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Application Engineering Europe

USE OF INVERTERS WITH COPELAND™ STREAM COMPRESSORS

1 Introduction

Inverters are used to vary the speed of motors and in this way can be used to control the capacity of a compressor. For refrigeration users they can be an effective method of accurately matching compressor capacity to load requirements. A way of reducing compressor output is needed in almost every application. With the emphasis today on saving energy by reducing head pressures, an effective capacity control method can bring enormous benefits. Without the means to run efficiently at low capacity, compressor cycling by switching on/off is most commonly used. This method introduces large fluctuations and high power consumption due to heavily loaded heat exchangers. Multiple compressor solutions overcome this problem to some extent and stepping by means of cylinder unloading is used with piston compressors.

The advantages of varying compressor speed are:

- the load is more closely matched with minimal variation in evaporating pressure, and fluctuations in load temperature are minimised;
- better system efficiency at part load;
- extended lifetime of equipment due to continuous operation instead of cycling;
- low starting current obviates the need for assisted-start devices;
- with gradual speed increase from standstill there is less risk of sudden liquid or oil return to the compressor at start-up.

The objective of this technical information is to provide technical guidelines to developers, designers or installers who intend to use inverters in refrigeration equipment with Stream semi-hermetic compressors. The operation of an inverter, the effect on the compressor application range, performance and power, precautions to be taken and some implications on system design are discussed.

2 Operation of an inverter

An inverter works by converting the input mains alternating current to direct current and, from this, regenerating a simulated AC signal at the required frequency. A compressor driven by a squirrel cage motor will run at a speed corresponding to the frequency. The speed will be in direct proportion to the frequency.

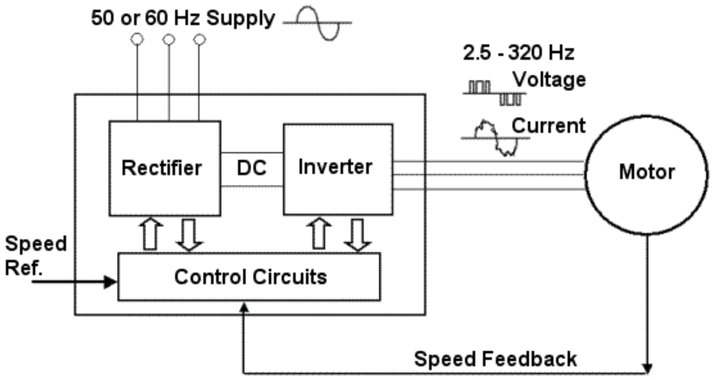


Figure 1

3 Evaluation and important considerations

Most inverters are capable of generating frequencies from 2.5 Hz to over 300 Hz. This is well outside the range of any refrigeration compressor. Care must be taken to respect the approved frequency range.

Limits arise due to the capability of the oil pump to maintain lubrication at low speed and motor cooling. Excessive losses at high speeds can result in inefficient operation and overheating (high discharge temperatures).

The power absorbed by a compressor operating with an inverter will always be more than for a direct connected compressor running at the same speed. It is important to choose a high quality inverter because the inverter absorbs a certain amount of power and also the nature of the electrical waveform at the motor is disjointed, resulting in increased motor losses.

When considering an inverter drive the following points should be taken into account:

- loss of efficiency unless care is taken with system design and control;
- conventional capacity control methods may not be used with inverter drive;
- vibration resonance may occur at certain speeds and these are very difficult to predict;
- restrictions on operating envelope may be necessary;
- risk of electrical disturbance to control signals.

4 Limits of use with Copeland™ brand compressors

With many inverters it is very easy to alter the maximum and minimum output frequencies and the frequency range, so care must be taken to ensure the frequencies are correctly adjusted to prevent serious damage to the compressor.

