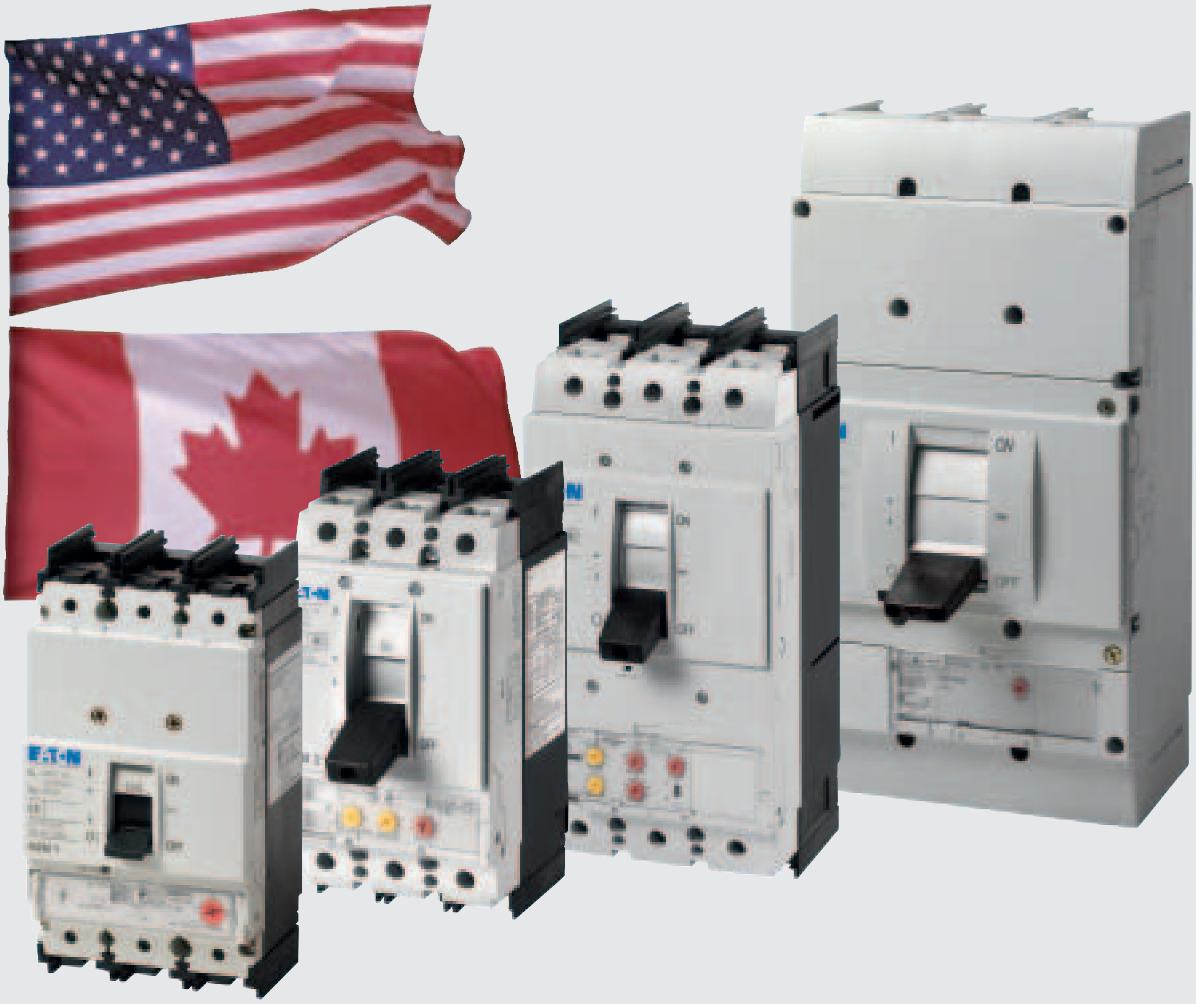
Molded case circuit breakers for applications in North America



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Powering Business Worldwide

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Introduction and summary overview

Differences between relevant electrical standards and market conventions in both North America (primarily the US and Canada) and the IEC world play a key role in shaping the design and determining the proper application of products such as *NZM* molded case circuit breakers and *NS* molded case switches, *N*, *PN* switch-disconnectors, and combination motor starters in those markets.

