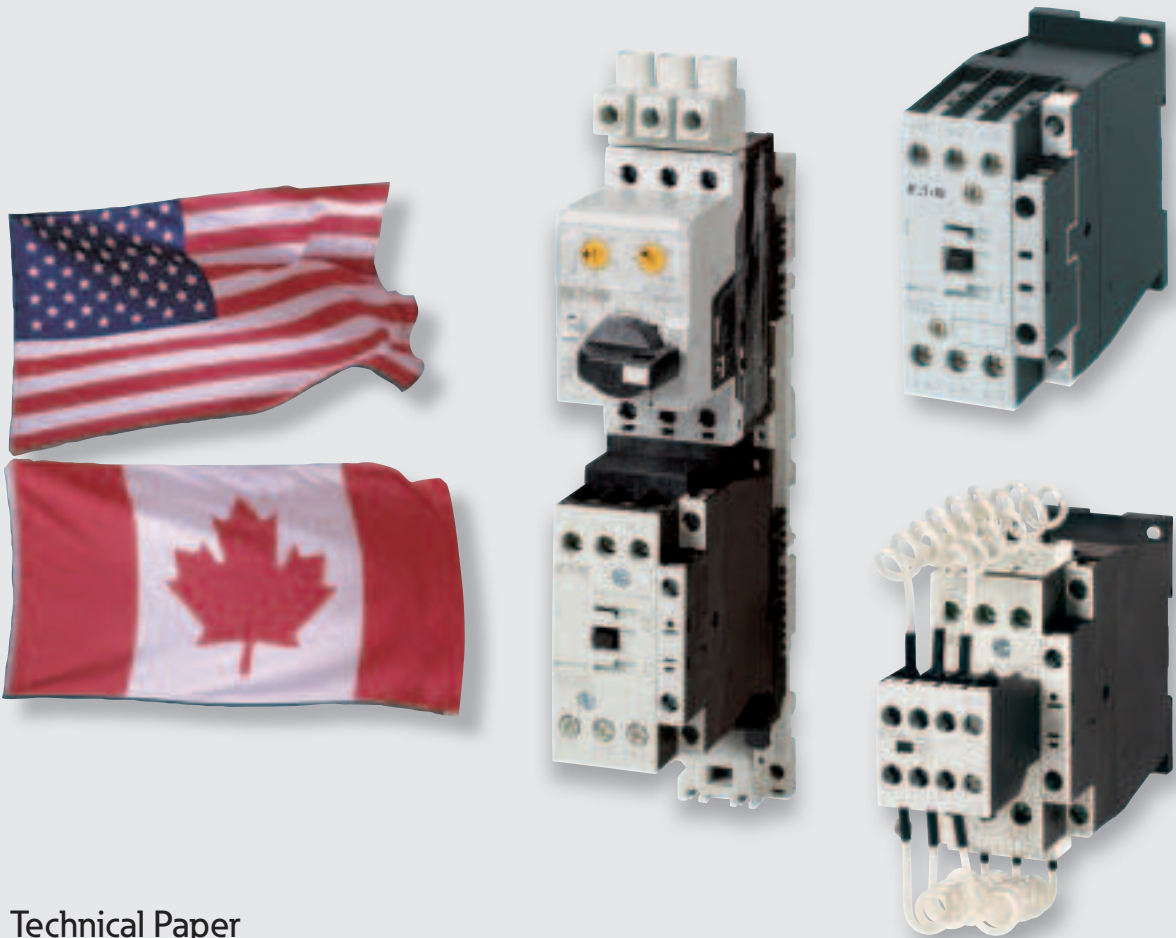


# Motor starters and “Special Purpose Ratings” for the North American market



Technical Paper

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**EATON**

*Powering Business Worldwide*

# Motor starters and “Special Purpose Ratings” for the North American market

– Featuring contactors from the new System xStart range of power products. Optimally rated to safely and economically handle special application switching duties in addition to standard motor loads –

This paper will be of particular interest to electrical designers based outside North America and will present descriptions of commonly encountered terms in the US and Canada dealing with various types of electrical loads and the ratings associated to the components used to switch them. These terms are invariably rooted in a few key American standards and are associated in part with certain product designs more conventionally found in

that market. They are also imbedded into the local market place vernacular and certain terms can even have overlapping definitions with respect to their function. Whereas in the IEC world there is a tendency to always gravitate towards a single but universally applicable range of products, albeit with a broad range of technical data to support this aspect, the situation in North America, generally speaking, tends to favor the availability of

customized ranges with differing price structures that are more focused on specific areas of the market place. As a result, the table provides the latest selection data recently established for Eaton’s newest line of *DIL M*, *DIL L* and *DIL K* UL listed and CSA certified contactors, which will facilitate successful exports to that market, either as individual components, or as part of complete engineered product assemblies.

Special Purpose Ratings per UL / CSA- Testing Criteria														
Type <i>DIL M..</i>	7	9	12	15	17	25	32	40	50	65 72	80	95	115	150 170
<b>AC Elevator Control</b>	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP
480 V 60 Hz, 3-pole	2	3	7 ½	7 ½	7 ½	10	20	25	30	30	50	60	75	75
600 V 60 Hz, 3-pole	3	5	7 ½	7 ½	10	15	20	30	40	40	60	75	100	100
<b>AC Refrigeration Control</b>	A	A	A	A	A	A	A	A	A	A	A	A	A	A
480 V 60 Hz, 3-pole	6	7.5	10	10	23	32	40	26	36	45	63	70	84	90
600 V 60 Hz, 3-pole	6	7.5	10	10	17	24	30	26	36	45	63	70	84	90
<b>AC Resistance Air Heating</b>	A	A	A	A	A	A	A	A	A	A	A	A	A	A
480 V 60 Hz, 3-pole	12	18	20	20	27	35	40	63	79	90	94	110	136	160
600 V 60 Hz, 3-pole	12	18	20	20	27	35	40	63	79	90	94	110	136	160
<b>AC Incandescent Lamps (Tungsten)</b>	A	A	A	A	A	A	A	A	A	A	A	A	A	A
480 V 60 Hz, 3-pole	8	11	14	14	23	32	40	55	74	90	85	100	136	160
600 V 60 Hz, 3-pole	8	11	14	14	23	32	40	55	74	90	85	100	136	160
<b>AC Electrical Discharge Lamps (Ballast)</b>	A	A	A	A	A	A	A	A	A	A	A	A	A	A
480 V 60 Hz, 3-pole	12	18	20	20	27	35	40	63	79	90	85	100	136	160
600 V 60 Hz, 3-pole	12	18	20	20	27	35	40	63	79	90	85	100	136	160
Type <i>DIL K..</i>			12			20	25			33	50			
<b>Capacitive Switching</b>														
480 V 60 Hz, 3-pole	A	18				28	36			48	72.1			
	kVAr	15				20	30			40	60			
600 V 60 Hz, 3-pole	A	14.4				28	38.4			48	72.1			
	kVAr	15				30	40			50	75			

Type DIL M and DIL K contactor selection table for specialized applications (Special Purpose Ratings) in North America.

<sup>1</sup> IEC = International Electrical Commission

<sup>2</sup> UL = Underwriter’s Laboratories (<http://www.ul.com>)

<sup>3</sup> CSA = Canadian Standards Association (<http://www.csa.ca>)

## General Purpose Ratings

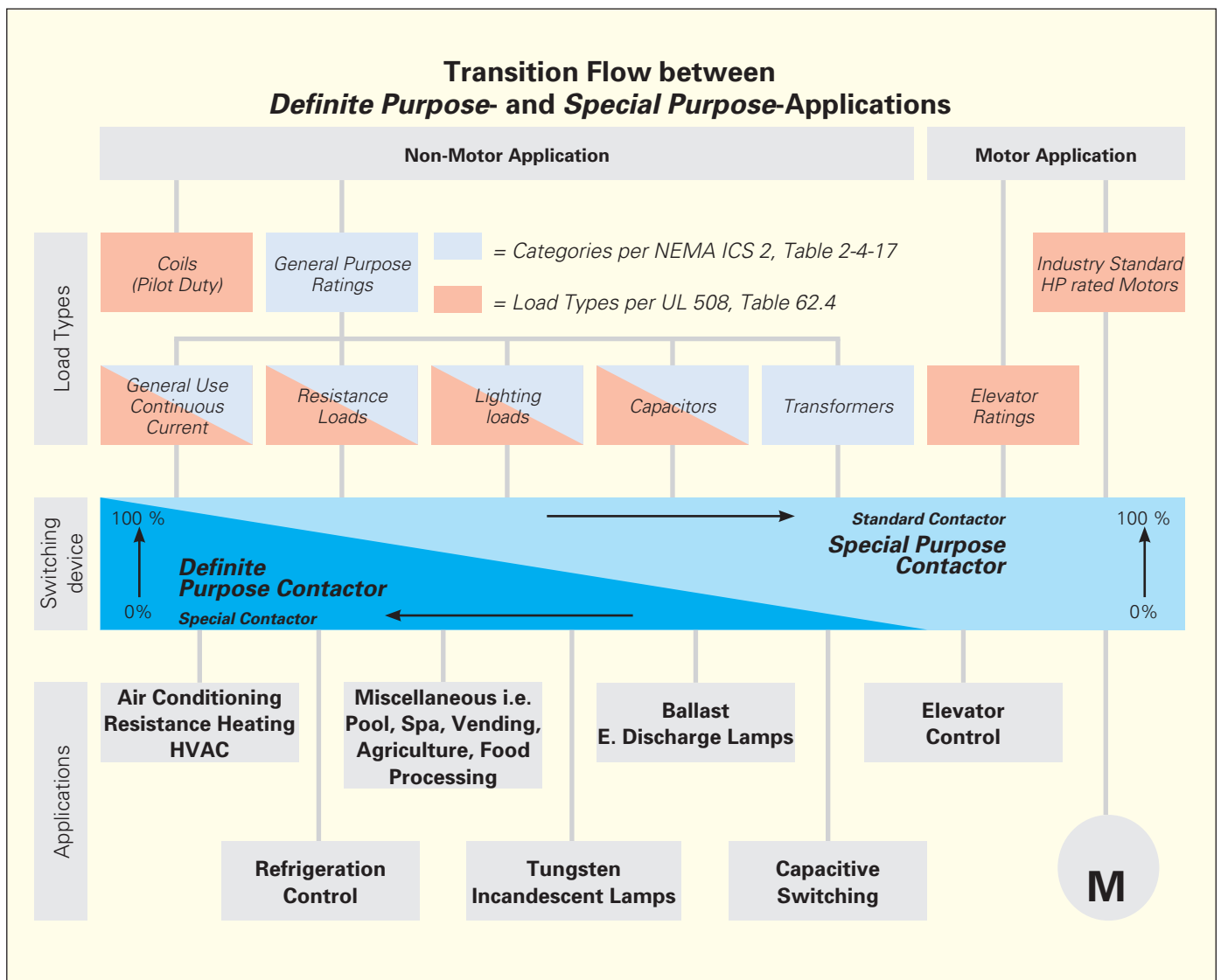
In view of the fact that this paper deals mainly with special applications (*Special Purpose Ratings* or *Definite Purpose Ratings*), it is perhaps advisable to first review some of what is covered under "general" applications. Or one could say, let's have a look at "*General Purpose Ratings*" (general applications) or "*General Purpose-Contactors*". **Diagram 1** shows, however, that the term "*General Purpose Ratings*", and the wording "*General Use*", also tend to more readily associate with a grouping of specialized applications. In actual fact, "*General Use*" is really the only term for which the qualifier "general" seems applicable. And it can't be even considered to be a common application for contactors. The term "*General Use*" actually refers to a current rating (*Continuous Current*), which corresponds to the utilization category AC-1 current (thermal current) from the

