Application Engineering

*Copeland Variable Speed Reciprocating Compressor Drives for A*V* Compressor Family*

BULLETIN NO: AE8-1437 R3

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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

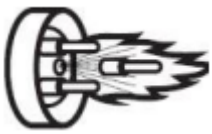
• OEMs are responsible for system design, selection of appropriate components, integration of this component into the system, and testing the system. OEMs must ensure that staff involved in these activities are competent and qualified.

• 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 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.

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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.**

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• 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.

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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.

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Introduction

Product Description

The Copeland Variable Speed Reciprocating Drives have been developed specifically for the Copeland Variable Speed Reciprocating Compressor A*V* Family. The drive will provide power to the compressor, control the compressor running speed, provide compressor and drive protection and run as a standalone drive. The drive requires cooling and is typically installed near the compressor.

The A*V* Copeland Variable Speed Reciprocating Compressors will be referred to as the “variable speed compressor” or simply “compressor” and the Copeland Variable Speed Reciprocating Compressor Drives will be referred to as “Variable Frequency Drive (VFD)” or “drive” throughout this bulletin.

Theory of Drive Operation

The primary purpose of the Variable Frequency Drive is to convert the 50/60 Hz AC input voltage into a variable frequency, variable voltage output to power the variable speed compressor. The drive conditions the AC input voltage through a series of processes to arrive at the desired output. The drive first converts the AC input voltage into a DC voltage. The DC voltage is then pulse-width modulated to replicate a sinusoidal current at the desired frequency and voltage.

Agency Recognition

When used with a matching compressor, the drives listed below are compliant with UL 60730-1 and IEC 60335-1 standards.

Technical Specifications

Drive Part Numbers

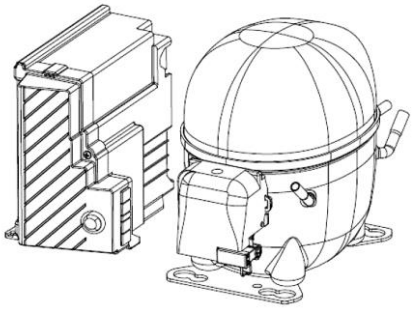
The listed compressors can only be used with the corresponding drive listed. This is due to the drive being the motor protection for the specific compressor.

Table 1 Drive Part Numbers

Compressor	Drive	Power	Input Voltage
ASVF112EU-HE9 (11 cc)	585-0373-02	1.0 kW	120V/240V (50/60hz) Single Phase Drive
ASVF061EU-HE9 (6cc)	585-0373-03	1.0 kW	120V/240V (50/60hz) Single Phase Drive
ASVF151EU-HE9 (15cc)	585-0373-04	1.0 kW	120V/240V (50/60hz) Single Phase Drive

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*Figure 1 Drive and Compatible A*V* Compressor*



Product Specifications

Table 2 Drive Storage and Operating Conditions

Storage Humidity	< 85%
Storage Temperature	-40°F(-40°C) to 185°F(85°C)
Operating Humidity	< 85%
Minimum Air Ventilation	394 FPM (2 m/s)
Ambient Temperature	-4 °F(-20°C) to 131°F(55°C)

Table 3 Drive Electrical Specifications

Input Voltage Rating	120VAC or 240VAC
Voltage Range (120V)	70 to 140VAC
Voltage Range (240V)	160 to 264VAC
Voltage Range Selection	Automatic
Input Frequency Range	50 to 60hz
Maximum Input Current	15.5 Amps
Maximum Input Power	1100 Watts
Output Frequency Range (ASVF series)	60 to 150hz
Maximum Output Current	6.2 Amps
Control Mode	Frequency, Serial Mode, Drop-in

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General Installation

Drive Handling

- Correct handling and storage of the drive is essential in preventing mechanical damage.
- To prevent possible electrostatic discharges, avoid having the drive cover contact with the internal electronic board.
- Never cut across the drive with any sharp materials.
- Do not stack the drives on each other.
- Do not drop the drive
- To avoid electrostatic discharges to the drive circuit, insert the ground terminals first.

NOTICE

Avoid holding the drive when your hand is in contact with Polyol Ester Oil (POE) to prevent damage to the plastic cover.

⚠CAUTION

Failure to use caution when installing the drive may result in bodily injury.

⚠WARNING

After unplugging the drive, wait for at least 30 seconds before touching the drive or drive terminals.

NOTICE

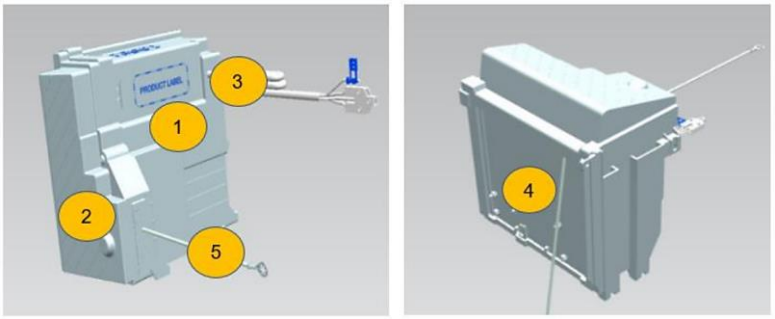
Personnel handling the drives in a manufacturing plant environment should guard against static electricity by using the appropriate equipment such as an anti-static wrist straps and mats.

Main Components

The Variable Frequency Drive comprises of the basic components below:

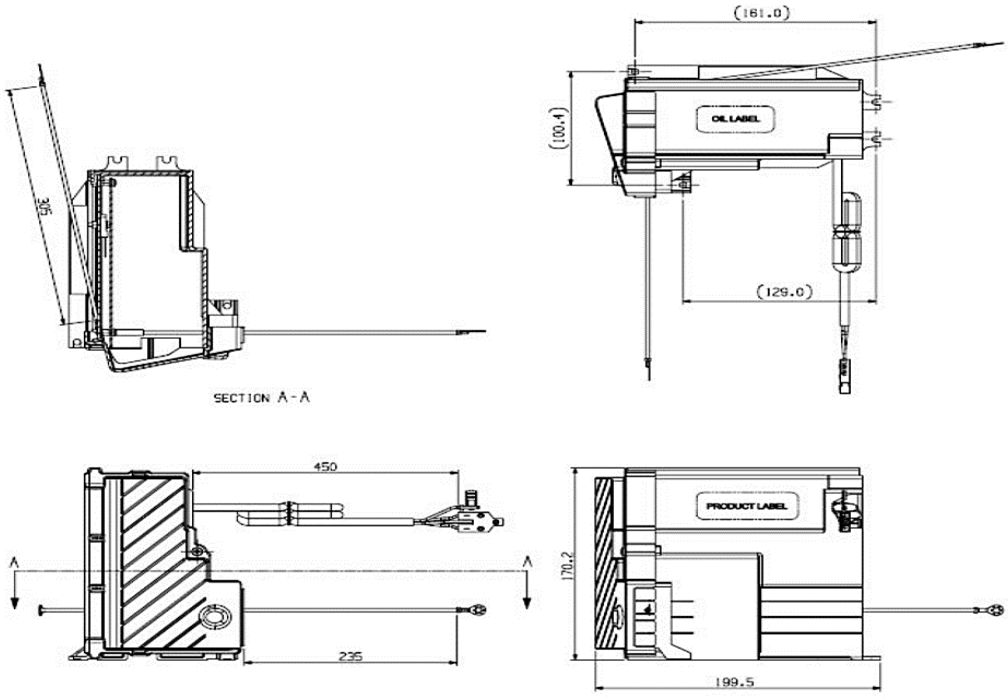
1 Drive Housing
2 Cover for Input Drive Connections
3 Compressor Output Connections
4 Heat Sink
5 Ground Wires

Figure 2 Drive Stand Alone View 585-0373-XX



No.	Description	585-0373-02	585-0373-03	585-0373-04
1	Drive Housing	NONE	NONE	NONE
2	Cover	005-2070-00	005-2070-00	005-2070-00
3	Compressor Output Connections	NONE	NONE	NONE
4	Heatsink	NONE	NONE	NONE
5	Communication Wires	029-0614-00 (White) 029-0614-01 (Yellow/Green)	029-0614-00 (White) 029-0614-01 (Yellow/Green)	029-0614-00 (White) 029-0614-01 (Yellow/Green)

Figure 3 Drive Dimensions



Electrical

WARNING

Disconnect the AC power supply before obtaining access to the connectors. Avoid contact of the Control Input Cable (low voltage) with high voltage or power supply cables, due to electrical hazard and potential equipment damage.

NOTICE

Motor connector must be properly mounted on the 3 pins of compressor hermetic terminal. Bad connection will cause compressor malfunction.

The handling of the drive box must be careful to avoid contact with the internal electrical board, to prevent possible electrostatic discharges.

Make sure all necessary connections are properly done before connecting the drive to the AC supply line.

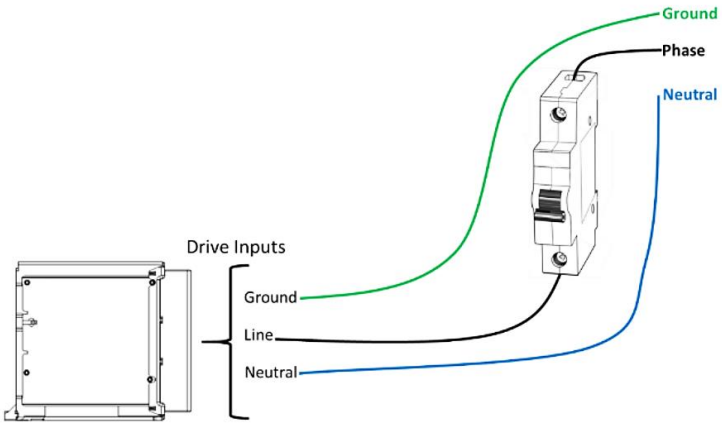
The electronic drive must be installed in the vertical position.

When using Serial, Frequency communication mode or Drop-in mode, the drive has reinforced isolation.

To avoid ESD discharge to the drive circuit, insert the ground terminals first.

The line phase wire must be protected with a circuit-breaker. In single phase installation, the line phase wire must be connected to the phase input connector of the drive and the line neutral to the neutral input connector of the drive.