NOTE: **In most variable frequency drives, it is possible to program "skip" frequencies to avoid vibration resonance that may occur at certain speeds.**

4.1 Approved frequency ranges with standard motors

Model family	Frequency range
4M, 6M	30 - 70 Hz

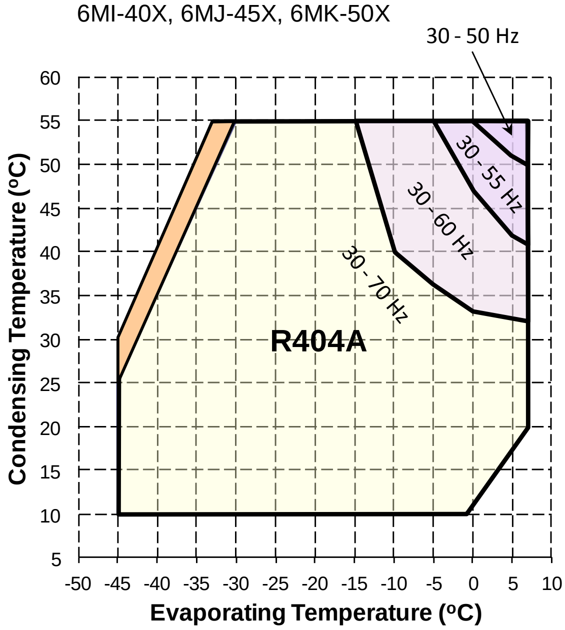
Table 1

4.2 Operating 50 to 70 Hz with standard motors

The output voltage from the drive cannot exceed the input voltage to the drive. Copeland® Stream compressors are designed to operate at 70 Hz speeds. However it must be noted that when connected to a 400V 50 Hz supply, the inverter can only deliver a maximum voltage of 400V. The standard motor requires a higher voltage above 50 Hz. In the range between 50 and 70 Hz, the amps could increase and therefore reduce the envelope, such as shown in the following envelopes for the compressor models listed below with R404A, R134a, R407C and R407F.

