

Problem solver for the North American market: *PKZM4-...-CB*



Technical paper
Dipl.-Ing. Wolfgang Esser

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– UL 489¹ Molded Case Circuit Breaker for smaller loads –

Electrical equipment for machines and assemblies

German and European made machinery and assemblies have always been in high demand because of their high standards for quality. Fortunately, the outlook for that particular sector of the industry, especially in the area of innovative and technologically sophisticated machinery destined for export, has shown signs of recovery following the recent downturn in the overall world economy. And the USA and Canada remain amongst the most important export destinations for that specialized segment of the industry.

Whereas electrical assemblies in the majority of countries around the world are primarily governed by IEC² standards, the North American market is still largely the domain of local codes and standards (NEC³, CEC⁴, UL 508A⁵, NFPA 79⁶), which still markedly differ from the IEC standards in many aspects. Market conventions [1] and customer sensibilities in North America also remain distinct and divergent in many ways from those encountered in the IEC world.

The North American versions of electrical equipment assemblies from various machinery manufacturers involved in the export trade will tend to vary from make to make, and reflect either a lack of knowledge of specialized North American requirements or an unwillingness, or lack of capability, in taking the necessary steps to bring their equipment in conformity with local regulations.

Space saving component designs and technologically modern solutions, combined with European advances in the field of functional

safety, are important reasons why German and European made machinery equipment designs are in such demand in North America.

Noticeable differences in both markets are not just evident in the handling and application of electrical components. There aren't many exporting panel builders today in a position to build and supply panels that are guaranteed to meet all the approval requirements of local electrical inspectors (AHJ⁷) in North America. It starts, as an initial step, in properly and correctly fulfilling the requirements of the electrical codes (NEC and CEC) and relevant assembly standards, such as UL 508A and NFPA 79. In addition, regional differences in locally enforced regulations, as well as market conventions in certain segments of the industry, must also be taken into consideration. An approval process generally requires a compilation of certification related documentation for verification purposes and submittal to the inspector. The art of mastering North American control panel design engineering is certainly akin to schooling at a graduate education level. It often requires more than just simply combining certified components together, as is often done in the IEC world. Eaton not only offers a comprehensive range of certified components, but also provides design engineering support and product application assistance. There are various options for manufacturers to consider in certifying complete custom control panels, whereby a certification process undertaken directly at the manufacturer's location is probably the most advantageous method used to minimize or virtually eliminate any approval rejections by local authorities at the end-user's site. It also simplifies the process of implementing any necessary corrections to the panel before it is shipped out. Purposely avoiding potential approval problems with local jurisdictions is easily the worst option to consider, and can lead to the costliest, and most time consuming, of remedial procedures.



1 UL 489 = North American product standard for molded case circuit breakers

2 IEC = International Electrotechnical Commission

3 NEC = National Electrical Code

4 CEC = Canadian Electrical Code

5 UL 508A = Standard for Industrial Control Panels

6 NFPA 79 = Standard for the electrical equipment of industrial machinery

7 AHJ = Authority Having Jurisdiction

North American concepts and regulations which may not be familiar in the IEC world

The issues shown below represent various elements of the North American electrical system which one absolutely needs to be aware of. They should be part of any seminar course designed to provide a fundamental understanding of the key requirements dealing with the successful export of electrical equipment into the North American market:

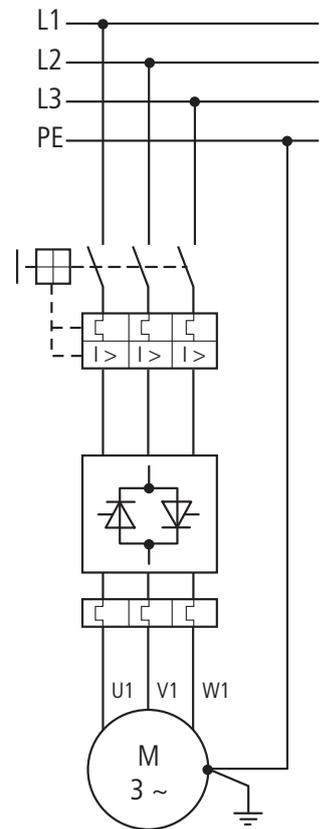
- Component classifications and main areas of application
- Equipment specific differences related to product certification
- Feeder Circuits⁸ and Branch Circuits⁹
- Restrictions imposed by certain power distribution networks
- Application specific differences related to product selection

