SMART Pulse Width Modulation Capacity Controller

Application Data

CONTENTS

GENERAL

In refrigeration applications where the thermal load may vary over a wide range, a means of precise capacity control is always desirable for optimum system performance, while maintaining low energy consumption. To meet these objectives, Carlyle has developed an innovative and efficient solution — the smart controller and pulse width modulation (PWM) valve, shown in Fig. 1. These new devices meet the demand for precise suction pressure control by modulating system capacity for all low, medium, and high temperature applications, providing leading edge performance in compressor cycling reduction, compressor life extension, and refrigeration system energy usage.

The smart unloading controller allows continuous modulation of the compressor capacity using the steps of mechanical unloading or PWM valve. An analog output signal from the system rack controller provides a 0 to 10 vdc signal to the smart controller. Based on the signal, the smart controller continuously modulates the compressor unloader coils to deliver an equivalent linear change in the compressor capacity output to precisely meet the load demand. In addition, the smart controller will control discharge temperature by operating the accessory cylinder head fan and liquid injection valve as required, maintaining safe and reliable operation. If discharge temperature exceeds allowable limits, the smart controller will automatically turn the compressor off to protect against compressor failure.

The smart controller is designed to operate a special solenoid valve installed in the compressor's suction line using pulse width modulation. As it does this, the smart controller will cycle the valve once every 30 seconds between the open (loaded) and closed (unloaded) positions. The relative duration of the loaded versus unloaded times creates a time average flow rate from the compressor that can be continuously varied. In turn, the time average flow rate from the compressor allows it to more precisely match the compressor capacity to the system cooling demand. A small bleed port in the solenoid valve keeps the compressor from pulling into a deep vacuum when the valve is in the closed position.

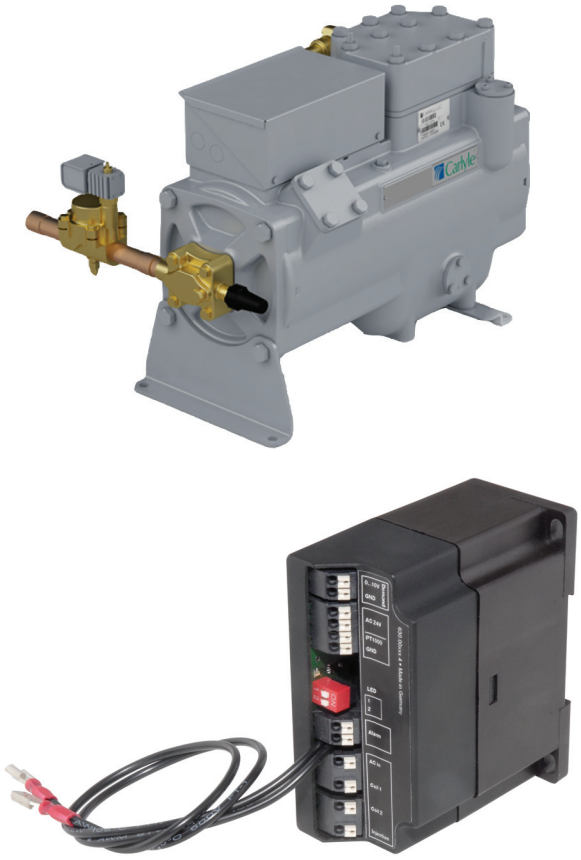


Fig. 1 — Smart Controller and PWM Valve

SYSTEM DESIGN CONSIDERATIONS

The smart controller is designed to operate with 06D, 06CC, and 06M compressor models for all low, medium, and high-temperature applications. Some 06E compressor applications may also be suitable for the PWM valve capacity control depending on the operating condition and pressure drop across the valve. See the Valve Selection section on page 7 for guidelines on valve selection.

Multiple Compressor Applications

The controller was designed primarily for rack refrigeration systems where multiple compressors share a common suction group and operate in tandem. Following these simple guidelines will ensure that the correct compressor is selected for smart unloading for a multiple compressor application.

- The compressor selected for PWM unloading should be designated as the lead compressor for the suction group. The compressor selected for PWM unloading should be the first compressor on and the last compressor off.
- Apply PWM unloading to only one compressor per suction group.
- Choose a compressor with the smallest capacity modulation range that covers the capacity gaps between stages of compressor capacity.
- A control signal (1 to 5 vdc) from the rack controller is a required input to the smart controller. Work with the rack controller manufacturer for implementation with the manufacturer's software. See the DIP Switch Setting section on page 3 for how input signal corresponds to the compressor load profile.
- A rack controller that has PID (proportional integral derivative loop) capability is recommended to provide the best control but is not required.

