

Application Engineering

*Economized Vapor Injection (EVI) for ZF*KVE and ZF*K5E Compressors*

BULLETIN NO: AE4-1327 R16

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Safety

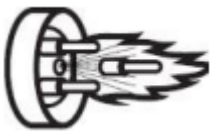
Important Safety Information

Those involved in the design, manufacture, and installation of a system, system purchasers, and service personnel may need to be aware of hazards and precautions discussed in this section and throughout this document. OEMs integrating the compressor into a system should ensure that their own employees follow this bulletin and provide any necessary safety information to those involved in manufacturing, installing, purchasing, and servicing the system.

Responsibilities, Qualifications and Training

- OEMs are responsible for system design, selection of appropriate components, integration of this component into the system, and testing the system. OEMs must ensure that staff involved in these activities are competent and qualified.
- OEMs are also responsible for ensuring that all product, service, and cautionary labels remain visible or are appropriately added in a conspicuous location on the system to ensure they are clear to any personnel involved in the installation, commissioning, troubleshooting or maintenance of this equipment.
- Only qualified and authorized HVAC or refrigeration personnel are permitted to install, commission, troubleshoot and maintain this equipment. Electrical connections must be made by qualified electrical personnel.
- Observe all applicable standards and codes for installing, servicing, and maintaining electrical and refrigeration equipment.

Terminal Venting and Other Pressurized System Hazards



If a compressor's electrical terminal pin loses its seal, pressurized oil, refrigerant, and debris may spray out. This is called "terminal venting".

The ejected debris, oil, and refrigerant can injure people or damage property. The oil and refrigerant spray can be ignited by electrical arcing at the terminal or any nearby ignition source, producing flames that may project a significant distance from the compressor. The distance depends on the pressure and the amount of refrigerant and oil mixture in the system. The flames can cause serious or fatal burns and ignite nearby materials.

Each compressor has a terminal cover or molded plug that covers electrical connections. The cover or plug helps to protect against electric shock and the risks of terminal venting. If terminal venting occurs, the cover or plug helps contain the spray of refrigerant and oil and reduces the risk of ignition. If ignition occurs, the plug or cover helps contain the flames. However, neither the terminal cover nor the molded plug can completely eliminate the risk of venting, ignition, or electric shock.

See [copeland.com/terminal-venting](https://www.copeland.com/terminal-venting) for more details about terminal venting. Additionally, a compressor's refrigerant lines keep refrigerant and oil under pressure. When removing or recharging refrigerant from this component during service, this can pose a pressurized fluid hazard.

Flammable Refrigerant Hazards



If flammable refrigerant is released from a system, an explosive concentration can be present in the air near the system. If there is an ignition source nearby, a release of flammable refrigerant can result in a fire or explosion. While systems using flammable refrigerant are designed to mitigate the risk of ignition if the refrigerant is released, fire and explosion can still occur.

See copeland.com/flammable-refrigerants for more information on flammable refrigerant safety.

Electrical Hazards



Until a system is de-energized, and capacitors have been discharged, the system presents a risk of electric shock.

Hot Surface and Fire Hazards



While the system is energized, and for some time after it is deenergized, the compressor may be hot. Touching the compressor before it has cooled can result in severe burns. When brazing system components during service, the flames can cause severe burns and ignite nearby combustible materials.

Lifting Hazards



Certain system components may be very heavy. Improperly lifting system components or the compressor can result in serious personal injury. Use proper lifting techniques when moving.

POE Oil Hazards

This equipment contains polyol ester (POE) oils. Certain polymers (e.g., PVC/CPVC and polycarbonate) can be harmed if they come into contact with POE oils. If POE oil contacts bare skin, it may cause an allergic skin reaction.

Precautions

- Always wear personal protective equipment (gloves, eye protection, etc.).
- Keep a fire extinguisher at the jobsite at all times.
- Keep clear of the compressor when power is applied.
- **IMMEDIATELY GET AWAY if you hear unusual sounds in the compressor. They can indicate that terminal pin ejection may be imminent. This may sound like electrical arcing (sizzling, sputtering or popping). However, terminal venting may still occur even if you do not hear any unusual sounds.**

- Never reset a breaker or replace a blown fuse without performing appropriate electrical testing
 - **A tripped breaker or blown fuse may indicate an electrical fault in the compressor. Energizing a compressor with an electrical fault can cause terminal venting. Perform checks to rule out an electrical fault.**
- Disconnect power and use lock-out/tag-out procedures before servicing.
 - Before removing the terminal cover or molded plug, check that ALL electrical power is disconnected from the unit. Make sure that all power legs are open. (Note: The system may have more than one power supply.)
 - Discharge capacitors for a minimum of two minutes
 - Always use control of hazardous energy (lock-out/tag-out) procedures to ensure that power is not reconnected while the unit is being serviced.
- Allow time for the compressor to cool before servicing.
 - Ensure that materials and wiring do not touch high temperature areas of the compressor.
- Keep all non-essential personnel away from the compressor during service.
 - For A3 refrigerants (R290) remove refrigerant from both the high and low sides of the compressor. Use a recovery machine and cylinder designed for flammable refrigerants. Do not use standard recovery machines because they contain sources of ignition such as switches, high- and low-pressure controls and relays. Only vent the R290 refrigerant into the atmosphere if the system is in a well-ventilated area. Never use a torch to remove the compressor. Only tubing cutters should be used.
- Never use a torch to remove the compressor. Only tubing cutters should be used for both A2L and A3 refrigerants.
- Use an appropriate lifting device to install or remove the compressor.
- Never install a system and leave it unattended when it has no charge, a holding charge, or with the service valves closed without electrically locking out the system.
- Always wear appropriate safety glasses and gloves when brazing or unbrazing system components.
- Charge the system with only approved refrigerants and refrigeration oils.
- Keep POE oils away from certain polymers (e.g., PVC/CPVC and polycarbonate) and any other surface or material that might be harmed by POE oils. Proper protective equipment (gloves, eye protection, etc.) must be used when handling POE lubricant. Handle POE oil with care. Refer to the Safety Data Sheet (SDS) for further details.
- Before energizing the system:
 1. Securely fasten the protective terminal cover or molded plug to the compressor, and
 2. Check that the compressor is properly grounded per the applicable system and compressor requirements.

Signal Word Definitions

The signal word explained below are used throughout the document to indicate safety messages.



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



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



CAUTION, used with the safety alert symbol, indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

Introduction

The refrigeration Economized Vapor Injection (EVI) compressor was developed to provide improved capacity and efficiency. EVI compressor systems benefit over standard refrigeration compressor systems of equivalent horsepower due to the following:

Capacity Improvement – The capacity is improved by increasing the h (change in enthalpy) in the system rather than increasing mass flow. This is accomplished without increasing compressor displacement. (Refer to Figure 1 and Figure 2 diagram for details.)

Increased Energy Efficiency Ratio (EER) – The gain in capacity is greater than the increase in the power that the compressor consumes, which improves efficiency.

Cost and Energy Advantage – Because a smaller horsepower compressor can be used to achieve the same capacity as a larger horsepower compressor, there is an inherent cost advantage.

Theory of Operation

Copeland Scroll EVI compressors are equipped with an injection connection for Economizer Operation. Economizing is accomplished by utilizing a subcooling circuit similar to that shown in Figure 1. This mode of operation increases the refrigeration capacity and in turn the efficiency of the system. The benefits provided will increase as the compression ratio increases, thus, greater gains will be achieved in summer when increased capacity may be required.

The schematic shows a system configuration for the economizer cycle. A heat exchanger is used to provide subcooling to the refrigerant before it enters the evaporator. This subcooling process provides the increased capacity gain for the system, as described above. During the subcooling process a small amount of refrigerant is evaporated and superheated. This superheated refrigerant is then injected into the mid compression cycle of the scroll compressor and compressed to discharge pressure. This injected vapor also provides cooling at higher compression ratios, similar to liquid injection of standard ZF Scroll compressors.

Nomenclature

The EVI compressor has a model designation with this pattern: ZF(D)***V*-XXX or ZF(D)***5*-XXX, example: ZF(D)18KVE-TFD. The model numbers include the nominal capacity without the economizer cycle for R404A refrigerant at 60 Hz Low Temperature ARI rating conditions.

Model Designation

Z F (D) 18K V E - TFD - 551
 1 2 3 4 5 6 7 8

- 1 Compressor Family: Z = Scroll
- 2 F = Low Temperature
- 3 D = Digital
- 4 Nominal Capacity [BTU/h] @ 60 Hz and ARI low temperature conditions using multipliers "K" for 1000, without vapor injection.
- 5 a. V = Vapor injection & wet injection when required
 b. 5 = Vapor injection/wet injection when required & liquid injection
- 6 POE oil
- 7 Motor Version
- 8 Bill of Material Number

The EVI rating curves have been developed to incorporate performance improvements while utilizing the economizer cycle. The capacity displayed is with maximum possible subcooling at the exit of the subcooling heat exchanger. Compressor performance information can be obtained by accessing the Online Product Information (Copeland.com/OPI) database at Copeland.com or by downloading PSS (Product Selection Software).

Approved Refrigerants

R-404A, R-507, R-407A/C/F, R-448A and R-449A are approved for use with Copeland Scroll EVI compressors. When using ZF*KVE or ZF*K5 compressors in low temperature applications with R407A/C/F or R-448A or R-449A, additional liquid injection is required in conjunction with vapor injection to protect the scrolls from excessive discharge temperatures.

Approved Oils

Polyol Ester (POE) lubricants are the only lubricants approved for the EVI compressors. For a complete list of approved POE lubricants, refer to **Form 93-11, Copeland Accepted Refrigerants/Lubricants**.



POE may cause an allergic skin reaction and must be handled carefully and the proper protective equipment (gloves, eye protection, etc.) must be used when handling POE lubricant. POE must not come into contact with any surface or material that might be harmed by POE, including without limitation, certain polymers (e.g. PVC/ CPVC and polycarbonate). Refer to the Safety Data Sheet (SDS) for further.

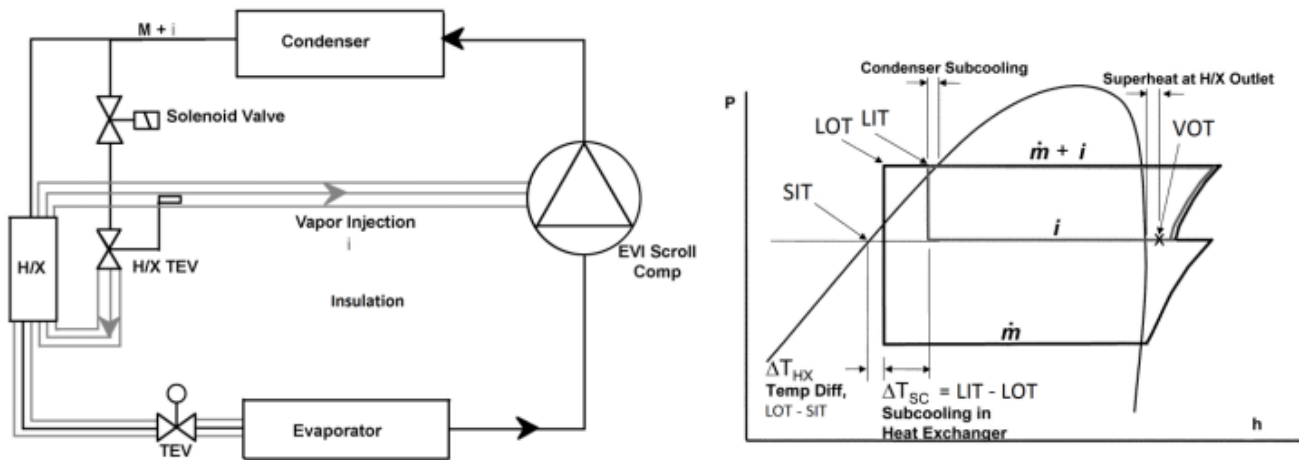


Figure 1 - Circuit Diagram and cycle for EVI

(Upstream extraction shown here. See System Configuration section for details.)

Definitions(s)	Description
T _c	Condensing temperature
LIT	Liquid temperature entering H/X
LOT	Subcooled liquid leaving H/X
P _i	Intermediate pressure
SIT	Saturated temperature at intermediate pressure
VOT	Vapor temperature leaving H/X
VIT	Vapor temperature entering H/X
T _{sc}	Liquid subcooling in H/X
M	Evaporator mass flow
I	Vapor Injection Mass Flow
ΔT _{HX}	Liquid temp out H/X-liquid-saturated temperature at intermediate
ΔT _{SC}	Liquid temp into H/X-subcooled liquid temp out H/X

The P-h diagram shows the theoretical gain in system performance achieved by using the economizer cycle. The extension outside of the vapor dome is what allows for the extra enthalpy increase in the evaporator, enhancing system performance. Although power increases due to the vapor injection into the compressor, there is still an efficiency gain given that the capacity gains exceed the power increase.

