EMERSON Climate Technologies

Application Engineering

Copeland brand products

BULLETIN

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Digital Capacity Control for Copeland™ and Intelligent Store Discus™ Refrigeration Compressors

Introduction

On refrigeration applications where the load may vary over a wide range, some means of capacity control is often desirable for optimum system performance and control. In addition, compressor capacity modulation can reduce power and energy consumption, reduce compressor cycling, and decrease the starting electrical load. In order to achieve the above objectives, Emerson Climate Technologies has developed Copeland Discus Digital™, a method for variable capacity in Discus™ compressors. Digital technology will, for the first time, permit digital modulation of Discus compressors for high, medium, and low temperature applications.

Theory of Operation

Digital capacity control is achieved by using a proven internal unloading method, blocked suction. Blocked suction has been applied to multiple bank compressors in the past, but digital modulation allows the technology to apply to single bank compressors as well, such as the 3D. By varying the percentage of duty cycle that the compressor is loaded and unloaded, capacity control between 10 and 100% can be achieved. During blocked suction operation, the flow of suction gas is blocked to all cylinders on a single bank; therefore there is no gas to compress and the power consumption is significantly lower. The unloader piston mechanism that controls flow of suction gas into the cylinders is driven by a solenoid valve. See the descriptions and figures below for the unloaded and loaded states for Copeland Discus Digital operation.

Digital technology is now also available on the 4D and 6D Discus compressors. Applied to one bank of the compressor it can provide 50-100% capacity modulation on a 4D Discus and when combined with a blocked suction bank on a 6D can provide 33-100% capacity on a 6D (without the blocked suction bank 67-100% digital modulation is available on the 6D platform).

Note! 6D Discus Digital(TM) is only available on the Intelligent Store Discus v2.x platform.

Figure 1: Unloaded Operation

1. Enters Compressor
2. Passes Through Body
3. Unloader Mechanism Blocks Gas Before Entering Valve Plate

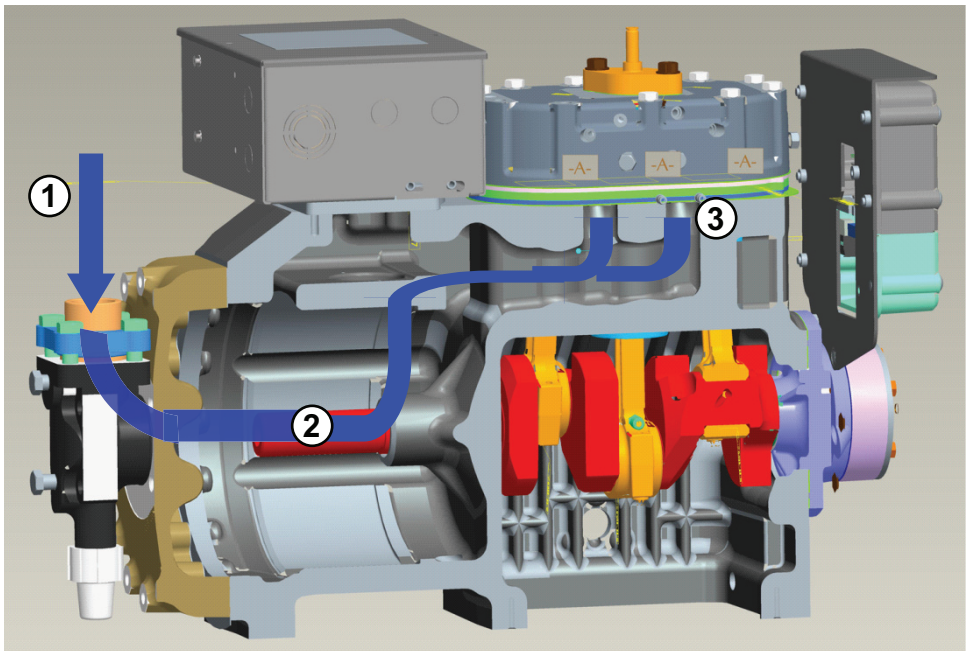


Figure 1
Copeland Discus Digital Unloaded Operation (Shown on a Copeland 3D Discus)

