Advansor CO2 Flex Booster Refrigeration System

INSTALLATION, START-UP & OPERATING MANUAL

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To ensure proper functionality and optimum performance, it is strongly recommended that Hillphoenix refrigeration systems be installed/serviced by qualified and certified technicians who have experience working with commercial refrigeration systems. For a list of Hillphoenix authorized installation/service contractors, please visit our Web site: www.hillphoenix.com

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2017 DOE COMPLIANT

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DISCLAIMER

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This volume is an Installation and Startup manual.

Hillphoenix Learning Center Systems Division

IMPORTANT

At Hill PHOENIX®, the safety of our customers and employees, as well as the ongoing performance of our products, are top priorities. To that end, we include important warning messages in all Hill PHOENIX installation and operations handbooks, accompanied by an alert symbol paired with the word "DANGER", "WARNING", or "CAUTION".

All warning messages will inform you of the potential hazard; how to reduce the risk of case damage, personal injury or death; and what may happen if the instructions are not properly followed.

⚠ DANGER
Indicates an immediate threat of death or serious injury if all instructions are not followed carefully.

⚠ WARNING
Indicates a potential threat of death or serious injury if all instructions are not followed carefully.

⚠ CAUTION
Indicates that failure to properly follow instructions may result in case damage.

Revision History

Rev.	Date	Change Description	Author
1.0	12/22	New Manual Creation - Updating to New Format	S. Montgomery

SCOPE OF SPECIFICATIONS & GENERAL NOTICE

Thank you for choosing Hillphoenix for your food merchandising needs. This handbook contains important technical information and will assist you with the installation and operation of your new Hillphoenix specialty cases. By closely following the instructions, you can expect peak performance, attractive fit and finish, and long case life.

We are always interested in your suggestions for improvements (e.g. case design, technical documents, etc.). Please feel free to contact our Marketing Services group at the number listed below. Thank you for choosing Hillphoenix, and we wish you the very best in outstanding food merchandising.

SECTION 1 - ADVANSOR CO2 BOOSTER REFRIGERATION SYSTEMS

1.A SCOPE OF SPECIFICATIONS

These specifications shall be considered as an addition to the common documentation supplied by the customer for complete installation of the supermarket's refrigeration system and are intended to describe the installation, testing, startup, and operation of a Hillphoenix Advansor Flex CO2 Booster Refrigeration System (hereafter referred to as Advansor) only. Failure to follow these specifications will void the manufacturer's warranty.

1.B GENERAL NOTICE

a. The Advansor system (equipment, devices, piping, insulation, etc.) shall be installed per the specifications contained in this "Advansor CO2 Flex Booster Refrigeration System Installation, Startup, and Operating Manual," the Hillphoenix Refrigeration Schedule (Legend), and the system piping diagram and installation drawings (if provided).

b. Any changes not approved by Hillphoenix will void the system warranty.

c. This specification may change without notice. Contact your Hillphoenix representative to verify the most current version of this document and any later developments which have not yet been published.

1.C ADVANSOR SYSTEM BASICS

Air-cooled condensing units require adequate ventilation for efficient performance. Machine-room temperatures must be maintained at a minimum of 65°F in winter and a maximum of 95°F in summer. Minimum condensing tem-peratures should be no less than 70°F.

1.C.I INTRODUCTION

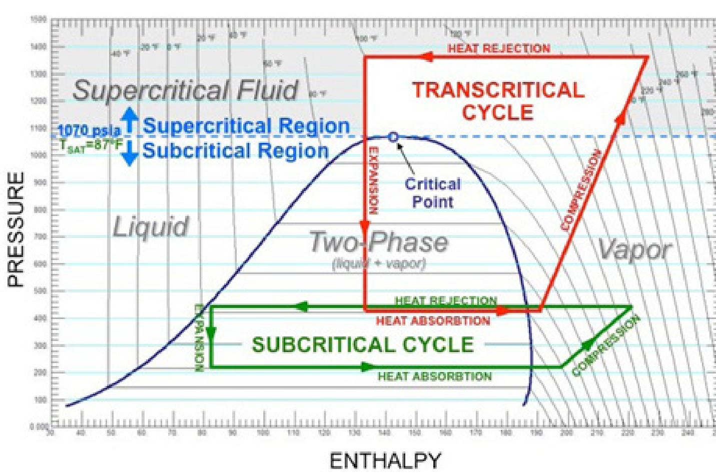
Advansor CO2 Booster Refrigeration Systems are the latest option in the Hillphoenix Second Nature product line that for the first time entirely utilize natural refrigerant. The Advansor system is the third type of CO2 system following the SNLT2 Secondary Coolant system and SNLTX2 Cascade system. Advansor systems, however, are not intended as a replacement to SNLT2, SNLTX2 systems, or any other type of system as each approach has unique characteristics that make them suitable for specific applications.

Advansor systems are considered Transcritical CO2 systems where the pressure of the CO2, depending on ambient conditions and other factors, may rise above the critical pressure of CO2. Operating pressures for these systems are higher than those in conventional direct-expansion systems. The components in the system and the entire system have been engineered to safely and efficiently handle those pressures. Typical operating pressures for Advansor systems are shown on page 28 of this manual.

1.C.II HOW THE SYSTEM WORKS

CO2 has several unique properties that make it ideal for use as a refrigerant in general and for booster systems in particular. The critical point of a substance is the point at which its liquid and vapor states cannot be distinguished. The critical point of CO2 for instance, is around **88° Fahrenheit** and is lower than that of other refrigerants such as R-134a **(214°F)** and R-410a **(162°F)**. Systems using these refrigerants always operate in the subcritical region. Systems using only CO2 to reject heat to ambient temperatures, on the other hand, do not always operate in the subcritical region. That requires system designers to approach the heat transfer process somewhat differently than they would for more commonly used refrigerants.

As the critical point is approached, the gas and liquid phases of a substance advance toward one another, resulting in only one phase at the critical point: a homogeneous supercritical fluid. There is no distinction between the two phases above this point. Above the critical temperature no additional amount of pressure will cause liquid to form.



The critical point is important in understanding the operation of the CO2 booster system. With its use of compressors, the system works in some ways like any other direct expansion

(DX) system but with a key difference. In a conventional DX system, the entire operation of the system takes place below the critical point, or in the subcritical region. Within this region, the refrigerant changes back and forth between only vapor and liquid. But as already pointed out, above the critical point another state is reached, that of a supercritical fluid and within that region no further state change such as condensation occurs.

> The term "critical point" refers to when an indistinct physical state of a substance is reached. It does not in any way imply any difficulty in dealing with the substance. It simply means that at a temperature and pressure above the critical point there is no distinction between the liquid and vapor states of a substance. In fact, above the critical point, a substance is said to exist as a supercritical fluid in which no further state change can occur, only changes in density can take place.

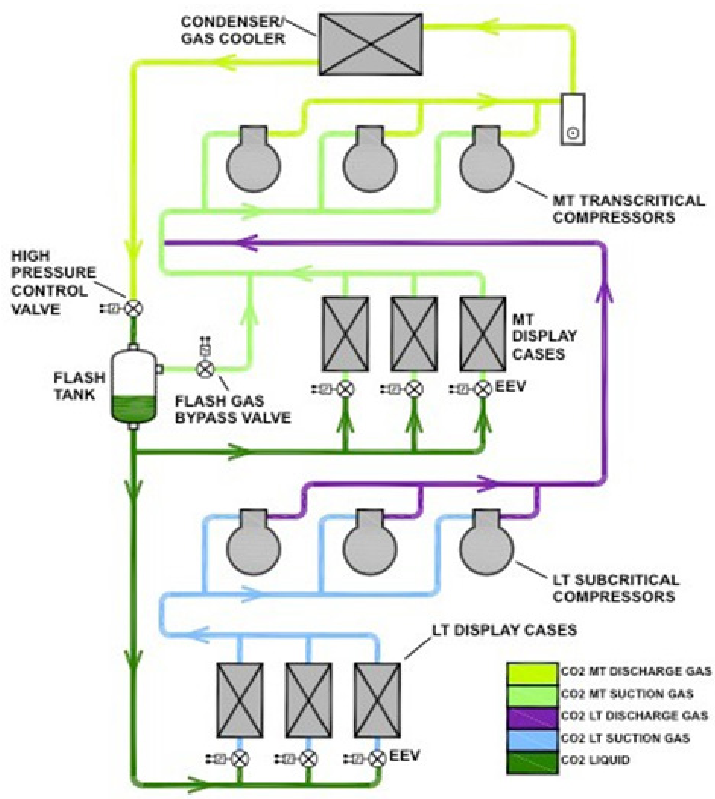
Certain aspects of the Advansor system will be familiar to anyone familiar with DX systems. Like those systems, the Advansor system has four main components that include compressors, evaporators, condensers, and expansion valves. Additionally, the system uses two types of specialized valves: a high-pressure control valve and a flash gas bypass valve.

Another key difference from traditional systems is that functionally the system operates as what is known as a two-stage booster system with the same refrigerant moving between the low and medium-temperature compressors. The low-temperature compressors discharge to the suction of the medium-temperature compressors. In other words, the medium-temp compressors serve as a booster to the low-temp compressors.

Suction gas from the low-temperature display case and freezer evaporators enters the low-temperature subcritical compressors at around **200 psig**, well below the critical point for CO2. The low-temp discharge gas at about **400 psig** then combines with the medium-temp suction gas from the medium-temp display cases and walk-in cooler evaporators before entering the medium-temp transcritical compressors. The medium-temp discharge gas leaves the compressors, depending on ambient conditions, anywhere from **560 psig** to as much as **1,450 psig**, which is above the critical point.

The medium-temperature compressors normally operate at pressures from **855 psig to 1,290 psig** depending upon ambient conditions.

Under warmer conditions in which the pressure rises above **1,055 psig**, the system enters the transcritical range. Under either condition, however, hot discharge gas from the medium-temp compressors feeds to a condenser/gas cooler where, as with any refrigeration system, the heat is rejected to the outside environment.



Simplified Advansor Piping

Sizing of the compressors on the low-temperature and medium-temperature stages of the system is carefully determined to provide optimal capacity control during partial load operation.

The condenser/gas cooler design is optimized to accomplish high-performance, even at high ambient temperatures when the system is operating in the transcritical range. (More about how these components work, and their specific operation, is described in greater detail in the next section.)

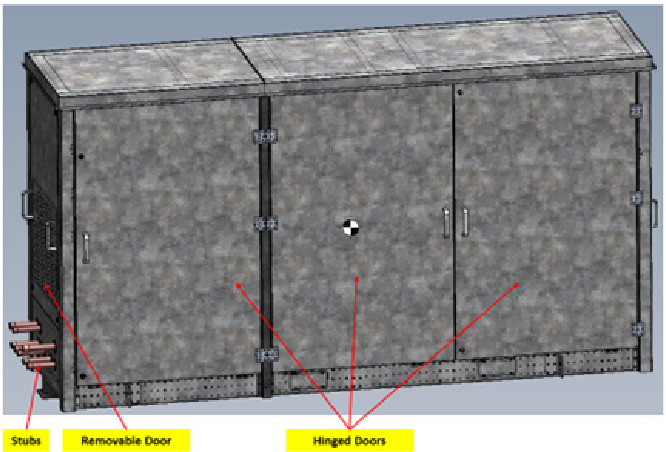
The CO2 leaving the condenser/gas cooler feeds to a high-pressure control valve that regulates the flow of CO2 into an intermediate pressure receiver, called a flash tank. The gas enters the valve at **560 psig to 1,450 psig**, depending on ambient conditions, and exits at approximately **540 psig**. The valve is designed to work as a hold-back valve in order to maintain optimum pressure through the condenser/gas cooler for the most efficient operational performance of the system.

Liquid refrigerant is supplied to the medium and low-temperature evaporators controlled by conventional electronic expansion valves. Vapor from the flash tank is fed through the flash gas bypass valve back to the medium-temperature compressors. The flash gas bypass valve maintains a constant pressure in the flash tank.

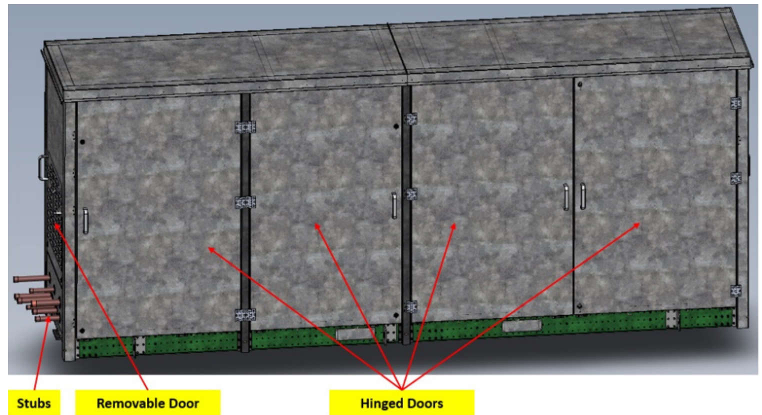
Apart from some of the unique components just described, the system works in a similar way to other types of DX systems. The main differences are related to the two-stage design of the system; all evaporators in the system are supplied with liquid from the same source. For most experienced technicians the system will not seem overly complicated.

