

# Application Engineering

## *Hot Gas Bypass Control Systems*

**BULLETIN NO:** AE-1160 R2

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## Safety

### Important Safety Information

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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.

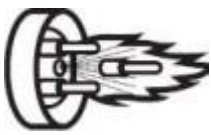
### Responsibilities, Qualifications and Training

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- 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

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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

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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](https://www.copeland.com/flammable-refrigerants) for more information on flammable refrigerant safety.

## Electrical Hazards

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

## Hot Surface and Fire Hazards

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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

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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

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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

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- 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 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

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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.

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## Introduction

### Hot Gas Bypass Control Systems

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On many refrigeration and air conditioning systems, the refrigeration load will vary over a wide range. This may be due to differences in lighting, occupancy, product loading, ambient weather variations, or other factors. In such cases compressor capacity control is a necessity for satisfactory system performance.

The simplest form of capacity control is "on-off" operation of the compressor. Under light load conditions this can result in compressor short cycling which may eventually lead to compressor failure.

On refrigeration applications where ice formation is not a problem, users frequently reduce the low-pressure cut-out setting to a point beyond the design limits of the system in order to prevent short-cycling. As a result, the compressor may operate for long periods at extremely low evaporating temperatures. Compressor capacity decreases rapidly with reduction in suction pressure, but the reduced refrigerant velocity frequently is inadequate to return oil to the compressor. Operation of the system at temperatures below those for which it was designed may also lead to overheating of the motor-compressor. Both of these conditions can cause compressor damage and ultimate failure.

If a compressor has unloaders, these may provide satisfactory capacity modulation, but frequently capacity control is required in systems without unloaders, or beyond the steps of unloading available. Unloaders are normally available only on larger compressors, they add substantially to the cost of the compressor, and they may not be suitable for low temperature operation.

### Compressor Capacity Control By Means Of Hot Gas Bypass

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Compressor capacity modulation by means of hot gas bypass is recommended where normal compressor cycling or the use of unloaders may not be satisfactory. Basically, this is a system of bypassing the condenser with compressor

discharge gas to prevent the compressor suction pressure from failing below a desired setting.

All hot gas bypass valves operate on a similar principle. They

open in response to a decrease in downstream pressure and modulate from fully open to fully closed over a given range. Introduction of the hot, high-pressure gas into the low-pressure side of the system at a metered rate prevents the compressor from lowering the suction pressure further.

The control setting of the valve can be varied over a wide range by means of an adjusting screw. Because of the reduced power consumption at lower suction pressures, the hot gas valve should be adjusted to bypass at the minimum suction pressure within the compressor's operating limits which will result in acceptable system performance.

### Continuous Operation

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If a refrigeration system is properly designed and installed, field experience indicates that maintenance may be greatly reduced if the compressor operates continuously within the system's design limitations as opposed to frequent cycling. Electrical problems are minimized, compressor lubrication is improved, and liquid refrigerant migration is avoided.

Therefore, on systems with multiple evaporators where the refrigeration load is continuous, but may vary over a wide range, hot gas bypass may not only provide a convenient means of capacity control, it may also result in more satisfactory and more economical operation.

### Bypass Into Evaporator Inlet

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On single evaporator, close connected systems, it is frequently possible to introduce the hot gas into the evaporator inlet immediately after the expansion valve. Distributors are available with side openings for hot gas inlet. Bypassing at the evaporator inlet has the effect of creating an artificial cooling load. Since the regular system thermostatic expansion valve will meter its feed as required to maintain its superheat setting, the refrigerant gas returns to the compressor at normal operating temperatures, and no motor heating problem is involved. High velocities are maintained in the evaporator, so oil return is aided. Because of these advantages, this type of control is the

simplest, least costly and most satisfactory bypass system. This type of bypass is illustrated in Figure 1.