Figure 4 Circuit Breaker Connection to Drive



Drive Connectors

Figure 5 Drive Cable Connectors

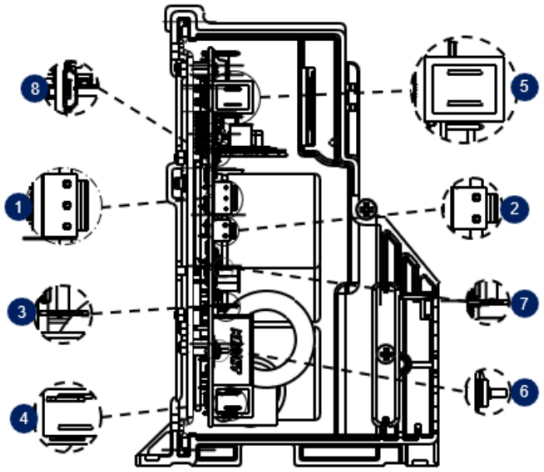


Table 4 Connector Location Guide

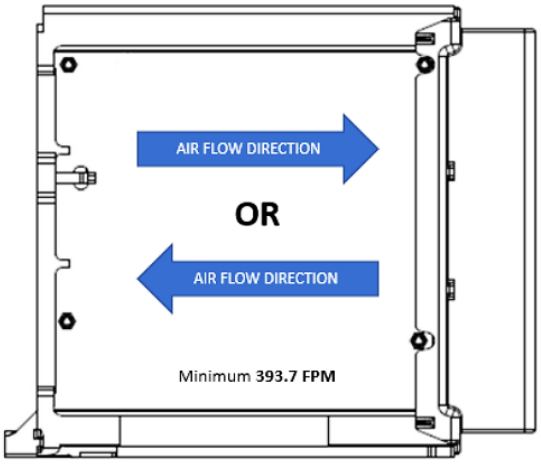
Connector Locations	
Number	**Description**
1	Serial Communication
2	Frequency Input
3	Drop In
4	AC input (L+N)
5	AC Fan*
6	EMI Earth
7	Defrost Input
8	Software Input

*Mates with ¼” faston receptable. Fan connector assembly is optional

Ventilation

Refer to **Figure 6** below for the recommended position of the fan for air ventilation.

Figure 6 Figure 6 Recommended Air Flow Direction



NOTICE

To avoid loss of performance, make sure that the heat sink is not obstructed from the air ventilation.

Maximum power is only achieved with minimum forced ventilation of 394 ft/min (2 m/s) over the drive heat sink and 306 cu. ft/min (520 cu. meter/hr) air flow over the compressor.

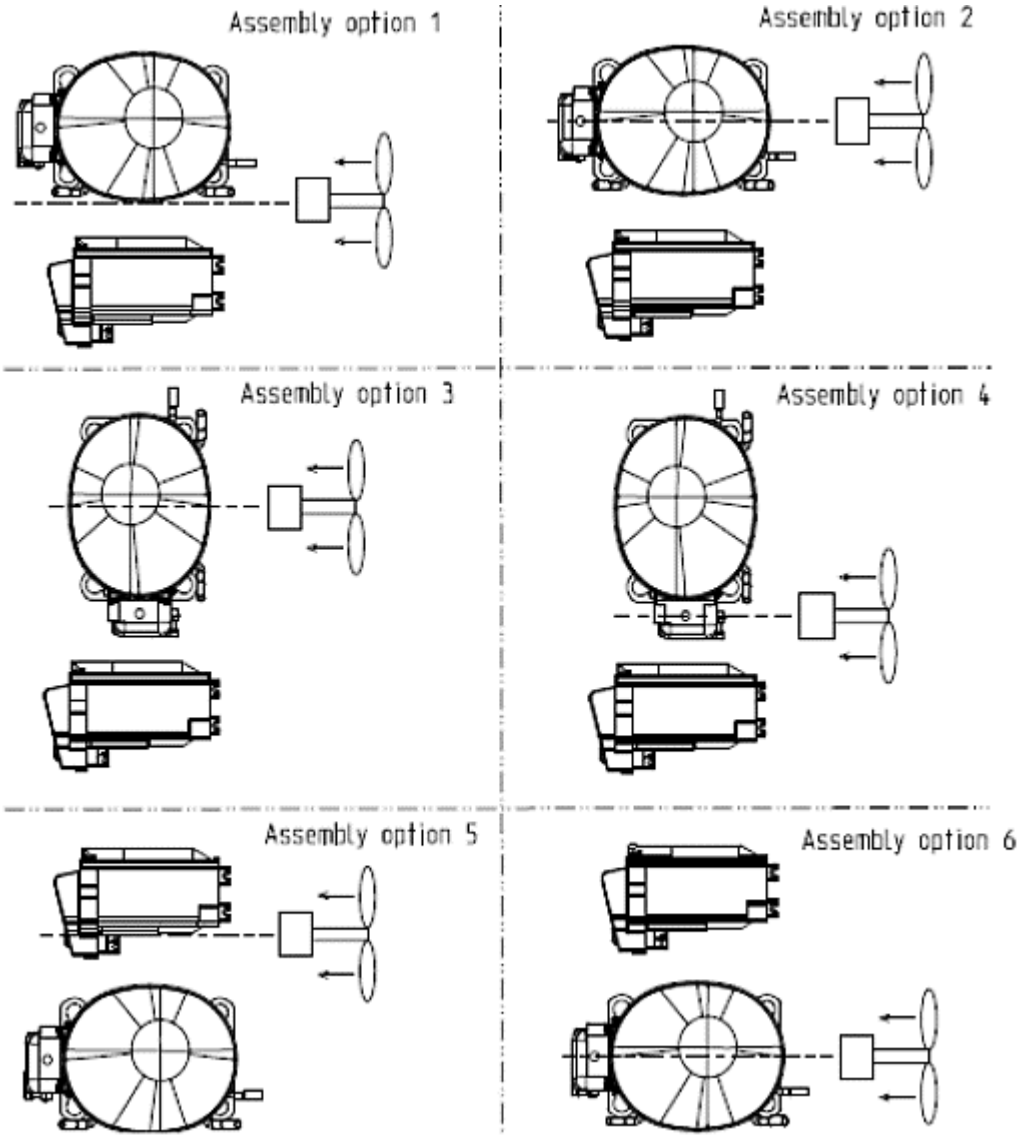
Fan to the compressor shell distance should be at most 11.8 inches (30 cm).

⚠CAUTION

To avoid burns and any possible injuries, avoid touching the heatsink as it could get very hot during the drive operation.

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Figure 7 Recommended Positions for Proper Air Ventilation



Note: All mentioned positions are acceptable.

Considering specific aspects as drive and motor-compressor cooling, the most recommended are positions 1-4. The least recommended but still acceptable are positions 5 and 6.

Both air flow directions are acceptable, but the one above illustrated is preferred.

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Compressor Cable Installation

The drive should be installed only in the vertical position. The drive should be kept close to the compressor as to not entirely stretch the connecting cable to guarantee functionality. The Drive comes with a cable to connect to the compressor, the drive should not be placed farther than the cable allows with some slack so the connector can still be firmly connected with the compressor fusite.

Refer to the steps 1-4 below for the cable installation procedures.

Step 1: Remove the terminal cover, insert a screwdriver into the clip in the top of the cover and push it down.	 
Step 2: Push the cover down and pull out of the compressor.	 
Step 3: To connect the drive to the compressor, attach the motor cable on the hermetic compressor terminal	 
Step 4: Assemble the compressor fence cover ***The screw for fixing the cables must be torque within 0.8 to 1.2 Nm.**	 

Optional AC Fan Switch Control

The drive can be equipped with AC Fan switch control. This switch is ON in case compressor is running and OFF once compressor is stopped. Note, that AC Fan switch control is not powered. It operates like a switch to interrupt the AC supply Line or Neutral of the FAN.

Following connections should be made for switching power of the AC Fan:

- one terminal of AC Fan output to the Phase (or Neutral);
- second terminal of AC Fan output to customer's AC Fan terminal;
- the remaining terminal of customer's AC Fan to the Neutral (or Phase)

⚠CAUTION

Check the drive carefully before operating. Make sure that all the wires are correctly and tightly connected. Improper operation may cause fire or injury to persons.

NOTICE

The drive should only use rated AC power supply. Use of incorrect power supply may damage the drive. A user should make sure that the correct combination of a power supply and drive was used. Do not connect the drive to a power supply above 264VAC. Similarly, input voltage outside the covered range (140V to 160V) can also reduce cooling capacity due to speed limitation.

Control Modes

The Variable Frequency Drive can support 3 different types of control modes (Serial, Frequency, Drop-in) which is dependent on what connector (**Figure 8**) is utilized on the drive itself. Once one of the three ports are connected, the drive with automatically select the respective control mode. To understand more about your systems control mode, read through the respective sections below.

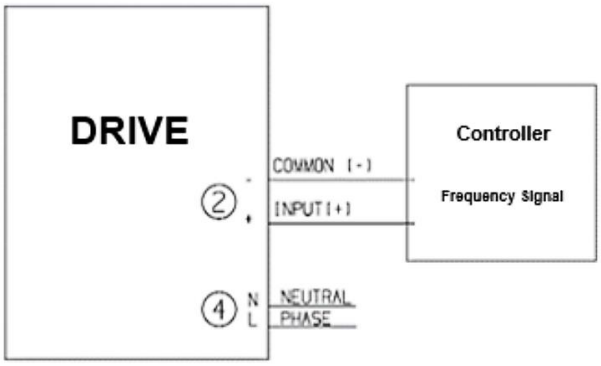
Frequency Control Mode

In this mode, an electronic thermostat provides frequency signal to the drive to control the compressor speed. The input resistance for this mode is 1,200 ohms.

Refer to **Figure 8** on how to connect the thermostat and drive using this control mode. Voltage signals ranging between +0.7V to +4.5V is not recommended when using the frequency control mode.

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Figure 8 Thermostat and Drive Connections using Frequency Control Mode



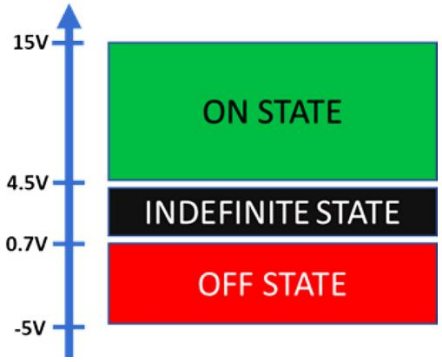
NOTICE

The limit speed shall be configured according to the system and compressor constraints (i.e. Maximum and Minimum Compressor speed). By default, these parameters are initially loaded into the Copeland Variable Speed Reciprocating Compressor Drive Software with the maximum/minimum allowed for the selected compressor.

Table 5 Frequency Control Mode Signal Range

Voltage Range	-5V to 15V
ON State	+4.5V to +15V
OFF State	-5V to +0.7V
Duty Cycle Range	30 to 70%
Maximum Current	15 mA at +15V

Figure 9 Voltage Signal



The maximum and minimum digital signal duty-cycle percentages shown in **Table 5** above refers to the percentage of time the drive signal is ON and running the compressor. For Example: A 50% Duty cycle means that based on the input frequency, the drive is signaling the compressor to run 50% of that period.