North American electrical product standards differentiate in significant respect between equipment deemed suitable for energy distribution (such as UL 489) [1] **versus those components normally grouped under industrial control** (per UL 508/ UL60947) [2]. This type of differentiation is not known in the IEC world. The basis for many design engineering errors from the IEC side, for example in motor starter circuits, was thus often rooted in the commonly misunderstood practice in North America of exclusively assigning the protective function in those circuits to devices with specific construction requirements, such as those featuring larger electrical clearances per standards like UL 489 resp. CSA-C22.2 No. 5-09, and the seemingly redundant need to place them ahead of motor protective devices, deemed to be self-protective in the IEC world, but meeting only the arguably less stringent constructional requirements of industrial control standards such as UL 508 and CSA-C22.2 No. 14. It is always quite a revelation, therefore, that proper design of such branch circuits will often times require the use of additional protective devices such as circuit breakers and fuses, a practice which is mostly deemed unnecessary in the IEC world.

The classic IEC style manual motor protective switch, e.g. a PKZM0, in its standard design, would fall short of circuit breaker requirements per North American product standards. For one, the harmonized editions of the UL 489 and CSA-C22.22 No. 5-09 circuit breaker standards constructionally require the use of much larger electrical clearances than deemed necessary by comparative IEC/EN standards. Physically smaller protective devices, such as the PKZM0, are more especially affected by this distinction since they are widely known and accepted in the IEC world as one of the most compact high performance circuit breaker designs available anywhere. The confusion is compounded by the fact that many other manufacturers of similar equipment also freely refer to their own devices as circuit breakers in ads and printed literature. This problem, however, has been somewhat alleviated in recent years with the introduction of new certifications in North America. Motor protectors with Type E and F certification [3] per UL 508 can now be equipped with large spacing incoming terminals and provide stand-alone branch circuit protection for individual motor starter circuits. Still, these applications are relegated solely to motor circuits, and can come with additional restrictions, such as usage in solidly grounded networks only, e.g. 480Y/277VAC, or slash rated systems per the electrical codes.

The molded case circuit breaker and switch series, types *NZM 1..-...-NA* through *NZM 4..-...-NA,* was developed to optimally fulfill all of the North American requirements for these products. All North American versions of the line are certified per the demanding UL 489 standard. Special versions for motor protection fulfil additional calibration requirements per the industrial control standard UL 508. Because the North American versions are identical to the IEC line dimensionally, panel design for both markets can follow very similar layouts. Alternatively, North American devices with suffix „-NA“ can be used as world market products globally, since they also meet all pertinent IEC component performance standards, and are CE marked.

The paper categorizes the Moeller series of circuit breakers from Eaton per the following criteria:

- Type of certification,
- Their switching and protective functions,
- Their correlation to product certification standards such as UL 489 and UL 508
- Their technological capabilites when combined with multi-function trip modules that customize breakers to best suit the application.

The line was designed to conform to North American market conventions, including component markings and accompanying installation instruction sheets. Circuit breakers with fixed overload trips are very seldom used in the IEC world (except possibly in Asia, or in the residential market). North American frame sizes often take on nominal current values which are not considered typical throughout the IEC world. Certain versions of the breakers have also undergone additional calibration testing per the industrial control standards to qualify their use as motor overload protective devices (**Table 1**). Switch-disconnectors with integrated short-circuit trips are new to the IEC, but are a common feature of North American molded case switches. Both products are very often used as the supply circuit disconnecting means in engineered assemblies such as industrial control panels.

Search assistance and classification of switch styles

The following pages will present many variations of switch-disconnectors and circuit breakers, along with the manner in which they are most commonly applied. In order to help the reader navigate more effectively through all the various tables, the paper will make use of **„Switch Style“** category codes, with additional letter qualifiers such as **A, B, C, D** and **E**. In addition, orientation will be supported with color coding of fields and sections. These qualifier letters are in no way related to any similar designations used in the electrical standards, such as those used to identify combination motor starter **“construction types”** in the industrial control standards. This form of internal coding was selected for use in this paper only, and does not appear in any other Eaton publication. Actual selection and/or combination of Eaton components is best carried out through the use of assigned part numbers and article numbers provided in main catalogs.

