sunlight, and by directing airflow at them using an un-heated fan. DO NOT use direct heating on CO_2 cylinders to raise their pressure/temperature.

The Compressed Gas Association provides additional guidelines for the safe use and handling of the CO_2 cylinders. For more information, contact: Compressed Gas Association / 703-788-2700 / www.cganet.com



NOTE

For systems without an CCP, LT/MT loads should be gradually bought online; and system operation and controls are validated prior to adding further charge under the guidance of experienced field contractor or field technician.

☐ Check CCP Pressure Control setpoint

☐ Power up CCP by temporarily lowering the CCP Pressure Control setpoint until it closes

☐ Confirm that CCP compressor and fans are running

☐ Return CCP Pressure Control to its proper setpoint. The switch should open and the CCP compressor will cycle off on its low pressure control

6.4.2. CONTROLS/INSTRUMENTATION CHECK

SOO (Sequence of Operation) is provided for individual systems. The SOO provides general information for programming of controls and various alarms.

Mechanical Pressure Switches

Confirm that mechanical switches are operating properly. All pressure controls should be adjusted until they actuate and it is verified that the desired result is achieved. The controls should then be set to their proper setpoints (reference SOO).

☐ MT and LT Compressor High Pressure Controls – reference SOO for setpoints

☐ Tag or Label MT and LT Mechanical High Pressure Cut-off Switches

☐ MT and LT Compressor and/or Suction Group Low Pressure Controls – reference SOO for setpoints

☐ Tag or Label preset MT and LT Mechanical Low Pressure Cut-off Switches

☐ CCP Pressure Control – 580 psig cut-in / 520 psig cut-out

☐ Tag or Label CCP Mechanical Control Switch – CCP optional

Pressure & Temperature Sensors

Check that all pressure and temperature sensors are calibrated and providing accurate readings at the controller using the IO sheet for a full list.

☐ Cases

☐ Gas Cooler Outlet

☐ Walk-ins

☐ Flash Tank

☐ Rack System (reference SOO)

☐ Oil Supply

☐ Gas Cooler (reference SOO)

☐ LT Suction

☐ MT Suction

☐ LT Discharge

☐ Heat Reclaim Outlet (if applicable)

☐ Outside Air Temperature/Humidity

☐ Oil Separator Outlet Pressure (if applicable)

☐ Flash Tank Level Indicator (if applicable)

Digital Input Verification

Check that all digital inputs are reading open or closed as expected. Exercise each component as possible and verify the results at the proper input point.

☐ Phase Loss Monitor

☐ Compressor Proofs

☐ Compressor Fails

☐ VFD Faults

☐ Flash Tank Level Switches

Relay Output Verification

All relay outputs should be exercised and the proper results verified.

☐ Compressor Runs

☐ VFD Bypasses (when provided)

☐ Hot Gas Dump Valve

☐ Liquid Injection Valve

☐ Gas Cooler Bypass Valve

☐ ETE Efficiency Module

Analog Output Verification

All analog outputs should be exercised and proper results verified.

☐ MT1 Compressor Speed Reference

☐ LT1 Compressor Speed Reference (if applicable)

☐ Gas Cooler Fan Speed Reference

☐ High Pressure Regulator Valve (HPV)

☐ Flash Gas Bypass Valve (FGV)

☐ Heat Reclaim Regulator Valves (if applicable)

☐ **VFD Set-up Verification**

Verify all Control Setpoints.

☐ MT/LT/Parallel Suction Pressure Targets

☐ Gas Cooler Outlet Temperature Differential Target (Supercritical)

☐ Flash Gas Pressure Target

☐ Oil Separator Dump Valve

☐ Hot Gas Dump Valve

☐ Liquid Injection Valve

☐ Gas Cooler Bypass Valve (Optional)

☐ Subcooler Expansion Valve (Temp Control)

☐ Subcooler Expansion Valve (Superheat Control)

Electrical Connections

Connections to the display cases and walk-in freezers have been completed and proper operation of lights, fans, and anti-sweat heaters has been established.

☐ Connections to the display cases and walk-in freezers are completed

☐ Verify the operation of lights

☐ Verify the operation of fans

☐ Verify the operation of anti-sweat heaters

6.4.3. LIQUID CO2 CHARGE TO FLASH TANK

Safety Precaution Note: Charging CO_2 refrigerant increases pressure in the system. For systems with an CCP, check that backup power and Auxiliary Cooling Systems are working properly to maintain safe pressures in the event of power outage or abnormal conditions. Otherwise loss of charge and/or damage to equipment could occur.

☐ MT Compressors should already be powered on in "stand-by" mode

☐ Close the main CO_2 liquid line valve

When CCP Unit is present:

☐ Manually turn on CCP

☐ Check that compressor is running, fan is turning, and unit is cooling

☐ Purge air from refrigerant tank supply hoses before attaching to the flash tank

☐ Fill liquid CO_2 directly to the flash tank

☐ Adjust the flow of CO_2 refrigerant by adjusting the valve on the refrigerant tank

☐ When the flash tank pressure reaches 520 psi, the FGBV should begin operating to maintain setpoint. The MT suction should begin increasing and compressors should cycle accordingly.

☐ Check design specification for initial charge level

☐ Once MT discharge pressure increases the Gas Cooler fans and HPV will begin modulating per their control strategies.

☐ Frost should form on the base of the refrigerant tank when the tank is close to empty

☐ Check to purge air from hoses when adding new refrigerant tank(s)

☐ Change the core of the filter drier on the charging port for every 500 lbs. of refrigerant added.

