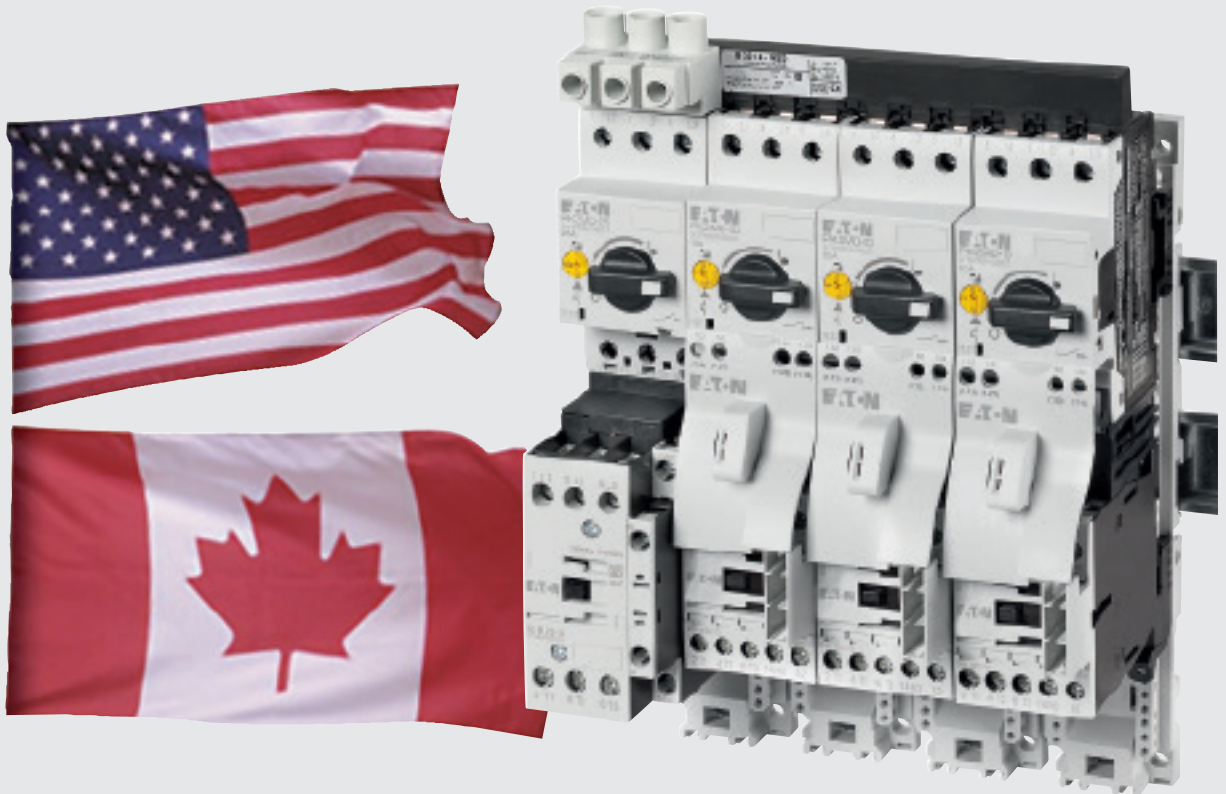


Special considerations governing the application of Manual Motor Controllers and Motor Starters in North America



Technical Paper

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Overview of contents and Foreword

Special considerations governing the application of Manual Motor Controllers and Motor Starters in North America

	Page
Recommendations on navigating through this comprehensive technical paper	4
Quick overview and summary of contents	4
Special considerations governing the application of manual motor controllers and motor starters in North America	5
Product certification requirements in North America	5
Influence of specifiers and users of certified electrical equipment	6
Requirements of various sales channels for certified electrical equipment	7
Electrical equipment groupings in North America	8
Manual Motor Controller or Circuit Breaker?	8
North American electrical ratings for Industrial Control Equipment	9
Equipment approvals conducted by electrical inspectors	9
Group installations per <i>NEC, Article 430-53</i> and <i>CEC Part 1, Rule 28-206 („Group Protection“)</i>	11
• Consequences of group installation requirements on motor branch circuit conductor sizing	12
Examples of popular components and combinations in Motor Branch Circuits	14
Additional items worthy of consideration with respect to enclosed equipment.	14
Basic concepts related to electrical products on the North American market	14
• Motor contactors for the North American market	14
– Combination „Contactor + Overload Relay“ (<i>Non-combination Motor starter</i>)	14
• Manual motor controllers for the North American market	15
– Manual Motor Controller (Starter) <i>PKZ</i>	15
– “Motor protective switch” <i>NZM...-ME...-NA</i> , “Motor protective circuit breaker”.	15
• Molded Case Circuit Breakers for the North American market	15
– <i>NZM...-S(E)-CNA</i> Instantaneous Trip circuit breakers	18
– <i>NZM...-A(V)(E)(F)...-NA</i> Inverse Time molded case circuit breakers	19
– Advantages of circuit breakers over fuses in North American motor branch circuits	19
• Manually operated disconnect switches in motor circuits	20
Motor Starters in accordance with North American specifications	21
• Combination Motor Starters	21
Various constructive solutions for „Combination Motor Starters“	22
• UL 508 Type E Self-protected Combination Motor Controller	22
• Self-Protected Combination Starter <i>MSC-...-...-M...-SP</i>	23
• <i>PKZM0-...+BK25/3-PKZ0-E</i> Manual Type E Self-Protected Combination Controller	23
+ <i>For applications in the US</i>	
+ <i>For applications in Canada</i>	
• UL 508 Type F Combination Starter	24
Tap Conductor Protector	25
Summary of Figure 12 (next page)	25
Validity	25
References	25
Figure 12, North American motor starter constructions	26
Useful Tables	28

Recommendations on navigating through this comprehensive technical paper

Readers who are pressed for time and wish to take a quicker road at finding possible answers to their questions are encouraged to skip ahead to the section entitled “**Various constructive solutions for Combination Motor Starters**”, indicated in bold in the Index of Contents.

Readers who would like to seek a better understanding of why they need to adopt these solutions for export to North America are encouraged to consult the segments under the introductory sections (not in bold in the Index of Contents) primarily dealing with:

- the main features of the North American electrical safety system
- the differing characteristics of „Energy Distribution“ and „Industrial Control“ electrical equipment.
- general knowledge on North American electrical equipment and assemblies
- the differing requirements of motor starter constructions

This technical paper is directed towards planners, project engineers, panel builders and users who are involved with the application of electrical equipment in North America, primarily from an export perspective. A detailed description of the equipment certification process and a discussion of specific component design details were purposely omitted. In spite of its breadth, the paper deals mostly with specific component related aspects of manual motor controllers and motor starters commonly encountered in the North American market. Comprehensive project design of North American engineered assemblies will require additional and specific knowledge to that effect.

Quick overview and summary of contents:

The paper sheds light into differing construction and application aspects of motor starter equipment which exist between market places in North America and the IEC world. Identical or similar terms used in both market

segments can vary significantly with respect to their proper application. The basis for much of the misunderstanding is rooted in the North American practice of requiring separate upstream branch circuit protective devices to be installed ahead of motor starter equipment (such as manual motor controllers per IEC/EN standards) normally certified under the *UL 508* and *CSA-C22.2 No. 14-05* industrial control standards. As a rule, North American product standards for protective devices, such as *UL 489* and *CSA-C22.2 No. 5-09*, require significantly larger air and creepage clearances on incoming terminations than standard industrial control equipment.

Machine manufacturers and panel builders who export and wish to standardize on one solution for machinery and its associated electrical equipment may well consider the following list of fuseless „Combination Motor Controllers Starters“ as the most viable option, and one which finds equal acceptance in the IEC world:

- **UL 508 Type E Self-Protected Combination Motor Controller**
 - Self-Protected Combination Controllers (Starters)
 - Manual Self-Protected Combination Motor Controllers (Starters)
- **UL 508 Type F Combination Motor Controllers (Starters)**

In such cases, however, it is necessary to keep in mind that North American engineering requirements related to the equipment, including the use of North American wiring materials and conductor color specifications, would have to be followed. **Figure 12** at the end of the paper details the constructional composition of various motor starter design solutions and their suitability to meet application requirements.

The fuseless based solutions mentioned above should make it much easier to reduce the need for two distinct versions of electrical equipment

for industrial machinery, i.e. one for North America and the other for the IEC, since the general structural layout of both panels afforded by these components can now become more or less the same, if not totally identical. The use of fuseless equipment can be especially advantageous for export assemblies since the procurement of North American fuses locally in Europe can sometimes be problematic, and certain fuse classes can mean an increase in overall panel size requirements.

The paper clearly highlights that the general topic of product certification and regulatory approval is rather complex. It is in a constant state of flux and changes must be monitored closely and diligently. There are many details of critical importance to a user which only the manufacturer would be in a position to know. Eaton Electric has the specialists in place who can keep you abreast of developments and provide you with the necessary engineering and design help, as well as localized support and start-up assistance directly in North America. You can put your trust in the experience we have accumulated over decades of involvement in the North American market place; certification of electrical equipment and assemblies has always been an Eaton specialty.

Eaton Industries GmbH, Bonn

Special considerations governing the application of manual motor controllers and motor starters in North America

Differing product standards and market customs in both Europe (*IEC-Guidelines*)¹ and North America (*NEC*² / *CEC*)³ can often lead to frustrating delays and/or costly and extensive alterations of European engineered assemblies exported to North America (e.g. control panels for industrial machinery). Conversely, there are only minor differences within North America between relevant US and Canadian based standards which cover such installations. These slight deviations will be discussed further in later sections. This paper will attempt to point out differing viewpoints between both major markets, and hopefully assist in preventing misunderstandings, irritating delays and costly reparations which may otherwise occur in projects involving the export of electrical equipment. We remain in constant touch with the activities of key certification agencies and with our Eaton colleagues in North America, who always keep us abreast of the latest developments in this regard.

The term „Motor Starter“, commonly used in North America for many years, has also now been adopted in Germany to a large extent, albeit with a somewhat differing interpretation. The introduction of the *IEC / EN 60947-4-1* [1] standard years ago was mostly responsible for popularizing the term in Europe on a broader basis. Among many motor starter related topics, this standard concerns itself with the co-ordination and performance of components such as contactors, overload relay and manual motor controllers under the effects of short circuit currents. These concepts have in the meantime been incorporated into the relatively recent set of North American harmonized standards, *UL 60947-4-1A* [2] in the US, and *CSA-C22.2 No. 60947-4-1-07* [3] in Canada.

Motor starters designed in accordance with international and European standards (excluding North America),

and marketed by various control gear manufacturers, generally share a similar construction and have been successfully applied by the millions world-wide. It's interesting to note in this respect that there is a very established market for IEC based products in North America, particularly in the machine tool industrial sector and the export of engineered assemblies back to the European continent. European products and control panel design engineering philosophies have thus become well established throughout North America. Still, there is a feeling that many technical innovations originating out of Europe remain generally unknown in North America, and that this perception is not necessarily rooted in the lack of certification for these newer product designs. Rather, it may have more to do with the absence of a suitable North American product standard which would allow recently introduced innovations and technological breakthroughs to take full advantage of their application possibilities, as is the case in the EU. However, conformity with internationally based standards, as well as knowledge derived from years of positive field experiences, simply don't add up to much in terms of verifying compliance with local North American electrical Code requirements. Would it thus be proper to conclude that we are indirectly dealing with the imposition of North American trade restrictions meant specifically to exclude European goods in favor of functionally equivalent, but dimensionally larger, North American products? We see things in a more positive light and consider the availability of the *UL 60947-4-1A* [2] standard as a true sign of a more globally harmonized future. That base number, not coincidentally, is well established throughout European and international communities and relates to the family of design and product performance standards for low voltage electrical equipment. The international standard for motor starters is assigned a similar number even though the performance requirements of motor starters in both IEC and NA based

standards are still not yet fully harmonized.

Product certification requirements in North America

In the US, equipment approvals and listings are mandated by the governmental agency *OSHA*⁴ and the *NEC*, which require third party certification⁵ or "listing" of electrical products and engineered assemblies by independent and nationally recognized testing laboratories (*NRTL*)⁵, e.g. *UL*⁶. In Canada, all electrical equipment must comply with the *CEC*, and *CSA* certification⁷ is a legally binding requirement for all electrical products and assemblies.

Equipment listings in North America are closely associated to third party certification marks which must appear on products to validate this claim. Components which have been successfully tested to applicable product standards will therefore be affixed with an appropriate laboratory stamp or mark. (**Table 1**). In the US and Canada, cataloging of certified products used to be published solely in book form. Today, this type of information is made largely available through the internet⁸ through the use of on-line directories from the certification agencies.

As a result of relaxed trade restrictions brought about by the *NAFTA-Agreement*⁹ it is now possible for clients to obtain product certifications from either UL or CSA which have legitimacy in both countries. The equipment would then bear a certification label from each agency

4 *OSHA* = Occupational Safety and Health Act (<http://www.osha.gov>)

5 *NRTL* = Nationally Recognized Testing Laboratories

6 *UL* = Underwriter's Laboratories (<http://www.ul.com>)

7 *CSA* = Canadian Standards Association (<http://www.csagroup.org>)

8 Access to UL database = <http://database.ul.com/cgi-bin/XYV/template/LISEXT/1FRAME/index.html>,
Access to CSA database = <http://www.csagroup.org/>

9 *NFTA* = North American Free Trade Agreement <http://www.csagroup.org/services/testing-and-certification/certified-product-listing/>

1 *IEC* = International Electro-Technical Commission

2 *NEC* = National Electrical Code

3 *CEC* = Canadian Electrical Code

with appropriately distinctive markings. Eaton has, up to this point, made relatively little use of this dual country marking option from a single certification agency, simply because many local inspectors and end-users appear reluctant to accept them.

Eaton Germany has adopted two product related solutions with respect to product certification requirements:

- Eaton refers to a component as a „World Market device“ whenever the requirements of both North American and international standards are satisfied by the same product design. A World Market device signifies that the product in question is in compliance with the certification

requirements of all major global markets and can therefore be successfully applied world wide. (Examples of these include contactors, overload relays, pushbuttons and pilot devices, i.e. components for which the IEC based design can be certified as is to North American standards and bear the appropriate North American certification marks).

- In cases where North American and international requirements cannot be unified under one design, or when production volume of components is strictly monitored by third party authorities and subject to additional inspection costs, the necessary course of action for Eaton usually

involves the establishment of two or even possibly three different versions of the same product. Circuit Breakers are a good example. These products are sometimes subject to certain modifications when certified to North American product standards and are correspondingly identified with the suffix „-NA“ or „-CNA“. These North American versions then become part of the follow-up reexamination testing requirements imposed by the North American certification agencies. From a design point of view, these devices are only slightly different from their IEC counterparts, and in some cases are identical.

As highlighted in Table 2, UL in the US differentiates between „Listed Equipment“ and „Recognized Equipment“. This also applies to Industrial Control equipment. Each type is identified with respective markings on products.

Influence of specifiers and users of certified electrical equipment

In Europe, people are familiar with so-called installation standards, such as IEC / EN 60 204-1 [5] (Electrical apparatus for machinery), which include many application based requirements that place greater emphasis on overall control panel engineering rather than just a simple component selection process. The responsibility for compliance and conformity with the standard, therefore, goes beyond the purview of the component manufacturer and extends to design engineers, panel builders, contractors and users alike.

The same situation applies in North America, and closely ties in to the equipment certification process. A type PKZM0 manual motor controller, as a stand-alone component, is UL listed and CSA-certified. That is certainly an important part of the picture, but not the only criteria for a successful and proper application of the product per North American codes and standards. Millions of IEC design based manual motor controllers have been successfully applied globally over decades, yet these identical controllers are simply not allowed to be used in North America under the same performance guidelines. For example, their base certification only allows them the ability to switch motors directly across-the-line, and to provide motor starting and running overload protection. This is an important point to





Type suffix added to the part number	Type of Certification	Certification marks	
-NA	The device is fully UL listed or CSA certified as a stand-alone component.		
-CNA	The device is component recognized by UL and its proper application is subject to additional Conditions of Acceptability. (COAs). The device is CSA certified and its proper application may also be subject to similar constraints from Canadian based Codes and Standards.		

Table 1: Eaton makes use of both types of UL component certifications and correspondingly identifies each classification with part number suffixes. Refer also to Table 2. CSA does not use separate marks to differentiate component certification in the same manner as UL does, but the application of recognized products in Canada may be subject to similar constraints and conditions.