I.C.III MAJOR SYSTEM COMPONENTS

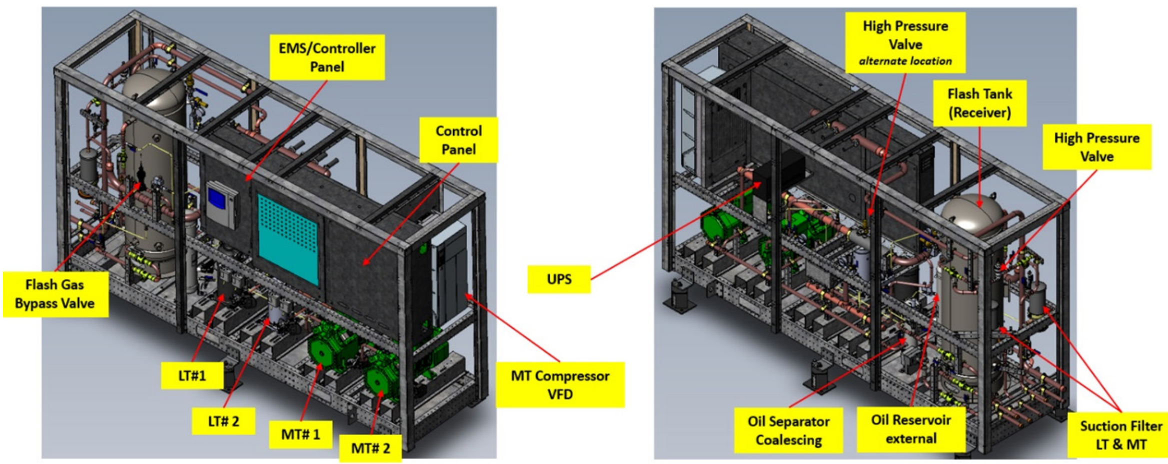
2x2 Rack – Enclosure



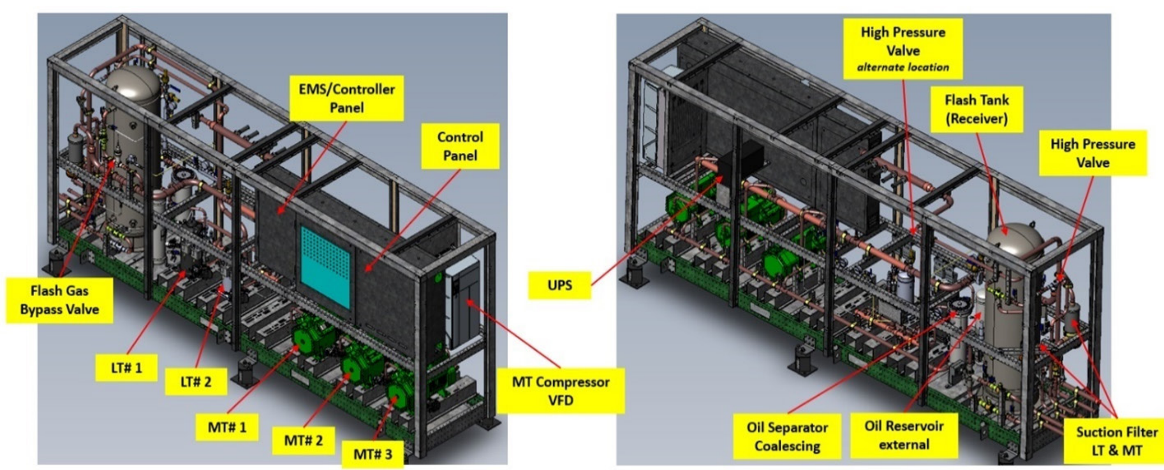
3x2 Rack - Enclosure



2x2 Rack - Front View & Rear View



3x2 Rack - Front View & Rear View



Advansor CO2 systems use many components that are common to other types of DX systems as well as some that are specifically designed for the application. Like any other DX type of system, the Advansor system relies on the four principle components which include compressors, evaporators, condensers and expansion valves.

1.C.III.a CO2 Compressors

As with any other type of DX system, the CO2 booster system uses compressors to move the refrigerant in it. Unlike most other types of these systems, which are typically divided between medium temperature and low-temperature applications, however, the Advansor system uses two sets of compressors in the same system.

The low-temperature "subcritical" compressors operate well below the critical point in much the same way CO2 compressors do in cascade systems. Like those compressors, the ones on the Advansor CO2 system receive suction gas from the low-temp evaporators. The suction gas enters the compressors at **183 psig** and the discharge gas leaves them at **410 psig**. At the same time, the discharge from the low temperature compressors combines with gas from the medium-temp evaporators to become the suction gas for the medium-temp compressors.

The Advansor system can use either scroll or semi-hermetic reciprocating compressors for the low-temp portion of the system.

Only semi-hermetic reciprocating compressors can be used for medium- temperature portion of the system. As medium-temp compressors, they discharge at anywhere from **560 psig to 1,450 psig**, depending on the ambient conditions. When viewed on a pressure-enthalpy (P-h) chart on page 2, the action of the medium-temp compressors can be seen in the upper section (shaded upper area) of the chart around **385 psig** when the gas enters the compressors. From there, again, depending on ambient conditions, the gas may reach to **1,385 psig** as it discharges from the compressors and enters the condenser/gas cooler. Of course, for the gas to reach that range, the ambient conditions must exceed **80°F**.

Each compressor is installed with some additional features including:

- Bolted to the frame on oil-resistant polymer mounts.
- Service valves on the suction and discharge sides
- OMC/INT280 electronic oil floats for active oil level management
- Pressure switches on the discharge side
- Some CO2 compressors contain relief valves to ambient (see the manufacturer's operating specifications for more information)
- Crankcase heaters to warm the oil when the compressor is not running
- Variable frequency drives (VFD) or Digital modulation on the lead compressor for better capacity control
  - Digital unloading on the Lead low-temp compressor
  - VFD or Digital unloading on the lead Medium-temp compressor

1.C.III.b Oil Separator and Oil Requirements

The Advansor system uses the same oil management components system as those on conventional DX systems except that they are designed for the higher operating pressures needed for CO2. These include electronic oil level sensors, a separator, a reservoir, and a filter or filter-less Multistage centrifugal separator with integrated reservoir. Once the medium-temperature discharge gas leaves the medium-temp compressors, it passes through a highly efficient oil separator using coalescing filters or highly efficient multistage centrifugal separator to separate the oil from the refrigerant.

Only manufacturer-approved oil is permissible for use in the Advansor system.

For very small systems (i.e., 2x1 models), the oil separator is equipped with an oil reservoir at the bottom of the unit from which the oil is fed back to the compressors according to demand. On booster rack models with external reservoirs, the oil separator is equipped with a larger filter. The oil from these units is fed from the oil separator to the reservoir through a solenoid valve that opens when the oil reaches a preset level in the separator. From there, the oil is fed from the reservoir to the compressors.

1.C.III.c Condenser/Gas Cooler

This component usually works the same way a condenser does in a conventional DX system. At ambient conditions below 80°F, medium-temperature discharge gas enters the condenser/gas cooler and rejects heat to the outside air as it passes through the coils of the unit. The main difference between it and a conventional condenser is that when the ambient temperature rises above 80°F, the system begins operating in the transcritical range. This means that the discharge gas passing through the system does not undergo any further state change but instead remains a supercritical gas, or fluid as it is otherwise known. This last point is a key distinction. Under transcritical conditions, the discharge gas enters the condenser/gas cooler as a supercritical fluid and stays that way throughout the condenser/gas cooler stage to the high-pressure control valve. No condensing of the gas takes place as in a regular condenser. Below 80°F, however, the unit then works just like a condenser in a typical DX system.

The condenser/gas cooler fans are controlled in the same way that compressors gain efficiency with variable speed drives. The condenser/gas cooler includes a shut-off valve for maintenance or other needs.

I.C.III.d High-Pressure Control Valve

Like the condenser/gas cooler, the high-pressure control valve works under two modes of operation. It usually controls subcooling in the condenser/gas cooler when that unit operates as a condenser. Under conditions during which the condenser/gas cooler is working as a gas cooler (above **80°F ambient**), the valve controls pressure in it.

Power to the valve is furnished from an uninterrupted power supply (UPS). The valve closes in case of a power failure.

I.C.III.e Flash Tank

The expanded gas from the high-pressure control valve flows into the flash tank. The flash tank is equipped with a flash gas bypass valve that maintains a set pressure in the tank. When opened, the valve bypasses excess vapor from the tank to the suction side of medium-temperature compressors.

I.C.4 OTHER SYSTEM COMPONENTS

I.C.4.a Piping

A high volumetric capacity is one of the benefits of CO_2. This allows for smaller diameter piping to be used than would otherwise be needed for a HFC system of similar capacity. In fact, smaller diameters add to the overall advantages of the system since they decrease the refrigerant charge and handle higher pressures. Piping and elbows to and from the condenser/gas cooler should be either C-194 copper, carbon steel, or stainless steel and should be installed to comply with appropriate standards. The steel piping that is welded must be coated with primer and varnish. During operation, the pipes can get hot (i.e., **250°F**) and insulation is recommended anywhere they might be touched.

1.D CONTROL STRATEGY

Advansor systems in North America are installed with energy management system controllers specified by the customer. All U.S. made systems, however, may have an additional control on the rack specifically for the condenser/gas cooler. The controller ensures the system's maximum performance by maintaining the optimal pressure in the gas cooler when regulation takes place in the transcritical range. This method of control provides optimum COP (coefficient of performance). Heat reclaim with a 0- 10-volt signal is also available through this approach.

The Advansor system usually operates like conventional DX systems during the subcritical mode of operation. Since the system is referred to as a transcritical booster system operating from the subcritical to supercritical range of CO_2, it differs significantly from conventional systems. To understand these differences, particularly with respect to how the system is controlled, a simplified configuration of the system excluding additional features best illustrates how the system works. The numbers used for this discussion are based in part on the system operating in the Hillphoenix lab where the condenser is sized for a five-degree temperature difference (TD). The TD for other systems will depend on the specific requirements of each specific installation. Regardless of those specifics, the control strategy for any Advansor system will change from one to another of three modes of operation (subcritical, transitional, or supercritical) depending on ambient temperature conditions.

1.D.I OPERATIONAL STAGES

1.D.I.a Subcritical Operation

When operating in CO_2's subcritical temperature range, the high side of the system is controlled by maintaining the liquid outlet temperature from the condenser/gas cooler with two devices: the condenser fans (either variable or constant-speed) and a high-pressure control valve (CCMT valve). On units with variable speed fan control, the condenser/gas cooler fan motors are wired in parallel so that they all operate at the same speed. The variable speed-controlled fans in a sense operate as a single big fan, ramping up and down and cycling on and off together instead of individually.

Taking a condenser sized for a five-degree TD (as noted above), both the condenser fans and the CCMT valve work together to maintain three degrees subcooling when ambient temperatures range from **41°F to 72°F**. Operating in the subcritical mode, the condenser fans are controlled so that the saturated liquid temperature set point at the exit of the condenser is kept to five degrees above ambient (i.e., at an ambient temperature of **72°F**, the saturated liquid temperature set point would be **77°F**, and at **41°F** ambient the saturated liquid temperature set point would be **46°F**. The controller achieves three-degree subcooled liquid by taking the saturated liquid temperature set point and calculating how much pressure is needed. The CCMT valve then modulates the refrigerant pressure to maintain the subcooled liquid by **3.6°F**. Thermodynamically speaking, when the saturated liquid temperature set point is **77°F**, its corresponding saturated pressure is **919 psig**. In order to sub cool CO_2 three-degrees at **77°F**, the saturation pressure at **80°F (77° + 3°)** that needs to be achieved is **955 psig**. The CCMT valve modulates the pressure of the refrigerant so that the CO_2 liquid becomes subcooled at **77°F and 955 psig**. A detailed description of how to set up the system from a controls perspective is included in the next section of this manual.

When ambient temperatures are colder than **41°F**, the fans in the condenser/gas cooler are generally not needed and will shut off. Natural convection extracts enough heat from the CO_2 vapor to condense into a subcooled liquid. The amount of subcooling that occurs when ambient temperatures fall below **41°F** is only controlled by the CCMT valve.

1.D.I.b Transitional Operation

When ambient temperatures are between **72° F and 83° F** the saturated liquid temperature set point no longer floats to five degrees above ambient. In this range, the condenser fan set point is fixed at **77° F**. On systems equipped with variable speed-controlled fans, the fans vary to maintain the set point to cool the CO_2 gas as much as possible. Although the CCMT valve uses a different algorithm to achieve the three degrees of subcooling, it continues to operate as it does in the subcritical operation mode. Once the ambient temperature hits the condenser/gas cooler discharge saturated liquid set point of 77° F, the fans go full on (100% on variable speed-controlled units and all on for non-variable speed-controlled systems).

1.D.I.c Transcritical Operation

Above 83° F ambient, the system operates in the transcritical range and the removal of latent heat that occurs in a conventional condenser no longer takes place. At this point the gas (now referred to as a supercritical fluid) cannot be converted to liquid, it can only be cooled. From 83°F and warmer, the system is unable to maintain the 5-degree above ambient setpoint and can only reduce its sensible heat content by running the fans at full speed.

The controller sends the control signal to CCMT valve which determines how to regulate the gas pressure depending on whether the system is in transcritical mode or subcritical mode. While in transcritical operation mode, the CCMT valve reduces the pressure of the supercritical CO2 fluid so that it returns to its subcritical state as a saturated liquid vapor mixture. From there the subcritical liquid vapor mixture reaches the flash tank. Through the flash gas bypass valve, a portion of the vapor returns to the inlet of the medium temp compressors thereby maintaining the flash tank operational pressure.

Algorithms controlling the CCMT valve enable it to achieve an optimum COP (coefficient of performance) for the compressors during transcritical operation.

1.E REFRIGERATION

1.E.I DIRECT EXPANSION REFRIGERATION USING CO2

Under normal conditions the system works much like the way a typical DX system does. Once the CO2 refrigerant has accumulated in the flash tank as a liquid, the refrigeration process and control strategy hardly differ from other DX systems. The liquid CO2 is distributed to both the medium and low temperature cases where their respective expansion valves control the refrigerant flow through the evaporator. As the liquid CO2 absorbs heat from the product, it changes phase to a superheated vapor. The vapor from the lines return to the low or medium temperature compressors, where the discharge CO2 is compressed to a pressure and temperature that is similar to the superheated vapor that returns from the medium temperature lines. This CO2 vapor is also mixed with the flash gas bypass CO2 vapor that is coming from the flash gas tank. All three vapor sources feed the medium temperature compressor suction line where the whole refrigeration process repeats itself.

1.E.I.a Compressor Control

Compressor control is for the most part handled like any other type of multiple suction-group DX system. Compressor capacity control is accomplished through the controllers. These controllers work on suction pressure and are a standard means for controlling multiple suction groups in any refrigeration system. The controllers can regulate variable speed for two compressors combined with one-step compressors of the same or different sizes, depending on the choice of coupling pattern.