The above mentioned points will be described in greater detail in the brochure[1]. These particular aspects, which differ from the international situation, often result in misunderstandings and incorrect component selections which can lead to problems with certification agencies doing inspection work at

the manufacturing location, or with electrical inspectors locally in North America. North American product certification is a complex matter and is subject to requirements that are constantly evolving. Keeping up with important changes is a daunting task if one only deals with exports on an occasional basis. It is advisable in those cases to seek assistance from experienced and appropriately certified panel builders, especially those who often deal with adapting IEC based designs to meet North American requirements.

Protection requirements for various load categories

The most important load category involved in the design of electrical equipment for industrial machinery, both in the IEC world and in North America, are motors. Motors are switched and protected in various ways and the rules which outline the requirements in North America are well established and defined. The UL 508¹⁰ standard recognizes various construction types¹¹ of combination motor controllers for this purpose. Types E and F are especially relevant in the IEC world, since they legitimize the



Motor branch circuit with a soft starter, e.g. Model DS7 from Eaton

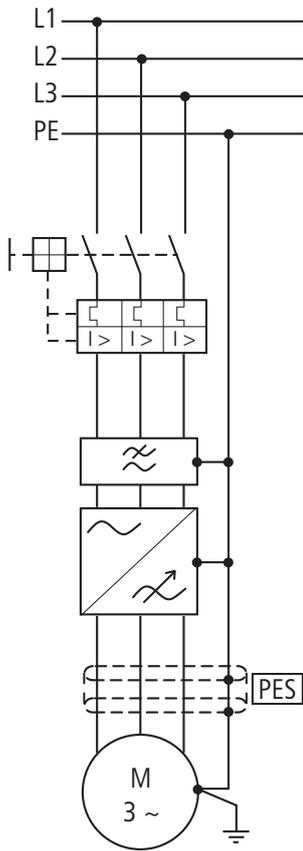
8 Feeder Circuits = Supply circuits for branch circuits
9 Branch Circuits = Load circuits

10 UL 508 = Standard for Industrial Control Equipment
11 Construction Types = Various combination configurations of motor controller, protective and disconnecting equipment

Selection and application guidelines for North American power fuses used in Feeder and Branch Circuits								
Suitable for use in:		UL/CSA Standards	Characteristics	SCCR	Typical ranges in Amps	Applications		Comments
USA	Canada							
Class H, "Code"	Class H, No. 59 "Code"	UL 248-6 / 7 C22.2 248-6/7	Fast-Acting	10kA / 250VAC 10kA / 600VAC	0...600	Residential, Commercial, Industrial		Class H, K and No. 59 "Code" fuses are physically interchangeable and fit in the same fuseholders. Refer to comments below under Class K.
Class CC	Class CC	UL 248-4 / C22.2 248-4	Fast-Acting & Time Delay	200kA / 600VAC	0,5...30	Fast-Acting: Protection of resistive and inductive loads.	Time Delay: Protection of inductive and highly inductive loads.	Extremely compact size! Current limiting per UL/CSA Standards!
Class G	Class G	UL 248-5 / C22.2 248-5	Fast-Acting Time Delay	100' / 480VAC A / 600VAC	21...60 0,5...20			Appliances, Heaters, Lighting, Mixed loads in Feeders and Branch Circuits.
Class J	Class J HRCI-J	UL 248-8 / C22.2 248-8	Fast-Acting & Time Delay	200kA / 600VAC	1...600	Appliances, Heaters, Lighting, Mixed loads in Feeders and Branch Circuits.	Electrical Motors, Transformers, Lighting...	Compact size! Current limiting per UL/CSA Standards! Non-interchangeable with any other fuse class.
Class K K1, K5	Class K K1, K5	UL 248-9 / C22.2 248-9	Fast-Acting & Time Delay	30kA, 100kA, 200kA / 600VAC	0...600			Not marked current limiting per UL/CSA Standards! That's why Class K fuses are often substituted by rejection-type Class RK... fuses.
Class L	Class L	UL 248-10 / C22.2 248-10	Fast-Acting & Time Delay	200kA / 600VAC	601...6000	Appliances, Heaters, Lighting, Mixed loads in Feeders and Branch Circuits.	Electrical Motors, Transformers, Lighting...	Current limiting per UL/CSA Standards! Non-interchangeable with any other fuse class.
Class R RK1, RK5	Class R HRCI-R RK1, RK5	UL 248-12 / C22.2 248-12	Fast-Acting & Time Delay	50kA, 100kA, 200kA / 600VAC	0...600			Current limiting per UL/CSA Standards! Types RK1, RK5 and HRCI-R fit in the same rejection-type fuseholders, and are non-interchangeable with any other fuse class. RK1 fuses have lower let through values than RK5 fuses.
Class T	Class T	UL 248-15/ C22.2 248-15	Fast-Acting	200kA / 300VAC 200kA / 600VAC	0...1200	-		Extremely compact size! Current limiting per UL/CSA Standards! Non-interchangeable with any other fuse class.