Listed Industrial Control Equipment No restrictions in terms of application	Component Recognized Industrial Control Equipment Application based on conditions of acceptability
<ul style="list-style-type: none"> • Devices listed for „field wiring“ • „factory wiring“ is covered by „field wiring“ provisions - Listed devices are suitable for control panels when used per the guidelines of the industrial control panel standard (UL 508A). - Listed devices are not subject to additional conditions of acceptability. 	<ul style="list-style-type: none"> • As components, products are suitable for „factory wiring“ only - Component selection is conducted by trained personnel and subject to Conditions of Acceptability - For use in control panels; designed, wired and tested by technically trained personnel in certified factories and panel shops.
Certification Marks: 	Certification Marks: 

Table 2: In the US, industrial control equipment falling under UL 508 could be certified as „Listed Industrial Control Equipment“, or „Recognized Component Industrial Control Equipment“. Other NRTLs do not differentiate in the same way with their certification marks.

always keep in mind. It is Eaton's intent, therefore, to insure that products are not only certified, but that they are also being applied properly, and in accordance with the installation guidelines established by the local North American electrical codes.

Requirements of various sales channels for certified electrical equipment

Eaton Germany considers the following sales channels to be its primary outlets for certified components and assemblies:

• Direct sales in North America

– For applications in North America

Component certification is a must in this case. Even then, certified *IEC* based equipment in many instances provides a local buyer with, at best, a compromise if their preference is for traditional *NEMA*¹⁰ products and design philosophies. That has made the sale of *IEC* based equipment harder to achieve, although it now stands to make significant progress due to the strength and presence of Eaton. On the other hand, there are a number of applications for which smaller physical dimensions, and a fuseless, or almost fuseless, design approach, provide Eaton with excellent opportunities to showcase its products. These applications provide an additional benefit from the point of view that much of what is learned from local field experience can be fed back directly into the design department in Germany, and thus positively influence current and future product developments for the North American market.

– For export out of North America

The overwhelming requirement in global export applications calls for *IEC* based electrical equipment designs and the overall smaller dimensional space these components will provide. That's especially the case whenever electrical equipment needs to conform to *IEC* based engineered assembly standards. Equipment certified to North American standards is of very little significance to this

Electrical Equipment Groupings in North America	
Energy distribution components <i>(Distribution Equipment)</i>	Motor control components <i>(Industrial Control Equipment)</i>
<i>e.g. UL 489, UL 98, UL 248 and CSA-C22.2 No. 5-09, CSA-C22.2 No. 5-04, CSA-C22.2 No. 248,</i>	<i>UL 508, UL 60947-1, UL 60947-4-1(A), and CSA-C22.2 No.14-05, CSA-C22.2 No.60947-1-07, CSA-C22.2 No.60947-4-1-07</i>
<ul style="list-style-type: none"> • Molded Case Circuit Breakers (UL 489) • Molded Case Switches (UL 489) • Enclosed and Dead-Front Switches (UL 98) • Fusible Disconnect Switches (UL 98) • Fuses (UL 248) <p><i>UL: CSA equivalent standards:</i> <i>UL 98 : CSA-C22.2 No. 4</i> <i>UL 248: CSA-C22.2 No. 248</i></p>	<ul style="list-style-type: none"> • Magnetic controllers (contactors) • Control Relays • Overload Relays • Manual Motor Controllers (protectors) • Rotary Cam Switches • Pushbuttons and Pilot Devices • Solid State controls and systems • Programmable Controllers¹⁾
<p>Special requirements:</p> <ul style="list-style-type: none"> • These devices need to be particularly robust in their construction and have larger electrical clearances than industrial control equipment: (e.g. for 301...600 V: 1 Inch through air, 2 Inches over surface in the area of field terminations). • Lower permissible temperature rise. • Product construction generally larger than <i>IEC</i> equivalent. • Incoming and outgoing power circuit components for energy distribution assemblies (Switchgear, Switchboards, Panelboards) must conform to these standards. • Main disconnect and protective switches used in industrial control assemblies must also conform to these standards. • Safety testing for these products maintain strict standards and factory production quality is closely monitored by inspectors from each certification agency. • <i>UL/CSA</i> Molded Case Circuit Breaker testing standards are amongst the most stringent in the industry worldwide. • Quarterly and extensive re-examination testing as a function of production. 	<p>Special requirements:</p> <ul style="list-style-type: none"> • These components are smaller in size and electrical clearances are not as large as those of energy distribution equipment. • Industrial control devices are installed primarily in control panels, in motor branch and associated load circuits, in Motor Control Centers (MCC) and also as components in some energy distribution assemblies. • They can be combined in the same circuit as energy distribution equipment in control panels, e.g. with a circuit breaker used as a main disconnect and protective switch in a motor branch circuit. • Factory production is also monitored by the certification agencies, but not to the same extent as applies to circuit breakers. • Generally speaking, more compatible with conventional <i>IEC</i>-designs.

1) in Canada per CSA-C22.2 No. 142-M1987, as of 2012 per CSA-C22.2 No. E61131-2.

Table 3: Differences in North American product grouping based on construction and certification requirements in product standards, e.g. UL 489 [6] and CSA C22.2 No.5-09 [7] for circuit breakers and UL 508 and CSA C22.2 No.14-05 [8] for industrial control equipment.

market. However, for obvious reasons, there is a definite tendency on the part of North American exporters to seek and standardize on equipment that conforms to both North American and *IEC* standards. It's advantageous for business purposes too that Eaton components

also bear the *CE*-Mark¹¹, particularly when they are subject for export to the European market.

10 *NEMA* = National Electrical Manufacturer's Association (www.nema.org)

11 *CE* = Conformite Europeenne. This mark allows products and equipment free access to markets within the European Common Market.

• **The export of electrical equipment to North America from IEC-countries**

The indirect export sector has historically been more significant commercially than going through direct sales channels in North America. The focus for Eaton Europe is mainly on machinery and its associated electrical controls, which typically are built in Germany or in the rest of Europe. This explains in part why the support provided by Eaton Electric to the machinery and panel assembly sector is so intensive. Exporting machine manufacturers would ideally like to build (series production) machinery with an identical electrical control scheme that would be suitable world-wide, or, if that's not possible, end up with an electrical control panel layout for North America that only differs slightly from the IEC model to account for specialized North American electrical code requirements. Machinery buyers in North America are generally very appreciative of European expertise in machine building, and they also recognize many of the technological advantages that modern European electrical controls offer as part of the package. Fuseless based solutions remain an important and desirable characteristic of modern electrical control panel design. The use of equipment which can be used in both 50Hz and 60Hz supply systems is also recommended for export purposes. Nominal voltage differences can be easily taken care of with the use of matching transformers. The field of export business is where Eaton's considerable experience and know-how can translate into real benefits for our clients. The main goal is to design an electrical control panel which will both maximize the use of European technological know-how and secure immediate approval by local electrical inspection authorities. This sector represents the single largest demand for the type of IEC style components which Kloeckner-Moeller and subsequently were designing and producing for decades. Now, the North American Eaton organization can offer even better service and support for these products, as well as more efficiently provide spare parts replacement business locally through its vast network of suppliers.

Electrical equipment groupings in North America

A marked differentiation exists in the US and Canada between components designed for installation in energy distribution circuits, and those that are

primarily located closer to the load (industrial control equipment). Please refer to **Table 3**. These two groupings are subject to different product certification standards, which entail a varying level of testing requirements and performance criteria. It's crucial to keep these two groupings in mind since they will often be referenced in this paper. They provide important insights in properly understanding the differences between products such as manual motor controllers and circuit breakers with respect to their evaluation and application per the North American standards. Both product categories will be frequently referred to in the ensuing text.

Manual Motor Controller or Circuit Breaker?

The term „Motor Protective Switch“ (“Motorschutzschalter“ in German) was coined by Kloeckner-Moeller many years ago in Germany. To many electricians in Europe the Eaton part number PKZM is synonymous with motor protective switches, regardless of manufacturer., or Kloeckner-Moeller, as the company was formerly known, has been manufacturing these manual switches since 1932. Other manufacturers also refer to their own devices as „Motor Protective Switches“, or they might interchange

the term “Circuit Breakers” to describe them, in spite of their relatively smaller nominal current ratings.

The term „Motor Protective Switch“ is actually not spelled out quite that way in the IEC product standards. However, all understand the device to be a 3 phase, manually operated protective switch rated for nominal currents up to 63A, that has been optimized for the protection of electric motors. According to international classifications it belongs in the grouping of „current sensitive, thermally delayed (inverse time) overcurrent protective devices“. This norm recognizes overload relays (with relay output circuitry) or overload tripping elements, which are functionally designed to interact directly with the switching mechanism of a protective switch and open its main power contacts. These main contacts can also be used to switch motors direct-on-line. The motor protective switch is usually combined with one or more magnetic controllers (contactors) in cases where a higher degree of switching frequency is required. The optimized motor protective features mentioned earlier mostly refer to the provision for phase failure sensitivity in accordance with IEC / EN 60 947-4-1 [1] and the capability of these switches to handle AC-4 type currents without

Load	Load Duty Ratings Rating data on equipment
1) Motors	Horsepower (HP)
2) Coils (Coils in auxiliary and control circuits)	Coils: Volts, Frequency, Voltampere Coil switching Control Circuit Contacts: Standard Pilot Duty or Heavy Pilot Duty.
3) Resistance (heating)	Amperes, resistance only
4) Incandescent lamps	Amperes or Watts, Tungsten
5) Ballast (electric discharge lamps)	Amperes, Ballast
6) General Use ¹	Amperes (A)

¹ The category „General Use“ applies for general usage, and is in accordance the IEC/EN utilization category AC1.

Table 4: Types of switching loads (Load Duty ratings)

nuisance tripping for the duration of motor start-up sequences. Generally speaking, a phase failure sensitivity feature for circuit breakers, which are frequently subject to uneven loading across the phases, would be problematic since it could lead to nuisance and unwarranted circuit breaker tripping. Eaton does offer circuit breakers with an optional phase failure sensitivity feature for nominal current ratings exceeding the range of motor protective switches.

In addition to the overload protective function, Eaton motor protective switches built in accordance with the international standards *IEC / EN 60 947-1* [10] and *IEC / EN 60 947-2* [11] also include magnetic trips for short circuit protection as well as power circuit isolating capabilities. They are thus able to be applied, with the use of appropriate accessories, as main disconnect switches per the requirements of the *IEC / EN 60 204-1* [5] standard. The short circuit protective

function, isolating characteristics and functionality as a main disconnect are only minimally recognized per North American standards (see ensuing sections for further clarifications).

North American electrical ratings for Industrial Control Equipment

The US and Canadian standards have defined various types or categories of switching duty requirements for industrial control equipment in similar fashion to the *IEC* standards, which define „Utilization categories for low voltage switching devices“ (AC-1, AC-3, AC-4 etc.). Each „Load Type“ in North America is assigned a Load duty rating as indicated in Table 4, which either appears on the rating label of each device or in technical data sheets supplied with the product, and identifies its suitability for the respective loading requirements.

It's important that these load duty classifications be strictly observed in all

cases for export to North America, particularly since in many instances the North American ratings can be less than their *IEC* equivalent.

Equipment approvals conducted by electrical inspectors

Generally speaking, there is a great deal of uncertainty on the part of North American electrical inspectors with respect to equipment imported from overseas. That aspect, combined with a fundamental lack of knowledge of North American standards on the part of European machinery exporters, invariably cause frequent misunderstandings and commissioning delays for any equipment being newly installed and subject for evaluation. The inspectors (*AHJ*-Authorities Having Jurisdiction) are local town and county government employees who are empowered to insure that electrical installations are properly evaluated and in compliance with local electrical codes and ordinances, which are

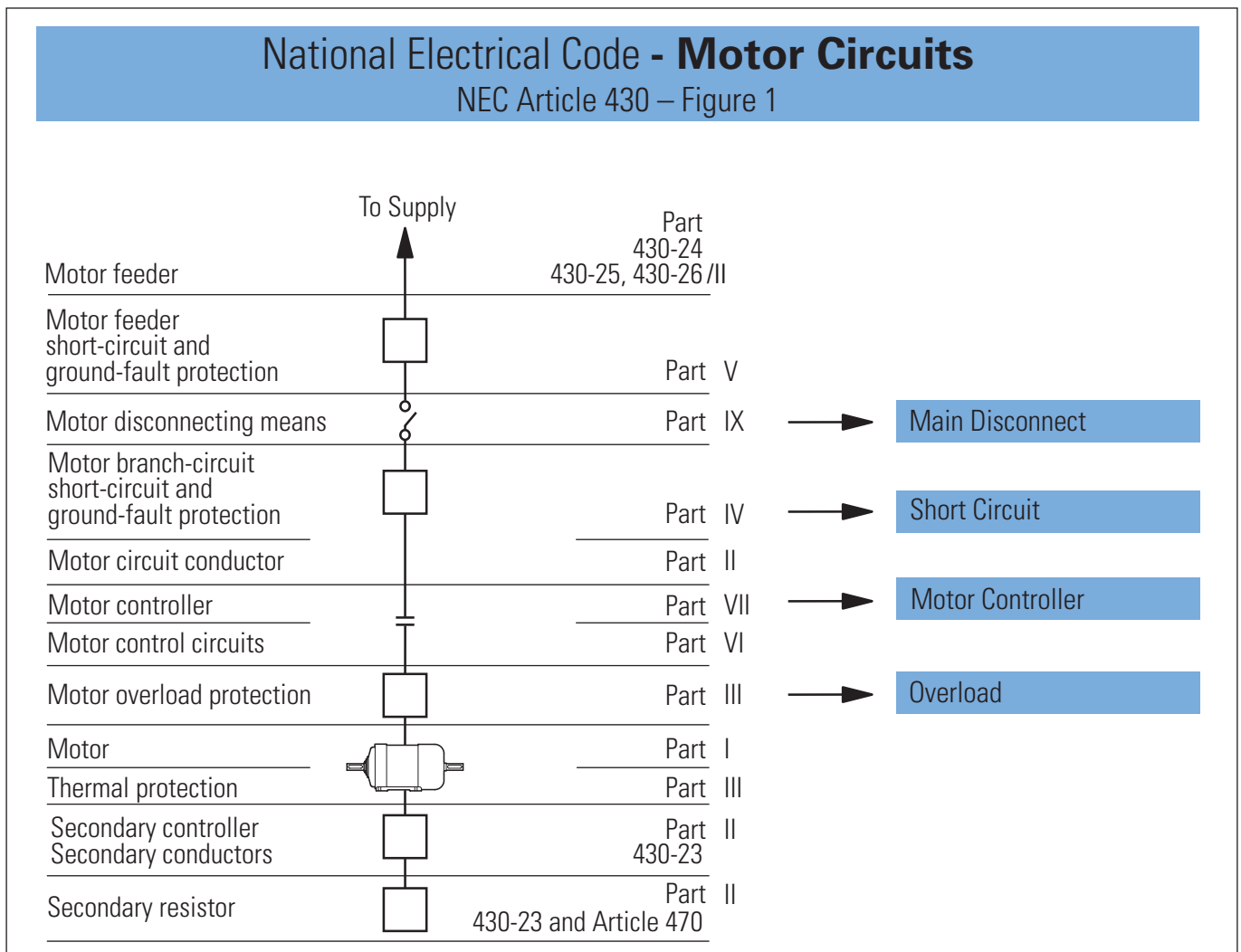


Figure 1: Diagram 430-1 from the National Electrical Code points out the important elements of the Motor Branch circuit. Differences between international and North American definitions of key terms are the basis for much of the misunderstandings and problems which can occur during equipment evaluation by North American inspection authorities. A similar diagram is also found in the CEC.

primarily derived from the *NEC*. The evaluation conducted by these electrical inspectors is a vital element in determining whether or not power from the local utility company can ultimately be delivered to the installation. Clearance granted by the inspection authority is also essential for building owners to secure insurance coverage for their plant and installation.

