

Recommended Contactor Selection for Three Phase Motor Control

- Styles of Contactors
- Establishing the Compressor Load
- Approved Vendors for Time Delay Relays and Contactors
- Tables for Sizing Contactors to Compressors
- How to Select a Compressor Contactor

Introduction

The contactor is one of the most important parts of any motor control circuit. It is vital that compressor applications for contactors are well understood and that the contactor is correctly sized for the load. An incorrectly sized contactor can destroy the best compressor.

As a general rule, contactors are designed for general purpose or definite purpose (specific use). Contactors can be further subdivided by listing categories for their use such as light or resistance (electric heating or lighting) loads and motor loads according to their severity.

NEMA Rated General Purpose Contactors

General purpose contactors are built for the severe industrial use. They are usually designed for a minimum life of over 1,000,000 electrical cycles on most types of motor loads. General purpose contactors, rated in the United States usually conform to NEMA (**N**ational **E**lectrical **M**anufacturers **A**ssociation) ratings. NEMA has standardized on electrical sizes of motor controls to make the manufacturing of these devices more universal. A person who has one manufacturer's NEMA size 1 contactor or motor starter can interchange his contactor with a NEMA size 1 from another vendor and be assured that the controller has been designed for the same broad spectrum of loads.

IEC Rated Contactors

There are many European test organizations for electrical controls. In order to obtain some degree of regulatory agency standardization, the International Electrotechnical Committee (IEC) was formed. If the requirements of this authority are met, an electrical device will meet most European test standards.

IEC contactors are listed in four basic utilization categories; "AC1" through "AC4". These categories describe the requirements for switching electrical loads from those with light inrush currents (resistive) to heavy duty motor applications.

An IEC designed contactor may be tested to any amperage or horsepower rating in any "AC" category the manufacturer chooses.

IEC tests are not designed specifically for hermetic refrigeration motors as are the ARI (Air Conditioning and Refrigeration Institute) tests. The ARI tests are, in part, used for Emerson Climate Technologies standards.

ARI test requirements for compressor contactors fall between IEC categories "AC3" and "AC4". The "AC3" rating is for starting of squirrel cage motors with locked rotor currents equal to eight times rated load amps, with voltages to 600VAC, but stopping the motor only at Rated Load Current, when the motor is up to speed. This means there are no "AC3" provisions for a contactor to open the compressor circuit under locked rotor conditions.

The "AC4" rated contactor is life tested, making and breaking motor locked rotor circuits at eight times Rated Load Amps with voltages to 600VAC. Because of the severity of this test, "AC4" devices are not normally selected for refrigeration compressor loads.

At the end of each series of IEC contactor tests, the manufacturer typically publishes contactor life curves. These curves allow the user to estimate the contactor's mechanical life and electrical contact life, based on his application, rather than on the contactor nameplate rating. These curves help the user to make a determination of the life expectancy of his contactor based on his application.

Refrigeration compressor users commonly estimate IEC contactor life expectancy by using a combination of "AC3" and "AC4" ratings. This combination results in a shorter contactor life expectancy than the manufacturer's "AC3" published rating curve, but it is more representative of actual field conditions.

The user must use these curves carefully. IEC has different test requirements for rating (nameplate) verification than for contact life curves.

The user should also verify the type of short circuit protection required, since this can vary with the IEC manufacturer.

Definite Purpose Contactors

To meet the needs of the refrigeration and air conditioning industry, electrical equipment manufacturers have developed definite purpose contactors. These contactors have been designed specifically for loads where their life can be statistically predetermined by their application. Definite purpose contactors normally have a lower initial cost compared to NEMA and IEC devices.

Although their cost is less, definite purpose compressor contactors must still be designed to meet harsh conditions such as rapid cycling, sustained overloads, and low system voltages. They must have contacts large enough to dissipate the heat generated by the compressor load currents, and their contact materials must be selected to prevent welding under starting and other LRA (Locked Rotor Amperage) conditions.

Three Phase, Three Contact, Contactor Requirement

Emerson contactor test requirements for both electrical application ratings and life expectancy, on three phase applications, are based on both making and breaking all three legs of a three phase power supply. Similarly, recommendations for proper contactor sizing are based on this testing criteria, and the expectation that the contactor will be applied so as to break all three legs.

On small single phase compressors, it has been common practice for many years to control motor operation by making and breaking only one leg of the two leg power supply through a relay or pressure control contact.

Since the voltage involved is either 115V or 230V, and the current flow relatively small, the control relay or pressure switch contact points have satisfactory lives and field problems are minimal.

From time to time, for reasons of economy, consideration is given to applying three phase motors in a similar fashion using a contactor with only two contact points to break two legs of the three phase power supply, while leaving the third leg connected to the supply. **Using two leg control, particularly on systems having a supply voltage of 460 Volts or higher, results in a serious field safety hazard. If this two contact approach is used, a danger will exist for service or operating personnel who fail to identify the unbroken power lead.**

There is also some evidence that unexplained air conditioning compressor motor failures on spring startup were actually caused by winter lightning strikes finding a path through the compressor motor contactor to the compressor by way of the unbroken line.