The characteristics and application guidelines mentioned above provide a rough overview only. For more precise information on local conditions it is recommended to consult with the end user. Most fuse types also carry DC ratings per UL and CSA standards.

Figure 1: Many machinery and panel builders want to avoid the use of North American fuses, mainly because they tend to be larger than equivalent European models and the proper fuse selection process is so difficult for them. Fuseless based systems are much quicker to get back in service after a fault, and they have better signalization capabilities in addition to opening all poles in case of single phasing.



Motor branch circuit with an adjustable frequency drive, e.g. Model M-Max from Eaton

use of IEC style motor protective switches to much greater extent [2].

Other important loads to consider are, for example, heaters, transformers, lighting and capacitors, in addition to the protection requirements of feeder and branch circuit conductors and specialized electronic controllers such as soft starters and adjustable frequency drives. IEC based manual motor controllers are often used internationally to protect such loads, particularly the ones drawing relatively lower currents. The situation is different in North America, where the use of comparable devices, certified as industrial control equipment under the UL 508 standard, is not readily sanctioned for overcurrent protective duty by the electrical codes. Most applications will allow only the use of molded case circuit breakers and fuses, certified to UL 489/CSA C22.2 Nr. 5-09 and UL 248/CSA C22.2 Nr. 248¹² respectively, as Branch Circuit Protective Devices¹³ for this purpose.

A recent development in the product standards will allow for testing and certification of Type E controllers as protective devices for adjustable frequency drives. The only stipulation will be that the make of the Type E controller used for the test will need to be provided in the form of a marking, as opposed to the marking requirements applicable whenever generic circuit breakers and fuses are used as overcurrent protective devices for the short circuit portion of the test. In the case of transformers, and especially control circuit trans-

formers, the use of IEC style manual motor controllers, or more specifically their “Transformer Protector” derivatives, which feature special short circuit trip settings that accommodate higher inrush currents, is very popular in European based electrical equipment. The PKZM0-...-T transformer protectors are commonly used in Europe for that purpose but do not have the necessary certification in North America to allow them for that usage. The protection of non-motor or special purpose loads is an area in which many mistakes are made on the part of design engineers who are attempting to convert an IEC based control panel layout into a North American equivalent. These types of errors are commonly flagged by certification agencies and inevitably require a product selection change in order to achieve a resolution of the problem. There is a common miss-perception in the IEC world that the use of Type E controllers, which are equipped with large spacing terminals on their supply side, are sanctioned by the electrical codes as protective devices for these non-motor applications. That perception is incorrect.