Control Module Specifications

Dimensions: 3.43 in. W x 1.57 in. H x 3.23 in. D
(87 mm W x 40 mm H x 82 mm D)

Control Voltage: 24 vac ± 10%, 50/60 Hz, 5va

Operating Range: –22°F to 158°F (–30°C to 70°C)

Ambient Enclosure Protection: IP20

Mounting: 35mm DIN rail or panel mount

Suction and Discharge Pressure Limits

The PWM valves can be applied across the full compressor operating envelope for the compressor. The operating envelopes can be found in the CARWIN™ rating software.

Discharge and Oil Temperature Limits

The cylinder head fan, return gas temperature, and oil temperature requirements are the same as the standard compressor and can be found in the compressor application guides.

Low Pressure Protection

It is recommended that a pressure transducer be installed on the compressor to allow the system controller to monitor crankcase pressure. It should be set up to trip the compressor off if in a vacuum for more than 120 seconds.

CONTROL MODULE

Figure 2 shows the connection points to the controller. These connection points are each described in more detail below. Figure 4 on page 4 shows the wiring diagram for the control module.

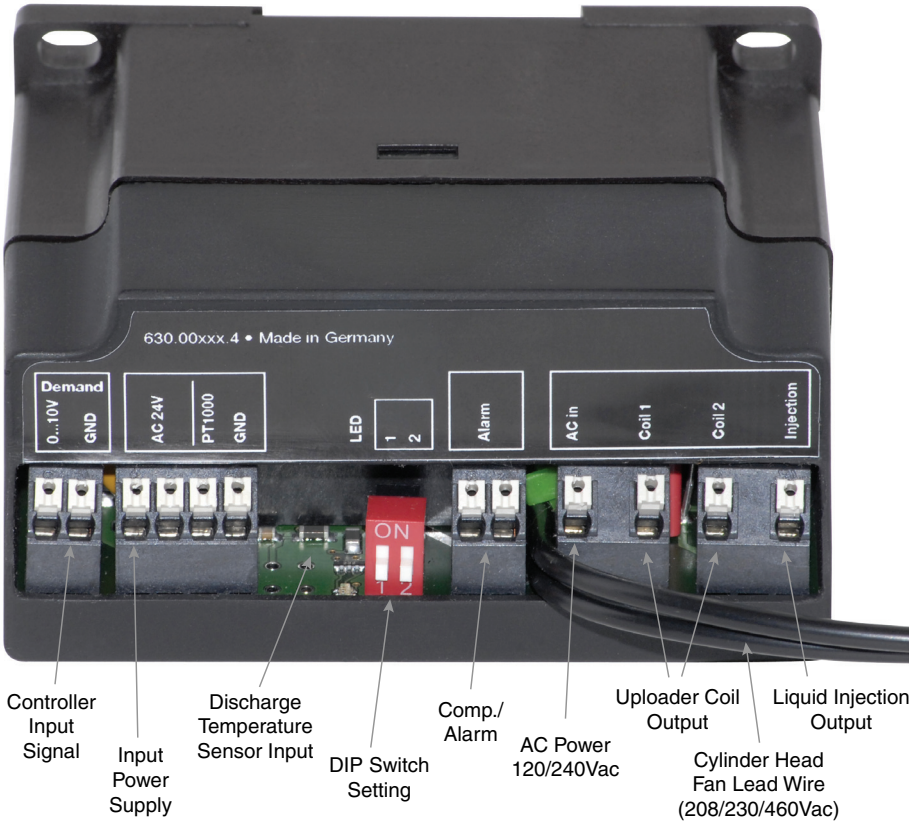


Fig. 2 — Connection Points

DIP Switch Setting

The DIP switch setting should both be in the "ON" position, as shown in Fig. 3, for proper control of the PWM solenoid valve. Controller power must be cycled off/on if the configuration switches are changed during system operation for that change to take effect.