*Table 1 - Low and High Pressure Control Settings for ZF*KVE and ZF*K5 EVI Scroll Compressors*

Application	Control Type	R-404A/ R-507	R-22	R-407A/R-407F/ R-448A/R-449A	R-407C
Medium Temp	LOW	17.1 PSIG Min.	10PSIG Min.	8 PSIG Min.	6 PSIG Min
	HIGH	445 PSIG Max.	381 PSIG Max.	428 Max.	402 PSIG Max
Low Temp	LOW	0 PSIG Min.	2 in. Hg Min.	4 in. Hg Min.	5 in. Hg Min.
	HIGH	400 PSIG Max	335 PSIG Max	375 PSIG Max.	352 PSIG Max

Application Envelopes

See Figure 16 to Figure 22 at the end of this bulletin.

Control Requirements

See Figure 2, shown below, for a detailed schematic for this system (shown for a single compressor application). The figure also shows the upstream extraction method for tapping the liquid for the heat exchanger. See [System Configuration](#) section for more details about extraction method.

Pressure Controls

Both high and low pressure controls are required and the minimum and maximum set-point limits are shown in Table 1 at the previous page.

Pump Down Recommendations

Refrigeration scroll compressors use a low-leak discharge valve to prevent high-pressure back-flow into the low side.

Typically, this check valve prevents system pressures from equalizing and pump down can be achieved.

However, during laboratory testing, Copeland has observed a potential short cycling condition on the smaller horsepower models.

This phenomenon can be attributed to several factors:

- Location of low-pressure control sensor. If it is located right at the suction inlet of the compressor, it will be more sensitive to pressure spikes.
- Actual low-pressure setting. Refer to our recommended setting in Table 1. If the differential pressure setting is too close, this will increase the possibility of short cycling.
- Type of Low-pressure control can have an effect on cycling. The encapsulated non-adjustable type is more susceptible to causing excessive cycling due to tolerances.
- If short cycling cannot be avoided, using a 3-minute time delay will limit the cycling of the compressor to an acceptable level.

Power Requirements

EVI compressors are only available for three phase power.

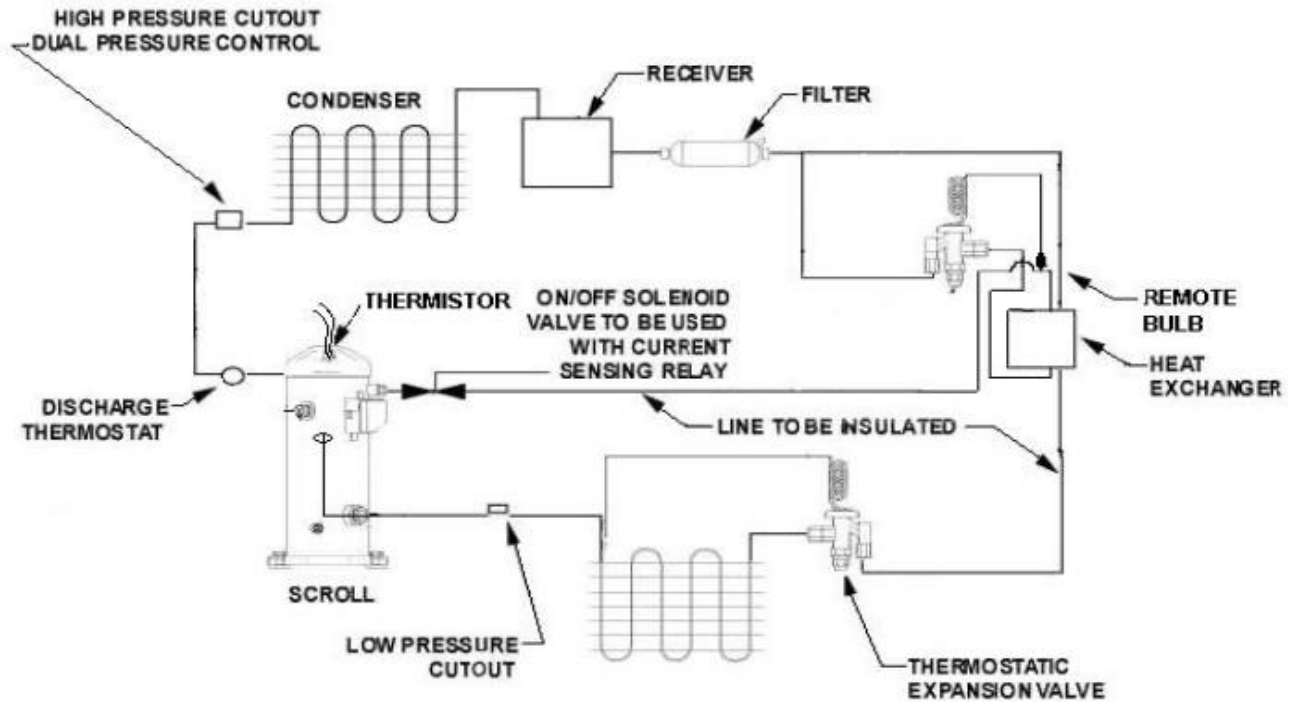


Figure 2 - EVI System Schematic Diagram

ZF(D)*KVE-XXX Compressors Models

Capacities shown below are obtained suited with R404R at ARI Low Temperatures Conditions Ratings (-25°F/105°F).

Model	Capacity with EVI ^{1,2}	HP	Status
ZF13KVE	19,900 BTU/hr	4.0	
ZFD13KVE	19,900 BTU/hr	4.0	
ZF18KVE	29,300 BTU/hr	6.0	
ZFD18KVE	19,900 BTU/hr	4.0	
ZF24KVE	34,300 BTU/hr	7.5	(phase-out)
ZF25KVE*	36,000 BTU/hr	7.5	
ZFD25KVE	36,000 BTU/hr	7.5	
ZF28KVE*	41,800 BTU/hr	9.0	
ZF33KVE	47,900 BTU/hr	10.0	(phase-out)
ZF40KVE	62,500 BTU/hr	13.0	(phase-out)
ZF48KVE	74,000 BTU/hr	15.0	(phase-out)

¹ Dew point pressures assumed

² Maximum possible subcooling

* The ZF25KVE and ZF28KVE have been developed as a higher efficiency, smaller footprint replacement for the models that are phased-out.

Note 1: For performance of ZF*KVE models with other refrigerants, refer to the Online Product Information at [Copeland Online Product Information](#) or download PSS (Product Selection Software).

Note 2: Capacities higher than 10 HP are covered by ZF*K5E models. See **AE4-1383** for more details.

Discharge Temperature Control

A discharge temperature control is not required on all ZF(D)*KVE-XXX compressors.

Phased out models ZF24KVE-TW*, ZF33KVE-TW*, ZF40KVE-TW* and ZF48KVE-TW* had an internal temperature sensor and no other discharge temperature

control was required for applications using R-404A or R507. No thermistor or thermostat was required when using the obsoleted Copeland Scroll Demand Cooling for low temperature applications.

For more details about Scroll compressors that used to be compatible with this obsolete system see **Appendix A: Service** Section: Copeland Scroll Demand Cooling for ZF*KVE Modetection.

For models ZF(D)13KVE-TF*, ZF(D)18KVE-TF*, ZF(D)25KVE-TF* and ZF28KVE-TF* discharge temperature control is required use one of the following two methods for discharge temperature control:

- Thermistor (998-0166-00 Kit Number)
- Discharge Line Thermostat

Thermistor

For low temperature applications with R-407A/C/F, R448A or R-449A, Copeland Scroll Demand Cooling (currently being obsoleted), DTC or EXV are required for use to run all conditions within the approved operating envelope. Additional information on Demand Cooling, DTC and EXV are provided in the [Wet Injection](#) section below.

A thermistor in the compressor control circuit, located in the thermal well in the top cap of the compressor, is used to protect against high discharge temperatures and must be wired to the rack control systems. The cutout temperature is to be set at 280°F. The temperature resistance values for the sensor (**kit part number 998-0166-00**) can be found in **Appendix B:** Temperature resistance values for sensor kit part number 998-0166-00

The table expresses the ratio of the resistance at the indicated temperature and the resistance at 25°C (77°F). The resistance at 25°C (77°F) is 86K ohms nominal. The curve fit is: Ratio = 0.8685e-0.0257x.

Warning: this curve fit is only valid for temperature range of 100 to 160°C (212-320°F).

NOTE: The system controller must open the contactor when the discharge line temperature exceeds 280°F.

Discharge Line Thermostat

Another method of discharge temperature control is the use of a discharge line thermostat. It is required in the

compressor control circuit. The thermostats have a cut out setting that will insure discharge line temperatures below the 260°F (127°C) maximum limit. (This value differs from the cut-out value set on the thermistor, which measures the temperature closer to the discharge gas from the scroll.).

The discharge line thermostat should be installed approximately 7 inches (178mm) from the discharge tube outlet. If a service valve is installed at the discharge tube outlet, the thermostat should be located 5 inches (127mm) from the valve braze.

For proper functioning, it is recommended the thermostat should be insulated to protect it from a direct air stream. Kits have been set up to include the TOD thermostat, retainer, and installation instructions.

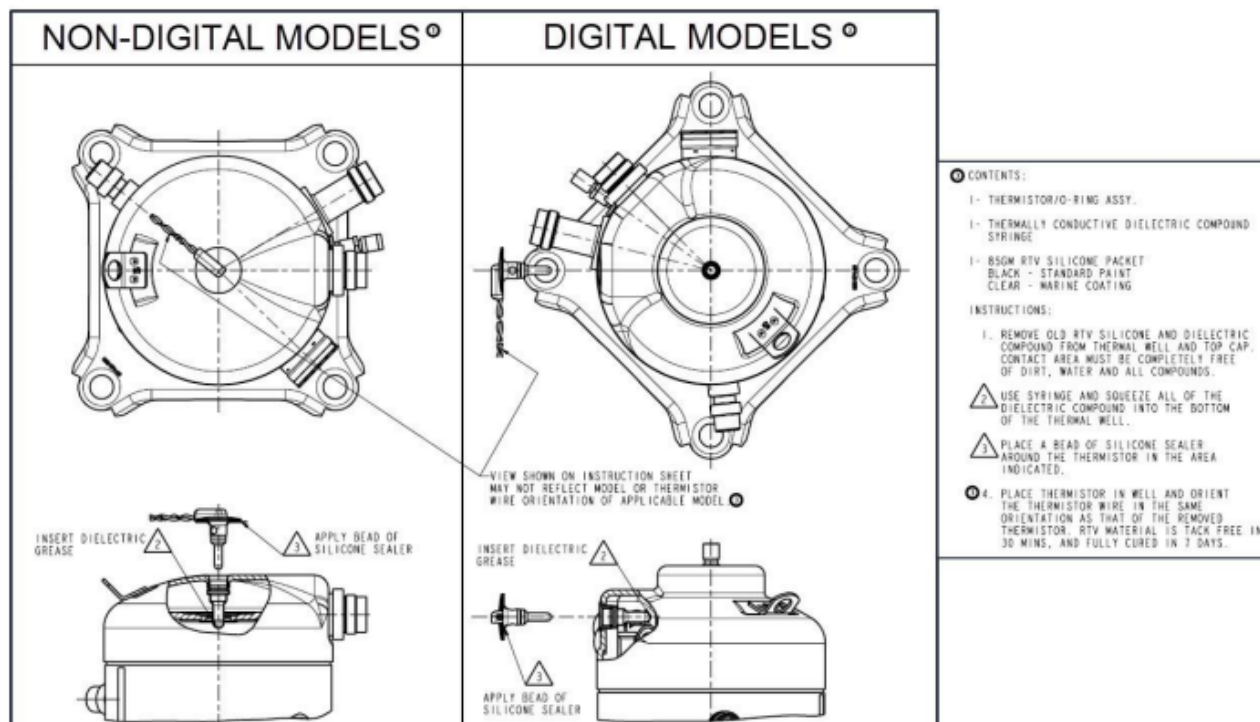


Figure 3 - 998-0166-00 Kit installation instructions

Except for the ZF25KVE and ZF28KVE models, these thermostats must be used with 1/2" O.D. discharge lines to ensure proper thermal transfer and temperature control (the ZF25KVE and ZF28KVE use a 3/4" discharge line, so the thermostat is sized accordingly)

They work with either 120 or 240 volt circuits and are available with or without an alarm circuit capability. See Table 2 for a list of discharge line thermostat kit numbers.

Table 2 - Discharge Line Thermostat Kit Numbers
(not required with K5 models)

Discharge Line O.D. size (in.)	Kit Number	Conduit Connector	Alarm Contacts
1/2	998-7022-08	Yes	No
	998-0540-00	No	No
	998-0548-00	No	Yes
3/4	998-0548-01	No	Yes
	998-7022-09	Yes	

Digital ZF**KVE Scroll Compressors

Digital ZF**KVE Scroll compressors are identified for a letter “D” after ZF designation: ZFD**KVE.

