Moduload® Capacity Control for 3D Compressors

On refrigeration and air conditioning applications where the refrigeration load may vary over a wide range, some means of compressor capacity control is often desirable for optimum system performance and control. In addition, compressor capacity modulation can reduce power and energy consumption, provide better dehumidification, reduce compressor cycling, and decrease the starting electrical load.

In order to achieve the above objectives, Emerson Climate Technologies has developed Moduload, a unique and highly efficient method for unloading small Discus® Copelametic® compressors.

Moduload will, for the first time, permit efficient unloading on Copeland® compressors with less than 4 cylinders for high, medium, and low temperature applications. Moduload assures smooth, vibrationfree operation in the unloaded mode by unloading all cylinders equally.

Theory of Operation

Moduload compressors unload by allowing compressed gas to fill a storage chamber above each cylinder and re-expand back into the cylinder during the suction stroke. As the gas re-expands, both volumetric efficiency and compressor capacity are reduced. The energy consumed during compression is almost completely recovered during re-expansion, resulting in high efficiency in the unloaded mode.

Moduload uses a piston, cylinder, and spring mechanism which are solenoid actuated. All cylinders are unloaded equally, thus providing well-balanced operation at all times.

Since compressed gas is re-expanded to obtain unloading, the percent capacity reduction is a function of operating compression ratio. The higher the compression ratio, the greater the percent capacity reduction during unloading.

Capacity Control Valve Construction

The unloading hardware consists of a spring and plunger assembly for each cylinder housed in a chamber mounted on top of the valve plate. See Figure 1.

In the fully loaded operating mode (with the solenoid valve de-energized), the solenoid needle valve is seated in the upper port, and the top of the unloading piston is exposed to discharge pressure through the discharge pressure port. The high pressure discharge gas on top of the unloader piston forces it to remain seated in the Discus valve.

When unloaded operation is required, the solenoid valve is energized. The needle valve seats in the lower port, and the unloading piston chamber (above the unloading piston) is exposed to suction pressure through the suction port. With suction pressure on top of the piston, the spring force underneath the piston is sufficient to move the piston to the top of the chamber. In this position, the unloader piston opens a passage in the center of the Discus valve through which high-pressure gas enters the expansion chamber during the compression stroke. During the suction stroke, the gas contained in the unloading chamber re-expands through the passage into the cylinder thus reducing capacity.

Moduload Performance

When operating unloaded, the percent of full load capacity is a function of operating compression ratio. The higher the ratio, the greater the capacity reduction. To determine actual performance at specific operating conditions, use Figures 2 through 5.

Example:
Determine part load performance of a 3DF3-0900 operating unloaded at -25°F evaporating and 110°F condensing for R-502.

Answer:
(Using Discus sales catalog for the 3DF3-0900) Fully loaded performance at -25/110°F is 38,400 Btu/hr and 7510 watts. For the unloaded capacity and power, use Figure 5. Compressor capacity is 54 percent of fully loaded capacity or .54 x 38,400 = 20,700 Btu/hr. Power is 60 percent of full load power or .60 x 7510 = 4506 watts.
APPLICATION

Control
When an unloading valve is switched from the loaded to the unloaded position, or vice versa, a new system balance takes place; i.e., evaporating and condensing temperatures will change slightly. In air-cooled systems, unloading will normally cause the suction pressure to rise and the condensing pressure to drop. In water-cooled systems, the suction pressure will rise, but the condensing pressure will normally remain substantially the same.

The unloading control (whether based on suction pressure or case temperature) should be set for as wide a differential as necessary to prevent rapid cycling of the unloading valve. A wider differential will normally be required with the pressure control method than the temperature control method because of the large thermal mass of the cooled medium. Actual system operation should determine the final control setting.

Operating Envelope

Low temperature as well as high and medium temperature applications are approved for Moduload unloading because of reductions in compressor operating temperatures due to Discus valving and improved internal gas flow. The boundaries of Figures 2 through 5 provide the operating envelope (loaded and unloaded) for stable and safe operation for all applications.

Depending upon the exact hardware configuration, tolerances, and spring force, stable operation of the Moduload unloader requires a minimum of 60 to 70 psi differential between suction and discharge pressure in order for the discharge pressure acting on top of the unloader piston to overcome the upward forces of the unloader spring and cylinder pressure. Differential pressures encountered in medium temperature R-12 floating head applications occasionally do not meet this criteria. Because of this, use of Moduload for medium temperature R-12 applications should be limited to floating head applications where the evaporating temperature is low enough that the discharge pressure never falls below a pressure corresponding to 70 psi above suction pressure, or to fixed head pressure and water-cooled applications where discharge pressure never falls below a pressure corresponding to 70 psi above suction pressure.