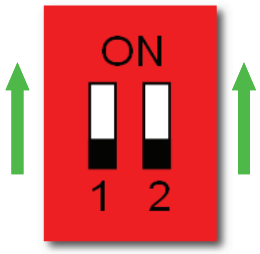


Fig. 3 — DIP Switch Settings

Controller Inputs

CONTROLLER INPUT SIGNAL

The smart controller receives a 1 to 5 vdc input signal from the system rack controller. This signal is directly proportional to the capacity demand required from the compressor. At 1 vdc input, the module will cycle the solenoid valve to control 20% compressor capacity. At 5 vdc input, the module will have the valve open continuously. Table 1 shows the linear relationship between input voltage and valve timing.

Table 1 — Input Voltage, Compressor Load, and Value Timing

INPUT VOLTAGE (VDC)	COMPRESSOR LOADING (%)	VALVE TIMING	
		OPEN	CLOSED
1.0	20	6	24
1.5	30	9	21
2.0	40	12	18
2.5	50	15	15
3.0	60	18	12
3.5	70	21	9
4.0	80	24	6
4.5	90	27	3
5.0	100	30	0

NOTE: A control signal less than 1 vdc will result in compressor capacities less than 20%. Do not allow the control voltage signal to drop below 1 vdc.

INPUT POWER SUPPLY

The smart controller requires a 24 vac (±10%), 50/60 Hz source to power the module. The maximum continuous rating is 5va. Control power should be isolated with a transformer from the main power supply.

DISCHARGE TEMPERATURE SENSOR INPUT

The smart controller has the capability to monitor and control the compressor's refrigerant discharge temperature. The thermistor input range is –22°F to 320°F (–30°C to 160°C), accuracy of –3%/+0%, with a maximum allowable sensor cable length of 30 ft. The smart controller will process the input from the discharge temperature sensor and operate the compressor's cylinder head fan and liquid injection valve as required to control compressor discharge temperatures below 230°F (110°C). The smart controller comes with a 1000-ohm resistor installed that will disable the discharge temperature related functions. Remove the resistor and replace with the discharge temperature sensor to enable these control functions. The two terminals labeled "NC," adjacent to the discharge temperature sensor input, are not used.

AC POWER

Line voltage input to provide power to the unloader solenoid coils and the liquid injection solenoid coil. Rated for 115/208-230 vac with a maximum continuous rating of 30va.

Controller Outputs

COMPRESSOR ALARM

The compressor alarm is a relay output. The relay operating voltage is 24 to 240 vac with a maximum continuous current of 2.5 amps (600 va). The compressor alarm output will open when any of the following conditions exist:

- Loss of 24 vac supply power
- Discharge temperature sensor failure, discharge temperature > 295°F (146°C)
- The input demand voltage is > 8.0 vdc.

The compressor alarm connection should be daisy chained into the compressor protection circuit when Carlyle discharge temperature sensor is being used to control compressor discharge temperature. When the compressor alarm contact opens, the triac outputs for Coil 1, Coil 2, and the LIV (Liquid Injection Valve) will open.

CYLINDER HEAD FAN LEAD WIRES

The smart controller has two 6-inch lead wires for wiring to the compressor's cylinder head fan. The smart controller will energize/de-energize the internal cylinder head fan relay to control discharge temperature. The lead wires are rated for up to 460 vac with a maximum continuous rating of 2.5 amps.

COIL 1 AND COIL 2

These are triac outputs for the solenoid valve coil. The triac is rated for 115/208-230 vac with a maximum continuous rating of 30va. The controller energizes the unloader solenoid coil in a pulse width modulated sequence per the 1-5 vdc analog input signal received by the controller.

LIQUID INJECTION

The liquid injection solenoid output is also a triac output. The triac is rated for 115/208-230 vac with a maximum continuous rating of 30 va. The controller will energize the liquid injection solenoid as required to provide compressor motor cooling and maintain compressor discharge below 230°F (110°C).