The digital scroll compressor unloads by taking advantage of the Copeland Scroll compressor's axial compliance. All Copeland Scroll compressors are designed so that the compression elements can separate axially. See Figure 4 for internal view. For more details about Digital capacity control operation, please refer to **AE21-1319** bulletin.

A normally closed (de-energized) solenoid valve is a key component for achieving modulation. When the solenoid valve is in its normally closed position, the compressor operates at full capacity, or loaded state.

When the solenoid valve is energized, the two scroll elements move apart axially, or into the unloaded state. During the unloaded state, the compressor motor continues running, but since the scrolls are separated, there is no compression. During the loaded state, the compressor delivers 100% capacity and during the unloaded state, the compressor delivers 0% capacity. A cycle consists of one loaded state and one unloaded state. By varying the time of the loaded state and the unloaded state, an average capacity is obtained.

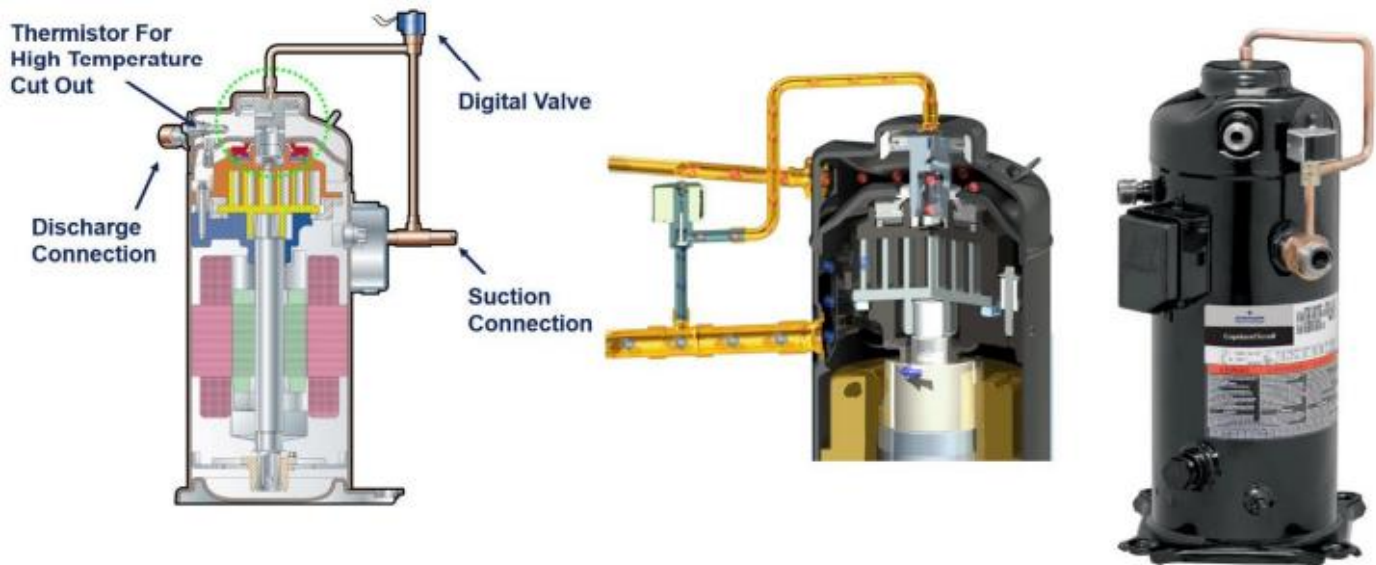


Figure 4 - Copeland Digital Compressor

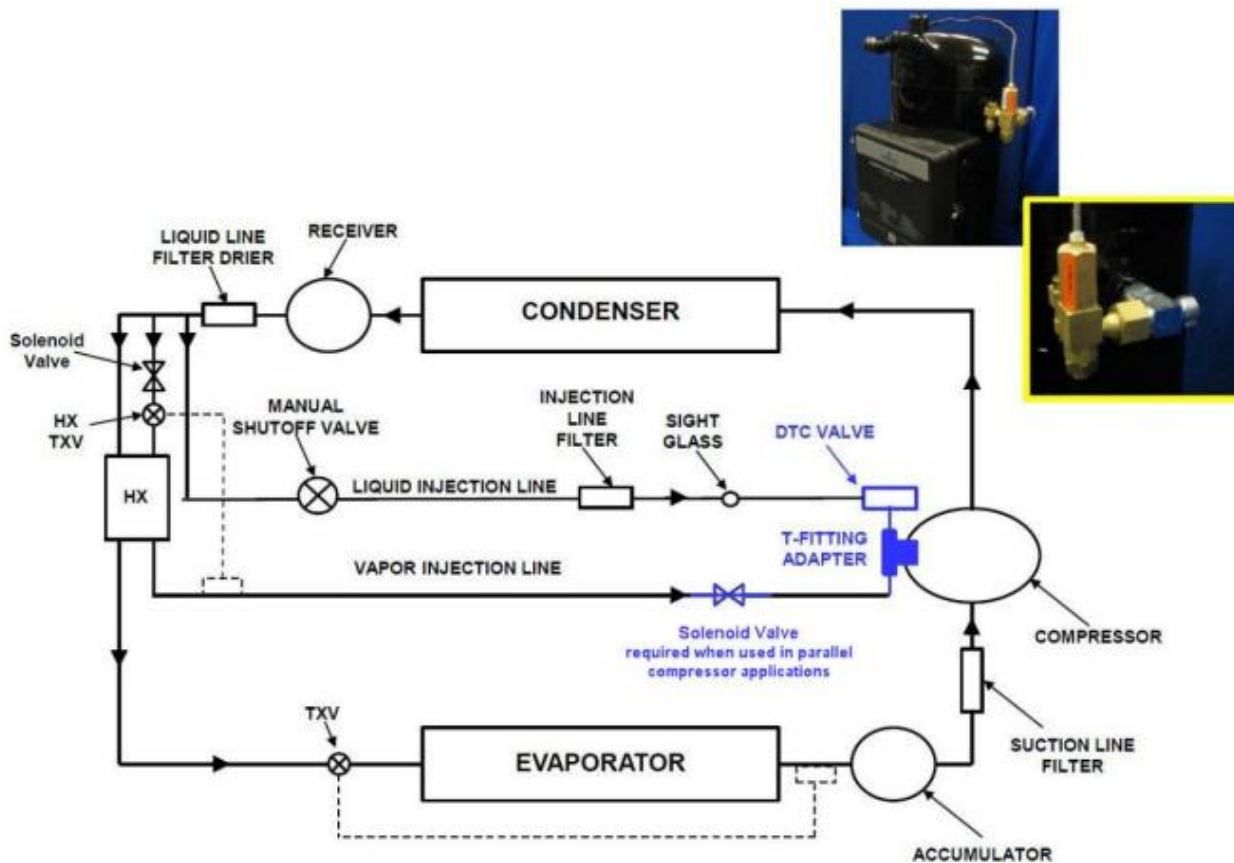


Figure 5 - Typical Single Compressor System Schematic with Wet Injection

A 20 second controller cycle is the base of modulation: In any 20 second cycle, if the loaded time is 10 seconds and the unloaded time is 10 seconds, the average capacity is 50%, or if the loaded time is 6 seconds and the unloaded time is 14 seconds the capacity during that 20 second period is 30%.

The digital solenoid can be controlled by:

1. XC-643, Copeland Closed Loop Digital Controller, for managing one Copeland™ digital compressor. Refer to AE8-1386.
2. IDCM: Digital module Digital Compressor Controller, part number 943-0086-00 or 943-0024-00 for rack applications. Refer to AE8-1328.

Low Temp Digital Compressor Operation

Due to lower mass flows, low temperature digital compressor operation is restricted to 30%-100%. By restricting to 30% minimum capacity this ensures enough mass flow to the compressor for safe operation.

Wet Injection required on ZF*KVE Envelope.

EVI compressors are compatible with liquid and vapor injection. This mechanism avoids high internal discharge temperatures that exceed the safe temperature limit for long term stability of refrigeration oil. These systems are mandatory for application inside the shaded area detailed inside envelopes in Figure 19 and Figure 22.

NOTICE

ZF*KVE are designed for optimized performance using wet or vapor injection. Running liquid injection only is not recommended.

Wet Injection is the combination of vapor and liquid injection, and is available by two mechanisms:

1. Copeland Scroll Demand Cooling. This system is being obsoleted and replaced with DTC. See **Appendix A: Service Section: Copeland Scroll Demand Cooling** for ZF*KVE Model for more details on Demand Cooling operation. For legacy systems, check with your local distributor for inventory.
2. DTC Valve

DTC Valve Liquid Injection for ZF*KVE compressors.

The objective of the DTC Valve is the same as the Demand Cooling System which it replaced: to avoid high internal discharge temperatures in the compressor. Furthermore, the DTC valve eliminates the need for additional capillary tubes and electronics controls.

Figure 5 shows details about DTC system

DTC Installation

The valve bulb must be installed in the top cap thermal well to adequately control scroll temperatures. The valve should be tightened on the injection fitting to a torque of 216-245 in-lbs. (24.4 - 27.7 Nm). A 90° orientation on the valve is recommended, however it will function properly in any orientation. The capillary tube connecting the valve to the bulb should be positioned such that it does not contact the compressor during operation. Do not bend the capillary tube within 1" (25.4mm) of the valve.

The DTC Valve comes with an insulating cap. If this additional height from the cap is an issue, the valve cap could be replaced with high temperature insulation. This should be applied to insulate and protect the valves remote bulb assembly. This will reduce the total height requirement by 0.5" (12.7mm).

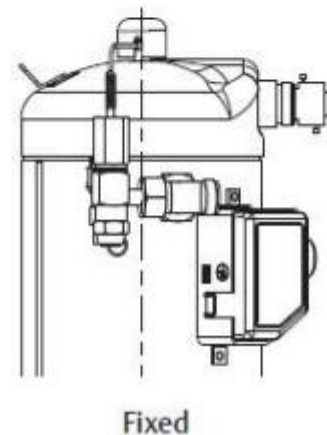


Figure 6 - DTC valve position in EVI Compressors

See **Figure 6** for more details about DTC position and **Figure 7** for a detail of parts required.

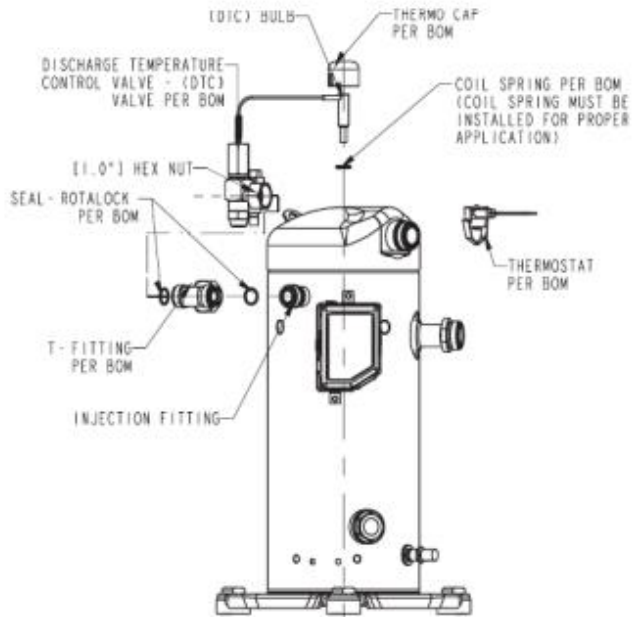


Figure 7 - DTC valve assembly, explosion

Suggested Application Techniques for DTC

For the most efficient thermal sensing, spread a thin film of thermal grease around the DTC Valve bulb before installing into the top cap well. However, for proper functioning of the valve, this is not required.

At your discretion, field serviceability can be improved by installing a shut-off valve in the liquid line just before the DTC Valve.

The DTC valve requires a solid column of liquid. A liquid line sight glass could be applied to visually verify liquid flow.

Compressor Or DTC Service

Replacing a ZF compressor using capillary tube, liquid injection solenoid, and current sensing relay:

The ZF compressor and DTC Valve eliminates the need for the solenoid and current sensing relay. These devices may be left on if desired, but they are not required.

Replacing a ZF compressor using the DTC Valve:

We recommend replacing both the DTC Valve and the compressor at the same time. If you wish to use the

existing DTC Valve, the valve filter (PN# 013-0119-00) should be cleaned and/or replaced.

Replacing a capillary tube on a ZF compressor:

The DTC Valve is not backward compatible on compressors with no thermal well in the top cap.

Replacement capillary tubes will be available through our **Authorized Copeland Wholesaler**.

Replacing a DTC Valve on a ZF compressors:

Before replacing the DTC Valve, clean and/or change the filter to verify there is an unobstructed column of liquid to the valve.