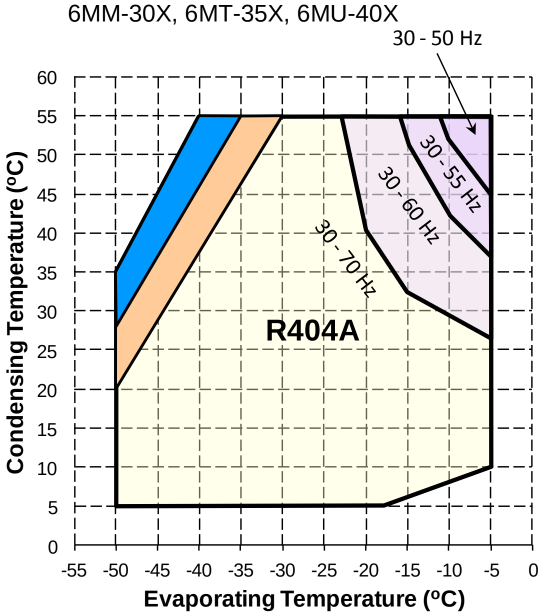
R404A – Stream large motor version

4MA-22X, 4MH-25X, 4MI-30X, 4MJ-33X, 4MK-35X, 6MI-40X, 6MJ-45X, 6MK-50X



R404A - Stream small motor version

4MF-13X, 4ML-15X, 4MM-20X, 4MT-22X, 6MM-30X, 6MT-35X, 6MU-40X



R404A - Stream small motor version

4MU-25X

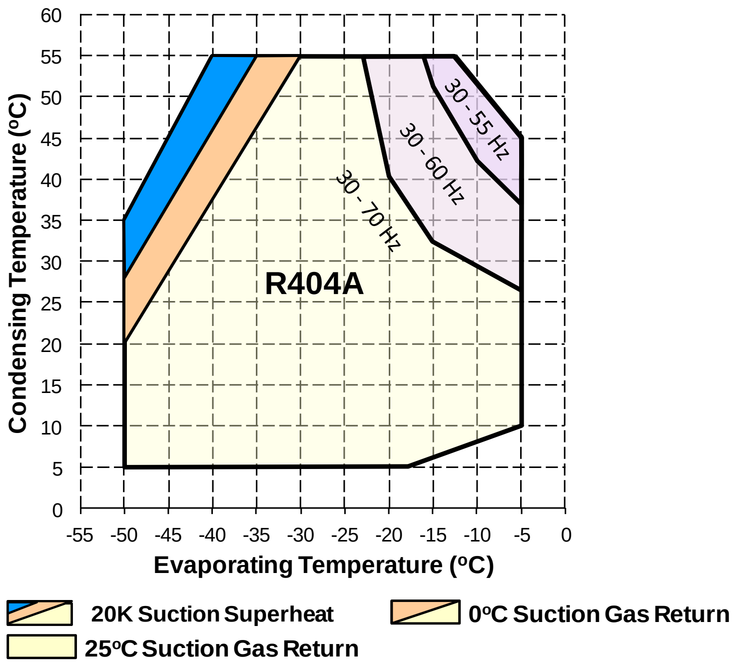
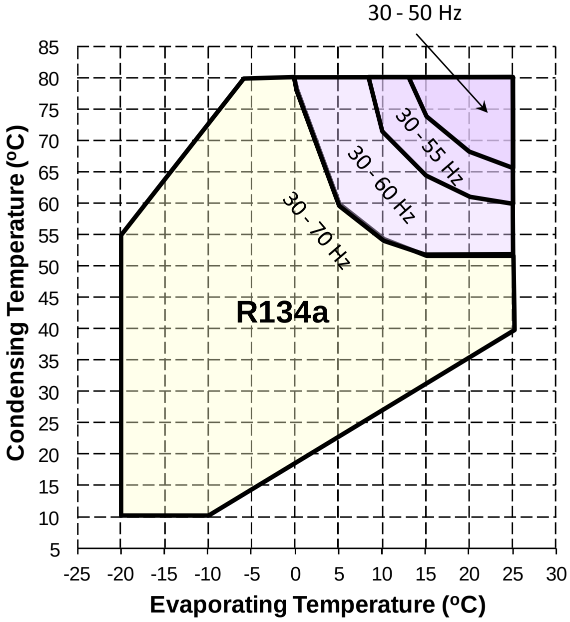