### Bypass Into Suction Line

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Where multiple evaporators are connected to one compressor, or where the condensing unit is removed from the evaporator it may be necessary to bypass hot gas into the refrigerant suction line. Suction pressures can be controlled satisfactorily with this method, but a desuperheating expansion valve is required to meter liquid refrigerant into the suction line in order to keep the temperature of the refrigerant gas returning to the

compressor within allowable limits. It is necessary to thoroughly mix the bypassed hot gas, the liquid refrigerant, and the return gas from the evaporator so that the mixture entering the compressor is at the correct temperature. A mixing chamber is recommended for this purpose, and a suction line accumulator can serve as an excellent mixing chamber while at the same time protecting the compressor from liquid flood-back. See Figure 2 for typical installation.

Another commonly used method of mixing is to arrange the piping so that a mixture of discharge gas and liquid refrigerant is introduced into the suction line at some distance from the compressor, in a suction header if possible. Figure 3 illustrates this mixing method.

### Solenoid Valves For Positive Shut-Off And Pumpdown Cycle

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In order to allow the system to pump down, a solenoid valve must be installed ahead of the hot gas bypass valve.

Since the hot gas valve opens on a decrease of downstream pressure, it will be open any time the system pressure is reduced below its setting. If the system control is such that this solenoid valve is closed during the normal cooling cycle, it may also prevent possible loss of capacity due to leakage.

A solenoid valve is also recommended ahead of the desuperheating expansion valve to prevent leakage and allow pump down. Both of the solenoid valves should be of the normally closed type, and wired so they are de-energized when the compressor is not operating.

### Desuperheating Expansion Valve

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If a desuperheating expansion valve is required, it should

be of adequate size to reduce the temperature of the discharge gas to the proper level under maximum bypass conditions. The temperature sensing bulb of the expansion valve must be located so that it can sense the temperature of the gas returning to the compressor after the introduction of the hot gas and the desuperheating liquid. Suction gas entering the compressor should be no higher than 65°F under low temperature load conditions, or 90°F under high temperature load conditions.

On low temperature applications where hot gas bypass is used to prevent the compressor suction pressure from falling below safe operating levels, valves with unusually high superheat setting may be required. For example, suppose a control was desired to prevent a system using R-502 from operating below -35°F. The temperature of the gas returning to the compressor must be prevented from exceeding 65°F. Therefore, when the desuperheating expansion valve is feeding, it will sense on one side of its diaphragm, the system pressure equivalent to -35°F. or 6.7 psig, and in order

to maintain 65°F return gas, it will require a superheat setting of 65°F plus 35°F or 100°F. Expansion valves with special charges are available from expansion valve manufacturers with superheat settings over extremely wide ranges, although these will not normally be available in a local wholesaler's stock. Contact the expansion valve manufacturer's local representative for assistance in selecting valves with nonstandard superheat settings.

### Typical Multiple - Evaporator Control System

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A typical hot gas bypass control system with three evaporators is illustrated in Figure 2, together with a schematic electric control system for cycling control of the compressor. The double pole thermostats close on a demand for refrigeration, and as long as any one evaporator is demanding cooling the compressor operates, and the hot gas bypass valve modulates flow as necessary to prevent the suction pressure from falling below a fixed set point.



If all evaporators are satisfied, all of the thermostats are open, and all liquid line solenoid valves and the hot gas solenoid valve are deenergized, and therefore closed. The compressor will then cycle off on low pressure control until thermostat again closes.

In order to protect the compressor against danger from liquid flooding in the event of a trip of a compressor safety device, provision must be made in the wiring circuit to deenergize the hot gas and the desuper-heating liquid line solenoid valves if the compressor is inoperative. On a pumpdown system, this can be accomplished by means of a solenoid valve control relay as shown in Figure 2.

If continuous compressor operation is desired, single pole thermostats can be used, and the hot gas and desuper-heating liquid line solenoid valves should be connected directly to the load side of the compressor contractor. In the event all three evaporators are satisfied, the compressor will operate on 100% hot gas bypass until cooling is again required.