6.4.4. START MT COMPRESSORS

NOTE

Groups of case piping circuits can be designated to start sequentially to allow easier troubleshooting during startup. A system controller is typically used to manage the operation of the various circuits.

☐ Change panel switch for compressors from OFF to ON

☐ Turn on case controllers for the first section of MT loads to be started

☐ Slowly open main CO_2 liquid line valve(s) to the MT loads

☐ MT compressors begin running and pulling down case pressures and temperatures.

☐ Add CO_2 Liquid Charge to maintain the flash tank level just above first site glass (no more than 25%) after cases are running at operating temperatures.

6.4.5. PULL DOWN MT CASES & WALK-INS

Confirm that MT Cases and Walk-Ins are meeting the required temperatures

6.4.6. START LT COMPRESSORS

☐ Slowly Open main CO_2 liquid line valve(s) to the LT loads

☐ Turn on case controllers for the first section of LT loads to be started (Never start at full load)

☐ LT compressors begin running and pulling down case pressures and temperatures.

☐ Add CO_2 Liquid Charge to maintain flash tank level (see note below) after cases are running at operating temperatures.

NOTE

CO_2 Charge Capacity - The CO_2 Flash tank has sufficient volume for various operating conditions. The final charge should be checked when the system is stable, and when the cases and walk ins are pulled down to their set-point temperatures.

6.4.7. PULL DOWN LT CASES & WALK-INS

☐ Continue bringing all cases and walk-ins online and adjusting charge as needed

☐ Confirm that LT Cases and Walk-Ins are meeting the required temperatures

6.5. DEFROST OPERATION

The standard system defrost design is off cycle and electric defrost. All defrost should be staged properly over a 24-hour period. Defrost should be programmed to operate with 10% to 20% of system load/capacity at a time. This ensures that the system has sufficient cooling capacity to maintain the temperature of the system while recovering after defrost periods. Defrosting CO_2 evaporators is similar to conventional systems. Defrosting the evaporators is accomplished in three sequential stages, referred to as operating modes:

- Pumpdown Mode
- Heating Mode
- Drip Mode

The controller can be programmed to start and manage the defrost modes based on routine time periods, or based on temperature set-points.

NOTE

Reference the SOO for additional controller details.

1. **Pumpdown (10-12 minutes duration)**

   The controller initiates pumpdown mode, the first defrost stage. During this stage, the evaporator circuit (or evaporator) solenoid valve (or EEV) is closed preventing refrigerant from flowing to the evaporator(s). The evaporator fans run while any liquid CO_2 refrigerant remaining in the evaporator continues to boil into vapor.

2. ☐ **Heating (45-60 minutes maximum)**

   After the pumpdown period, electric heaters are turned on to melt accumulated ice on the evaporators. Evaporator fans are always off during the heating stage. The heater power is typically terminated when the evaporator temperature reaches a temperature set-point. The set-point is based on a temperature sensor located at the center of case evaporators, or at the U bend on walk-ins. The heater may also be terminated based on a set maximum (fail safe) time period. Circuits with various size cases should also have a defrost Klixon and relay installed to individual smaller cases to avoid over-heating.

3. ☐ **Drip Mode (10 minutes)**

   After the heating stage is complete, condensate continues to drip off the evaporator to the drain of the case or walk-in. The heater and fans are off during this stage. After Drip mode, the system resumes normal operation, with the evaporator cooling the load back to the set temperature.

07 MAINTENANCE AND TROUBLESHOOTING

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MAINTENANCE AND TROUBLESHOOTING

7.1. GENERAL MAINTENANCE PROCEDURES

Proper maintenance is critical to long term reliability and efficiency. For more detailed maintenance procedures, refer to the maintenance schedule or requirements for the specific system. The following are some general maintenance procedures.

7.1.1. INITIAL STARTUP

Operators should be especially careful during initial startup procedures. The following are some recommended maintenance steps to take during initial startup.

☐ Change all filters and driers by end of first week of startup

☐ If filters are dirty, repeat in 7 days

After 90 days:

☐ Change the filter driers

☐ Replace oil coalescing media

Suction Filter

Replaceable core suction filters are supplied for all units. The flanged shell holds replaceable pleated filter elements suitable for installation in the suction line of refrigeration systems. In this way any contaminants left in the system at start-up can be removed before they circulate back to the compressor. The suction filters are shipped loose for field installation.

Pressure Relief Valves (PRVs)

If the system is de-energized, venting of the R744 through the pressure-regulating relief valves on the equipment can occur. In such cases, the system might need to be recharged with R744, but in any case, the pressure regulating relief valve(s) shall not be defeated or capped. The relief setting shall not be altered.

7.1.2 PUMP-DOWN AND RESTART SEQUENCE FOR SERVICE



Figure 7-1. Suction Filter.

Pumping-down the system for service:

1. Close liquid CO_2 supply ball valve from flash tank. If pumping down for extended periods proceed to steps 3-7.
2. System starts to self-pump-down. Wait until there is no pressure rise in LT and MT suction. Pressure rise in LT and MT suction is the indication of liquid present in the system. When MT and LT compressors stays off for 10 minutes continuously move to step 3.
3. Turn OFF compressors using their switches on control panel.
4. Isolate flash tank. Close valves to FGBV, Oil reservoir, and from HPEV. if needed to be off for a long duration.
5. Use change over valve on the flash tank to switch to 870 psig psi pressure relief valve.
6. Turn OFF the breakers for all the LT and MT compressors
7. System pump-down is complete.