Figure 2: Loaded Operation

1. Enters Compressor
2. Passes Through Body
3. Into Valve Plate
4. Compressed by Pistons
5. Exits Compressor

Nomenclature

The Copeland Discus Digital™ compressor model numbers are designated by a "D" or an "X" in the fourth character, e.g. 3DS**D**R17ME-TFD, 4DA**D**F47KE-TSK or 4DJ**X**R28ME-TSK. Discus digital model numbers include additional information about the compressor, consistent with the standard Discus model nomenclature.

For more information on available Discus digital models visit the website **www.emersonclimate.com** or contact your Emerson Climate Technologies representative.

Digital Performance

The nominal power consumption per nominal capacity output varies. An example of the power required as a percent of load is shown in **Figure 3** for a 3D Discus digital.

Operating Envelope

The operating envelopes for Discus digital compressors are the same as the standard Discus compressor envelopes. The head fan, return gas and oil cooler requirements are the same as those for the standard Discus compressors.

Control

Capacity modulation is achieved by energizing and de-energizing the solenoid valve. When the solenoid valve is de-energized, the compressor capacity is 100%. When the solenoid valve is energized, the compressor capacity is zero. Therefore, the capacity achieved is the time average capacity, which is a variable from 10 – 100% on a 3D. Example: If you have a 20-second cycle and the solenoid is de-energized for 16-seconds, and then energized for 4-seconds, the resulting capacity will be approximately 80%.

For 4D/6D Models one bank of the compressor remains loaded 100% while the digital bank will modulate 0-100% to provide the additional capacity. On a 6D with blocked suction the blocked suction bank will unload when demand capacity is less than 67% and load when the demand capacity is higher than 67%. The Digital bank will continue to load and unload providing continuous capacity across the 33-100% range.

Note! 6D Discus Digital is only available on Intelligent Store Discus v2.x compressors.

Copeland Digital Compressors and Pumpdown Cycle

In systems that require a compressor pumpdown, special attention should be paid to the control logic for the digital unloader coil. Inherent to the Digital control, the compressor will effectively ramp down and track the suction pressure by loading and unloading to decreasing modulation rates. In order to avoid an

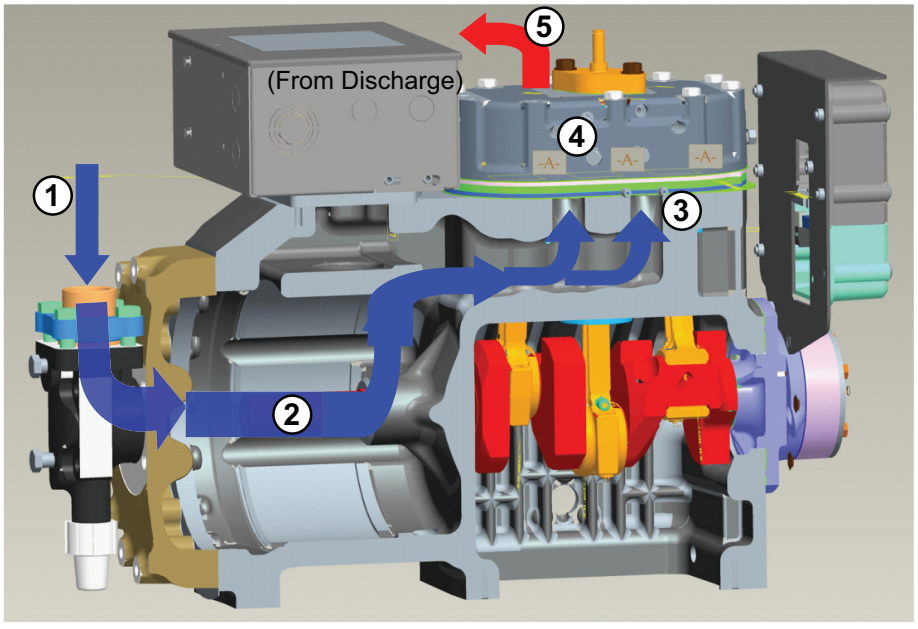


Figure 2 – Copeland Discus Digital Loaded View (shown on a Copeland 3D Discus)