In the best interests of both Emerson and the user, Emerson only lists those contactors that break all three legs of a three phase circuit. For reasons of safety and reliability, Emerson does not recommend the two leg break approach and would particularly discourage any two leg break for power supplies greater than 240VAC.

Amperage Ratings of NEMA and Definite Purpose Contactors

General Purpose (NEMA) rated contactors are listed by sizes that are generally related to motor horsepower groupings. They are also rated in current, a more useful rating for compressors. DP (Definite Purpose) contactors, on the other hand, are usually listed for current alone, although occasionally a manufacturer qualifies his contactor for horsepower ratings. The Definite Purpose contactor has less ability to handle inrush (Locked Rotor Amps or LRA) currents than does the General Purpose contactor. The amount of inrush current each DP contactor can carry is usually inversely proportional to the system voltage, while General Purpose contactors keep the same inrush current ratings with system voltages as high as 600VAC.

FLA (Full Load Amps) is the term used by most industries to represent a maximum running current rating. Compressor manufacturers use RLA (Rated Load Amps).

The inrush and applicable amperage rating for several NEMA size General Purpose contactors and comparable, DP contactors are shown in Table 1. Notice the much broader selections of Definite Purpose contactors that enable them to be more closely tailored to the load.

Caution! Most contactors have a resistive rating as well as a motor rating. The resistive rating is higher in amperage value than the motor rating amperage value. This is because a resistive load is not called on to make and break motor currents. **You must use motor load ratings for motor loads.**

Table 1 shows the differences between a current rated general purpose contactor, and a definite purpose contactor. Notice that the general purpose contactor has no voltage limitations on its inrush or LRA (locked rotor amp) rating, while the definite purpose goes by the "six-five-four" rule. This rule means the contactor's

LRA rating for a load is six times the RLA for 230V, it is five times for 460V, and four times for 575V.

Establishing the Compressor Contactor Load

U.L. (Underwriter’s Laboratories), tests compressor motors to verify their contactor requirements and overcurrent protection needs. Their tests are designed to be in conformance with Articles 430 and 440 of the NEC (National Electric Code). These articles, in part, outline the requirements of contactors in compressor motor circuits.

In general, U.L. requires that a maximum continuous running current rating be established for each compressor for each application. By definition the maximum continuous current is that current drawn just prior to protector trip. In effect, this extreme continuous current value is then used to establish a running current value for the compressor called RLA (Rated Load Amps). Article 440 of the NEC sets the Maximum Continuous Current (MCC) rating of a compressor motor at 156% of it’s RLA value.

The National Electric Code definition of RLA is really applicable only if a compressor is installed in a complete system. If only this definition of the compressor load was used, and a compressor was to be rated only after it was installed in a condensing unit or a system, there would be a huge number of possible Rated Load Amp values.

As a practical matter, U.L. accepts the compressor Rated Load Amps (RLA) value in lieu of testing each condensing unit with the wide variety of evaporators to which it might be applied.

Since there is no test criteria to insure contactor operation at 156% of its RLA rating, there is no assurance that a contactor can stand prolonged

exposure to an overload of the magnitude which would be incurred just prior to a protector trip.

Therefore **Emerson Climate Technologies has established a rated load current for all pilot circuit protected compressors at a more conservative value. Maximum Continuous Current for all Copeland® compressors is 140% of Rated Load Amps. It is a specification of the Emerson warranty that the contactor size must not be less than the Emerson nameplate Rated Load Amp value.**

Emerson Contactor Application Specifications

The following Emerson specifications are based on contactor ratings as listed with U.L.

- A. The contactor must meet the operational and test criteria in ARI (Air Conditioning and Refrigeration Institute) Standard 780- 78, “Standard For Definite Purpose Contactors.”
- B. The contactor must be certified by the manufacturer to close at 80% of the lowest nameplate voltage at normal room temperatures. (166 Volts for contactors used on 208/230 Volt rated equipment.)
- C. On single contactor applications, the rating of the contactor for both full load amperes and locked rotor amperes (LRA) must be greater than the corresponding nameplate amperage rating of the compressor motor RLA plus the nameplate amperage ratings of any fans or other accessories also operated through the contactor.
- D. For two contactor applications, each contactor must have a part winding locked rotor rating equal to or exceeding the half winding locked rotor rating of the compressor.

**Table 1
NEMA (General Purpose) and Definite Purpose Contactor Current Ratings**

NEMA Size	NEMA		Definite Purpose			
	Amperage rating (Through 600VAC)		FLA (RLA)	Amperage Ratings for Common System Voltages		
	FLA	LRA		LRA		
				230V	460V	575V
1	27	288	25	150	125	100
			30	180	150	125
			40	240	200	160
2	45	483	50	300	250	200
			60	360	300	240
			75	450	375	300
3	90	947	90	540	450	360
			120	720	600	480

Very often, since half winding LRA is larger than 50% of the compressor full winding LRA, and definite purpose contactors are sized in part by the locked rotor rating, the two contactors needed to meet the part-winding locked rotor requirement will have a combined full load rating in excess of the compressor nameplate full load rating.

Time Delay Relays

For part winding start applications, a time delay relay is required between contactors with a setting of 1 second plus or minus 1/10 second. The operation of a delay relay can be affected by low voltage.