Cooling Requirements

Head cooling fans are required when the saturated suction temperature is at or below 0°F for both the loaded and unloaded mode.

Wiring

The capacity control valve is in the loaded position when de-energized and in the unloaded position when energized. The solenoid valve may be energized either by means of a reverse-acting low pressure control or a temperature-control thermostat.

Although the leak-back rate when the coil is energized during a compressor off cycle is minimal, to prolong the solenoid coil life it is recommended that the capacity control solenoid valve be de-energized when the compressor is not operating.

Note: As with any unloading compressor it is recommended the unloader solenoid be de-energized before pumping down the low side. Operating in the unloaded mode will greatly increase the time period for pumpdown.

In control circuits operating at line voltage, the solenoid valve and control can be connected to the load side of the contactor as in Figure 6. The unloader solenoid valve will then be de-energized and closed when the compressor is not operating.

On large installations, the control circuit may have a power source independent of the compressor power supply. In such cases, the unloading solenoid valve and control may be connected as shown in Figure 6 or they may be connected in parallel with the compressor contactor coil as in Figure 7.

Piping

A very important factor to be considered in the design of any refrigerant system equipped with an unloading-type compressor is gas velocity in refrigerant-system piping. This is especially true for low and medium temperature single-compressor systems. Gas velocity must be maintained at a sufficiently high level to ensure oil return to the compressor when it is unloaded. To ensure oil return when an unloading-type compressor is employed on a single evaporator with a single suction line, it may be necessary to employ double risers constructed as shown in Figure 8. Where oil return is marginal, use of an oil separator and float system is recommended.

If an unloading-type compressor is to be installed on a system employing multiple evaporators with solenoid valves to control the flow of refrigerant to the individual evaporators, a separate suction line should be run from each evaporator to the machine room and then connected into a common suction line, which should slope downward toward the compressor to ensure adequate oil return.
Expansion valves for systems with unloading compressor must be sized to be able to control the refrigerant flow while the compressor is unloaded as well as loaded. Expansion valves should not be oversized since they usually cannot control well when operating 25-35 percent below their rated capacity.


HFC Refrigerants
HFC’s are not compatible with the seal material (viton) used in the standard Moduload cylinders.

New HFC models have an alternate seal material (HSN) that is compatible; however, it cannot be used with CFC or HCFC refrigerants. This issue becomes very important when retrofitting and may necessitate replacing Moduload assemblies.

Table 1 lists the model nomenclature for the appropriate 3D Models for use with both HFC and CFC refrigerants.

Field Service and Conversion
Moduload may be added to standard 3D compressors by means of the appropriate conversion kit (Consult factory for kit numbers or Parts List PS-1260).
Figure 2
Moduload Discus 3D Compressors
Typical Unloader Performance Factors
R404A & R-502 Low Temperature Applications
Figure 3
Moduload Discus 3D Compressors
Typical Unloader Performance Factors
R404A & R-502 Medium Temperature Application
Figure 4
Moduload Discus 3D Compressors
Typical Unloader Performance Factors
R-22 High Temperature Applications
Figure 5
Moduload Discus 3D Compressors
Typical Unloader Performance Factors
R-12 Medium and High Temperature Applica
Figure 6
Typical Control Circuit for Compressor with Unloading Valve

Figure 7
Typical Control Circuit for Compressor with Unloading Valve and Separate Power Source Control Circuit
Installation
The Moduload valve and coil assembly (240 volt) is included in the Moduload model standard -200 bill of material as a “ship remote” item. The Moduload model compressor can be operated without the unloading valve and coil installed, if desired for any reason. It is critical for the gasket to be matched to intended usage before starting the compressor, per the following instructions.

Unloading Valve Gasket. Use this gasket when installing the Moduload solenoid valve & coil. The compressor will run unloaded when the solenoid is energized, and will be fully loaded when the solenoid is de-energized.

Shipping Gasket. This gasket is under the shipping plate covering the Moduload mounting pad on the cylinder head, as shipped from the Emerson factory. Replace it with the appropriate gasket (Figure 10 or 11) before operating the compressor. If not replaced, the compressor will run unloaded.

Full Load Gasket. Use this gasket with the shipping plate if the solenoid valve & coil are not installed. Compressor will run only fully loaded.
Table 1
Moduload Model Nomenclature

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<tr>
<th>Ref</th>
<th>CFC/HCFC Loaded Model No.</th>
<th>CFC/HCFC Unloaded Model No.</th>
<th>HFC Ref</th>
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