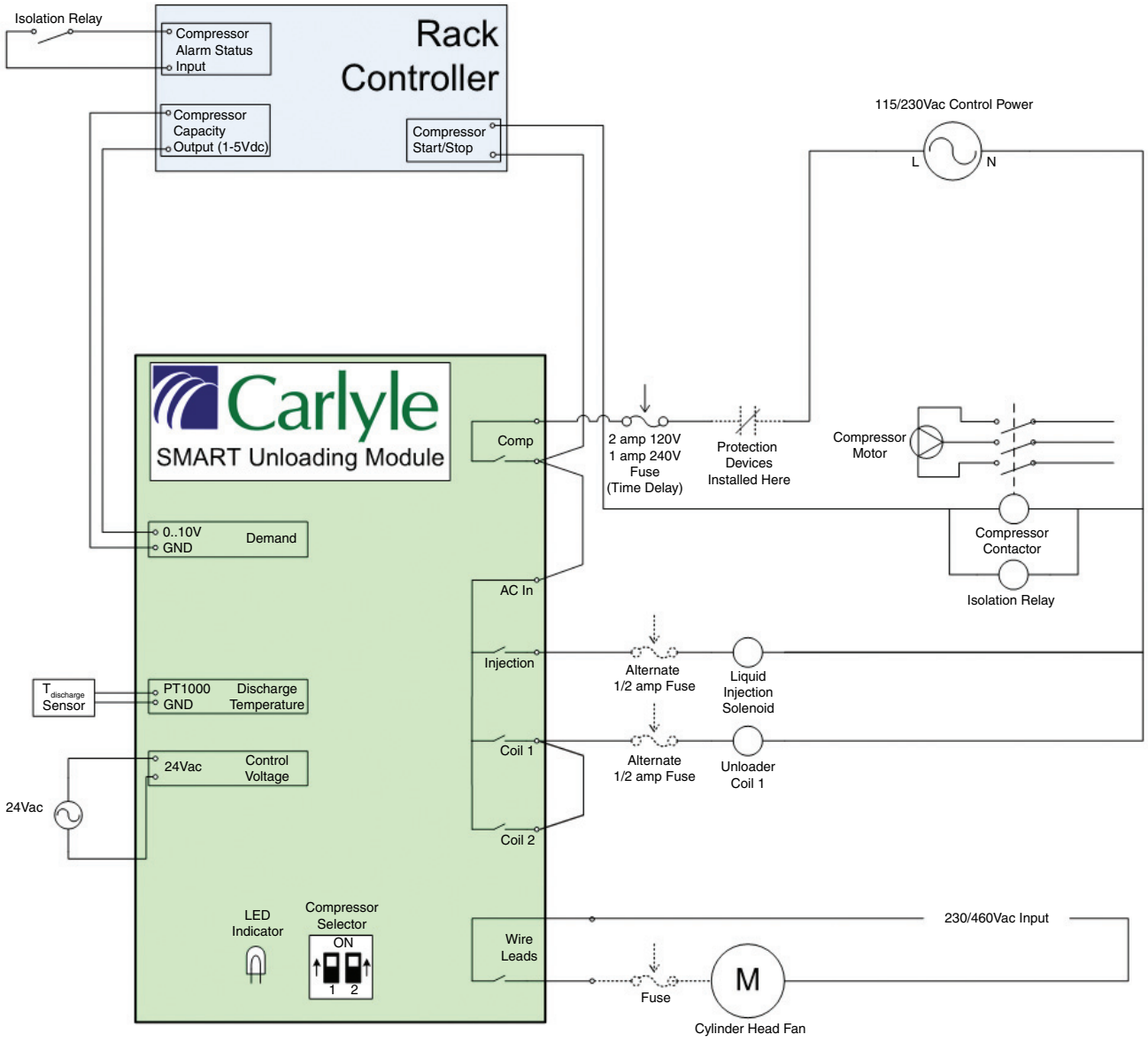


Fig. 4 — Wiring Schematic

Installation Notes for Control Module

1. Inspect the smart controller for shipping damage to the body, electrical connection points, and lead wires.
2. The smart controller must be connected by trained electrical personnel. Verify that all electrical power is disconnected. Follow all recognized safety practices and procedures when working with electricity.
3. The smart controller comes with a 1000-ohm resistor installed in the discharge temperature sensor input. Remove only if installing the Carlyle discharge temperature sensor for discharge temperature control; otherwise, do not remove the resistor.
4. The module is rated IP20 and must be mounted in a suitable secondary enclosure.
5. Mount the module in the control panel either by the 35 mm DIN rail or by screw mounting directly to the panel using two no. 10 self-tapping sheet metal screws, at least 1/2 inch in length. Dimensions for screw mounting are shown in Fig. 5.