Restarting the system after pumping-down and service

1. Make sure gas cooler fans are operating or ready to operate.
2. Make sure all the compressors switches are OFF. For short duration pump down slowly open the main liquid valve. For extended pump down follow steps 2-15.
3. Turn on all the breakers ON.
4. Check to make sure controller is calling for open FGBV and close HPEV. High pressure in FGT above the max pressure set point (580 psig) will make the controller open the FGBV and close the HPEV.
5. Turn ON the switch for the lead MT compressor. Use only the lead MT compressor to operate in steps 4 to 12 by turning the switches OFF for remaining of compressors. LT compressors switches have to be OFF during the steps 4 to 14.
6. Gradually open angle valve from HPEV. Since controller is calling for close HPEV there should be no increase in flash tank pressure.
7. Gradually open the ball valve to FGBV. Initially barely open till lead MT compressor starts running. This will cause the suction pressure of MT compressors to rise and controller should start the lead MT compressor. Let the pressure in the flash tank decrease. Do not let

the MT suction pressure float higher than (500). Caution: Opening the ball valve fast can result in releasing refrigerant charge from MT suction PRV.

8. When operating the lead MT compressors to reduce the FGT pressure, pay attention to gas cooler pressure and do not let it rise above 1400 psig. In case of having plate HTX as Gas coolers where the internal volume is very small, the high side pressure is very sensitive.
9. Flash tank pressure should stabilize around 520 psig.
10. Use change over valve on flash tank to switch to 650 psig pressure relief valve
11. Turn ON switches for the rest of MT compressors and make sure they are ready to operate.
12. Gradually open Liquid CO_2 supply angle valve. The system should start running and pulling down MT cases.
13. After MT cases are stable turn ON LT compressor switches. Controller should start LT compressor and start pulling LT cases down.
14. Double check to make sure the valves from HPEV, oil reservoir, FGBV to flash tank and liquid CO_2 supply are fully open and 650 psig PRV on flash tank is in service.

7.1.2.1. PUMPING-DOWN THE SYSTEM FOR STANDBY (EXTENDED PERIOD)

1. Close liquid CO_2 supply ball valve from flash tank.
2. System starts to self-pump-down (MT pump-down pressure set point is 350 psig and LT pump-down pressure set point is 160 psig). Wait until there is no pressure rise in LT and MT suction. Pressure rise is in LT and MT suction is in the indication of liquid present in the system. When LT and MT compressors stays off for 10 minutes, continuously move to step 3.
3. You can leave the system standby at this point as long as there is a need for it. The system automatically maintain flash tank pressure. Compressors will come on if there is a need.
4. To start up the system, simply open liquid CO_2 supply ball valve from flash tank.

7.1.3. SCHEDULED MAINTENANCE

Table 7-1 shows the recommended inspection items for a scheduled maintenance program.

Action	Bimonthly	Yearly
Visually inspect equipment.	☐	☐
Check refrigerant charge.	☐	☐
Check compressor oil level and color.	☐	☐
Check compressor crankcase heater operation.	☐	☐
Check main power and control voltage.	☐	☐
Check appearance of area around the unit.	☐	☐
Check system pressures.	☐	☐
Check the system for leaks.	☐	☐
Check suction filters and liquid line filter driers for pressure drop.	☐	☐
Check all flanged connection bolts, fittings and line clamps for tightness.	☐	☐
Inspect condenser fan blades and motor mounts for cracks, loose set screws or mounting bolts.	☐	☐
Tighten all electrical connections.	☐	☐
Check operation and condition of contactors.	☐	☐
Check operation of auxiliary equipment.	☐	☐
Obtain oil sample for analysis; change oil if required.		☐
Change liquid line filter drier and suction filter cores.		☐
Test all operating and safety controls and record in service log book		☐

Table 7-1. Recommended Scheduled Maintenance

NOTE

The above information is provided only as a general guideline to aid servicing personnel and equipment owners in maintaining equipment.

NOTE

Actual service intervals may vary from the recommended due to variables in the actual equipment application, operating conditions, and environment.

Compressor Burnout Cleanup

The following is a recommended sequence to use in case of a motor burnout

- Determine the extent of the burnout. For mild burnouts where contamination has not spread through the system, it may be economical to save the refrigerant (see note after below).
- Replace all strainers and filter-driers.
- Install a replacement compressor and make a complete electrical check.
- Make sure the suction line adjacent to the compressor is clean. Replace the liquid line filter-drier (or replaceable cartridge) designed for “cleanup”. (After 90 days, the suction line filter should be removed.)
- Install a burnout core in the liquid line shell.
- If the refrigerant is removed from the system, add charge as needed.
- Start the compressor.
- Record the pressure drop across the suction line filter and keep for reference.
- Replace the suction line filter-drier core(s) if the pressure drop becomes excessive. After 90 days, the suction line filter should be removed.

NOTE

The refrigeration charge can be saved if the system has service valves. A severe burnout exists if the oil is discolored, an acid odor is present and contamination products are found in the high and low side. With this condition, extreme caution should be exercised to avoid breathing the acid vapors and to prevent contaminated liquid from making contact with the skin. If needed, thoroughly clean and verify operation of system controls, such as expansion valves, solenoids, check valves, reversing valves, oil separators, suction accumulators, etc. In extreme cases, components may need to be replaced.

	AFTER 4 HOURS	Observe the system during the first 4 hours. Replace filter cores as often as required, until no further change in pressure drop is observed.
	AFTER 48 HOURS	After the system has been in operation for 48 hours, check the condition of the oil for acids. If the oil test indicates an acid condition, replace the liquid and suction line filter- driers.
	AFTER 2 WEEKS	Check the system again after approximately 2 weeks of operation. If the oil is still discolored, or checks acid, replace the liquid and suction line filter-driers. Cleanup is complete when the oil is clean, odor free, and is determined to be acceptable by testing for acids or other contaminants. Replace the suction line filter-drier with suction line filters cores to minimize suction line pressure drop and to provide maximum compressor protection.
	AFTER 90 DAYS	Suction Line filter should be removed

Table 7-2. Compressor Burn-out Time Line

One key benefit of a suction filter is its use in cleanup of a system after a burnout. Standard liquid cores can be installed in the shell to aid in the cleanup of acids and other contaminants from a motor burnout.