The provisions of the *NEC* require that electrical components and assemblies be "listed" by third party certification agencies (*NRTL* - Nationally Recognized Testing Laboratories) e.g. *UL*, in accordance with their application. The inspectors depend heavily on the use

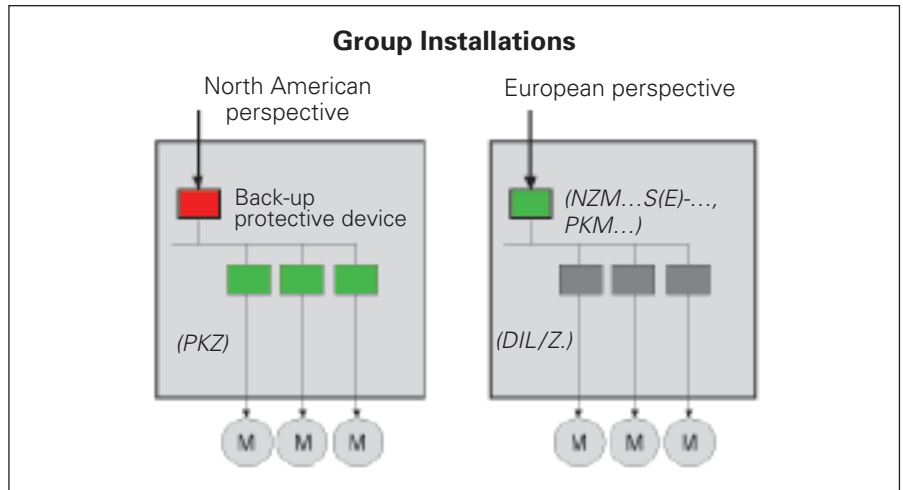


Figure 2: Misunderstandings can arise from differing interpretations of Group Installations.

Short Circuit Current Ratings for single protection, group protection, tap conductor protectors, UL 508 Type E and UL 508 Type F controllers									
Type	Overload trip [A]	Contactor	Accessories	SCCR		Fuse max.		Circuit Breaker max.	
				[kA]	[kA]	[A]	[A]	[A]	[A]
1. Manual motor controller in group installations with upstream back-up protective device				480 V	600 V	480 V	600 V	480 V	600 V
<i>PKZM0</i> -...	0,1 - 6,3	-	-	50	50	600	600	600	600
<i>PKZM0-10</i>	6,3 - 11	-	-	30	30	600	600	600	600
<i>PKZM0</i> -...	9 - 12			65	18	600	600	600	600
<i>PKZM0</i> -...	10 - 16	-	-	10	10	150	150	125	125
<i>PKZM0</i> -...	10 - 16		with CL-PKZ0	50	50	600	600	600	600
<i>PKZM0</i> -...	16 - 25	-	-	10	10	150	150	125	125
<i>PKZM0</i> -...	16 - 25	-	with CL-PKZ0	18	18	600	600	600	600
<i>PKZM0</i> -...	24 - 32	-	-	18	10	600	600	150	125
<i>PKZM0</i> -...	24 - 32	-	with CL-PKZ0	18	18	600	600	600	600
<i>PKZM4-50</i>	up to 52	-	-	65	42	600	600	600	600
<i>PKZM4-58</i>	up to 56	-	-	65	42	600	600	600	600
<i>PKZM4-63</i>	up to 58	-	-	65	42	600	600	600	600
2. Tap Conductor Protectors suitable for use in group installations				480 Y/277 V*	600 Y/347 V*				
<i>PKZM0</i> -...	up to 11			50	50	The maximum rating of the branch circuit protective fuse or circuit breaker is determined per the 1/10th rule.			
<i>PKZM0</i> -...	up to 16			42	18				
<i>PKZM0</i> -...	up to 32			18	-				
<i>PKZM4</i> -...	up to 40	-	-	65	25				
<i>PKZM4</i> -...	up to 58	-	-	65	-				
3. UL 508 Manual Type E Self-Protected Combination Controller (Starter)				480 Y/277 V*	600 Y/347 V*				
<i>PKZM0</i> -...	0,1 - 10	-	with <i>BK25/3-PKZ0-E</i>	65	50	-	-	-	-
<i>PKZM0</i> -...	10 - 12			65	18				
<i>PKZM0</i> -...	12 - 16	-		42	-	-	-	-	-
<i>PKZM0</i> -...	16 - 27	-		18	-	-	-	-	-
<i>PKZM4</i> -...	10 - 40	-	with <i>BK50/3-PKZ4-E</i>	65	25	-	-	-	-
<i>PKZM4</i> -...	up to 52	-		65	-	-	-	-	-
4. UL 508 Type F- Combination Controller (Starter)				480 Y/277 V*	600 Y/347 V*				
<i>PKZM0</i> -...	0,1 - 10	DILEM,	with <i>BK25/3-PKZ0-E</i>	50	50	-	-	-	-
<i>PKZM0</i> -...	10 - 12	DILM7, 9, 12		65	18	-	-	-	-
<i>PKZM0</i> -...	12 - 15	DILM15		50	-	-	-	-	-
<i>PKZM0</i> -...	15 - 27	DILM17, 20, 25, 32		18	-	-	-	-	-
<i>PKZM4</i> -...	10 - 40	DILM32, 40	with <i>BK50/3-PKZ4-E</i>	65	50	-	-	-	-
<i>PKZM4</i> -...	up to 52	DILM65		65	-	-	-	-	-

* solidly grounded system Status: April 2016

Table 5: Maximum short circuit current rating and sizing of back-up overcurrent protective fuses and circuit breakers in group installations per *NEC*, Article 430-53 and *CEC* Part 1, Rule 28-206. *PKZM0* with and without *CL-PKZM0* current limiter.

of UL listing and UL marks on products to conduct their evaluation work, simply because it greatly minimizes the risk they would otherwise have to undertake if the equipment to be evaluated were uncertified. A similar situation exists in Canada. A case could certainly be made that inspectors are generally more wary and critical of foreign equipment, and that there is a varying degree of tolerance among them as to what they would deem to be acceptable. Nevertheless, there is always a keen interest on the part of inspectors to look for, and find, familiar *UL* and *CSA* marks on the equipment they evaluate, and to make sure that the products are applied properly per their North American electrical ratings. It's also helpful in their view to be confronted by panel layouts and wiring schematics which are in obvious conformity with local conventions and installation guidelines. It can't be emphasized enough that exporters need to pay close and strict attention to North American requirements, because approval issues raised by electrical inspectors can have serious consequences and should be avoided at all costs.

In line with their philosophy of supplying „more than products“, Eaton offers consulting sessions and extensive customer seminars on the export of electrical equipment to North America. Our sales offices will be more than happy to put you in touch with the right people.

An important guide used by electrical inspectors in their evaluation work is the chart provided by figure 430-1 of the *NEC* (**Figure 1**). This chart will also be the basis for many of the clarifications provided.

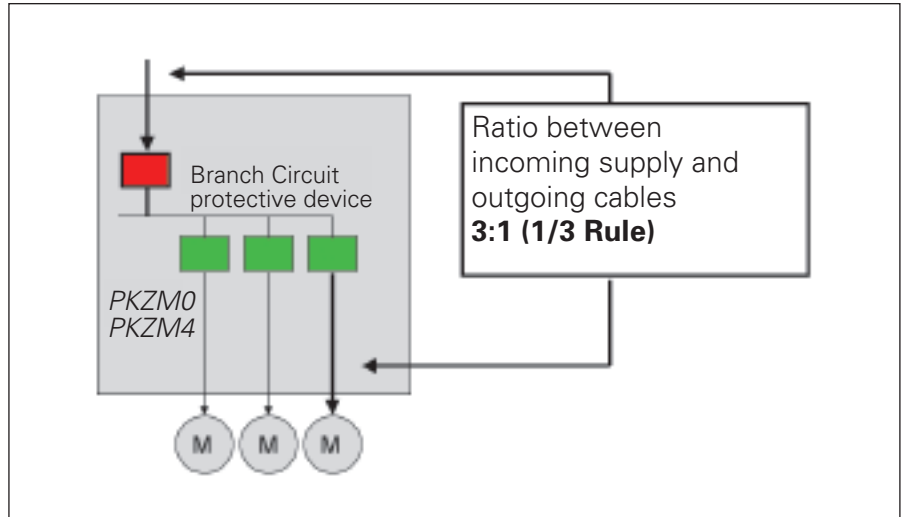


Figure 3: Maximum ratio between incoming supply and outgoing motor circuit conductors in group installations per the 1/3 rule

Note that the current *NEC* has switched from using letters to denote Part A through Part J to roman numerals Part I through Part IX.

The Code requires that the Motor Branch circuit include 4 basic functions:

- Main Disconnect
- Short Circuit protection
- Motor Controller (Contactor)
- Motor Overload protection

The main difference in the evaluation of conventional European style motor protective switches, like PKZM or similar devices, is that they are certified in North America as „Manual Motor Controllers“ and fulfill only a motor overload protective function, even when they are additionally evaluated for group installations. Devices of this construction and certification are not considered as motor branch short

circuit protective devices by the electrical codes. (Exceptions to this are UL 508 Type E and F controllers, to be covered later.)

Group installations per *NEC*, Article 430-53 and *CEC* Part 1, Rule 28-206 („Group Protection“)

The use of a PKZM manual motor controller in a North American motor branch circuit usually means that both motor main disconnect and short circuit functions will be fulfilled by an upstream protective switch. That protection will need to be provided by either a circuit breaker (Molded case circuit breaker per *UL 489*, *CSA-C22.2 No. 5-09*) or fuses. This motor branch circuit protective device is mounted separately.

The North American HVAC (Heating, Ventilation and Air Conditioning) group, many years ago, was the industry mostly responsible for pushing through

UL listed / CSA certified Components and Combinations	Evaluation per Figure 1 <i>NEC 430-1</i> ,			
	Part IX	Part IV	Part VII	Part III
	Main Disconnect	Short Circuit protection	Controller (Contactor)	Overload protection
1 Inverse Time Circuit Breakers <i>NZM...A(V)(E)(F)...-NA</i>	Yes	Yes	No	No
2 Manual Motor Starter with <i>PZMO</i> + Contactor <i>DIL M</i>	No	No	Yes	Yes
3 Motor Controller <i>MSC-...-M...-SP</i> Type E Self-Protected Combination Motor Controller	Yes	Yes	Yes	Yes
4 Instantaneous only circuit breaker + magnetic contactor + overload relay <i>NZM...-S(E)...-CNA + DILM + Z</i>	Yes	Yes	Yes	Yes

Table 6: Functional evaluation of various motor protective and circuit breaker component combinations of European design, from the perspective of Figure 430-1 of the *NEC*. The peculiar aspects of these component combinations will be highlighted further in the body of the text.

Group Installation regulations through the *NEC/CEC*. Group Installation refers to the practice of setting up a number of tapped circuits, each with a motor controller and motor overload protective device, under one back-up (group) branch circuit overcurrent protective device. This type of installation can also be used when manual motor starters such as *PKZM* are applied as manually operated motor controllers incorporating motor overload protection.

Controllers and motor overload devices, for example *PKZM0* manual motor controllers in this case, are specifically evaluated and certified for use in group Installations. All *PKZM0*-.. and *PKZM4*-.. manual motor controllers are *UL listed and CSA certified for this application* and can be thus grouped under one overcurrent protective device per *NEC* and *CEC* group installation guidelines.¹²

¹² At the time of this writing the certification process for the new electronic PKE controller had been initiated.

From the European standpoint group protection would refer to one protective device protecting many circuits e.g. consisting of multiple contactors with overload relays. (Figure 2).

• **Consequences of group installation wiring requirements on motor branch circuit conductor sizing**

There are also specific rules in European and international standards governing sizing and co-ordination of conductor cross-sections and overcurrent protective devices. A strict set of conditions must be observed when reducing the cross-section of a conductor, simply because the overcurrent protective device could otherwise end up being too oversized to provide adequate protection for the smaller conductor. The same reasoning applies with respect to North American sizing requirements. In group installations per *NEC/CEC*, the general rule is that the ampacity ratio between

incoming feeder conductors and outgoing supply cables (cannot exceed a factor of 3:1 (1/3 rule). (Figure 3)

There are additional possibilities to reduce conductor cross-sections in group installations with the use of „*Tap Conductor Protectors*“. Tap Conductor Protectors, as explained later, can represent a suitable alternative to Type E Combination Motor Controllers. Conductor sizing in group installations must always be within the guidelines established by the *NEC/CEC* electrical codes. There are also a number of additional wiring factors to consider besides limited conductor lengths on taps, incl. cable bundling and ambient temperature, protection against damage etc...

Examples of popular components and combinations in Motor Branch Circuits

Table 6 shows how several popular component combinations are evaluated in motor branch circuits from the

Three Phase NEMA Contactors NEMA-Sizes	Rated Current	Three Phase HP ratings ¹⁾			
		200 V / 60 Hz	230 V / 60 Hz	460 V / 60 Hz 575 V / 60 Hz	Service-Limit Current Ratings
	A	HP (PS)	HP (PS)	HP (PS)	A
00	9	1 ½	1 ½	2	11
0	18	3	3	5	21
1	27	7 ½	7 ½	10	32
2	45	10	15	25	52
3	90	25	30	50	104
4	135	40	50	100	156
5	270	75	100	200	311
6	540	150	200	400	621
7	810	-	300	600	932
8	1215	-	450	900	1400
9	2250	-	800	1600	2590

1) HP ratings for 3-Phase contactors, single speed motors, with no jogging, reversing and dynamic current braking.

Table 7: NEMA-Sizes for contactors in relation to HP-ratings and rated nominal current levels.

DILM/Z Non-Combination motor starters for applications in North America

Maximum Motor HP Rating 3 Phase, 60Hz				Motor Full Load Current FLC A	Contactor Type	Overload Relay Type	Maximum upstream short circuit protective device in North America		
208 V (200 V) HP	240 V (230 V) HP	480 V (460 V) HP	600 V (575 V) HP				Fuses per CEC / NEC ¹⁾ A	Circuit Breaker Rated Current A	Short Circuit Instantaneous Trip A
-	-	½	½	1	DILEEM	ZE-1	3	15	-
-	-	¾	1	1.4	DILEEM	ZE-1.6	6	15	-
½	½	1	1½	2.3	DILEEM	ZE-2.4	6	15	-
1	1	2	3	3.9	DILEEM	ZE-4	15	15	-
1½	1½	3	-	6	DILEEM	ZE-6	20	15	-
1½	2	-	-	6.8	DILEEM	ZE-9	35	15	-
1½	2	5	5	7.8	DILEM	ZE-9	35	15	-
1½	3	5	5	9.6	DILEM	ZE-12	45	-	-
-	-	½	½	1	DILM7	ZB12-1	3	25	200
-	-	½	1	1.4	DILM7	ZB12-1.6	6	25	200
½	½	1	1½	2.3	DILM7	ZB12-2.4	6	25	200
1	1	2	3	3.9	DILM7	ZB12-4	15	25	200
1½	1½	3	-	6	DILM7	ZB12-6	20	25	200
3	-	-	7½	9	DILM9	ZB12-10	25	25	200
3	3	5	7½	9.6	DILM12	ZB12-10	25	25	200
3	-	7½	10	11	DILM12	ZB12-12	40	25	200
5	5	10	-	15.2	DILM15	ZB12-16	40	30	320
-	-	½	½	1	DILM17	ZB32-1	3	25	200
-	-	¾	1	1.4	DILM17	ZB32-1.6	6	25	200
½	½	1	1½	2.3	DILM17	ZB32-2.4	6	25	200
1	1	2	3	3.9	DILM17	ZB32-4	15	25	200
1½	1½	3	-	6	DILM17	ZB32-6	20	25	200
-	3	5	7½	9.6	DILM17	ZB32-10	25	25	200
-	-	7½	10	11	DILM17	ZB32-12	40	30	320
5	5	10	-	15.2	DILM17	ZB32-16	40	30	320
7½	7½	15	20	22	DILM25	ZB32-24	90	100	1200
10	10	20	25	32.2	DILM32	ZB32-32	125	125	1200
-	3	5	7.5	9.6	DILM40	ZB65-10	40	40	380
-	5	10	10	15.2	DILM40	ZB65-16	60	60	760
-	7½	20	25	32.2	DILM40	ZB65-24	90	90	1200
10	10	20	30	34	DILM40	ZB65-40	125	125	1200
15	20	40	50	54	DILM50	ZB65-57	200	150	2000
20	20	50	50	63	DILM65/72	ZB65-65	200	150	2000
25	30	60	75	80	DILM80	ZB150-70	250	250	2500
25	40	75	100	104	DILM95	ZB150-100	J 400	J 400	3200
40	50	100	100	130	DILM115	ZB150-125	J 400	J 500	4000
40	60	125	125	156	DILM150/170	ZB150-150	J 600	J 600	4800
50	60	125	150	156	DILM185A	Z5-160	700 CLASS L	600	7200
60	75	150	200	192	DILM225A	Z5-220	700 CLASS L	600	7200
75	100	200	250	248	DILM250	Z5-250	700 CLASS L	600	7200
100	125	250	300	312	DILM300A	ZW7-400	800 CLASS L	600	7200
125	150	300	400	382	DILM400	ZW7-400	800 CLASS L	600	7200
150	200	400	500	480	DILM500	ZW7-540	800 CLASS L	600	7200
-	200	400	600	480	DILM580	ZEV-XSW820	2000	-	-
-	250	500	600	600	DILM650	ZEV-XSW820	2000	-	-
-	300	600	700	700	DILM750	ZEV-XSW820	2000	-	-
-	350	700	860	860	DILM820	ZEV-XSW820	2000	-	-

1) Applicable for North American branch circuit fuse classes only.