The circuit breaker selection process is fairly straight-forward, even for the more

Suitability for main and supplemental applications										
Main applications						**Supplemental applications**		**Type**	**Search reference help guide for this paper**	
Short Circuit Protection	Inverse Time, short circuit and overload protection for: Energy distribution systems	Cables	Generators Transformers	Selective networks with intentionally delayed short circuit trips	Motors	Main disconnect switch	Emercency OFF switch		Refer to these tables for more descriptive informationon each type	Switch styles (Internal Classification code for each switch type described in this paper)
1)						X	X	***NS..-..-NA***	11	A
X 2)					(X) 3)	(X) 5)	(X) 5)	***NZM..-S..-CNA***	17 a/b	B.1
X 2)					(X) 3)	(X) 5)	(X) 5)	***NZM..-SE..-CNA***	18	B.2
	X	X			(X) 3)	X	X	***NZM..-AF-..-NA***	13 a/b/c	C.1
	X	X			(X) 3)	X	X	***NZM..-AEF..-NA***	14	C.2
	X	X	X	X	(X) 3)	X	X	***NZM..-VEF..-NA***	21/23	C.3
	X	X			(X) 3)	X	X	***NZM..-A..-NA***	15	D.1
	X	X			(X) 3)	X	X	***NZM..-AE..-NA***	16	D.2
	X	X	X	X	(X) 3)	X	X	***NZM..-VE..-NA***	22/23	D.3
	X	X			X 4)	X	X	***NZM..-ME..-NA***	20	E

(X) Conditionally applicable, motor overload function provided by separately furnished overload relay.
1) Switches have internal self-protection, up the maximum short circuit ratings shown in Table 1
2) For use only in certified combination motor controllers per North American electrical codes and standards.
3) For use only in combination with suitable motor contactor and overload relay
4) For use only in combination with suitable motor contactor
5) For use only in individual motor controller branch circuits

Table 1: The significance of the table coloring scheme is explained in the body of the paper. The table shows the suitability of each switch style for any given application. The use of additional switching and protective devices may be required depending on the application.

demanding applications such as motor branch circuits. Eaton offers the OEM or panel builder at least two viable alternatives, both technically and economically:

- The more conventional North American **combination motor starter** solution, **consisting of 3 components**
  - UL 489 – Instantaneous Trip circuit breakers ***NZM..-S(E)..-CNA***
  - UL 508 – Motor controller (contactor) ***DIL M***
  - UL 508 – Motor overload relay ***ZB*** or ***ZEV***

or

  - UL 489 – Inverse time, fixed overload trip circuit breaker ***NZM..-A(E) F..- NA*** oder ***NZM..- VEF..-NA***
  - UL 508 – Motor controller (contactor) ***DIL M***
  - UL 508 – Motor overload relay ***ZB*** or ***ZEV***

- Or a **combination motor starter** solution more in line with IEC conventions, consisting of **2 components,** which are also certifed per UL and CSA standards:
  - UL 489 – Inverse time circuit breaker ***NZM..-ME...-NA*** with additional motor overload calibration per *UL 508-*
  - UL 508 – Motor controller (contactor) ***DIL M***.

The paper will also discuss in greater detail the use of current limiting circuit breakers, which can play a special role in the determination of the overall short circuit current rating *(SCCR)* of an industrial control panel per the Supplement SB [4] of the UL 508A standard. Finally, the paper will address differing North American requirements with respect to the operating means of disconnect switches used in assemblies falling under the industrial machinery scope of UL 508A and NFPA 79 [5]. The selection of suitable operating handles for supply circuit main disconnect switches can be a common source of errors in the design of equipment exported to

Eaton molded case circuit breaker		
Type	Internal classification code used in this paper: **Switch style**	Certification in the US per:
NS..-..-NA	**A**	UL 489
NZM..-S..-CNA	**B.1**	UL 489
NZM..-SE..-CNA	**B.2**	UL 489
NZM..-AF..-NA	**C.1**	UL 489
NZM..-AEF..-NA	**C.2**	UL 489
NZM..-VEF..-NA	**C.3**	UL 489
NZM..-A..-NA	**D.1**	UL 489
NZM..-AE..-NA	**D.2**	UL 489
NZM..-VE..-NA	**D.3**	UL 489
NZM..-ME..-NA	**E**	UL 489