Exporting firms, especially those exporting to North America, prefer to avoid the use of fuses. Generally speaking, UL/CSA branch circuit fuses are often larger than equivalent European models and procurement of North American fuses and fuse bases can be a difficult process in the IEC world. There is also much uncertainty on the part of European based designers in selecting the right kind of fuse because of the many choices and classes of North American fuses available (**Figure 1**). The use of fuses actually runs counter to the concept of a universal panel design which would be in conformity with all global

¹² UL 248 = North American product standard for fuses
¹³ BCPD = Branch Circuit Protective Devices

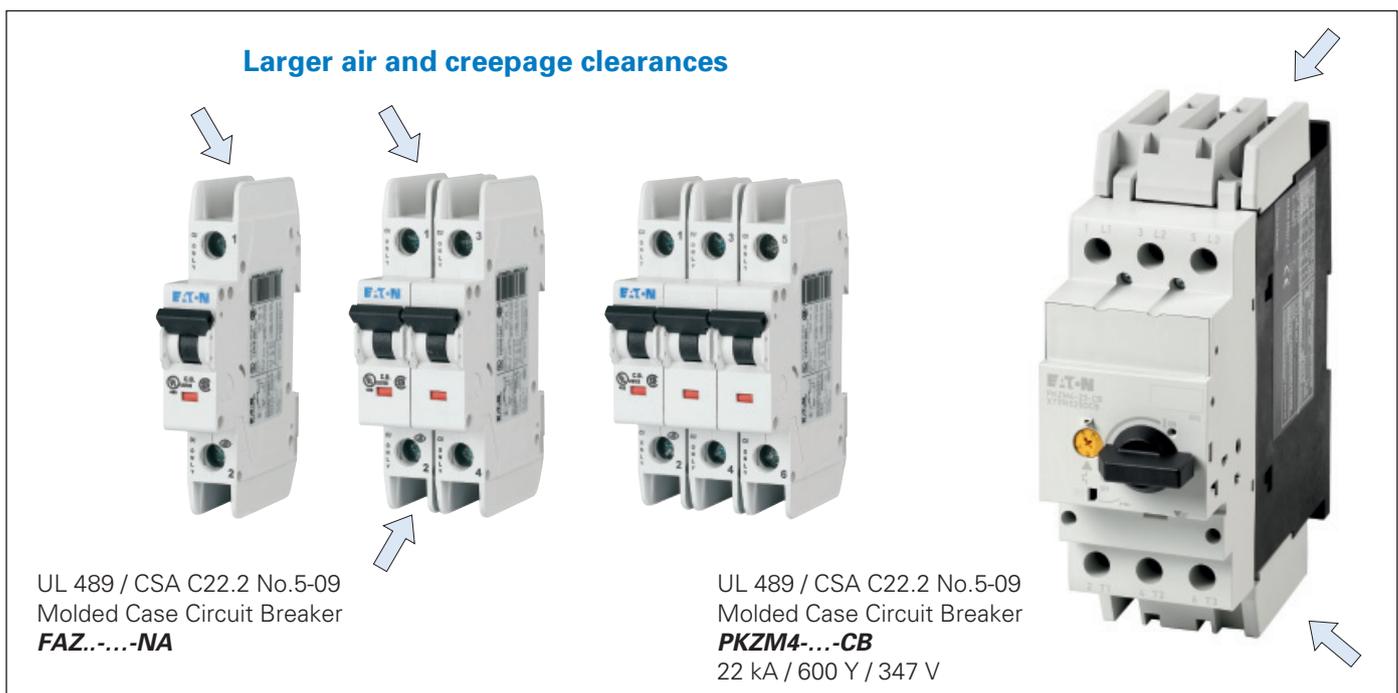


Figure 2: Two distinct solutions for the protection of non-motor loads in industrial control panels for export to North America. Both solutions are especially suited for smaller currents, and can be applied in both feeder and branch circuits per the electrical codes.

standards. It is thus advisable to use certified molded case circuit breakers (UL 489/ CSA C22.2 Nr. 5-09) as protective devices for all non-motor and special purpose loads.

Circuit breakers as protective devices for special purpose loads

Circuit breakers are mainly known in the IEC world as protective devices for relatively larger current loads. This was the panel design engineer's first hurdle. The smallest, conventional North American circuit breaker from Eaton, model type NZM1, has a lowest adjustable setting of 15A. Many special purpose loads are solely designed to draw much lesser currents. To be fair, the requirements imposed by the electrical codes are in place to mostly protect the associated conductors against overheating. The protective device, allowing for any necessary correction factors imposed by the NEC and CEC for conductor ampacity levels, is sized in accordance with the conductor ampacity rating. A potential solution for protecting small, special purpose loads could be a relatively recent product introduction from Eaton consisting of IEC based miniature circuit breakers that have been modified and certified as molded case circuit breakers per the UL 489 product standard. These carry the model designation FAZ...-NA and are available in very small current ratings. There is admittedly the potential of confusing this line with the similar looking series of FAZ miniature breakers, which are recognized-only components certified under a different standard: UL 1077. Some additional clarifications will be helpful in this regard.