Status: April 2016

Table 8: "Contactor + Overload Relay" combinations for the North American market, with data on the maximum back-up branch circuit protective fuse or molded case circuit breaker (UL 489).

perspective of **Figure 1** (*NEC*-Figure 430-1.)

Additional items worthy of consideration with respect to enclosed equipment.

International *IP*.- code environmental ratings for enclosures are not officially recognized by electrical inspectors. A North American environmental rating in accordance with *NEC* 430-110.20 / *CEC* must appear on the equipment itself or on accompanying technical documentation. Individual conductors are enclosed in conduits which are terminated directly onto the enclosure. These conduits, which are offered in various "NPT" (National Pipe Thread) Trade Sizes, can be part of an installation's grounding circuit. European PG fixtures¹³ or metric sized conduits are unknown. Eaton offers for that reason product dedicated insulating material enclosures *CI-K2-PKZ0-NA-G(R)(V)* with smooth sided bases and drill starts to better accommodate cable entries with North American style NPT trade size conduits. Continuity of ground must be established when conductors are connected to the enclosures via conduits. If fuses are involved, care must be taken to include only certified North American fuses and fuse bases. Use only wiring material that is certified per North American standards (*UL/CSA*). Conductor cross-section sizing and color schemes must be in accordance with North American electrical code requirements.

Basic concepts related to electrical products on the North American market

Certain aspects related to the application of motor starters in North America will be briefly touched upon since product evaluation and performance capabilities of low voltage equipment designed per North American and international guidelines can vary so much from each other. It's necessary to know these differences in order to gain better insight into the proper application of these products in North America. By design, electrical motors in North America are assigned load duty ratings referred to as *Service Factor* (SF) which, generally speaking, provides an indication as to how much over the nameplate current rating a motor can

be driven without exceeding temperatures that would otherwise lead to overheating. The overload protective settings I_r of *UL/CSA* certified overload relays and manual motor controllers take motor service factor into account in order to provide the required motor overload tripping protection required by Code. Nearly all

adjustable motor overload protective devices of European design have an overload tripping point that is 125% of the dial setting current, which allows the devices to be set to the motor full load current and provide protection for motors with a service factor of 1.15 and greater. Most motors up to 200HP will fall in that category. In cases where the motor has a service factor less than 1.15, a corrective factor would need to be applied. This can be easily accommodated by adjusting the dial setting of the motor overload protective devices accordingly. Typically, the following values would apply:

$$\begin{aligned} SF = 1,15 &\rightarrow I_r = 1 \times I_{n\text{mot}} \\ SF = 1 &\rightarrow I_r = 0,9 \times I_{n\text{mot}} \end{aligned}$$

• Motor contactors for the North American market

Motor contactors in North America are industrial control devices (Industrial Control Equipment per *UL 508* and *CSA-C22-2 No. 14*). North American buyers specify contactors either in "NEMA-Sizes" or, as it is commonly done in the IEC world, by matching motor and controller Horsepower (HP) ratings to more closely fit the application. **Table 7** shows the relationship of power and nominal current ratings corresponding to each respective *NEMA*-size.

- Combination "Contactor + Overload Relay" („Non-combination Motor Starter")

Table 8 provides an overview of Eaton contactor HP ratings. Contactors and overload relays make up an assembly that is referred to in North America as a "non-combination motor starter". North American buyers usually order these assemblies by specifying the required HP rating, much like the purchase of individual contactors.

Table 8 clearly indicates that combining "IEC style" contactors *DIL M* with overload relays Type *Z* creates many more starter combinations than the choice of starter assemblies based on *NEMA* sizing. **Table 8** would infer a more efficient way of applying contactors than using *NEMA* sized controllers.

Such motor branch circuit combinations (with overload relay!) under European practices, with very few exceptions, would be combined with fuses as the short circuit protective element, and would then be identified as fusible or "fuse based" motor starters accordingly.

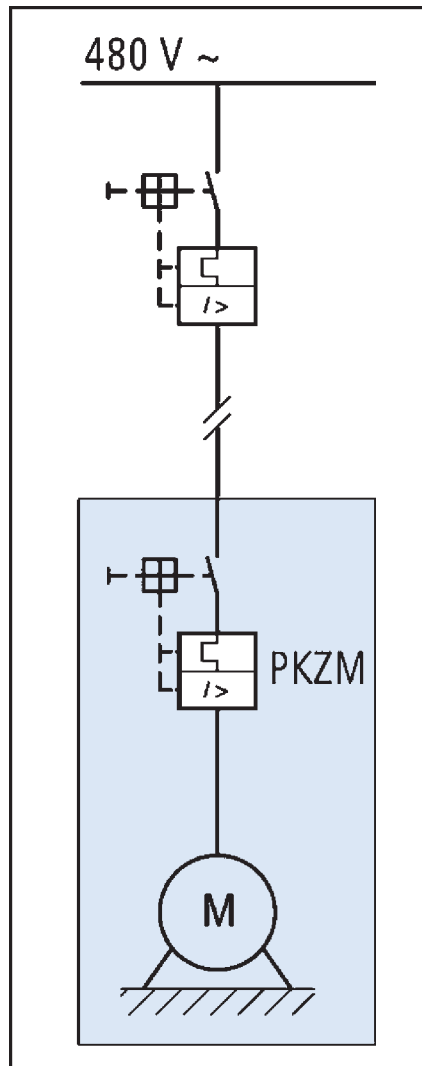


Figure 4: Manual Motor Controllers, such as PKZM0, PKZM4 and PKE with a base certification per *UL 508 / CSA-C22.2 No. 14*, would require an upstream over-current protective device in the motor branch circuit per *NEC/CEC* regulations. *UL 489* listed molded case circuit breakers would be suitable for the purpose, and are part of the certification testing process for all manual motor controllers. The presence of a full voltage¹⁾ rated upstream protective would allow the controllers to be used in both grounded and ungrounded North American power distribution networks.

1) Full voltage in this case refers to the voltage rating of the network, e.g. 480 VAC, which would require a full voltage rated protective device, as opposed to a slash rated, solidly grounded distribution networks such as 480Y/277 VAC.

13 PG, from the German Panzerrohr-Gewinde

- **Manual Motor Controllers (Starters) for the North American market**

- **PKZ Manual Motor Controllers**

Manual motor controllers are Industrial Control devices that are evaluated and certified per *UL 508* and *CSA-C22.2 No. 14-05*. PKZM manual motor controllers are world market devices. They feature fixed instantaneous trips (PKZM0, PKZM4 and PKE) magnetic trips for short circuit protection, adjustable bimetal or electronic trips for motor overload protection and they can switch motors directly across the line. The PKE electronic controllers have an additional trip class selection setting (Class 5 through 20) as well as a motor overload setting range that is much broader than conventional, thermal based controllers. These devices can all be equipped with auxiliary contacts for control circuit switching requirements. *Per current North American product standards, the functionality of the instantaneous short circuit trips built into these controllers is not recognized as providing the necessary branch circuit overcurrent protective function.* (Exception: UL 508 Type E and F controllers, to be described later.)

Manual motor controllers of this design are used primarily as manually operated protective switches in industrial control panels as well as individually enclosed starters for single motor loads. They are selected in North America in accordance with the motor *HP* rating and are primarily used in motor branch circuits for motor switching and protective functions.

As is the case with molded case circuit breakers, North American and international approaches and viewpoints with respect to manual motor controllers tend to be far apart philosophically. It would be preferable if North American standards could better recognize the performance capabilities and greater application range possibilities offered by these components.

From an **international point of view**, these devices represent compact and stand-alone manually operated motor protective switches which offer all of the following functionality aspects:

- Main Disconnect and isolating characteristics
- Short circuit protection
- Overload protection
- and direct-on-line switching capabilities

and, with the provision of certain key accessories, can also be applied as a supply circuit disconnecting means (Main Disconnect and Emergency-OFF switches). Devices in the smaller adjustable current ranges are all short circuit proof and self-protective. Self-protective means that their inner resistance (primarily the bimetal trip assembly) is so great, that available short circuit currents as high as 150 kA are reduced to a level low enough to allow the switch, without the need of an additional back-up protective device, to protect itself and safely handle the fault current without any damage. These devices are well established globally and provide international end-users with a technically viable and economically attractive solution to meet their needs. The protective features of these switches have been verified so often, and in so many millions of cases, that no one outside North America would ever doubt their effectiveness and overall performance capabilities.

From a North American perspective, the IEC motor protective switch is categorized simply as a „manual motor controller“, and does not provide a short circuit protective function to the branch circuit. All of these controllers, aside from those that have undergone additional evaluation as explained in a later section, require an upstream overcurrent protective device in the circuit. (**Figure 4**). This applies equally in cases where the device is operating in its self-protective range and also when it is additionally *UL* listed and *CSA* certified for group installations. This reduced performance capability is not the result of failed product testing. Rather, it has to do with the fact that, historically, North American product standards have assigned the short circuit protective function to a separate grouping of overcurrent protective devices specifically listed or certified for the purpose. However, as the following clarifications will show, there has been a rapprochement of sorts between both the NA and *IEC* worlds in this regard.

Eaton manual motor controllers are available for North American applications in current ranges up to 58 A and come in several family versions (*PKZM0, PKZM4 and PKE*). Availability of the PKE controller should expand the current range to higher levels.

- **Motor Protective Switches, NZM...-ME...-NA “Motor Protective Circuit Breaker”**

Motors, of course, also come in larger sizes. Eaton is now introducing a new range of *NZM...-ME...-NA* motor protective circuit breakers to cater to North American motor starter applications in higher ratings. These devices have been certified as full fledged inverse time circuit breakers per *UL 489* and *CSA-C22.2 No. 5-09*, but have also undergone calibration testing per the motor overload protective function requirements of the industrial control product standards *UL 508* and *CSA-C22.2 No. 14-05*. At the time of this writing this type of circuit breaker had not yet been incorporated into the North American standards. The circuit breaker is normally combined with a magnetic contactor to form a 2 component style combination motor starter as an alternative to the more traditional 3 component North American combination starter (circuit breaker + contactor + overload relay).

- **Molded Case Circuit Breakers for the North American market**

Molded case circuit breakers for the North American market, as referenced in **Table 3**, are considered to be low voltage energy distribution equipment and are designed, tested and certified per the product safety standards *UL 489* und *CSA-C22.2 No. 5-09*. These standards are amongst the most demanding and stringent of all component standards in North America. The main task of molded case circuit breakers and fuses in industrial applications is to protect control equipment, conductors and assemblies against the destructive effects of short circuit currents. They are often applied in this respect as “branch circuit protective devices (BCPD)” for outgoing loads such as motor circuits. Both fuses and circuit breakers are the only types of protective devices which the North American electrical codes allow for non-motor loads.

All *NZM* type circuit breakers mentioned in this paper refer to

„Molded Case Circuit Breakers“ per *UL* and *CSA* standards. The smallest certified molded case circuit breaker in Eaton’s line is the IEC/EN miniature circuit breaker type FAZ...-NA¹⁴, followed in size by the PKZM4...-CB.

– **NZM...-S(E)...-CNA Instantaneous Trip Circuit Breakers** (without thermal or electronic overload trips)

These devices contain adjustable magnetic or electronic trips for short circuit protection. They do not feature any bimetal or electronic overload trips. They do not provide any motor overload protective function. It’s possible in certain cases for these breakers to still incorporate a bimetal element, but this would be done strictly to provide a

¹⁴ These devices are commonly referred to as “Mini-Breakers” in the North American market-

place even though that term does not appear in any standard or norm.

Standards terminology: Motor Controller									
Generally speaking, a „Motor Controller“ refers to the following concept in North America:	All power components and assemblies that are used for switching electrical motors ON and OFF, and which may or may not include additional protective functions.								
Significance:	Controller is the official term used in the <i>NEC</i> , and since <i>UL</i> -standards are based on the <i>NEC</i> , it is the term most commonly used throughout <i>UL</i> -standards to identify components and assemblies used in motor switching applications.								
Some examples within the Eaton family of components and assemblies:	<ol style="list-style-type: none"> 1. Contactors <i>DIL M</i>, without protective function, 2. Motor starter combinations <i>DIL / Z</i> with overload protective function, 3. Manually operated <i>P</i> und <i>T</i> switches, without protective function, 4. Manual Motor Controller <i>PKZM0</i> with overload protective function, 5. Manual self-protected combination starter <i>PKZM0...+BK25...-E</i> (Type E-Starter) with motor overload and motor branch short circuit protective functions. 								
Market terminology: Motor Starter									
Generally speaking, a „Motor Starter“ refers to the following concept in North America:	Individual or group of „Motor Controller“ components which additionally feature a protective function.								
Significance:	The industry in North America refers to this term much more commonly when denoting motor controllers with protective functions.								
Some examples within the Eaton family of components and assemblies:	<ol style="list-style-type: none"> 1. Motor protective switches <i>PKZM</i> and <i>PKZ</i> (manual motor starters) 2. Magnetic motor starter combination <i>DIL / Z</i>, (Non-combination motor starter) 3. Combination magnetic motor starter combination <i>NZM / DIL / Z</i>, (Combination motor starter) 								
Further differentiation within Motor Starter groupings									
without Contactor	with Contactor								
	<table border="1"> <thead> <tr> <th>Non-combination motor starter</th> <th>Combination motor starter¹⁾ or Combination motor controller²⁾</th> </tr> </thead> <tbody> <tr> <td></td> <td> ¹⁾+ ²⁾ identical terms: ¹⁾ Industry terminology, ²⁾ UL 508 terminology </td> </tr> <tr> <td> <ul style="list-style-type: none"> • No isolation function (main disconnect), • No short circuit protection Both these functions need to be separately provided. </td> <td> fulfills all 4 motor branch circuit functions per <i>NEC</i> Figure 430-1: <ul style="list-style-type: none"> • Isolation (main disconnect), • Motor switching (controller), • Short circuit protection, • Overload protection </td> </tr> <tr> <td>Examples within the Eaton family of components and assemblies:</td> <td> <i>MSC...-...-M...-SP</i> <i>PKZM0...+BK25/3-PKZ0-E³⁾</i> + <i>DILM</i> (UL 508 Type F- Combination motor controller) ³⁾ Manual Self-protected Combination Controller </td> </tr> </tbody> </table>	Non-combination motor starter	Combination motor starter¹⁾ or Combination motor controller²⁾		¹⁾ + ²⁾ identical terms: ¹⁾ Industry terminology, ²⁾ UL 508 terminology	<ul style="list-style-type: none"> • No isolation function (main disconnect), • No short circuit protection Both these functions need to be separately provided.	fulfills all 4 motor branch circuit functions per <i>NEC</i> Figure 430-1: <ul style="list-style-type: none"> • Isolation (main disconnect), • Motor switching (controller), • Short circuit protection, • Overload protection 	Examples within the Eaton family of components and assemblies:	<i>MSC...-...-M...-SP</i> <i>PKZM0...+BK25/3-PKZ0-E³⁾</i> + <i>DILM</i> (UL 508 Type F- Combination motor controller) ³⁾ Manual Self-protected Combination Controller
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	¹⁾ + ²⁾ identical terms: ¹⁾ Industry terminology, ²⁾ UL 508 terminology								
<ul style="list-style-type: none"> • No isolation function (main disconnect), • No short circuit protection Both these functions need to be separately provided.	fulfills all 4 motor branch circuit functions per <i>NEC</i> Figure 430-1: <ul style="list-style-type: none"> • Isolation (main disconnect), • Motor switching (controller), • Short circuit protection, • Overload protection 								
Examples within the Eaton family of components and assemblies:	<i>MSC...-...-M...-SP</i> <i>PKZM0...+BK25/3-PKZ0-E³⁾</i> + <i>DILM</i> (UL 508 Type F- Combination motor controller) ³⁾ Manual Self-protected Combination Controller								