In order to insure reliability, time delay relays listed as meeting Emerson specifications for nominal 208/230 Volt control systems must be guaranteed by the manufacturer to function properly at 170 Volts in a -40F ambient. See **Table 2**.

Approved Vendors of Time Delay Relays and Contactors

The following time delay relays are listed by U.L., have met Emerson’s performance specifications, and to the best of Emerson’s knowledge have had a record of satisfactory field experience.

However since Emerson does not continually monitor these devices and has no control over the materials or workmanship involved in manufacture, any defects must be the responsibility of the manufacturer.

The Emerson warranty does not extend to external electrical components furnished by others, and the failure of such components resulting in compressor failure, will void the compressor warranty. In addition, Emerson reserves the right to issue credit to Wholesalers for 4, 6, or 8 model semi-hermetic service compressors that are determined to have a single-phase motor burn caused by an Emerson contactor. Single phase motor burns are not the result of manufacturing defects. See **Table 3** for a description.

**Table 2
Time Delay Relays For Part Winding Start Applications**

Manufacturer	Nominal Voltage	Model Number
Omnetics (ICM Corp.) Cicero, N.Y. 13211	115V.	MMS115A1Y1B
	230V.	MMS230A1Y1B
Artisan Controls Corp. Parsippany, N.J. 07054	115V.	4380F-115-1
	230V.	4380F-230-1

Emerson part number for 115V 50/60 time delay relay : 040-0109-01
(Wholesaler replacement part no. 998-0109-01)

Emerson part number for 230V 50/60 time delay relay : 040-0109-00
(Wholesaler replacement part no. 998-0109-00)

**Table 3
Emerson Approved Contactors**

Emerson Part #	Description
912-1025-00	1 Pole, 25A Ind. 24v
912-1025-01	1 Pole, 25A Ind. 120v
912-1025-02	1 Pole, 25A Ind. 208/240v
912-1030-00	1 Pole, 30A Ind. 24v
912-1030-01	1 Pole, 30A Ind. 120v
912-1030-02	1 Pole, 30A Ind. 208/240v
912-1040-00	1 Pole, 40A Ind. 24v
912-1040-01	1 Pole, 40A Ind. 120v
912-1040-02	1 Pole, 40A Ind. 208/240v
912-1925-00	1 Pole, 25A Ind. 24v w/Shunt
912-1925-01	1 Pole, 25A Ind. 120v w/ Shunt
912-1925-02	1 Pole, 25A Ind. 208/240v w/ Shunt
912-1930-00	1 Pole, 30A Ind. 24v w/ Shunt
912-1930-01	1 Pole, 30A Ind. 120v w/ Shunt
912-1930-02	1 Pole, 30A Ind. 208/240v w/ Shunt
912-1940-00	1 Pole, 40A Ind. 24v w/ Shunt
912-1940-01	1 Pole, 40A Ind. 120v w/ Shunt
912-1940-02	1 Pole, 40A Ind. 208/240v w/ Shunt
912-2020-00	2 Pole, 20A Ind. 24v
912-2020-01	2 Pole, 20A Ind. 120v
912-2020-02	2 Pole, 20A Ind. 208/240v
912-2025-00	2 Pole, 25A Ind. 24v
912-2025-01	2 Pole, 25A Ind. 120v
912-2025-02	2 Pole, 25A Ind. 208/240v
912-2030-00	2 Pole, 30A Ind. 24v
912-2030-01	2 Pole, 30A Ind. 120v
912-2030-02	2 Pole, 30A Ind. 208/240v
912-2040-00	2 Pole, 40A Ind. 24v
912-2040-01	2 Pole, 40A Ind. 120v
912-2040-02	2 Pole, 40A Ind. 208/240v
912-3015-00	3 Pole, 15A Ind. 24v
912-3015-01	3 Pole, 15A Ind. 120v
912-3015-02	3 Pole, 15A Ind. 208/240v
912-3015-03	3 Pole, 15A Ind. 440v
912-3025-00	3 Pole, 25A Ind. 24v
912-3025-01	3 Pole, 25A Ind. 120v
912-3025-02	3 Pole, 25A Ind. 208/240v
912-3025-03	3 Pole, 25A Ind. 440v
912-3030-00	3 Pole, 30A Ind. 24v
912-3030-01	3 Pole, 30A Ind. 120v
912-3030-02	3 Pole, 30A Ind. 208/240v
912-3030-03	3 Pole, 30A Ind. 440v
912-3040-00	3 Pole, 40A Ind. 24v
912-3040-01	3 Pole, 40A Ind. 120v
912-3040-02	3 Pole, 40A Ind. 208/240v
912-3040-03	3 Pole, 40A Ind. 440v
912-3050-00	3 Pole, 50A Ind. 24v