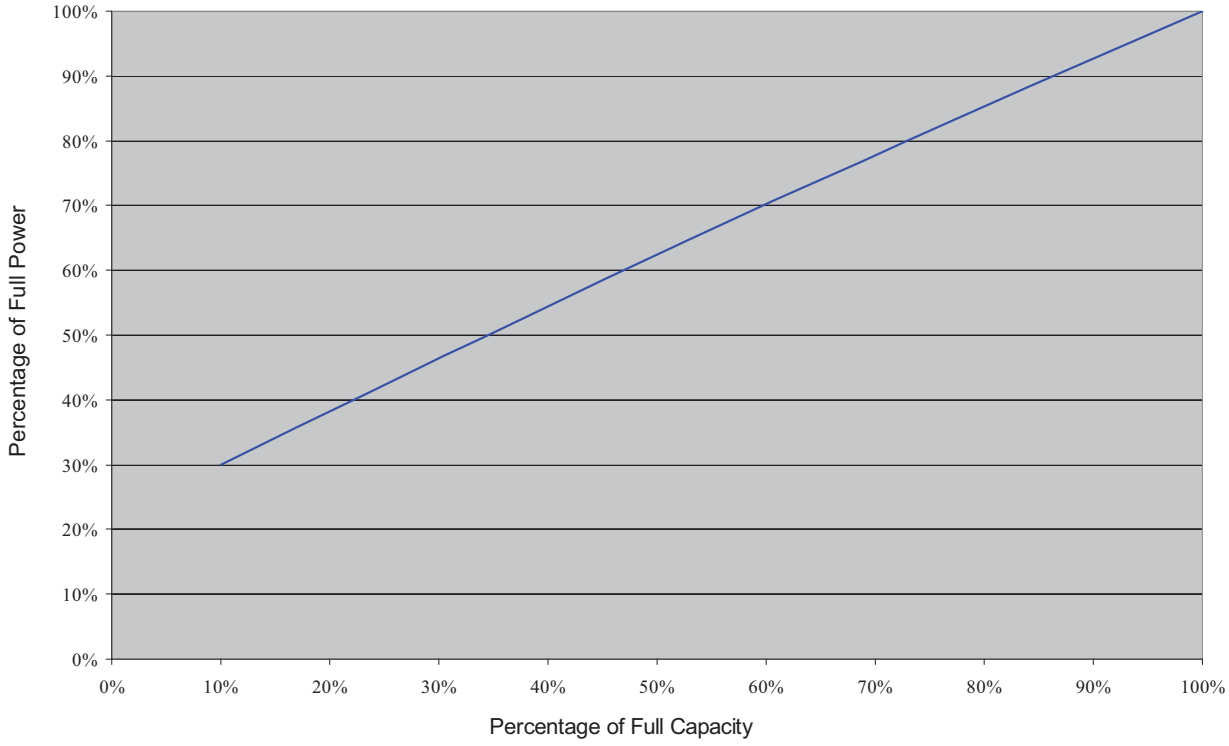


Figure 3
Typical Modulated Power Reduction (for 3D Discus Digital)