1) Switches have internal self-protection, up to the maximum short circuit ratings shown in Table 11

Table 2: Molded case circuit breaker and switch types NS mended for export to North America. All switch variation component, IEC style, motor branch circuit solutions for motor protective circuit breaker.

the North American market. A method by which a switch can be intentionally operated *(Deliberate Action)*, with an opened control panel door, will also be presented. It will be shown that fulfilling the intent of the standards does not solely reside on the shoulders of the manufacturer, but that full compliance with the requirements is a shared responsibility of all parties involved, including both panel builder and user.

It will become apparent from this paper that product certification is a challenging task, and sometimes difficult to understand. [6]. It is a constantly evolving process frequently subject to changes, which must always be closely monitored. There are often many details vital to the end-user which only a manufacturer is in a position to know and communicate. Besides the use of certified components, a panel builder involved in export should also be thoroughly familiar with local installation codes and engineering requirements. Ideally, the panel manufacturing location itself should be able to list and certify assemblies. The manufacturing plant SAE Schaltanlagenbau Erfurt GmbH[1], which originated as the Moeller factory Erfurt, can build, design and label complete panel assemblies with UL listing and CSA certification marks. Clients can confidently place their trust in our vast experience and successful history: Equipment certification was always a Moeller specialty.

Focus on key sections

Table 2 provides comprehensive selection recommendations on circuit breakers used in North American energy distribution and motor starter circuits. Breakers that have been recommended for motor circuit applications in export related assemblies offer particularly good value to the modern control panel designer, even if they do not yet quite reflect typical North American conventions. All circuit breakers are certified per current and relevant North American product standards. They facilitate the use of space-saving 2 component combination motor starter solutions (circuit breaker and contactor) up to 200A, just as it is typical in the IEC world. These modern combinations will surely gain popularity in North America once users become more familiar with their potential benefits and grow comfortable with the technological validity of the approach. Naturally, the more conventional combinations consisting of a circuit breaker, contactor and separate motor overload relay Type *ZB* or *ZEV* can also be realized. Circuit breakers must always be cabled per their maximum current rating. Breakers with electronic trips usually feature a much broader current setting range so it's possible that, within a given range, the difference between the required load setting current and the maximum breaker setting would cover more than one cable size. It may thus be worthwhile, in certain cases, to consider the use of a fixed overload trip device in order to possibly enable the use of smaller, and more economical, cable cross-sections. This could be a particularly good cost-saving approach in applications with long cable runs.

Remarks

The paper is directed primarily towards international planners, design engineers and panel builders involved in export projects with North America as a target market. That is an important consideration because many of the solutions presented

1 www.sae-erfurt.de

and switch selection recommendations for export to the North American market (Moeller series).

Certification in Canada per:	Additional qualification evaluations for the US and Canadian market	Overload protection	Short circuit protection undelayed	delayed	Significance of these various switch types in the North American market	Selection recommendations for export to North America
CSA-C22.2 No 5-09	-	none	1)	-	Very significant as Molded Case Switches	Feeder circuit disconnect, Main disconnect switch
CSA-C22.2 No 5-09	-	none	EM	-	Very significant in North American motor starters	for 3 component combination motor controllers > 200 A
CSA-C22.2 No 5-09	-	none	EL	-		
CSA-C22.2 No 5-09	-	Thermal, fixed	EM	-	Very significant in North American motor starters and energy distribution systems	Not necessarily advantageous for export puposes*
CSA-C22.2 No 5-09	-	Electronic, fixed	EL	-		
CSA-C22.2 No 5-09	-	Electronic, fixed	EL	EL		
CSA-C22.2 No 5-09	-	Thermal, adjustable	EM	-	Very significant in systems and cable protection	Recommended for energy distribution protective requirements
CSA-C22.2 No 5-09	-	Electronic, adjustable	EL	-		
CSA-C22.2 No 5-09	-	Electronic, adjustable	EL	EL	Very significant in systems, cable, transformer and generator protection	Energy distribution with additional requirements, such as selectivity
CSA-C22.2 No 5-09	Calibration test per UL 508, CSA-C22.2 No.14	Electronic, adjustable	EL	-	Not yet predominant, as it is a relatively new concept	for 2 component combination motor controllers

* there could be some potential financial savings involved with possible reductions in cable cross-section sizing requirements.