7.2. ALARMS

See the Sequence of Operation (SOO) for a summary of alarms.

7.3. COMMON MAINTENANCE ACTIONS

7.3.1. FREQUENT CAUSES FOR HIGH CO2 PRESSURE

Causes of High CO_2 Pressure on MT or LT compressor suction:

- Non-condensable gases
- High evaporator load
- High store ambient conditions (temperature or humidity)

- LT compressor group stopped (LT compressor suction only)
- MT compressors tripped (MT compressor suction only)

7.3.2. EVACUATING NON-CONDENSABLE GASES

Non-condensable gases are prevented by:

- Following proper evacuation steps
- Purging refrigerant lines during charging process
- Ensuring that valves are never opened such that a vacuum is created in the piping.

7.3.3. PREPARATION FOR PIPING REPAIRS

Use the following steps for the maintenance of piping or for replacing in-line components:

1. Close upper isolation valves first to allow liquid to drain downward
2. Close isolation valves to cases and walk-in freezers and manually start a defrost cycle to boil remaining CO_2 liquid from the evaporators
3. Continue to remove liquid keeping piping pressures above 100 psig
4. When all liquid is removed, vapor CO_2 can be released safely through a hose to a well-ventilated space or outside the work area.
5. Keep CO_2 gas cylinder attached to the system when possible with regulator set to 10 psig to prevent any air entering the piping.
6. Conduct repairs or replace parts
7. Before restarting the system, evacuate the piping according to customer specifications. (See section 0 Testing and Evacuation).
8. Break vacuum with CO_2 vapor, and pressurize the piping to 150 psig.
9. Return isolation valves to the open (or normal operating) position.

7.3.4. SYSTEM SHUT DOWN

The CO2 system should be pumped down before turning off the rack to prevent loss of CO2 through the relief valves. Use the following steps to turn off the ECO2 Large rack

LT Pumpdown: Close the LT liquid supply ball valve allowing the compressors to continue running, in order to pumpdown the CO_2 refrigerant at the system LT side. CO_2 refrigerant will flow to the flash tank.

MT Pumpdown: Close the main liquid supply valve at the outlet of the flash tank, and allow the compressors to continue running, in order to pumpdown the CO_2 refrigerant at the system MT side. CO_2 refrigerant will continue to flow to the flash tank. MT compressors will cycle off at the low suction pressure setpoint. The compressor crankcase heaters will automatically turn on as the compressors cycle off.

With CCP Option: As an option, systems are equipped with an CCP to maintain CO_2 temperature and pressure to prevent venting CO_2 refrigerant from the system. The CCP is set to a slightly higher operating pressure so it doesn't run during normal operation.

Refrigerant: CO_2 refrigerant charge should be verified and possibly added to normal level after restarting the system

7.4. TROUBLESHOOTING

Refrigeration systems are complex and run constantly. Problems have to be quickly corrected or expensive food will be ruined.

Troubleshooting is a logical and systematic search for the source of a problem in order to correct the problem and make the system operational again in a minimal amount of time.

When troubleshooting a system, it is important to have a systematic approach to collecting and analyzing data. Table 7-3 is an example of a general troubleshooting process.

NOTE

Table 7-3 is an example only. Operators should develop a troubleshooting methodology for their own specific equipment.

Table 7-3. Example troubleshooting Table

	PROBLEM	POSSIBLE CAUSES	POSSIBLE CORRECTIVE STEPS
COMPRESSOR	Compressor will not run	Main switch open	Close switch.
		Fuse blown	Check electrical circuits and motor winding for shorts or grounds.
			Investigate for possible overloading.
			Replace fuse after fault is corrected.
		Thermal overloads tripped	Check Compressor Temperatures and Electrical.
			Check line.
		Defective contactor or coil	Repair or replace.
		System shut down by safety devices	Determine type and cause of shut-down and correct it before resetting safety switch.
		No cooling required	None. Wait until calls for cooling.
		Liquid line solenoid will not open	Repair or replace coil.
		Motor electrical trouble	Check motor for open windings, short circuit or burn out.
		Loose wiring	Check all wire junctions. Tighten all terminal screws.
		Phase loss monitor inoperative	Refer to Phase Loss manual. Make sure 3 phases of power are supplied to module
	Compressor noisy or vibrating	Flooding of refrigerant into crankcase	Check setting of expansion valves.
		Improper piping support on suction or liquid line	Relocate, add or remove hangers.
		Worn compressor	Replace compressor.
		Scroll compressor rotation reversed	Rewire for phase change.
		Oil levels too high	Reset oil float and/or drain excess oil from system.
	Compressor thermal protector switch open	Operating beyond design conditions	Add components to bring conditions within acceptable limits (i.e., CPR)
		Discharge valve partially shut	Open discharge valve.
		Blown valve plate gasket	Replace gasket.
		Dirty condenser coil	Clean coil.
		Overcharged system	Reduce charge.
PRESSURE	High discharge pressure	Non-condensable gas in system	Remove the non-condensable gas.
		System overcharges with refrigerant	Remove excess.
		Discharge shutoff valve partially closed	Open valve.
		Fan not running	Check electrical circuit.
		HPEV stuck almost closed	Check HPEV opening in EMS.
		Dirty condenser coil	Clean.
	Low discharge pressure	Faulty condenser temperature regulation	Check gas cooler control operation.
		Suction shutoff valve partially closed	Open valve.
		Insufficient refrigerant in system	Check for leaks. Repair and add charge.
		Variable head pressure valve	Check valve setting.
	High suction pressure	Excessive load	Reduce load or add additional equipment.
		Expansion valve overfeeding	Check remote bulb. Regulate superheat.
	Low suction pressure	Lack of refrigerant	1. Check for leaks. Repair and add charge.
		2. Evaporator dirty or iced	2. Clean.
		3. Clogged liquid line filter drier	3. Replace cartridge(s).
		4. Clogged suction line or suction gas strainers	4. Clean strainers.
		5. Expansion valve malfunctioning	5. Check and reset for proper superheat.
		Condensing temperature too low	Check means for regulating condensing temperature.
		Improper TXV	Check for proper sizing.
OIL	Little/No Oil Pressure	Clogged suction oil strainer	Clean.
		Worn oil pump	Replace.
	Compressor loses oil	Lack of refrigerant	Check for leaks and repair. Add refrigerant.
		Excessive compression ring blow by	Replace compressor.
		Refrigerant flood back	Maintain proper superheat at compressor.
		Improper piping or traps	Correct piping.