Figure 2: Inverter operation with standard motor 30 to 70Hz – R404A

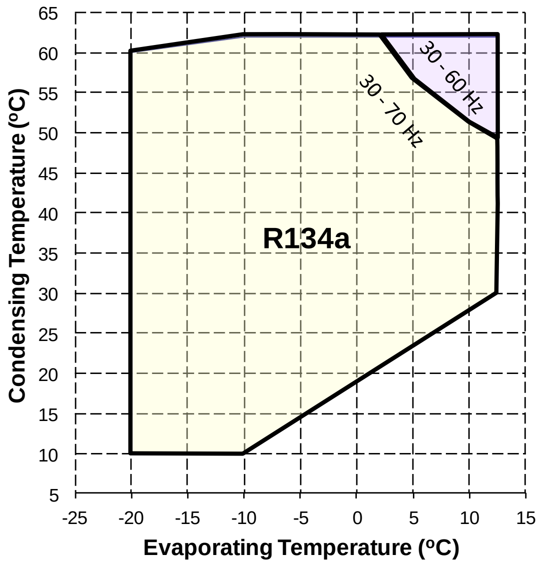
R134a – Stream large motor version

4MA-22X, 4MH-25X, 4MI-30X, 4MJ-33X, 4MK-35X, 6MI-40X, 6MJ-45X, 6MK-50X



R134a - Stream small motor version

4MF-13X, 4ML-15X, 4MM-20X, 4MT-22X, 4MU-25X 6MM-30X, 6MT-35X, 6MU-40X

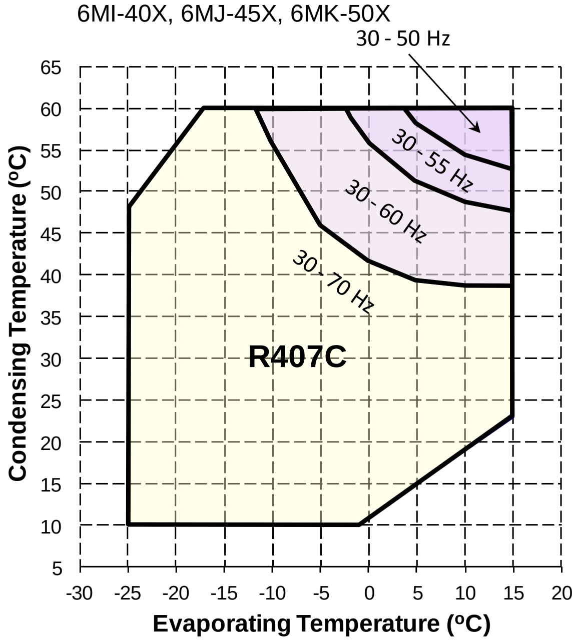


20K Suction Superheat   25°C Suction Gas Return

Figure 3: Inverter operation with standard motor 30 to 70 Hz – R134a

R407C - Stream large motor version

4MA-22X, 4MH-25X, 4MI-30X, 4MJ-33X, 4MK-35X, 6MI-40X, 6MJ-45X, 6MK-50X



20°C Suction Gas Return

Figure 4: Inverter operation with standard motor 30 to 70 Hz – R407C

R407F – Stream large motor version
4MA-22X, 4MH-25X, 4MI-30X, 4MJ-33X, 4MK-35X, 6MI-40X, 6MJ-45X, 6MK-50X

R407F - Stream small motor version
4MF-13X, 4ML-15X, 4MM-20X, 4MT-22X, 4MU-25X 6MM-30X, 6MT-35X, 6MU-40X