**Table 3
Emerson Approved Contactors (Continued)**

Emerson Part #	Description
912-3050-01	3 Pole, 50A Ind. 120v
912-3050-02	3 Pole, 50A Ind. 208/240v
912-3050-03	3 Pole, 50A Ind. 440v
912-3060-00	3 Pole, 60A Ind. 24v
912-3060-01	3 Pole, 60A Ind. 120v
912-3060-02	3 Pole, 60A Ind. 208/240v
912-3060-03	3 Pole, 60A Ind. 440v
912-3075-00	3 Pole, 75A Ind. 24v
912-3075-01	3 Pole, 75A Ind. 120v
912-3075-02	3 Pole, 75A Ind. 208/240v
912-3075-03	3 Pole, 75A Ind. 440v
912-3090-00	3 Pole, 90A Ind. 24v
912-3090-01	3 Pole, 90A Ind. 120v
912-3090-02	3 Pole, 90A Ind. 208/240v
912-3090-03	3 Pole, 90A Ind. 440v
912-3120-00	3 Pole, 120A Ind. 24v
912-3120-01	3 Pole, 120A Ind. 120v
912-3120-02	3 Pole, 120A Ind. 208/240v
912-3120-03	3 Pole, 120A Ind. 440v
912-3200-00	3 Pole, 200A Ind. 24v
912-3200-01	3 Pole, 200A Ind. 120v
912-3200-02	3 Pole, 200A Ind. 208/240v
912-3200-03	3 Pole, 200A Ind. 440v
912-3300-00	3 Pole, 300A Ind. 24v
912-3300-01	3 Pole, 300A Ind. 120v
912-3300-02	3 Pole, 300A Ind. 208/240v
912-3300-03	3 Pole, 300A Ind. 440v
912-3360-00	3 Pole, 360A Ind. 24v
912-3360-01	3 Pole, 360A Ind. 120v
912-3360-02	3 Pole, 360A Ind. 208/240v
912-3360-03	3 Pole, 360A Ind. 440v
Auxilliary Contact Kits (Side Mounted)	
912-0001-10	1 NO - For 15-75A
912-0001-11	1 NC - For 15-75A
912-0001-12	1 NO/1 NC - For 15-75A
912-0001-13	2 NO - For 15-75A
912-0001-14	2 NC - For 15-75A
912-0001-15	1 NO - For 90A
912-0001-16	1 NC - For 90A
912-0001-17	1 NO/1 NC - For 90A
912-0001-18	2 NO - For 90A
912-0001-19	1 NO - For 120-360A
912-0001-20	1 NC - For 120-360A
912-0001-21	1 NO/1 NC - For 120-360A
912-0001-22	Mech. Interlock - For 15-75A

**Table 4
Contactor Specifications & Selection Guide**

Model	230 volt - 1 contactor			230 volt - 2 contactors			460 volt - 1 contactor			460 volt - 2 contactors		
	LRA	RLA	Contactor Amp Rating	LRA	RLA	Contactor Amp Rating	LRA	RLA	Contactor Amp Rating	LRA	RLA	Contactor Amp Rating
4DA3-100E-TSK-800	240	42	50	140	42	2-25	120	21	25			
4DA3-101E-TSK-800	240	42	50	140	42	2-25	120	21	25			
4DE3-100E-TSK-800	240	42	50	140	42	2-25	120	21	25			
4DA3-200E-TSK-800	308	66	75	188	33	2-40	154	33	40			
4DA3-2000-FSD-800							173	34	40	104	17	2-25
4DA3-2000-TSK-800	308	66	75	188	33	2-40	154	33	40			
4DA4-2000-TSK-800	308	66	75	188	33	2-40	154	33	40			
4DE3-200E-TSK-800	308	66	75	188	33	2-40	154	33	40			
4DE3-2000-FSD-800							173	34	40	104	17	2-25
4DE3-2000-TSK-800	308	66	75	188	33	2-40	154	33	40			
4DB3-2200-TSK-800	374	66	75	222	33	2-40	187	33	40			
4DC3-2200-TSK-800	374	66	75	222	33	2-40	187	33	40			
4DH3-150E-TSK-800	278	58	75	170	29	2-40	139	29	40			
4DH3-250E-TSK-800	428	82	90	250	41	2-50	214	41	50			
4DH3-2500-TSK-800	428	82	90	250	41	2-50	214	41	50			
4DJ3-3000-TSK-800	470	94	120	292	47	2-50	235	47	50			
4DK3-150E-TSK-800	278	58	75	170	29	2-40	139	29	40			
4DK3-250E-TSK-800	428	82	90	250	41	2-50	214	41	50			
4DK3-2500-FSD-800							206	41	50	132	20	2-30
4DK3-2500-TSK-900	428	82	90	250	41	2-50	214	41	50			
4DL3-150E-TSK-800	278	53	60	170	26	2-40	139	26	40			
4DN3-101E-TSK-800	220	46	50	134	23	2-25	110	23	25			
4DP3-150E-TSK-800	278	53	60	170	26	2-40	139	26	40			
4DP8-150E-TSK-800	278	53	60	170	26	2-40	139	26	40			
4DR3-200E-TSK-800	346	66	75	208	33	2-40	173	33	40			
4DR3-300E-TSK-800	470	94	120	292	47	2-50	235	47	50			
4DR3-3000-FSD-800							235	45	50	141	23	2-30
4DR3-3000-TSK-800	470	94	120	292	47	2-50	235	47	50			
4DS3-220E-TSK-800	374	66	75	222	33	2-40	187	33	40			
4DT3-220E-FSD-800							180	34	40	108	17	2-25
4DT3-220E-TSK-800	374	66	75	222	33	2-40	187	33	40			
4RA3-100A-TSK-800	240	55	60	140	27	2-30	120	27	30			
4RA3-200A-TSK-800	308	71	75	188	36	2-40	154	36	40			
4RA4-200A-TSK-800	308	71	75	188	36	2-40	154	36	40			
4RE2-200A-FSD-800							135	33	40	82	17	2-20
4RE2-200A-TSK-800	308	71	75	188	36	2-40	154	36	40			