Compressors equipped with inherent protection can cycle on the inherent protector independently of the contractor. To avoid flooding the compressor with liquid refrigerant in the event the inherent protector should trip, the hot gas solenoid valve and the liquid line solenoid valve should be connected through a current sensing relay such as the Penn R-10A, as shown in Figure 4.

### Power Consumption with Hot Gas Bypass

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Since the power consumption as well as the capacity of a compressor is reduced with a decrease in compressor suction pressure, the control system should be such that the system is allowed to reach its lowest satisfactory operating suction pressure before hot gas is bypassed.

Where major reductions in capacity are required, operating economy may be best achieved by handling the load with two compressors. One can be cycled for a 50% reduction in both capacity and power, while the capacity of the compressor remaining on the line is modulated by hot gas control.

It is not necessarily true that continuous compressor operation with hot gas bypass will result in a higher power bill than cycling operations for a given load. Almost all utilities make a monthly demand charge based on peak loads. Since the peak motor demand occurs when locked rotor current is drawn on start-up, the utility demand charge may reflect motor starting requirements rather than the true running load. With continuous operation, once the motors are on the line, starting peaks may be eliminated, and the reduction in the demand charge may offset the increased running power consumption.

### Compressor Operating Limits

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Compressors should not be operated outside of the operating limits shown on the published compressor specification sheets, and low pressure controls should not be set below the minimum settings shown in Table 1 without prior written approval of the Copeland Application Engineering Department.

Operating below the allowable minimum suction pressure may result in excessive discharge temperatures which can

cause cylinder and valve damage and may result in lubrication problems. Since high discharge temperatures can occur even though the motor is cool, the motor thermostat will not protect the compressor against these conditions.

Operation of motor-compressors beyond the established recommended operating limits will be considered misuse and abuse, and damage resulting from such operation is not covered by the Copeland warranty.