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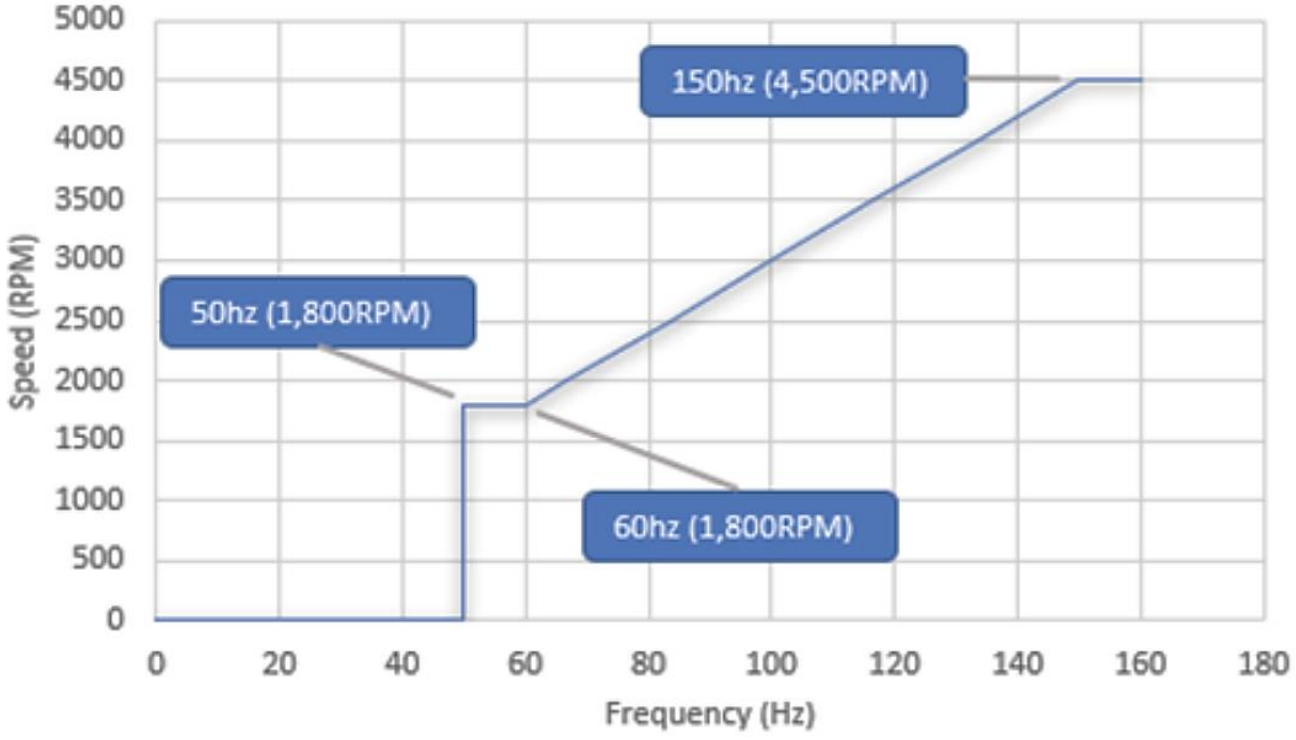
Table 6 Input Frequency versus Compressor Speed RPM

Input Frequency (Hz)	A*V* Compressor Speed (RPM)
0 to 50	0
50 to 60	1800
60 to 66	30 x Hz
66 to 150	30 x Hz
>150	4500

100Hz input Freq. Signal @ 50% Duty Cycle= 5ms on of a period of 10ms

The Variable Speed Compressor, when energized, will run at the RPM specified from the frequency signal that was sent to the drive from the installed frequency controller. The relationship between the Drive Input Frequency and Compressor RPM is shown above in **Table 6**.

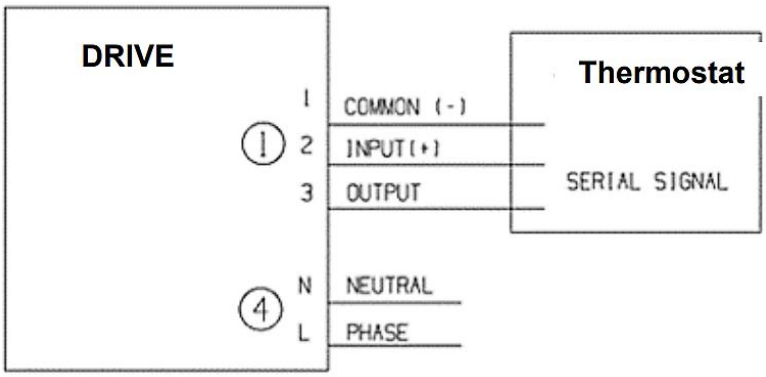
Figure 10 Graphical Illustration of Input Frequency Signal vs. Compressor Speed



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Serial Control Mode

Figure 11 Thermostat and Drive Connection using Serial Control Mode



The serial control mode uses an electronic thermostat to controls the drive through the serial communication protocol. When using this mode, it is possible to define the compressor speed and check other parameters.

When using serial control mode, it is not recommended to use signals between +0.7V to +4.5V. The input resistance for the serial communication is 1.2kΩ.

Table 7 Serial Control Mode Signal Range

Voltage Range	-5V to 15V
FALSE State	+4.5V to +15V
TRUE State	-5V to +0.7V
Maximum Current	2 mA at +15V

Table 8 Serial Mode Basic Communication Settings

Communication Type	UART (Half Duplex)
Baud Rate	600 Baud
Parity	None
Flow Control	None
Unit Size	5 Bytes

The serial communication structure is based on 2 main structures: Command Structure and Receive commands Structure. The 1st byte in the 5-bit command structure is the identification byte. After the inverter identifies a valid A5H as the identification byte it will start to read the next four bytes. After the inverter reads a valid command (examples in **Table 9**) it will give a response based on the Receives Command (examples in **Table 10**).

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Table 9 Transmit Command Structure

Command	ID	CMD	LSB	MSB	CK
Set Speed	A5h	C3h	Speed (RPM)		CK
Read Set Speed	A5h	3Ch	80h	39h	CK
Read Operation Status	A5h	3Ch	83h	39h	CK

Table 10 Receive Command Structure

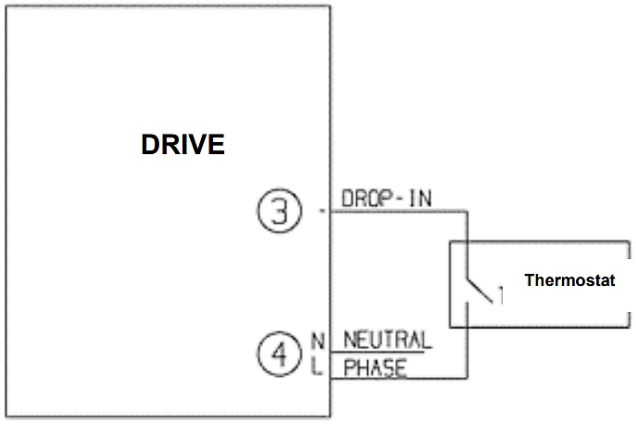
Response to	ID	CMD	LSB	MSB	CK
Set Speed	5Ah	83h	Status*		CK
Read Set Speed	5Ah	80h	Speed (RPM)		CK
Read Operation Status	5Ah	83h	Status*		CK
Communication Error	5Ah	Code* *	FFh	FFh	CK

* See Status Data table
**See Error Code table

Drop In Control Mode

Drop-in control mode does not require sensors to operate, only the thermostat outputs (On/Off and Optional Defrost).

Figure 12 Thermostat and Drive Connections using Drop-in Control Mode



NOTICE

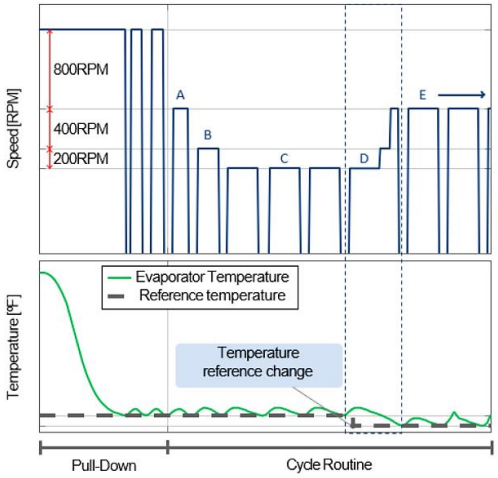
Whenever the drive is turned-off from the power grid, the Drop-in logic will start at pull-down routine when it is powered on next.

The Drop-in mode was designed with focus on meeting the cooling capacity and efficiency. The logic can be split into two main routines:

- Pull Down Routine;
- Cycle Routine

Both routines are described further in the next section below. **Figure 13** below shows an example of what the drive routines and RPM adjustments look like during a on cycle.

Figure 13 Pull-down and Cycle Routine in the Drop-in Control Mode



Upon startup, the appliance will immediately go into pulldown routine for the first three (3) cycles as shown on **Figure 13** above. Afterwards, the speed is adjusted to achieve the Target Time On (A and B cycles), then once the routine reaches the TTO, it will maintain a stable compressor speed (C cycle). In case the appliance temperature setpoint changed (D cycle), the speed will be increased or decreased to find a new stable condition (E cycle).

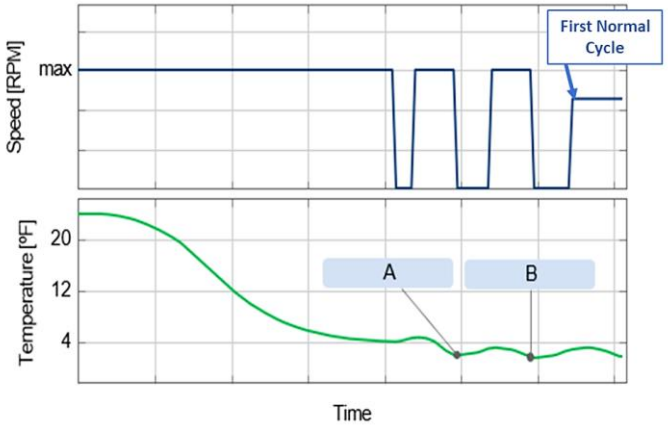
Pull Down Routine

When the drive is powered up, the logic considers a pull-down state, and the compressor runs on the maximum allowed speed to reduce the pull-down time. To identify the end of pulldown, the system compares the two last measured load values when the thermostat sends turn-off signal. If this variation is inside a specific range, the pull-down is considered as finished.

Figure 14 shows an example of the pull-down behavior, presenting the speed and cabinet temperature waveform. The difference between the measured load at turn-off on the couple first cycles is large, which indicates that the cabinet temperature is not stable, and the appliance should continue in pull-down. However, when the difference between the measured load at turn-off on two consecutive cycles is small, as shown at points A and B, this indicates that the temperature is uniform and stabilized. Thus, the appliance exits pull-down and enters normal cycle mode.

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Figure 14 Pull-down Routine



Drop-In Parameters

Before using the Copeland Drop In software to optimize your drive, please read the **End User License Agreement in Appendix B**. The Drop-In parameters including the description and range of values are shown on the table below.

Table 11 Drop-in Parameters Range and Default Values

Parameters	Description	Min Value	Max Value	Default	Unit
Minimum Speed Step	Defines the minimum step of speed of the compressor. This parameter will affect the increase and decrease of speed	10	1000	200	RPM
Target Time On (TTO)	Maximum time the compressor should be ON each cycle. The control will adjust the speed taking this value as reference.	1	1092	75	minutes
Target Time On Timeout (TTO Timeout)	Time after the cycle reaches the TTO, where the logic will increment speed each time it reaches TTO Timeout.	1	1092	20	minutes
Disturbance Detection	Determines the sensibility of the system to detect thermal load variations. The higher the gain, less sensitive is the system.	0.25	4	100	x
Max Speed	Maximum compressor speed allowed.	Min Speed	Max Compressor Speed	4500	RPM
Min Speed	Minimum compressor speed allowed.	Minimum Compressor Speed	Max Speed	1800	RPM

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Cycle Routine

The normal logic is the main routine and it controls the compressor's behavior during the entire working time after pull-down. This routine is composed by three (3) methods that run in parallel.