**Table 4
Contactor Specifications & Selection Guide (Continued)**

Model	230 volt - 1 contactor			230 volt - 2 contactors			460 volt - 1 contactor			460 volt - 2 contactors		
	LRA	RLA	Contactor Amp Rating	LRA	RLA	Contactor Amp Rating	LRA	RLA	Contactor Amp Rating	LRA	RLA	Contactor Amp Rating
4RH1-150A-TSK-800	278	63	75	170	32	2-40	139	32	40			
4RJ1-300A-FSD-800							200	59	60	121	30	2-30
4RK2-250A-FSD-800							165	45	50	100	23	2-25
4RK2-250A-TSK-800	428	89	90	250	44	2-50	214	44	50			
4RL1-150A-TSK-800	278	63	75	170	32	2-40	139	32	40			
4RL2-150A-TSK-800	278	63	75	170	32	2-40	139	32	40			
4RR1-300A-FSD-800							200	59	60	121	30	2-30
4RR1-300A-TSK-800	470	102	120	292	51	2-60	235	51	60			
4RR2-300A-TSK-800	470	102	120	292	51	2-60	235	51	60			
6DB3-3000-TSK-800	565	105	120	340	53	2-60	283	53	60			
6DC3-270E-TSK-800	450	81	90	263	40	2-50	225	40	50			
6DD3-270E-TSK-800	450	81	90	263	40	2-50	225	40	50			
6DE3-300E-TSK-800	470	96	120	292	48	2-50	235	48	50			
6DF3-300E-TSK-800	470	96	120	292	48	2-50	235	48	50			
6DG3-350E-TSN-800	594	125	150	340	63	2-75	297	63	75			
6DG3-3500-FSD-800							315	66	75	195	33	2-40
6DG3-3500-TSN-800	594	125	150	340	63	2-75	297	63	75			
6DH3-200E-TSK-800	346	75	75	208	38	2-40	173	38	40			
6DH3-350E-TSK-800	565	125	150	340	54	2-75	283	63	75			
6DH3-3500-FSD-800							260	55	75	156	28	2-40
6DH3-3500-TSK-800	565	107	120	340	54	2-75	283	54	75			
6DJ3-300E-TSK-800	470	100	120	292	50	2-50	235	50	50			
6DJ3-400E-TSN-800	594	142	150	340	71	2-75	297	71	75			
6DJ3-4000-TSN-800	594	142	150	340	71	2-75	297	71	75			
6DK3-200E-TSK-800	346	75	75	208	38	2-40	173	38	40			
6DK3-350E-TSK-800	565	107	120	340	54	2-75	283	54	75			
6DK3-3500-FSD-800							260	55	75	156	28	2-40
6DK3-3500-TSK-800	565	107	120	340	54	2-75	283	54	75			
6DL3-270E-TSK-800	450	81	90	263	40	2-50	225	40	50			
6DM3-3500-FSD-800							315	66	75	195	33	2-40
6DM3-3500-TSN-800	594	125	150	340	63	2-75	297	63	75			
6DN3-350E-TSN-800	594	125	150	340	63	2-75	297	63	75			
6DN3-3500-FSD-800							315	66	75	195	33	2-40
6DN3-3500-TSN-800	594	125	150	340	63	2-75	297	63	75			
6DP3-200E-TSK-800	346	75	75	208	38	2-40	173	38	40			
6DP3-350E-FSD-800							260	55	75	156	28	2-40
6DP3-350E-TSK-800	565	107	120	340	54	2-75	283	54	75			
6DP3-3500-FSD-800							260	55	75	156	28	2-40
6DP3-3500-TSK-800	565	107	120	340	54	2-75	283	54	75			