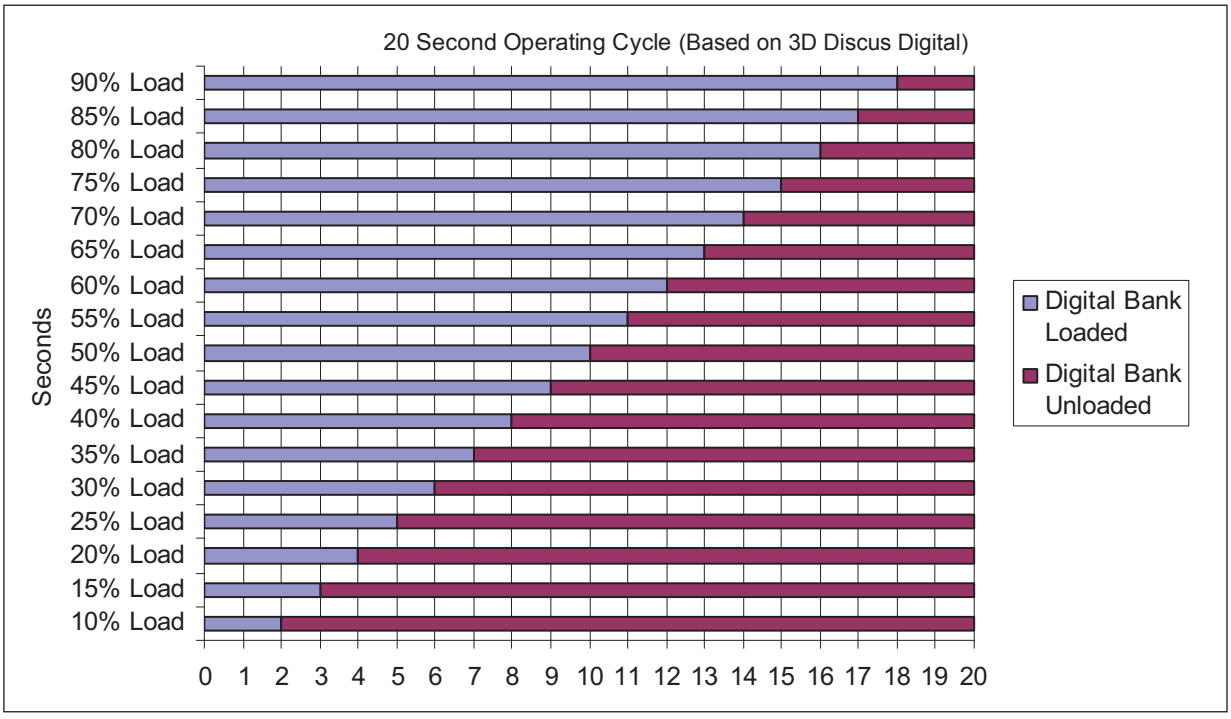
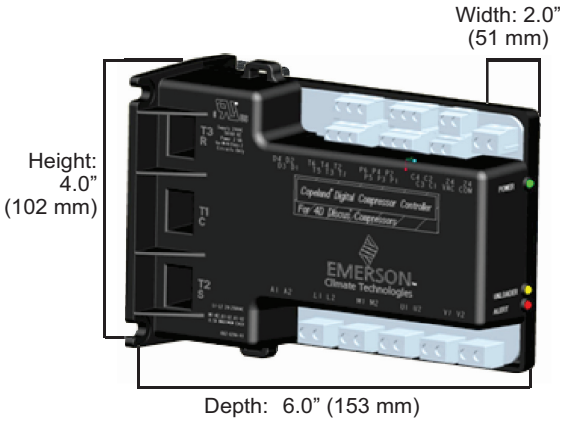


Figure 4
% Loaded vs Time

extended compressor pumpdown cycle, the Digital solenoid should be wired/controlled such that when a pump down cycle is initiated the coil is de-energized. This will force the compressor to run fully loaded (100% capacity).