1.F CO2 PROPERTIES AND HANDLING

Before handling Carbon Dioxide (CO2), the contractor should be familiar with the Material Safety Data Sheet (MSDS) and the materials physical properties. An MSDS for CO2 is available from any supplier of industrial gases or the Compressed Gas Association– see next page.

Carbon Dioxide is a colorless, odorless, slightly acidic gas that is approximately 50% heavier than air. It is non-flammable and will not support combustion. Table 1. shows selected properties of CO2.

Carbon Dioxide has excellent thermodynamic properties which make it ideally suited for use as a refrigerant. Table 2 below shows selected properties of CO2 at -20°F and +20°F. A detailed pressure-temperature chart for CO2 is also shown in Appendix 1.

Table 1. Selected Properties of Carbon Dioxide

Molecular Weight	44.01
Boiling Point @ 1 atm.	-109.1°F
Triple Point @ 60.4 psig	- 69.8°F
Critical Temperature	87.9°F
Critical Pressure	1056 psig
Specific Gravity of Gas @ 1 atm.	1.53
OSHA TLV-TWA[1]	5,000 ppm (0.5%)

Note 1: Threshold Limit Value, Time Weighted Average

Table 2. Selected Thermodynamic Properties of CO2

Property	@-20°F	@+20°F
Saturation Pressure, Psig	200.2	407.2
Liquid Density, Lb/Ft3	66.9	60.3
Vapor Density, Lb/Ft3	2.40	4.94
Heat of Vaporization, Btu/Lb	129.6	107.5

1.F.I CO2 SAFETY

Carbon Dioxide is a naturally occurring substance present in air at concentrations of 300-400 parts per million (ppm) or 0.030%-0.040%. The Occupational Safety and Health Administration (OSHA) has listed for CO2 a TLV- TWA level of 5,000 ppm or 0.5%. This (Threshold Limit Value–Time Weighted Average) is the time-weighted average concentration for a normal 8-hour workday and 40-hour workweek, to which nearly all persons may be repeatedly exposed to without adverse effects. CO2 compares favorably to the TLV-TWA value of 3,000 ppm for typical HFC refrigerants (R-404A and R-507).

Operating temperatures for an Advansor system are similar to those of other types of DX systems. Typical operating pressures usually range from **870 psig to 1,305 psig** on the medium-temp discharge, and approximately **375 psig to 440 psig** on medium-temp suction. The low-temp suction pressure operates at approximately **180 psig to 220 psig**. Rapid depressurization of CO2 in liquid or liquid-vapor at pressures below the **60 psig** triple point will cause the liquid to convert directly from a liquid to a solid, forming dry ice at a temperature of **-109.3°F**.

More information on the safe use and handling of CO2 can be found in the Compressed Gas Association, Standard CGA-G-6-1997 “Carbon Dioxide.” This and other related standards can be obtained from:

Compressed Gas Association
4221 Walney Road, 5th Floor
703.788.2700
Chantilly, VA 20151
www.cganet.com

1.F.II CO2 GRADES

Carbon Dioxide is produced as a byproduct of several different manufacturing processes including the formation of hydrocarbons and various distillation and fermentation processes. In addition, CO2 exists naturally in wells. After the CO2 gas has been isolated, it is purified into different levels through the filtration of impurities and removal of moisture and non- condensable gases which result in different grades of CO2 for different applications. Examples of various grades of CO2 are shown in Table 3.

Carbon Dioxide purchased for use in refrigeration systems must be of a purity level high enough to prevent accumulation of non-condensable gases and moisture in the condenser-evaporator. A build-up of these gases can block the heat transfer surface and cause inefficient operation or malfunction of the system. Remove non-condensables, which may get charged into the system, by using an available access valve in the system to vent off CO2.

NOTE: *Hillphoenix recommends using Instrument (Coleman) CO2 which contains less than 0.01% non-condensable gases and moisture.*

Table 4 shows typical specifications for Instrument Grade CO2.

⚠ WARNING

Some CO2 gas suppliers offer a "cap-charge" of helium or other inert gases for liquid cylinders which increases tank pressure to speed the charging process. **DO NOT accept any cylinders with this cap-charge; use only cylinders that are PURE CO2.** Use of cylinders with a cap-charge will likely introduce large amounts of non-condensable gas, rendering the system inoperable, and require purging, evacuating, and recharging the entire system

To determine if a cylinder has a cap-charge, measure the tank pressure using a regulator and compare this with the saturation pressure at the approximate storage temperature of the tanks – tanks with a cap-charge will have a pressure significantly higher (**>200 psig**) than the corresponding saturation pressure.

Table 3. Common Grades of CO2

Industrial	99.5%
Bone-Dry	99.8%
Anaerobic	99.9%
Instrument	99.99%
Research	99.999%
Ultra-Pure	99.9999%

Table 4. Specifications of Instrument Grade CO2

Minimum Purity of CO2	99.99%
Nitrogen, N2	< 50 ppm
Oxygen, O2	< 20 ppm
Water, H2O	< 10 ppm

Introduction of lower-grade CO2 with purity-levels less than those of Instrument Grade is not recommended and should only be done in emergency situations.

Although 99.99% purity level (Instrument grade) CO2 is recommended, it is not necessarily required for the system to effectively operate. Using CO2 with purity levels less than that recommended by Hillphoenix is acceptable provided that the following precautions are taken:

a. Include a filter drier in the line as part of the charging process.

b. Thoroughly check for non-condensables, which may get charged into the system and have available a means for removing.

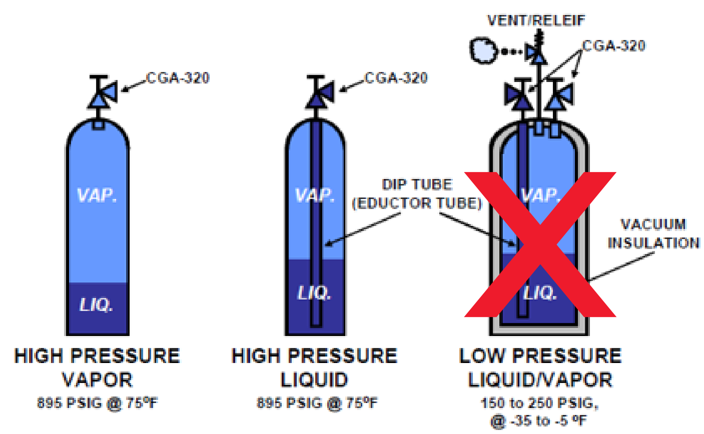
Use of Carbon Dioxide of a higher purity level than 99.99% is also acceptable though typically neither cost effective nor readily available in the quantities usually needed to charge an entire system.

Instrument Grade CO2 is widely available throughout North America by suppliers of industrial gases.

1.F.III CO2 CYLINDERS

CO2 is available in both liquid and vapor form and in a variety of cylinder sizes. The most common types and sizes of CO2 Cylinders are shown schematically in Figure 5 and are:

- High-Pressure Vapor Cylinder, 50 lbs. of CO2
- High-Pressure Liquid Cylinder, 50 lbs. of CO2
- Low-Pressure Liquid/Vapor Cylinder, 350 lbs of CO2



NOTE: *Low-Pressure Liquid/Vapor cylinders are not recommended for use with booster systems due to their lower pressure ratings.*

High-pressure cylinders contain CO2 at a saturation pressure corresponding to the temperature of their surroundings. At a room temperature of **75°F** this corresponds to **895 psig**. CO2 can be stored in high-pressure cylinders indefinitely.

Low-pressure cylinders contain CO2 at a saturation pressure corresponding to the pressure setting of the vent/relief valve installed on the tank, typically between **200 to 300 psig**, maintaining the temperature of the CO2 between **-20°F and**

0°F. The cylinder is a double-walled construction with a vacuum between the inner- and outer-tanks which acts as insulation to minimize heat transfer. As heat enters the tank, the CO2 pressure rises until the vent/ relief valve opens, releasing vapor CO2. This causes a small amount of CO2 liquid to evaporate, cooling the remaining CO2 in the tank and lowering the pressure. The frequency and duration of the opening of the relief valve varies and depends on the valve setpoint and the temperature of the surroundings. CO2 stored in low-pressure cylinders will last for 1-5 months before completely venting through the relief valves.

CO2 can be charged in both liquid and vapor form. Breaking the vacuum and initial system pressurization must be performed using vapor. Field experience has shown that once this has been completed, the remainder of the charging should be performed using high-pressure liquid tanks. Section 2.C.II details the various equipment needed for both methods of charging and the different procedures that are required.

1.F.IV CO2 LEAK DETECTION

Since CO2 is both present in the atmosphere at concentrations of 300-400 ppm and is also a byproduct of human respiration and other processes, detection of leaks in a piping network can be more difficult than with conventional refrigerants.

Leaks occurring on liquid lines will often be visible, emitting a small amount of CO2 vapor which can appear cloudy. Larger leaks will show evidence of a very cold ice-ball and possibly the formation of dry ice on the outside of the insulation.

For detecting small liquid or vapor leaks, hand-held detectors are available. These typically consist of a detector element connected to a hand-held display containing the electronics. Response time on these instruments can be slower and should be taken into consideration when moving the detector element from one position to another. Different examples of leak detectors which have been used successfully are shown below.

Inficon manufactures a hand-held, portable detector that is similar in operation to portable meters used for HFC and HCFC leak detection.

Response time is quick; this is the preferred leak detector for use with CO2. Vaisala also manufactures a variety of detectors for both mechanical room (wall-mounted), duct-mounted, and hand-held applications. Response time for the Vaisala hand-held probe is slower (20-30 seconds) and is less well-suited for finding leaks in the field.

Additional information on CO2 leak detectors can be obtained from:

Inficon	Vaisala Inc.
Two Technology Place	10-D Gill Street
East Syracuse, NY 13057	Woburn, MA 01801
315.434.1100	781.933.4500
www.inficon.com	www.vaisala.com

A variety of manufacturers supply fixed-location probes for CO2 monitoring of mechanical rooms and other non-refrigerated spaces including suppliers of rack controllers for commercial refrigeration systems (Carel, CPC/ Emerson, Danfoss, etc.) The recommended range for fixed-location probes is 0-10,000 ppm. Since CO2 is heavier than air, fixed-location probes should be mounted near the floor (around 12" above the floor). CO2 sensors should also not be mounted near sources of combustion including furnaces, gas heaters, and loading docks as higher levels of CO2 can be present in these locations.

Examples of Carbon Dioxide Leak Detectors

SECTION 2 - ADVANSOR INSTALLATION, START-UP & OPERATING PROCEDURES

The procedures covered in this manual should be followed along with the installation documentation and any other documentation supplied by the consulting engineers for the complete installation of the refrigeration system. The specific steps described here are only for the installation, testing, and initial start-up of an Advansor refrigeration system. Failure to follow these specifications may void the manufacturer's warranty.

2.A SYSTEM INSTALLATION

2.A.I ADVANSOR PIPING

NOTE: *Note that all pressure conversions are shown in barg (gauge).*

Piping Specifications for a Typical R-744 (CO2) Booster System1		
Item	Design Pressure	Field-Installed Line Type
Low Temp (LT) Suction	435 psig (30 barg)	Standard Type K2 Copper
Medium Temp (MT) Suction	653 psig (45 barg)	Type K2 Copper
To/From Gas Cooler	1,885 psig (130 barg)	C194 copper or Steel3,4,5
Liquid Line	653 psig (45 barg)	Type K2 Copper
Hot Gas Defrost Line	653 psig (45 barg)	Type K2 Copper
Low Temp (LT) Hot Gas Suction	653 psig (45 barg)	Type K2 Copper

NOTE 1: *Design pressures are job-specific*

NOTE 2: *Mueller Streamline Type L copper may be acceptable*

NOTE 3: *Carbon steel per ASTM A106 or ANSI/ASME B36.10*

NOTE 4: *Stainless steel per ASTM A312 or ANSI/ASME B36.19*

NOTE 5: *Butt weld or socket weld connections are acceptable*

Line sizes for any type of CO2 system are generally one to two sizes smaller than those used for HFC applications. The installation drawings for the job usually specify the lines sizes required. However, if line sizes have not been provided or are missing, contact the Hillphoenix representative for the job.

⚠ CAUTION

Always keep in mind that any deviation from the line sizes specified by Hillphoenix can result in improper operation of the system.

Liquid supply lines are sized to ensure a proper and evenly distributed pressure drop and velocity of the CO2 liquid. A minimum line size of 3/8" OD is used for both liquid and suction lines. Line sizes are specified by engineering drawings for the specific project and should be strictly adhered to. Changing 3/8" liquid lines to 1/2" size is not recommended as it increases the charge of CO2 required for proper system operation.

NOTE: *The pressure-temperature chart for CO2 is at the end of this manual.*

Suction return lines carrying vapor CO2 and small amounts of oil in both horizontal and vertical configurations are sized to ensure the effective return of oil back to the compressors.

Any time a suction line turns vertically upward, this is considered a vertical riser. Follow the line size as specified for vertical risers on the refrigeration schedule or drawings.

2.A.I.a Field Installed Copper Piping Recommendations

Copper pipe is the recommended material for connecting the Advansor rack to evaporators. Any consideration of alternative piping materials should always be reviewed with the Hillphoenix representative for the job.

Type L Copper Tube Specifications for Field-Installed Piping*			
Type L Tube Size OD, Inches	**Tube Wall** Inches	**Standard Copper Tube MAWP1**	**Mueller Streamline® Tube MAWP23**
3/8"	0.030	912 psig / 63 barg	731 psig / 50 barg
1/2"	0.035	779 psig / 54 barg	700 psig / 48 barg
5/8"	0.040	772 psig / 50 barg	700 psig / 48 barg
3/4"	-	-	700 psig / 48 barg
7/8"	0.045	582 psig / 40 barg	700 psig / 48 barg
1-1/8"	0.050	494 psig / 34 barg	700 psig / 48 barg
1-3/8"	0.055	439 psig / 30 barg	700 psig / 48 barg
1-5/8"	0.060	408 psig / 28 barg	700 psig / 48 barg
2-1/8"	0.070	364 psig / 25 barg	650 psig / 45 barg
2-5/8"	0.080	336 pisg / 23 barg	550 psig / 37 barg

* Unless specified otherwise by local, or state building codes or other requirements.