**Table 4
Contactor Specifications & Selection Guide (Continued)**

Model	230 volt - 1 contactor			230 volt - 2 contactors			460 volt - 1 contactor			460 volt - 2 contactors		
	LRA	RLA	Contactor Amp Rating	LRA	RLA	Contactor Amp Rating	LRA	RLA	Contactor Amp Rating	LRA	RLA	Contactor Amp Rating
6DR3-300E-TSK-800	470	100	120	292	50	2-50	235	50	50			
6DR3-400E-FSD-800							315	70	75	195	35	2-40
6DR3-400E-TSN-800	594	142	150	340	71	2-75	297	71	75			
6DR3-4000-FSD-800							315	70	75	195	35	2-40
6DR3-4000-TSN-800	594	142	150	340	71	2-75	297	71	75			
6DS3-300E-TSK-800	470	100	120	292	50	2-50	235	50	50			
6DS3-400E-TSN-800	594	142	150	340	71	2-75	297	71	75			
6DS3-4000-FSD-800							315	70	75	195	35	2-40
6DS3-4000-TSN-800	594	142	150	340	71	2-75	297	71	75			
6DT3-300E-FSD-800							235	43	50	141	21	2-30
6DT3-300E-TSK-800	470	100	120	292	50	2-50	235	50	50			
6DW3-3000-FSD-800							260	50	50	156	25	2-40
6DW3-3000-TSK-800	565	105	120	340	53	2-60	283	53	60			
6DY3-3000-FSD-800							260	50	50	156	25	2-40
6DY3-3000-TSK-800	565	105	120	340	53	2-60	283	53	60			
6RA4-100A-TSK-800	240	44	50	140	22	2-25	120	22	25			
6RA4-200A-TSK-800	308	67	75	188	34	2-40	154	34	40			
6RB2-100A-TSK-800	240	43	50	140	22	2-25	120	22	25			
6RB2-200A-TSK-800	308	61	75	188	31	2-40	154	31	40			
6RE2-200A-TSK-800	308	67	75	188	34	2-40	154	34	40			
6RH1-200A-TSK-800	308	72	75	188	36	2-40	154	36	40			
6RL1-250A-TSK-800	428	97	120	250	49	2-50	214	49	50			
6RN2-300A-TSK-800	470	105	120	292	53	2-60	235	53	60			
6RP2-200A-TSK-800	308	72	75	188	36	2-40	154	36	40			
6RP2-350A-FSD-800							225	68	75	150	34	2-40
6RP2-350A-TSK-800	565	135	150	340	68	2-75	283	68	75			
6RS2-400A-FSD-800							239	64	75	147	32	2-40
6RS2-400A-TSN-800	594	142	150	340	71	2-75	297	71	75			
6RT1-300A-TSK-800	470	111	120	292	56	2-60	235	56	60			
6TM1-2000-TSK-800	308	66	75	188	33	240	154	3	40			
8DP1-5000-FSD-800							510	91	120	330	46	2-75
8DP1-5000-TSK-800	1070	180	200	654	90	2-120	535	90	120			
8DS1-6000-FSD-800							510	97	120	330	48	2-75
8DS1-6000-TSK-800	1070	224		654	112	2-120	535	112	120			

**Table 4
Contactor Specifications & Selection Guide (Continued)**

Model	200 volt - 1 contactor			200 volt - 2 contactors		
	LRA	RLA	Contactor Amp Rating	LRA	RLA	Contactor Amp Rating
6DG3-3500-FSU-800	650	135	150	400	68	2-75
6DM3-3500-FSU-800	650	135	150	400	68	2-75
6DN3-350E-FSU-800	650	135	150	400	68	2-75
6DN3-3500-FSU-800	650	135	150	400	68	2-75
6DS3-4000-FSU-800	754	150	150	463	75	2-90
6RS2-400A-FSU-800				388	85	2-90
Model	575 volt - 1 contactor			575 volt - 2 contactors		
	LRA	RLA	Contactor Amp Rating	LRA	RLA	Contactor Amp Rating
4DA3-2000-TSE-800	135	25	40	81	12	2-25
4DC3-2200-TSE-800	135	27	40	81	13	2-25
4DK3-2500-TSE-800	172	34	50	103	17	2-30
4DR3-3000-TSE-800	200	39	50	130	20	2-40
4RK2-250A-TSE-800	160	35	40	113	17	2-20
6DG3-3500-TSE-800	245	46	60	152	23	2-40
6DH3-3500-TSE-800	230	43	60	138	21	2-40
6DN3-3500-TSE-800	245	46	60	152	23	2-40
6DP3-3500-TSE-800	230	43	60	138	21	2-40
6DS1-4000-TSE-800	245	54	60	152	27	2-40
8DP1-5000-TSE-800	405	75	120	262	38	2-75

RLA - Rated load amps.

LRA - The current drawn by a motor which is "locked" and cannot rotate.
It occurs instantly during start up.

4 Steps to Select a Compressor Contactor

1. Determine the system voltage.
2. Determine if the compressor is to be started by Full Voltage or Part-Winding (one contactor or two contactor start).
3. Obtain the compressor RLA and LRA values from Table 4 of this bulletin, from the compressor nameplate, or from Emerson Climate Technologies specifications.
4. Check Emerson Approved Contactor Description Refer to Table 4 for contactor requirements.

If the compressor is not listed in a table, the contactor can always be sized for full voltage starting by selecting a contactor of the next amperage rating larger than the compressor's rated load amperage (RLA), and then checking its LRA requirements against the rating of the chosen contactor.

TESTS FOR CONTACTOR QUALITY

Definite Purpose Contactor Requirements

Of the two general requirements all motor contactors must meet, dissipating the heat generated in the contacts while running, and cycling on and off under locked rotor conditions, the locked rotor cycling requirement is the hardest to understand. The compressor normally undergoes a locked rotor condition, at startup, for such a very short period of time that it is difficult to measure in the field. Yet, it is under this condition that the contactor "points" are subjected to their maximum currents. If two contactors are used for starting the compressor ("parallel winding start" or "part winding start"), the situation is further complicated by the fact that when only 1/2 of the motor winding is energized, the locked rotor current drawn is in excess of 1/2 of the full motor locked rotor current because of the inductive transformer effect of the non-energized winding.