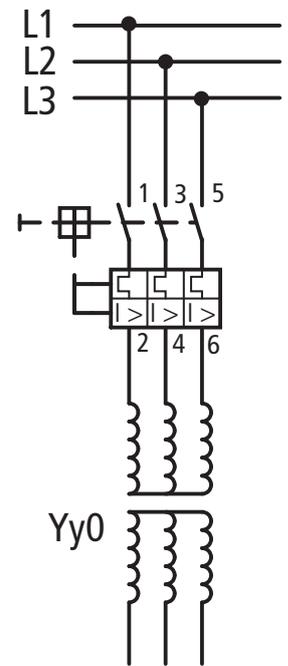
Many users were happy to hear that the Eaton line of FAZ miniature circuit breaker had been expanded and modified to accommodate a broader scope of application. The FAZ line, like most of the competitive products in the marketplace, was certified under the afore-mentioned UL 1077 standard, which does not permit these devices to be installed in North America as BCPDs. Rather, the certification allows their application only as Supplementary Protectors¹⁴ under the electrical codes. They are Recognized components¹⁵ only and not listed. They must be installed on the load side of a BCPD and their purpose essentially is to provide an additional protective capability to connected loads and circuits. As an alternative, they can also be installed where the use of a BCPD is not specifically mandated, such as in the protection of tapped circuits that are not considered branch circuits by the codes, or for the protection of control circuit transformers. They are particularly useful as a toggle operated means to iso-

late and protect the secondary side of a control circuit transformer. The listed molded case circuit breaker¹⁶ (per UL 489/ CSA C22.2 Nr. 5-09) FAZ...-NA version was created by modifying certain constructive aspects of the FAZ line, primarily the addition of larger electrical clearances on the device's terminations. [4]

By definition (NEC), a circuit breaker is a device designed to open and close a circuit by non-automatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating. Determination of operational loads and potential overcurrent levels will establish the proper selection and rating of the circuit breaker. Overcurrents per the NEC definition could be any current in excess of the rated current of equipment or the ampacity of a conductor, and would include overload, short circuit and ground fault currents. These high performance devices are naturally suitable for the protection of special purpose loads. The FAZ...-NA line is available in single, two pole and three pole versions. Wiring accessories include single and multi-pole busbar connector links and incoming terminals that accommodate larger supply conductor cross-sections. Unfortunately, these very compact devices have some application limitations by virtue of their relatively low interrupting (SCCR) ratings, which fall in the 10 to 14kA range. These breakers are suitable for applications in solidly grounded networks up to 480Y/277VAC, and in delta and ungrounded systems up to 240V max.

Closer examination of circuit breaker applications with respect to SCCR values

The 2005 edition of the NEC featured the introduction of a new Article, Article 409 on Industrial Control Panels, and with it the requirement to establish an overall short-circuit current rating (SCCR) for the control panel assembly¹⁷. For very small control panels, the overall SCCR value could easily be the listed short circuit rating of a sole combination starter assembly. For more complex panels the value is usually established through the use of an approved method. As an example of an approved method, the NEC mentions Supplement SB of the UL 508A standard on Industrial Control Panels [3]. The primary goal is to establish a value of short circuit current which the entire panel can safely withstand for the time it takes the associated protective devices to respond and clear the fault current. A short circuit inside the panel cannot result in a hazardous situation on the outside of the panel which could cause harm or injury. The scope of the SCCR determination includes all power circuits as well as the primary circuits feeding con-



Protection of a 3 phase power transformer

¹⁴ Supplementary Protectors = Devices used to provide additional protection to circuits and loads

¹⁵ Recognized Components = Certification with inherent limitations or conditional acceptability