NOTE 1: *Maximum Allowable Working Pressure based on allowable stress for 100°F (38°C) maximum operating temperature*

NOTE 2: *Maximum Allowable Working Pressure applies only to Mueller-manufactured pipe based on allowable stress for 250°F (121°C) maximum operating temperature*

NOTE 3: *2-5/8" Muller Type L Copper may be applicable only for Low Temperature Suction Line Design Pressures*

The Maximum Allowable Working Pressure (MAWP) on the suction side of the Advansor system is generally **420 psig** for the low-temp and typically **638 psig** for the medium-temp. These pressures match the setting of the main pressure relief valves installed on the system (refer to the factory-supplied piping diagram to confirm relief settings and locations). Relief valves set at a higher pressure than the main reliefs are also located in selected positions throughout the system to protect specific equipment against pressures higher than their ratings. Type L copper piping can be used on some pipe sizes; however, Type K copper should be used on larger sizes. The tables on the previous page show specifications for Type L and Type K copper tubing based on the system design pressures for a maximum operating temperature of **100°F** applicable for liquid and suction line applications on field installations.

Type K Copper Tube Specifications for Field-Installed Piping*			
Type L Tube Size OD, Inches	**Tube Wall** Inches	**Standard Copper Tube MAWP[1]**	**Mueller Streamline® Tube MAWP[23]**
3/8"	0.035	1,074 psig /74 barg	860 psig / 59 barg
1/2"	0.049	1,130 psig /78 barg	904 psig / 62 barg
5/8"	0.049	891 psig / 61 barg	713 psig / 49 barg
3/4"	-		700 psig / 48 barg
7/8"	0.065	852 psig / 59 barg	700 psig / 48 barg
1-1/8"	0.065	655 psig / 45 barg	700 psig / 48 barg
1-3/8"	0.065	532 psig / 37 barg	700 psig / 48 barg
1-5/8"	0.072	494 psig / 34 barg	700 psig / 48 barg
2-1/8"	0.083	435 psig / 30 barg	700 psig / 48 barg
2-5/8"	0.095	389 psig / 27 barg	700 psig / 48 barg

* Unless specified otherwise by local, or state building codes or other requirements.

NOTE 1: *Maximum Allowable Working Pressure based on allowable stress for 100°F (38°C) maximum operating temperature*

NOTE 2: *Maximum allowable working pressure applies only to Mueller-manufactured pipe based on allowable stress for 250°F (121°C) maximum operating temperature*

NOTE 3: *Mueller has not performed testing in Type K for 3/8" thru 1-3/8"*

Additional information on copper tube stress and design temperature effects is in The Copper Tube Handbook available from the Copper Development Association.

The Copper Development Association
260 Madison Ave.
212.251.7200
New York, NY 10016
www.copper.org

2.A.I.a.i Brazing

Joints in the copper piping for the CO2 system are brazed the same way as for conventional refrigeration systems. **Nitrogen must be used to reduce oxidation of the piping during the brazing process.**

2.A.I.a.ii Mechanical Joints

Threaded or flared joints should be avoided to reduce the likelihood of leaks developing over the lifetime of the system. If these joints must be used, the following guidelines should be applied to ensure a leak-free joint.

2.A.I.a.iii Joint Sealants

Threaded joints applied to Advansor systems must only be used with Permabond MH052 thread sealant. The tape should be spiral wrapped around each joint. Use of thread sealants other than Permabond may result in improper system operation and leakage of CO2. The sealant can be obtained from the manufacturer.

Permabond LLC
14 Robinson St.
732-868-1372
Pottstown, PA 19464
permabond.com

2.A.I.a.iv Sloping Lines

All CO2 piping (liquid supply and suction return lines) must be installed to slope or pitch downward towards the machine room to enable proper return of refrigerant oil. This is the same practice used for conventional DX systems with HFCs (example slope: 1" per 20' or greater).

2.A.I.a.v Expansion Loops

Installation of expansion loops is recommended to minimize stress on the piping network. Most expansion requirements can be accommodated through the normal direction changes of the piping network. Long straight runs of pipe should include extra changes in direction to accommodate this expansion; a horizontal offset or expansion loop can be applied in these circumstances. Additional information regarding expansion joints can be found in the ASHRAE HVAC Systems and Equipment Handbook (Chapter 46 - Pipes, Tubes and Fittings in the 2012 edition).

2.A.I.a.vi Traps

Traps must be installed in all suction lines when transitioning to piping that runs vertically upward (risers) to assist with oil return. Typically, the riser pipe size should be one to two sizes smaller than the horizontal pipe size. Transition from the horizontal to the riser size should be made at the outlet of the p-trap. Inverted or reverse traps are recommended although not required on Advansor system piping.

2.A.I.B RELIEF VALVES

Relief valves are used in positions where the maximum design pressure may be exceeded. Relief valves are either factory-installed or must be field- installed as per the system piping schematic.

Relief valves used for CO2 applications are designed for use on cryogenic systems and should not be replaced with relief devices typically installed on conventional refrigeration systems. Relief valve manufacturers recommend replacing any that have blown.

Vapor relief valves mounted at the rack are piped to a common header from which a vent line must be field installed to terminate outside the building, as required per local code.

Obtain replacement relief valves from the Hillphoenix Service Parts Department.

Hillphoenix Systems Service Parts Dept.
Ph: 800-518-6630 ext. 3205
Fax: 770-285-3076
www.hillphoenix.com

On all pipe sections that can be isolated when valves are closed, safety valves are installed to protect those areas. Fittings and accessories should be easily accessible and thus positioned to insure safe operation as well as maintenance. The valves should also be situated so that the release of any pressure does not affect surrounding piping, components or material. All outlets from the vapor safety valves should be joined and connected to the outside through hoses or type "K" copper pipes.

Ultimately, the system is equipped with high-pressure switches that ensure that the compressors are cut-off before they can reach the maximum acceptable pressure and prior to blowing the safety valves on the high- pressure side.

Pressure switches on the system are electrically independent from the energy management system controls.

2.A.I.C SUPPORTS

All insulated pipes should use supports that have a plastic (e.g. PVC) or metal saddle with a smooth bearing surface, is a length of at least three (3) times the external diameter of the insulation, and cradles the bottom 120 degrees of the pipe. Edges should be rounded to minimize cutting into the insulation. This will reduce possible stress concentrations and protect the insulation from damage.

A minimum air space of one inch (1") should be provided between insulated lines to prevent condensation on the surface of the insulation.

Closed trenches (not open and accessible) should be used for underground piping. These should be designed so that the pipe can be installed without damage to the insulation.

Rigid clamps should not be used to directly supporting the piping as they conduct heat from the piping, are difficult to insulate, and will cause continuous condensation during system operation.

2.A.I.D INSULATION

2.A.I.d.i General Guidelines

Insulation should generally be applied in accordance with local building codes, the consulting engineers' and insulation manufacturer's specifications.

The use of any insulation material other than those listed in this manual requires the written approval of Hillphoenix and the customer.

Piping system should always be insulated in order to reduce heat transfer between the fluid lines and the surrounding ambient air. Insulating the lines also prevents condensation or ice formation on the pipe surfaces and minimizes corrosion of the piping materials. When insulation requirements are determined, the following major factors should be considered:

- Application (Fluid) Temperature
- Ambient Conditions including:
  - Dry-Bulb Temperature
  - Relative Humidity
  - Surrounding Air Velocity
  - Insulation Material
  - Desired Performance

The application temperature used in this manual is for an Advansor system with a low temp CO2 evaporating temperature of **-15 to -20°F**. For systems with significantly higher or lower evaporating temperatures, consult the insulation manufacturer about proper thickness recommendations.

Insulation sizing is determined based on either of two different ambient conditions:

- Normal Conditions: Maximum severity of **85°F** dry bulb temperature, 70% relative humidity, and 0 ft/min air velocity
- Severe Conditions: Maximum severity of **90°F** dry bulb temperature, 80% relative humidity, and 0 ft/min air velocity

Hillphoenix recommends the use of insulation sized for "Normal- Conditions" for typical indoor air-conditioned space and insulation sized for "Severe-Conditions" for outdoor applications and non- conditioned spaces.

The normal condition is applicable for most indoor air-conditioned environments in North America. A typical supermarket indoor design point of **75°F** dry bulb temperature and 55% relative humidity can be considered equivalent to this normal condition for the purpose of sizing insulation. Although insulation thickness is given for the more difficult condition of "severe," determining which of these to use depends on local ambient conditions and should be evaluated for each installation site. It is also important to consider that even in some air-conditioned environments, air at or near the ceiling or roof can be much hotter than elsewhere in the store and that evaluating these conditions is extremely important for systems containing overhead piping.

The insulation sizes recommended in this section are designed to limit heat gain into the piping network and as a rule, are one size larger than those needed for control of condensation only. Although insulation could be sized and installed for the purpose of prevention of condensation only, the additional heat transfer through the insulation would result in lower energy efficiency of the refrigeration system, and possible system malfunction during peak load and/or high ambient conditions.

All valves, controls, and fittings in contact with CO2 should be insulated to allow easy removal for component servicing. Components should also be insulated to minimize air pockets or voids, which can over time collect moisture.

Running piping in non-air-conditioned spaces should be avoided wherever possible in order to minimize insulation thickness requirements and reduce heat gain.

2.A.I.d.ii Insulation Materials

The recommended insulation materials for field-installed Advansor system piping are:

- Flexible Closed-Cell Elastomeric Foam
- Styrofoam
- Trymer

The most common materials used for field-installed piping are flexible, closed-cell, elastomeric materials. Products of this type are manufactured by both Armacell and Nomaco. Technical information and detailed installation instructions for these materials may be obtained from:

Armacell LLC	Nomaco K-Flex
7600 Oakwood St. Ext.	100 Nomaco Drive
Mebane, NC 27302	Youngsville, NC 27596
919.304.3846	800.765.6475
www.armaflex.com	www.kflexusa.com

Styrofoam and Trymer are also acceptable for field-installed piping. Both products of the Dow Chemical Company, these materials are manufactured in rectangular bunstock and fabricated into sheets, pipes, and fittings. Styrofoam is an expanded, extruded, closed-cell polystyrene foam and Trymer is a polyurethane-modified polyisocyanurate cellular foam. Both have a minimum required thickness and should be covered with an appropriate vapor-barrier (e.g. Saran) and jacketing material. Additional information on these materials may be obtained from:

Dow Plastics
PO Box 1206
Midland, MI 48641
866.583.2583
www.dow.com

Recommended Insulation Thickness of Elastomeric and Rigid Insulation Materials for Field Piping

Pipe Size (OD)	Normal Conditions 85°F (29°C) Dry Bulb 70%RH, 0 fpm			Severe Conditions 90°F (32°C) Dry Bulb 80%RH, 0 fpm		
	Liquid	LT Suction Return	MT Suction Return	Liquid	LT Suction Return	MT Suction Return
3/8”	3/4”	3/4”	3/4”	1”	1-1/2”	1”
1/2”	3/4”	3/4”	3/4”	1”	1-1/2”	1”
5/8”	3/4”	1”	3/4”	1”	1-1/2”	1”
7/8”	3/4”	1”	3/4”	1”	1-1/2”	1”
1-1/8”	3/4”	1”	3/4”	1”	1-1/2”	1”
1-3/8”	N/A	1”	N/A	N/A	1-1/2”	N/A
1-5/8”	N/A	1”	N/A	N/A	1-1/2”	N/A
2-1/8”	N/A	1”	N/A	N/A	1-1/2”	N/A

NOTE: *Additional thickness may be needed beyond the minimum requirements due to design and surrounding conditions.*

2.A.I.e UNDER FLOOR AND UNDER-GROUND PIPE INSTALLATIONS

Where piping overhead is not feasible, under-floor piping is permitted (though not recommended). Under-floor piping should be insulated inside of PVC piping or equivalent rigid pipe to prevent damage to the insulation material.

The void between the insulation and the PVC pipe, where the insulated piping exits the PVC, should be filled with expanded polyurethane foam to prevent air from entering the pipe.

Hillphoenix does not recommend “direct burial” of insulated piping.

2.A.I.f Labeling Requirements

All CO2 piping, whether factory or field installed, should be labeled to indicate:

- Fluid type (i.e., Carbon Dioxide)
- Arrows indicating direction of flow

In general, it is recommended that labeling comply with ANSI/ ASME Standard A13.1-81, “Scheme for the Identification of Piping Systems.”

Pipe labeling materials may be obtained from a number of suppliers including Brimar Industries and Seton.

Brimar Industries	Seton
64 Outwater Lane	20 Thompson Road
Garfield, NJ 07026	Branford, CT 06405
800.274.6271	800.243.6624
www.brimar.com	www.seton.com

2.A.II ADVANSOR COMPONENTS

Technicians familiar with standard refrigeration components and configurations will recognize many aspects of the Advansor system. The components briefly described in the first section of this manual include the compressors, the pressure safety controls, direct expansion valves, the filter drier, the oil separator and filter, and associated components.

2.A.II.a Compressors

On the rack, low-temperature (LT) compressors are located on top and medium-temp (MT) compressors are on the bottom. However, with 3x1 systems, a medium-temp compressor will be stacked on the top of the rack.

All compressors are equipped with service valves on the suction side. An electronic oil float is mounted on the side of the crankcase of each compressor. The float controls the oil level by cyclically opening the integrated solenoid valve when the oil level is low.

Safety valves are mounted on the discharge side of the transcritical compressors. The compressors are bolted to the frame on shock and oil resistant polymer machine feet. A sightglass in the center of each reciprocating compressor’s end-cover allows for visual inspection of the oil lubrication (oil should always appear when the compressors are operating).

2.A.II.b Compressor Operating Pressures

MT discharge pressure: Approx.: **870 to 1,395 psig**
Receiver pressure: Approx.: **493 to 580 psig**
MT suction pressure: Approx.: **377 to 435 psig**
LT suction pressure: Approx.: **17 to 218 psig**

A pressure gauge for each of these is typically mounted on the rack.