IEC world. **Diagram 1** refers to additional and specialized applications and selection criteria, which are referenced as General Purpose ratings in NEMA ICS 2, Table 2-4-17 [13] or as various load types subject to differing test criteria in UL 508 [4], e.g. Table 62.4 of that standard. This data can sometimes also appear on the rating labels of contactors. With respect to "Special Purpose Ratings", which are described later, the data used for selection allow for customized sizing of contactors based on the specific application. **Table 1** compares load types for contactors in North America with the corresponding Utilization Categories per IEC. The comparison refers primarily to the type of load, without touching upon the underlying and divergent test criteria which generate ratings for each respective market. The load types "*Coils / Pilot Duty*" needed to be somewhat further separated as a non-motor application category, since they are more closely asso-

ciated to control circuit loading, whereas the remaining terms specifically deal with elements of the power circuit.

## A Basic Function: Switching Motors

The majority of contactors in North America are also used mainly for the purpose of switching motors. A term encountered frequently to describe this application would be "*Across-the-Line-Motor-Starting*", which generally refers to a contactor combined with overload protection, possibly including also an overcurrent protective device. When energized, this assembly would permit full line voltage to appear at the motor terminals, as opposed to using the alternative method of reduced voltage as a means of starting the motor. Contactors, such as Eaton Types *DIL M* [1, 2] rated for World markets, have broad appeal as the ideal solution for these applications. (**Diagram 1 + 2**). Motor switching is, of course, a major



**Photo 1:** Presentation of various North American designations associated to load switching requirements for contactors (top), followed by available product solutions to accommodate these (middle) and lastly, a sampling of the varied loads addressed by these contactors (bottom). This technical document deals mainly with the appropriate selection data established for these products to address these differing applications.

Various load types and their equivalent utilization categories			
North America, as per UL 508, CSA 22.2 No. 14, NEMA ICS 2		As per IEC 60 947	
Load Type	Load identification Electrical Data on rating label	Utilization Category (incomplete and based on AC only)	Description
1 <i>Motors</i>	Horsepower (HP) FLA, LRA for <i>Definite Purpose applications</i> , e.g. Compressors for use in refrigeration.  FLA = Full load amp rating LRA = Locked rotor amp rating	AC-2	Slip-Ring motors: Starting, Stopping
		AC-3	Squirrel-cage motors: Starting, Stopping during running, occasional Jogging or reverse current braking
		AC-4	Squirrel-cage motors: Starting, reverse current braking, Reversing, Jogging
2 <i>Coils, in auxiliary and control circuits</i>	Code Designation, Voltamps, VA Standard Pilot Duty or Heavy Pilot Duty	AC-15 DC-13	Control of electro-magnetic loads
3 <i>Resistance (heating)</i>	Amperes, resistance only (A)	AC-1	Non-inductive or slightly inductive loading, Resistive heating
4 <i>Incandescent lamps</i>	Amperes or Watts, tungsten filaments	AC-5B	Switching of incandescent lighting loads
5 <i>Ballast (electric discharge lamps)</i>	Amperes, ballast	AC-5A	Switching of electric discharge lighting loads
6 <i>General Use</i>	Amperes, A	AC-1	Non-inductive or slightly inductive loading, Resistive heating
The load category General Purpose comprises all loads, which don't fall under 1 to 5.			

**Table 1: A comparison of various North American load designations with their respective equivalent in terms of IEC utilization categories. This doesn't take into account differing test criteria, and represents only an excerpt showing AC applications. The IEC provides additional utilization categories not mentioned above.**

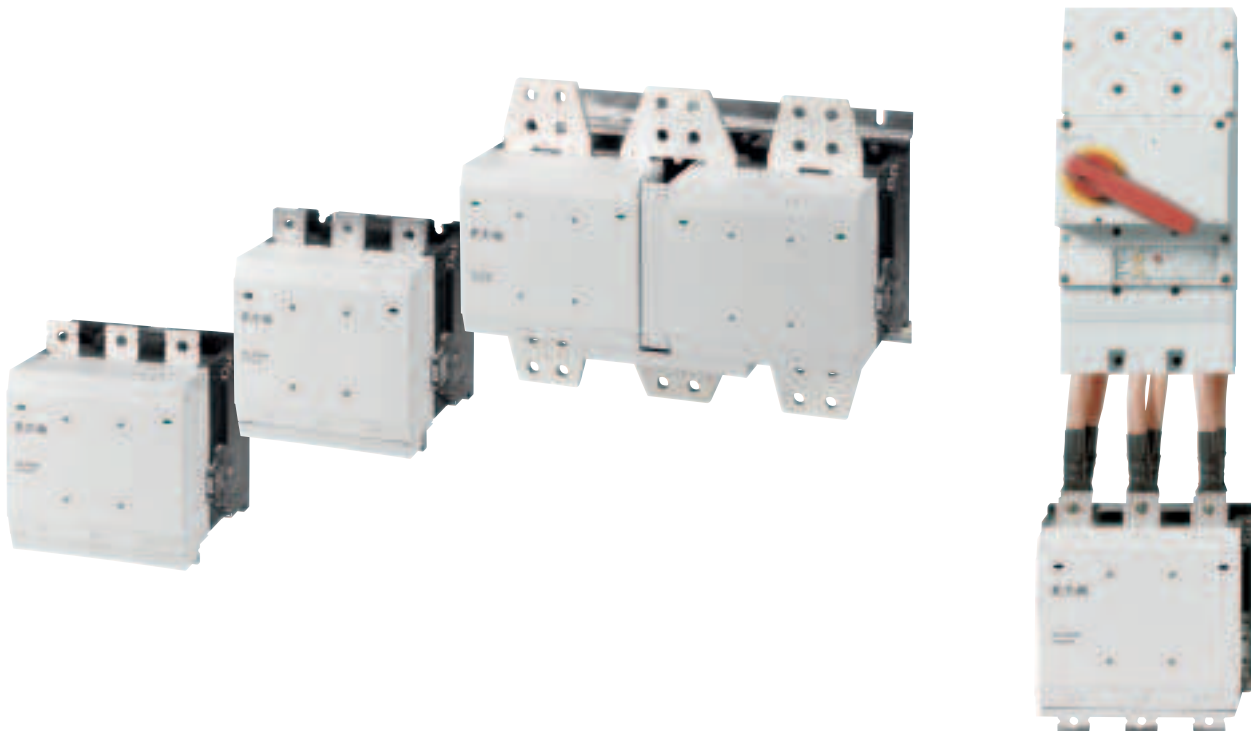


**Photo 2:** Universally applicable World Market rated contactors for the xStart Product Range. The motor starters rated up to 150A are ideally suited for normal industrial motor switching but the contactors themselves can be applied just as well in North America for "Special Purpose applications".

part of the load category array referenced in **Table 1**. However, it cannot rightfully be grouped under the specialized applications addressed by North American terminology such as "General Purpose", "Special Purpose" or "Definite Purpose" since it is a domain largely covered by standard motor contactors with assigned HP values on their rating labels.

Generally speaking, one thinks less in North America of applying individual contactors for any given application. Rather, one tends to encounter more complete solutions involving assemblies, such as motor starters. The term motor starter infers more complexity, and in its most complete form, such an assembly would incorporate at least 4 essential elements of a motor branch circuit:

- Main Disconnect
  - Overcurrent Protection
  - Motor controller (switching)
  - Motor Overload Protection
- and would mostly be realized by combining a grouping of components to fulfill these functions.



**Photo 3:** For larger size contactors Eaton has now for years been employing vacuum technology [12] rather than using air as a medium for switching contacts, thus enabling higher component life and reducing overall dimensions. Most of them are applied in motor starter combinations.