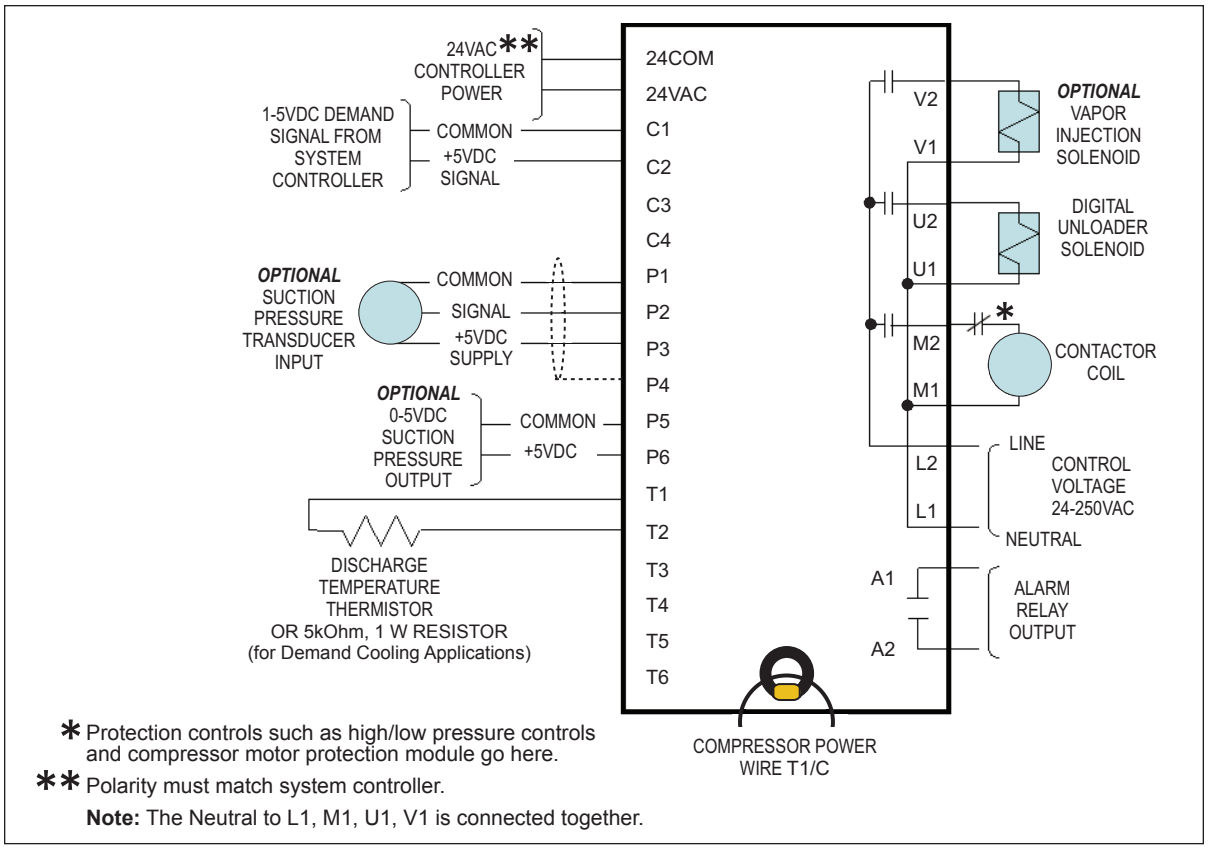
Control Requirements with Copeland™ Digital Compressor Controller

The Digital Compressor Controller is an electronics interface between the Copeland Discus Digital compressor and the system controller. The system controller measures temperature or pressure to calculate the needed compressor capacity and communicates that capacity to the Digital Compressor Controller via an analog signal.



Note! For more information on the Copeland(R) Digital Compressor Controller refer to the application guidelines in **AE8-1328,** Copeland™ Digital Compressor Controller.

Four #10 self tapping sheet metal screws, at least ½" length, are required for installation. The maximum mounting screw torque is 20 in. lbs. Locate the Digital Compressor Controller inside the electrical enclosure near the compressor contactor (wire routing for compressor power wiring will be easier in this position). The maximum wire terminal screw torque is 7 in. lbs. The Digital Compressor Controller will operate in any mounting orientation where the green power LED is at the top. Mount the Digital Compressor Controller such that all LEDs are visible from a comfortable viewing position. A service panel label (**Form 2003CC-80**) describing the terminals and ALERT flash codes is included with each Digital Compressor Controller. This label should be in a visible location for the technician when troubleshooting the system.