- Stability
- Heavy Duty
- Defrost Routine

Stability

This is the main method of Smart Drop-in; it selects the optimal speed to run the compressor to achieve the Target Time On (TTO). The TTO parameter is selected by using the Variable Frequency Drive Software. This is the most important parameter in the Drop-in control mode, and it needs to be determined based on tests with appliance.

Table 12 Smart Drop-in Variables

Variables	Description
Next_Speed	Indicates the speed of the next cycle
Current_Speed	Indicates the speed of the next cycle
Min_Speed_Step	Defines the minimum speed step of the compressor (default value is 100 RPM)
TTO (Target Time On)	Maximum time the compressor should be ON at each cycle
TTO_Timeout	Time where the logic will increment speed after the cycle reaches TTO
N	Number of steps performed after reaching TTO

Table 12 presents the 6 key variables that are necessary to understand the logic of how the drive controls the compressor. The variables can also be modified to the user's preferences that can help determine recovery time and optimize the systems performance. For stability routine the Minimum speed step and TTO variables will be important.

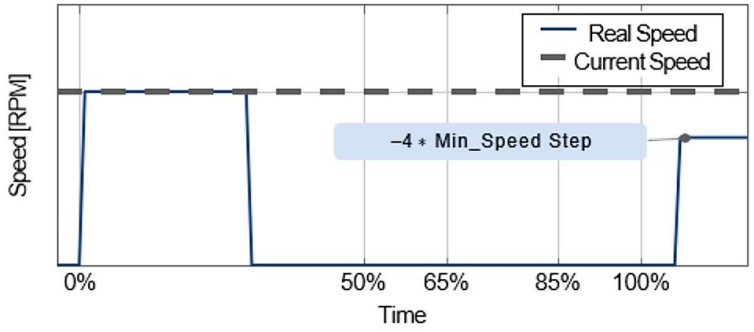
As described above, the Target Time On (TTO) is the first important parameter that must be selected on the drive. This is the amount of time you want the compressor to run for to reach set point per on cycle. Once the TTO is set the drive will adjust the compressors speed based on its prior cycles run time to allow it to better satisfy the set TTO on the next cycle. **Figures 15-21** below describe the 5 possible actions the drive can perform to best optimize its speed.

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Table 13 Drop-in Control Mode Logic

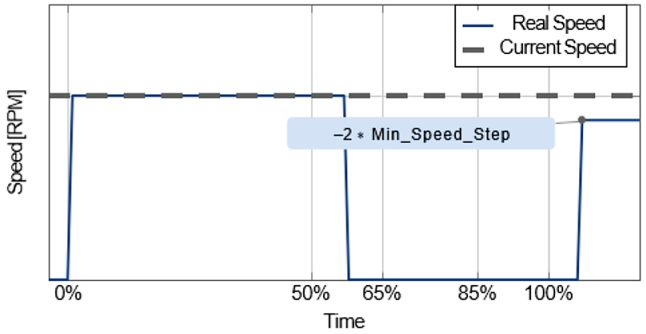
Cycle Time on Value	Possible Actions (Next_Speed)
If less than 50% of TTO	Current_Speed – (4* Min_Speed_Step)
If between 50% to 65% of TTO	Current_Speed – (2* Min_Speed_Step)
If between 65% to 85% of TTO	Current_Speed – (1* Min_Speed_Step)
If between 85% to 100% of TTO	Current_Speed
If greater than TTO but cycle ends after 50% of TTO_Timeout	Current_Speed + (Min_Speed_Step*N)
If greater than TTO but cycle ends before 50% of TTO_Timeout	Current_Speed

Figure 15 Cycle Time On is less than 50% of TTO



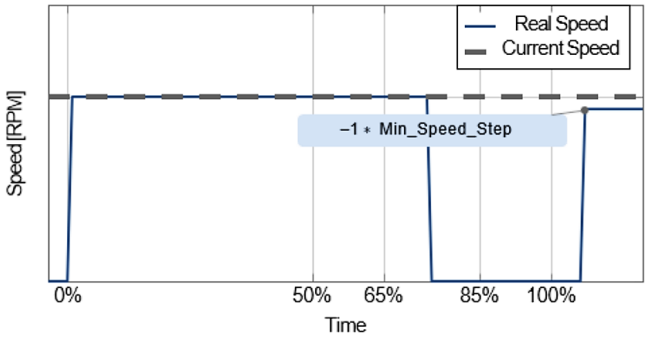
If the Target Time On (TTO) is set on the drive for 20 minutes and the system gets to the set point in less than 10 minutes, it means the compressor is running much faster than it needs to satisfy the TTO. As **Figure 15** shows, to try and improve its speed the drive will take the current speed and decrease it by 4 minimum speed steps.

Figure 16 Cycle Time On between 50% to 65% of TTO



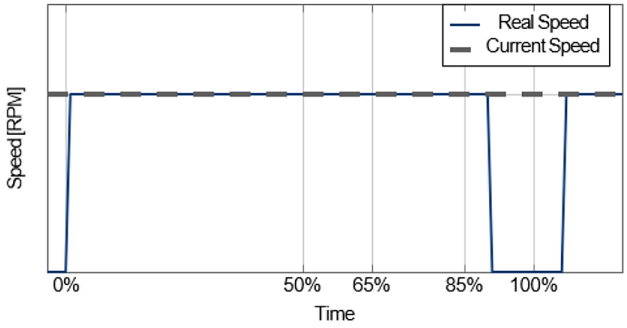
If the Target Time On (TTO) is set on the drive for 20 minutes and the system gets to the set point between 10-13 minutes, it means the compressor is still running faster than it needs to satisfy the TTO. The drive will decrease its speed by 2 minimum speed steps to get closer to the TTO time of the compressor as shown in **Figure 16**.

Figure 17 Cycle Time On between 65% to 85% of TTO



If the Target Time On (TTO) is set on the drive for 20 minutes and the system gets to the set point between 13-17 minutes, it means the compressor is still running faster than it needs to satisfy the TTO. In this case the drive will only decrease the speed by 1 minimum speed step as shown in **Figure 17**.

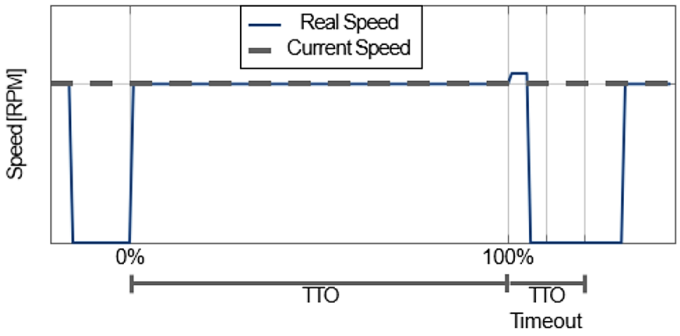
Figure 18 Cycle Time on Greater than 85% but less than TTO



If the Target Time On (TTO) is set on the drive for 20 minutes and the system gets to the set point between 17-20 minutes, it means the compressor is running at a speed that satisfies the TTO. In this case the drive will not change the speed and will run the same speed during its next on cycle as shown in **Figure 18**.

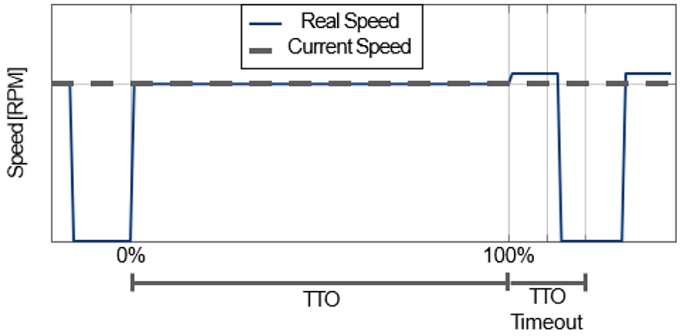
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Figure 19 CTO > TTO cycle ends before 50% TTO Timeout



In the event where the cycle time on runs longer than the set TTO the drive will increase the compressor speed by your minimum speed step times the number of steps after TTO (N variable) to get to set point quickly. In the case where the cycle time on runs longer than the set TTO and shorter than 50% of your manually set TTO Timeout the compressor will temporarily increase its speed by your minimum speed step multiplied by the number of steps after TTO (N variable) to get to set point quickly as shown in **Figure 19**. The next time the compressor runs it will go back to running its original speed from the last cycle.

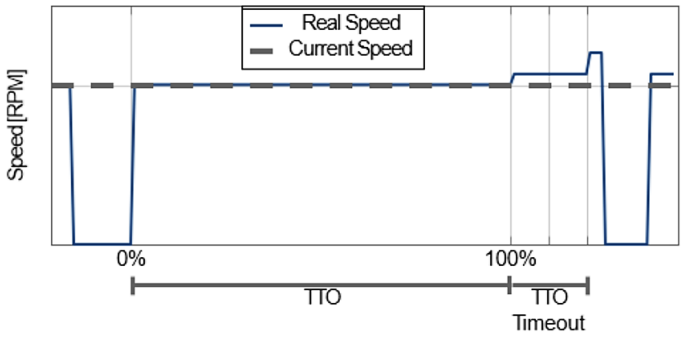
Figure 20 CTO > TTO cycle ends after 50% TTO Timeout



If the cycle time on runs longer than the set TTO and longer than 50% of your manually set TTO timeout the compressor will temporarily increase its speed to get to set point quickly as shown in **Figure 20**. When the drive cycles on again it will start at its final speed from the last cycle. In an example where your TTO is set to 20 minutes and your TTO Timeout is set to 5 minutes; if your compressor runs for 24 minutes to reach set point the drive will increase the speed by your minimum speed step multiplied the number of steps N until it reaches set point. Once the drive cycles back on it will run at the final speed from the last cycle.

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Figure 21 Cycle Time On larger than Target Time On

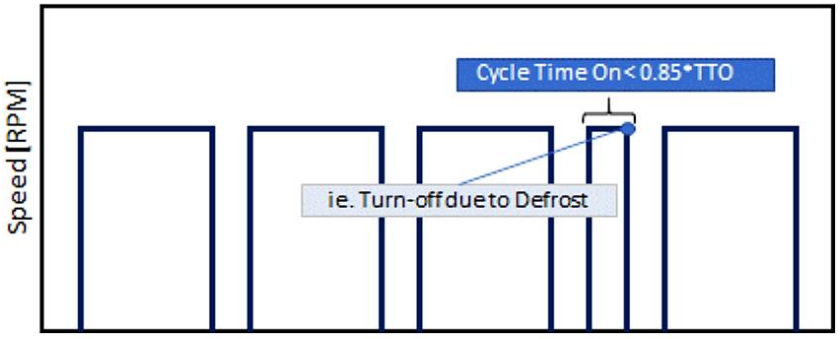


In the event where the compressor runs longer than the specified TTO and the speed increase cannot satisfy the TTO Timeout, the drive will run the compressor at max speed until the set point is satisfied. The next on cycle will start at the step speed during the TTO timeout as shown in **Figure 21**.

Lock Decrease

The Smart Drop-in logic has a method to avoid changing stable speed due to a single short cycle as presented on Figure 22. This is to avoid losing stability because due to a cycle that ended due to a defrost. Therefore, in such cases, the speed decrease is allowed just after two (2) consecutive reduction requests.