**Motor starter combinations (Non-Combination Motor Starters) DILM / Z for use in North America**

Rating data for approved types								Circuit-breaker	Contactor	Overload relay
Maximum HP Ratings, 3-phase, 60 Hz, at:				Max. rated motor current	Rated short-circuit breaking capacity			Part no.	Part no.	Part no.
200 V 208 V	230 V 240 V	460 V 480 V	575 V 600 V		480 V	600 V/ 347 V <sup>1)</sup>	600 V			
HP	HP	HP	HP	A	kA	kA	kA			
–	–	–	½	0.9	100	50	–	NZMH2-S1,6-CNA	DILM17-...(…)	ZB32-1
–	–	½	¾	1.3	100	50	–	NZMH2-S1,6-CNA	DILM17-...(…)	ZB32-1,6
–	–	¾	–	1.6	100	50	–	NZMH2-S2,4-CNA	DILM17-...(…)	ZB32-1,6
–	–	1	1	2.1	100	50	–	NZMH2-S2,4-CNA	DILM17-...(…)	ZB32-2,4
–	½	–	1½	2.4	100	50	–	NZMH2-S5-CNA	DILM17-...(…)	ZB32-2,4
¾	¾	2	3	3.9	100	50	–	NZMH2-S5-CNA	DILM17-...(…)	ZB32-4
–	1	–	–	4.2	100	50	–	NZMH2-S5-CNA	DILM17-...(…)	ZB32-8
1	1½	3	–	6	100	50	–	NZMH2-S8-CNA	DILM17-...(…)	ZB32-6
1½	2	–	5	6.9	100	50	–	NZMH2-S8-CNA	DILM17-...(…)	ZB32-10
2	3	5	7½	9.6	100	50	–	NZMH2-S12-CNA	DILM17-...(…)	ZB32-10
3	5	10	10	15.2	100	50	–	NZMH2-S18-CNA	DILM17-...(…)	ZB32-16
5	–	–	15	17.5	100	50	–	NZMH2-S26-CNA	DILM17-...(…)	ZB32-24
–	7½	15	20	22	100	50	–	NZMH2-S26-CNA	DILM25-...(…)	ZB32-24
7½	–	–	–	25.3	100	50	–	NZMH2-S33-CNA	DILM25-...(…)	ZB32-32
–	10	20	25	28	100	50	–	NZMH2-S33-CNA	DILM32-...(…)	ZB32-32
10	–	–	–	32.2	100	50	–	NZMH2-S40-CNA	DILM32-...(…)	ZB32-32
–	–	25	30	34	100	50	–	NZMH2-S40-CNA	DILM40(…)	ZB65-40
–	–	30	–	40	100	50	–	NZMH2-S50-CNA	DILM40(…)	ZB65-40
–	15	–	40	42	100	50	–	NZMH2-S50-CNA	DILM40(…)	ZB65-57
15	20	40	50	54	100	50	–	NZMH2-S63-CNA	DILM50(…)	ZB65-57
20	–	50	60	65	100	50	–	NZMH2-S80-CNA	DILM65(…)	ZB65-65
–	25	–	–	68	100	50	–	NZMH2-S80-CNA	DILM80(…)	ZB150-70
25	30	60	75	80	100	50	–	NZMH2-S100-CNA	DILM80(…)	ZB150-100
–	40	75	100	104	100	50	–	NZMH2-S125-CNA	DILM95(…)	ZB150-100
30	–	–	–	92	100	50	–	NZMH2-S125-CNA	DILM115(…)	ZB150-100
40	–	100	125	125	100	50	–	NZMH2-S160-CNA	DILM115(…)	ZB150-125
–	50	–	–	130	100	50	–	NZMH2-S160-CNA	DILM115(…)	ZB150-150
–	–	125	–	156	100	50	–	NZMH2-S200-CNA	DILM150(…)	ZB150-150
50	60	–	150	154	100	50	–	NZMH2-S200-CNA	DILM185A/22(…)	Z5-160/FF225A
60	75	150	200	192	100	50	–	NZMH2-SE220-CNA	DILM225A/22(…)	Z5-220/FF225A
75	100	200	250	248	100	50	50	NZMH3-SE350-CNA	DILM250/22(…)	Z5-220/FF250
100	–	–	300	289	100	50	50	NZMH3-SE350-CNA	DILM300A/22(…)	ZW7-290
–	125	250	–	302	100	50	50	NZMH3-SE450-CNA	DILM300/22(…)	ZW7-400
125	150	300	400	382	100	50	50	NZMH3-SE450-CNA	DILM400/22(…)	ZW7-400

1) North American type fuses only.

**Table 2: Motor starter with overload relay, fuses or UL 489 type circuit breakers as protective devices, for applications in North America.**

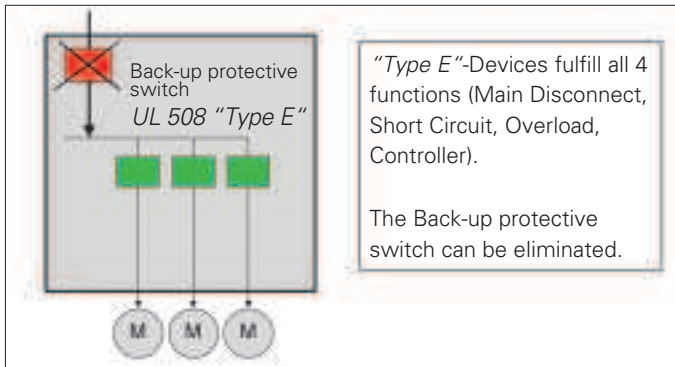


Photo 4: A PKZM0 motor protective starter grouping is linked on its supply side via a 3 phase bus connector bus. The motor protectors are fed using a common incoming terminal block BK25...-E , which features larger, distribution size electrical clearances to fulfill the requirements of a "Type E construction".

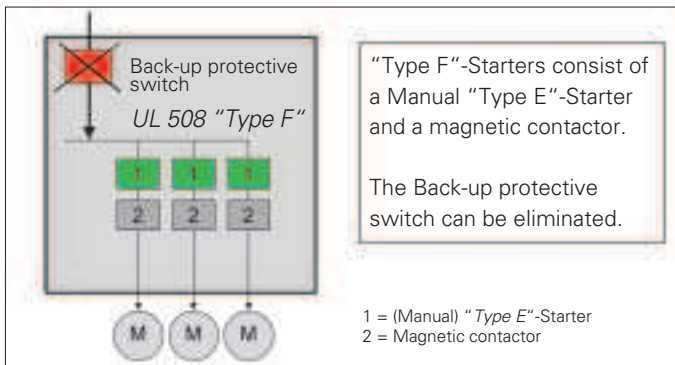


Photo 5: Examples of UL 508 Type F Combination Starters, which consist of UL 508 manual self-protected Type E Combination controllers combined with standard magnetic contactors.

UL 508 Type F Combination Motor Controllers, can be applied without a contactor as UL 508 Manual Type E Self-Protected Combination Motor Controller												
Maximum Motor HP Rating 3 Phase, 60Hz				Trip settings		Interrupting Capacity = Short Circuit Current Rating SCCR			Components			
200 V 208 V [HP]	230 V 240 V [HP]	460V 480 V [HP]	575 V 600 V [HP]	Adjustable thermal [A]	Instantaneous Trip, Fixed [A]	240 V [kA]	480Y/ 277 V <sup>2)</sup> [kA]	600Y/ 347V <sup>2)</sup> [kA]	Motor Protector Part no.	Supply Terminal Part no.	Contactor Part no.	
1)				0.1 - 0.16	2.2	50	50	50	PKZM0-0,16	BK25/3-PKZ0-E	DILEM	
				0.16 - 0.25	3.4	50	50	50	PKZM0-0,25	BK25/3-PKZ0-E	DILEM	
				0.25 - 0.4	5.6	50	50	50	PKZM0-0,4	BK25/3-PKZ0-E	DILEM	
				0.4 - 0.63	8.8	50	50	50	PKZM0-0,63	BK25/3-PKZ0-E	DILEM	
				0.63 - 1	14	50	50	50	PKZM0-1	BK25/3-PKZ0-E	DILEM	
		¾	¾	1 - 1.6	22	50	50	50	PKZM0-1,6	BK25/3-PKZ0-E	DILEM	
½	½	1	1 ½	1.6 - 2.5	35	50	50	50	PKZM0-2,5	BK25/3-PKZ0-E	DILEM	
¾	¾	2	3	2.5 - 4	56	50	50	50	PKZM0-4	BK25/3-PKZ0-E	DILEM	
1 ½	1 ½	3	5	4 - 6.3	88	50	50	50	PKZM0-6,3	BK25/3-PKZ0-E	DILEM	
3	3	7 ½	10	6.3 - 11	140	50	50	50	PKZM0-10	BK25/3-PKZ0-E	DILEM	
1)				0.1 - 0.16	2.2	65	65	-	PKZM0-0,16	BK25/3-PKZ0-E	DILM7	
				0.16 - 0.25	3.4	65	65	-	PKZM0-0,25	BK25/3-PKZ0-E	DILM7	
				0.25 - 0.4	5.6	65	65	-	PKZM0-0,4	BK25/3-PKZ0-E	DILM7	
				0.4 - 0.63	8.8	65	65	-	PKZM0-0,63	BK25/3-PKZ0-E	DILM7	
				0.63 - 1	14	65	65	-	PKZM0-1	BK25/3-PKZ0-E	DILM7	
		¾	¾	1 - 1.6	22	65	65	-	PKZM0-1,6	BK25/3-PKZ0-E	DILM7	
½	½	1	1 ½	1.6 - 2.5	35	65	65	-	PKZM0-2,5	BK25/3-PKZ0-E	DILM7	
¾	¾	2	3	2.5 - 4	56	65	65	-	PKZM0-4	BK25/3-PKZ0-E	DILM7	
1 ½	1 ½	3	5	4 - 6.3	88	65	65	-	PKZM0-6,3	BK25/3-PKZ0-E	DILM7	
3	3	7 ½	10	6.3 - 11	140	65	65	-	PKZM0-10	BK25/3-PKZ0-E	DILM12	
3	3	7 ½	-	9 - 12	168	50	50	-	PKZM0-12	BK25/3-PKZ0-E	DILM15	
3	-	-	-	10 - 16	224	18	18	-	PKZM0-16	BK25/3-PKZ0-E	DILM17	
5	-	-	-	16 - 20	280	18	18	-	PKZM0-20	BK25/3-PKZ0-E	DILM25	
-	7 ½	15	-	20 - 25	350	18	18	-	PKZM0-25	BK25/3-PKZ0-E	DILM25	
7 ½	10	20	-	24 - 32	448	18	18	-	PKZM0-32	BK25/3-PKZ0-E	DILM32	
3	5	10	15	10 - 16	224	65	65	50	PKZM4-16	BK50/3-PKZ4-E	DILM32	
5	7 ½	15	20	16 - 27	350	65	65	50	PKZM4-25	BK50/3-PKZ4-E	DILM32	
7 ½	10	25	30	24 - 34	448	65	65	50	PKZM4-32	BK50/3-PKZ4-E	DILM32	
10	-	30	30	32 - 40	560	65	65	50	PKZM4-40	BK50/3-PKZ4-E	DILM40	
-	15	30	-	40 - 52	700	65	65	-	PKZM4-50	BK50/3-PKZ4-E	DILM50	
-	-	40	-	50 - 56	812	65	65	-	PKZM4-58	BK50/3-PKZ4-E	DILM65	
-	-	40	-	52 - 58	882	65	65	-	PKZM4-63	BK50/3-PKZ4-E	DILM65	

1) In this range, select devices per motor full load current. Refer to NEC Table 430-250.