EM = Electro-magnetic EL = electronic

..-..-NA, NZM..-A(E)-..-NA and, for more complex protective requirements, type NZM..-VE..-NA electronic trip circuit breakers, are especially recom-
s in this new circuit breaker generation are very compact, thus enabling a modern layout design more in line with IEC style configurations. Two
North America, i.e. without a separately furnished overload relay, can now be realized for motor rated currents up to 200A using the NZM..-ME..-NA

tend to mimic IEC philosophies as closely as possible. This is done intentionally since modern machine manufacturers and panel builders tend to overwhelmingly prefer solutions which can be universally applied. Comprehensive descriptions of product certification testing and detailed construction aspects were purposely omitted in order not to distract from the essential theme. Although the breadth of the paper is quite extensive, its focus deals solely with fundamental aspects of molded case circuit breaker and switch design in North America, and their usage in certain key applications, such as motor circuits. Design engineers involved in complete electrical assembly project work would best supplement their knowledge base with additional information on North American installation code requirements, as well as familiarize themselves more thoroughly with local market and application based conventions.

In order to keep the paper as succinct and as clearly arranged as possible, discussions of the following topics:
- Approval requirements per the NEC, OSHA and CEC standards,
- Basic certification requirements of protective and switching equipment for the North American market
- Legal implications of the North American electrical system and,
- Typical North American market conventions

will also be referenced to a comprehensive technical paper already published and entitled „Special considerations governing the application of Manual Motor Controllers and Motor Starters in North America“ [3]. This paper can be requested free of charge from Eaton in both English and German or, as is the case with a host of other North American export related publications, available as a free download from the Internet. As is the case with motor starters, the proper application of circuit breakers in North America needs to take into account many fundamental differences between the requirements of that market for those products, and what is typically applicable and acceptable in the IEC world. The paper will thus elaborate on the above themes only to the extent that it is necessary for an understanding of the material presented herein. In areas where the paper specifically mentions Eaton products, it will be referencing the newly introduced *NZM 1..* through *NZM 4* line of molded case circuit breakers and switches. Similar offerings and solutions from previous generations of Eaton circuit breakers and switches are not being addressed in this paper.

The paper makes references throughout to established North American terminology such as *Branch Circuit, Feeder Circuit, Branch Circuit Protective Device, Short Circuit Current Rating* etc. and did not attempt to substitute equivalent European terms. It was felt that usage of the proper North American references for the purposes of this paper would provide more clarity in the presentation of the informational content.

The US and Canada each possess their own set of applicable electrical standards. For brevity purposes, the paper will often solely specify the applicable US based standard. For the most part, Canada will have a corresponding standard, either very similar to, or in some cases, even harmonized with the US document. Still, there are some outstanding differences remaining in certain key standards from both countries. Generally speaking, however, new standards or changes to existing ones tend to originate mostly in the US, with likely adoption or recognition into the Canadian system at a later date, most often with few changes.

Introduction: Foreign lands, foreign rules

Do you consider yourself a risk taker? It's only natural to think about ways to get around unfamiliar rules, but in the electrical industry business, the consequences of running afoul of local North American inspection authorities can be indeed quite penal. Admittedly, the IEC standards can also present their fair share of seemingly ambiguous regulations, especially when one does not deal with the requirements on a daily basis. As a general rule, Eaton much prefers to follow the wiser route of minimizing risks by clearly understanding the regulations ahead of time so that assembly design and equipment choices are more accurate and easier to plan. It's certainly easier for our clients to have issues resolved in the early stages of a project rather than wait until problems surface down the road. When traveling by car through Europe one has to be aware that individual countries may have their own driving laws and conventions in effect. Travel on the right, or the left, different speed limits etc... all valid reasons for drivers to be aware of, and respect, the travel rules in each visited country. It would be impossible to find someone who could legitimately alter the rules to fit their own particular travel wishes. Even the presence of a good lawyer as a traveling companion wouldn't eliminate all the potential pitfalls of a very unpleasant situation. Alone the risk of breaking unknown laws in foreign countries should be deemed a strong enough deterrent.