2.A.II.c High Pressure Control Valve

The Danfoss CCMT high-pressure control valve controls sub-cooling when the condenser/gas cooler operates as a condenser during normal (subcritical) operation based on a predetermined set of points from a pressure/temp relationship between the ambient temp and the CO2 outlet temp during transcritical operation (when the condenser/gas cooler is operating as a gas cooler). The maximum working pressure for the valve is **2,030 psig**.

The valve must be powered from a UPS and shuts down under a complete power failure.

2.A.II.d Flash Gas Bypass Valve

The Danfoss CCM Flash Gas Bypass Valve is situated between the flash tank/ receiver and the suction to the MT compressors. The CCM valve is an electric stepper motor valve, maintaining a set pressure in the receiver. The maximum working pressure for the valve is 2,030 psig.

In case of power failure, the valve will shut down by means of a required UPS in the control panel.

2.A.II.e Oil System Components

The oil system is optimized by use of:

- 200 ppm coalescing filter or Multistage Centrifugal type
- OMC/INT280 electronic oil floats on each compressor

Oil separator with an internal or external reservoir

2.A.II.e.i Separator

The system is equipped with a highly efficient oil separator with coalescing filters or Multistage centrifugal separator that prolong the lifetime of the compressors. Filter cartridges should only be switched according to the manufacturer's service instructions. Depending on the overall system design, the oil separator is equipped either with or without an external oil reservoir.

2.A.II.f Filter Drier

The filter shell accommodates two high-water 48-inch capacity, cartridge cores, which must be installed upon startup of the system per standard refrigeration practice. Remove the top cover to replace the filter drier.

2.B INSTALLATION PROCEDURES

Installation must be carried out in accordance with local code.

As with any other type of rack system, Advansor systems must be installed on a flat, level and stable surface capable of supporting the weight of the equipment. The rack may be mounted on vibration isolation to prevent any vibration from spreading to the rest of the building.

The rack should only be installed in properly ventilated, fire-protected, dedicated spaces. Such spaces should be ones that are not subject to excessive heat or cooling, as well as the risk of collision from other equipment or associates that can occur in non-dedicated spaces. Given those considerations, the system can be installed either indoors or outdoors. For outdoor installation, the system must be installed in an enclosure.

The installation site should also have available adequate lighting and working space in which to access and carry out service and maintenance tasks safely.

2.B.I PIPING INSTALLATION

2.B.I.a Condenser/Gas Cooler Piping

Specific steps for installing the condenser piping include:

- Assembly of C-194 copper pipes to condenser
  - Connections should be TIG-welded to ensure adequate weld quality, strength and an aesthetic appearance
  - Assembly must be carried out by a certified welder in accordance with local code

Outdoor piping where moisture can occur have to be coated with primer and varnish. During operation, the pipes can get hot (**250°F**) so insulation is recommended in areas that might be touched.

Make sure that the medium-temp side of the system is shut off by closing the Discharge Line Isolation Ball Valve, isolation ball valve located between the receiver and the CCMT.

- Purge the system through a valve located at the highest elevation, which is typically right before the condenser/gas cooler.
- Cut-off the ends of the pipe from the rack.
- Remove the discharge line 130 Barg Relief Valve on the medium temp side of the system and leak and pressure test with nitrogen.
- Make the final connection to condenser/gas cooler.
- Once the piping is completed between the rack and the condenser/ gas cooler, blow off the nitrogen in the system and reinstall the 130 Barg Relief Valve and reopen the high pressure CCMT.

NOTE: See Steel Pipe Handling Procedures for more detail

2.B.I.b Evaporator Piping

Specific steps for installing the evaporator piping include:

- Assembly of pipes to evaporators
  - Copper pipe of 7/8" maximum dimension for 870 psig or of 11/8" maximum dimension for 580 psig as indicated on the Hillphoenix CO2 piping chart
  - Field piping selected and installed based on construction documents

Correct choice of appropriately sized EEVs and nozzles as well as controller programming confirmed

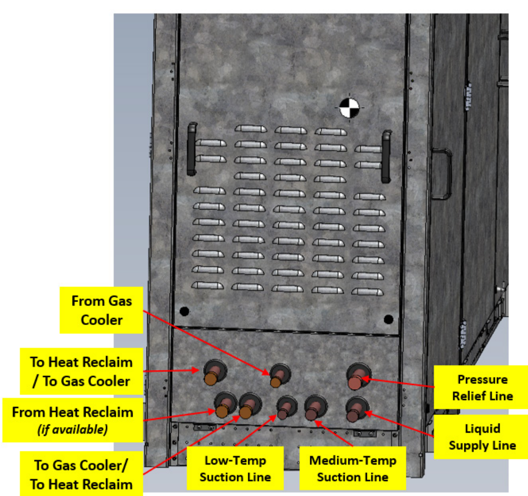
Steps for connecting the cases and walk-ins include:

- Purge the compressor system on both the liquid and suction lines for both the medium and low-temp sides by opening the Access Valves located on medium and low temp suction manifolds.
- Leak and pressure test to approximately **435 psig** through the Flash Tank Outlet Service Valve for the low-temp and **653 psig** for the medium-temp (once the piping is completed between the rack and the evaporators) with the vessel isolated at the Hot Gas Injection Service Valves into the medium and low temp suctions. This should only be done with the Relief Safety Valves on the medium and low temp suction manifolds removed and the fittings plugged along with all electronic expansion valves closed to the low-temp side.

NOTE: *See 2.A.I.a for max pipe size and type of copper*

- Pressurize the low and medium temp suctions via the Access Valves on the respective suction manifolds. The low-temp Compressor Discharge and Service Valves should also be closed if needed.
- Release the nitrogen in the piping and re- assemble the Relief Safety Valves on the medium and low temp suction manifolds.

Connections for the condenser, suction and liquid lines are typically located at the receiver-end of the rack. The liquid line is common for medium-temp and low-temp and should be insulated.



2.B.II ELECTRICAL CONNECTIONS

Advansor racks come from the factory with the control panel and all internal electrical connections pre-wired. As with any other system, a certified electrician must make all field connections.

Specific aspects of the electrical connections to take note of include the required electrical supply for the system, which depends on job site requirements, and cable and component markings.

2.C STARTUP PROCEDURES

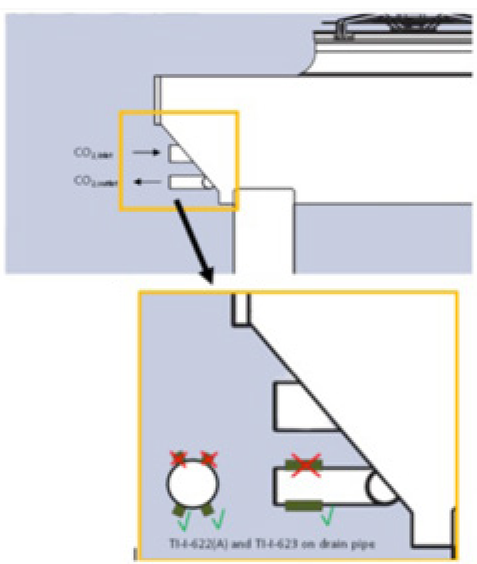
As with any other type of system, the steps for starting up the Advansor system should only be performed by qualified technicians following the completed installation of all mechanical and electrical components of the system.

The startup procedures outlined below should be followed in the order they are presented. A flowchart of major steps involved in the process is at the end of this Manual in the appndix. It provides a graphic overview of the process.

2.C.I PRIOR TO STARTUP

- Mechanical and electrical systems confirmed properly installed as per code and regulatory requirements
- Piping Installed (refer to section 2.B.I for condenser/gas cooler and evaporator piping procedures)
  - Note: The Rack is pressure tested at the factory prior to the mounting the relief valve, therefore, do not remove the relief valve unless pressure testing the rack as part of overall system
  - If pressure testing portions of the rack, use the table in section 2.A.I for details
  - Do not exceed 10% above the rated design pressure
  - Filter/drier cores installed
    - High water capacity
- All Compressor Service Valves OPEN
- All System Isolation Valves OPEN
- High Pressure Regulating Valve OPEN
- All Inputs and Outputs verified operational
- System Triple-Evacuated to Recommended Level or Customer Specification for Minimum Duration or Customer Specification, whichever is more stringent
  - Evacuation for minimum 24 hours
  - Include every subsystem during evacuation by opening all valves
  - Break vacuum of overall system first with nitrogen, and then two more times with CO2 vapor
- Filter drier core(s) & suction filter shell(s) installed as applicable

- Oil Charged - 2 Gallon to the reservoir or 1 Gallon to the Separator with Integral reservoir
  - ○ Use only compressor manufacturer specification for correct oil type
- Pressurized to **150 psig** with CO2 vapor
- Wiring Completed
  - ○ Verify Energy Management System is the latest correct program installed on the controller/computer
  - ○ All inputs and outputs on condenser installed and confirmed
    - Outdoor air temperature sensor located in the airstream under the condenser
    - Gas leaving transducer located on the rack for high-pressure control
    - Gas leaving temperature probe located on the condenser for fan control
    - **IMPORTANT: These sensors must be installed correctly as shown in the drawing**



  - ○ All sensors, transducers, valves, VFDs checked and proofed
  - ○ Test all pressure and temperature sensors for each evaporator making sure that they are both mounted in the right location and properly working
    - Calibrate the pressure transducers and temperature probes to ensure that measured pressure values (e.g., **145 pisg**) match the corresponding evaporation temperatures (**145 psig = -36°F**)
      - * Always ensure that the probes are wired correctly by means of cold spray or ice bath

2.C.II DURING STARTUP

- Shut valves
  - ○ All EEV valves at the evaporators
  - ○ Main Liquid Line Ball Valve to the store
- Check all valves for correct positioning before pre-pressurizing, charging, and operation
  - ○ Check that all compressors service valves are open
  - ○ Ensure all compressors have oil — Red lights on the oil sensors, on each compressor are ON (illuminated)
  - ○ Check oil system valves for proper operation
  - ○ Check valves for store/circuit pipe system
- Turn on the compressor crankcase heaters
- Verify that EMS is programmed and installed, ready to operate
- Check rotation direction of fans on gas cooler/condenser
  - ○ With on/off controlled fans: check startup sequence of the fans
  - ○ The fans nearest the CO2 header must be the first ones to start up and the last to stop
- Charge liquid refrigerant
  - ○ Until CO2 receiver level reaches the middle of the second sight glass from the bottom of the vessel
  - ○ Check and confirm that Flash Gas Bypass Valve opens and operates correctly
  - ○ Verify medium temp compressors are cycling on/off based on rise of suction pressure
- Medium Temp Compressors started
  - ○ Continue to monitor refrigerant level and add as necessary to maintain minimum level in vessel (CO2 should always be visible in the bottom sightglass
  - ○ Slowly open the main liquid line ball valve and start up each medium-temp circuit one at a time
  - ○ Activate the gas cooler controller as soon as the MT compressor controller is activated
  - ○ Activate half of the EEV valves on MT side one at a time (keep the other half closed)
  - ○ Check and confirm that each compressor starts one at a time
  - ○ Open one or more circuits to the store (depending on the size of the store)
    - Allow the MT operating conditions to stabilize with the current MT EEV valves open (10% MT operating capacity)
  - ○ Complete the MT startup procedure by opening and adding the remaining MT circuits for stabilized

operating conditions at full capacity (100% MT operating capacity)

- Check and confirm that the receiver pressure and condenser/gas cooler pressure regulate correctly
  - Compare sensor inputs with the corresponding pre-programmed reference set points in the controller
- Low-Temp Compressors started
  - Activate half of the EEV valves on LT (the other half are kept closed)
  - Check and confirm that each compressor starts one at a time
  - Open one or more circuits to the store (depending on the size of the store)
    - Allow the LT operating conditions to stabilize with the current LT circuits open (10% LT operating capacity)
    - Complete the LT start-up procedure by opening and adding the second half of LT circuits for stabilized operating conditions at full capacity (100% LT operating capacity)
- Continue running system until temperature setpoints are reached, fine-tuning the system
  - Closely observe the compressor suction temperature
    - Make sure that no liquid returns from evaporator
    - Check pressure and ambient sensors (S2) at the cases and confirm that the amount of superheat is correct compared to the degree of EEV opening
  - Inspect the oil system
    - Make sure that all compressors are supplied with oil
    - Make sure that there is enough oil in the oil reservoir (**NOTE:** *See Oil Filling procedure starting on the next page*)
  - Check MT-control as well as gas bypass control
  - Compare sensors
  - Check compressor capacity step control (start and stop of compressors)
  - Check evaporator control
- Test, confirm, and adjust for proper operation
  - Defrost
  - Pumpdown
  - All other functions
  - All safeties

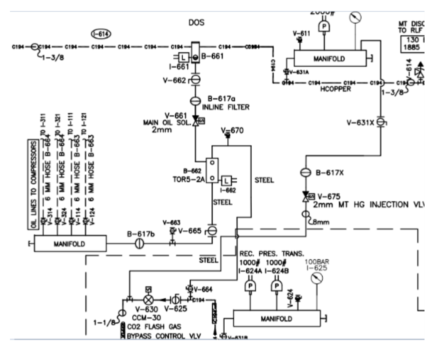
2.C.II.a Oil Charging Procedure

After startup it is often necessary to add oil to the system for it to properly operate. Filling additional oil into the system, however, does not require the system to be stopped when doing so. The Oil Vent Line Service Valve maintains a receiver pressure of **536 psig** in the oil reservoir during operation on systems with external oil reservoirs.