Because definite purpose contactors are so critical to the successful operation of a compressor system, Emerson Climate Technologies has worked with both U.L. and ARI to develop contactor ratings and methods of test. There are very important tests that relate to the life of the contactor. Emerson subscribes to, and the contactor requirements follow, the harsher of the two tests recommended by the two organizations.

1. The Mechanical Life Test

ARI requires that the contactor shall have no mechanical malfunction after 500,000 cycles with no electrical load. This test checks the moving parts of a contactor and its coil.

2. Endurance Test Under Rated Load

ARI states that the contactor must withstand 200,000 starting cycles with no failure, when making its rated locked rotor current and breaking 125% of its rated load current.

3. Locked Rotor Endurance Test

For refrigeration and air conditioning applications with automatic reset pilot duty protection and for single contactor applications, ARI recommends a locked rotor test, based on the contactor making and breaking locked rotor amps, of 10,000 cycles.

4. Part Winding and Two Contactor Test

For part winding or two contactor applications, the U.L. requirement is based on 30,000 cycles making full load and breaking locked rotor current. This is a very difficult test to pass. This test requirement can result in a substantial difference in the locked rotor rating of the contactor. Some contactors cannot successfully complete this test without lowering their inrush current ratings. These contactors are listed as derated to 80% of their single contactor inrush current rating for two contactor (which includes part winding) applications.

5. Low Voltage Pull In Test

The marginal nature of the power supply in some sections of the United States can result in dangerously low voltages during heavy demand periods.

On 208 Volt systems, which appear to be the most critical, the supply voltage at the utility may be as low as 191 Volts, and if the distribution and installation wiring is heavily loaded, it is possible that voltage at the compressor contactor coil may be well below 180 volts during the starting period when high inrush current is drawn.

Unless the contactor coil has adequate capability to pick-up (close its contacts), the low voltage condition can cause contact chatter, and potential contactor and compressor failure. In order to insure increased reliability, definite purpose contactors listed as meeting Emerson specifications with coils for nominal 208/230 Volt power must be guaranteed by the manufacturer to give a clean pick-up at 166 Volts at normal room temperature.

Any chattering or failure of a contactor to function properly under low voltage conditions should be investigated. If the voltage supplying the contactor is too low, or the voltage "drops" to an unacceptable level when the contactor is energized, the system voltage should be corrected.

The Contactor and Motor Overload Protection

Contactors play a role in any compressor overload protection scheme, but they are particularly important when they are part of pilot operated protection systems. When the compressor pilot or control circuit contains the contact of a modern electronic overload protector, the protector, in conjunction with a properly operating contactor of the correct size, provides an excellent motor safeguard. The protector accurately senses a change in motor temperature caused by a mechanical or an electrical overcurrent problem and signals the contactor coil to remove the compressor from the power supply. In spite of this protection, motor burnouts attributed to power supply problems continue to be a source of motor failure. Improperly sized contactors can contribute to this problem, even if it does not originate with them.

Power Supply Problems

An all too common power supply problem is the loss of one phase in the lines from the secondary of the power supply transformer to the compressor. If the motor is stopped this "single phasing" will cause the compressor to draw heavy rotor currents, but be unable to start.

If the compressor is running at the time of the fault, it will continue to run but with a large current overload. The motor windings will of course rapidly overheat and the motor protector will signal the contactor coil to remove the compressor from the line. But, as soon as the compressor motor windings cool down to normal operating temperatures, the protector will signal the compressor to restart, but the motor is unable to restart generating locked rotor current which will cause the protector to trip again. No compressor motor is designed to indefinitely cycle on a single phase condition.

During the sustained locked rotor condition, the motor not only overheats rapidly but the motor windings undergo a continuing mechanical stress that is far beyond their starting and running design. If the problem exists over a long period of time the motor life will be shortened, and the protector will fail. The protector will either fail open, preventing a compressor start, or it will fail closed. If the protector fails closed, the motor will lose all protection and will burn out during the next single phase cycle.

Because of unbalanced loading on all three voltage lines, single phasing can also produce the side effect of erratic voltages in the control circuit. These very rapid fluctuations can cause contactor chatter. The chattering contactor continually connects the motor to the line, then disconnects it. The motor is subjected to heavy magnetic torquing of its stator windings as well as heavy inrush currents as it is needlessly cycled on and off. This condition is one of the most destructive to a motor. Motor windings move and rub together each

time the contactor closes, and in a short time under these rapid cycling conditions winding insulation fails, windings are shorted together and the destruction continues until the motor fails. This is a source of motor failures against which the compressor overload system was not designed to protect. In addition to the motor stress, the chattering contactor is taking a beating. No contactor can last long under this condition. After a time, even the best contactor's coil will fail. If the contactor's coil fails, it can seize the contactor armature in such a way that all contacts are not closed or not opened evenly, with single phasing as a result.