Table 9: Clarifications on commonly used terms „Motor Controller“, „Motor Starter“, „Combination Motor Controller“, „Combination Motor Starter“ and „Non-Combination Motor Starter“

	North America		IEC-World		
Remotely (magnetically) operated	<i>P2.../F...-CNA</i> + Class H, R or J Fuses + <i>DILM</i> + <i>Z</i>	„Combination Motor Starter“ • Fusible Type • Self-Protected Type • Inverse Time Circuit Breaker Type • Instantaneous Trip Circuit Breaker Type • Fusible Type	• Fuse + Contactor + Overload relay	Motorstarter	Fuse based motor starters
	<i>MSC...-M...-SP</i>		• Motor protective switch + Contactor		Fuseless motor starters
	<i>NZM...-A(E)..-NA,</i> <i>NZM...-VE...-NA</i> + <i>DILM</i>		• Circuit Breaker + Contactor		
	<i>NZM...-A(E)F...-NA,</i> <i>NZM...-VEF...-NA</i> + <i>DILM</i> + <i>Z</i>		• Circuit Breaker + Contactor + Overload relay		
	not allowed, respectively consider additional conditions		• Motor protective switch (without overload function) + Contactor + Overload relay		
	<i>NZM...-S(E)..-CNA</i> + <i>DILM</i> + <i>Z</i>		• Circuit Breaker (without overload function) + Contactor + Overload relay		
	≤ 2 HP und 300 V: <i>P1</i> + Class CC or J Fuse + <i>DILM</i> + <i>Z</i>		• Fuse + Cam switch + Contactor + Overload relay		Fuse based motor starters
Manually operated	<i>PKZM0</i> <i>PKE</i> not allowed, respectively consider additional conditions	„manual motor controller“	• Motor protective switch	Fuseless motor starters	
			Legend: <div style="display: flex; align-items: center; margin-bottom: 5px;"> <div style="width: 20px; height: 10px; background-color: #d9ead3; border: 1px solid #ccc; margin-right: 5px;"></div> = commonly used </div> <div style="display: flex; align-items: center;"> <div style="width: 20px; height: 10px; background-color: #fff2cc; border: 1px solid #ccc; margin-right: 5px;"></div> = less conventional </div>		

Table 10: Differences between typical North American and IEC motor starter assemblies.

better degree of internal self-protection and not be mechanically linked in any way to the external tripping function. These breakers are rated in continuous nominal amperes. They can also be equipped with auxiliary contacts (pilot duty rated) for control circuit switching purposes. *UL/CSA* certification does not allow for individual short circuit interrupting ratings to be marked on these breakers. Any short circuit rating would be applicable to the entire motor starter assembly into which they are contained (refer to next section). That's the main reason why instantaneous-trip circuit breakers are recognized only per *UL* standards, and subject to "Conditions of Acceptability" (CoAs). These types of circuit breakers are always combined with a magnetic contactor and overload relay to form a „Combination Motor Starter“.

In these 3 component type combination starters, the contactor provides across-the-line motor switching duties, the overload relay

fulfills the motor overload protective function and the circuit breaker provides short circuit protection. This array makes it possible, with the use of overload relay and circuit breaker auxiliary contacts, to differentiate between overload and short circuit tripping indications, an aspect which is also considered advantageous in the *IEC* world. In addition, they are considered useful in applications involving long duration motor starting sequences which could otherwise cause an inverse time circuit breaker to possibly nuisance trip during start.

These starters are primarily installed in North America as Motor Control Centers (*MCC*) units or as industrial control panel assemblies. They are also often separately mounted in individual enclosures. They can be installed in circuits up to their maximum short circuit rating. The determining factor in the short circuit rating is always based on the weakest component within the motor starter and must always verified

through testing. Per the *NEC*, all combination motor starters featuring instantaneous trip circuit breakers must be *listed*.(e.g. *UL*)

- NZM...-A(V)(E)(F)...-NA Inverse Time Circuit Breakers

These are the typical circuit breakers found in energy distribution assemblies throughout North America and also featured prominently in motor control centers and industrial control panels. They are rated in amperes and are clearly marked with short circuit interrupting capacities, usually shown in kA. They can also be equipped with auxiliary contacts that generally feature pilot duty control circuit load ratings.

These breakers feature an adjustable magnetic or electronic instantaneous response trip for short circuit protection and either a fixed (Type suffix *-A(E)F*) or adjustable bimetal- or electronic, (Type suffix *-(A(E))*) long time response setting overload range for the

Constructive solutions for „Combination Motor Controllers“ per the UL 508 standard				
Configuration	Part IX	Part IV	Part VII	Part III
Construction Type	Main Disconnect	Branch Circuit Short Circuit Protection	Motor Controller	Motor Overload
A	Listed component certified to <i>UL 98 / 489</i> Molded Case Switch e.g.: <i>NS1...-NA</i>	Listed branch circuit fuses certified to <i>UL 248</i> series <i>Class J or RK5</i>	Listed component certified to <i>UL 508</i> Ex: + <i>DIL M</i>	Listed component certified to <i>UL 508</i> Ex: + <i>Z</i> , + <i>PKZM 0</i>
B	This particular constructive design is no longer available in the market place.			
C	Inverse Time Breaker <i>UL 489</i> e.g. <i>NZM...-A(E)..-NA</i> , <i>NZM...-VE...-NA</i> Or: <i>NZM...-ME...-NA</i>		Listed component certified to <i>UL 508</i> e.g.: + <i>DILM</i>	Listed component certified to <i>UL 508</i> In this case: <i>NZM...-ME...-NA</i> • By virtue of additional calibration tests per <i>UL 508</i>
D	Instantaneous Trip Breaker <i>UL 489</i> Ex: <i>NZM...-S(E)..-CNA</i>		Listed component certified to <i>UL 508</i> Ex: + <i>DIL M</i>	Listed component certified to <i>UL 508</i> Ex: + <i>Z</i>
E	Self-Protected Combination Motor Controller Ex: <i>MSC...-...-M...-SP</i>			
F	Manual Self-Protected Combination Motor Controller, Manual Type-E-starter Ex: <i>PKZM0...+BK25...-E</i>		Listed component certified to <i>UL 508</i> Ex: + <i>DIL M</i>	

Table 11: Various solutions of „UL 508 - Combination Motor Starters“, alphabetically identified in the standard by construction types „A“ through „F“. Construction Types E and F are particularly interesting in view of this paper's focus on IEC style motor protective components. Note that Types „A“ through „E“ are also currently described in the analog *CSA-C22.2 No. 14-05* standard, whereas Type F starters are only found in the *UL* standard. Although not officially a part of Canadian based product standards, Type F starters find acceptance amongst Canadian based regulatory agencies and inspection authorities.

protection of cables and non-motor loads. They are also utilized as the main disconnect and short circuit protective device for motor branch circuits, usually in association with contactors and separately provided motor overload relays. Their auxiliary contacts are used to switch associated control circuitry. They can be installed in circuits with available faults up to their maximum short circuit interrupting ratings without the need for any additional upstream overcurrent protection and also fulfill all Code requirements as Main Disconnect switches in service entrance and/or feeder circuit applications. Circuit breakers Type *NZM...V(E)(F)...-NA* feature an additional, intentionally delayed short circuit trip element.

– Advantages of molded case circuit breakers over fuses in North American motor branch circuits

Assuming that proper component selection guidelines, as highlighted in previous sections, have been followed, the choice of fuseless based solutions using circuit breakers and suitably certified manual motor controllers can

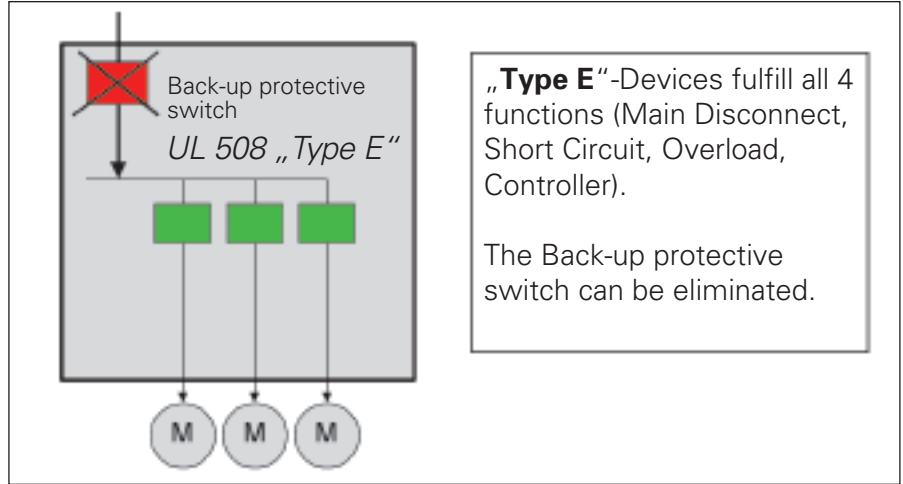


Figure 5: UL / CSA „Type E“-Controllers fulfill all 4 functions required in the motor branch circuit. There is no need for a back-up protective switch up to the controller's highest short circuit rating. „UL 508 Type E“- controllers are also referred to as Self-protected. For electronic motor-protective circuit-breakers PKE a contactor, as shown in Figures 6 and 9, is required already for Type E.

offer significant advantages over fuse based engineering:

- ▶ Only North American fuses are considered suitable for applications in North America. The use of IEC/EN type fuses is not accepted.

- ▶ Fuse bases for certain types of fuses, e.g. Class R, are relatively large, and take up a lot of panel room. Combining such fuses with contactors and overload relays does not usually lead to optimal utilization of available space.

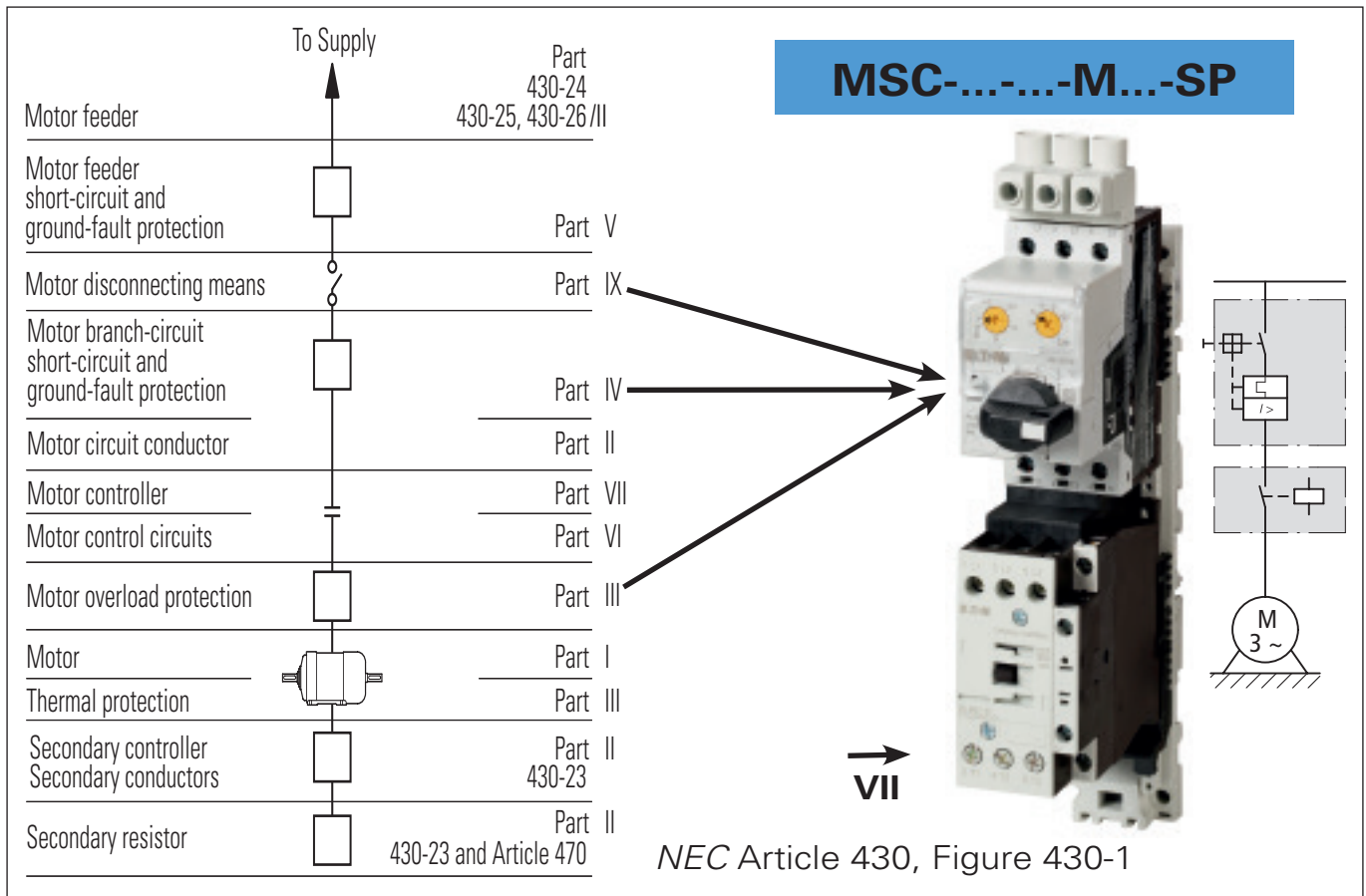


Figure 6: The above diagram shows that the essential requirements of the motor branch circuit outlined in NEC Diagram 430-1 are fulfilled by the constructive elements of the UL listed and CSA certified MSC-.....-M...-SP Self-protected Combination Motor Controller. Both The PKZ 2's disconnect(Part IX) and contactor (Part VII) modules each feature a set of current limiting contacts which provide the starter with its high capacity and high fault rating performance capability. The device can also be used world-wide.



Figure 7: Self-Protected Combination Starter, UL 508 Type E for motor-protective circuit-breakers PKE up to 32 A a contactor is always required.

- ▶ An NZM inverse time circuit breaker combines the functions of isolator, short circuit protection, overload protection and trip signalization all in one device, and is often smaller and more economical than a comparable fusible disconnect device.
- ▶ It's possible in certain cases to mix incompatible fuses and fuse bases. The use of additional markings indicating the correct type of fuses is necessary to avoid mishaps.
- ▶ Machine exporters often complain of long delivery times and high prices when sourcing North American fuse equipment in Europe.