2) Solidly grounded power distribution system.

Stand: March 2010

Table 3a: Electromechanical motor-protective circuit-breaker PKZM in UL 508 Type F Combination Starters

UL 508 Type E - Self-Protected Combination Motor Controllers								
consisting of electronic motor-protective circuit-breaker PKE and contactor DILM, can also be used as "UL 508 Type F Combination Motor Starters"								
Max. HP-Rating				SCCR [kA]		Design using switchgear:		Type
200 V, 60 Hz	240 V, 60 Hz	480Y/277 V, 60 Hz	600Y/347 V, 60 Hz	480Y/277V, 60 Hz	600Y/347V, 60 Hz	Motor-protective circuit-breaker plus BK25/3-...-E	Contactor (mandatory)	
-	-	0.5	0.5	14	14	PKE1,2	DIL M17	MSC...-1,2-M17-SP
0.75	0.75	2	-	18	-	PKE4	DIL M17	MSC...-4-M17-SP
3	3	7.5	-	18	-	PKE12	DIL M17	MSC...-12-M17-SP
5	7.5	15	-	18	-	PKE32	DIL M32	MSC...-32-M32-SP

**Table 3b: Electronic motor-protective circuit-breaker PKE in UL 508 Type E Self-Protected Combination Motor Controllers. Caution: In this case when motor-protective circuit-breakers PKE are used, a contactor is already included in the Type E controller. Here UL 508 type E combinations can be used as well as UL 508 type F combinations.**

As it is the practice in other countries which have adopted IEC standards, there is also a tendency in North America to differentiate between motor starters which feature fuses as the primary overcurrent protective device (Table 2a + 2b) and those which are considered fuseless, (Table 3a + b, Photos 3 +4), and have either motor protectors or molded case circuit breakers as their core overcurrent protective element. The latter combinations are rapidly gaining in popularity because of the many additional features and benefits they can offer in modern installations. The tables reflect motor starter combinations featuring Eaton's conventional line

of DIL M motor switching contactors. These standard contactors are part of Eaton's comprehensive new line of "Systems xStart" industrial control motor starter components. (Diagram 5). A brand new feature of this innovative new line is the toolless connector system which provides the mechanical and electrical link between the motor protector and the magnetic contactor. (Diagram 6). It's also designed and rated to cover the highest volume range of motors. These new, and labor saving connector pieces are UL listed and CSA certified and can also be used in combination with Eaton motor starter assemblies mounted on customized space saving bus bar adapt-

ers. Furthermore, they feature UL/CSA high fault short circuit ratings, making them particularly desirable in North American industrial control panel assemblies which now mandate short circuit ratings for compliance with domestic electrical Codes. Refer to Table 3a + b for selection guidance on these motor starter components.

Particular North American requirements on motor starters, as well as component assemblies considered unconventional in the IEC world, are covered at length in a separate Eaton technical document [3] available for reference. The special considerations described therein are due

NEMA-Sizes für Contactors per the NEMA ICS 2 standard						
3 Phase contactors per NEMA NEMA-Sizes	Rated current A	HP Ratings <sup>1)</sup>				
		1-phase		3-phase		
		120 V 60 Hz (115 V 60 Hz)	240 V 60 Hz (230 V 60 Hz)	208 V 60 Hz (200 V 60 Hz)	240 V 60 Hz (230 V 60 Hz)	480 V 60 Hz (460 V 60 Hz) 600 V 60 Hz (575 V 60 Hz)
		HP (PS)	HP (PS)	HP (PS)	HP (PS)	HP (PS)
00	9	½	1	1 ½	1 ½	2
0	18	1	2	3	3	5
1	27	2	3	7 ½	7 ½	10
2	45	3	7 ½	10	15	25
3	90	7 ½	15	25	30	50
4	135	-	-	40	50	100
5	270	-	-	75	100	200
6	540	-	-	150	200	400
7	810	-	-	-	300	600
8	1215	-	-	-	450	900
9	2250	-	-	-	800	1600

<sup>1)</sup> HP Ratings for single speed motors, without jogging, reversing and current breaking.

**Table 4: North American NEMA-Sizes for contactors. A NEMA-Size has an assigned general purpose current rating along with definite HP values at various motor nominal voltage ratings. All values per each NEMA size must be covered by one device in order for it to be assigned that designation.**

<sup>4</sup> SCCR = Short Circuit Current Rating

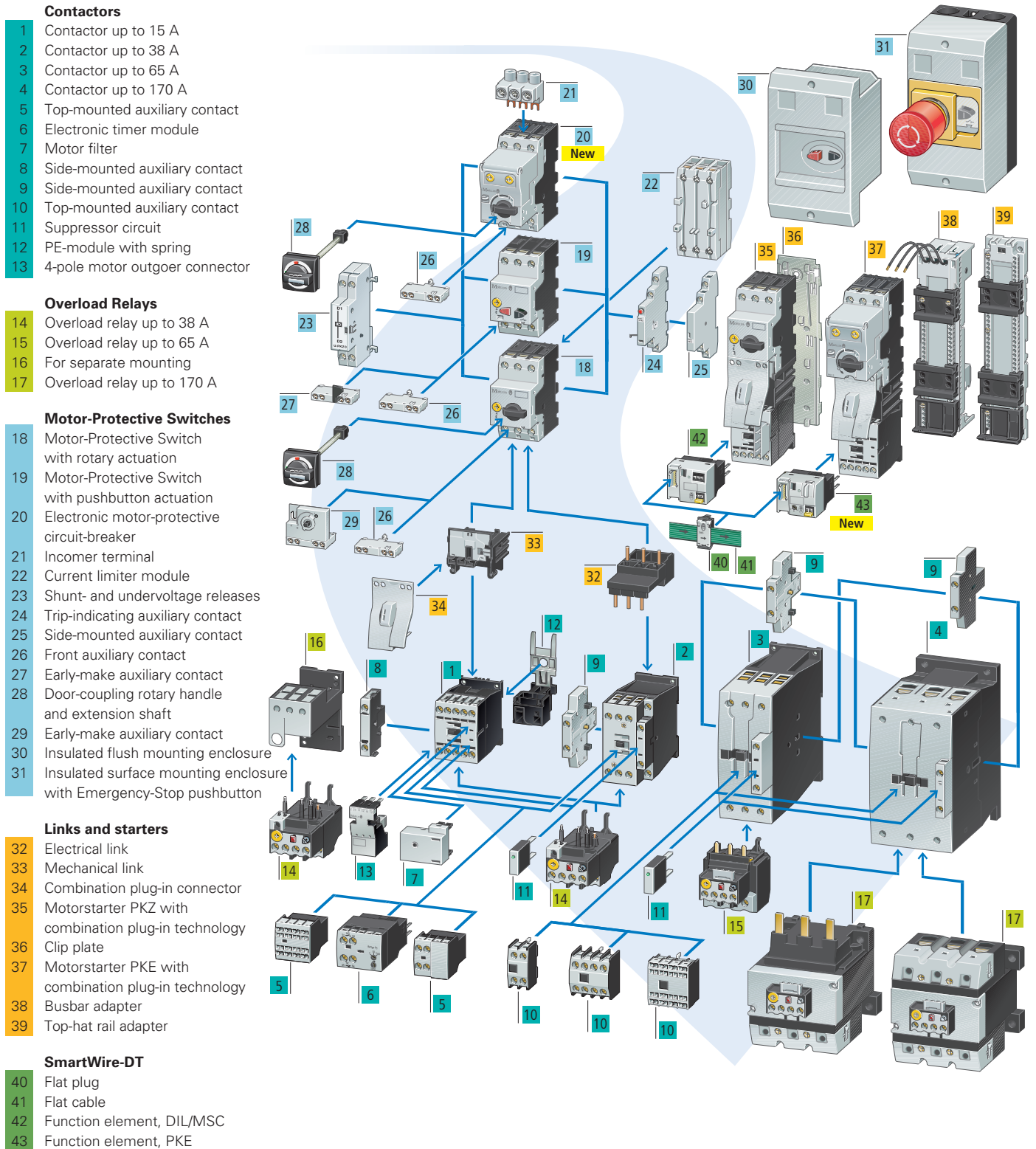
<sup>5</sup> HP = Horsepower, 1 HP = 1 PS



# Excerpt from the System

View without PKZM 4. For the complete range, see the current Main Catalogue.

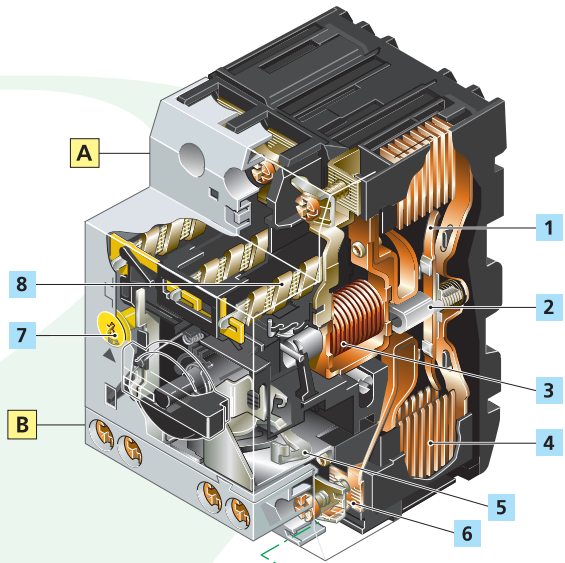
Auxiliary and main current connections up to 15 A, either with screw terminals or spring-loaded terminals.