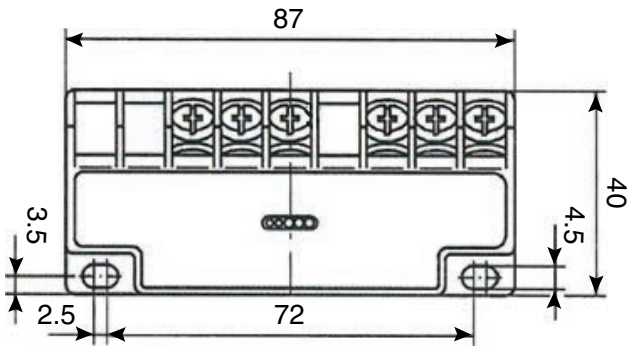


Fig. 5 — Mounting Dimensions (mm)

6. Do not route the low voltage wires with compressor power wires or high voltage 115/230/460 wires. Provide wire strain relief to ensure good connections.
7. Once the smart controller is mounted, use the electrical diagram in Fig. 4 for all electrical connections.

A service panel label identifying alert codes and wiring connections is provided and should be placed with the controller for the technician when troubleshooting the system.

PWM SOLENOID VALVE

Installation Notes for PWM Solenoid Valve

The Carlyle pulse width modulation (PWM) solenoid valve is a robust high-cycle capacity control valve designed to modulate and control compressor capacity from 20% to 100% of compressor full load. The valve is designed to open/close at a specified rate to modulate compressor capacity. When the valve is closed, the compressor crankcase will pull into a vacuum. The compressors have been functionally tested and approved to operate in this manner.

The PWM valve installs in the suction line of the compressor. The valve should be installed as close as possible to the compressor suction service valve.

The valve must be mounted horizontally so the solenoid coil valve stem is vertical. Mounting in any other orientation may result in valve malfunction. The valve is pilot duty and has a specific direction of flow, as indicated by an arrow on the top of the valve. (See Fig. 6.)

The PWM valve has connections for brazed installation. Do not braze the valve with the solenoid coil installed, and always protect the valve against any heat damage during the brazing process.

The PWM valve is a normally closed valve and requires a solenoid coil to be energized to open the valve. In the event of valve failure, the valve is equipped with a manual lifting stem that, when front seated, will force the valve fully open.

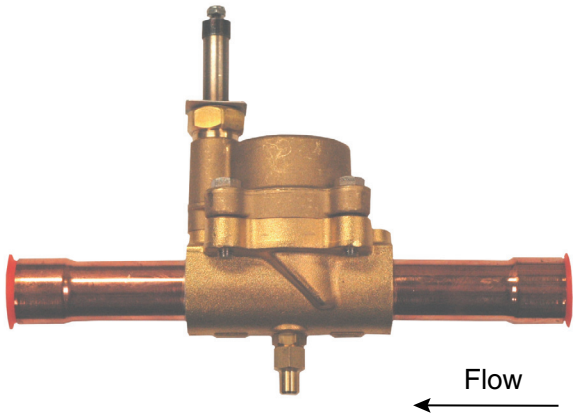


Fig. 6 — PWM Solenoid Valve

Once the PWM valve is brazed in place, the solenoid coil can be installed. Use only Carlyle recommended solenoid coils. These coils have been qualified for the high cycle rates of this application. The use of any other coil is not approved by Carlyle.

Power to the PWM valve solenoid coil should be interrupted whenever the compressor trips off or is intentionally taken out of service.

PWM Valve Specifications

Normally Closed Valve

Maximum Operating Pressure: 500 psig (33.5 Bar)