Figure 22 Lock Decrease



Heavy Duty

This method runs on background to identify disturbances or exceptional cases during equipment operation. It checks the compressor's load, which is proportional to the evaporator temperature. The speed will increase if the load deviation matches one of the predefined patterns. Each pattern has a different speed step multiplier.

The disturbances or exceptional cases can be caused by different types of actions such as door openings, reloads, defrosts, changes on room temperature or other events that can affect the thermal load from the appliance.

Figure 23 shows an example of a large disturbance, in which the logic increases the compressor speed (cooling capacity) to make the appliance return to desired temperature.

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Figure 23 Large Disturbance

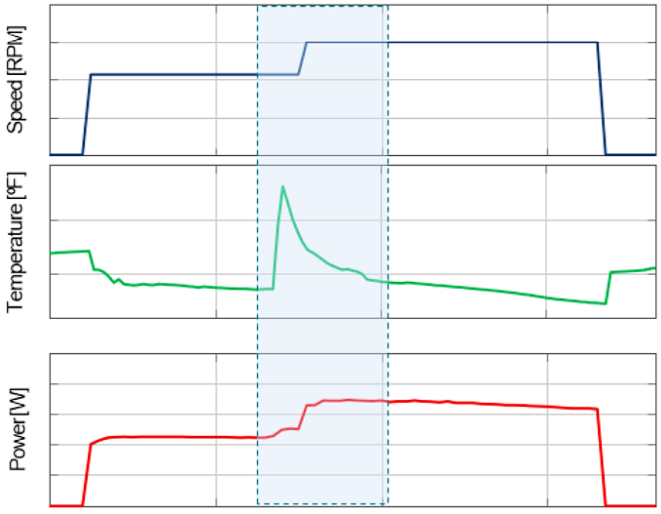
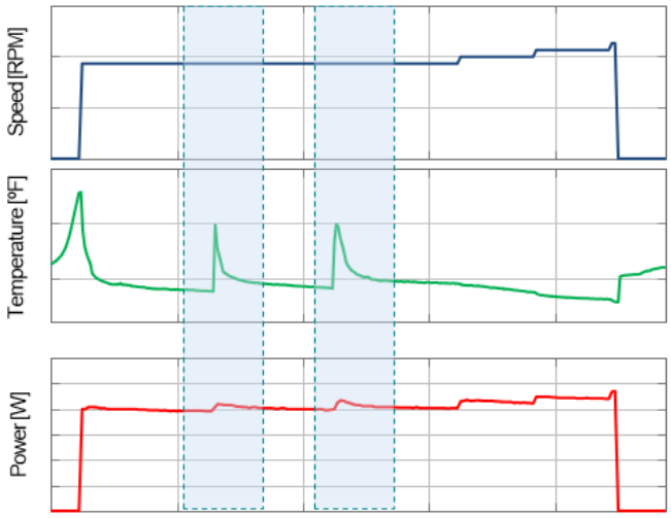


Figure 24 shows an example where the disturbance is so small that there is no need to increase compressor speed (cooling capacity).

Figure 24 Small Disturbance



To detect disturbances that may happen while the compressor is turned-off and there is no load to measurement, the drive also compares the load difference between the current and last cycles during the first minutes of operation. If the current cycle's measurement is higher than the last, the logic will consider that a disturbance on the appliance's temperature happened, and the speed will change.

It is important to note that this detection depends on measurements received by the drive, Thus, depending on the characteristics of the system, some events may not be detected by this method. Considering this scenario, the user can improve the method precision by changing the parameter 'Disturbance Detection' on the Copeland Variable Speed Reciprocating Compressor Drive Software.

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NOTICE

This routine needs 6 minutes to start compressor's load measurement after the thermostat sends a turnon signal. This is required to avoid incorrect load measurements due compressor startup and pressures stabilization.

Defrost Routine

This method aims to improve the appliance operation while or after a defrost happens. The type of defrost (heater or hot gas) is also considered when performing actions accordingly. For both defrost cases, the cycle after defrost will start at higher speed in order to recover the appliance internal temperature faster; furthermore, during hot gas defrost the compressor will increase speed to maximum in order to increase heating capacity and reduce defrost duration. There are two possible ways of using the defrost routine:

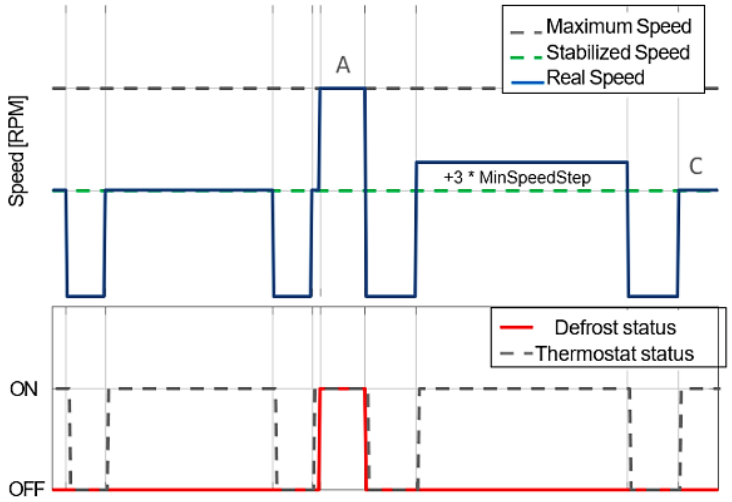
- with defrost input signal or
- without defrost input signal

This signal needs to be connected to drive defrost input.

With Defrost Input Signal

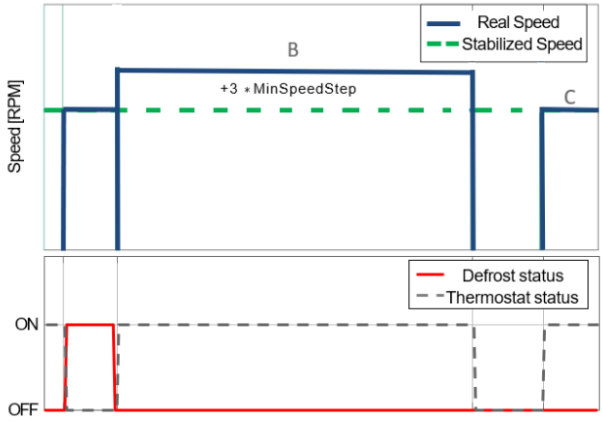
The use of this additional signal enhances the defrost detection and allows the method to act instantaneously. **Figure 25** shows an example of the hot gas defrost behavior. When the defrost input is activated while thermostat is on the compressor speed is set to the maximum value (step A). On the cycle after defrost (step B), the compressor speed is increased by 3 'Minimum Speed Steps' based on stabilized speed. Afterwards, the speed will resume to the stabilized speed (step C).

Figure 25 Hot gas Defrost Response with Defrost Input



The use of a heater with defrost pin is presented on Figure 26. in this case, the Smart Drop-in will increase the compressor speed on the cycle after defrost (step B), to recover the appliance internal temperature faster, and resume to the stabilized speed (step C).

Figure 26 Heater Defrost Response with Defrost Input



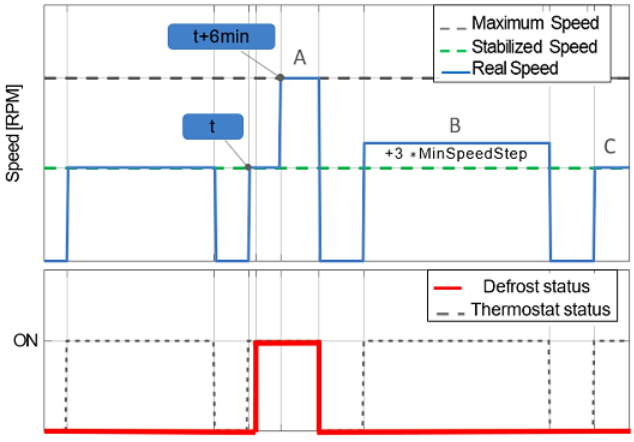
NOTICE

By using the signals of Thermostat (Drop-in) and Defrost, the method will detect automatically the defrost type (heater or hot-gas).

Without Defrost Input Signal

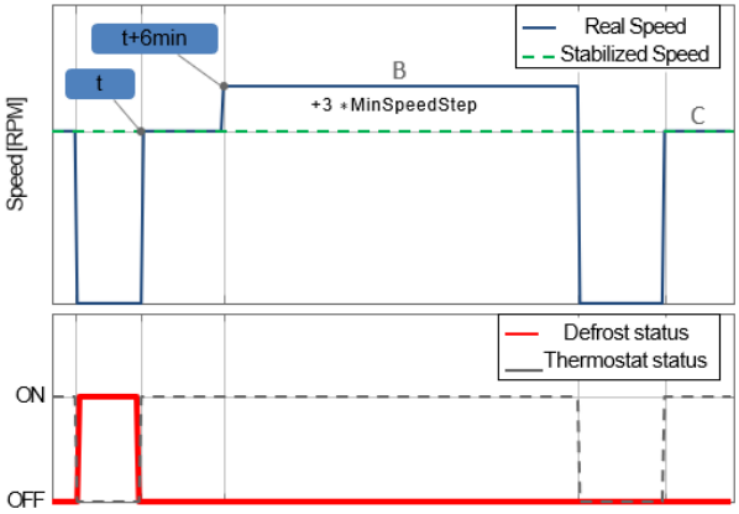
The compressor load measurement is used to detect if a defrost is happening or happened during the last turn-off, however, this measurement is only performed 6 minutes after the cycle starts. This delay is needed to avoid incorrect measurements due to compressor startup. **Figure 27** presents an example of the hot gas defrost behavior without defrost input. The defrost is detection happens after 6 minutes, when the compressor speed is set to the maximum value (step A). On the cycle after defrost (step B), the compressor speed is increased by 3 'Minimum Speed Steps' based on stabilized speed. Afterwards, the speed will resume to the stabilized speed (step C).

Figure 27 Hot gas Defrost without Defrost Input



The use of a heater defrost without defrost pin is presented on Figure 28. in this case, the Drop-in will have a 6 minutes delay to increase the compressor speed on the cycle after defrost (step B). The next cycle will start with the previous stabilized speed (step C).

Figure 28 Heater Defrost without Defrost Input



NOTICE

The figure is considering the 6 min detection, if the detections was caused by the defrost pin, the cycle will start with the speed in +3 Min Speed Step.

Copeland Variable Speed Reciprocating Compressor Drive Software

This section covers the installation of the Variable Frequency Drive Drop-In Software as well as the hardware connections required. This software is to be used when operating with the Drop-In Control mode to set the parameters and optimize your system.

Using the Software

To become more familiar with the setup of the Drop-In software interface please use Appendix A in this document as it shows the quick start guide for setting up the hardware to communicate to the drive and the two programs that are used.

Minimum System Requirements

For normal operation, the following minimum system requirements must be meet.

- Operating system: Windows 7, Windows 8 or Windows 10 or higher;
- Available hard-disk memory: 40 MB ’Copeland Control Development Tool’ and ’10 MB for ’You Control Production Tool’;
- .NET Framework: 4.5 or higher;
- DirectX: 9 or higher;

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- Available USB port: 1 port 1.1 or 2.0 standard.