**Photo 6: System xStart motor starter breakdown, with particular emphasis on advantageous mounting and wiring aids such as toolless plug-in connectors and bus bar adapters. These components and combinations have been designed as world market products and feature UL and CSA approvals for use in North America.**

**A Motor-protective switch**

- 1 Contact system
- 2 Striker pin
- 3 Short-circuit release
- 4 Arcing chamber
- 5 Switch mechanism
- 6 Contact with connection lug
- 7 Overload release setting button
- 8 Overload release (bimetal)



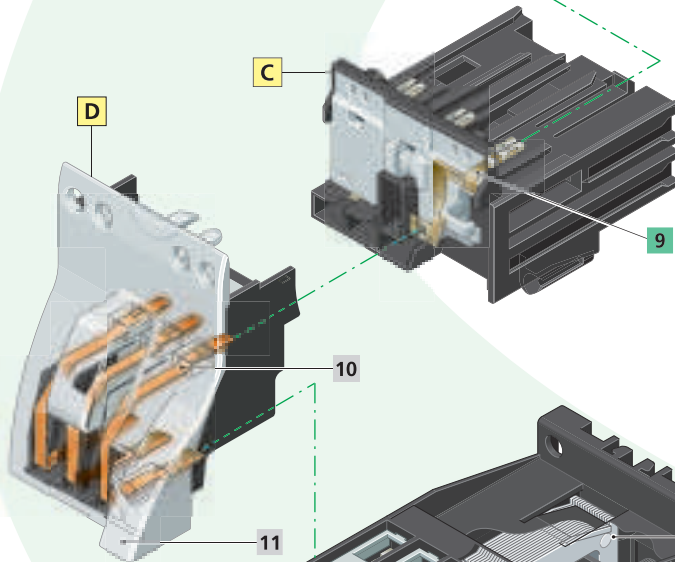
**B Auxiliary switch**

**C DS mechanical connection module**

- 9 Current link

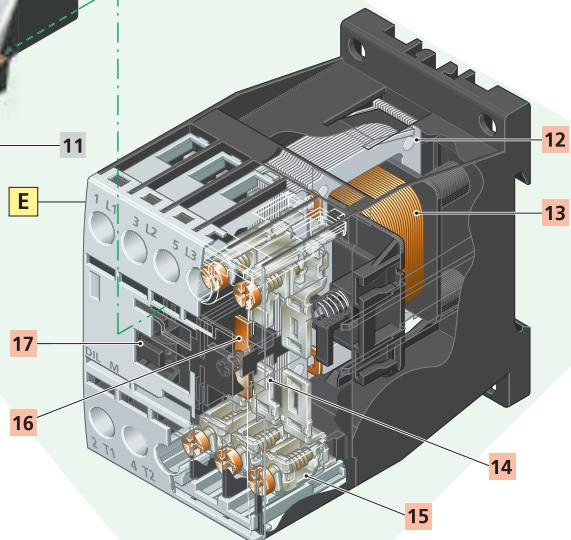
**D DS electric contact module**

- 10 Conductor with spring contact
- 11 Cable feed-through



**E Contactor**

- 12 Magnet
- 13 Coil
- 14 Contact – fixed
- 15 Box terminal
- 16 Contact – movable
- 17 Coupling for auxiliary contact



**Photo 7:** Display of the new, toolless plug-in connector piece linking the motor protector to the contactor. These compact new starter combinations are UL listed and CSA certified. They can also be mounted on custom Eaton bus bar adapter sets which are also approved for export to North America.

largely in part to the peculiar categories under which motor protectors and circuit breakers used in motor starter assemblies are grouped per the relevant UL 508 [4] and UL 489 [5] product testing standards in the US, and the respective counterpart CSA-C22.2 No. 14 [6] and CSA-C22.2 No. 5-02 [7] standards in Canada. The first set of standards mentioned for each respective country deals mostly with devices and assemblies used in the "controller portion of the circuit" (*Industrial Control Equipment*), whereas the second grouping is considered more stringent in terms of component demands since it applies to devices with primary protective functions in the feeder and branch energy distribution portion of the electrical system (*Distribution Equip-*

*ment*). Energy distribution components also feature prominently in the electrical systems for machines and general industrial control apparatus, particularly in the supply side as well as on feeder bus systems used throughout the more complex assemblies.

In the US it's still common to select contactors based on NEMA sizes which, as can be interpreted from the selection guidelines outlined in **Table 4**, consist of defined HP sizes for a range of industrial voltages along with a corresponding Continuous Current rating. (per NEMA standard ICS 2). The term "NEMA size" is also commonly used in Canada. NEMA contactors per NEMA ICS 2 must also have the capability of accommodating

certain wire cross-section sizes for field wiring terminations. The IEC standard makes no such stipulation with respect to sizing. For example, there is no requirement that a contactor with a 4kW rating at 400V needs to have any particular standardized rating at 690V. The establishment of individual ratings in the IEC world is determined on the basis of test results performed in accordance with the IEC / EN 60 947-4-1 [8] standard, which imparts sole responsibility onto the manufacturer for achieving published ratings. It would, therefore, be pure coincidence if the ratings of an IEC contactor were to correspond exactly to those of a particular NEMA size in its entirety, notwithstanding the obvious need to translate from kW to HP sizing. Further devia-

Selection guide for Eaton contactors in North America								
IEC-Data 3-phase AC-3 400 V 50 Hz  kW	Contactor  Part no.	UL/CSA approved HP Ratings for applications in North America						$I_{th}$ open 40 °C  A
		Single Phase Max HP Rating		Three Phase Max HP Rating				
		120 V 60 Hz (115 V 60 Hz) HP	240 V 60 Hz (230 V 60 Hz) HP	208 V 60 Hz (200 V 60 Hz) HP	240 V 60 Hz (230 V 60 Hz) HP	480 V 60 Hz (460 V 60 Hz) HP	600 V 60 Hz (575 V 60 Hz) HP	
3	DILM7	¼	1	1 ½	2	3	5	20
4	DILM9	½	1 ½	3	3	5	7 ½	20
5.5	DILM12	1	2	3	3	10	10	20
7.5	DILM15	1	3	5	5	10	10	20
7.5	DILM17	2	3	5	7 ½	10	15	35
11	DILM25	2	5	7 ½	7 ½	15	20	35
15	DILM32	3	5	10	10	20	25	40
18.5	DILM40	3	7 ½	10	15	30	40	55
22	DILM50	3	10	15	20	40	50	65
30	DILM65	5	15	20	25	40	60	80
37	DILM80	7 ½	15	25	30	60	75	125
45	DILM95	7 ½	15	25	40	75	100	125
55	DILM115	10	25	40	50	100	125	160
75	DILM150	15	30	40	60	125	125	160
90	DILM185A	-	-	50	60	125	150	225
110	DILM225A	-	-	60	75	150	200	250
132	DILM250	-	-	75	100	200	250	350
160	DILM300A	-	-	100	125	250	300	350
200	DILM400	-	-	150	150	300	400	450
250	DILM500	-	-	150	200	400	500	550
315	DILM580	-	-	200	200	400	600	630
355	DILM650	-	-	200	250	500	600	700
400	DILM750	-	-	250	300	600	700	800
450	DILM820	-	-	290	350	700	860	850
560	DILM1000	-	-	-	420	850	980	

Table 5: Eaton contactors rated in HP and at various North American nominal voltage levels can be selected per the above table.

tions would also include voltage and frequency ratings, which are different on the North American continent. NEMA Sizes simply reflect an in-country standardization method and a convenient method for component selection, and is neither an indication of any particular quality level, nor is their usage always strictly required. NEMA-contactors are usually also larger in size dimensionally.

In the IEC world the selection process for a contactor normally involves the use of a manufacturer's catalog along with specific knowledge of the rating and type of load to be switched, the corresponding utilization category and the voltage at which the load is operating. In North America the process can be as straightforward as requesting a distributor to

supply a "NEMA Size 2" contactor, which could then come from a variety of manufacturers. It would then feature all the typical ratings associated to that size, including standardized HP ratings and corresponding continuous current.

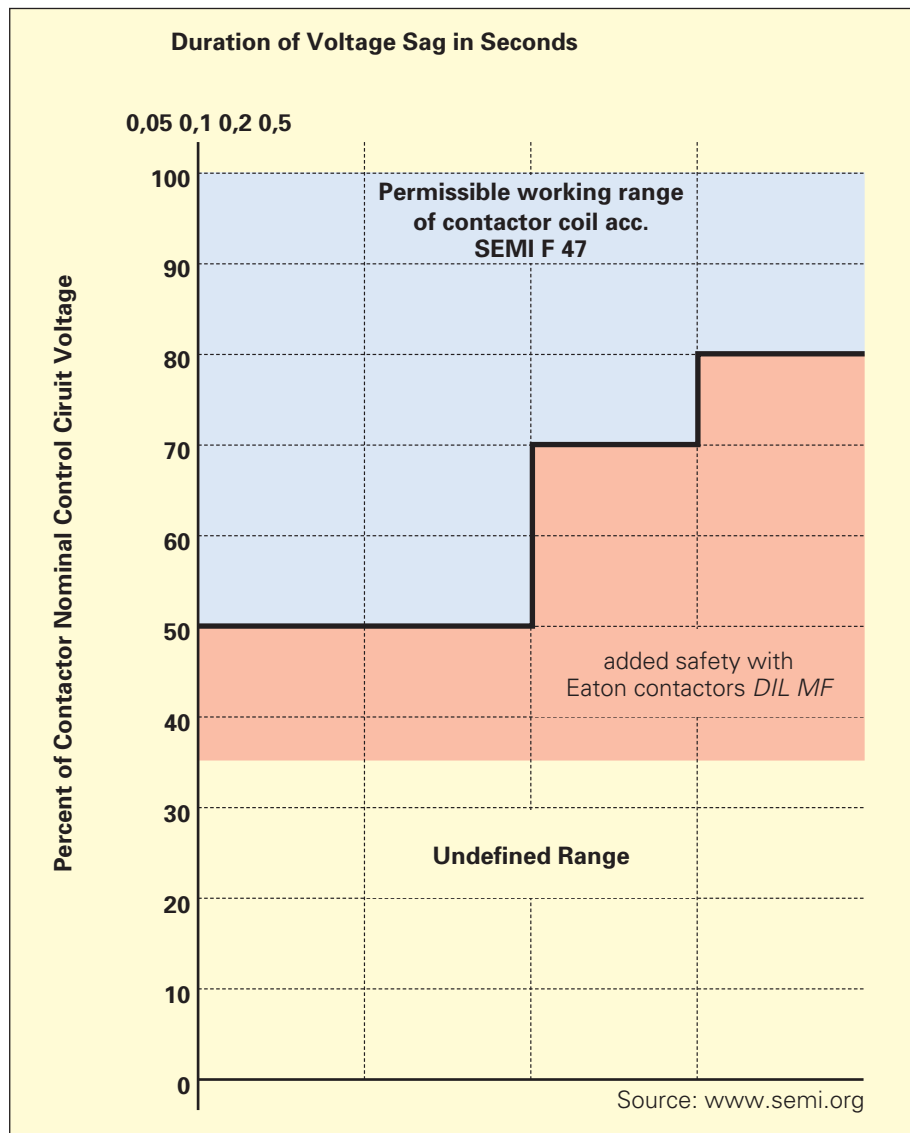
In view of the fact that, in any given application, there is the greater likelihood of having a single set of voltage/current parameters, it is questionable whether the idea of a device providing additional standardized HP pairings at different voltage levels can be that advantageous in the majority of cases.