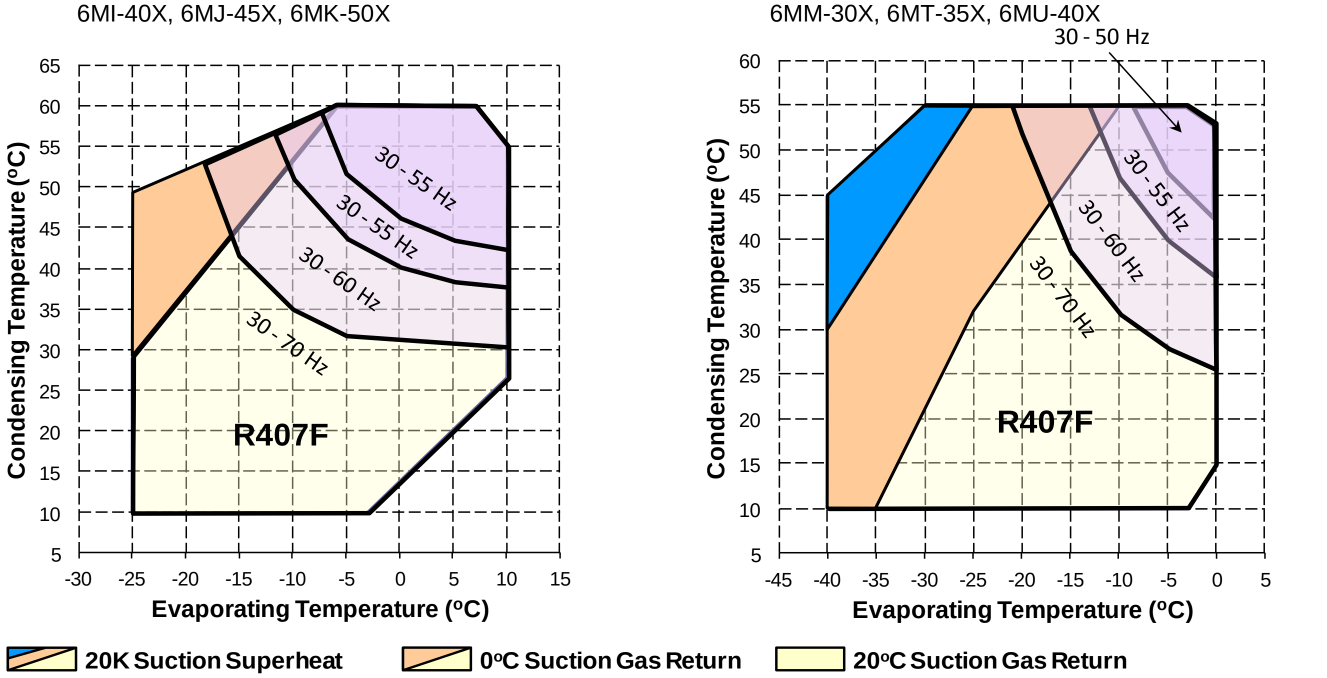


Figure 5: Inverter operation with standard motor 30 to 70 Hz – R407F

4.3 Minimum speed

The minimum allowable frequency of 30 Hz is governed by the lowest speed at which the lubrication system can operate effectively.

4.4 Over-speed with special motors

By using a motor designed for a voltage lower than 400V/50 Hz, in conjunction with a 400V supply, it is possible for the inverter to increase the voltage during over-speed. Normally the ratio of voltage/frequency (V/f) is kept constant, and it is only when the required voltage is above the supply voltage that the amps increase. For example, a 380V/60 Hz motor will only require 320V at 50 Hz according to the constant V/f rule, and can therefore be safely operated at all conditions up to 70 Hz with a suitable inverter. By moving to 230V/50 Hz motor, the scope for increased voltage speed is even greater.

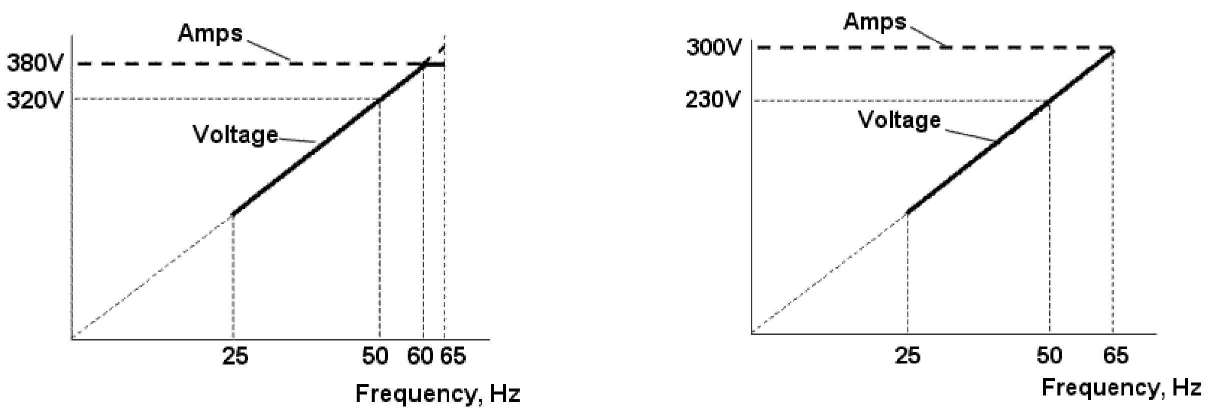


Figure 6

***NOTE:* It is important to note that when using special motors in this way there is no option of running direct-on-line in the event of inverter failure.**

5 Control of inverter frequency

The signal necessary to control the inverter depends on the type of inverter used. They are normally controlled by a 4 to 20mA or a voltage signal. This can be driven from the parameter which is used to control the refrigeration system, for example suction pressure or room temperature.