08 DATA, DEFINITIONS AND ACRONYMS

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DATA, AND DEFINITIONS AND ACRONYMS

8.1. DATA

Subsection 8.1 contains the following data-related information:

- Dimensions of an ECO_2 Large rack
- Example Piping Diagram
- CO_2 pressure/temperature charts
- Temperature and pressure conversion charts

8.1.1. DIMENSIONS FOR ECO2 LARGE RACK & FTE 1.0 MODULE

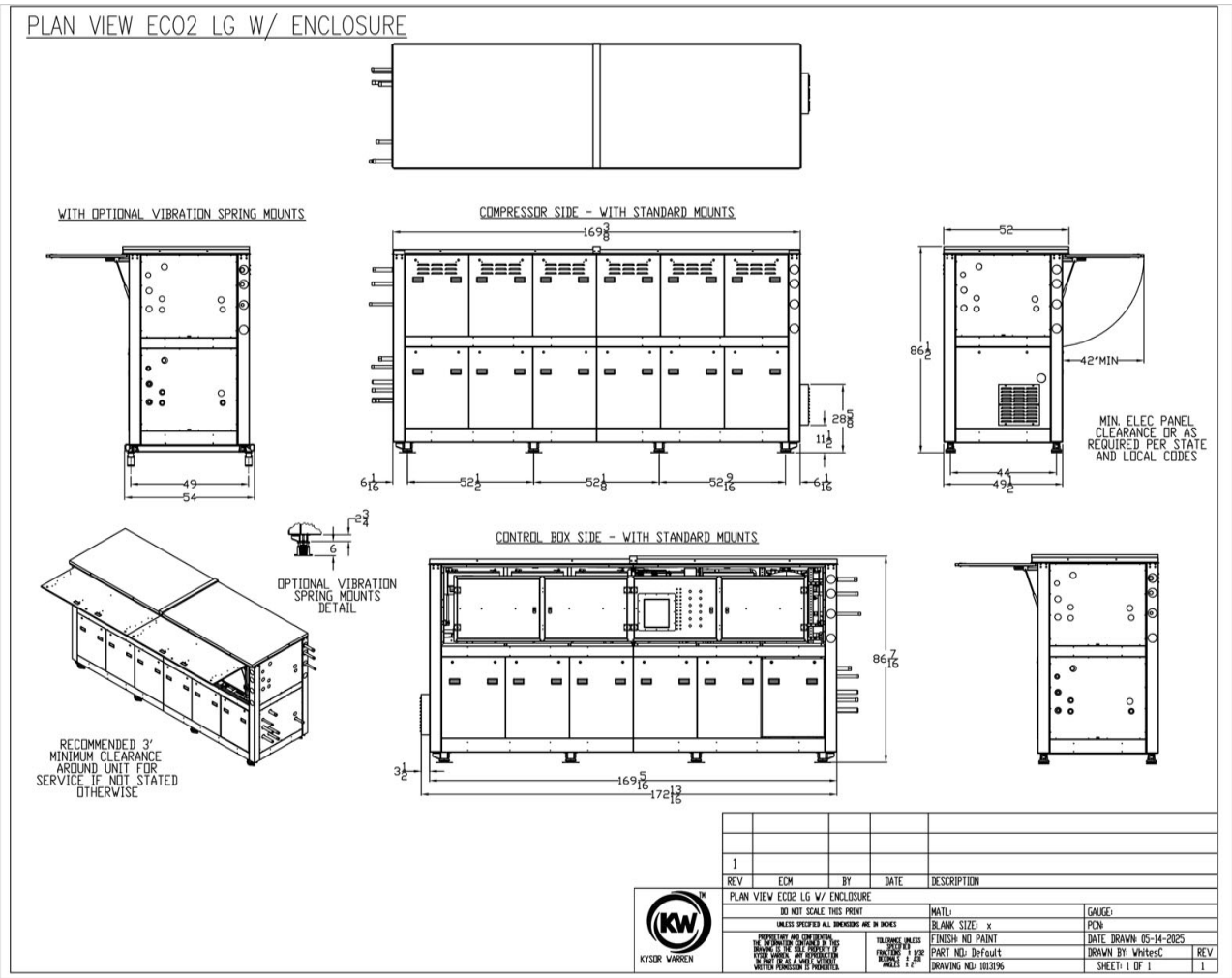

Figure 8-1. Global envelope for 1000mm

Note - FTE 1.0 is a separate module. FTE 2.0 is incorporated into the flash tank and included on the rack, unless a standalone FTE module is requested.