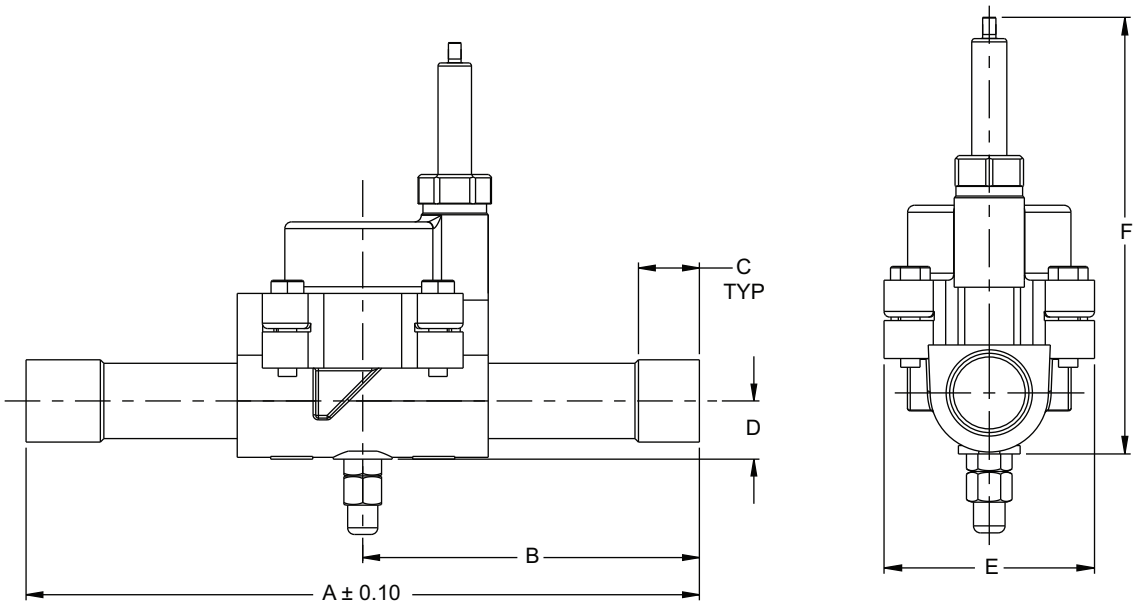
Maximum Differential Pressure: 250 psid (17.2 Bar)

Refrigerant Temperatures: –40°F to 240°F
(–40°C to 116°C)

Ambient Temperature: –40°F to 120°F (–40°C to 49°C)

Corrosion Protection: 2000 hours salt spray per ASTM B-117 (American Society for Testing and Materials)

PWM Valve Dimensions (See Fig. 7)



VALVE SIZE	DIMENSIONS					
	A	B	C	D	E	F
1-1/8"	10.06" (255.5mm)	5.03" (127.8mm)	0.91" (23.1mm)	0.87" (22.1mm)	3.00" (76.2mm)	6.23" (158.2mm)
1-5/8"	11.06" (280.9mm)	5.53" (140.5mm)	1.11" (28.2mm)	1.14" (29.0mm)	3.47" (88.1mm)	7.12" (180.8mm)

Fig. 7 — Valve Dimensions

Solenoid Coil Specifications

Voltage: 120 vac or 208/240 vac
Current: 120 vac - 0.39 amps @ 60 Hz
Current: 240 vac - 0.14 amps @ 60 Hz
Watts: 10w
Ambient Temperature Range: –40°F to 120°F
(–40°C to 49°C)
Humidity: 0 to 100%
UL File Number: MH4576
CSA File Number: LR19953

Solenoid Coil Dimensions (See Fig. 8)