NOTE: *Oil should never exceed the top sightglass during normal operation.*

The steps for adding oil after startup on these types of systems are:

- Shut off the oil reservoir by closing the following:
  - Main Oil Line Service Valve (located after the oil separator)
  - Oil Vent Line Service Valve
  - Oil Line Service Valve (located after the oil reservoir)
- Connect gauges to the Oil Vent Line Access Valve and vent down to **10 psig**
- Add oil through the Oil Reservoir
  - Drain Valve while monitoring the sightglass or level-switch in the oil reservoir



- Add oil until the level reaches the sightglass:
  - Pressurize the oil reservoir through the Oil Vent Line Service Valve while keeping the valve open during operation
  - Open the Main Oil Line Service Valve (located after the oil separator) and the Oil Line Service Valve (located after the oil reservoir)
- During operation, ensure that the valves listed below are in the correct positions:
  - Open: Main Oil Line Service Valve (located after the oil separator)
  - Open: Oil Vent Line Service Valve
  - Closed: Oil Reservoir Drain Valve
  - Closed: Oil Vent Line Access Valve

NOTE: *Oil can also be added with a hydraulic pump – pumping oil in against pressure.*

On systems without external oil reservoirs (usually smaller systems depending on the capacity of the system), the steps for adding oil are:

- Pump down and turn off the system
- Isolate the system on the high-temperature side
- Isolate the Oil separator with integral reservoir from the compressors and gas cooler
- Relive the pressure from separator to be vented down to **10 psig**.
    - Add oil through the Oil Separator with Integral Reservoir Drain Valve to half the sight glass.

NOTE: *Smaller systems (1 vessel) typically require from 1 to 1.5 gallon(s) of oil to reach the middle of the first sightglass.*

-

2.C.II NSTALLATION AND STARTUP FOR CONTROLS

From a controls standpoint, the steps required for installing and starting up the system are similar to those in the mechanical startup of the system although they do vary somewhat. The following procedure outlines those steps specifically for systems with Micro Thermo controls, although certain of the steps are applicable to systems with other types of controllers. A description of the steps required to setup systems with Danfoss controls follows the steps for Micro Thermo-controlled systems.

NOTE: *As of this version of the manual, the procedures for installing and starting up systems with controllers from other manufacturers besides Micro Thermo and Danfoss have not been specified and until those procedures are available, the installation and startup of systems with other types of controllers will have to be addressed on a case-by-case basis.*

2.C.II.a Prior to Startup for Carel Controller equipped Systems

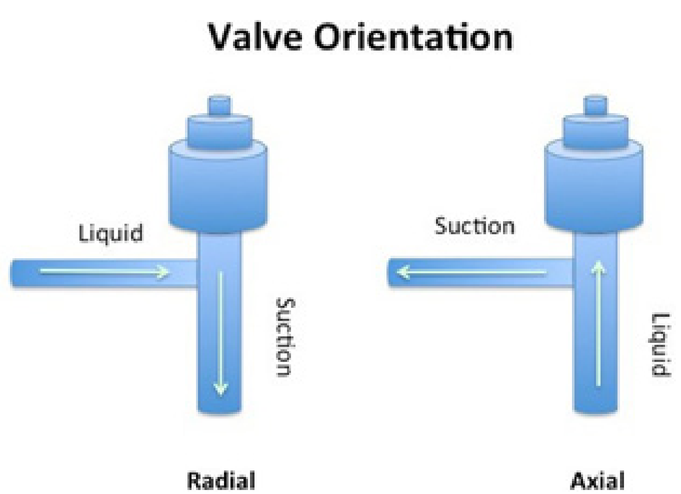
- Computer setup and connected in appropriate location
- Software loaded and pre-configured
- All network connections landed
- Proper grounding and cable shielding of all wiring confirmed
    - Special attention should be paid to drives
- All network, power, and valve connections at the rack confirmed properly connected
    - Check all wire strands in connectors
        - Ensure wires are pulled through terminals and tightened sufficiently
    - Check ohmage on all network connections to confirm it is between 52Ω and 58Ω
    - Check voltage on all power terminals to confirm between 24.5 volts and 36 volts
        - Alarm board, repeater between 16 volts to 25 volts
        - EEPR boards (on dedicated transformers) between 16 volts to 25 volts
- Each individual board addressed (service pins)
- All store inputs and outputs proofed
    - Pressure transducers operation and location confirmed
        - Constant pressure applied through entire system and transducers checked for accuracy, calibrated, or replaced if necessary
        - Transducer locations checked by disconnecting each to confirm it records in the right location

NOTE: *In normal operation it takes from two and a half minutes to five minutes to commission and install each board. When the service pin is pushed on a board, that board must be commissioned and installed before a next board can be added. The Delayed Install function, however, allows the computer to keep the address of each board on which the service pin has been pushed but not commissioned and installed until the function is begun.*

- Temperature sensors operation and location confirmed
    - Location at the case – Air, Coil, and Defrost (sensor leads: green, blue, orange respectively)

NOTE: *Compressed air (from an upside-down spray can) is an effective way to freeze the sensors and note that the sensor temperature drops*

- Check sensors properly secured
- Door switches confirmed
- Fan relays confirmed
    - State change from On to Off (or reverse) verified
- EEVs proofed
    - Model number matched to software
    - Confirm refrigerant flow verified and entered as either from side (Radial) or toward motor (Axial)
    - Wiring sequence checked (i.e., 1,2,3,4 = Sporlan: red, green, white, black)



  - Multi-zone leak detector (if equipped) confirmed
- Condenser/gas cooler operation confirmed
  - Temperature sensors confirmed
- Location at the condenser/gas cooler – Outlet and ambient air (at 5 and 7 o'clock per Advansor specification)
  - Fan Relays confirmed
  - Fan Rotation checked
  - Fan Sequencing checked (confirm first fan closest to header)
- Rack Sensors confirmed with breaker off power voltage i.e., 208/480 or 600-volt
  - Temperature sensors confirmed
  - Pressure transducers confirmed
  - Signal conditioner confirmed
  - Compressor safety lines (compressor error) confirmed
  - Discharge over-pressure switch confirmed
  - Refrigerant Liquid Level
  - Power outage confirmed
  - Liquid injection solenoid confirmed
  - Compressor contactor confirmed
  - Rack leak detector tested

On systems equipped with Hot Gas Defrost, following confirmation of the Gas Cooler Operation, the Defrost Sensors must be proofed:

- Main Electronic Defrost Regulating Valve confirmed
- Suction Stops (EEPR, Ball Valve or Solenoid) and Hot Gas
- Solenoids (and Liquid Solenoids if equipped at header) confirmed
- Defrost Header confirmed
  - EEPR checked that it closes with the correct circuit in defrost

The Hot Gas Dump solenoid rack sensor must also be confirmed.

- Oil system sensors confirmed
  - Test compressor filling/lockout and reservoir emergency fill sequence after ensuring oil is fully charged into the system (per listed procedure)
    - Bypass compressor ON and unplug the oil sensor from the compressor and check that the interface indicates that the number of pulses is increasing
  - Check that the fill solenoid for the compressor is activating (pulsing)
    - Check that after approximately half the maximum lockout pulses (30 for lockout), the valve between the separator and the receiver has opened along with the solenoid
    - Confirm that the compressor locks out after the specified number of pulses
    - Confirm that triggering a low receiver condition, causes the valve between oil separator and the oil receiver to open
    - Oil receiver low-level switch alarm trigger confirmed
    - Oil separator high-level switch alarm trigger confirmed
- Variable Frequency Drives checked
  - Fault Signal confirmed received

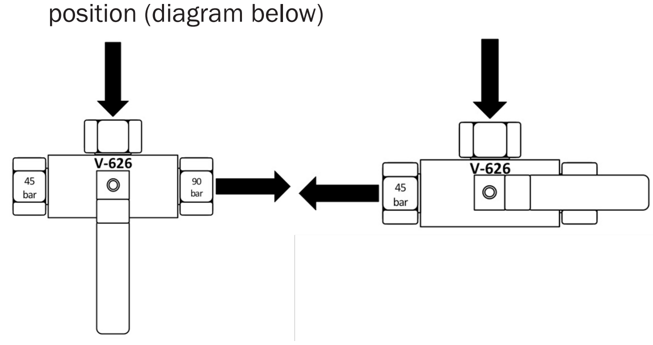
The most effective way to set the base value is to look at the average valve opening during the store normal operating hours and put that value in the base value

Good superheat control can be obtained by having a low enough cut-off at which the valve is completely shut to avoid liquid in the compressors, but at the same time having a band wide enough to be able to choke the valve before it reaches the cut-off.

2.D SERVICE PROCEDURES

2.D.I PUMP DOWN TO RECEIVER - FOR STANDSTILL PURPOSES (i.e., SERVICING)

- Close the Flash Tank Outlet Service Valve (main liquid supply isolation ball valve) feeding the store loads
  - Verify that the Hot Gas Injection Service Valve into the medium temp suction (manual by-pass valve) is Closed.
- If the CO_2 liquid at or below the highest sightglass and the LT and MT compressors have pumped down and cycled off (i.e., suction pressure no longer rising):
  - Turn Off compressor panel switches
  - Close the Flash Gas Bypass Service Valve
  - Close the Flash Tank Inlet Service Valve
  - Rotate the Three-Way Valve for the relief valves at the flash tank from the 45-bar position to the 90-bar position (diagram below)



- Close the Oil Reservoir Vent Line Service Valve

The CO2 refrigeration system at this point is now pumped down and the receiver is isolated from the rest of the system

- If the CO2 liquid level rises above the highest sightglass:
  - Immediately Close the Flash Gas Bypass Service Valve
  - Immediately Close the Flash Tank Inlet Service Valve

  NOTE: *The MT compressors will go off-line on high discharge pressure*

  - Turn Off all MT and LT compressor switches
  - Close the Oil Vent Line Service Valve
  - Vent CO2 liquid from store piping system down to 290 psig
  - Vent MT suction line down to **290 psig**
  - Vent LT suction line down to **203 psig**
  - Shut down all circuits, Close all EEVs on all cases, coolers, freezers, etc., turn Off all fans and all defrost heaters
  - Vent Condenser/Gas Cooler down to **870 psig**
  - Monitor all store piping to ensure CO2 pressures do not rise and vent if necessary

2.D.II COMING OUT OF PUMP DOWN - FOR NORMAL OPERATION

- Slowly Open the Flash Gas Bypass Service Valve
- Open the Oil Vent Line Service Valve
- Continuously check system pressure (LT suction, MT suction, MT discharge) and the receiver liquid level
- Open the Flash Tank Inlet Service Valve
- Slowly Open the Flash Tank Outlet Service Valve
- During active operation of receiver, position the three-way valve (see diagram above) so that the port connected to the 45-bar relief valve is opened to the receiver pressure
- Turn On both the LT and MT systems through the pack controller
- When both the LT and MT compressors are running, slowly Open the Flash Gas Bypass Service Valve

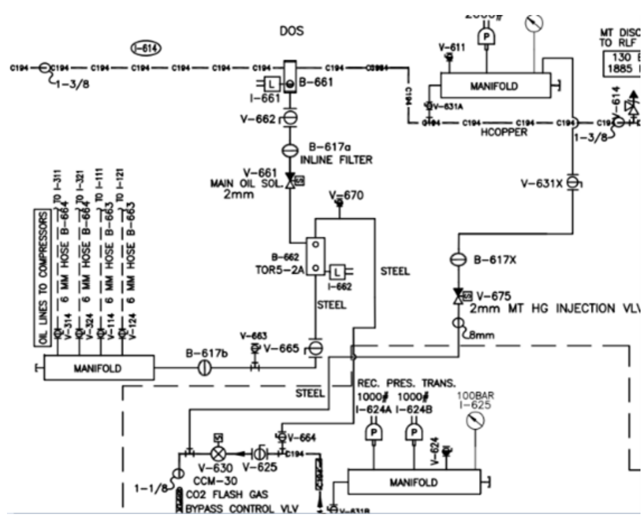
2.D.III CHARGING THE SYSTEM WITH CO2 VAPOR

- Make sure all EEVs are Open
- Charge the system through the Receiver Access Valve until the pressure reaches **145 psig**
- Close all EEVs when the system is pressurized
- Charge the receiver with liquid CO2


Receiver Access Valve

2.D.IV ADDING OIL TO THE SYSTEM

- Leak test the system and make any repairs needed.
- Close the Main Oil Line Service Valve (located after the oil separator) in order to isolate the top of the oil reservoir and vent the pressure inside the reservoir to **75 psig** of vapor pressure
- Close the oil line service valve (located after the oil reservoir)
- Connect a vacuum pump to the Oil Vent Line Access Valve, which is located on the vent line from the oil reservoir
- Triple-evacuate the system to ensure the removal of moisture and non-condensable (This procedure is the same as for a DX or HFC system)
- Break the 3rd vacuum with **150 psig** of CO2 vapor pressure (This keeps dry ice from forming inside the system)
- Using an oil hand pump, fill the oil reservoir with the compressor manufacturer-approved oil thru the Oil Reservoir Drain Valve (located downstream of oil the reservoir)
  - Be careful to ensure that no moisture is pumped in the oil
  - Add oil until the level rises above the oil level sensor
- Once the reservoir is full of oil, make sure that the electronic oil level switch on each compressor is powered
- Pressurize the oil vent line by opening the Oil Vent Line Service Valve, which is located between the oil reservoir and the receiver
- Open the isolation valves around the oil reservoir
  - The Main Oil Line Service Valve (located after oil separator)
  - The Oil Line Service Valve (located after oil reservoir)



- Allow the oil level switches, once they have been powered, to call for oil and fill the compressors (as they would during normal operation)
- Check that when the proper oil level for the compressors has been reached, the oil level switches shut off and the crankcase heaters are energized

2.E MAINTENANCE PROCEDURES - ANNUAL AND PERIODIC

Any service performed on the system must be in accordance with local code requirement as well as the directions in this manual in order to maintain the safe and reliable operation of the system. Service should be only performed by authorized contractors, or customer-designated technicians. Hillphoenix strongly recommends that any technician working on the system have attended a Hillphoenix Learning Center training course for Advansor systems. See hillphoenixlc.com for more information.