From a practical standpoint, companies which export to North America should best select contactors such as those outlined in **Table 5**, or from motor starter combination tables providing

selections with or without protective devices. Table 5 outlines contactor sizes which would more closely match any given motor rating, thus allowing the choice of a possibly smaller and more economical device for the purpose.

Selections per **Table 5** can be easily and readily done since all ratings shown are approved and appear on the contactor's rating label.

The large majority of contactors are used in full voltage, across-the-line motor starting applications, both in non-reversing and reversing combinations. Electro-magnetic contactors are still found in a number of applications involving reduced voltage starting, the most popular of which in North America would include the use of motor starting auto-transformers and special part-winding motors. Open transition star-delta motor starting is not as popular there as it is in Europe, due in part to the relatively lesser amount of electrical networks using the  $1/\sqrt{3}$  vectorial relationship provided with supply conductors in 4 wire systems. On the other hand, certain industries such as refrigeration do on occasion employ star-delta motors for large hermetic motor compressors, and switching duties for those could be shared with up to 4 contactors since these would more than likely feature closed transition starting. Eaton contactors are world market devices and thus the same version can be safely applied on all continents. Eaton contactors also feature export friendly double voltage coils, which can be reliably energized with control power sources at both 50Hz and 60Hz standard control circuit voltage levels. Contactors are increasingly being energized with power supplied from electronic control sources. The majority of these cases would involve the use of export neutral DC coils, mostly in 24VDC [9] versions. During the first half of 2006 Eaton will be introducing specially designed coils which will be in full compliance with the more stringent voltage sag immunity requirements (SEMI1 F47 [10]) of the American semiconductor industry (**Diagram 7**). Eaton contactors can be conveniently selected using either kW or HP ratings depending on the actual motor rating. Machine manufacturers exporting to North America will often include IEC motors in their designs, and these will invariably be rated in kW as well as incorporate metric dimensioning features. It's especially useful in these cases, therefore, to use components such as Eaton contactors with both kW and HP values on their rating labels since many local inspectors will not accept motor controllers which are not rated in HP, as it is a violation of the local electrical Codes.











**Photo 8:** The American Semi-Conductor industry in its SEMI F47 standard requires an increased level of safeguarding against premature contactor coil drop-out during normal operation. In the area shaded in green, the main contacts of the contactor are not allowed to open. This requirement can be fully accommodated with specialized magnet systems in Eaton's System xStart range of contactors.

<sup>6</sup> SEMI = Semiconductor Equipment and Materials Institute

<sup>7</sup> HVAC = Heating Ventilation Air Conditioning

**Selection guide for Eaton contactors in North America**

		Maximum HP-Ratings (UL / CSA) for switching of Motors						NEMA Sizes
		1-phase, 60 Hz		3-phase, 60 Hz				
		120 V (115 V)	230 V (240 V)	208 V (200 V)	240 V (230 V)	480 V (460 V)	600 V (575 V)	
	DILM7	¼	1	1½	2	3	5	
		⅓	1	1½	1½	2	2	00
	DILM9	½	1½	3	3	5	7½	
		1	2	3	3	5	5	0
	DILM12	1	2	3	3	10	10	
	DILM15	1	3	5	5	10	10	
	DILM17	2	3	5	5	10	15	
		2	3	7½	7½	10	10	1
	DILM25	2	5	7½	7½	15	20	
	DILM32	3	5	10	10	20	20	
		3	7½	10	15	25	25	2
	DILM40	3	7½	10	15	30	40	
	DILM50	3	10	15	20	40	50	
	DILM65	5	15	20	25	50	60	
		7½	15	25	30	50	50	3
	DILM80	7½	15	25	30	60	75	
	DILM95	7½	15	25	40	75	100	
		-	-	40	50	100	100	4
	DILM115	10	25	40	50	100	125	
	DILM150	15	30	40	60	125	125	
	DILM185A	-	-	50	60	125	150	
	DILM225A	-	-	60	75	150	200	
		-	-	75	100	200	200	5
	DILM250	-	-	75	100	200	250	
	DILM300A	-	-	100	125	250	300	
	DILM400	-	-	150	150	300	400	
		-	-	150	200	400	400	6
	DILM500	-	-	150	200	400	500	
	DILM580	-	-	200	200	400	600	
	DILM650	-	-	200	250	500	600	
		-	-	-	300	600	600	7
	DILM750	-	-	250	300	600	700	
	DILM820	-	-	290	350	700	860	
		-	-	-	450	900	900	8
	DILM1000	-	-	-	400	800	1000	

**Table 6:** Catalog excerpt from the North American sales organization. A display of traditional NEMA-Size HP ratings is provided as supplemental information for comparison purposes.

Whereas **Table 5** provides the IEC ratings at 400V/50 Hz and the North American continuous rated currents as additional information, **Table 6** gives an indication of NEMA sizes for orientation purposes to further assist in the selection process. The impact of NEMA sized contactors has been somewhat diminished over the years by the steady increase in North America of machines and electrical assemblies imported from overseas. It can be argued that foreign manufacturers of machines and electrical equipment have enjoyed a technological edge in many aspects and this has led to greater acceptance and appreciation on the North American market for the positive design aspects of the smaller IEC style switching and protective components. It is worth noting that most American manufacturers of electrical equipment have in the meantime expanded their product lines to include smaller design IEC devices to meet the increased demand, not only in their own domestic backyard but on foreign soil as well. To make progress on the European front it's also mandatory to secure the CE mark in order to gain legal access to the EU markets. A portion of their product range expansion has come from Eaton's own design rooms and production facilities. The recently introduced American standard UL 60947 will promote to an even greater degree the march towards harmonization with the IEC 60947 standard, whereby a certain amount of reciprocity to allow American aspects into the IEC normative document will surely also take place.

### Special Purpose Contactors

It's also the case in North America that not all electrical loads consist typically of squirrel cage motors, and that particular requirements based on specific loading duties, including specialized applications, need to be taken into consideration. For this reason there are special testing criteria in place to match the power and current parameters placed upon components by these specialized applications, e.g. elevator duty and refrigeration control to name a few, and verify the ability of contactors to safely and reliably handle those particular load demands. Additional non-motor type loads include typical industrial lighting (*Tungsten, Incandescent Lamps*) as well as Ballast and Gas Discharge Lamp assemblies, resistive type loading (*Air conditioning and Resistance Heating, HVAC 2*) and the switch-

ing of Capacitors, typically used in individual or group power factor compensation applications.

The scope of "Special Purpose Ratings" assigned to standard or customized contactors for special markets can expand into a variety of applications, including:

- *Pumps and compressors*
- *Hoists and cranes*
- *Welding equipment*
- *Power supplies*
- *Food processing*
- *Vending machines*
- *Agricultural applications*

(Refer also to the various loads specified in the lower portion of **Diagram 1**).

Some of these applications are also covered through specialized testing under IEC Utilization Categories, referenced in

**Table 1.** These involve standardized test set-ups with prescribed synthetic loading<sup>3</sup>, which more or less mimic the actual demands placed on switching devices in those applications. Eaton, however, places a greater emphasis on duplicating actual field conditions to test the suitability of its devices by performing tests using actual load equipment, often in

concert with various well-known manufacturers of equipment such as capacitors, lighting, gas discharge lamps etc... in order to obtain more practical and relevant verification of the true capabilities of its components.

Contactors for *Special Purpose Applications* could, in theory, require to be specially designed to handle these differing switching demands. Eaton chooses instead to test and assign the large share of special purpose duties to its line of universally applicable motor switching *DIL M* contactors. There is an exception to that approach and it concerns Eaton contactors Type *DIL K*, which have been specially optimized to reliably switch capacitors in capacitor banks. Eaton is currently in the process on achieving special purpose contactor ratings for 3 phase applications. Whereas *General Purpose* and *Definite Purpose* ratings are mentioned and covered in the UL 508 Industrial Control standard, the term *Special Purpose* is one which has been used mostly by manufacturers and users of electrical equipment to address these specialized applications. Eaton considers the majority of these special purpose applications to be well within the grasp of its standard motor switching line of *DIL M* con-

deutsch	englisch
Aufzug	Elevator
Paternoster, Umlaufaufzug	Paternoster elevator
Rolltreppe, Fahrtreppe	Escalator
Fahrsteige	Moving walkways
Personenseilbahnen	Passenger ropeways
Bauaufzüge	Construction hoists
Behindertenaufzüge	Lifts for persons with physical disabilities
Treppenstuhlaufzüge	Stairchair lifts
Plattformlifte	Platform lifts
Schrägaufzüge	Incline lifts
Einkaufswagen-Schrägaufzüge	Shopping Cart Conveyors
Skilifte	Ski lifts
Speiseaufzüge	Dumb waiters
Bühnenaufzüge	Stage lifts
Parkaufzüge	Automobile parking lifts

**Table 7: Various "elevator" type loads, for which the use of "Special Purpose"-Contactors with elevator ratings (Elevator Control) in North America could be applied.**

<sup>3</sup> not actual loads, but simulations consisting of ohmic, inductive and capacitive circuit elements.