6 Power measurement and cable sizing

The inverter can cause distortion of the sinusoidal current waveform, and between the inverter and the motor there is a stepped current approximating to a sine wave. High-quality inverters will introduce less distortion and power losses. Power can be measured using the two wattmeter methods on the input to the inverter.

Currents can exceed the amounts calculated from this power. Cables, fuses and contactors will need to be sized for the true RMS current flowing through them. General rules for this are:

- cable from motor to inverter - size for 10% more current than standard;
- cable from inverter to mains - size for 20% more current than standard.

7 Start contactor positioning

The inverter should not be allowed to operate with the output from the inverter to the motor open circuit. There should be a contactor each side of the inverter, ie, between the inverter and the mains and between the inverter and the compressor motor. They should be interlocked to break the mains side first. When switching on, the motor side contactor should be made first.

When using an inverter bypass, care should be taken to ensure there can be no voltage feedback to the inverter. Therefore when the bypass contactor is closed and the bypass is in operation, the contactors on either side of the inverter must be open.

8 Starting and ramp-up

An inverter is capable of delivering a soft start, but at the same time care must be taken to ensure that stalling does not occur. The inverter must be able to deliver sufficient power at the lower frequencies to ensure that the compressor accelerates to nominal speed in approximately 1 to 4 seconds. Only general guidance can be given here, because the exact torque requirements will depend on system pressures at the time of start-up. Longer ramp-up times could result in inadequate lubrication. It may be necessary to set the inverter to deliver a slightly increased voltage (compared to the normal V/f rule in **Section 4.4**) at the low frequency applicable during ramp-up, but this should not result in deviation from the V/f rule during normal operation. A ramp down is not necessary.

9 Electrical shielding and voltage rise

Wiring of the electrical enclosure and the installation must be carefully conducted in accordance with EMC recommendations. High-quality reliable pressure sensors must be used and it is necessary to follow EMC measures to ensure that the inverter does not disturb the signals from pressure transducers. Suction and high pressure sensors signals must be noise-free to the controller input. The inverter itself can be fitted with suitable EMC filters, eg, EN 55011 Class B.

Since the waveform generated by the inverter is built up from pulses, there is a danger that the rate of voltage rise on an individual pulse can be too fast. Generally this is measured in kV per microsecond, and limits at the motor terminals which should be adhered to during the first microsecond are given in EN 60034. In order to minimize the risk of motor problems, it is suggested that the variable frequency drive be operated at its lowest switching frequency and that the distance between the frequency drive and the compressor be as short as possible.

10 Vibration

A compressor running at fixed speed imposes vibrations on its associated framework at a set group of frequencies. The framework can of course be designed so that its natural frequencies differ from the imposed frequencies. A compressor driven at variable speed will impose different frequencies at each speed, so the framework design to eliminate vibration throughout the speed range is more complex.

The framework structure should be stiff enough so that its resonant frequencies are above the maximum frequency, ie, 70 Hz. Designing with natural frequencies below the minimum speed of 20 or 25 Hz, could lead to vibration problems during start-up. Spring mounts should not be used as they have a natural frequency below 70 Hz.

NOTE: **The system should be designed or the variable frequency drive control should be configured (skip frequencies programmed) so that there is no operation at resonant frequencies between 20 and 70 Hz.**

11 CoreSense™ Diagnostics

Copeland Stream compressors are factory-equipped with CoreSense™ compressor protection. CoreSense is an ingredient brand name for compressor electronics associated with Copeland™ brand products. CoreSense technology uses compressor as a sensor to unlock information from within the compressor providing value added features such as advanced motor protection, diagnostics, power consumption measurement and communication.