8.1.2. EXAMPLE PIPING DIAGRAM

Figure 8-3 displays an example piping diagram for a ECO_2 Large rack. Actual systems will be different in detail but should have the same general features.

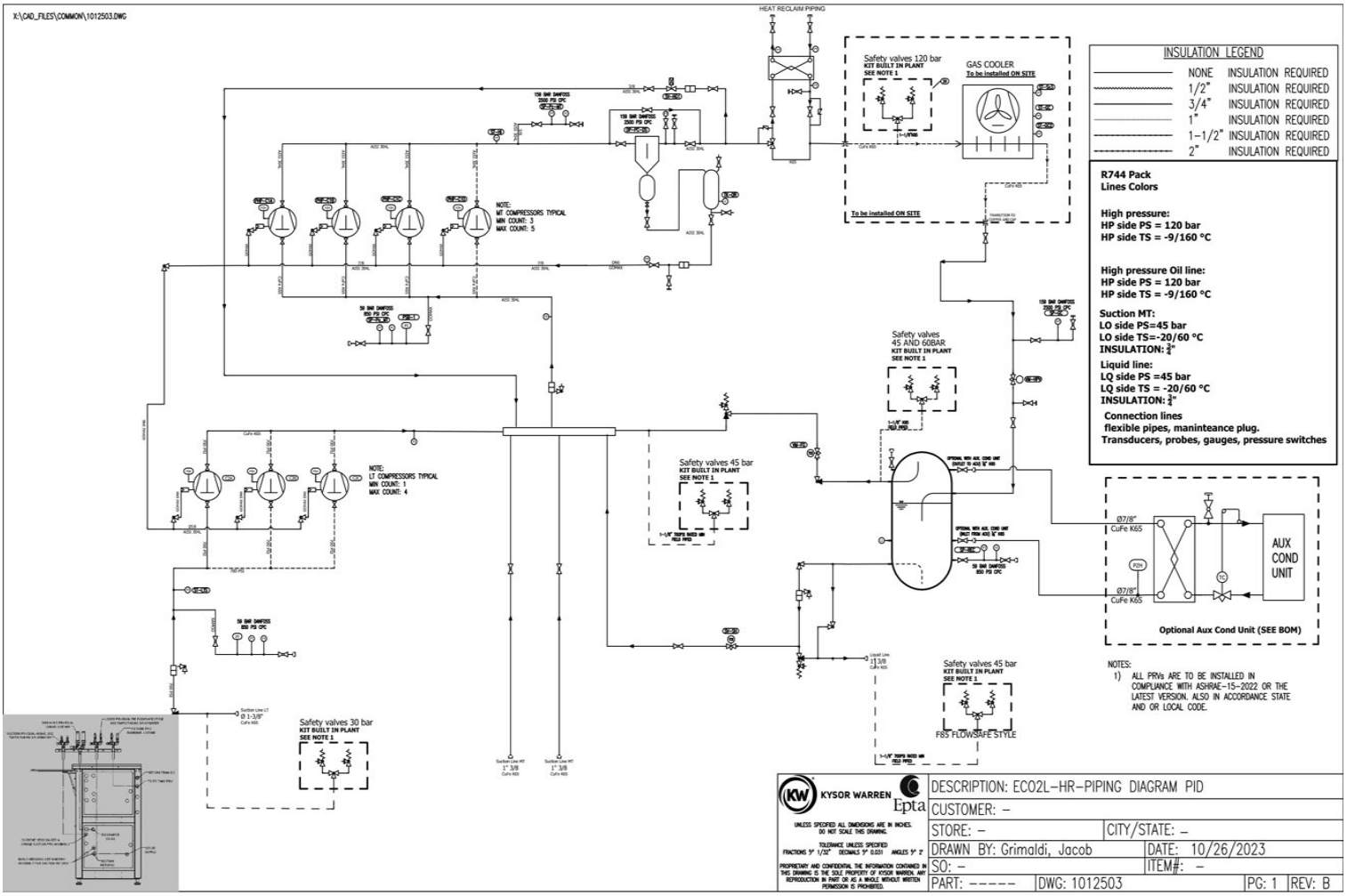

Figure 8-3. Example Piping Diagram

8.1.3. PRESSURE-TEMPERATURE CHART FOR CO_2 (R744) Below (Table 8-1) is the pressure-temperature chart for R744.

Temperature		Pressure	
(°C)	(°F)	(Bar-abs)	(psig)
-50.0	-58.0	6.8	84
-49.0	-56.2	7.1	88
-48.0	-54.4	7.4	93
-47.0	-52.6	7.7	97
-46.0	-50.8	8.0	101
-45.0	-49.0	8.3	106
-44.0	-47.2	8.6	111
-43.0	-45.4	9.0	116
-42.0	-43.6	9.3	121
-41.0	-41.8	9.7	126
-40.0	-40.0	10.0	131
-39.0	-38.2	10.4	136
-38.0	-36.4	10.8	142
-37.0	-34.6	11.2	148
-36.0	-32.8	11.6	154
-35.0	-31.0	12.0	160
-34.0	-29.2	12.5	166
-33.0	-27.4	12.9	172
-32.0	-25.6	13.3	179
-31.0	-23.8	13.8	185
-30.0	-22.0	14.3	192
-29.0	-20.2	14.8	199
-28.0	-18.4	15.3	207
-27.0	-16.6	15.8	214
-26.0	-14.8	16.3	222
-25.0	-13.0	16.8	229
-24.0	-11.2	17.4	237
-23.0	-9.4	17.9	245
-22.0	-7.6	18.5	254
-21.0	-5.8	19.1	262
-20.0	-4.0	19.7	271
-19.0	-2.2	20.3	280
-18.0	-0.4	20.9	289
-17.0	1.4	21.6	298
-16.0	3.2	22.2	308
-15.0	5.0	22.9	317
-14.0	6.8	23.6	327
-13.0	8.6	24.3	338
-12.0	10.4	25.0	348
-11.0	12.2	25.7	359
-10.0	14.0	26.5	369