¹⁶ Listed molded case circuit breakers = Circuit breakers with UL listing

¹⁷ SCCR = Short Circuit Current Rating of an industrial control panel

trol circuit transformers. Control circuits and external components to the panel are not part of the overall determination. Generally speaking, a tally of all power circuit components and their associated short circuit rating is made in order to identify the weakest (i.e. lowest SCCR) links in the chain. The overall SCCR can be increased through the use of current limiting protective devices in the feeder circuit. The interrupting rating of each protective device in the panel, however, must be equal to or greater than the overall SCCR that's been established for the panel. The use of listed "Series ratings" between protective devices, similar to those used in panelboards, has not yet been sanctioned for use in industrial control panels per the UL 508A and NFPA 79 standards. The overall calculation established through the use of an approved method such as Supplement SB of UL 508A is used to determine the overall SCCR value that will appear on the industrial control panel's nameplate. This value must always be equal to, or greater than, the maximum short circuit fault current available at the incoming supply terminals of the control panel.

The topic of SCCR leads us to reflect on issues that may not have been as obvious in the past. The short circuit ratings of individual components mounted in a panel assembly now play a much larger role in the overall picture. Relatively low interrupting ratings on protective components, like the 10 to 14kA @ 480Y/277V values previously mentioned for the FAZ.-NA line molded case circuit breakers, may not make them suitable in a number of appli-

cations where higher available faults may be present at the point of installation. As previously indicated, an increase in the overall short circuit rating brought about by series connected protective devices, as currently practiced in the IEC world, is not yet part of the approved method to determine short circuit ratings per the UL 508A standard. This means that in North America, all protective devices in a control panel must have a short circuit current rating that is equal to, or greater than, the marked short circuit current rating appearing on the panel's nameplate. The aforementioned 10 to 14kA rating on a branch circuit protective device could turn out to be fairly small compared to the interrupting rating of a feeder current limiting circuit breaker or fuse. The net result would be a lowering of the overall panel SCCR value to that level. The newly introduced PKZM4-CB circuit breaker, with a short circuit interrupting rating of 65kA, is in a much better position to fulfill the demands of a BCPD in a high fault rated control panel assembly. In North American control panels, as opposed to IEC/EN practices, the lower let-through values of an upstream current limiting device does not have the same impact on the sizing requirements of downstream BCPDs relative to their interrupting ratings as they do with the short circuit ratings of passive components in the power circuit. The current limiting effect on downstream BCPDs is simply omitted from consideration in the overall determination. Of course, the short circuit ratings of individual power components in downstream circuits may also only be 5 or 10kA, and thus it

	Circuit Breaker	Circuit Breaker
Features	FAZ...-NA	PKZM4...-CB
Product standards	UL 489, CSA C22.2 No. 5-09, IEC/EN 60 947-2	UL 489, CSA C22.2 No. 5-09, IEC/EN 60 947-4-1
Certification	UL-Listed, CSA-Certified, CE-Mark	UL-Listed, CSA-Certified, CE-Mark
Rated currents	0,5 .. 32 A in increments	16 .. 32 A in increments
Thermal overload setting	fixed	$I_r = 0,6 - 1,0 \times I_u$
Short-circuit trip setting	fixed	fixed
Characteristic per IEC 60....	B, C, D	-
Rated Voltage	480Y/277 V, 60 Hz	480Y/277 V, 600 Y/347 V, 60 Hz
Number of poles	1, 2, 3	3
Short Circuit Current Interrupting Rating	10 kA @ 480Y / 277 V	65 kA @ 480Y / 277 V, 22 kA @ 600Y / 347 V
Application	Branch Circuit Protective Device (BCPD)	Branch Circuit Protective Device (BCPD)
Operating handle	Toggle	Rotary, optionally padlockable, Door mounted rotary handle (Not suitable as a supply circuit disconnecting means per NFPA 79 at this time)
Optional Accessories:		
Auxiliary contacts	Yes	Yes
Voltage trips, Undervoltage and shunt	Yes	Yes
Bus connector links	1-, 2- 3-pole	-
Mounting	DIN rail, multi-pole on busbar adapter shoes	Screw mounted, DIN rail and on busbar adapter shoes
Dimensions, 3-pole, W x H x D	53.1 x 105 x 70 mm	55 x 165 x 171 mm

Table 1: Differentiation between FAZ...-NA and PKZM4...-CB molded case circuit breakers used to protect smaller loads

is always best to make sure that all power circuit components in the panel are closely scrutinized to determine their short circuit rating. There are thus many open questions left to answer before fully resolving the manner in which a SCCR value for a control panel can be best determined and there is, unfortunately, little in the way of practical information available as to how applicable SCCR values in the field are accurately established.