• **Manually operated disconnect switches in motor circuits**

Type *T* rotary cam switches and Type *P1* and *P3* motor circuit disconnects are also products that are primarily applied in North American motor branch circuits. All of these components have been listed and

certified per the North American industrial control equipment *UL 508* und *CSA-C22.2 No. 14* product standards as HP rated manual motor controllers and have been additionally evaluated as fuse protected motor circuit disconnect switches per the requirements of the electrical codes. In most applications, this would mean installation on the load side of the final branch circuit overcurrent protective device (BCPD) which, in the case of fuses, would make it necessary for the upstream supply circuit disconnect to isolate the circuit in order to exchange blown fuses. Unlike in the IEC world, the *P* and *T* products are not suitable as feeder circuit main disconnect switches. They are, however, particularly well suited as individually enclosed lock-out/tag-out isolator switches local to the motor per the intent of NFPA 70E [12] since their location in this regard would place them on the load side of the motor branch circuit protective fuse. They all feature pilot duty rated auxiliary contacts as accessories which can be

PKZM0(4), UL 508 Type E „Manual self-protected combination motor controllers“											
Maximum Motor HP Rating 3 Phase, 60Hz				Trip settings		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 * [kA]	600Y/347V * [kA]	Motor Protector Type	Asseccories Type	
1)				0.1 - 0.16	2.5	65	65	50	PKZM0-0,16	BK25/3-PKZ0-E	
				0.16 - 0.25	3.9	65	65	50	PKZM0-0,25	BK25/3-PKZ0-E	
				0.25 - 0.4	6.2	65	65	50	PKZM0-0,4	BK25/3-PKZ0-E	
				0.4 - 0.63	9.8	65	65	50	PKZM0-0,63	BK25/3-PKZ0-E	
				0.63 - 1	16	65	65	50	PKZM0-1	BK25/3-PKZ0-E	
	¾	¾	1 - 1.6	25	65	65	50	PKZM0-1,6	BK25/3-PKZ0-E		
½	½	1	1 ½	1.6 - 2.5	39	65	65	50	PKZM0-2,5	BK25/3-PKZ0-E	
¾	¾	2	3	2.5 - 4	62	65	65	50	PKZM0-4	BK25/3-PKZ0-E	
1 ½	1 ½	3	5	4 - 6.3	98	65	65	50	PKZM0-6,3	BK25/3-PKZ0-E	
2	3	5	7 ½	6.3-11	155	65	65	50	PKZM0-10	BK25/3-PKZ0-E	
3	3	7 ½	10	9 - 12	186	65	65	18	PKZM0-12	BK25/3-PKZ0-E	
3	5	10	-	10 - 16	248	42	42	-	PKZM0-16	BK25/3-PKZ0-E	
5	-	-	-	16 - 20	310	18	18	-	PKZM0-20	BK25/3-PKZ0-E	
-	7 ½	15	-	20 - 25	388	18	18	-	PKZM0-25	BK25/3-PKZ0-E	
7 ½	10	20	-	24 - 32	496	18	18	-	PKZM0-32	BK25/3-PKZ0-E	
3	5	10	10	10 - 16	248	65	65	25	PKZM4-16	BK50/3-PKZ4-E	
5	7 ½	15	20	16 - 27	388	65	65	25	PKZM4-25	BK50/3-PKZ4-E	
7 ½	10	20	30	24 - 34	496	65	65	25	PKZM4-32	BK50/3-PKZ4-E	
10	-	30	30	32 - 40	620	65	65	25	PKZM4-40	BK50/3-PKZ4-E	
-	15	30	-	40 - 52	775	65	65	-	PKZM4-50	BK50/3-PKZ4-E	
-	-	40	-	50 - 56	899	65	65	-	PKZM4-58	BK50/3-PKZ4-E	
-	-	40	-	52 - 58	977	65	65	-	PKZM4-63	BK50/3-PKZ4-E	

1) In this range, select devices per motor full load current. Refer to NEC Table 430-250.
2) Solidly grounded power distribution system.

Table 12: UL 508 Type E “Manual self-protected combination motor controllers“

Type E Combination Motor Controller								
Maximum motor rating Three-phase current				Setting Ranges overload release	Rated short-circuit breaking capacity			Combination Motor Starter
200V HP	230V HP	460V HP	575V HP	A	240V kA	480Y/277V kA	600Y/347V kA	
		1/2	1/2	0,3-1,2	14	14	14	MSC-DE-1,2-M17-SP(...)
3/4	3/4	2	-	1-4	18	18	-	MSC-DE-4-M17-SP(...)
3	3	7 1/2	-	3-12	18	18	-	MSC-DE-12-M17-SP(...)
5	7 1/2	15	-	8-32	18	18	-	MSC-DE-32-M32-SP(...)

Table 13: MSC-DE-...-M...-SP, Type E Combination Motor Controller with PKE



Figure 8: A group of PKZM0 manual motor controllers is linked via a common link bus connector. The controllers are fed by a common BK25/3-PKZ0-E terminal block. The incoming terminal's large electrical clearances at the point of supply enable the entire assembly to meet self-protected "Construction Type E" requirements. The circuit breakers' thumb grips must be lockable.

used to switch associated control circuitry loads.

Motor Starters in accordance with North American specifications

Table 9 provides basic clarifications of the most commonly used terms and expressions used in association with various motor starter configurations. The concept of non-combination motor Starters was already introduced on page 12. Table 10 compares a wide range of the most popular, as well as lesser known, motor starter assemblies used throughout the IEC-world and North America.

• Combination Motor Starter

A motor starter of European origin, which includes all the necessary components to fulfill motor short circuit and overload protective functions, as well as motor switching duties (e.g. Circuit breaker + Contactor + Overload relay) is referred to in the US and Canada as a "Combination Motor Starter". Apart from Type E self-protected combination starters (explained in the upcoming section)

these starters are by definition considered to be individually enclosed assemblies in North America, which is again a departure from traditional European definitions. They can more or less be thought of as small engineered control panels which include all the necessary parts and pieces to complete a stand alone motor starter assembly. The selection of contactors and

overload relays follows the same process as referred to in Table 8.

Various constructive solutions for „Combination Motor Starters“

The functional composition of a North American motor starter was presented earlier in Figure 1. From an international viewpoint, however, the figure does not

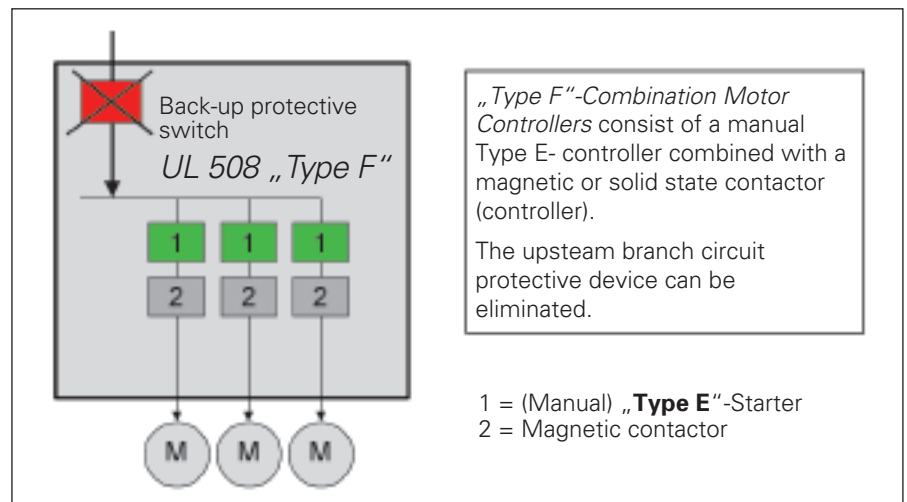


Figure 9: „Type F Combination Motor Starters“ fulfill all 4 functions of a combination motor starter per UL 508. The back-up protective switch can be eliminated.

readily highlight a fundamental difference in motor starter configuration, namely, that components fulfilling Parts IX „Main Disconnect“ und IV „Short circuit protection“ are often provided separately in the North American motor branch circuit (refer to **Figure 4**). In ensuing years, conventions changed and progress opened the door for more global and technologically diverse solutions to emerge and establish themselves.

Table 11 highlights the developments in motor starter construction in this respect. The various combination motor starter configurations currently available are alphabetically tagged as a function of their construction (Types A through F at this time per UL standards).

• **UL 508 Type E Self-protected Combination Motor Controller**

The introduction of “Construction Type E” in the product standards *UL 508* [8] and *CSA-C22.2 No. 14* [9] represented a significant step in the expansion of combination motor controller design in North America. The larger electrical clearances, which are specified in product standards such as *UL 489* [6] and *CSA-C22.2 No. 5-05* [7], are necessary on the incoming supply side field wiring terminals of these controllers since they also fulfill the main disconnect and short circuit protective functional requirements of the motor branch circuit into which they are installed (**Figure 5**). The Type

E controllers in the Eaton family of components all feature very high short circuit ratings (SCCR) which by design are both voltage and current dependent due to varying levels of impedance in the overall component assembly¹⁵. Currently available „Type E“- Self-protected combination controllers are certified for use in solidly grounded, 4 wire power distribution networks (e.g. 480Y/277 VAC Slash voltage rating).

The use of Type E Self-protected combination controllers provides numerous benefits:

Simplified engineering, no need to co-ordinate with a back-up overcurrent protective device (often

PKZM0(4), „UL 508 Type F Combination Motor Controllers“													
Maximum Motor HP Rating 3 Phase, 60Hz				Trip settings		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 ²⁾ [kA]	600Y/ 347V ²⁾ [kA]	Motor Protector Type	Supply Terminal Type	Contactor Type		
1)				-	0.1 - 0.16	2.5	50	50	50	PKZM0-0,16	BK25/3-PKZ0-E	DILEM	
				-	0.16 - 0.25	3.9	50	50	50	PKZM0-0,25	BK25/3-PKZ0-E	DILEM	
				-	0.25 - 0.4	6.2	50	50	50	PKZM0-0,4	BK25/3-PKZ0-E	DILEM	
				-	0.4 - 0.63	9.8	50	50	50	PKZM0-0,63	BK25/3-PKZ0-E	DILEM	
				-	0.63 - 1	16	50	50	50	PKZM0-1	BK25/3-PKZ0-E	DILEM	
				¾	¾	1 - 1.6	25	50	50	50	PKZM0-1,6	BK25/3-PKZ0-E	DILEM
½	½	1	1 ½	1.6 - 2.5	39	50	50	50	PKZM0-2,5	BK25/3-PKZ0-E	DILEM		
¾	¾	2	3	2.5 - 4	62	50	50	50	PKZM0-4	BK25/3-PKZ0-E	DILEM		
1	1 ½	3	5	4 - 6.3	98	50	50	50	PKZM0-6,3	BK25/3-PKZ0-E	DILEM		
2	3	5	7 ½	6.3 - 11	155	50	50	50	PKZM0-10	BK25/3-PKZ0-E	DILEM		
1)				-	0.1 - 0.16	2.5	65	65	18	PKZM0-0,16	BK25/3-PKZ0-E	DILM7	
				-	0.16 - 0.25	3.9	65	65	18	PKZM0-0,25	BK25/3-PKZ0-E	DILM7	
				-	0.25 - 0.4	6.2	65	65	18	PKZM0-0,4	BK25/3-PKZ0-E	DILM7	
				-	0.4 - 0.63	9.8	65	65	18	PKZM0-0,63	BK25/3-PKZ0-E	DILM7	
				-	0.63 - 1	16	65	65	18	PKZM0-1	BK25/3-PKZ0-E	DILM7	
				¾	¾	1 - 1.6	25	65	65	18	PKZM0-1,6	BK25/3-PKZ0-E	DILM7
½	½	1	1 ½	1.6 - 2.5	39	65	65	18	PKZM0-2,5	BK25/3-PKZ0-E	DILM7		
¾	¾	2	3	2.5 - 4	62	65	65	18	PKZM0-4	BK25/3-PKZ0-E	DILM7		
1	1 ½	3	5	4 - 6.3	98	65	65	18	PKZM0-6,3	BK25/3-PKZ0-E	DILM7		
2	3	5	7 ½	6.3-11	155	65	65	18	PKZM0-10	BK25/3-PKZ0-E	DILM12		
3	3	7 ½	10	9 - 12	186	50	50	18	PKZM0-12	BK25/3-PKZ0-E	DILM12		
3	5	10	-	10 - 16	248	18	18	-	PKZM0-16	BK25/3-PKZ0-E	DILM17		
5	-	-	-	16 - 20	310	18	18	-	PKZM0-20	BK25/3-PKZ0-E	DILM25		
-	7 ½	15	-	20 - 25	388	18	18	-	PKZM0-25	BK25/3-PKZ0-E	DILM25		
7 ½	10	20	-	24 - 32	496	18	18	-	PKZM0-32	BK25/3-PKZ0-E	DILM32		
3	5	10	10	10 - 16	248	65	65	50	PKZM4-16	BK50/3-PKZ4-E	DILM32		
5	7 ½	15	20	16 - 27	388	65	65	50	PKZM4-25	BK50/3-PKZ4-E	DILM32		
7 ½	10	20	30	24 - 34	496	65	65	50	PKZM4-32	BK50/3-PKZ4-E	DILM32		
10	-	30	30	32 - 40	620	65	65	50	PKZM4-40	BK50/3-PKZ4-E	DILM40		
-	15	30	-	40 - 52	775	65	65	-	PKZM4-50	BK50/3-PKZ4-E	DILM50		
-	-	40	-	50 - 56	899	65	65	-	PKZM4-58	BK50/3-PKZ4-E	DILM65		
-	-	40	-	52 - 58	977	65	65	-	PKZM4-63	BK50/3-PKZ4-E	DILM65		

1) In this range, select motor protector per motor full load current. Refer to NEC Table 430-250.
2) Suitable for solidly grounded power distribution systems.

Table 14: Motor-protective circuit-breaker – UL 508 Typ F Combination Starters

unknown) due to its stand-alone rating.

The amount of necessary layout space is greatly reduced.

No assembly and wiring required between individually mounted starter components.

Lower component costs

Lower panel wiring and assembly charges

A design more in line with current control panel technology used throughout the IEC-world.

• **Self-Protected Combination Starter MSC-...-M...-SP**

The MSC-...-M...-SP Self-Protected Combination Starter (**Figure 6**) fulfills all requirements for Type E controllers. This compact combination starter consists of a thermal-magnetic manual motor protective switch *PKE* combined with a contactor. The *PKE* manual motor protective portion features the large electrical clearances on its incoming supply side field wiring terminals in accordance with *UL 489*. The high capacity magnetic contactor features a set of current limiting power contacts and a customized internal magnetic trip to provide the Type E starter's high level short circuit rating and fault clearing capability.

The self-protected starter's main design features include:

A plug-in, adjustable thermal-magnetic trip module in line with North American motor full load current ratings, and a high capacity, high fault current limiting contactor for motor switching purposes that is contoured to mould fit directly into the protective switch portion.

All system component modules, e.g. auxiliary contacts, voltage trips and remote control drive are *UL* listed and *CSA* certified accessories which can be field installed (**Figure 7**).

• **PKZM0-...+BK25/3-PKZ0-E Manual Type E Self-Protected Combination Controller**

Even the smaller sized *PKZM0* manual motor controller, when equipped with the *BK25/3-PKZ0-E* incoming supply terminal, fulfills the stringent „*Type E*“-requirements to provide stand-alone

branch circuit protective functionality without the need of additional back-up protection. This version covers motor full load currents up to 28A. (Order number for the *BK25/3-PKZ0-E* terminal:262518). The Type E *PKZM4* controller with terminal *BK50/3-PKZ4-E* provides the same starter configuration in a larger size and covers motor full load currents up to 52A. At the time of this writing the certification process for the new electronic *PKE* controller had been initiated.

The requirements in North America for this style of controller are not always regionally identical:

– **For applications in the US**

The large electrical clearances are required on the device's incoming supply side field wiring terminals. When the controller is mounted „open“ (i.e. on a mounting plate in a control panel equipped with an upstream padlockable main disconnect switch) each individual device is not required to be padlockable.

On the other hand, if the self-protected controller is individually enclosed (e.g. in a Motor Control Center unit or in a separate *CI...K-NA* insulating material enclosure) a *padlocking feature* is required. That's because, as an individually enclosed combination motor starter, the Type E controller assumes the main disconnect and isolator functions for the branch circuit, and must thus be padlockable in the OFF position.

– **For applications in Canada**

The *PKZM0-...*, *PKE-...* or the *PKZM4*, as Type E manual self-protected combination controllers per CLASS 3211-08, must always *be equipped with the padlockable knob AK-PKZ0(4)* for applications in Canada. The larger clearances on the switch's supply side terminals, a requirement in the US, are (as of this writing) not necessary in Canada, however, they are certainly acceptable when provided. In Canada, therefore, the *PKZM0-...*, *PKE* or *PKZM4* manual Type E controllers can be applied with or without the larger clearances as stand-alone branch circuit protective controllers without the need for any back-up protection, as long as they are equipped with the padlockable knob accessory.

By using specialized wiring accessories, primarily the combination

of a 3 phase bus connector and the large spacing *BK25/3-PKZ0-E* incoming supply terminal (**Figure 8**), it's possible to create an array or grouping of open mounted Type E controllers for application in industrial control panels. The larger electrical clearances in this case are required only on the incoming terminal *BK25...-E*, since this is the point at which the controller grouping receives its supply from the feeder portion of the circuit. A wide selection of certified Type E and Type F controllers can be configured in this fashion to suit a broad range of industrial control panel applications. This use of modern wiring techniques is very much in line with current *IEC* control panel design and engineering methods which cater to a more ergonomic and efficient use of space in engineered assemblies. The need for the larger clearance terminal block does represent a more stringent requirement for starters mounted in this particular configuration, but is really the only issue that differentiates the assembly from a true IEC design. The larger spacing terminal block, moreover, can be used world-wide without any restriction, and both the terminal and the commoning bus links from Eaton are fully *UL* and *CSA* certified.