In addition to the tools, components, parts and materials needed for service, this section covers the procedures for:

- Checking the system's general condition including compressors, valves, pipes and insulation, heat exchanger and receiver
- Checking oil and refrigerant levels in compressors and reservoir
- Checking safety pressure switch and safety valves
- Checking instruments and gauges
- Changing Oil filters
- Changing liquid filters
- Checking system for moisture
- Extraction of oil samples for acid and water content
- Gas alarms for rooms and ventilation

Maintenance of the compressors, pressure vessels (receiver and oil reservoir) and pipe systems should be conducted as specified by Hillphoenix and the component manufacturers. A logbook should be kept with the system to note:

- Any changes (loss and additions) to the system's refrigerant charge
- Oil testing
- Problems with, and corrections/repairs made to, the system

Service on the pipe system and vessels should be performed on a regular basis. Pressure-switches have to be checked every year and service on vessels equipped with safety valves should be carried out every other year. Safety valves on vessels and pipes should also be inspected every other year.

2.E.I TOOLS AND COMPONENTS NEEDED FOR SERVICE

These in general include:

- Hydraulic or vacuum pump for oil charging
- Tubes, fittings, and pressure gauges suitable for the system's operating pressures to secure the fitter during filling of the system

2.E.1.a Parts and materials needed during Service

- Oil filter (B-661): Westermeyer/Temprite, 1-piece set including O-rings
- Filter-drier cartridge(s): Danfoss type 48-DM, 1 piece including gasket
- R-744 (CO_2): Instrument-grade (99.99%) or better
- Strainer elements and filter drier cores
- Oil: refer to the compressor manufacture's specification for the type and quantity of oil required
- Thread sealing: Permabond MH052 (see page 21)
- Paint for pipes (see page 46 for steel pipe paint specifications) and frames as well as insulation material Armaflex (cold/hot)

3.E.II SERVICE AFTER STARTUP

Perform the following checks after startup:

- Refrigerant charged to the proper level – add if necessary
- Oil in the compressors, separator(s) and reservoir charged to the proper level – add if necessary
- Oil is uncontaminated and clear – change oil and oil filter if necessary
- Pressure and temperatures are within the specifications:
    - MT: suction/ pressure: **350 to 475 psig** with 20 to 50 degrees of superheat, high-pressure gas approximately **230°F**
    - LT: suction/ pressure: **189 to 363 psig** with 20 to 50 degrees of superheat, high-pressure gas approximately **149°F**

2.E.III SERVICE AFTER 3-4 WEEKS OF OPERATION

- Change oil separator filters if dirt loading is above 13 psid (0.9 bar-d) across the separator.
- Add oil if necessary
- Check for pressure drop across the filter-drier and change filter if pressure drop is found
- Check for leakage and tighten fittings, and repair, if leaks are found
- Add refrigerant if necessary
- Make any other adjustment and repairs that are necessary for the safe and efficient operation of the system

2.E.IV ONGOING SERVICE PROCEDURES

Following the startup and initial service of the system, annual and periodic procedures listed below should be performed.

2.E.IV.a Annual Service (or otherwise as noted)

Compressor Service	
Inspect each compressor prior to service. Investigate any unusual sounds or vibrations to determine the cause and repair or replace as necessary.	
Specific components to check include: Vibration isolation mounts Oil system Compressor oil levels Reservoir oil level Solenoid operation Insulation Flex tubes	Note the condition and steps taken in the log book: Check that the vibration isolation mounts are intact and investigate any wear that is apparent to determine and correct the cause Check the oil system, retightening any fittings that are loose Check compressors oil levels via sight glass (typically medium-temp) and sensors (medium and low-temp) Test all solenoids and switches Inspect insulation and repair any damage or deterioration Inspect and tighten any flex tubes as necessary
Collect an oil sample to submit for analysis.	Oil sample – see below
Receiver and Piping System Service	
Carefully inspect and repair any insulation for the receiver, piping, or piping system component that shows signs of damage or deterioration.	Examine the insulation for the receiver, piping and all components including valves, manometers, and safety valves for corrosion or any other condition requiring repair or replacement
Inspect the oil piping system on a regular basis -- at least 3 to 4 a year. Any stains, spills or other indications of leaks should be carefully examined and corrected.	Check that the oil piping system and fittings are tight and free of corrosion — tighten, repair and repaint as necessary. Be sure to include all valves and solenoids when checking for operation and tightness.
Note any spills or leaks found, and the actions taken to correct them in the logbook.	
Condenser/Gas Cooler Service	
Inspect the condenser/gas cooler to make sure the fans (and inverters) are operating properly and that any problems are corrected.	Confirm that the fans are operating and running in the right direction. Check for dirt on the coils and remove and clean as necessary.
Suction line Filter-Drier	
Prior to service, check for any pressure drops across the filter drier. Change the filter if a drop of 5 psig is found.	Change the filter cartridge after any service has been performed, or every other year of operation.
Oil Separator Filter	
Check if the oil in the separator is clear and verify that there is a pressure drop of no more than 5 psig.	Change the filter cartage if the oil is unclear or discolored, or if the pressure drop ahead of the oil separator is too high.
Liquid Strainer	
Check for pressure loss and flash-gas in the liquid line.	Change the filter if the pressure drop is too high (i.e., greater than 5 psig).
Oil Sample Collection	
Test oil for water and acid contents annually.	Take oil samples from either the oil separator or reservoir. Note that the sample may foam since the oil contains refrigerant which expands when extracted.

Safety Equipment Inspection	
Inspect safety pressure switches for proper operation and replace if necessary.	Refer to local code requirements and regulations pertaining to the testing and replacement of safety valves.
Inspect safety valves and replace if necessary with new or unused valves.	
Check machine room-mounted (and any adjacent) leak detectors and confirm they are operating properly. Since any concentration of refrigerant around sensors increases their readings, ensure that ventilation in the machine room (and anywhere else sensors are located) is adequate and not obstructed. Inspect and ensure emergency stop and alarm functions are working.	Ensure entry and exit to and from the machine room is unobstructed and that all safety equipment is in working order.
Instruments and Pressure Gauges	
Check all pressure gauges that they are reading accurately before and after pumping down the system.	Compare readings between pressure gauges and transmitters. Check that temperature sensors are mounted properly and that they are sending signals correctly.
Electric System	
Check of level switches Inspect cables and pipes Check that controller display is working correctly Check UPS	Check all level switches for oil and CO2 Visual inspection Visual inspection

2.E.IV.b Every Other Year Service

Following first year of operation

Oil Separator Filter	
Change the oil separator filter.	Removed the oil separator top flange by loosening the screw bolts Make sure to change the O-ring with the filter cartridge
Suction Line Filter Drier	
Check to if the oil in the separator is clear and verify that there is a pressure drop of no more than 5 psig.	Filter type: 48-DM, 1-2 pcs
Mechanical Parts	
Change metal flex tubes on both the liquid and suction sides of the compressor. Inspect and confirm operation of oil system solenoids valves.	Change metal flex tubes showing any sign of wear Replace any solenoids as necessary

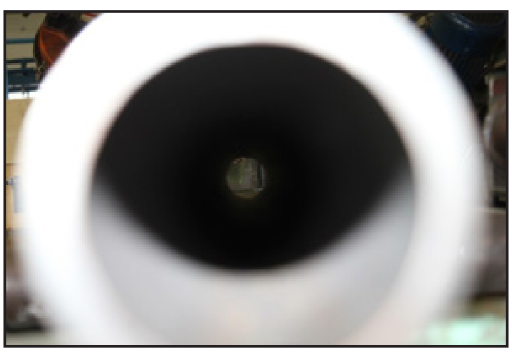
Mechanical Parts (Cont.)	
Check all mechanical parts and piping (particularly around compressor suction lines) for ice formation that could impact operation.	Carefully remove any ice formations that could potentially bend pipes and displace components

2.F STEEL PIPE HANDLING PROCEDURES

Tube type	P235GH
Traceability	The right pipe with certificate - labeling
Dimensions	See pipe drawings
Cutting	Machine
Joining	Welding, Certificate + welding procedure
Purity	The pipe should be externally shot blasted and the interior sandblasted. Any sections of pipe that are not painted on the exterior must be inspected and ensured 100% pure after welding.
Welding for valves and filters that are screwed into the pipe work	All threaded connections must be tightened followed by a seal weld. Use proper materials (e.g. wet cloths to provide external cooling to keep valve seats and seals from exceeding rated temperatures.

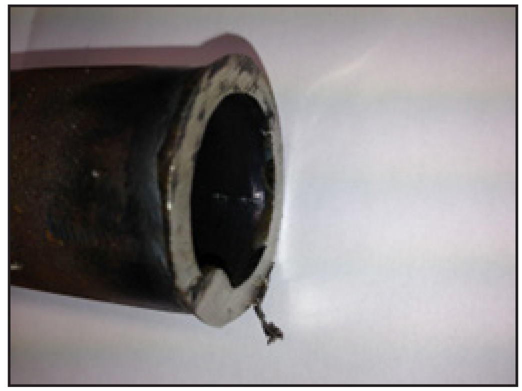
2.F.I PREPARING TO WELD

Do not use cold water when shortening and tapping pipe. Fog lubrication can be used for cutting and core drilling holes. The pipe must be blown and kept clean throughout the operation before and during welding.



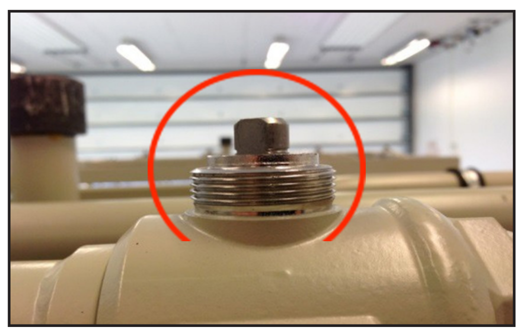
Always check for dirt and debris before and during welding.

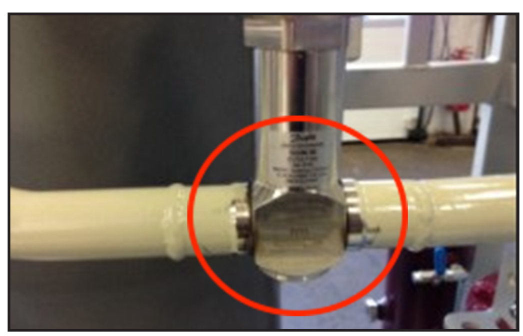
2.F.II WELDING PIPES



Ensure that the piping of welded joints places the joints perpendicular to one another.

2.F.III PREPARING PIPES FOR PAINTING





All threaded ends, sleeves, tags and flow directions should be hedged.

2.G CO2 PRESSURE-TEMPERATURE CHART

Hill PHOENIX Pressure-Temperature Chart for CO2

Low Temp Suction, Typical (-25 °F to -15 °F)

Temp °F	CO2 (R-744) Pressure psi(g)	CO2 (R-744) Pressure bar(g)	Temp °C
-39	134.2	9.3	-39.4
-38	137.2	9.5	-38.9
-37	140.3	9.7	-38.3
-36	143.5	9.9	-37.8
-35	146.7	10.1	-37.2
-34	149.9	10.3	-36.7
-33	153.2	10.6	-36.1
-32	156.5	10.8	-35.6
-31	159.9	11.0	-35.0
-30	163.3	11.3	-34.4
-29	166.8	11.5	-33.9
-28	170.3	11.7	-33.3
-27	173.9	12.0	-32.8
-26	177.5	12.2	-32.2
-25	181.2	12.5	-31.7
-24	185.0	12.8	-31.1
-23	188.7	13.0	-30.6
-22	192.6	13.3	-30.0
-21	196.5	13.5	-29.4
-20	200.4	13.8	-28.9
-19	204.4	14.1	-28.3
-18	208.5	14.4	-27.8
-17	212.6	14.7	-27.2
-16	216.7	14.9	-26.7
-15	221.0	15.2	-26.1
-14	225.2	15.5	-25.6
-13	229.6	15.8	-25.0
-12	234.0	16.1	-24.4
-11	238.4	16.4	-23.9
-10	242.9	16.7	-23.3
-9	247.5	17.1	-22.8
-8	252.1	17.4	-22.2
-7	256.8	17.7	-21.7
-6	261.5	18.0	-21.1
-5	266.3	18.4	-20.6
-4	271.2	18.7	-20.0
-3	276.1	19.0	-19.4
-2	281.1	19.4	-18.9
-1	286.1	19.7	-18.3
0	291.2	20.1	-17.8
1	296.4	20.4	-17.2
2	301.7	20.8	-16.7
3	307.0	21.2	-16.1

Medium Temp Suction, Typical (15 °F to 25 °F)

Temp °F	CO2 (R-744) Pressure psi(g)	CO2 (R-744) Pressure bar(g)	Temp °C
4	312.3	21.5	-15.6
5	317.8	21.9	-15.0
6	323.2	22.3	-14.4
7	328.8	22.7	-13.9
8	334.4	23.1	-13.3
9	340.1	23.5	-12.8
10	345.9	23.8	-12.2
11	351.7	24.3	-11.7
12	357.6	24.7	-11.1
13	363.6	25.1	-10.6
14	369.7	25.5	-10.0
15	375.8	25.9	-9.4
16	382.0	26.3	-8.9
17	388.2	26.8	-8.3
18	394.5	27.2	-7.8
19	400.9	27.6	-7.2
20	407.4	28.1	-6.7
21	414.0	28.5	-6.1
22	420.6	29.0	-5.6
23	427.3	29.5	-5.0
24	434.0	29.9	-4.4
25	440.9	30.4	-3.9
26	447.8	30.9	-3.3
27	454.8	31.4	-2.8
28	461.9	31.8	-2.2
29	469.0	32.3	-1.7
30	476.3	32.8	-1.1
31	483.6	33.3	-0.6
32	491.0	33.9	0.0
33	498.5	34.4	0.6
34	506.0	34.9	1.1
35	513.6	35.4	1.7
36	521.4	35.9	2.2
37	529.2	36.5	2.8
38	537.1	37.0	3.3
39	545.0	37.6	3.9
40	553.1	38.1	4.4
41	561.2	38.7	5.0
42	569.5	39.3	5.6
43	577.8	39.8	6.1
44	586.2	40.4	6.7
45	594.7	41.0	7.2
46	603.2	41.6	7.8