Slash Rated Voltage

FAZ..-NA and PKZM4-CB molded case circuit breakers are suitable for use in wye type, solidly grounded power distribution "slash voltage"¹⁸ systems such as 480Y/277VAC, and in some cases 600Y/347VAC, or in delta and ungrounded networks up to max. 240VAC. The rating is similar to that which applies for the overwhelming majority of UL 508 Type E and F combination motor controllers.

If a protective component in a panel carries a slash rating, then the voltage rating marked on the control panel nameplate would also have to reflect that slash rating. By this time, a project engineer should have come to the realization that a sound grasp of the requirements in North American codes and standards is essential in order to design electrical equipment and panels for industrial machinery that are both technically sound and applicable for that market.

Circuit breakers with high interrupting ratings, but for smaller loads

The PKZM4-CB, certified to UL 489 and CSA C22.2 no. 5-09, was developed primarily under the assumption that a protective

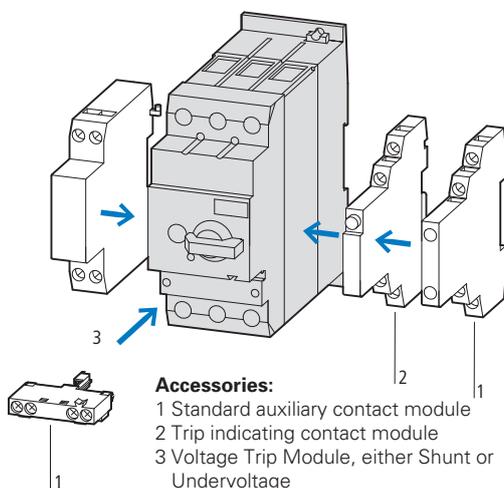
device with a 10 to 14kA rating and a voltage of 480Y/277VAC would be insufficiently rated to fulfill the protective requirements of small special purpose loads in all applications. With ratings of 65kA@480Y/277VAC and 22kA@600Y/347VAC, the PKZM4-CB is in a much better position to address this need. This high interrupting rating was achieved in a very compact housing, which features a frame width of only 55mm. Excellent short circuit ratings in combinations with contactors are also expected, because the device's high interrupting ratings and performance are tied to its very quick operation and fault clearing design capabilities. **Figure 2** shows the device along with its main accessories and **Table 1** provides more details on its features.

Please note that protective devices which carry certified ratings of 480Y/277VAC and 600Y/347VAC are not suitable in installations where the power distribution network has (full) 480VAC (line to line) ratings.

Summary:

A control panel is an essential element of the electrical equipment for machines and assemblies. Simply said, most machinery is not functional without electrical control equipment. The protection of motors is a fully developed and well defined concept in North American codes and standards. The proper choice of protective devices for "special purpose" loads is more narrowly defined in North America than it is in the IEC world. The selection of fuseless, high fault rated alternatives for these smaller current, special purpose loads was a vexing problem for exporters to North America. The newly introduced PKZM4-.-CB molded case circuit breaker fits in especially well in this regard as a problem solver to fill that need.

18 Slash Voltages = North American term to define solidly grounded power distribution networks. The slash separates the two voltage ratings of each network



The accessories for the PKZM4 family of motor protective switches also fit the PZKM4-CB molded case circuit breaker.

Dipl.-Ing. Wolfgang Esser
 Product support ICD
updated July 2012

Eaton Industries GmbH,
 Bonn

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E-Mail: AfterSalesEGBonn@Eaton.com
www.moeller.net/aftersales

Eaton Industries GmbH
Hein-Moeller-Str. 7-11
D-53115 Bonn
Germany

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