You will find more details about DTC kit Parts lists in **Table 3**.

Table 3 - DTC valve Kit# 998-1000-52 (only used on ZF13KVE-T, ZF18KVE-T, ZF25KVE-T, ZF28KVE-T models)

DTC Kit# 998-1000-52 Spare Parts detail		
Description	QTY	Part Number
Spring-Coil for Thermistor	1	006-0542-00
	1	
Thermal Grease	1	093-0044-00
Seal Rotalock Fitting	2	020-0028-00
Thermostat	1	085-7022-15
	1	085-7022-16
Instruction Form	1	FM2021ECT-2
T- Fitting kit	1	998-0177-00
DTC-Valve	1	510-0994-00

ZF(D)*K5E-XXX Compressors Models

For larger capacity compressors with EVI, Copeland offers the ZF(D)*K5E-XXX family. ZF*K5E compressors are provided with an injection port that can be used for either liquid or vapor injection. See **AE4-1383** Bulletin for more details about capacities and performance.

Discharge Temperature Protection with CoreSense™ Diagnostics for K5 Compressors

Copeland Scroll K5 compressors for refrigeration with CoreSense Diagnostics come standard with discharge temperature protection. Depending on the application and refrigerant, a certain mode of protection will be used whether it is a top cap thermistor, Discharge Temperature Control (DTC) valve with discharge line thermistor or an EXV valve with a top cap thermistor. The CoreSense module identifies the protection device based on the pin locations in the connector. Refer to Application Engineering Bulletin **AE4-1383** for additional information.

Wet injection for ZF*K5E compressors.

Wet injection in ZF*K5E compressors is achieved by DTC (Discharge Temperature Control) valve or an EXV (Electronic Expansion Valve). The DTC/EXV © 2019 Copeland. 14 AE4-1327 R14 valve is approved for all refrigerants in this product range. A DTC/EXV valve must also be used for ZF**K5E applications with R-407A, R-407C, R407F, R-448A and R-449A with vapor injection via a special T-fitting adapter. Further details and part numbers related to the DTC/EXV valve are listed in See **AE4-1383** Bulletin for detailed information about liquid injection in ZF*K5E compressors.

Thermostatic Expansion Valve (TXV) & Heat Exchanger

In order to properly use an Enhanced Vapor Injection compressor, a thermostatic expansion valve (TXV) and heat exchanger are needed in the system. Copeland provides a kit that has these components properly sized for the ZF13,18, 25 and 28KVE single compressor applications, see Table 4. For multiple compressor applications, the subcooling components may be designed

using the subcooling load and pressure and temperature data provided by the EVI calculator program.

System Configuration

There are two methods of controlling refrigerant flow at the heat exchanger - downstream and upstream extraction.

Downstream Extraction

The downstream extraction is the preferred method employed in the United States. In downstream extraction, the TXV is placed between the liquid outlet and vapor inlet of the heat exchanger. The advantage of downstream extraction is that subcooling is ensured because the liquid is further subcooled as it flows through the heat exchanger. Therefore, more subcooled liquid enters the TXV which increases the probability that the valve will not hunt the disadvantage with this method is that it is not as efficient as the upstream method; however, the difference is too small for practical purposes Figure 8.

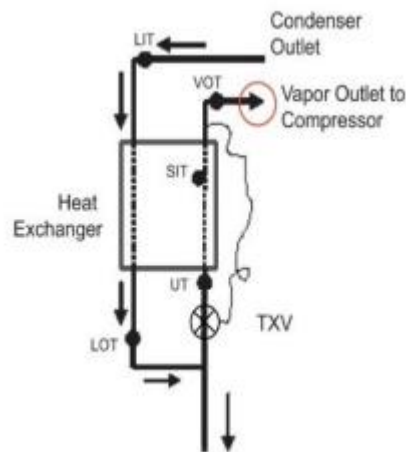


Figure 8 - Downstream Extraction

Upstream Extraction

In upstream extraction the TXV is placed between the condenser and the heat exchanger. The TXV regulates the flow of subcooled refrigerant out of the condenser and into the heat exchanger. With this type of configuration there is a potential for flash gas which would cause the valve to hunt. See Figure 9.

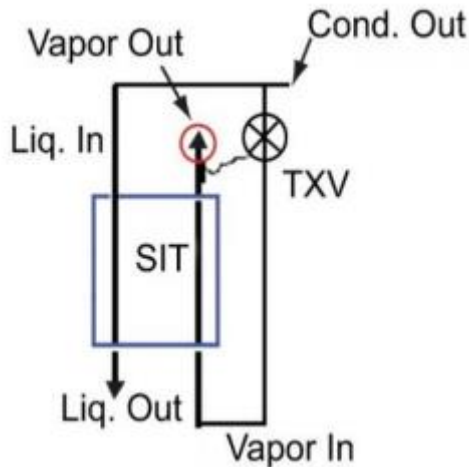


Figure 9 - Upstream Extraction

Heat Exchanger Piping Arrangements

Best subcooling effect is assured if counter flow of gas and liquid is provided as shown in Figure 10. In order to guarantee optimum heat transfer, the plate heat exchanger should be mounted vertically, and vapor should exit it at the top.

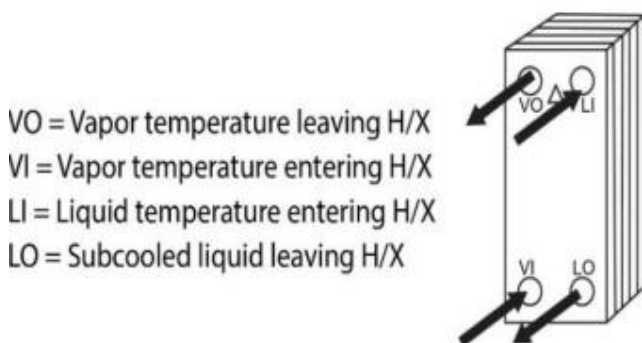


Figure 10 - H/X Piping Arrangement

System Design Guidelines:

NOTE: The following sections discuss system design guidelines for the EVI product. Please refer to the Copeland Product Selection Software, which can be found in the Online Product Information (OPI) database located at www.Copeland.com, for further information needed to accommodate your sizing needs.

Heat Exchanger Sizing

Heat exchangers should be sized so that they have adequate design margin for the entire range of system operation, but they should be optimized for normal operating conditions. The parameters used to determine the proper heat exchanger size are described below:

- SIT = Heat Exchanger saturated evaporating temperature at its outlet pressure.
- LIT = Liquid in Temp ~ Condensing Outlet
- LOT = Liquid Out Temp = SIT + TD
- VIT = Vapor In Temp ~ SIT + Loss
- VOT = Vapor Out Temp = SIT + Superheat
- H = Enthalpy
- HX Subcooling= (ΔT_{sc}) = LIT – LOT
- Superheat = TVO – TSI
- TD = LOT- SIT
- HX BTU/hr =Heat Exchanger BTU/hr Capacity

Note: See **Figure 1** for reference of the Cycle for EVI.
Example of Heat Exchanger Sizing Optimized ZF18KVE, R404A

Step 1

- Known Conditions $-25^{\circ}/105^{\circ}/0^{\circ}/65^{\circ}$ Te/Tc/Cond. SC/Suct.RG

Step 2

- Determine Flow Mo 355 lb/hr From Product Data

Step 3

- Estimate SIT from Guideline 12°

Step 4

- Use the 10° Guideline to Derive
- $LIT = TO - 10^\circ = 105^\circ - 10^\circ = 95^\circ$
- $LOT = TSI + 10^\circ = 22^\circ$
- $HX SC = \Delta T_{sc} = TLI - TLO = 73^\circ$
- From R-404A Saturation Properties-Temp. Table: ♦ $LIT = 95^\circ \rightarrow Hft = 47.0$ ♦ $LOT = 22^\circ \rightarrow Hlot = 20.1$
- $HX BTU/hr = Mo \times (Hft - Hlot) = 9550 BTU/hr = 355 \times (47.0 - 20.1)$

Example of Heat Exchanger Sizing Fixed Liquid Temperature ZF18KVE, R404A**Step 1**

- Known Conditions $-25^\circ/105^\circ/0^\circ/65^\circ$ $T_e/T_c/Cond. SC/Suct.RG'$

Step 2

- Determine Flow Mo 355 lb/hr From Product Data

Step 3

- Use the 10° Guideline To Derive
- $LIT = TO - 10^\circ = 105^\circ - 10^\circ = 95^\circ$
- LOT , User Defined = 50°
- $HX SC = \Delta T_{sc} = LIT - LOT = 45^\circ$
- From R-404A Saturation Properties-Temp. Table: ♦ $LIT = 95^\circ \rightarrow Hft = 47.0$ ♦ $LOT = 50^\circ \rightarrow Hlot = 29.7$
- $HX BTU/hr = Mo \times (Hft - Hlot) = 6140 BTU/hr = 355 \times (47.0 - 29.7)$

The key parameter in determining the proper heat exchanger is the Saturated Injection Temperature (SIT). It is imperative the previous procedure be followed for optimized performance. The SIT has been derived experimentally and can be approximated by using **Figure 11**. After determining the SIT, a 10°F Condenser Subcooling, TD, and Superheat are targeted. This is done in order to optimize system performance while at the same time maintaining system reliability and functionality. Once these parameters have been established, the heat exchanger BTU/Hr capacity can be established, which gives the required heat exchanger size.

For multiple compressor applications, the same process can be used to determine the heat exchanger size needed by adding together the individual heat exchanger capacities for each compressor.

Line Sizing

In single compressor applications, the vapor injection line from the heat exchanger to the compressor should be 3/8" - 1/2" and kept as short as possible in order to minimize pressure drop loss.

The liquid line from the heat exchanger to the evaporator should be insulated and kept as short as possible in order to maximize the subcooling at the evaporator. If a vapor injection header is used, the header diameter should be such that the cross-sectional area is equal to the sum of the cross-sectional areas of the individual cross-sectional lines to the compressor.

For example, for four compressors, each with a 3/8" vapor injection line, the header tube diameter should be a 7/8" tube. In addition, the individual injection lines to the compressors should tap into the header either on top or on the sides of the header tube; a bottom tap will increase the risk of returning liquid into the compressor through the vapor injection line.

Available Rotalock to Stub Tube Adapter Kit: 998-0034-18

Description:

1" x 14 thread size to 1/2" Stub tube Sweat

Heat Exchanger TXV Sizing

TXV's should be sized so that they have adequate design margin for the entire range of system operation, but they should be optimized for normal operating conditions. Select a TXV that is able to handle the BTU/hr capacity of the heat exchanger determined in the section above.

Solenoid Valve & Ball Valve

A solenoid valve is required to stop the flow of vapor from the system to the compressor when the compressor is in the off cycle. This must be a vapor solenoid sized equivalent to or larger than the vapor injection tube size.

For minimum orifice sizes see **Table 5**. For service purposes, a mechanical ball valve (not provided by Copeland) is also recommended in the vapor injection line.