Pressure		Pressure	
(°F)	Psi(Pressure)	(°C)	bar(press)
18	409.1	-7.8	28.20
20	421.9	-6.7	29.09
22	435.1	-5.6	30.00
24	448.6	-4.4	30.93
26	462.3	-3.3	31.87
28	476.4	-2.2	32.85
30	490.8	-1.1	33.84
32	505.5	0.0	34.85
34	520.6	1.1	35.89
36	536.0	2.2	36.95
38	551.6	3.3	38.03
40	567.6	4.4	39.13
42	584	5.6	40.27
44	600.7	6.7	41.42
46	617.7	7.8	42.59
48	635.2	8.9	42.59
50	653.0	10.0	45.02
52	671.2	11.1	46.28
54	689.7	12.2	47.55
56	708.7	13.3	48.86
58	728	14.4	50.19
60	747.8	15.6	51.56
62	767.9	16.7	52.94
64	788.5	17.8	54.37
66	809.5	18.9	55.81
68	830.9	20.0	57.29
70	852.8	21.1	58.80
72	875.2	22.2	60.34
74	898	23.3	61.91
76	921.4	24.4	63.53
78	945.3	25.6	65.17
80	969.6	26.7	66.85
82	994.5	27.8	68.57
84	1020	28.9	70.32
86	1046.3	30.0	72.14
88	1074.1	31.1	74.06

Table 8.1. Pressure-temperature chart for R744 – CO_2

8.1.4. ADDITIONAL TEMPERATURE AND PRESSURE CONVERSIONS

See Table 8-1 for temperatures and pressures below the CO_2 critical point. Table 8-2 lists the unit conversions for pressuresand temperatures above the critical point are shown below.

Temperature		Temperature	
(°F)	Psi(Pressure)	(°C)	bar(press)
-50	115.1	-45.6	7.94
-48	121.3	-44.4	8.36
-46	128.6	-43.3	8.87
-44	134.7	-42.2	9.29
-42	139.8	-41.1	9.64
-40.0	145.7	-40.0	10.05
-38	151.7	-38.9	10.46
-36	158	-37.8	10.89
-34	164.4	-36.7	11.33
-32	171	-35.6	11.79
-30	177.8	-34.4	12.26
-28	184.8	-33.3	12.74
-26	192	-32.2	13.23
-24	199.2	-31.1	13.76
-22	207.1	-30.0	14.28
-20	214.9	-28.9	14.82
-18	223	-27.8	15.36
-16	231.2	-26.7	15.94
-14	239.7	-25.6	16.53
-12	248.4	-24.4	17.13
-10	257.4	-23.3	17.75
-8	266.6	-22.2	18.38
-6	276	-21.1	19.03
-4	285.7	-20.0	19.70
-2	295.6	-18.9	20.38
0	305.7	-17.8	21.08
2	316.2	-16.7	21.80
4	326.9	-15.6	22.53
6	337.9	-14.4	23.28
8	348.9	-13.3	24.06
10	360.4	-12.2	24.85
12	372.1	-11.1	25.66
14	384.2	-10.0	26.49
16	396.5	-8.9	27.34
18	409.1	30.0	72.14

Pressure		Pressure	
(°F)	Psi(Pressure)	(°C)	bar(press)
18	409.1	-7.8	28.20
20	421.9	-6.7	29.09
22	435.1	-5.6	30.00
24	448.6	-4.4	30.93
26	462.3	-3.3	31.87
28	476.4	-2.2	32.85
30	490.8	-1.1	33.84
32	505.5	0.0	34.85
34	520.6	1.1	35.89
36	536.0	2.2	36.95
38	551.6	3.3	38.03
40	567.6	4.4	39.13
42	584	5.6	40.27
44	600.7	6.7	41.42
46	617.7	7.8	42.59
48	635.2	8.9	42.59
50	653.0	10.0	45.02
52	671.2	11.1	46.28
54	689.7	12.2	47.55
56	708.7	13.3	48.86
58	728	14.4	50.19
60	747.8	15.6	51.56
62	767.9	16.7	52.94
64	788.5	17.8	54.37
66	809.5	18.9	55.81
68	830.9	20.0	57.29
70	852.8	21.1	58.80
72	875.2	22.2	60.34
74	898	23.3	61.91
76	921.4	24.4	63.53
78	945.3	25.6	65.17
80	969.6	26.7	66.85
82	994.5	27.8	68.57
84	1020	28.9	70.32
88	1074.1	31.1	72.14

Table 8.2. Temperature and Pressure Conversions

8.2. DEFINITIONS AND ACRONYMS

The definitions and acronyms listed below are used within this manual.