Compressor Controller Wiring Diagram

Compressor Wiring

The Digital Compressor Controller senses compressor motor current for diagnostics and protection. The compressor motor leads must be run through the holes in the plastic housing for a current transformer to sense motor current.

For Three Phase 3D Discus™ compressors: the compressor's T1, T2 and T3 wires must be routed through the holes in the Digital Compressor Controller module marked "T1," "T2" and "T3." The Digital Compressor Controller module is phase insensitive and will NOT detect reverse phasing of the compressor.

NOTE! Do not bundle low voltage wires with compressor power or high voltage wires.

NOTE! Attach cable ties through loops on side of the housing for wire strain relief.

Control Requirements with Intelligent Store Discus™ v2.x

Discus Digital compressors are also compatible with Intelligent Store™ v2.1 and newer technology. Using Intelligent Store Discus™ eliminates the need for the separate Copeland™ Digital Compressor Controller in system wiring. **NOTE! Discus Digital is not compatible with Intelligent Store Discus 1.0.**

Master Controller

The Copeland Discus Digital™ compressor is approved for use with E2 v2.3 facility management system and higher. The compressor should be specifically identified as digital in the E2 in the staging setup. For any other system controllers please check with your Application Engineer. If using a Discus digital compressor with Intelligent Store Discus™ v2.x with the E2 system controller, E2 v 2.6 or newer is required. You do not need the Digital Compressor Controller when using Intelligent Store Discus™. More information on the E2 system controller can be found in the E2 User Manual available at **http://www.emersonclimate.com/en-US/products/controls/facility_controls/e2/rx.aspx.** For additional information on Intelligent Store Discus v2.1 refer to the application guidelines in **AE8-1368**, Intelligent Store Discus™ 2.1.

Recommended Application Settings for the Modulation on Copeland Discus Digital Compressors

The system design should follow the required and recommended guidelines as detailed in the various Application Engineering Bulletins, which can be found on the website at **www.emersonclimate.com.** The compressor motor should only be restarted after an appropriate time delay. The digital modulation cycle time recommended is 20 seconds; for other values, check with your Application Engineer.

The minimum load and unload times should be limited to 2 seconds. These described load and unload times will give the compressor an operating range during a 20 second cycle from 10% load up to 90% load (on 3D only – 4D and 6D minimum percent capacity would be 50%, 33% or 67% depending on compressor configuration). The compressor can also operate at a 100% load for the full modulation sequence. The 2 seconds minimum times will give the unloader piston assembly time to both load and unload fully.

If the load required is less than 10% minimum percent capacity of the digital compressor (10% for 3D, 50% for 4D or 33% or 67% for 6D) the compressor motor should be shut down. Restarting of the compressor will be governed by the capacity rising above the10% minimum percent capacity or more based on a modulation time of 20 seconds, and by the motor starting logic.

Solenoid Valve/Gaskets

Due to the high life cycle requirements in a hot gas environment, a special valve has been developed. Due to reliability requirements, only Emerson solenoid valves may be used. All compressor warranties are null and void if the Emerson valve is not used. Solenoid coils will be sold separately for all non-Intelligent Store Discus orders. See **Table 1** for the appropriate solenoid kit number for your application. Furthermore, Discus digital compressors use special head and valve plate gaskets which have modifications to ensure gas flow for proper digital modulation. Only Emerson approved gaskets may be used. All compressor warranties are null and void if the Emerson gaskets are not used.

Table 1

Solenoid Coil Voltage	Kit Part Number
24V	923-0084-00
120V	923-0084-01
240V	923-0084-02

Thermistor

The thermistor must conform to the curve characteristics outlined in **Table 2**. The table expresses the ratio of the resistance at the indicated temperature and the resistance at 25°C (77°F). The resistance at 25°C (77°F) is 86K ohms nominal. The curve fit is: Ratio = 0.8685e-0.0257x. Warning: this curve fit is only valid for temperature range of 100 to 160°C (212-320°F).