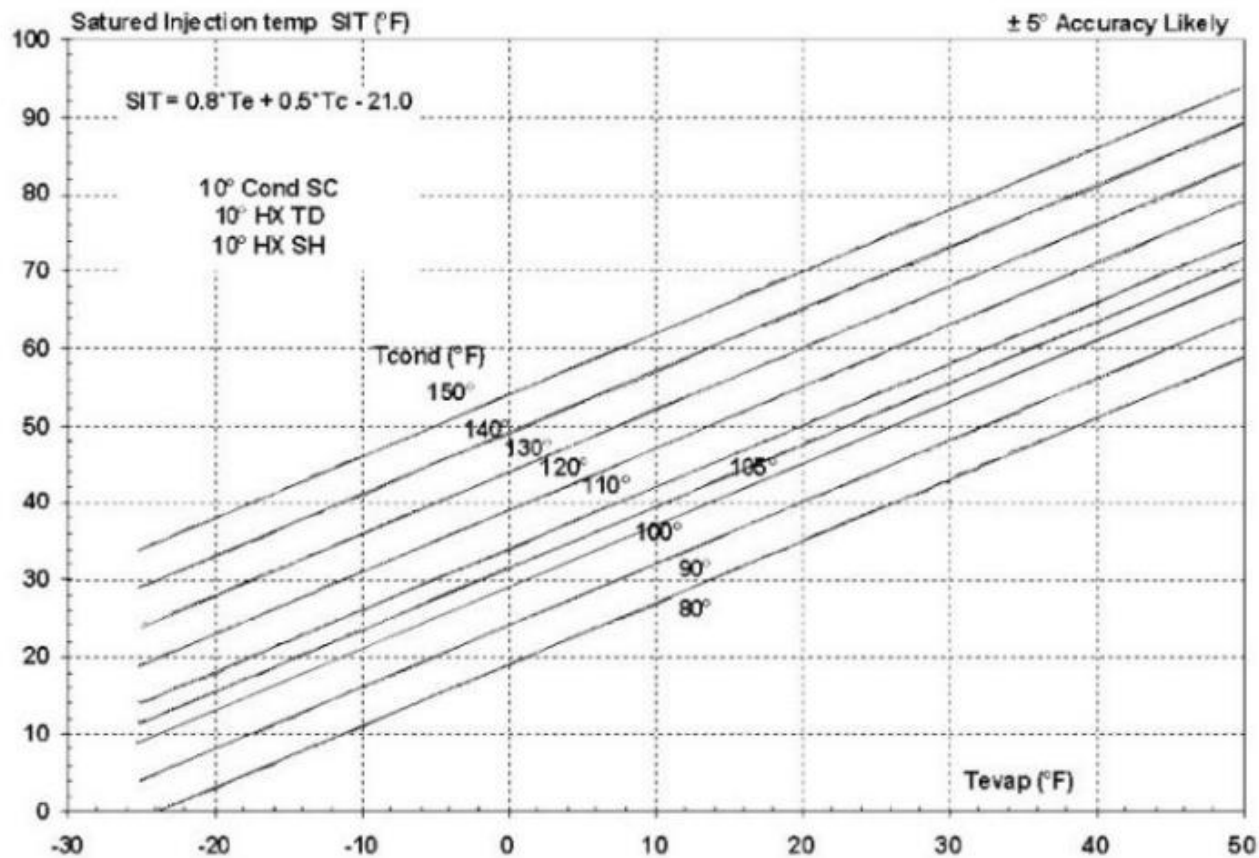


Figure 11 - Saturated Injection Temperature Graph

Model	24V	120V	240V	Kits Include
ZF13KV	985-1500-00	985-1500-01	985-1500-02	TXV, Solenoid Valve, Current Sensing Relay, Heat Exchanger
ZF18KV				
ZF24KV	N/A	N/A	N/A	
ZF25KV	985-1500-00	985-1500-01	985-1500-02	
ZF28KV				
ZF33KV	N/A	N/A	N/A	
ZF34K5				
ZF40KV				
ZF41K5				
ZF48KV				
ZF49K5				
ZF54K5				

Table 4 - Current Sensing Relay Kit

Model	Minimum Orifice Size	Flow Control Valve Series
ZF13KV	3/16"	200RB 3
ZF18KV		
ZF24KV	1/4"	200RB 4
ZF25KV		
ZF28KV		
ZF33KV		
ZF34K5		
ZF40KV	5/16"	200RB 5
ZF41K5		
ZF48KV		
ZF49K5		
ZF54K5	200RB 5	200RB 6

Table 5 - Vapor Injection Solenoid Orifice Size

Current Sensing Relay

To prevent the solenoid from remaining open during a 'motor protector trip' a current sensing relay must be provided that senses whenever the compressor is 'OFF' and closes the solenoid to stop injection. See Table 4 for a kit with the correct current sensing relay.

Multiple Compressor Applications

EVI can also be used in multiple compressor applications. Unlike a standard compressor system, the EVI compressor system changes its delivered capacity by changing the amount of sub-cooling provided at the subcooling heat exchanger. The result is that in high ambient temperature conditions (summer operation) and in low ambient temperature conditions (winter operation), the same number of compressors tend to run. It is important to note this since most personnel are used to seeing fewer compressors in operation in the cooler winter months compared to the hotter summer months; with EVI, almost the same number of compressors will be running in the summer and winter.

Multiple EVI compressors can be used with either a single heat exchanger for each compressor or a common heat exchanger for all compressors. In case of a common heat exchanger, a solenoid valve should be installed on each individual vapor injection line.

Special care has to be given to the design of the heat exchanger and of the thermostatic expansion valve (TXV) to allow for part load operation. Good refrigerant distribution is required in the common heat exchanger as well as sufficient velocities for oil return, even at part load.

In the case of a large range of capacity modulation (more than 2 compressors in parallel), the use of an Electronic Expansion Valve (EXV) or of two different TXV(s) controlled by individual solenoid valves, may improve performance. For example, one at 100% full load and the second solenoid valve for 30% of full load. (See **Figure 12** and **Figure 13**).

It is necessary to ensure that the solenoid valves, vapor injection lines and header(s) are adequately sized in order to keep pressure drop to a minimum. At the same time, the layout should be such that excessive amounts of oil do not accumulate in the header.

Controlling Liquid Out Temperature

The Liquid Out Temperatures (LOT) will typically be determined by the operating condition of the compressor. If the LOT needs to be fixed at any specific value (for example, 50°F) for purposes of good system control, an Evaporator Pressure Regulator (EPR) valve may be introduced at the vapor outlet of the subcooling heat exchanger.

Table 6 shows approximate EPR settings for different liquid temperature.

Copeland Product Selection Software can be used to determine the effect of fixing LOT on the capacity and efficiency of the compressor. See Figure 14 and Figure 15.

General Guidelines and More Information

For general Copeland Scroll compressor please log in to Online Product Information at Copeland.com/OPI, refer to the Application Engineering bulletins listed below, or contact your Application Engineer.

AE-1383	Application Guidelines for ZF*K5E & ZB*K5E Copeland Scroll™ K5 Compressors for Refrigeration 8-17 HP with CoreSense™ Diagnostics
AE-1299	Application Guidelines for K4 Refrigeration Copeland Scroll™ Compressors 2 - 9 Horsepower
AE-1328	Copeland™ Digital Compressor Controller

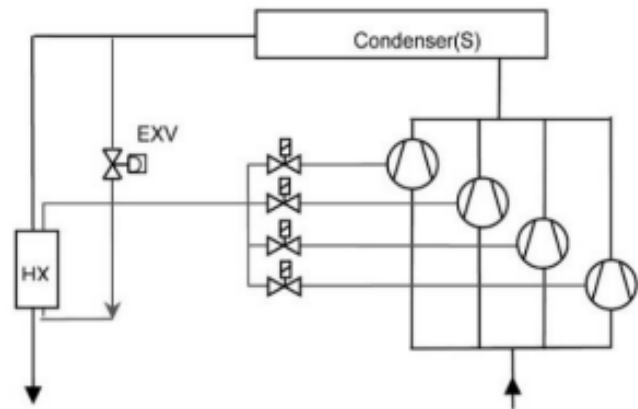


Figure 12 - EVI Paralleling with HW Thermostatic Valves of Different Capacity

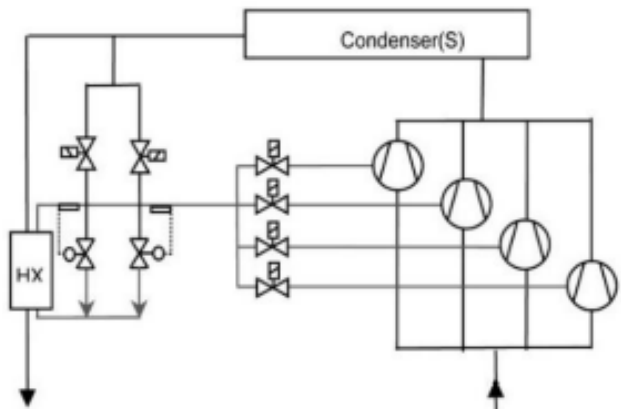


Figure 13 - EVI Paralleling with HW Electronic Expansion Valve (EXV)

Table 6 - Approximate EPR Settings

	R-407A/C/F, R-448A and R-449A (Based on Dew Point Properties)	R-404A (Based on Dew Point Properties)
Subcooler Liquid Out Temperature, °F	Approximate EPR Setting, psig (psia)	
60	86.1 (100.8)	103.6 (118.3)
50	69.4 (84.1)	85.4 (100.1)
40	54.8 (69.5)	69.3 (84.0)

NOTE: Assumes a 10°F DT across EVI Heat Exchanger

The screenshot displays the 'ZF18KVE-TFD' software interface. On the left, under 'Inputs', the 'Economizer Settings' dropdown is set to 'Automatic'. Below this, various temperature and pressure values are listed. A blue box highlights the 'Economizer Subcooling (°F)' value of 68.4, with an arrow pointing to a text box that reads 'Maximum Sub-cooling Obtained'. Another blue box points to the 'Automatic' dropdown with the text 'Economizer Settings Defaults To "Automatic" For Maximum Sub-cooling'. On the right, the 'Results' section shows various performance metrics. At the bottom, there are buttons for 'Report', 'Calculate', 'Reset', and 'Close'.

Inputs		Results	
ZF18KVE-TFD 460 V, 60Hz, 3 Ph, R-404A Low Temp, Economized		Compressor Capacity (Btu/hr):	26,000
Economizer Settings: Automatic		Net Refrigerant Effect (Btu/hr):	22,300
Condensing Temperature (°F):	105.0	Power (kW):	5,000
Evaporator Temperature (°F):	-25.0	Compressor EER (Btu/kWh):	5.60
Return Gas Temperature (°F):	85.0	Evaporator EER (Btu/kWh):	4.46
Evaporator Superheat (°F):	10.0	Refrigerant Flow Rate (lb/hr):	349.0
Compressor Superheat (°F):	90.0	Current (Amps):	7.5
Total Subcooling (°F):	0.0	Isentropic Efficiency (%):	87.8
Economizer Subcooling (°F):	68.4	Liquid Temp. (°F):	36.6
Economizer Superheat (°F):	10.0	Economizer Load (Btu/hr):	8,605
Economizer ΔT (°F):	10.0	Injection Pressure (psig):	66.3
		Injection Mass Flow (lb/hr):	185.3
		Sat. Injection Temp. (°F):	26.6
		Economizer Pressure (psig):	66.3
		Sat. Economizer Temp. (°F):	26.6
		Discharge Temp. (°F):	NA

Figure 14 - Screenshot of Copeland Product Selection Software Showing the Maximum Subcooling Obtained When the Default 'Automatic' is Selected for Economizer Settings

Economizer Settings Is Set To "Constant Liquid Temp." For Fixing Liquid Out Temperature (LOT)

Liquid Temperature Is Fixed At Input Value

ZF16KVE-TFD
460 V, 60Hz, 3 Ph, R-404A
Low Temp, Economized

Inputs

Economizer Settings: **Constant Liquid Temp.**

Condensing Temperature (°F): 105.0
Evaporator Temperature (°F): -25.0
Return Gas Temperature (°F): 65.0
Evaporator Superheat (°F): 10.0
Compressor Superheat (°F): 90.0
Total Subcooling (°F): 0.0
Liquid Temp. (°F): 50
Economizer Superheat (°F): 10.0
Economizer ΔT (°F): 10.0

Note: For Air-Conditioning Compressor Models the Return Gas Temp. is limited to 75°F (23.8°C) whereas for Refrigeration Compressors the Return Gas Temp. is limited to 65°F (18.3°C).

Results

Compressor Capacity (Btu/hr): 26,500
Net Refrigerant Effect (Btu/hr): 20,800
Power (W): 4,870
Compressor EER (Btu/W-hr): 5.40
Evaporator EER (Btu/W-hr): 4.27
Refrigerant Flow Rate (lb/hr): 349.0
Current (Amps): 7.3
Isentropic Efficiency (%): 87.1
Liquid Temp. (°F): 50

Economizer Load (Btu/hr): 7,026
Injection Pressure (psig): 66.3
Injection Mass Flow (lb/hr): 146
Sat. Injection Temp. (°F): 26.6
Economizer Pressure (psig): 87.6
Sat. Economizer Temp. (°F): 40.00
Discharge Temp. (°F): NA

Envelope Report Calculate Reset Close

Figure 15 - Screenshot of the Product Selection Software Showing the Constant Liquid Temperature at Outset of the Subcooling Heat Exchanger

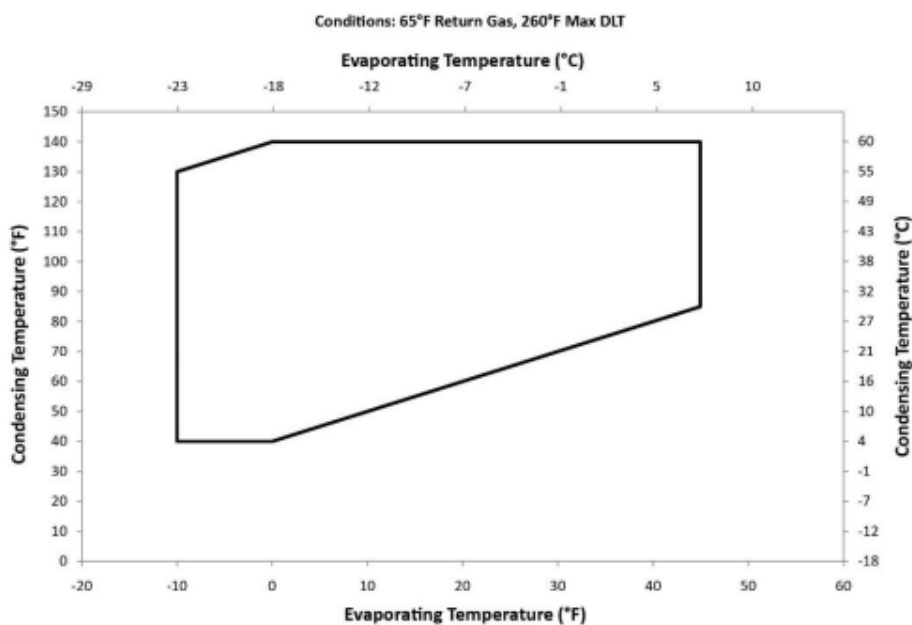


Figure 16 - Medium Temperature ZF**KVE Envelope (R-404A/R-507)