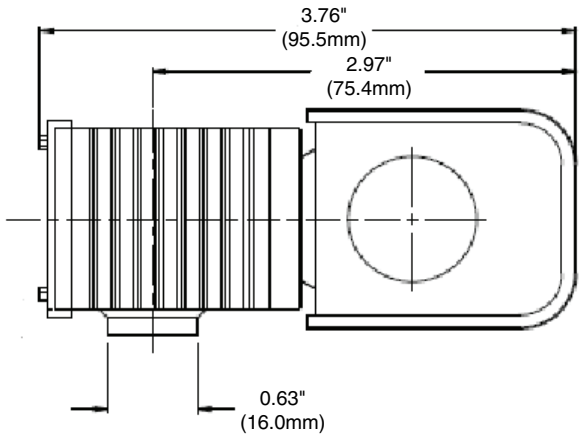


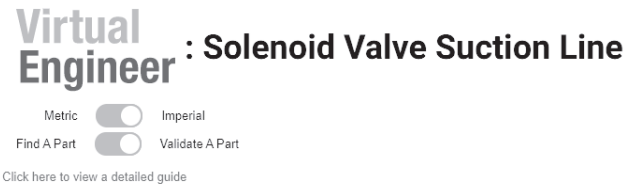
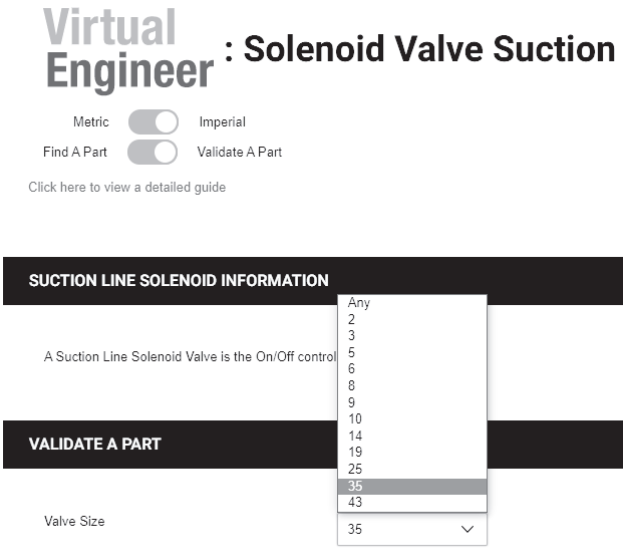
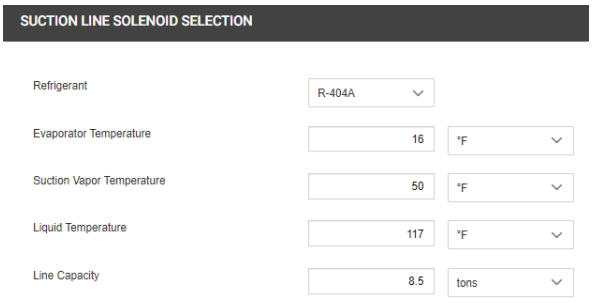
Fig. 8 — Coil Dimensions

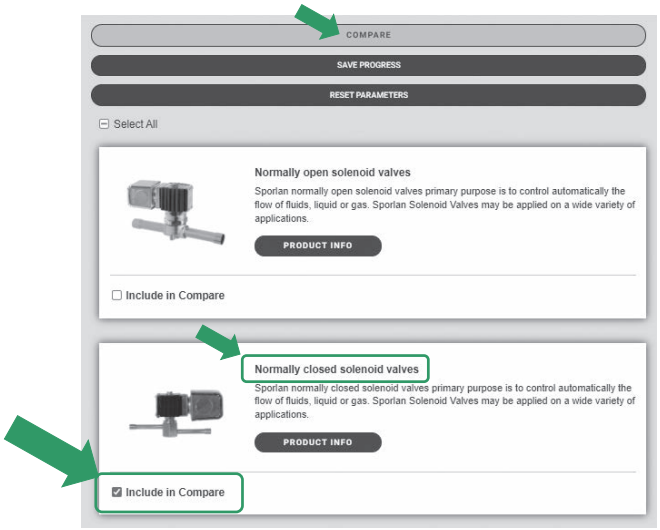
Valve Selection

The Carlyle PWM valve is designed to work specifically with the Carlyle 06D, 06CC, and 06M compressor models for all low, medium, and high-temperature applications. The application of the PWM valve may be limited in the application due to the pressure drop across the valve.

System designers should use Parker Sporlan's Virtual Engineer online software to determine the PWM valve pressure drop. This program is intended only for calculating the pressure drop of the valve. DO NOT use this software to select a valve online; use only valves purchased through Carlyle for this application.

The following instructions will assist in sizing the PWM valve correctly.

Step	Instructions	Associated Website Detail
1	Go to the Parker Sporlan Virtual Engineer website at http://solutions.parker.com/sporlanvirtualengineer. Scroll down to the Solenoid Valves section and click the Next arrow to reach the "Suction Solenoid Valve" image. Click the image to begin the sizing process.	
2	Use slide bars to choose "Validate a Part" and either "Metric" or "Imperial" units.	
3	Choose "35" for 1-1/8" valve (Carlyle Part No. 8ADB000690) or "43" for 1-5/8" valve (Carlyle Part No. 8ADB000907). NOTE: Choose only "35" or "43." DO NOT choose other valve sizes. Use ONLY the Carlyle valves for this PWM application. These valves from Parker Sporlan contain a non-standard bleed port that allows a small amount of flower even when the valve is de-energized. The use of any other valves in this application will void the compressor warranty.	
4	Enter design condition.	

5	Click “Include in Compare” only for Normally Closed Solenoid Valves. Then click the “Compare” button.	
6	Review results. NOTE: The PWM valve requires a minimum of 1 psid pressure drop across the valve to work properly in the application. If the “Is Valid?” field contains a red "x," then the selection should be repeated. A green check mark (✓) in the “Is Valid?” field indicates a satisfactory selection. If neither the “35” nor “43” size valve provides acceptable valve performance, then the PWM solenoid valve capacity control is not recommended for the application.