Multiple Compressor Application

To ensure smooth and continuous modulation, selection of the digital and non-digital compressor capacities can be made according to the following rule.

Rule: For optimum suction pressure control, the following guideline is recommended in the selection of Discus digital and fixed compressors, per suction header:

- D > F1
- F2 < D+F1
- F3< D+F1+F2
- ….
- FN<D+F1+2+….FN-1

In the above equations, D is digital Discus capacity or horse power, F1,…FN are the standard Discus compressor capacity or horse power. The compressor selected should be the smallest compressor capacity that still covers all the gaps between steps to ensure the most efficient system control.

When using this rule keep in mind the digital range, for example on a 4D you have continuous capacity from 50 to 100%, therefore when selecting a 4D digital compressor you should have a fixed compressor behind it that is 50%-100% of the full load of the digital compressor. For example, if a 4DADF47KL-TFD (full capacity is about 47,000 Btu per hour, 50% capacity is about 23,500) is chosen a standard 3DA3F28KL-TFD (full capacity is about 28,000 Btu per hour) could be chosen as the second compressor stage behind the digital compressor.

Note! For best results, the digital compressor needs to be the lead compressor. It must be the first compressor on and last compressor off in multiple compressor applications.

Example:

Cooling Demand (HP)	Digital (HP)	Fixed (HP)	Fixed (HP)	Fixed (HP)	System Output (HP)
Load = 0	OFF	OFF	OFF	OFF	0
10.10 < Load < 17.50	0.10 - 10	7.5	OFF	OFF	10.10 -- 17.50
17.10 < Load < 25	0.10 - 10	7.5	7.5	OFF	17.10 -- 25
23.10 < Load < 31.50	0.10 - 10	7.5	7.5	7.5	23.10 -- 31.50

General Guidelines and More Information

For general Discus® compressor and digital control guidelines please log in to Online Product Information at **www.emersonclimate.com**, refer to the Application Engineering Bulletins listed below, or contact your Application Engineer.

AE4-1135 **Cooling Requirements for Copelametic® Compressors**

AE4-1287 **Copeland Discus® Demand Cooling**

AE4-1334 **Low Condensing Temperature Bulletin**

AE8-1328 **Copeland® Digital Compressor Controller**

AE8-1351 **Intelligent Store Discus™ 2.0**

AE4-1357 **Upgrade Procedures for Digital Capacity Control for Copeland Discus® Refrigeration Compressors**