Software Interface Installation

Please see **Appendix A** for the step-by-step interface installation procedures on your computer.

NOTICE

Before using the Drop-In Software please see Appendix B and read the End User License Agreement.

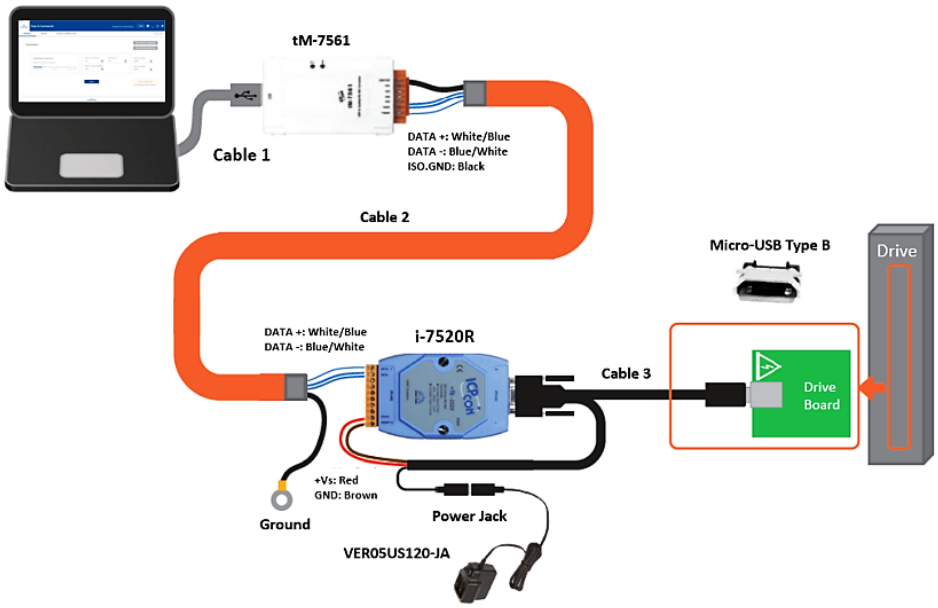
Modules

The Copeland Control Kit includes:

- 2.5 kV isolation USB/RS485
- 3 kV isolation RS485/RS232
- 3kV isolation 12V power supply
- RS485 Cable
- USB to USB cable (type A to type B)

Figure 29 below shows the overview of the kit and how they are connected.

Figure 29 Copeland Control Kit Connections



WARNING

To avoid serious electrical shock to user and damage to the drive do not handle Cable 3, the i-752R module or the VER05US120-JA supply with the drive powered on.

NOTICE

Avoid the use of serial communication with the drive while using the Variable Frequency Drive Software.

Hardware Connections

Please see **Appendix A** for the step-by-step installation of the cables and modules.

Copeland Variable Speed Reciprocating Compressor Drive Software

The Variable Frequency Drive Software was developed by Copeland to allow the customization of the drive Smart Drop-in control mode, enabling the user to change parameters and find an optimal operation condition for each appliance. This customization can be in real-time done during development stage, adjusting the parameters to meet the appliance requirements and standards. The selected set of parameters will be latter used in the final product. The interface also presents information about the compressor, such as real speed, power. All this information can also be exported to a spreadsheet file.

Please see **Appendix B** for the information and guide how to navigate Variable Frequency Drive Software.

Diagnostics

The drives have two diagnostics method:

1 Using LED indication
2 Using serial communication protocol

LED Indication

Normal Operation
When the drive is in a normal state (no protection and fault), the LED will flash GREEN once for 30 seconds.

Communication Problem
When the drive is having communication fault, the LED will flash GREEN two (2) times for 5 seconds. Refer to the Troubleshooting section within the Addendum for more information.

Drive Problem
When the drive is the one having problem, the LED will flash RED three (3) times for 5 seconds. Refer to the Troubleshooting section within the Addendum for more information.

Compressor Problem
When the there's a compressor fault, the LED will flash ORANGE four (4) times for 5 seconds. Refer to the Troubleshooting section within the Addendum for more information.

No Power or Damaged Drive
The LED will have no light, when there's no power or the drive was damaged,

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Table 14 LED Status Description

LED Status	Period	Color	Description
1 Flash	30s	Green	Normal
2 Flashes	5s	Green	Communication Problem
3 Flashes	5s	Red	Drive Problem
4 Flashes	5s	Orange	Compressor Problem
No Flash	-	-	No Power / Damaged Drive

Note: The drive does not have the capability to recall recent LED status

Troubleshooting

The drive may indicate fault or protection for various reasons. If fault or protection occurs, users should power down the drive, check the drive, and check the drive running condition carefully. For the description, check and handling of these faults or protections, please refer to the table below.

Compressor Does Not Start

Problem	Action
Compressor disconnected from the drive	Verify the compressor cable connection
No AC power supply; or wrong voltage/terminals connected	Verify AC input cable connection and measure AC input voltage.
No control signal input or bad connection	Verify control input cable connection and measure the signal from the thermostat.
Blown fuse (due to previous major failure)	Return the unit to manufacturer, replacing it with new one.
Open compressor motor winding	Measure winding for open circuit between all pair of pins on the hermetic terminal. If any winding is open, return compressor to manufacturer.
Compressor with locked rotor (due to mechanical damage)	Replace compressor with new one and test for confirmation. Return damaged unit to manufacturer.
Dropped, damaged, burnt drive	Replace with new one and test for confirmation. Return damaged unit to manufacturer.
Drive on waiting time after failed start	Wait the necessary time or reset the drive disconnecting it from the AC power supply. The reset time is about 50s.
Demagnetized rotor (only if compressor was previously connected directly to the AC power supply)	Replace compressor with a new one and test for confirmation. Return damaged unit to manufacturer.
Unequaled pressures between discharge and suction pressures in the refrigerating system	Allow the drive to equalize pressure between suction and discharge sides.
Low input voltage supplied to the drive	Measure AC voltage to confirm

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Compressor Does Not Run at Selected Speed

Problem	Action
High compression load, with compressor being subjected to a stall condition.	Review system design, refrigerant gas load or compressor capacity is not suitable for the application. If system is appropriated designed, speed will reach set value when load condition is stabilized.
No or incorrect control signal.	Check if the appropriate control signal is being correctly applied to the Control Input Connection.

Drop-in Does not work properly

Problem	Action
Connection Timeout	Verify if Copeland Control Kit' modules and cables are correctly connected. Check if USB port (PC) is working. Check if PC is recognizing the virtual COM. Check if the correct COM port was selected.
Copeland Variable Speed Reciprocating Compressor Drive Software Communication Error	If the interface doesn't reduce automatically the baud rate, stop the test, slide the 'Auto Baud Rate' to Off mode and set a lower baud rate (acceptable values 600, 1200, 2400, 4800, 9600). Check Error Code table on Table 12
No control signal input or bad connection	Check that the drive power supply. Check thermostat signal connection to the Drop-in input.

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Appendix Section

Appendix A: Quick Start Guide for Drop-In Control Mode setup of Copeland Variable Speed Compressor Drive

WARNING

To avoid serious electrical shock to user and damage to the drive do not handle Cable 3, the i-752R module or the VER05US120-JA supply with the drive powered on.

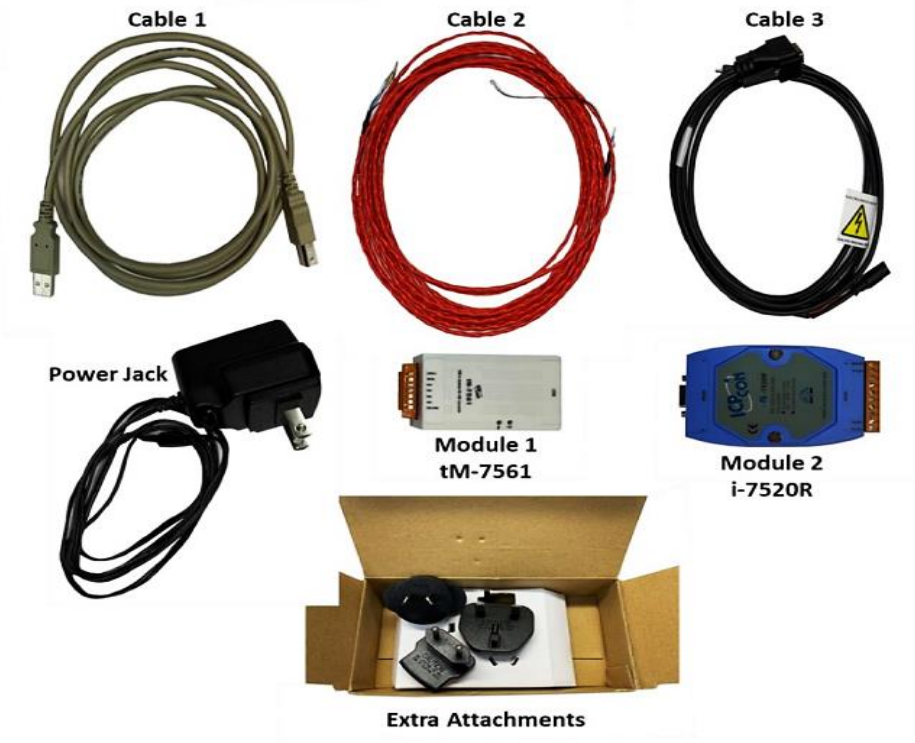
NOTICE

Avoid the use of serial communication with the drive while using the Copeland Variable Speed Reciprocating Compressor Drive Software.

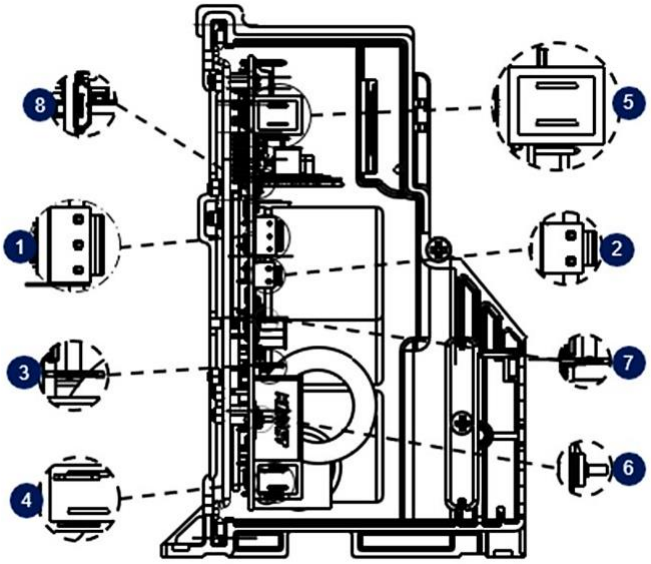
Overview

Thank you for choosing Copeland Variable Speed Reciprocating Compressor Drive. This document guides you through connecting the Variable Frequency Drive to your computer for the initial set up and install of the drive for the drop in control mode. For more details on its application please refer to AE-1437 bulletin. For guidance on testing and optimizing the drive for your application contact Application engineering.