Special Purpose Ratings per UL / CSA- Testing Criteria														
Type <i>DIL M..</i>	7	9	12	15	17	25	32	40	50	65 72	80	95	115	150 170
<b>AC Elevator Control</b>	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP
480 V 60 Hz, 3-pole	2	3	7 ½	7 ½	7 ½	10	20	25	30	30	50	60	75	75
600 V 60 Hz, 3-pole	3	5	7 ½	7 ½	10	15	20	30	40	40	60	75	100	100
<b>AC Refrigeration Control</b>	A	A	A	A	A	A	A	A	A	A	A	A	A	A
480 V 60 Hz, 3-pole	6	7.5	10	10	23	32	40	26	36	45	63	70	84	90
600 V 60 Hz, 3-pole	6	7.5	10	10	17	24	30	26	36	45	63	70	84	90
<b>AC Resistance Air Heating</b>	A	A	A	A	A	A	A	A	A	A	A	A	A	A
480 V 60 Hz, 3-pole	12	18	20	20	27	35	40	63	79	90	94	110	136	160
600 V 60 Hz, 3-pole	12	18	20	20	27	35	40	63	79	90	94	110	136	160
<b>AC Incandescent Lamps (Tungsten)</b>	A	A	A	A	A	A	A	A	A	A	A	A	A	A
480 V 60 Hz, 3-pole	8	11	14	14	23	32	40	55	74	90	85	100	136	160
600 V 60 Hz, 3-pole	8	11	14	14	23	32	40	55	74	90	85	100	136	160
<b>AC Electrical Discharge Lamps (Ballast)</b>	A	A	A	A	A	A	A	A	A	A	A	A	A	A
480 V 60 Hz, 3-pole	12	18	20	20	27	35	40	63	79	90	85	100	136	160
600 V 60 Hz, 3-pole	12	18	20	20	27	35	40	63	79	90	85	100	136	160
Type <i>DIL K..</i>			12			20	25		33	50				
<b>Capacitive Switching</b>														
480 V 60 Hz, 3-pole	A		18			28	36		48	72.1				
			kVAr			20	30		40	60				
600 V 60 Hz, 3-pole	A		14.4			28	38.4		48	72.1				
			kVAr			30	40		50	75				

**Table 8: Type DIL M und DIL K contactor selection table for specialized applications (Special Purpose Ratings) in North America.**

factors, and conducts tests accordingly to generate the necessary data associated to these applications in order to verify their suitability.

### Definite Purpose Contactors

Besides contactors optimized for North American Special Purpose ratings, which Eaton covers with its line of conventional and high volume industrial contactors Type *DILM*, the North American market features a particular variety referred to as "Definite Purpose" contactors. *Definite Purpose* contactors (Contactors especially designed to accommodate specific applications) consist mostly of specialized, and cost optimized, constructions generally considered to be a notch below the design level of conventional industrial switching contactors (e.g. they generally feature reduced lifespan, greater amounts of exposed parts with consequent reduced shock hazard protection, and are usually equipped with less sophisticated connection means).

These controllers often display unconventional designs or they consist mostly of single and double pole constructions. *Definite-Purpose* contactors will certainly cross paths to various degrees with contactors used in the range of applications previously described as Special Purpose. They are especially popular in HVAC applications and a host of other applications, including low cost serial production equipment such as vending machines and the like. Domestically available products are usually the components of choice preferred by North American users for these applications. The Definite Purpose contactor market is not one in which Eaton actively participates, with the possible exception of specific customer related requirements which are normally met with the standard industrial control line of contactors. The next paragraphs will highlight in greater detail significant aspects of contactor selection criteria with respect to various loading duties (as referenced in the lower portion of **Diagram 1**).

### Elevator control

One could get the impression that contactors rated for elevator duty represent only a small segment of the market. However, as **Table 7** infers, that doesn't necessarily seem to be the case. Although it may not encompass all variations, the table still reflects a good number of constructively related derivations of this particular transportation mode for which the same switching duty requirements could also be deemed applicable. At the very least, it's a market segment which is expanding in significance. In Europe, for example, where space in narrow and crowded cities is always at a premium, the need arose years ago to provide car parking elevator facilities in certain city venues. That same trend can be seen spreading across North America. The requirement to provide additional transport means in varying sizes and configurations is evidently also becoming a necessity on that continent.

The endurance tests to verify elevator duty controller ratings, which are performed at twice the motor full load current, rank amongst the most stringent in special purpose application verification testing. Contactors with elevator duty ratings are used primarily for the main motors which govern motion. Certain elevator manufacturers take it a step further and include them in additional safety related aspects such as braking or, for example, as part of the mechanism to operate doors, which can be considered just as vital when it comes to the overall safety and reliability of the entire elevator assembly. The selection data for Eaton contactors rated for elevator duty can be found in **Table 8**.

**Resistive loading** (*Air conditioning und Resistance Heating, HVAC*)

Switching resistive loads, i.e. loads which are primarily resistive or perhaps feature only a slightly inductive or capacitive component (IEC Utilization category AC-1) can be characterized as amongst

the easiest for a contactor to handle, simply because switching demands are performed at, or nearly at, the contactor's continuous current rating. The need to make, and possibly break, a multiple of the load current, such as is the case with motors, lighting, capacitors and transformers, does not apply. The lighter duty encountered in resistive switching applications will minimize contact burning on the contactor's main switching contact elements. In Canada, the endurance requirements for resistive heating loads in accordance with local standards is 2.5 times greater than corresponding requirements per US standards, and the test is made even more demanding since it is run at the higher nominal voltage rating of 600V, which is the predominant nominal voltage rating in Canada.

AC-1 current values of Eaton DIL M contactors are higher than their corresponding motor switching ratings. That means that smaller and more economical devices can be used to adequately handle resistive loads of the same ampacity

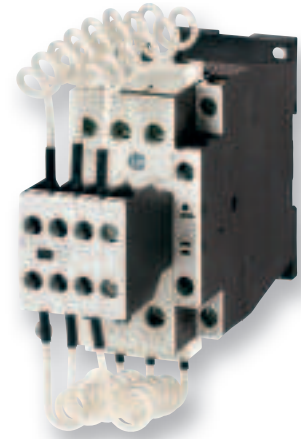
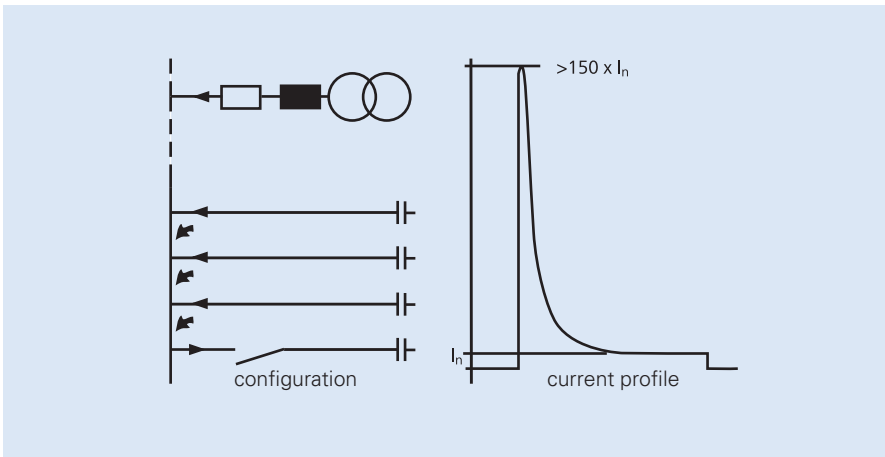
as more inductive motor loading levels. AC-1 switching conditions relate frequently to loads such as resistive heating ovens and electric space heaters. That's been the basis, therefore, for the commonly encountered term "Heating Contactors", a reference which has been popularly associated in the market place to devices used in those applications. Resistive loads such as these will quite often be single phase only. The *DILM-XP1* paralleling bridge accessory will then permit all 3 poles to be switched in parallel. (**Photo 8**). That allows the permissible thermal current rating of a 3 pole contactor to increase by a factor of 2.5, thus enabling the selection of a smaller device to handle the load. The use of a load protective overload relay is usually not required in resistive heating applications since it is not possible to generate overloading in a heater. Suitable protection of conductors and cables is, however, necessary, and the ampacity levels of conductors used in continuous duty applications is generally not allowed to exceed 80% of maximum loading. The conventional solution in North America would be to provide listed molded case circuit breakers as protective devices, equipped with fixed overload and overcurrent settings.

AC-1-Contactors will also often be used in conjunction with power electronic switching devices for galvanic separation of loads within a circuit. In those applications the load current is switched ON and OFF electronically and the contactor is subject solely to the continuous current. Proper electrical interlocking circuitry should be introduced to insure load free switching of the contactor. In the event that the contactors would also be called upon to occasionally accomplish Emergency-OFF switching duties, it would be necessary during the contactor selection process to factor in a likely number of required Emergency-OFF operations, and to consider how high of a current would need to be switched during those operations. Because the heat losses of mechanical contacts are so much less than corresponding electronic power switchin components, AC1-Contactors are also often used as by-pass contactors for soft starters. They can also be deemed in that capacity to be providing a certain protective or "insurance" function, in that during the time the current is flowing through the bypass contactors, the more vulnerable power electronic devices are not subject to potentially damaging overload and short-circuit current levels. The selection guidelines for Eaton contactors in these applications is provided in **Table 8**.



**Photo 9:** The paralleling bridge allows the AC-1 "General Purpose" 3 phase current rating of the contactor to be increased by a factor 2.5 times its value. This accessory is especially useful when switching single phase resistive loads (such as heaters). It permits the use of smaller, and more economical, contactors to handle the load.





**Photo 10:** Special Type DIL K capacitor switching contactors can be used to switch banks of capacitors for power factor compensation purposes. The charging resistors reduce the extremely high inrush current peaks. Regular DILM contactors can be used for individual compensation or when capacitor banks are equipped with inductive choking means.

## Refrigeration control

This type of application for contactors falls under the IEC Utilization Categories AC-8A and AC-8B, which cover the switching requirements of hermetically enclosed compressor motors used for air conditioning and refrigeration purposes. A reference to Refrigeration Control is found specifically in the CSA Industrial Control Standard, and thus more directly addresses applications for the Canadian market when identified as such. Nevertheless, similar testing occurs in the analogous UL standard for Industrial Control (UL 508) under the particular category of "Definite Purpose" controllers, in order to address the same need. The Locked-Rotor endurance portion of the CSA Refrigeration Control test is typically conducted at 6 times the motor rated current (LRA, Locked Rotor Current) and at an unfavorable power factor ( $\cos \phi$ ). The inrush current for each operation is maintained for at least one second, which reflects a much greater duration than the flow time of an actual inrush current condition.