Table 2
Temperature and Resistance Ratio for Thermistor

Temperature Sensor Resistance Values

Temp	Ratio	Temp	Ratio	Temp	Ratio	Temp	Ratio	Temp	Ratio
-40°C	33.60000	5°C	2.53960	50°C	0.36030	95°C	0.07870	143°C	0.02190
-39°C	31.44900	6°C	2.41710	51°C	0.34690	96°C	0.07641	144°C	0.02139
-38°C	29.45200	7°C	2.30130	52°C	0.33400	97°C	0.07420	145°C	0.02090
-37°C	27.59700	8°C	2.19180	53°C	0.32170	98°C	0.07206	146°C	0.02039
-36°C	25.87300	9°C	2.08830	54°C	0.30990	99°C	0.07000	147°C	0.01990
-35°C	24.27000	10°C	1.99030	55°C	0.29860	100°C	0.06800	148°C	0.01942
-34°C	22.76100	11°C	1.89720	56°C	0.28780	101°C	0.06612	149°C	0.01895
-33°C	21.35700	12°C	1.80900	57°C	0.27740	102°C	0.06430	150°C	0.01850
-32°C	20.05100	13°C	1.72550	58°C	0.26750	103°C	0.06255	151°C	0.01801
-31°C	18.83400	14°C	1.64640	59°C	0.25790	104°C	0.06085	152°C	0.01754
-30°C	17.70000	15°C	1.57140	60°C	0.24880	105°C	0.05920	153°C	0.01708
-29°C	16.63420	16°C	1.50000	61°C	0.24000	106°C	0.05760	154°C	0.01663
-28°C	15.64040	17°C	1.43230	62°C	0.23150	107°C	0.05605	155°C	0.01620
-27°C	14.71340	18°C	1.36810	63°C	0.22350	108°C	0.05456	156°C	0.01584
-26°C	13.84820	19°C	1.30710	64°C	0.21570	109°C	0.05310	157°C	0.01549
-25°C	13.04020	20°C	1.24930	65°C	0.20830	110°C	0.05170	158°C	0.01515
-24°C	12.28070	21°C	1.19420	66°C	0.20110	111°C	0.05027	159°C	0.01482
-23°C	11.57100	22°C	1.14180	67°C	0.19430	112°C	0.04889	160°C	0.01450
-22°C	10.90750	23°C	1.09210	68°C	0.18760	113°C	0.04755	161°C	0.01418
-21°C	10.28680	24°C	1.04490	69°C	0.18130	114°C	0.04625	162°C	0.01388
-20°C	9.70600	25°C	1.00000	70°C	0.17520	115°C	0.04500	163°C	0.01358
-19°C	9.15880	26°C	0.95710	71°C	0.16930	116°C	0.04372	164°C	0.01328
-18°C	8.64630	27°C	0.91640	72°C	0.16370	117°C	0.04248	165°C	0.01300
-17°C	8.16620	28°C	0.87760	73°C	0.15820	118°C	0.04128	166°C	0.01275
-16°C	7.71620	29°C	0.84070	74°C	0.15300	119°C	0.04012	167°C	0.01250
-15°C	8.29400	30°C	0.80560	75°C	0.14800	120°C	0.03900	168°C	0.01226
-14°C	6.89570	31°C	0.77200	76°C	0.14310	121°C	0.03793	169°C	0.01203
-13°C	6.52190	32°C	0.74010	77°C	0.13850	122°C	0.03690	170°C	0.01180
-12°C	6.17110	33°C	0.70960	78°C	0.13400	123°C	0.03590	171°C	0.01157
-11°C	5.84150	34°C	0.68060	79°C	0.12970	124°C	0.03494	172°C	0.01134
-10°C	5.53190	35°C	0.65300	80°C	0.12550	125°C	0.03400	173°C	0.01112
-9°C	5.23920	36°C	0.62660	81°C	0.12150	126°C	0.03315	174°C	0.01091
-8°C	4.96400	37°C	0.60140	82°C	0.11770	127°C	0.03233	175°C	0.01700
-7°C	4.70520	38°C	0.57740	83°C	0.11400	128°C	0.03153	176°C	0.01049
-6°C	4.46170	39°C	0.55460	84°C	0.11040	129°C	0.03075	177°C	0.01029
-5°C	4.23240	40°C	0.53270	85°C	0.10700	130°C	0.03000	178°C	0.10090
-4°C	4.01530	41°C	0.51170	86°C	0.10370	131°C	0.02926	179°C	0.00989
-3°C	3.81090	42°C	0.49180	87°C	0.10050	132°C	0.02854	180°C	0.00970
-2°C	3.61820	43°C	0.47270	88°C	0.09740	133°C	0.02784	181°C	0.00949
-1°C	3.43670	44°C	0.45440	89°C	0.09440	134°C	0.02716	182°C	0.00928
0°C	3.26540	45°C	0.43700	90°C	0.09150	135°C	0.02650	183°C	0.00908
1°C	3.10300	46°C	0.42030	91°C	0.08885	136°C	0.02586	184°C	0.00889
2°C	2.94980	47°C	0.40420	92°C	0.08610	137°C	0.02525	185°C	0.00870
3°C	2.80520	48°C	0.38890	93°C	0.08355	138°C	0.02465	186°C	0.00853
4°C	2.66860	49°C	0.37430	94°C	0.08108	139°C	0.02407	187°C	0.00837
						140°C	0.02350	188°C	0.00821
						141°C	0.02295	189°C	0.00805
						142°C	0.02242	190°C	0.00790