## Figures and Tables

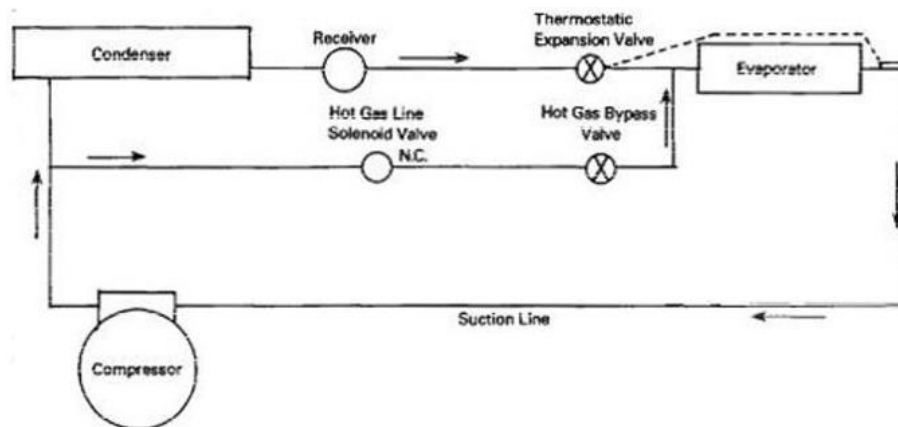


Figure 1 Typical Schematic Connection - Bypass into Evaporator Inlet

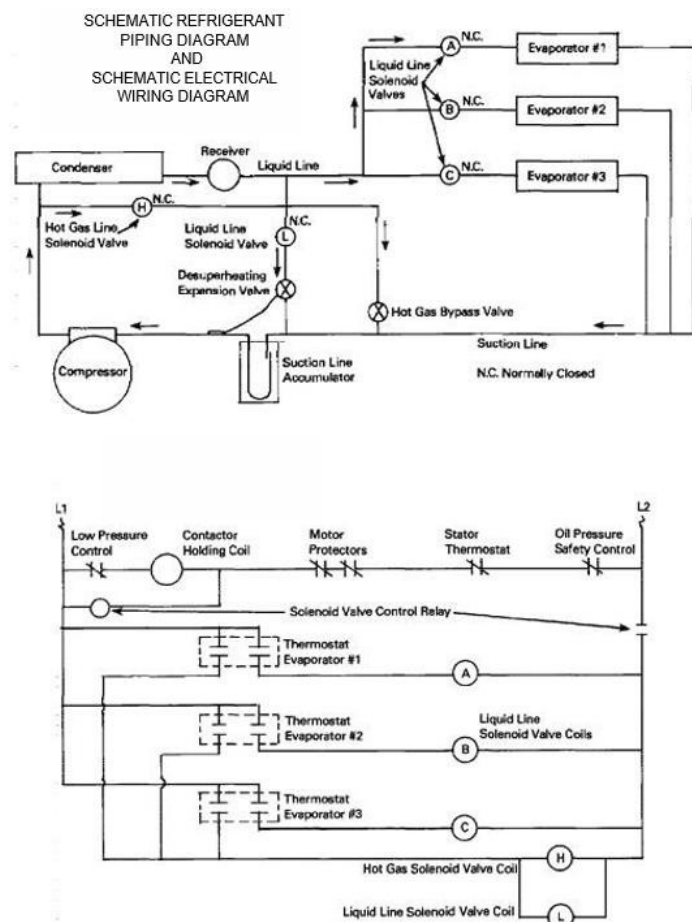


Figure 2 Typical Hot Gas Bypass Control System with Bypass into Suction Line

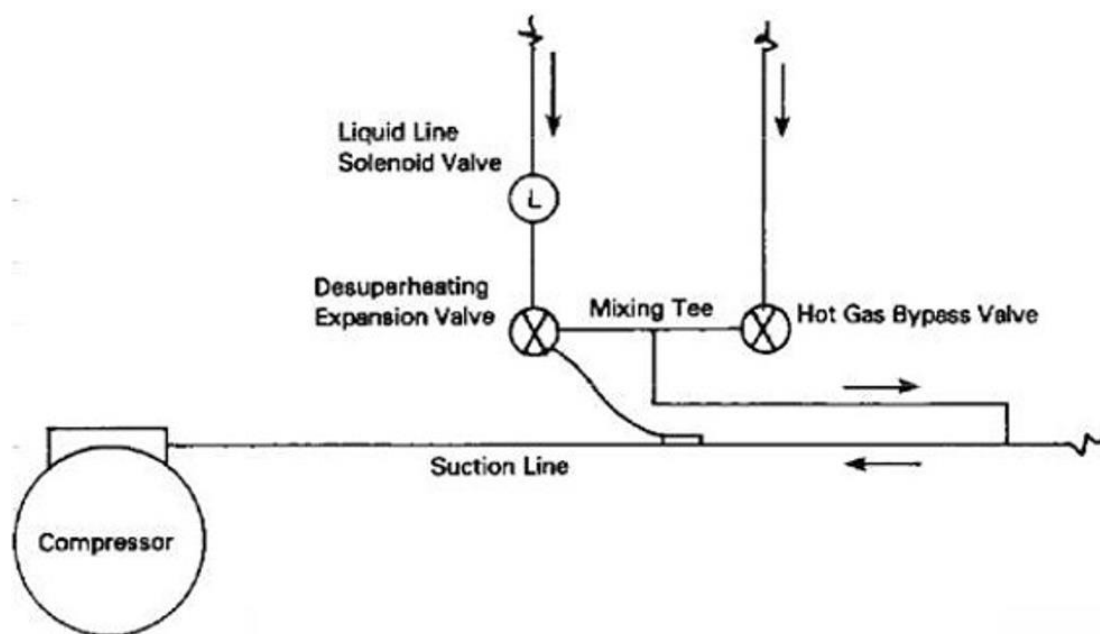
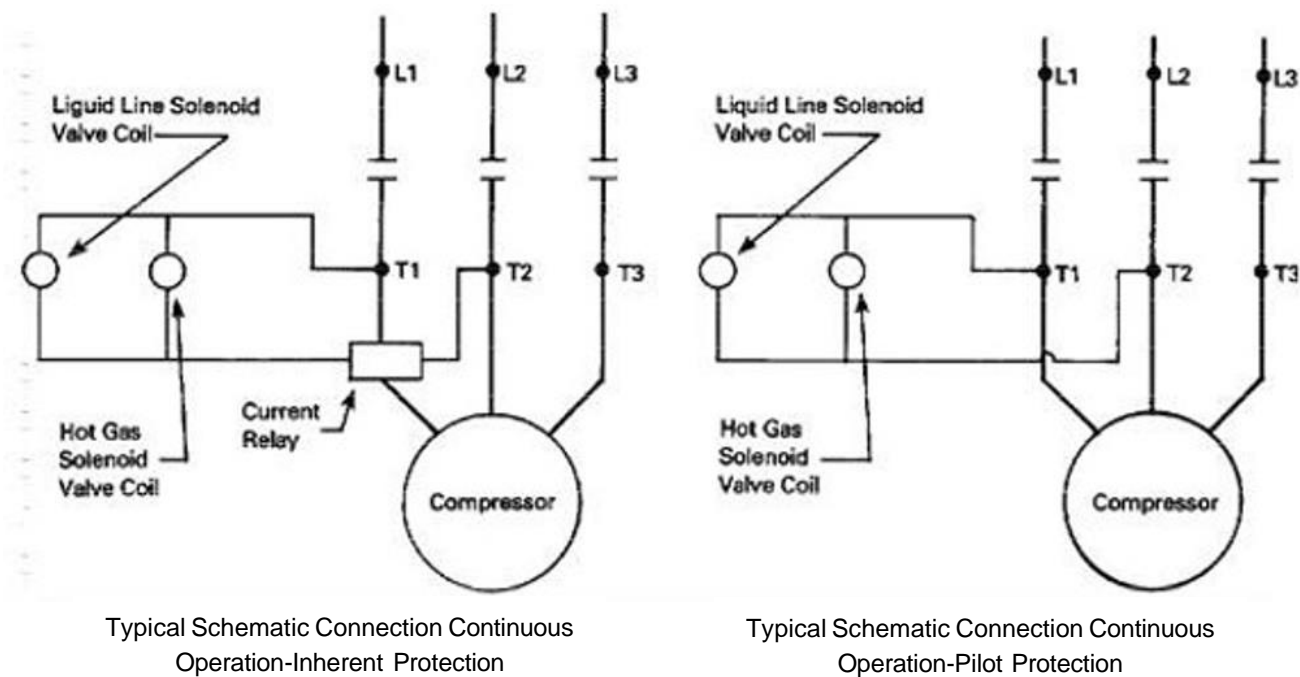


Figure 3 Alternative Method of Bypass into Suction Line



Typical Schematic Connection Continuous  
Operation-Inherent Protection

Typical Schematic Connection Continuous  
Operation-Pilot Protection

Figure 4

*Table 1 Recommended Minimum Suction Pressure and Low-Pressure Control Setting for Single Stage Copelametic Compressors Without Unloaders*

Compressor Applications	Recommended Suction Pressure Limits		Minimum Recommended Low pressure Control Setting		
	Minumum	Maximum	R-12	R-22	R-502
High Temperature	0 F	55 F	5 psig	16 psig	22 psig
Medium Temperature	0 F	25 F	5 psig	16 psig	22 psig
*Medium Temperature	-5 F	25 F	2 psig	13 Psig	19 psig
*Low Temperature	-40 F	0 F	15" VAC	6" Vac	0 psig
*Extra Low Temperature	-40 F	-20 F	15" VAC	6" Vac	0 psig

\*Refrigerant-cooled compressors require additional air-cooling operation at these conditions. See AE4-1135

### Revision Tracking R2

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

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