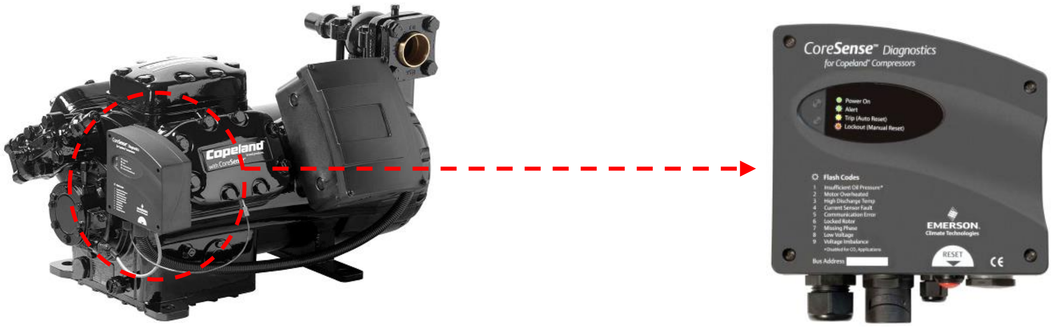


Figure 7: Stream compressor with CoreSense Diagnostics

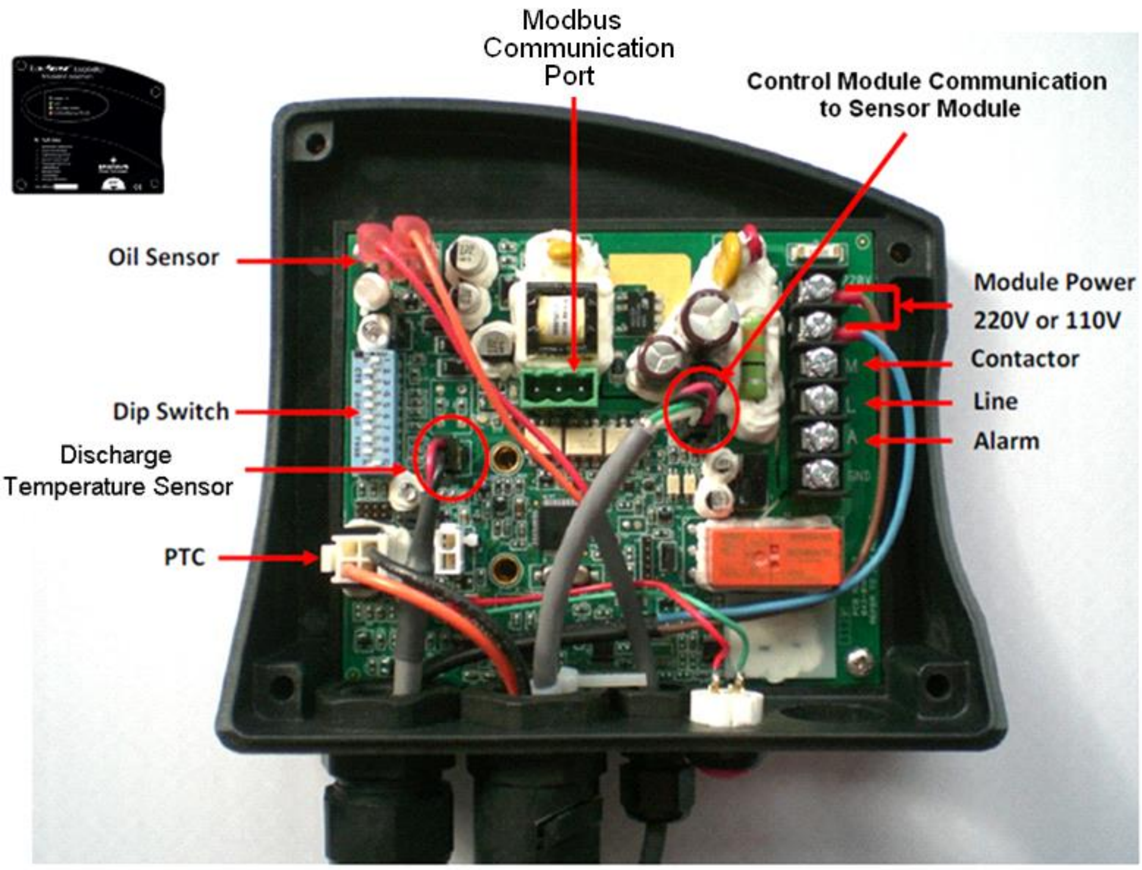


Figure 8: CoreSense wiring terminals description

12 DIP-switch settings

Verify the DIP-switch settings: DIP-switch 6 must be manually set to "On", to enable inverter operation.