Package Contents



Drive Ports Layout



Connector Locations	
Number	**Description**
1	Serial Communication
2	Frequency Input
3	Drop In
4	AC input (L+N)
5	AC Fan*
6	EMI Earth
7	Defrost Input
8	Software Input

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Connecting the Hardware

Materials Needed

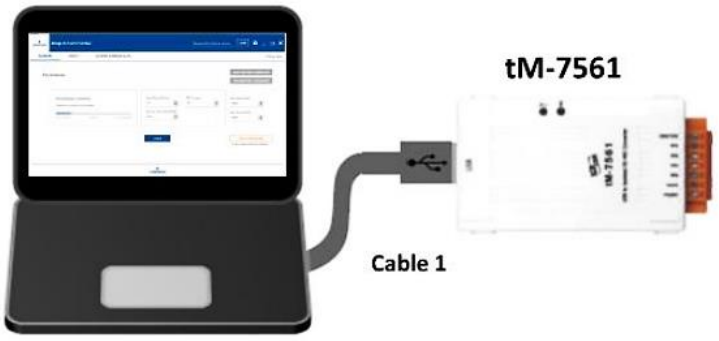
- 1 pc. flat head screw drive (2.4mm)
- Copeland Drop-in Control Kit

Procedures

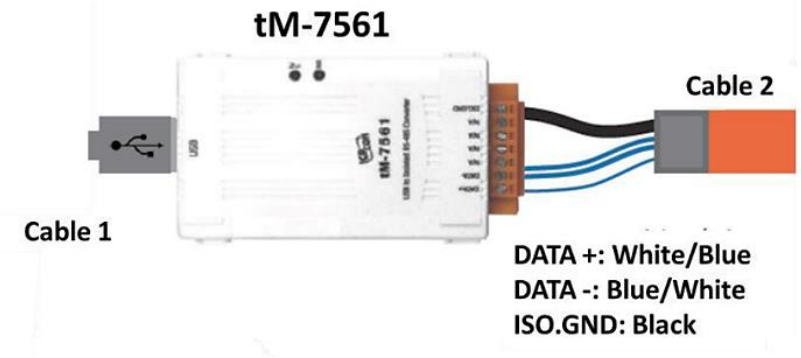
1 Check all drive connector/module kits are complete and damaged-free.

2 Make sure the inverter is powered off while connecting hardware

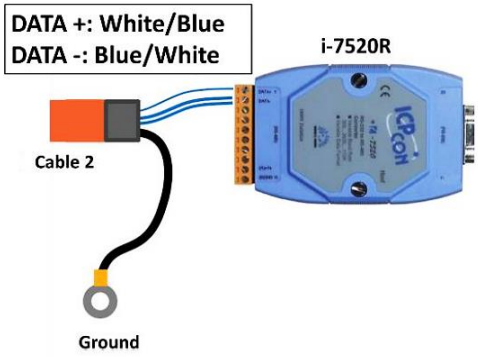
3 With the drive OFF, connect Gray CABLE 1 from the USB port of the PC or Laptop to White MODULE 1



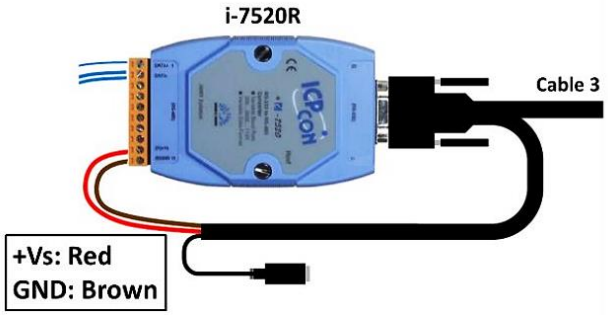
4 With the drive OFF, connect Red Cable 2 to Module 1 as shown below.



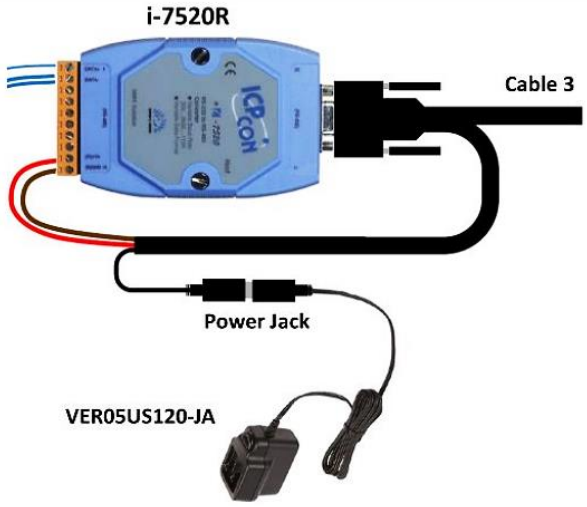
5 With the drive OFF, connect the other end of Red CABLE 2 to Blue MODULE 2 as shown below. Note: Grounding connection is optional but recommended to reduce any noise.



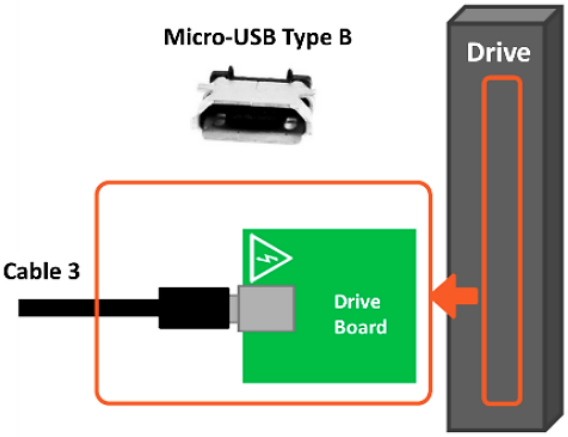
6 With the drive OFF, connect the red and brown wires of Black CABLE 3 into Blue MODULE 2. Also connect the DB9 connector on the other side as shown below.



7 Connect the power supply into the designated connection on Black CABLE 3. **Do not plug in wall jack yet*

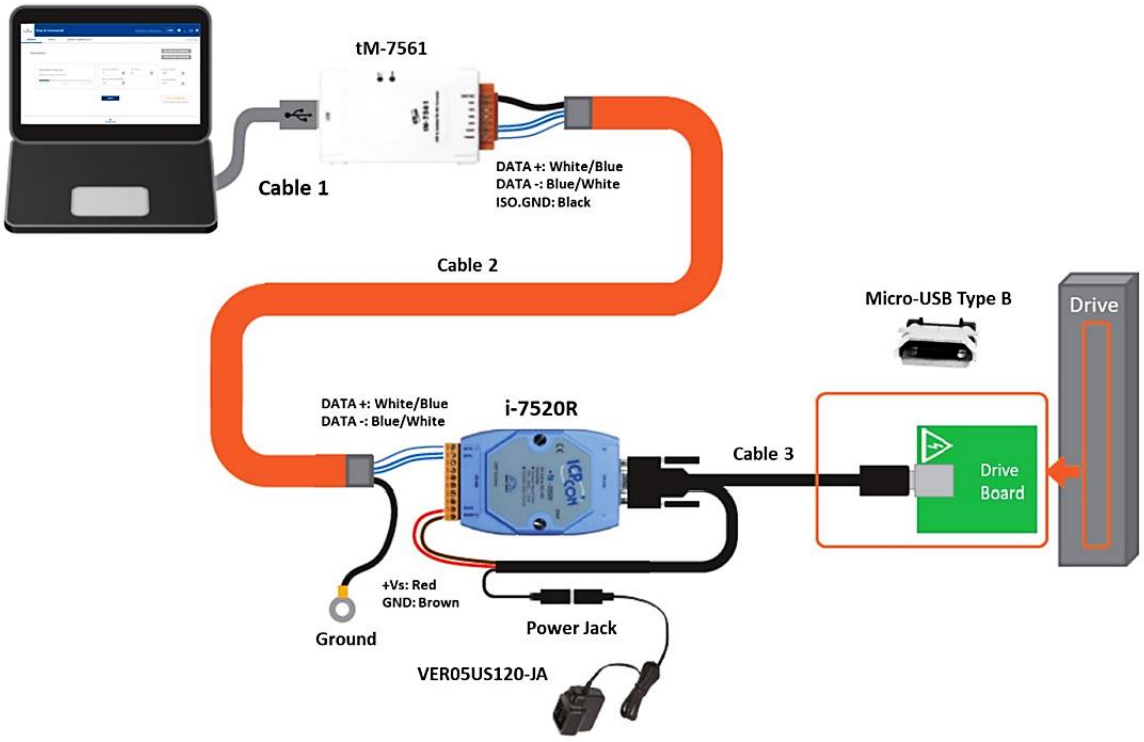


8 Connect Black CABLE 3 on the micro-USB port on the drive (port 8 as shown in Figure 1 above)



9 After all connections are made, the power jack can be connected to add power to the system.

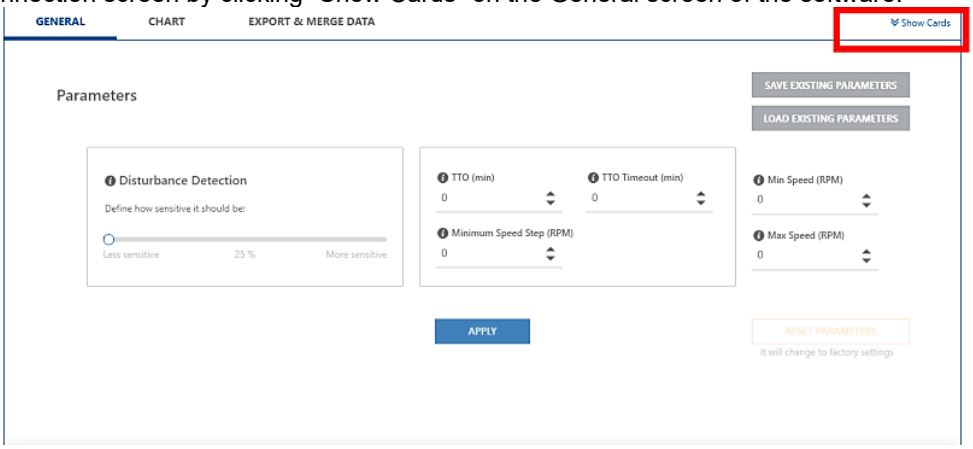
10 After connecting all the cables and modules, the full setup should look like below:



Loading the Parameters using the Development Tool

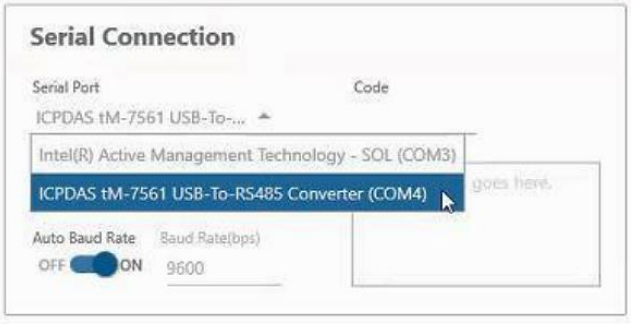
Note: The steps below assume that all desired parameters enumerated on AE-1437 has been established

1 Contact Application Engineering to obtain a copy of the software. Download and install on your computer.
2 After installation, connect the drive to the laptop using the procedures enumerated on Section 4 of this document.
3 On your computer or laptop, open the variable speed software by double-clicking its icon.
4 Go to the connection screen by clicking “Show Cards” on the General screen of the software.