Contactors used to switch compressors in refrigeration and air-conditioning applications do so in bistable fashion, i.e. either ON or OFF. Solutions which rely solely on the use of contactors, at least in the larger sizes, are no longer considered to sufficiently cover all requirements. Various aspects, such as efficient use of energy, reduction of associated noise during switching operations and overall increase in mechanical endurance, will all necessitate more comprehensive and exacting solutions in the future. Alternative solutions, at least in the afore-mentioned larger sizes, would likely consist of motors equipped with

electronic soft starting apparatus to ramp them up and, under certain circumstances, also ramp them down. The selection guidelines for Eaton contactors in these applications can be found in **Table 8**.

## Capacitor Switching

The line of System xStart products will feature a range of contactors specially designed to switch undamped capacitor banks which produce very high surge currents. Contactors involved in capacitor switching generally address the following applications:

- Single compensation, or individual Power Factor correction (Single Capacitors)
- Group compensation (In capacitor banks equipped with inductive reactor coils or limiters used to limit the surge current)
- Group compensation (In capacitor banks not provided with inductive reactor coils or limiters used to limit the surge current)

These applications place varying demands on the switching capabilities of contactors. In *individual compensation*, or *group compensation* sections in which capacitor banks are equipped with surge limiters, contactors may likely switch inrush currents with a magnitude of up to 30 times the rated current of the capacitive load. Group compensation sections with surge limitation are often used in supply networks featuring invertors, which can produce non-sinusoidal (non-linear) currents with high offset peaks. The surge limiters, often consisting of air core reactors or inductive coils, provide

the benefit of limiting the peak currents generated by capacitors to acceptable levels. Standard Eaton Type *DIL M* contactors from the System xStart are able to reliably handle these particular types of capacitive switching requirements. The number of installed capacitor banks equipped with surge limitation appears also to be on the increase, which would enable these same conventional motor switching contactors to more often be the product of choice to handle such loads. The Eaton catalog provides individual capacitor switching selection guidelines in addition to conventional motor related data.

The demands placed on contactors to switch capacitor banks with very little or no inductive choking or surge limitation (*Capacitor banks without surge limiters*) are appreciably more difficult. In this case, the switching currents are not only drawn from networks with relatively low reactive impedance values (from transformers and conductors mostly), but directly from capacitor banks of fully charging capacitors with negligible inductive content. (**Photo 9**). In this instance it's not uncommon to generate, in a matter of a few milliseconds, surge currents on the order of 180 to 200 times the capacitive rated load current ratings. Specially designed capacitor switching contactors would be required for this application [11]. The Eaton Type *DIL K* capacitor switching contactors feature two switched currents paths in parallel. One path is introduced by means of early-make auxiliary contacts and low-impedance resistors or air core reactors (inductors), and initiates charging of the capacitors. This is followed by the closing of the main contacts a few milliseconds

later. The main contacts are now providing the second current path, through which the capacitor rated current flows. As an added improvement to earlier designs, the capacitor switching contactors from the Eaton xStart generation no longer keep the pre-charging auxiliary contacts (from the first path) in the circuit when switching off the capacitors. This new feature effectively eliminates any possible thermal overloading of the contacts and of the associated surge limiters. The line of Eaton *DIL K* capacitor switching contactors is offered to accommodate the most frequently encountered range of Capacitor Bank sizes used in such group compensation assemblies. (**Table 8**). IEC-Data for selecting contactor sizes can be referenced in [11].

### Tungsten, Incandescent Lamps

From an electrical point of view, the switching of tungsten filament lamps or incandescent bulbs is really only a function of the ohmic resistance involved. In the OFF or "cold" state, the overall resistance of the lamp filament is relatively low. At the moment of switching on, this initial low resistance will lead to a momentary high inrush current which will quickly dissipate down to the rated current of the lamp once the resistance of the circuit path builds up as the filament gets hotter. On the average, the high instantaneous inrush currents generated by tungsten filament lamps can easily reach a momentary peak of at least 16 times the continuous current rating of the lamp.

When switching tungsten lamp loads, or for that matter any load with a high momentary inrush, careful consideration should be given in the design phase to the number of such loads which would be switched by a single contactor. The respective summation of inrush currents from all lamps would need to be taken into consideration and, whereas the contactor selected may be able to adequately handle the requirement, the high current peaks generated by a single switching operation could end up creating undue burdens for the rest of the installation. Dividing lamp loads into various sub-groups using a number of smaller contactors would represent a more beneficial approach with respect to the overall functionality of the layout. For example, in the event of a fault, at least a portion of the lighting would still be functional if the overall load were to be shared by a greater number of devices. Refer to **Table 8** for Selection guidelines on appropriate Eaton contactors for this application.

### Ballast, Electrical Discharge Lamps

Electric Discharge Lamps encountered throughout the industry are primarily of the High-Intensity Discharge Lamp variety, the majority of which consist of Mercury Vapor Lamps, Metal Halide and High-Pressure Sodium lamps, as well as a number of additional types such as Electroluminescent and Low-Pressure Sodium Lamps. Not included in this category would be the more commonly known neon fluorescent lights (High voltage lamps not covered as part of this paper). The main demands placed on electrical components for these types of lighting applications involve switching of the ballast necessary for the High Intensity Discharge lamps and the compensation capacitors which may be involved in limiting ballast reactance levels. Capacitors will often be added to the ballast circuit for this purpose, and must thus be taken into consideration when selecting a proper switching component such as a contactor. Ballasts essentially represent an inductive type load for a contactor.

They produce the necessary voltage pulse to ignite the high intensity lamp discharge and they subsequently act to limit the current flowing through the lamp. It's crucial for this current limitation to occur, otherwise the decreasing resistance of the gas medium would lead to increase current flow which would ultimately destroy the lamp. The process to select the proper ballast (pre-charging element) to match the characteristics of a particular type of HID lamp needs to be closely coordinated. Currently, there are two distinct types of ballasts encountered: The more economical electromagnetic type ballast, and the newer, more efficient electronic type ballast. According to available published literature, the energy saving potential of using an electronic ballast can be quite significant, up to at least 25% in many instances. The newer "Energy saving" lamps are fluorescent types equipped with pre-charging, electronic type ballasts. There are many advantages associated to the use of electronic ballasts, not the least among which is the beneficial effect to the human eye by reducing the amount of flicker normally produced by those lights. The electronic ballasts operate at a much higher frequency than normal supply network levels, and are thus able to significantly reduce the flickering effect. Both the European Union<sup>4</sup> and the American government are taking strong steps to improve the efficiency of energy usage in commercial and industrial sectors in the coming years by making recommendations to replace electro-mechanical ballasts with more efficient

lighting solutions using electronic versions.

As mentioned, High Intensity Discharge Lamps are available in various forms and feature different operating characteristics. When first energized they will display differing levels of inrush currents as well as duration times for the warm up and starting phases, possibly also involving very high momentary surge currents in the millisecond range due to the use of charging capacitors. This type of parallel capacitive loading would be a crucial factor in determining the ultimate rating of the contactor. Some High-Pressure-Sodium lamps as well as Mercury-vapor lamps employ the use of dispersion field transformers to mitigate the effect. For these types of lamps the starting phase can take as long as 10 minutes, during which time a current in the magnitude of 2.2 times the lamp's rated current can flow. Three crucial aspects must consequently be observed in order to properly determine the ultimate rating of the contactor:

- Its continuous rated current and thermal loading capability,
- Its making capacity,
- its making capacity for capacitive load switching

These contactor parameters must never be exceeded. We are currently conducting evaluation testing for specific lighting loads, the results of which will be published in an upcoming technical paper on the subject. These types of tests will provide more precise selection data to determine proper contactor sizes for lighting loads, than what is presently available using the NEMA General Purpose Tests referenced in **Table 8**.

In Electric Discharge Lamps the voltage level present at the lamp terminals will have a marked influence on the overall lamp temperature. This temperature can play a crucial role in its own right in certain applications, such as promoting plant growth in commercial nurseries for example. Eaton has developed a line of

specialized type *DIL L* lighting contactors for this purpose, which feature a markedly reduced resistance across their contact surfaces combined with the capability to accommodate larger cross-sections for conductor connection. Both design features act to significantly reduce the amount of voltage drop present on the lamp terminals. This also helps to achieve a more uniform distribution of maximum voltage levels throughout an installation, which is especially useful in applications involving numerous lamp loads.

## Summary:

The most pertinent Special Purpose application test results achieved through extensive testing for our contactors are presented in **Table 8**.

Test sequences to cover these various applications differentiate themselves mostly in the criteria established for the Overload and electrical Endurance portion of the testing. A standardized test to verify the dielectric integrity of the devices after testing is performed at a voltage level of  $1000V + 2 \times U_n = 2200V$  AC (since all Eaton contactors for the North American market are rated at a maximum voltage of  $U_n = 600V$ .) The tested values are valid for 3 phase loading at the respective supply voltages indicated. It's not possible to directly compare values tested in accordance with UL 508 and CSA C22.2 No.14 with those established per the IEC standards, or empirically transfer from one set of standards to the other. The voltage difference alone, say between 400V and 480V, has an enormous impact on the switching capabilities of contactors from all manufacturers. All the data presented, with the exception of "Capacitive Switching", are covered with standard, off-the-shelf Eaton Type *DIL M* motor switching contactors. In order to switch capacitor banks of capacitors not equipped with surge current limiters, Eaton offers its line of specialized Type *DIL K* contactors, for both the IEC world and the North American market. Individual compensation applications, as well as group compensation capacitor banks equipped with surge limitation, can be reliably handled on all continents by the conventional, and

more economical, Type *DIL M* motor switching contactors. Even those customers who aren't exporting to North America can still benefit from the highly modernized advances and features offered by these products since all the Eaton contactors presented in this paper are world market devices which can be universally applied. The contactors are also CE marked and provided with IEC rating information in order to enable their export from North America to the rest of the world.

## Validity:

The information contained herein was dutifully and thoroughly researched, but does not purport to serve as a substitute for the informational content of current and pertinent North American standards, since more detailed information is often required for comprehensive design and engineering purposes. At the time of print, all approval testing for the Eaton contactors and assemblies presented had been successfully completed, but the approval reports issued by the testing agencies were still in preparation.

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