DIP-switch	DIP-switch meaning	Default	Comment
1	Node address	On	Change it only if communication with pack controller is used
2	Node address	Off	Change it only if communication with pack controller is used
3	Node address	Off	Change it only if communication with pack controller is used
4	Node address	Off	Change it only if communication with pack controller is used
5	Node address	Off	Change it only if communication with pack controller is used
6	Enable frequency inverter	Off	Change it only if frequency inverter is used (On: Frequency inverter is enabled)
7	Communication Baud rate	Off	Change it only if communication with pack controller is used (Off: 19200; On: 9600)
8	Communication parity	Off	Change it only if communication with pack controller is used (Off: No parity; On: Even parity)
9	Communication with pack controller or service laptop	Off	Change it only if communication with pack controller or service laptop is used (Off: Stand-alone mode; On: Communication mode)
10	DLT probe	On	Change it only if DLT probe is disconnected (Off: DLT probe disconnected; On: DLT probe connected)

Table 2: CoreSense DIP-switch settings

NOTE: **For more information, see Technical Information D7.8.4 "CoreSense™ Diagnostics for Stream Refrigeration Compressors".**

13 Inverter operation with Digital or standard capacity control

Copeland Stream compressors can be applied either for Digital and standard capacity control or for variable speed with inverter. A combination of inverter usage with Digital and/or standard capacity control is NOT possible.

14 Recommended inverter range

Emerson Climate Technologies recommends the use of Unidrive M brand inverter from Emerson Industrial Automation with Stream compressors.

The corresponding cross-reference list can be found in Section 16, Cross reference list.

15 Summary

The following is a summary of the main considerations when using inverter drive as capacity control:

- The compressor must not operate outside the range 30 to 70 Hz.
- The compressor application range might be reduced for motor loading, if over-speed is used.
- The capacity of the compressor will be in direct proportion to the speed.
- The power input to the compressor will depend on the efficiency of the inverter and the frequency.
- The framework should be designed such that resonance frequencies are above 70 Hz.
- The system should be designed or the variable frequency drive should be configured (skip frequencies programmed), such that there is no operation at resonant frequencies.
- There are inherent inefficiencies associated with the operation of the inverter.
- Care must be taken when setting up the inverter to ensure it does not operate outside the specified frequency range, and that it operates at maximum efficiency.
- Cable sizing from the mains supply and to the compressor motor must be sized to account for higher currents than for a similar size system without inverter.
- The control circuit should be designed such that the inverter cannot operate with the output from the inverter to the motor open circuit.
- Reduced gas velocities at lower speed may necessitate re-design of discharge and suction pipe work.

16 Cross-reference list

Stream compressors and corresponding inverters from Control Techniques (product range = Commander SK):

Compressor	Control Techniques Inverter Commander SK	Compressor	Control Techniques Inverter Commander SK
4MF-13X	M200 06 400 420	6MM-30X	M400 07 400 770
4MA-22X	M200 06 400 420	6MI-40X	M400 07 400 770
4ML-15X	M200 06 400 470	6MT-35X	M400 07 401 000
4MH-25X	M200 06 400 470	6MJ-45X	M400 07 401 000
4MM-20X	M400 07 400 660	6MU-40X	M400 07 401 000
4MI-30X	M400 07 400 660	6MK-50X	M400 07 401 000
4MT-22X	M400 07 400 660		
4MJ-33X	M400 07 400 660		
4MU-25X	M400 07 400 770		
4MK-35X	M400 07 400 660		

Table 3