Term or Acronym	Definition
Bar	Unit of pressure measurement equal to 100 kPa, or 14.5 psi (Bar is Bar-gauge)
Booster System	A booster refrigeration system is type of refrigeration system where two stage compression occurs with the first stage compression discharge connected to the second stage suction in order to boost the second stage suction pressure. The first stage compression group provides cooling at a lower temperature than the second stage compression group
BPHE	Brazed Plate Heat Exchanger
CCP	CO_2 Charge Protector
Critical Point	Critical point is the end point of a phase equilibrium curve, where distinct liquid and gas phases do not exist. For CO_2, the critical temperature and pressure are 87.77°F (30.98°C) and 1055 psig (73.77 bar).
Design Pressure	The maximum pressure for which a system or specific part of a refrigerating system is designed. This corresponds to the advertised maximum working pressure. For parts, this is also called: Maximum allowable working pressure Rated pressure Pressure rating
EEV	Electronic Expansion Valve
EMS	Energy Monitoring System
Enthalpy	The measure of energy content in a fluid. Measured in British thermal units per pound (Btu/lb)
EPA	Environmental Protection Agency
Expansion Device	A component that reduces the pressure and temperature adiabatically in a refrigeration system. There are several types but a thermal expansion valve is most common for air conditioning applications. The device is located in the liquid line as close to the evaporator as possible.
FGBV	Flash Gas Bypass Valve
GreenChill	EPA Program that recognizes food retailers that have implemented technology that reduces refrigerant emissions, and decreases their impact on the ozone layer and climate change.
GWP	Global Warming Potential. For exemple: (CO2/R744=1, R22=1810, R410A=2088)
Heat Recovery	Heat recovery units use the waste heat (compressor superheat) generated by the compressors in order to heat a closed loop water circulation which in turn is used to heat air, tap water, or other heating applications.
High Side	The section of the system containing all components between the MT compressor discharge and the inlet of the HPEV. All components and piping in this side of the system and piping have a design pressure of at least 120 bar (1740 psig). Typical working pressures on this side are expected between 45 and 100 bar (652 to 1450 psig) depending on ambient conditions.
Hot Gas Dump	A method of preventing liquid slugging in the MT compressors by injection of hot gas from the MT compressor discharge back to the suction controlled by a solenoid valve.
HPEV	High Pressure Expansion Valve. Also known as HPV – high pressure valve, or HPCV – high pressure control valve.
IDLH	Immediate Danger to Life and Health
Intermediate Pressure Stage	The section of the system containing all components between the HPEV outlet and the inlet of the EEV's at the cases. All components and piping in this side of the system have a design pressure of at least 45 bar (652 psig). KWE offers an option of up to 90 bar intermediate pressure rating
Liquid Hammer	In compressors, if a considerable amount of liquid enters the compressor house, a very large pressure can be built up when the piston reaches its top position. This phenomenon is called liquid hammer, and may cause severe damage to the valves or crankshaft.
Liquid Injection	A method to control the superheat in the MT compressor suction when necessary by injecting liquid refrigerant into that stream. This will be triggered and controlled when the MT suction superheat exceeds a pre-determined set point.

Low Side	The section of the system between the outlet of the LT EEVs and suction of the LT compressors. All components and piping in this section have a design pressure of at least 30 bar (435 psig). Normal operating pressures are expected around 13 to 15 bar (188 to 218 psig).
LT (Low Temperature)	The low temperature side of a CO_2 trans-critical refrigeration system is the portion that deals with the refrigerant at very low temperature and pressure, 22°F and 218 psig (30°C and 15 bar). This is generally the LT evaporator suction lines. The compressor that operates at the LT side is called LT compressor.
Micron	Microns are a measure of vacuum and equals I milliTorr or 1/1,000 of a Torr. 1 micron = 0.1333 Pascals (Pa).
MT (Medium Temperature)	The medium temperature side of a CO_2 trans-critical refrigeration system is the portion that deals with the refrigerant at medium temperature and pressure (-6°C and 30 bar). This is generally the MT evaporator suction lines. The compressor that operates at the MT side is called MT compressor.
ODP	Ozone Depletion Potential. For exemple: (CO2/R744=0, R134a=0, R22=0.055, R410A=0)
Oil Management System	Both MT & LT compressors require lubrication to run in order to avoid wear & tear and overheating. The equipment and protocol that deals with circulation of oil in the compressors is known as the oil management system. The equipment for oil management systems are oil separator, oil reservoir, oil level switch, oil regulator, respective solenoid valves, crankcase heater, etc.
PRV	Pressure Relief Valve
Refrigerant	Working fluid of refrigeration system
Riser	A refrigerant pipe that runs vertically.
SOO	Sequence of Operation provides a general summary of the control functions and settings.
Subcooling	Subcooling is the process by which saturated liquid is cooled below the saturation temperature. This can be achieved by heat transfer from cold suction gas or by a dedicated evaporator.
Subcritical State	Subcritical state of fluid is any substance at a temperature or pressure below its critical point, where distinct liquid and gas phases exist. The saturation point of the fluid exists at a unique temperature and pressure.
Supercritical State	Supercritical state of a fluid is any substance at a temperature and pressure above its critical point, where distinct liquid and gas phases do not exist. Also called Supercritical Fluid.
Superheat, SH	Temperature of vapor above its saturation temperature at that pressure.
TLV	Threshold Limit Value (related to exposure to refrigerants)
Transcritical Cycle	A refrigeration cycle in which the heat rejection (condenser/gas cooler) occurs at a pressure above the critical point of the refrigerant. For CO_2, the critical pressure is 1055 psig (73.77 bar).
TWA	Time Weighted Average (related to exposure to refrigerants)
Upper Cascade	The refrigerant circuit in a cascade system that removes heat from a refrigerated load and transfers the heat to the upper-cascade
VFD	Variable Frequency Drive
Working Pressure	The pressure applied to a part or system while operating. (See Design Pressure)

Table 8.3. Definitions and Acronyms

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