* For ZF25KVE and ZF28KVE operating envelope see Figure 20

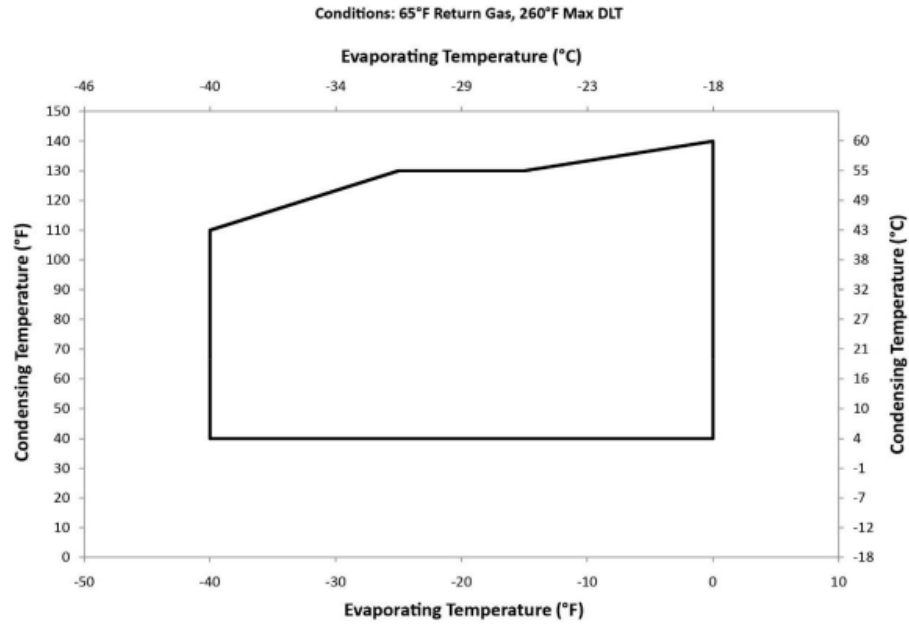


Figure 17 - Low Temperature ZF**KVE and ZF**K5E Envelope (R-404A/R-507)

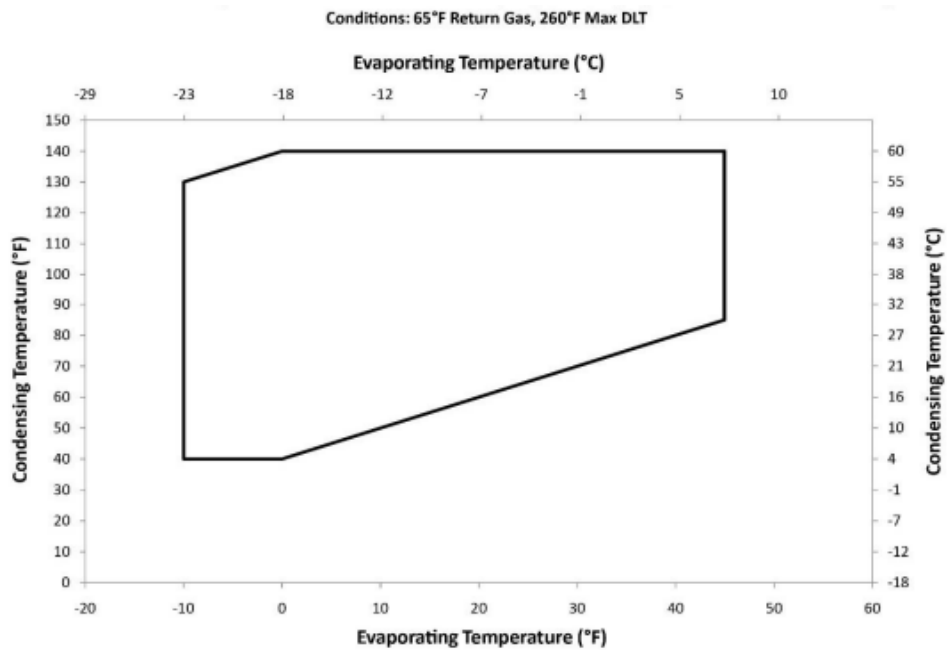


Figure 18 - Medium Temperature ZF**KVE Envelope (R-407A/C/F, R-448A and R-449A)

* For ZF25KVE and ZF28KVE see Figure 20 for operating envelope.

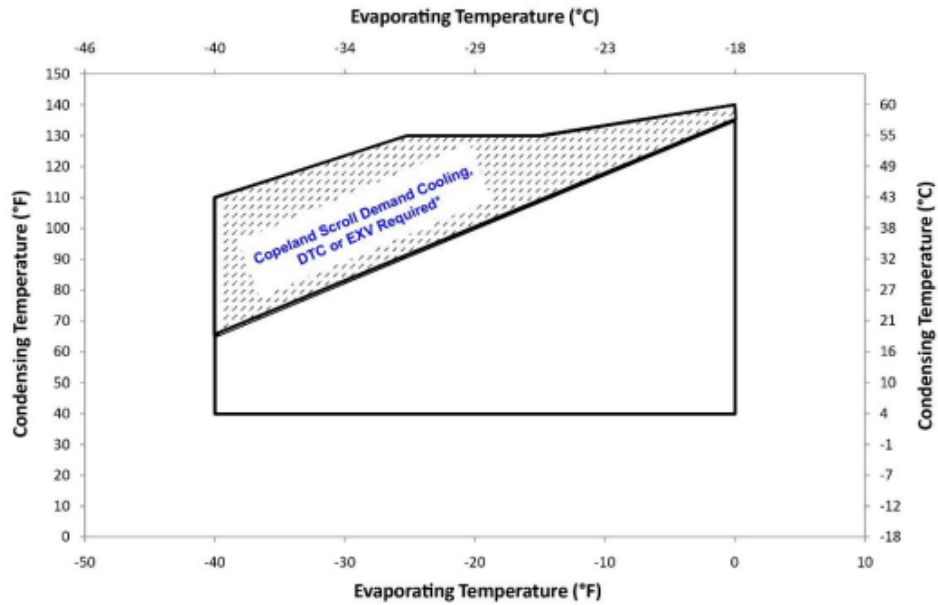


Figure 19 - Low Temperature ZF**KVE Envelope (R-407A/C/F, R-448A and R-449A)
Condition: 65°F Return Gas, 260°F Max DLT

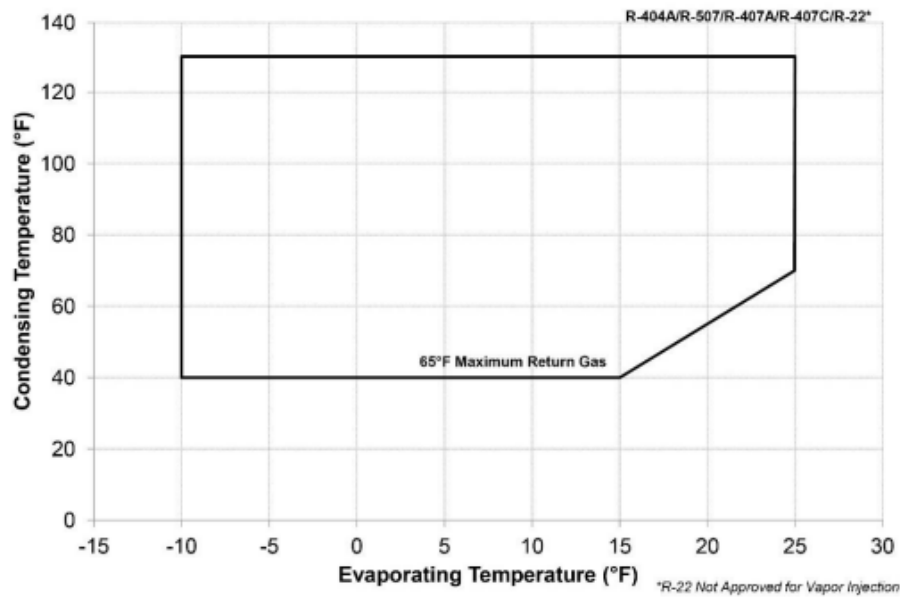


Figure 20 - ZF*K5E (Excluding ZF49K5E), ZF25KVE
Medium Temperature Operating Map with and without Vapor injection

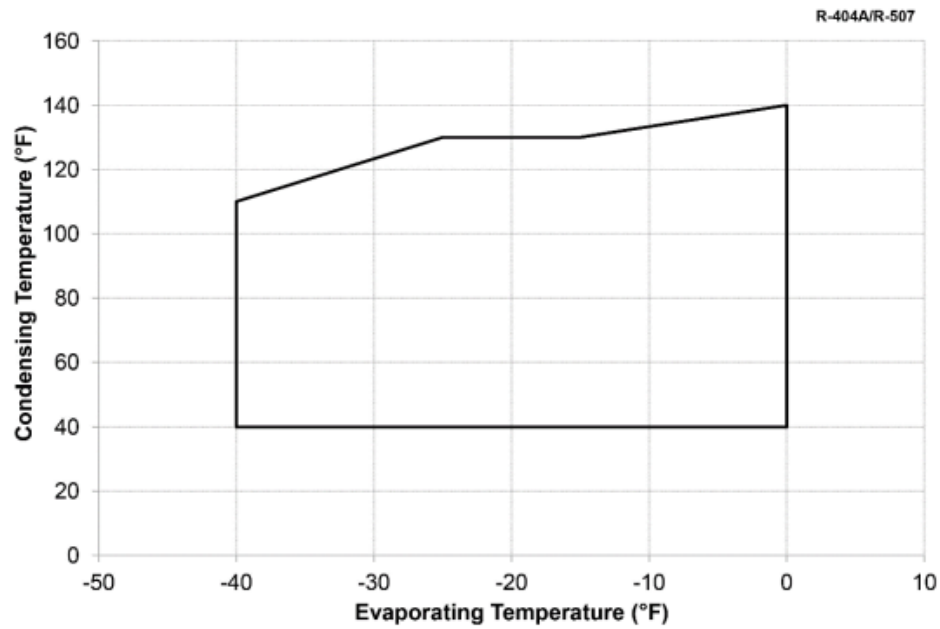


Figure 21 - ZF*K5E Low Temperature Vapor Injection Operating Map
(65°F Return Gas)

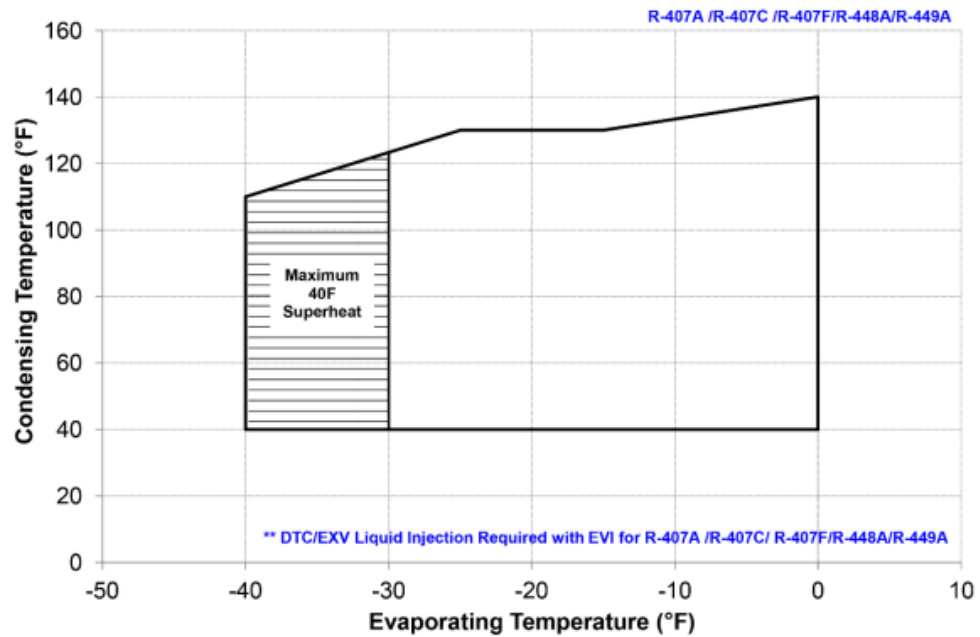


Figure 22 - Low Temperature Vapor Injection** Operation Map
(65°F Return Gas)

Appendix A: Service Section: Copeland Scroll Demand Cooling for ZF*KVE Mode

Introduction

The Demand Cooling for Scroll Compressors is obsolete and being replaced with a DTC valve. Please check your local distributor for inventory.