If the contactor has been undersized, its contacts will be unable to withstand the arcing and high temperatures generated by the extreme cycling or "machine-gun" effect of an erratic control circuit voltage, and they will very likely weld together or become dislodged from their contact carrier. Welded contacts will create a permanent single phase condition that makes the overload protector continuously cycle on and off. Dislodged contacts force the copper contact carriers of the contactor to try to make and break heavy electrical currents and they will also weld. When welding occurs, the contactor will perpetuate the single phase condition through its welded or missing contacts.

After a single phase condition has been corrected, the contactors and relays of the control circuit should be inspected for damage if they could have been adversely effected. If a compressor contactor fails with its contacts or contact carrier welded, the motor can also fail at a later time even though the power supply problem has been corrected, and in addition a hazardous condition has been created since the system safety controls cannot remove the compressor contactor from the line in case of an overload

Primary Phase Failure

The effect of an open phase in the primary circuit of a power transformer depends on the type of transformer connection. Where both primary and secondary windings are connected in the same fashion, wye-wye or delta-delta, a fault in one phase of the primary will result in a low current in one phase of the secondary, and high currents in two phases, with results similar to the simple load circuit single phase condition.

But in wye-delta or delta-wye connected power transformers, an open circuit or single phase on the primary side of the transformer will result in a high current in only one phase of the motor with low currents in the other two phases.

Under locked rotor conditions, the high phase will draw an amperage slightly less than nameplate locked

rotor current, while the other two legs will each draw approximately 50% of that amount. Under operating conditions, the current in the high phase could be in excess of 200% of full load amperes, depending on load, while the current in the other two legs will be slightly greater than normal full load amperes.

Unbalanced Supply Voltage

A properly wound three phase motor connected to a supply source in which the voltages in each phase are balanced at all times will have nearly identical currents in all three phases.

The differences in motor windings in modern motors are normally so small that the effect on amperage draw is negligible. Under ideal conditions, if the phase voltages were always equal, a single motor protector in just one line would adequately protect the motor against damage due to an excessive running overcurrent draw.

As a practical matter, balanced supply voltages are not always maintained, so the three line currents will not always be equal.

The effect of unbalanced voltages is equivalent to the introduction of a “negative sequence voltage.” This exerts a force opposite to that created with balanced voltages.

These opposing forces will produce currents in the windings greatly in excess of those present under balanced voltage conditions.

Voltage unbalance is calculated as follows:

$$\% \text{ VU (Voltage Unbalance)} = (100 \times \text{Maximum Voltage Deviation from the Average Voltage of the three phases}) / \text{Average Voltage of the three phases}$$

As an example, a nominal 230V 3PH power source, produces the following voltages at the terminals of a three phase compressor:

$$\text{L1-L2} = 220\text{V}, \text{L1-L3} = 230\text{V}, \text{L2-L3} = 216\text{V}$$

Using the percentage voltage unbalance formula, we get the following:

$$\text{Average voltage} = (220\text{V} + 230\text{V} + 216\text{V})/3 = 222\text{V}$$

$$\text{Maximum Deviation} = 230 - 222 = 8$$

$$\% \text{ voltage unbalance} = (100 \times 8)/222 = 3.6 \%$$

As a result of the voltage unbalance, the locked rotor currents will be unbalanced to the same degree. However, the unbalance in load currents at normal operating speed may be from 4 to 10 times the voltage unbalance, depending on the load. With the 3.6% voltage unbalance in the previous example, load current

in one phase might be as much as 30% greater than average line current being drawn.

The NEMA Motors and Generators Standards Publication states that the percentage increase in temperature rise in a phase winding resulting from voltage unbalance will be approximately two times the square of the voltage unbalance.

$$\% \text{ Increase in Temperature} = 2 \times \text{Voltage Unbalance}^2$$

Using the voltage unbalance from the previous example, the % increase in temperature can be estimated as follows:

$$\% \text{ Increase in Temperature} = 2 \times (3.6 \times 3.6) = 25.9\%$$

As a result of this condition, it is possible that one phase winding in a motor may be overheated while the other two have temperatures within normal limits.

A common source of unbalanced voltage on a three phase circuit is the presence of a single phase load between two of the three phases.

A large unbalanced single phase load, for example a lighting circuit, can easily cause sufficient variations in motor currents to endanger the motor. If at all possible, this condition should be corrected by shifting the single phase load as necessary. Supply voltages should be evenly balanced as closely as can be read on a commercial voltmeter.

A national survey by U.L. indicated that 36 out of 83 utilities surveyed, or 43%, allowed voltage unbalance in excess of 3%, and 30% allowed voltages unbalance of 5% or higher.

In the event of a supply voltage unbalance, the power company should be notified of such unbalance to determine if the situation can be corrected.

Solid state protection provides excellent temperature characteristics, and will protect the motor even with unbalanced current. However, consistently high current in one or two phases can materially shorten the motor life, and may be the source of failure.

It is important that the system operator be made aware that to prevent unnecessary failures additional circuit current and voltage devices may be required especially if the power supply has had a problem history. The operator should also understand that any replacement under warranty of a compressor failing due to a motor burn is contingent on the proper application of a contactor meeting Emerson specifications. It is vital to the compressor that contactors are properly applied.