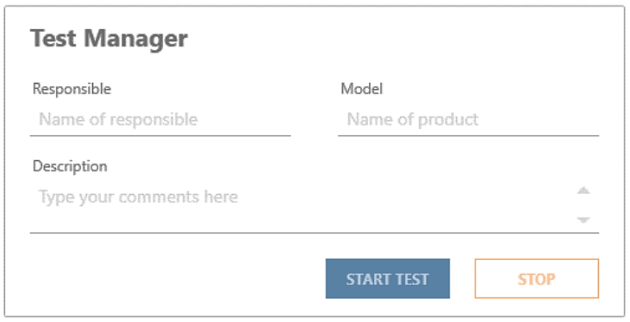


5 On the serial port select ICPDAS tM-7561 USB-To-RS485 Converter. Set Auto Baud Rate to ON.

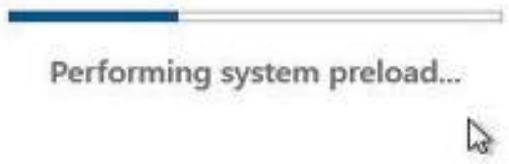
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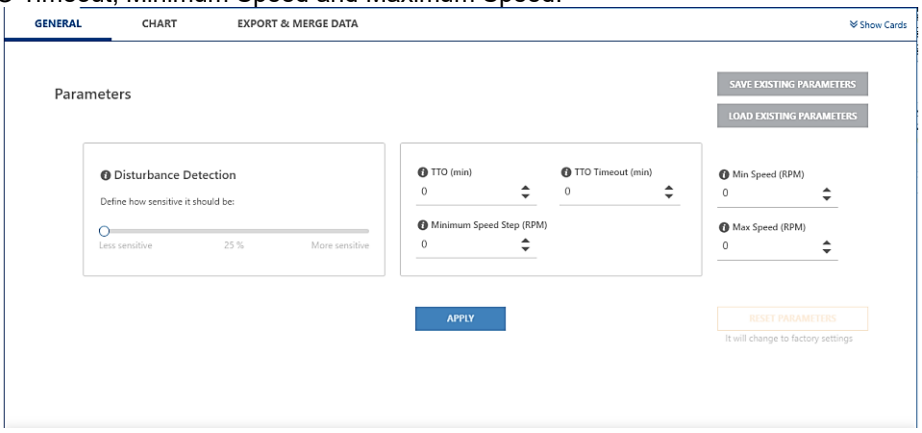
6 On the same page, enter the details of the test including who is doing the test, model and description. Click “Start Test”.



7 Wait for the system to pre-load. If an error occurs, a code and description will be displayed.



8 Go back to the general tab to view the default parameters loaded on the drive such as Target Time ON, Minimum Speed Step, TTO Timeout, Minimum Speed and Maximum Speed.

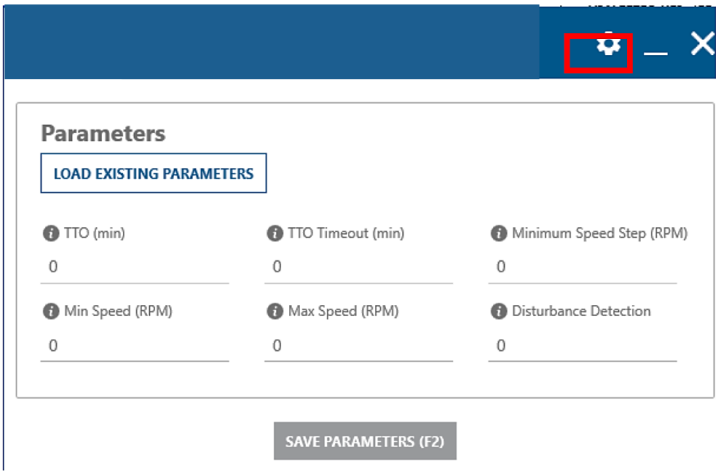


9 Each parameter can be changed manually and saved to the drive clicking “Apply” button.

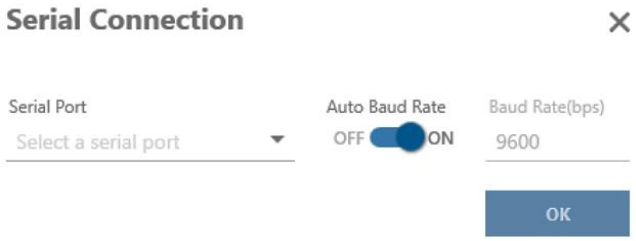
Loading the Parameters using the Production Tool

Note: The steps below assume that all desired parameters enumerated on AE-1437 has been established

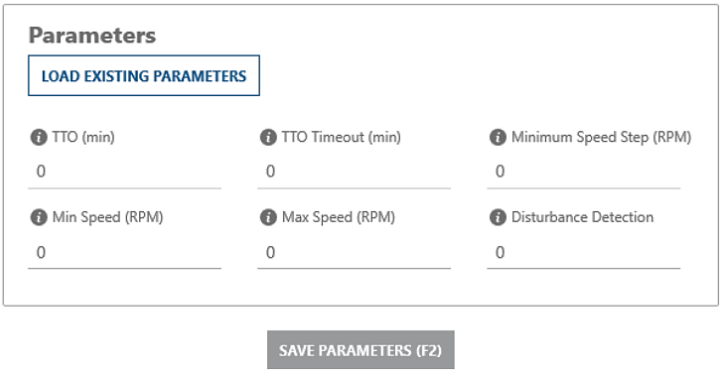
1 To download the software, open your browser using a PC or laptop go to Copeland Online Product Information website.
2 Click “Software Downloads”
3 Connect the drive to the laptop using the procedures on Section 4 of this document.
4 On your computer or laptop, open the variable speed software by double-clicking its icon.
5 Go to the connection screen by clicking on the gear icon on the top right of the screen



6 On the serial port select ICPDAS tM-7561 USB-To-RS485 Converter. Set Baud Rate to ON. Click “OK”.



7 Click “Load Existing Parameter” if you have reference file containing established parameters. Click “Save Parameter” to save the parameters into the drive.



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Appendix B: Copeland End User License Agreement

Copeland Cold Chain End User License Agreement

June 1, 2023

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iii. Arbitration Agreement. Any claims by Copeland, or claims by Licensee not resolved by the informal resolution procedure or in small claims court as provided above, arising out of, relating to, or connected with this EULA or the Software Product must be asserted individually in binding arbitration administered by the American Arbitration Association ("AAA") in accordance with its Commercial Arbitration Rules and Supplementary Procedures for Consumer-Related Disputes (including utilizing desk, phone or video conference proceedings where appropriate and permitted to mitigate costs of travel). This EULA and each of its parts evidence a transaction involving interstate commerce, and the Federal Arbitration Act (9 USC §1, et. seq.) will apply in all cases and govern the interpretation and enforcement of the arbitration rules and arbitration proceedings. The arbitration shall be held at a location determined by AAA pursuant to the Rules and Procedures (provided such location is reasonably convenient for you), or at such other location as may be mutually agreed by Licensee and Copeland. Judgment on the award rendered by the arbitrator may be entered in any court of competent

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jurisdiction. In addition to and notwithstanding the terms stated above, the following will apply to your dispute(s): (1) thearbitrator, and not any federal, state, provincial, or local court or agency, will have exclusive authority to resolve any dispute relating to the interpretation, applicability, enforceability, or formation of this EULA including any claim that all or any part of this EULA is void or voidable; (2) the arbitrator will not have the power to conduct any form of class or collective arbitration nor join or consolidate claims by or for individuals; (3) the arbitrator's decision shall be controlled by the terms and conditions of this EULA and any of the other agreements referenced herein that Licensee may have entered into in connection with the Services; (4) the arbitrator shall apply Delaware law consistent with the AAA and applicable statutes of limitations, and shall honor claims of privilege recognized at law; (5) to the extent permitted by law, the arbitrator shall not have the power to award punitive, incidental, or consequential damages against Licensee or Copeland; (6) in the event the administrative fees and deposits that must be paid to initiate arbitration against Copeland exceed $125 USD for claims less than $10,000 or $375 for claims greater than $10,000 but less than $75,000, and Licensee is unable (or not required under the applicable Rules and Procedures) to pay any fees and deposits exceeding this amount, Copeland agrees to pay and/or forward them on Licensee’s behalf, subject to ultimate allocation by the arbitrator. Further, if Licensee can demonstrate the costs of arbitration will be prohibitive as compared to the costs of litigation, Copeland will pay as much of Licensee’s filing and hearing fees in connection with the arbitration as the arbitrator deems necessary to prevent the arbitration from being cost-prohibitive; and (7) with the exception of subpart (3) above, if any part of this arbitration provision is deemed to be invalid, unenforceable or illegal, or otherwise conflicts with the Rules and Procedures established by AAA, the balance of this arbitration provision shall remain in effect and shall be construed in accordance with its terms as if the invalid, unenforceable, illegal, or conflicting provision were not contained herein. If, however, subpart (3) is found to be invalid, unenforceable, or illegal, then the entirety of this Arbitration Provision shall be null and void, and neither you nor Copeland shall be entitled to arbitrate their dispute. For more information on AAA and/or AAA Rules and Procedures, visit the AAA Website at http://www.adr.org.

g. Third-Party Terms and Beneficiaries: Licensee must comply with all applicable third-party terms of agreement when using the Software Product. If Licensee is using the Software Product on an Apple iOS device or on a Google Android device, Apple and Apple’s subsidiaries and Google and Google’s subsidiaries, are third party beneficiaries of this EULA and upon Licensee’s acceptance of this EULA, Apple and Google will have the right (and will be deemed to have accepted the right) to enforce this EULA against your as a third party beneficiary thereof. Copeland affiliates are third party beneficiaries of this EULA and upon your acceptance of this EULA, Copeland affiliates will have the right (and will be deemed to have accepted the right) to enforce this EULA against Licensee as a third-party beneficiary thereof.

h. Entire Agreement: This EULA shall constitute the entire Agreement between the parties relating to the license of the Software Product. Any waiver or modification of this EULA shall only be effective if it is in writing and signed by both parties. If any part of this EULA is found invalid or unenforceable by a court of competent jurisdiction, the remainder of this EULA shall remain in full force and effect and shall be interpreted so as to reasonably effect the intention of the parties.

i. Assignability, Severability, Relationship, & Wireless or Mobile Charges: Except as provided in Section 10, Licensee’s rights and obligations under this EULA are not assignable. Copeland may freely assign its rights and obligations in its sole discretion and without notice to Licensee. This EULA shall bind and inure to the benefit of the parties and their successors and permitted assigns. If Copeland fails to insist upon or enforce strict performance of any provision of this EULA, it shall not thereby waive any provision or right. Neither the course of conduct between the parties nor trade practice shall act to modify any provision of this EULA. Both parties are acting as independent contractors with respect to the activities hereunder. The Software Product will communicate information using the wireless capabilities of Licensee’s Device. STANDARD DATA FEES AND TEXT MESSAGING RATES MAY APPLY BASED ON LICENSEE’S PLAN WITH ITS INTERNET AND/OR MOBILE PROVIDER.

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j. Contact Information: Copeland may be contacted at: 8100 West Florissant Ave., St. Louis, MO, USA 63136

Revision Tracking R3

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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