This Demand Cooling section is included only for service purposes.

Demand Cooling uses electronics to provide a reliable cost-effective solution to high internal discharge temperatures encountered in low temperature applications using R-407A/C/F or R448A & R449A. Demand Cooling had traditionally been applied to the Copeland Discus™ product line to control high internal discharge temperatures that exceed the safe temperature limit for long term stability of refrigeration oil. Copeland approved the use of Demand Cooling for the Copeland Scroll Economized Vapor Injection (EVI) product line using low temperature R-407A/C/F, R-448A or R-449A. The integration of Demand Cooling with EVI scroll creates a 'wet-injection' approach to discharge temperature control. Copeland approved the following EVI scrolls for use in low temperature applications with Demand Cooling:

ZF(D)13KVE	ZF(D)18KVE
ZF(D)25KVE	ZF28KVE
ZF33KVE	ZF24KVE
ZF40KVE	

The Demand Cooling module uses the signal of a discharge line temperature sensor to monitor discharge gas temperature. If a critical temperature is reached, the module energizes a long life injection valve which meters a controlled amount of saturated refrigerant into the vapor injection line. The injection will continue until the discharge line temperature reaches a lower preset temperature. This process controls the discharge temperature to a safe level. If, for some reason, the discharge temperature rises above a preset maximum level, the Demand Cooling module will turn the compressor off (requiring a manual reset) and actuate its alarm contact.

The injection valve orifice has been carefully chosen to be large enough to provide the necessary cooling when

required but not so large that a dangerous amount of liquid is injected, or that excessive system pressure fluctuation occurs during injection valve cycling. It is important to use the correct valve for the EVI scroll.

Performance data for Demand Cooling compressors includes the effects of injection when it is required. The approximate conditions where injection occurs are shown in **Figure 19** for R-407A/C/F, R-407F, R-448A or R-449A. At the conditions where Demand Cooling is operating, the performance values are time averages of the instantaneous values, since small fluctuations occur as the Demand Cooling injection valve cycles.

The Demand Cooling system addresses the capacity and efficiency issues by limiting injection to those times when it is required to control discharge temperatures to safe levels. For most applications, this will only be during periods of high condensing temperatures, high return gas temperatures, or abnormally low suction pressure. The Demand Cooling system has been designed to meet the same high reliability standards as Scroll compressors.

Demand Cooling™ System Design for Low Temp. Compressors Models (Obsolete and replaced with DTC or EXV injection)

When Demand Cooling operates, it "diverts" refrigeration capacity in the form of injected saturated refrigerant from the vapor injection circuit to the compressor (See Figure 23 or a typical single system schematic). Demand Cooling injects a small amount of liquid to the vapor injection stream to cool the discharge. This does not affect the mass flow significantly. However, when the valve injects the system will lose some capacity because the EVI pressure increases and thus decreases EVI performance.

Note! A separate Demand Cooling kit is required for each compressor.

The Demand cooling temperature sensor should be located close to the compressor to ensure an accurate discharge temperature reading. The optimal location is

between 5 and 7 inches from the compressor on the discharge line (Figure 23).

The injection valve should be installed as close as possible to the compressor vapor injection inlet, no more than **3 feet**. The line **MUST** be well insulated. If there is substantial heat gain along the vapor injection line, injection may result in a substantial loss in vapor injection capacity during Demand Cooling operation. In order to minimize this loss, good practice indicates Demand Cooling operation be kept to a minimum through proper system design and installation practices. There are three areas which can be addressed to minimize the impact of Demand Cooling operation on performance:

1. **Compressor Return Gas Temperature:** Suction lines should be well insulated to reduce suction line heat gain. Return gas superheat should be as low as possible consistent with safe compressor operation.
2. **Condensing Temperatures:** It is important when using R-407A/C/F, R-448A or R-449A as a low temperature refrigerant that condensing temperatures be minimized to reduce compression ratios and compressor discharge temperature.
3. **Suction pressure:** Evaporator design and system control settings should provide the maximum suction pressure consistent with the application in order to have as low a compression ratio as possible.

Demand Cooling with Copeland™ Digital Compressor Controller

In order to control a ZFD*KVE Copeland Scroll Digital™ compressor (not required on ZFD*K5E models), the Copeland Digital Compressor Controller (IDCM, P/N 943-0086-00) may be used in multiple compressor applications. This digital compressor controller has its own discharge temperature protection. However, for applications using Demand Cooling, the Demand Cooling module should have primary control of the temperature protection. **To ensure the Demand Cooling system functions appropriately, jumper the T1 and T2 inputs on the Copeland Digital Compressor Controller, with a 5kOhm, 1 Watt resistor.** See Figure 25 for more detail.

For more details about IDCM refer to **AE-1328** Bulletin.

Demand Cooling System Components

The Demand Cooling system consists of: the discharge line temperature sensor, the Demand Cooling module, and the injection valve solenoid.

Demand Cooling Specifications

Demand Cooling is designed to operate and protect the compressor within the evaporating and condensing envelope identified in **Figure 19**. Operating set-points and control actions are listed in **Table 7**

Demand Cooling Wiring Schematic

Figure 24 shows a recommended wiring schematic for the Demand Cooling assembly.

The normally closed (NC) contact of the alarm relay (L-M) should be wired in the compressor contactor control circuit so that opening this contact removes the compressor from the line and removes power to the CM.

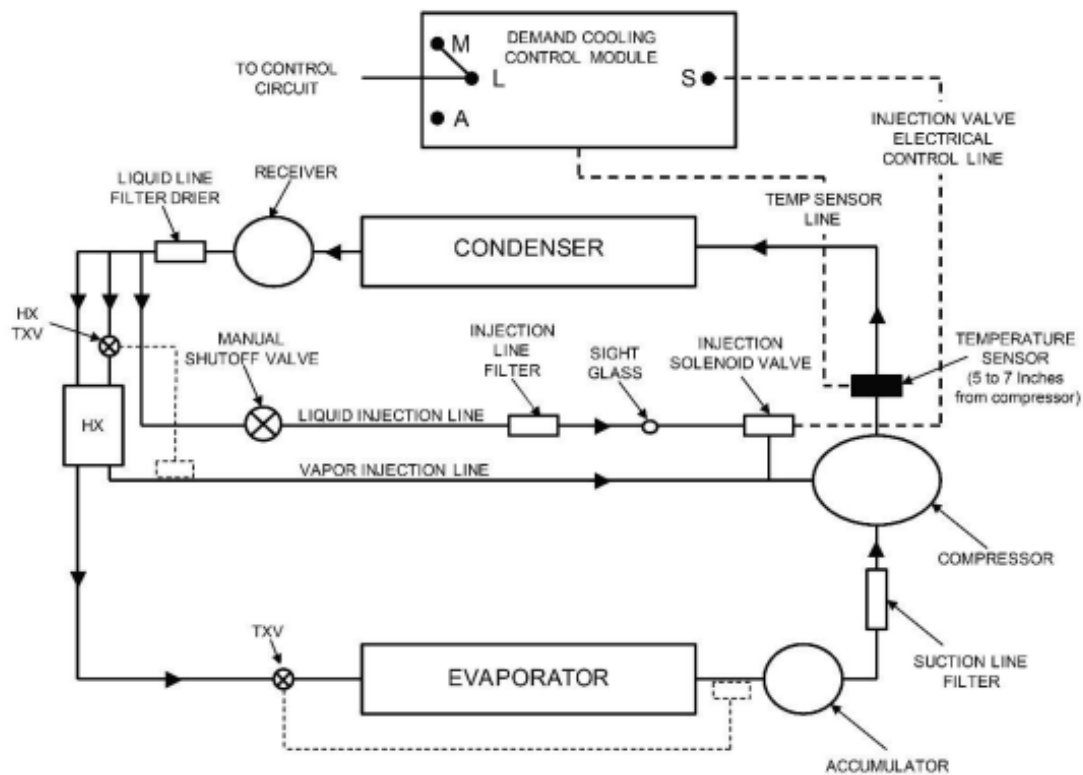


Figure 23 - Typical Single Compressor System Schematic with obsolete Demand Cooling System
(only for service purposes)

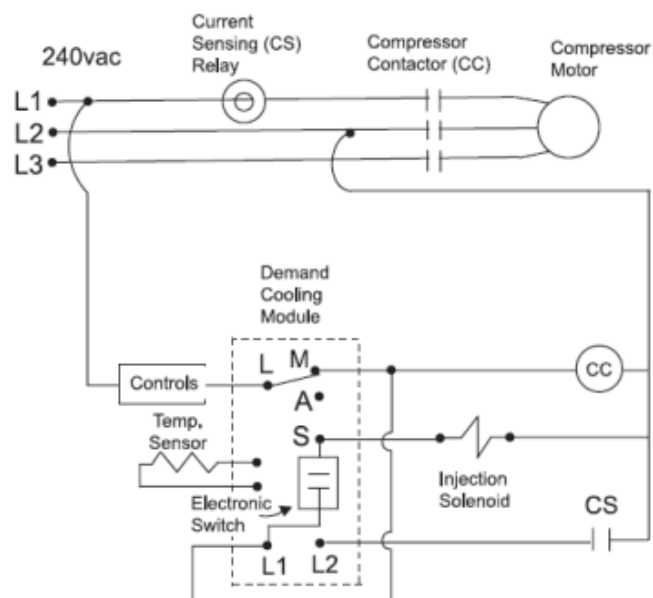


Figure 24 - Demand Cooling Module Wiring Diagram
(Obsolete, only for service purpose)

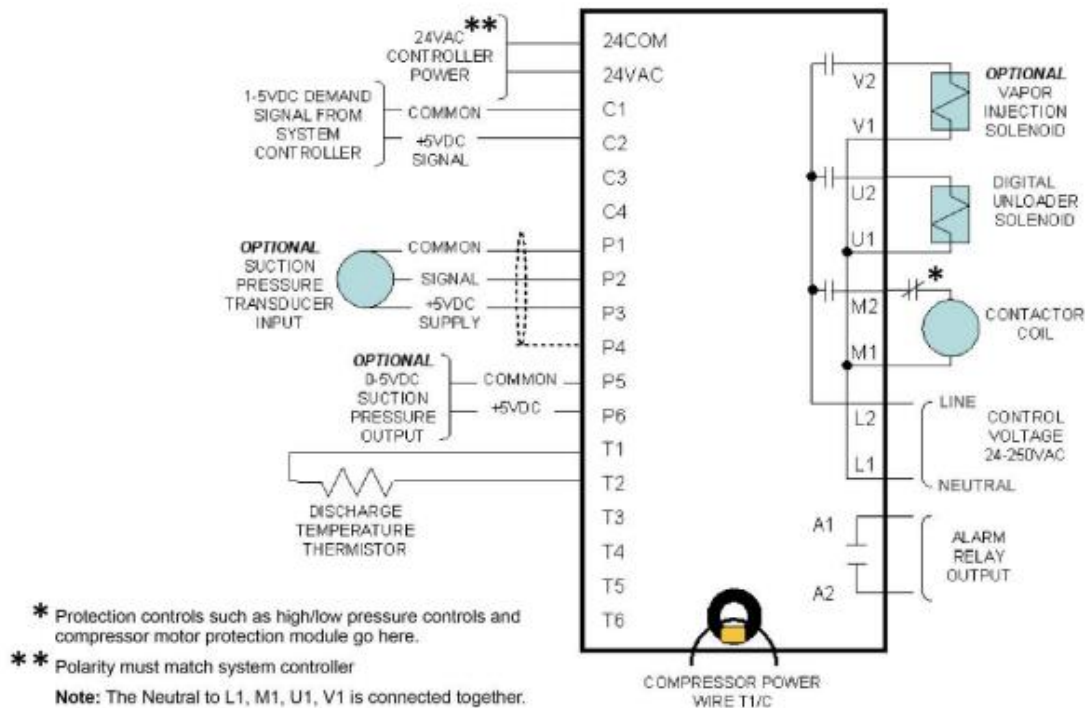


Figure 25 - IDCM: Digital module Digital Compressor Controller Wiring Diagram

Note: IDCM doesn't require any connection to DTC components.