Hill PHOENIX Pressure-Temperature Chart for CO2

Temp °F	CO2 (R-744) Pressure psi(g)	CO2 (R-744) Pressure bar(g)	Temp °C
47	611.9	42.2	8.3
48	620.7	42.8	8.9
49	629.5	43.4	9.4
50	638.5	44.0	10.0
51	647.5	44.6	10.6
52	656.7	45.3	11.1
53	665.9	45.9	11.7
54	675.2	46.6	12.2
55	684.6	47.2	12.8
56	694.2	47.9	13.3
57	703.8	48.5	13.9
58	713.5	49.2	14.4
59	723.3	49.9	15.0
60	733.3	50.6	15.6
61	743.3	51.2	16.1
62	753.4	51.9	16.7
63	763.6	52.7	17.2
64	774.0	53.4	17.8
65	784.4	54.1	18.3
66	795.0	54.8	18.9
67	805.7	55.5	19.4
68	816.4	56.3	20.0
69	827.3	57.0	20.6
70	838.3	57.8	21.1
71	849.4	58.6	21.7
72	860.7	59.3	22.2
73	872.0	60.1	22.8
74	883.5	60.9	23.3
75	895.1	61.7	23.9
76	906.9	62.5	24.4
77	918.7	63.3	25.0
78	930.7	64.2	25.6
79	942.8	65.0	26.1
80	955.1	65.9	26.7
81	967.5	66.7	27.2
82	980.0	67.6	27.8
83	992.7	68.4	28.3
84	1005.6	69.3	28.9
85	1018.6	70.2	29.4
86	1031.8	71.1	30.0
87	1045.1	72.1	30.6
87.8	1055.5	72.8	31

*All data from NIST Refprop 8.0 [Barometric Press=14.50377psi]

Transcritical Gas Cooler
Pressure and Temperature correlations

Below are approximate gas cooler pressures at *dropleg temperatures* that a system might be subject to

Dropleg Temp °F	Gas Cooler CO2 psi(g)	Gas Cooler CO2 bar(g)	Dropleg Temp °C
81	1037	71.5	27.2
82	1055	72.8	27.8
83	1073	74.0	28.3
84	1091	75.2	28.9
85	1109	76.5	29.4
86	1127	77.7	30.0
87	1145	79.0	30.6
88	1163	80.2	31.1
89	1180	81.4	31.7
90	1198	82.6	32.2
91	1216	83.9	32.8
92	1234	85.1	33.3
93	1252	86.3	33.9
94	1270	87.6	34.4
95	1288	88.8	35.0
96	1306	90.1	35.6
97	1323	91.2	36.1
98	1341	92.5	36.7
99	1359	93.7	37.2
100	1377	95.0	37.8
101	1395	96.2	38.3
102	1413	97.4	38.9
103	1431	98.7	39.4
104	1449	99.9	40.0
104+	1450	100.0	40.0+

2.H INSTALLATION & START-UP OVERVIEW

Advansor CO2 Booster System Installation & Start-Up Process

During Installation

Mechanical & Electrical Systems
- ❑❑ Properly Installed per Code and Construction Documents
- ❑❑ Ensure All Circuit Breaker and Switches are **OFF**

Piping Installed
- ❑❑ Black Steel or Stainless-Steel Pipes to Condenser assembled
  - o Connections TIG-welded by Certified Welder
- ❑❑ Copper Pipe to Evaporators Assembled
  - o Piping Selected per HP CO2 Piping/ Pressure Chart
- ❑❑ System Pressure Tested and purged per HP recommendations

All Valves Positioned for Evacuation
- ❑❑ All Compressor Service Valves **OPEN**
- ❑❑ All System Isola-on Valves **OPEN**
- ❑❑ High Pressure Regulating Valve **OPEN**
- ❑❑ All Inputs and Outputs verified operational

System Triple---Evacuated
- ❑❑ First break with Nitrogen, second and third with CO2 Vapor
- ❑❑ Filter/Drier Cores installed
- ❑❑ Pressurize to 150 psi (10 bar) with CO2 Vapor

Oil Charged to Reservoir
- ❑❑ With approximately 1 gallon of Compressor Manufacturer-Specified Oil between second and third Evacuation

Wiring Completed
- ❑❑ All Sensors, Transducers, Valves, VFDs checked and proofed
- ❑❑ All Pressure and Temperature Transducers at each Evaporator tested and verified working properly
- ❑❑ Set Safety Switches

During Start-Up

Valves Closed
- ❑❑ All Electronic Expansion Valves at the Evaporators
- ❑❑ Main Loop Isolation Valves
- ❑❑ Main Liquid Line Ball Valve to the Store

Pre-Start Checks
- ❑❑ All Valves Checked for Start position
- ❑❑ EMS and Controllers verified ready to operate
- ❑❑ Compressors verified ready to start
- ❑❑ Crankcase Heaters ON
- ❑❑ Condenser Fans Rotational Direction checked
  - o Startup Sequence of On/Off Fans checked
  - o Fans nearest CO2 Header First to Start and Last to Stop (*if applicable*)

Liquid Charged CO2
- ❑❑ Initial liquid charged into the receiver until it reaches the middle of the second Sightglass from the bottom
- ❑❑ Flash Gas Bypass Valve verified operational
- ❑❑ Medium-Temperature Compressors verified cycling On/Off based on Suction Pressure Rise

Medium Temperature Compressors Started
- ❑❑ Refrigerant Level monitored and maintained as necessary
- ❑❑ Main Liquid Line Ball Valve slowly **OPENED**
- ❑❑ One Medium-Temperature Evaporator started at a time
- ❑❑ As many Evaporators as possible allowed to pull down to temperature
- ❑❑ Each Compressor verified operating as it starts
- ❑❑ Flash Gas Bypass Valve and High-Pressure Regulating Valve verified correctly operating
- ❑❑ Remaining Circuits to the Store **OPENED** until the system is operating as close to Full Capacity as possible

Proceed to Start Low Temp Compressors

Low Temperature Compressors Started
- ❑❑ Refrigerant Level monitored and maintained as necessary
- ❑❑ 30% (at least) of the Medium-Temperature Load confirmed operating
- ❑❑ One Low-Temperature Evaporator started up at a time
- ❑❑ Each Evaporator allowed to pull down to temperature
- ❑❑ Each Compressor checked and confirmed operating as it starts
- ❑❑ Flash Gas Bypass Valve and High-Pressure Regulating Valve verified correctly operating
- ❑❑ Remaining Circuits to the Store **OPENED** until the system is operating at Full Capacity

Test, Confirm, & Adjust for Proper Operation
- ❑❑ Continue running system until each Evaporator's Setpoints are reached
- ❑❑ Oil System confirmed operating and Oil added if needed
- ❑❑ Flash Gas Bypass Valve and High-Pressure Regulating Valve verified correctly operating
- ❑❑ Compressor Capacity Step-Control verified correctly operating
- ❑❑ Evaporators checked for Proper Operation Including correct Super Heat
- ❑❑ Refrigerant Level monitored and maintained as necessary

2.1 HILLPHOENIX WARRANTY VALIDATION CHECKLIST

This checklist provides the means for confirming that the steps and procedures required to start up the Advansor system, as laid out in the guide, have been properly performed. Sign (on the following page) and submit the completed checklist to Hillphoenix for validation of warranty coverage.

Mail: Systems Operations 2016 Gees Mill Rd. Conyers, GA 30013 Fax: 770.285.3080 Email: info@Hillphoenix.com Or your local Field Service Engineer	Contact Information Technician performing checks: Name: ____________________ Phone: ____________ Email: ____________________

Prior to Startup

☐ **Mechanical & Electrical Systems**

1. Properly installed per code and regulator requirements
2. All Circuit Breaker and Switches are OFF

☐ **Piping Installed**

3. Black steel or stainless-steel pipes or C194 copper to condenser assembled (**Note:** *Connections TIG-welded by a certified welder*)
4. Copper pipe to evaporators assembled **(NOTE**: *Piping selected per HP CO2 piping chart*)
5. System pressure tested and vented per HP recommendations

☐ **All Valves Checked for Evacuation Positioning**

6. All compressor service valves OPEN
7. All system isolation valves OPEN
8. High-pressure regulating valve OPEN
9. All inputs and outputs verified operational

☐ **System Triple–Evacuated**

10. All subsystems Included for min. 24 hrs.
11. 1st flush with nitrogen, 2nd & 3rd with CO2 vapor
12. Filter/drier cores installed
13. Leak test and pressurize to 150 psig (10 bar-g)

☐ **Oil Charged - After 2nd Evacuation**

14. With approx. 1 gal. of compressor manufacturer-specified oil per compressor

☐ **Wiring Completed**

15. EMS verified
16. All inputs and outputs installed and confirmed
17. All sensors, transducers, valves, and VFDs checked and proofed
18. All pressure transducers and temperature sensors at each evaporator tested and working properly
19. Safety switches set

During Startup

☐ **Valves Closed**

1. All EEVs at the evaporators
2. Main loop isolation valves
3. Main liquid line ball valve to the store

☐ **Pre-Start Checks Completed**

4. All valves checked for Start position
5. EMS and controllers verified ready to operate
6. Compressors verified ready to start
7. Crankcase heaters ON
8. Condenser fans rotational direction checked

☐ **Liquid Charged CO2**

9. Until receiver level reaches the middle of 2nd sightglasses
10. Flash gas bypass valve verified operational
11. Medium temperature compressors verified cycling On/Off based on suction pressure rise

☐ **Medium Temp Compressors Started**

12. Continue to monitor refrigerant level and add as needed
13. Main liquid line ball valve slowly OPENED
14. One medium-temperature evaporator started at a time
15. As many evaporators as possible allowed to pull down to temperature
16. Each compressor verified operating as it starts
17. Flash gas bypass valve and high-pressure regulating valve verified as operating correctly
18. Remaining circuits to the store OPENED until operating conditions as close to full capacity

☐ **Low Temp Compressors Started**

19. Refrigerant level monitored and maintained as needed
20. 30% (at least) of the medium temperature load confirmed operating
21. One low temperature evaporator started up at a time

22. Each evaporator allowed to pull down to temperature
23. Each compressor checked and confirmed operating as it starts
24. Flash gas bypass valve and high-pressure regulating valve verified operating correctly
25. Remaining circuits to the store OPENED until operating conditions at full capacity

☐ **Test, Confirm & Adjust for Proper Operation**

26. Continue running system until each evaporator's setpoints are reached
27. Oil system confirmed operating and oil added if needed
28. Flash gas bypass valve and high-pressure regulating valve verified operating correctly
29. Compressor capacity step-control verified operating correctly
30. Evaporators checked for proper operation including correct super heat
31. Refrigerant Level monitored and maintained as necessary

Signature: ________________________________

Date: _______________

Hill PHOENIX, Inc.
Hereinafter Referred To As Manufacturer

LIMITED WARRANTY

GENERAL WARRANTY

Manufacturer's products are warranted to be free from defects in materials and workmanship under normal use and maintenance for fourteen months from date of shipment from manufacturer (the "Base Warranty Period"). In the event of a qualifying warranty claim, a new or rebuilt part to replace any defective part will be provided without charge. The replacement part is covered under this warranty for the remainder of the applicable Base Warranty Period. In order to be eligible for warranty coverage, customer must: (i) notify Manufacturer promptly upon discovery of a warrant defect, and (ii) comply with the warranty claim procedures provided by Manufacturer from time to time.

This equipment warranty does not include labor or other costs incurred for diagnosing, repairing, removing, installing, shipping, servicing, or handling of either defective parts or replacement parts.

The warranty shall not apply:
1. To any unit or any part thereof which has been subject to accident, alteration, negligence, misuse or abuse, or which has not been operated in accordance with the manufacturer's recommendations, or in conditions outside of Manufacturer's specifications, or if the serial number of the unit has been altered, defaced, or removed.
2. When the unit, or any part thereof, is damaged by fire, flood, or other act of God.
3. To products that are impaired or damaged due to improper installation.
4. When installation and startup forms are not properly completed or returned within two weeks after startup.
5. If the defective part is not returned to the Manufacturer.
6. To service, maintenance or wear and tear parts (such as lights, starters and ballasts)

MODIFICATIONS TO GENERAL WARRANTY

The following sets forth certain modifications to the General Warranty for specific products of Manufacturer:

DISPLAY CASE AND SPECIALTY PRODUCTS CLEARVOYANT® LED LIGHTING
The warranty period for Clearvoyant LED lighting components within the Clearvoyant lighting system is five years from date of shipment.

REMEDY LIMITATION/DAMAGES EXCLUSION
THE REMEDY OF REPAIR OR PROVISION OF A REPLACEMENT PART WITHOUT CHARGE SHALL BE THE EXCLUSIVE REMEDY FOR ANY WARRANTY CLAIM HEREUNDER. WITHOUT LIMITING THE FOREGOING, MANUFACTURER SHALL NOT BE LIABLE UNDER ANY CIRCUMSTANCES FOR INCIDENTAL, INDIRECT OR CONSEQUENTIAL DAMAGES, INCLUDING LOSS OF PROFIT, LABOR COST, LOSS OF REFRIGERANT OR FOOD PRODUCTS.

EXCLUSIVE WARRANTY
THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY WITH RESPECT TO THE PRODUCTS. ALL OTHER WARRANTIES, WHETHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION, THE WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE HEREBY DISCLAIMED AND EXCLUDED. NO IMPLIED WARRANTY SHALL BE DEEMED CREATED BY COURSE OF DEALING OR USAGE OF TRADE. NO OTHER PERSON IS AUTHORIZED TO EXPAND OR CREATE ANY OBLIGATION GREATER THAN OR MORE EXPANSIVE THAN THE WARRANTY PROVIDED HEREIN.

Submit warranty claims to:

Hillphoenix Refrigeration & Power Systems Division
2016 Gees Mill Road
Conyers, GA 30013
Warranty / Service
Phone: 1-833-280-5714

Hillphoenix Display Case Division
1925 Ruffin Mill Road
Colonial Heights, VA 23834
Warranty / Service
Phone: 1-833-280-5714

Hillphoenix Specialty Products Division
703 Franklin Street
Keosauqua, IA 52565
Warranty / Service
Phone: 1-833-280-5714

4844-3514-3187.2