• **UL 508 Type F Combination Starter**

The *UL 508* standard established a „*Type F Combination Motor Controller*“ as its most recent category of combination motor controller constructions: A Type F combination controller consists of a manual self-protected „*Type E*“ combination motor controller (e.g. a *PKZM0-...* with the large clearance terminal block Type *BK25...-E*) combined with a magnetic or solid state contactor (controller). As shown in **Figure 9** „*Type F Combination Motor controllers*“ do not require additional back-up overcurrent protective devices in the motor branch circuit up to the controller's highest short circuit rating. All combinations must be *UL* and *CSA* certified. (**Table 14**) (**Figure 10**). As is the case with Type E controllers, currently certified Type F controllers are suitable only for applications in solidly grounded power distribution networks at their highest voltage rating (e.g. 480Y/277 V). Please note that „*Type F*“-combination controllers are not yet recognized by Canadian standards and are only part of US based product standards at this time. However, the combinations are generally accepted by all *CSA* and



Figure 10: Example of a UL 508 Type F combination motor controller array, each consisting of a manual Type E self-protected controller and associated magnetic contactor.

provincial based inspection authorities throughout Canada.

The capability of a manufacturer or independent panel builder to combine *UL* and *CSA* products and self-certify the resulting starter or assembly, as is done in the *IEC* world per *IEC* regulations, does not exist as such in North America. It is possible, however, to have a *UL* listed or *CSA* certified panel shop or manufacturing location which is able to label or certify assemblies that are covered by a procedure or file. In the case of *UL 508A* industrial control panels, it is also possible for listed panel builders to independently access combination motor starter offerings by multiple manufacturers from *UL*'s database of short circuit rated controllers in order to design their own *UL 508A* assemblies. It is strongly recommended, therefore, that manufacturing locations and/or panel builders work closely with the component manufacturer for the latest certification updates and component rating information, since there are always ongoing design improvements being developed which could represent significant technological and economical advantages to their business needs and application requirements.

It is generally accepted that the equipment certification process is both necessary and vital for the industry, but it can also be a timely and cost intensive undertaking which can often unduly delay the introduction of new products and technology into the market place. This not only puts the

component manufacturer at a disadvantage but can also be detrimental to the end-user, since the introduction of certain technological innovations could translate into significant improvements and benefits for their own business endeavors. Because of the very high export quota of European based industrial machinery it is also neither practical nor feasible for a manufacturer to develop and introduce new products and technologies that are not yet certifiable to North American standards, even when a significant portion of this equipment is destined for the domestic EU market and would remain in Europe. The equipment certification process also effectively rules out customized assembly designs that

would combine products from various manufacturers. Mixed combinations are also not common in the *IEC* world because manufacturers are best able to verify the electrical coordination and performance of components of their own make, particularly with respect to short circuit testing and determination of proper overcurrent coordination performance levels. Product „*Declarations of Conformity*“ provided by manufacturers for their equipment must, by definition, be current because they essentially serve as the user's verification that a particular product or assembly reflects the actual ongoing production quality levels which is in place at the time the „*Declaration of Conformity*“ is being issued. Practically speaking, mixing and matching components of different makes to produce starters and assemblies would make it difficult to keep up with ongoing design changes in manufacturer products, which could be significant in view of the consequences it may have on short circuit coordination values and component performance levels.

Tap Conductor Protector

The „*Tap Conductor Protector*“ can sometimes be an adequate alternative to the use of stand-alone manual Type E controllers. The controller in that particular configuration does not require the large distribution clearances on its incoming supply terminals which is required for Type E starters. A „base model“ *PKZM0* manual motor controller can be used for the purpose, but only because it has been

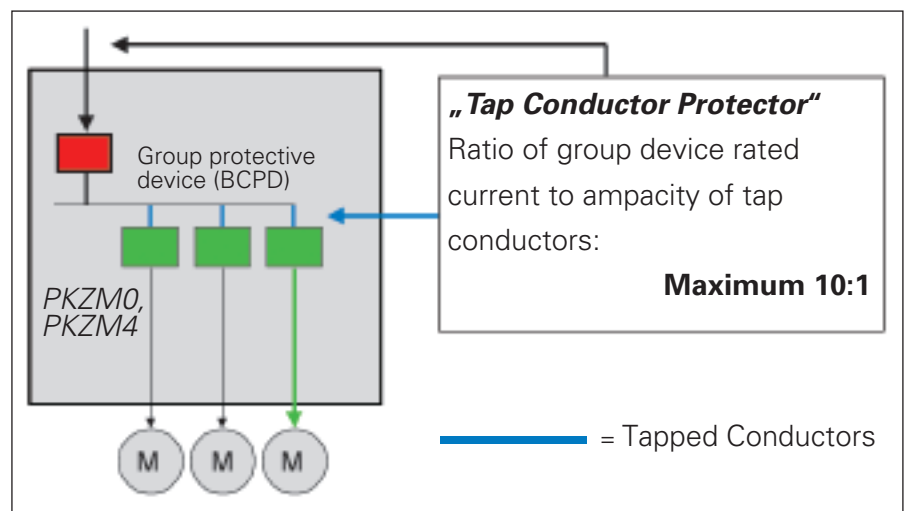


Figure 11: Maximum ratio between the rated current of the Back-up protective switch and the ampacity of the outgoing motor circuit conductors when using "Tap Conductor Protectors".

additionally certified by UL for this application, and carries the necessary markings. Both the *PKZM0* and *PKZM4* controllers have been successfully certified by UL in this regard and are listed as "tap conductor protectors suitable for group installations" per NEC requirements in motor full load current ranges of 28 A and 52A resp. @ 480Y/277VAC and 16A and 40A resp. @ 600Y/347VAC.

Tap Conductor Protectors provide overload and short circuit protection for outgoing motor circuit conductors, as well as overload protection for the motor. The drawback is, however, that the use of a tap conductor protector does not eliminate the need for a back-up (and group) branch circuit overcurrent protective device as shown in **Figure 1**.

The use of Tap Conductor Protectors means that, as shown in **Figure 11** and as per NEC requirements, the ratio between the rating of the branch circuit protective device and the ampacity of the tapped conductors cannot exceed 10:1. Example:

- The ampacity of an AWG 14-conductor is 15A,
- The maximum rating of the group branch circuit protective device is 150A and could be accommodated by a NZM..2-AF150-NA UL listed and CSA certified molded case circuit breaker.

Summary of Figure 12 (next page)

On the next page there is a graphical representation of the major starter concepts presented in this paper and dwells in particular on the significant aspects of Construction Types E, F and the Tap Conductor Protector. To use the chart effectively it's important to first determine whether a particular controller configuration requires a back-up overcurrent protective device in the circuit, or if, more in line with IEC practices, the controller design eliminates the need for an additional branch circuit protective in the motor branch circuit.

Validity:

This paper reflects the standards and product certification status in effect as of August 2012.

References:

- [1] *IEC / EN 60947-4-1* und *DIN VDE 0660-102* „Niederspannungsschaltgeraete - Teil 4-1: Schuetze und Motorstarter - Elektromechanische Schuetze und Motorstarter“ (IEC 60947-4-1:2000 + Corrigendum:2001 + A1:2002 + A2:2005); Deutsche Fassung EN 60947-4-1:2001 + A1:2002 + A2:2005
- [2] *UL 60 947-4-1A* „Low-Voltage Switchgear and Controlgear - Part 4-1: Contactors and motor-starters - Electromechanical contactors and motor-starters
- [3] *CSA-C22.2 NO. 60947-4-1-07*, „Low-Voltage Switchgear and Controlgear - Part 4-1: Contactors and Motor-Starters - Electromechanical Contactors and Motor-Starters“
- [4] *UL 60 947-1*, „Low-Voltage Switchgear and Controlgear - Part 1: General rules, third edition (Edition date: 2007-01-26) “
- [5] *IEC / EN 60 204-1* und *EN 60204-1*, „Sicherheit von Maschinen - Elektrische Ausrüstung von Maschinen - Teil 1: Allgemeine Anforderungen“ (IEC 60204-1:2005, modifiziert); Deutsche Fassung EN 60204-1:2006
- [6] *UL 489*, „Molded Case Circuit Breakers, Molded Case Switches and Circuit Breaker Enclosures“
- [7] *CSA-C22.2 No. 5-09*, „ Moulded Case Circuit Breakers“
- [8] *UL 508*, „Industrial Control Equipment“
- [9] *CSA-C22.2 No. 14-05*, "Industrial Control Equipment, Industrial Products“
- [10] *IEC / EN 60 947-1*, „Niederspannungsschaltgeraete Teil 1: Allgemeine Festlegungen“ (IEC 60947-1:2007); Deutsche Fassung EN 60947-1:2007“
- [11] *IEC / EN 60 947-2*, „Niederspannungsschaltgeraete - Teil 2: Leistungsschalter“ (IEC 60947-2:2006); Deutsche Fassung EN 60947-2:2006
- [12] NFPA 70E, „Standard for Electrical Safety in the Workplace, 2009 Edition“ National Fire Protection Association, Quincy, MA, 02169, www.nfpa.org

Please take note of additional technical papers accessible at the following internet link: www.eaton.eu/publications, These papers are also available in print form and can be requested in either German or English versions.

North American Motor Starters in accordance with *UL 508 and CSA C 22.2 No. 14*
Solution Processing Chart, Search criteria: Favoring fuseless installations and, wherever possible, in line with IEC design solutions.

Main Disconnect and Branch Circuit protective devices per *UL 489* and *CSA C 22.2 No. 5-02* are in the supply circuit or intended to be provided

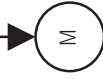
Tap Conductor Protector
 per *UL 508 USA only*

- for motor controller switching functions
- for motor overload and circuit conductor protection

Use of certified components
 per *UL 508 and CSA C22.2 No. 14*

- For motor controller switching functions
- for overload protection

Not the main focus of this paper. Shown for completeness purposes only.



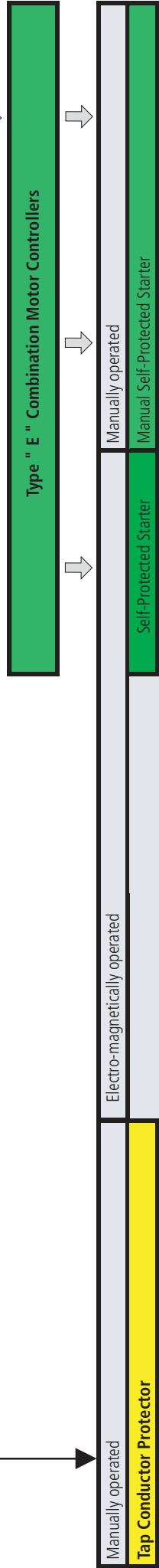
Main Disconnect and Branch Circuit protective devices per *UL 489* and *CSA C 22.2 No. 5-02* are not in the supply circuit and not known or otherwise separately provided

Combination Motor Starter
 per *UL 508 and CSA C22.2 No. 14*
 Fulfill all 4 main functions in a North American motor branch circuit:

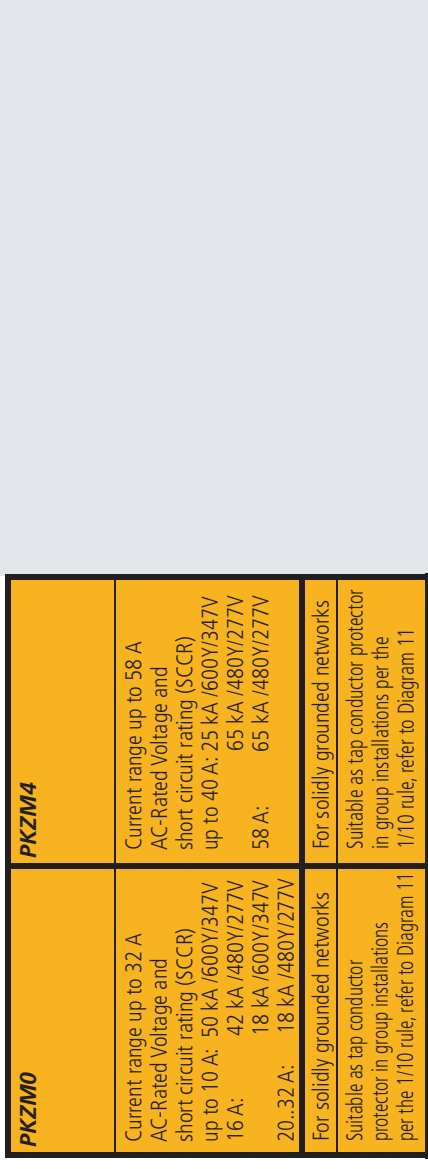
- Main Disconnect
- Short Circuit Protection
- Controller
- Overload Protection

Protection with fuses	Fuseless protection (short circuit ratings may vary)
Construction Type "A" Refer to Table 11 for examples of Eaton offerings in this category.	Construction Type "B" No Eaton offering
Construction Type "C" Refer to Table 11 for examples of Eaton offerings in this category.	Construction Type "D" Refer to Table 11 for examples of Eaton offerings in this category.
Construction Type "E" Characteristics: - High short circuit rating - Large electrical clearances on the component incoming supply side per <i>UL 508 and CSA C22.2 No. 14</i>	

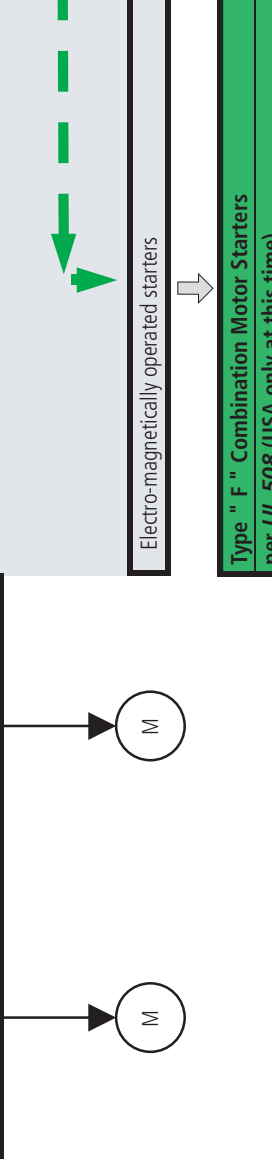
The above construction types are not the main focus of this technical paper and are shown here for completeness purposes only.



PKZM0 + Supply terminal BK25...-E optional: Commoning link	PKZM4 + Supply terminal BK50...-E optional: Commoning link
Current range up to 32 A AC-Rated Voltage and short circuit rating (SCCR) up to 10 A: 50 kA /600Y/347V 16 A: 42 kA /480Y/277V 20..32 A: 18 kA /480Y/277V	Current range up to 58 A AC-Rated Voltage and short circuit rating (SCCR) up to 40 A: 25 kA /600Y/347V 65 kA /480Y/277V 58 A:
For solidly grounded wye type 4 wire power distribution systems If ratings are insufficient are otherwise unsuitable: Refer to Table 5 for group installation ratings. Conductor protection subject to the 1/3 rule per Diagram 3	



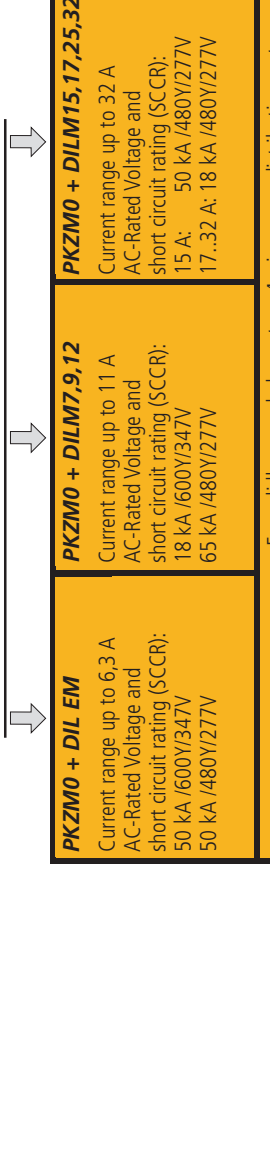
PKZM0 + Supply terminal BK25...-E optional: Commoning link	PKZM4 + Supply terminal BK50...-E optional: Commoning link
Current range up to 32 A AC-Rated Voltage and short circuit rating (SCCR) up to 1,2A: 600Y/347V > 1,2A: 480Y/277V Short circuit current rating: 18kA /480Y/277V 14kA /600Y/347V	Current range up to 27A AC-Rated Voltage and short circuit rating (SCCR) up to 10A: 50 kA /600Y/347V 16A: 42 kA /480Y/277V 20..32A: 18 kA /480Y/277V
For solidly grounded wye type 4 wire power distribution systems If ratings are insufficient are otherwise unsuitable: Refer to Table 5 for group installation ratings. Conductor protection subject to the 1/3 rule per Diagram 3	



PKZM0 + Commoning link + Supply terminal BK25...-E + Contactor	PKZM4 + Commoning link + Supply terminal BK50...-E + Contactor
Current range up to 11 A AC-Rated Voltage and short circuit rating (SCCR): 18 kA /600Y/347V 65 kA /480Y/277V	Current range up to 32 A AC-Rated Voltage and short circuit rating (SCCR): 15 A: 50 kA /480Y/277V 17..32 A: 18 kA /480Y/277V
For solidly grounded wye type 4 wire power distribution systems If ratings are insufficient are otherwise unsuitable: Refer to Table 5 for group installation ratings. Conductor protection subject to the 1/3 rule per Diagram 3	



PKZM0 + DIL EM Current range up to 6,3 A AC-Rated Voltage and short circuit rating (SCCR): 50 kA /600Y/347V 50 kA /480Y/277V	PKZM0 + DILM7,9,12 Current range up to 11 A AC-Rated Voltage and short circuit rating (SCCR): 18 kA /600Y/347V 65 kA /480Y/277V	PKZM4 + DILM32-65 Current range up to 58 A AC-Rated Voltage and short circuit rating (SCCR): 65 kA /480Y/277V bis 40 A: 50 kA /600Y/347V
For solidly grounded wye type 4 wire power distribution systems If ratings are insufficient are otherwise unsuitable: Refer to Table 5 for group installation ratings. Conductor protection subject to the 1/3 rule per Diagram 3		



Note:
This table does not yet include motor-protective circuit-breaker PKE and starter variants with the PKE. A separate publication will be issued on completion of the approvals.