Table 7 - Demand Cooling Operating Setpoints and Control Actions

Discharge Line Temperature	Demand Cooling Module Operation	Approximate Sensor Resistance
Rising Through 258°F	Demand Cooling Solenoid ON	3,820
Falling Through 237°F	Demand Cooling Solenoid OFF	5,000
Rising Through 286°F	Alarm Contact Energized	2,620
At Room Temp (77°F) D	Demand Cooling Solenoid OFF	86,000 (when compressor has cooled)

Note: Demand Cooling for Scroll is obsolete. Table for Reference and for service only

Appendix B: Temperature resistance values for sensor kit part number 998-0166-00

Temp. Coefficient °C											
Temp	Ratio	Temp	Ratio	Temp	Ratio	Temp	Ratio	Temp	Ratio	Temp	Ratio
-40°C	33.6	-1°C	3.4367	38°C	0.5774	77°C	0.1385	116°C	0.04372	155°C	0.0162
-39°C	31.449	0°C	3.2654	39°C	0.5546	78°C	0.134	117°C	0.04248	156°C	0.01584
-38°C	29.452	1°C	3.103	40°C	0.5327	79°C	0.1297	118°C	0.04128	157°C	0.01549
-37°C	27.597	2°C	2.9498	41°C	0.5117	80°C	0.1255	119°C	0.04012	158°C	0.01515
-36°C	25.873	3°C	2.8052	42°C	0.4918	81°C	0.1215	120°C	0.039	159°C	0.01482
-35°C	24.27	4°C	2.6686	43°C	0.4727	82°C	0.1177	121°C	0.03793	160°C	0.0145
-34°C	22.761	5°C	2.5396	44°C	0.4544	83°C	0.114	122°C	0.0369	161°C	0.01418
-33°C	21.357	6°C	2.4171	45°C	0.437	84°C	0.1104	123°C	0.0359	162°C	0.01388
-32°C	20.051	7°C	2.3013	46°C	0.4203	85°C	0.107	124°C	0.03494	163°C	0.01358
-31°C	18.834	8°C	2.1918	47°C	0.4042	86°C	0.1037	125°C	0.034	164°C	0.01328
-30°C	17.7	9°C	2.0883	48°C	0.3889	87°C	0.1005	126°C	0.03315	165°C	0.013
-29°C	16.6342	10°C	1.9903	49°C	0.3743	88°C	0.0974	127°C	0.03233	166°C	0.01275
-28°C	15.6404	11°C	1.8972	50°C	0.3603	89°C	0.0944	128°C	0.03153	167°C	0.0125
-27°C	14.7134	12°C	1.809	51°C	0.3469	90°C	0.0915	129°C	0.03075	168°C	0.01226
-26°C	13.8482	13°C	1.7255	52°C	0.334	91°C	0.08885	130°C	0.03	169°C	0.01203
-25°C	13.0402	14°C	1.6464	53°C	0.3217	92°C	0.0861	131°C	0.02926	170°C	0.0118
-24°C	12.2807	15°C	1.5714	54°C	0.3099	93°C	0.08355	132°C	0.02854	171°C	0.01157
-23°C	11.571	16°C	1.5	55°C	0.2986	94°C	0.08108	133°C	0.02784	172°C	0.01134
-22°C	10.9075	17°C	1.4323	56°C	0.2878	95°C	0.0787	134°C	0.02716	173°C	0.01112
-21°C	10.2868	18°C	1.3681	57°C	0.2774	96°C	0.07641	135°C	0.0265	174°C	0.01091
-20°C	9.706	19°C	1.3071	58°C	0.2675	97°C	0.0742	136°C	0.02586	175°C	0.017
-19°C	9.1588	20°C	1.2493	59°C	0.2579	98°C	0.07206	137°C	0.02525	176°C	0.01049
-18°C	8.6463	21°C	1.1942	60°C	0.2488	99°C	0.07	138°C	0.02465	177°C	0.01029
-17°C	8.1662	22°C	1.1418	61°C	0.24	100°C	0.068	139°C	0.02407	178°C	0.1009
-16°C	7.7162	23°C	1.0921	62°C	0.2315	101°C	0.06612	140°C	0.0235	179°C	0.00989
-15°C	8.294	24°C	1.0449	63°C	0.2235	102°C	0.0643	141°C	0.02295	180°C	0.0097
-14°C	6.8957	25°C	1	64°C	0.2157	103°C	0.06255	142°C	0.02242	181°C	0.00949
-13°C	6.5219	26°C	0.9571	65°C	0.2083	104°C	0.06085	143°C	0.0219	182°C	0.00928
-12°C	6.1711	27°C	0.9164	66°C	0.2011	105°C	0.0592	144°C	0.02139	183°C	0.00908
-11°C	5.8415	28°C	0.8776	67°C	0.1943	106°C	0.0576	145°C	0.0209	184°C	0.00889
-10°C	5.5319	29°C	0.8407	68°C	0.1876	107°C	0.05605	146°C	0.02039	185°C	0.0087
-9°C	5.2392	30°C	0.8056	69°C	0.1813	108°C	0.05456	147°C	0.0199	186°C	0.00853
-8°C	4.964	31°C	0.772	70°C	0.1752	109°C	0.0531	148°C	0.01942	187°C	0.00837
-7°C	4.7052	32°C	0.7401	71°C	0.1693	110°C	0.0517	149°C	0.01895	188°C	0.00821
-6°C	4.4617	33°C	0.7096	72°C	0.1637	111°C	0.05027	150°C	0.0185	189°C	0.00805
-5°C	4.2324	34°C	0.6806	73°C	0.1582	112°C	0.04889	151°C	0.01801	190°C	0.0079
-4°C	4.0153	35°C	0.653	74°C	0.153	113°C	0.04755	152°C	0.01754		
-3°C	3.8109	36°C	0.6266	75°C	0.148	114°C	0.04625	153°C	0.01708		
-2°C	3.6182	37°C	0.6014	76°C	0.1431	115°C	0.045	154°C	0.01663		

Temp. Coefficient °F											
Temp	Ratio	Temp	Ratio	Temp	Ratio	Temp	Ratio	Temp	Ratio	Temp	Ratio
-40.0 °F	33.6	30.2 °F	3.4367	100.4 °F	0.5774	170.6 °F	0.1385	240.8 °F	0.04372	311.0 °F	0.0162
-38.2 °F	31.449	32.0 °F	3.2654	102.2 °F	0.5546	172.4 °F	0.134	242.6 °F	0.04248	312.8 °F	0.01584
-36.4 °F	29.452	33.8 °F	3.103	104.0 °F	0.5327	174.2 °F	0.1297	244.4 °F	0.04128	314.6 °F	0.01549
-34.6 °F	27.597	35.6 °F	2.9498	105.8 °F	0.5117	176.0 °F	0.1255	246.2 °F	0.04012	316.4 °F	0.01515
-32.8 °F	25.873	37.4 °F	2.8052	107.6 °F	0.4918	177.8 °F	0.1215	248.0 °F	0.039	318.2 °F	0.01482
-31.0 °F	24.27	39.2 °F	2.6686	109.4 °F	0.4727	179.6 °F	0.1177	249.8 °F	0.03793	320.0 °F	0.0145
-29.2 °F	22.761	41.0 °F	2.5396	111.2 °F	0.4544	181.4 °F	0.114	251.6 °F	0.0369	321.8 °F	0.01418
-27.4 °F	21.357	42.8 °F	2.4171	113.0 °F	0.437	183.2 °F	0.1104	253.4 °F	0.0359	323.6 °F	0.01388
-25.6 °F	20.051	44.6 °F	2.3013	114.8 °F	0.4203	185.0 °F	0.107	255.2 °F	0.03494	325.4 °F	0.01358
-23.8 °F	18.834	46.4 °F	2.1918	116.6 °F	0.4042	186.8 °F	0.1037	257.0 °F	0.034	327.2 °F	0.01328
-22.0 °F	17.7	48.2 °F	2.0883	118.4 °F	0.3889	188.6 °F	0.1005	258.8 °F	0.03315	329.0 °F	0.013
-20.2 °F	16.6342	50.0 °F	1.9903	120.2 °F	0.3743	190.4 °F	0.0974	260.6 °F	0.03233	330.8 °F	0.01275
-18.4 °F	15.6404	51.8 °F	1.8972	122.0 °F	0.3603	192.2 °F	0.0944	262.4 °F	0.03153	332.6 °F	0.0125
-16.6 °F	14.7134	53.6 °F	1.809	123.8 °F	0.3469	194.0 °F	0.0915	264.2 °F	0.03075	334.4 °F	0.01226
-14.8 °F	13.8482	55.4 °F	1.7255	125.6 °F	0.334	195.8 °F	0.08885	266.0 °F	0.03	336.2 °F	0.01203
-13.0 °F	13.0402	57.2 °F	1.6464	127.4 °F	0.3217	197.6 °F	0.0861	267.8 °F	0.02926	338.0 °F	0.0118
-11.2 °F	12.2807	59.0 °F	1.5714	129.2 °F	0.3099	199.4 °F	0.08355	269.6 °F	0.02854	339.8 °F	0.01157
-9.4 °F	11.571	60.8 °F	1.5	131.0 °F	0.2986	201.2 °F	0.08108	271.4 °F	0.02784	341.6 °F	0.01134
-7.6 °F	10.9075	62.6 °F	1.4323	132.8 °F	0.2878	203.0 °F	0.0787	273.2 °F	0.02716	343.4 °F	0.01112
-5.8 °F	10.2868	64.4 °F	1.3681	134.6 °F	0.2774	204.8 °F	0.07641	275.0 °F	0.0265	345.2 °F	0.01091
-4.0 °F	9.706	66.2 °F	1.3071	136.4 °F	0.2675	206.6 °F	0.0742	276.8 °F	0.02586	347.0 °F	0.017
-2.2 °F	9.1588	68.0 °F	1.2493	138.2 °F	0.2579	208.4 °F	0.07206	278.6 °F	0.02525	348.8 °F	0.01049
-0.4 °F	8.6463	69.8 °F	1.1942	140.0 °F	0.2488	210.2 °F	0.07	280.4 °F	0.02465	350.6 °F	0.01029
1.4 °F	8.1662	71.6 °F	1.1418	141.8 °F	0.24	212.0 °F	0.068	282.2 °F	0.02407	352.4 °F	0.1009
3.2 °F	7.7162	73.4 °F	1.0921	143.6 °F	0.2315	213.8 °F	0.06612	284.0 °F	0.0235	354.2 °F	0.00989
5.0 °F	8.294	75.2 °F	1.0449	145.4 °F	0.2235	215.6 °F	0.0643	285.8 °F	0.02295	356.0 °F	0.0097
6.8 °F	6.8957	77.0 °F	1	147.2 °F	0.2157	217.4 °F	0.06255	287.6 °F	0.02242	357.8 °F	0.00949
8.6 °F	6.5219	78.8 °F	0.9571	149.0 °F	0.2083	219.2 °F	0.06085	289.4 °F	0.0219	359.6 °F	0.00928
10.4 °F	6.1711	80.6 °F	0.9164	150.8 °F	0.2011	221.0 °F	0.0592	291.2 °F	0.02139	361.4 °F	0.00908
12.2 °F	5.8415	82.4 °F	0.8776	152.6 °F	0.1943	222.8 °F	0.0576	293.0 °F	0.0209	363.2 °F	0.00889
14.0 °F	5.5319	84.2 °F	0.8407	154.4 °F	0.1876	224.6 °F	0.05605	294.8 °F	0.02039	365.0 °F	0.0087
15.8 °F	5.2392	86.0 °F	0.8056	156.2 °F	0.1813	226.4 °F	0.05456	296.6 °F	0.0199	366.8 °F	0.00853
17.6 °F	4.964	87.8 °F	0.772	158.0 °F	0.1752	228.2 °F	0.0531	298.4 °F	0.01942	368.6 °F	0.00837
19.4 °F	4.7052	89.6 °F	0.7401	159.8 °F	0.1693	230.0 °F	0.0517	300.2 °F	0.01895	370.4 °F	0.00821
21.2 °F	4.4617	91.4 °F	0.7096	161.6 °F	0.1637	231.8 °F	0.05027	302.0 °F	0.0185	372.2 °F	0.00805
23.0 °F	4.2324	93.2 °F	0.6806	163.4 °F	0.1582	233.6 °F	0.04889	303.8 °F	0.01801	374.0 °F	0.0079
24.8 °F	4.0153	95.0 °F	0.653	165.2 °F	0.153	235.4 °F	0.04755	305.6 °F	0.01754		
26.6 °F	3.8109	96.8 °F	0.6266	167.0 °F	0.148	237.2 °F	0.04625	307.4 °F	0.01708		
28.4 °F	3.6182	98.6 °F	0.6014	168.8 °F	0.1431	239.0 °F	0.045	309.2 °F	0.01663		

Revision Tracking R16 - The document format has been updated to the new Copeland format.

- All occurrences of "Emerson" have been removed.
- A note regarding A3 and R290 venting has been updated

Revision Tracking R15 Pg.3 - Updated and Revised Safety Information Sheet

Revision Tracking R14 Pg. 6 - POE warning note updated. Pg. 11 - Figure 5: Solenoid valve added recommended single compressor system schematic.

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