Useful Tables

Table 430-248. Full-Load Currents in Amperes Single-Phase Alternating-Current Motors

The following values of full-load currents are for motors running at usual speeds and motors with normal torque characteristics. Motors built for especially low speeds or high torques may have higher full-load currents, and multispeed motors will have full-load current varying with speed, in which case the nameplate current ratings shall be used.

The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120 and 220 to 240 volts.

HP	115 Volts	200 Volts	208 Volts	230 Volts
1/6	4.4	2.5	2.4	2.2
1/4	5.8	3.3	3.2	2.9
1/3	7.2	4.1	4.0	3.6
1/2	9.8	5.6	5.4	4.9
3/4	13.8	7.9	7.6	6.9
1	16	9.2	8.8	8
1 1/2	20	11.5	11	10
2	24	13.8	13.2	12
3	34	19.6	18.7	17
5	56	32.2	30.8	28
7 1/2	80	46	44	40
10	100	57.5	55	50

Table 310-16. Allowable Ampacities of Insulated Conductors Rated 0 through 2000 Volts, 60° to 90°C (140° to 194°F) Not More Than Three Current-Carrying Conductors in Raceway or Cable or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

Size	Temperature Rating of Conductor. See Table 310-13						Size
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
AWG kcmil	Types TW ¹ , UF ¹	Types FEPW ¹ , RH ¹ , RHW ¹ , THHW ¹ , THW ¹ , THWN ¹ , XHHW ¹ , USE ¹ , ZW ¹	Types TBS, SA SIS, FEP ¹ , FEPB ¹ , MI RHH ¹ , RHW-2, THHN ¹ , THHW ¹ , THWN-2 ¹ , USE-2, XHH, XHHW ¹ , XHHW-2, ZW-2	Types TW ¹ , UF ¹	Types RH ¹ , RHW ¹ , THHW ¹ , THW ¹ , THWN ¹ , XHHW ¹ , USE ¹	Types TBS, SA, SIS, THHN ¹ , THHW ¹ , THWN ¹ , THWN-2 ¹ , RHH ¹ , RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	AWG kcmil
	Copper			Aluminum or Copper-Clad Aluminum			
18	....	....	14	....	....	....	....
16	....	....	18	....	....	....	....
14	20 ¹	20 ¹	25 ¹	....	....	....	....
12	25 ¹	25 ¹	30 ¹	20 ¹	20 ¹	25 ¹	12
10	30	35 ¹	40 ¹	25	30 ¹	35 ¹	10
8	40	50	55	30	40	45	8
6	55	65	75	40	50	60	6
4	70	85	95	55	65	70	4
3	85	100	110	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	150	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	190	230	255	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	355	420	475	285	340	385	600
700	385	460	520	310	375	420	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	450	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	520	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	560	665	750	470	560	630	2000

CORRECTION FACTORS

Ambient Temp°C	For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities shown above by the appropriate factor shown below.						Ambient Temp°F
21-25	1.08	1.05	1.04	1.08	1.05	1.04	70-77
26-30	1.00	1.00	1.00	1.00	1.00	1.00	78-86
31-35	.91	.94	.96	.91	.94	.96	87-95
36-40	.82	.88	.91	.82	.88	.91	96-104
41-45	.71	.82	.87	.71	.82	.87	105-113
46-50	.58	.75	.82	.58	.75	.82	114-122
51-55	.41	.67	.76	.41	.67	.76	123-131
56-60	....	.58	.71	....	.58	.71	132-140
61-70	....	.33	.58	....	.33	.58	141-158
71-80	....	....	.41	....	....	.41	159-176

¹Unless otherwise specifically permitted elsewhere in this code, the overcurrent protection for conductor types marked with an obelisk (¹) shall not exceed 15 amperes for No. 14, 20 amperes for No. 12, and 30 amperes for No. 10 copper; or 15 amperes for No. 12 and 25 amperes for No. 10 aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

Table 430-250. Full-Load Current Three-Phase Alternating-Current Motors

The following values of full-load currents are typical for motors running at speeds usual for belted motors and motors with normal torque characteristics.

Motors built for low speeds (1200 RPM or less) or high torques may require more running current, and multispeed motors will have full-load current varying with speed. In these cases the nameplate current ratings shall be used.

The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120, 220, 440 to 480, and 550 to 600 volts.

HP	Induction Type Squirrel-cage and Wound-Rotor						Synchronous Type Unity Power Factor [*] Amperes					
	115 Volts	200 Volts	208 Volts	230 Volts	460 Volts	575 Volts	2300 Volts	230 Volts	460 Volts	575 Volts	2300 Volts	
1/2	4.4	2.5	2.4	2.2	1.1	0.9	-	-	-	-	-	
3/4	6.4	3.7	3.5	3.2	1.6	1.3	-	-	-	-	-	
1	8.4	4.8	4.6	4.2	2.1	1.7	-	-	-	-	-	
1 1/2	12.0	6.9	6.6	6.0	3.0	2.4	-	-	-	-	-	
2	13.6	7.8	7.5	6.8	3.4	2.7	-	-	-	-	-	
3	-	11.0	10.6	9.6	4.8	3.9	-	-	-	-	-	
5	-	17.5	16.7	15.2	7.6	6.1	-	-	-	-	-	
7 1/2	-	25.3	24.2	22	11	9	-	-	-	-	-	
10	-	32.2	30.8	28	14	11	-	-	-	-	-	
15	-	48.3	46.2	42	21	17	-	-	-	-	-	
20	-	62.1	59.4	54	27	22	-	-	-	-	-	
25	-	78.2	74.8	68	34	27	-	53	26	21	-	
30	-	92	88	80	40	32	-	63	32	26	-	
40	-	120	114	104	52	41	-	83	41	33	-	
50	-	150	143	130	65	52	-	104	52	42	-	
60	-	177	169	154	77	62	16	123	61	49	12	
75	-	221	211	192	96	77	20	155	78	62	15	
100	-	285	273	248	124	99	26	202	101	81	20	
125	-	359	343	312	156	125	31	253	126	101	25	
150	-	414	396	360	180	144	37	302	151	121	30	
200	-	552	528	480	240	192	49	400	201	161	40	
250	-	-	-	-	302	242	60	-	-	-	-	
300	-	-	-	-	361	289	72	-	-	-	-	
350	-	-	-	-	414	336	83	-	-	-	-	
400	-	-	-	-	477	382	95	-	-	-	-	
450	-	-	-	-	515	412	103	-	-	-	-	
500	-	-	-	-	590	472	118	-	-	-	-	

^{*}For 90 and 80 percent power factor, the above figures shall be multiplied by 1.1 and 1.25 respectively.

Table 110.20. Motor Controller Enclosure Selection Table

Provides a Degree of Protection Against the Following Environmental Conditions	For Outdoor Use Enclosure Type Number ¹						
	3	3R	3S	4	4X	6	6P
Incidental contact with the enclosed equipment	X	X	X	X	X	X	X
Rain, snow and sleet	X	X	X	X	X	X	X
Sleet*	-	-	X	-	-	-	-
Windblown dust	X	-	X	X	X	X	X
Hosedown	-	-	-	X	X	X	X
Corrosive agents	-	-	-	-	-	X	X
Occasional temporary submersion	-	-	-	-	-	X	X
Occasional prolonged submersion	-	-	-	-	-	-	X

^{*}Mechanism shall be operable when ice covered

Provides a Degree of Protection Against the Following Environmental Conditions	For Indoor Use Enclosure Type Number ¹									
	1	2	4	4X	5	6	6P	12	12K	13
Incidental contact with the enclosed equipment	X	X	X	X	X	X	X	X	X	X
Falling dirt	X	X	X	X	X	X	X	X	X	X
Falling liquids and light splashing	-	X	X	X	X	X	X	X	X	X
Circulating dust, lint, fibers, and flyings	-	-	X	X	-	X	X	X	X	X
Settling airborne dust, lint, fibers and flyings	-	-	X	X	X	X	X	X	X	X
Hosedown and splashing water	-	-	X	X	-	X	X	-	-	-
Oil and coolant seepage	-	-	-	-	-	-	-	X	X	X
Oil or coolant spraying and splashing	-	-	-	-	-	-	-	-	-	X
Corrosive agents	-	-	-	X	-	-	X	-	-	-
Occasional temporary submersion	-	-	-	-	-	X	X	-	-	-
Occasional prolonged submersion	-	-	-	-	-	-	X	-	-	-

¹ Enclosure type number shall be marked on the motor controller enclosure.

Useful Tables

Table A (millimeters to inches)											
mm	inches	mm	inches	mm	inches	mm	inches	mm	inches	mm	inches
1	0.0393	26	1.0236	51	2.0078	76	2.9921	105	4.1338	260	10.2362
2	0.0787	27	1.0629	52	2.0472	77	3.0315	110	4.3307	270	10.6299
3	0.1181	28	1.1023	53	2.0866	78	3.0708	115	4.5275	280	11.0236
4	0.1574	29	1.1417	54	2.1259	79	3.1102	120	4.7244	290	11.4173
5	0.1968	30	1.1811	55	2.1653	80	3.1496	125	4.9212	300	11.811
6	0.2362	31	1.2204	56	2.2047	81	3.1889	130	5.1181	325	12.7952
7	0.2755	32	1.2598	57	2.2440	82	3.2283	135	5.3149	350	13.7795
8	0.3149	33	1.2992	58	2.2834	83	3.2677	140	5.5118	375	14.7637
9	0.3543	34	1.3385	59	2.3228	84	3.3070	145	5.7086	400	15.748
10	0.3937	35	1.3779	60	2.3622	85	3.3464	150	5.9055	425	16.7322
11	0.4330	36	1.4173	61	2.4015	86	3.3858	155	6.1023	450	17.7165
12	0.4724	37	1.4566	62	2.4409	87	3.4252	160	6.2992	475	18.7007
13	0.5118	38	1.4960	63	2.4803	88	3.4645	165	6.4960	500	19.685
14	0.5511	39	1.5354	64	2.5196	89	3.5039	170	6.6929	525	20.6692
15	0.5905	40	1.5748	65	2.5590	90	3.5433	175	6.8897	550	21.6535
16	0.6299	41	1.6141	66	2.5984	91	3.5826	180	7.0866	575	22.6377
17	0.6692	42	1.6535	67	2.6378	92	3.6220	185	7.2834	600	23.622
18	0.7086	43	1.6929	68	2.6771	93	3.6614	190	7.4803	650	25.5905
19	0.7480	44	1.7322	69	2.7165	94	3.7007	195	7.6771	700	27.559
20	0.7874	45	1.7716	70	2.7559	95	3.7401	200	7.874	750	29.5275
21	0.8267	46	1.8110	71	2.7952	96	3.7795	210	8.2677	800	31.496
22	0.8661	47	1.8503	72	2.8346	97	3.8189	220	8.6614	850	33.4645
23	0.9055	48	1.8897	73	2.8740	98	3.8582	230	9.0551	900	35.433
24	0.9448	49	1.9291	74	2.9133	99	3.8976	240	9.4488	950	37.4015
25	0.9842	50	1.9685	75	2.9527	100	3.937	250	9.8425	1000	39.37

Table B			
decimal	fraction equivalent	decimal	fraction equivalent
0.0156	1/64	0.5156	33/64
0.0312	1/32	0.5312	17/32
0.0469	3/64	0.5469	35/64
0.0625	1/16	0.5625	9/16
0.0781	5/64	0.5781	37/64
0.0937	3/32	0.5937	19/32
0.1094	7/64	0.6094	39/64
0.125	1/8	0.625	5/8
0.1406	9/64	0.6406	41/64
0.1562	5/32	0.6562	21/32
0.1719	11/64	0.6719	43/64
0.1875	3/16	0.6875	11/16
0.2031	13/64	0.7031	45/64
0.2187	7/32	0.7187	23/32
0.2344	15/64	0.7344	47/64
0.25	1/4	0.75	3/4
0.2656	17/64	0.7656	49/64
0.2812	9/32	0.7812	25/32
0.2969	19/64	0.7969	51/64
0.3125	5/16	0.8125	13/16
0.3281	21/64	0.8281	53/64
0.3437	11/32	0.8437	27/32
0.3594	23/64	0.8594	55/64
0.375	3/8	0.875	7/8
0.3906	25/64	0.8906	57/64
0.4062	13/32	0.9062	29/32
0.4219	27/64	0.9219	59/64
0.4375	7/16	0.9375	15/16
0.4531	29/64	0.9531	61/64
0.4687	15/32	0.9687	31/32
0.4844	31/64	0.9844	63/64
0.5	1/2	1.0	1

How to use conversion table A and B

To convert millimeters to inches:

- a) 27 mm - from table A, 27 mm = 1.0629"
 - + from table B, 0.0629 = 1/16" Therefore 27 mm = 1-1/16"
- b) 295 mm - from table A, 290 mm = 11.4173"
 - + 5 mm = 0.1968"
 - + from Table B, 0.6141 = 39/64" Therefore 295 mm = 11-39/64"

To convert	to...	multiply by....	
Atmospheres	pounds per square inch	14.7	
Cubic centimeters	cubic inches	0.06102	
Cubic Inches	cubic centimeters	16.39	
Feet	meters	0.3048	
Gallons (Br. imp.)	liters	4.546	
Gallons (U.S.)	liters	3.785	
Grams	ounces (avoirdupois)	0.0353	
HP	kilowatts	0.7457	
Kilograms	pounds	2.205	
Kilograms	tons (2,000 lb)	0.001102	
kilograms	tons (2,240 lb)	0.0009842	
Kilometers	miles	0.6214	
Kilowatts	HP	1.341	
Joules	calories	0.239	
Liters	gallons (Br. imp.)	0.220	
Liters	gallons (U.S.)	0.2642	
Meters	feet	3.281	
Meters	yards	1.094	
Miles	kilometers	1.609	
Millimeters	inches	0.03937	
Newton (force)	pounds	0.2248	
Ounces (avoirdupois)	grams	28.349	
Pounds	kilograms	0.4536	
Tons (2,000 lb)	kilograms	907.18	
Tons (2,240 lb)	kilograms	1016.0	
Yards	meters	0.9144	
Newton meter	foot-pounds	.737	

BP-212

200

190

180

170

160

150

140

130

120

110

100

90

80

70

60

50

40

30

20

10

0

FP-30

20

10

0

F°

100

90

80

70

60

50

40

30

20

10

0

-10

-20

C°

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