A similar parallel can be drawn with respect to global standards for machinery and electrical equipment. Like arbitrarily set speed limits on roads, the rules in electrical standards can sometimes appear haphazardly put together and not always logical. The only sure way, therefore, is to deal with the requirements directly, and ahead of time, however inconvenient that may be. Many of the hurdles can already be satisfied through the use of Eaton certified equipment. On the other hand, potential conflict issues beyond the use of certified product could still develop during the approval process. Some of these are not always explicitely spelled out in the standards. Consulting certification agencies during the design stage is thus another useful way to avoid future problems. Assemblies destined for export to North America and certifed ahead of time, i.e. labeling through a local UL or CSA panel builder, always stand the best chance of a smooth approval process during the commissioning stages at the final destination. If at all possible, direct contact with local approval authorities during the planning stages is also a great way to clarify any issues and misunderstandings which could otherwise become a source of problems at the installation site. Admittedly, that's not always possible, particularly in the case of mass produced machinery whose final destination cannot be known ahead of time. The panel builder should also take into consideration the difficulty of having to subsequently modify an assembly already supplied to a job site in North America. Doing so would inevitably involve the intervention of local electrical contractors to perform the work. If the decision is made to risk the supply of a non-compliant panel, then the panel builder best have a sound back-up plan in place to deal with potentially serious regulatory issues related to the approval process. As a general rule, Eaton recommends to avoid all risks by insuring that all relevant North American requirements in the assembly and design of export related electrical equipment be strictly followed at all times.

Equipment for world markets, or market specific product lines

Differences between electrical standards and market conventions in both Europe and North America, if not properly taken into consideration, can lead to unavoidable delays in the approval process and the need for remedial actions on non-compliant assemblies (e.g. controls for industrial machinery) in North America. The paper describes key design aspects in this respect which are different in both markets as they relate to the application of circuit breakers. The UL 508A [4] standard for *Industrial Control Panels* references at least 70 additional standards which could be of relevance when dealing with electrical control assemblies for industrial machinery. As a manufacturer of electrical components, Eaton makes sure to comply with all the requirements in the relevant product standards at the design stage in order to achieve certification and permit application in these assemblies. Of particular importance is NFPA 79, the electrical standard for industrial machinery.

A comprehensive knowledge base is vital in the ability to design compliant North American electrical assemblies. Having a local presence on the continent can also be an added bonus. The company SAE Schaltanlagenbau Erfurt GmbH is a partner of Eaton as well as a certified UL and CSA manufacturing location, and they can be entrusted to undertake the build and design of compliant electrical assemblies for North America. Eaton can also name additional qualified builders in other parts of Germany who regularly install certified Eaton components in their assemblies. These panel builders are also staffed to competently undertake design and engineering duties.

European and North American Eaton employees are also active participants in important North American standards organizations, which enables them to be on top of all of the latest developments.

Eaton prefers to offer ***world market*** devices whenever a component design is able to satisfy the certification requirements of both the North American and international standards relevant to that product (**Figure 1**). The component is then marked accordingly, and bears rating and certification data from all the major global product standards. Power components such as motor contactors and motor protectors, as well as control circuit pilot and signalling devices, fall into this category. Circuit breakers and molded case switches are often part of separate product lines, partly because the appropriate standards in both major markets tend to be more divergent. But the reasons for the separation go beyond just that, and are rooted in additional certification related expenditures which manufacturers must bear and which are only applicable to product exported to North America. In isolated cases, serious discrepancies between production and certification reports could lead to production stoppage, a potential reality which all manufacturers of certified equipment must face.

The ongoing production of certified equipment is closely monitored by the *Follow-up-Service* department of third party certification agencies. Circuit breakers are also additionally subject to quaterly re-examination testing performed by the *Institute for International Product Safety* (I2PS) in Bonn, which is an accredited facility within the Eaton Group to perform these tests on behalf of the certification agencies. The testing laboratory is thus empowered to independently perform UL and CSA certification testing for interested third party clients such as switchgear manufacturers and panel builders.

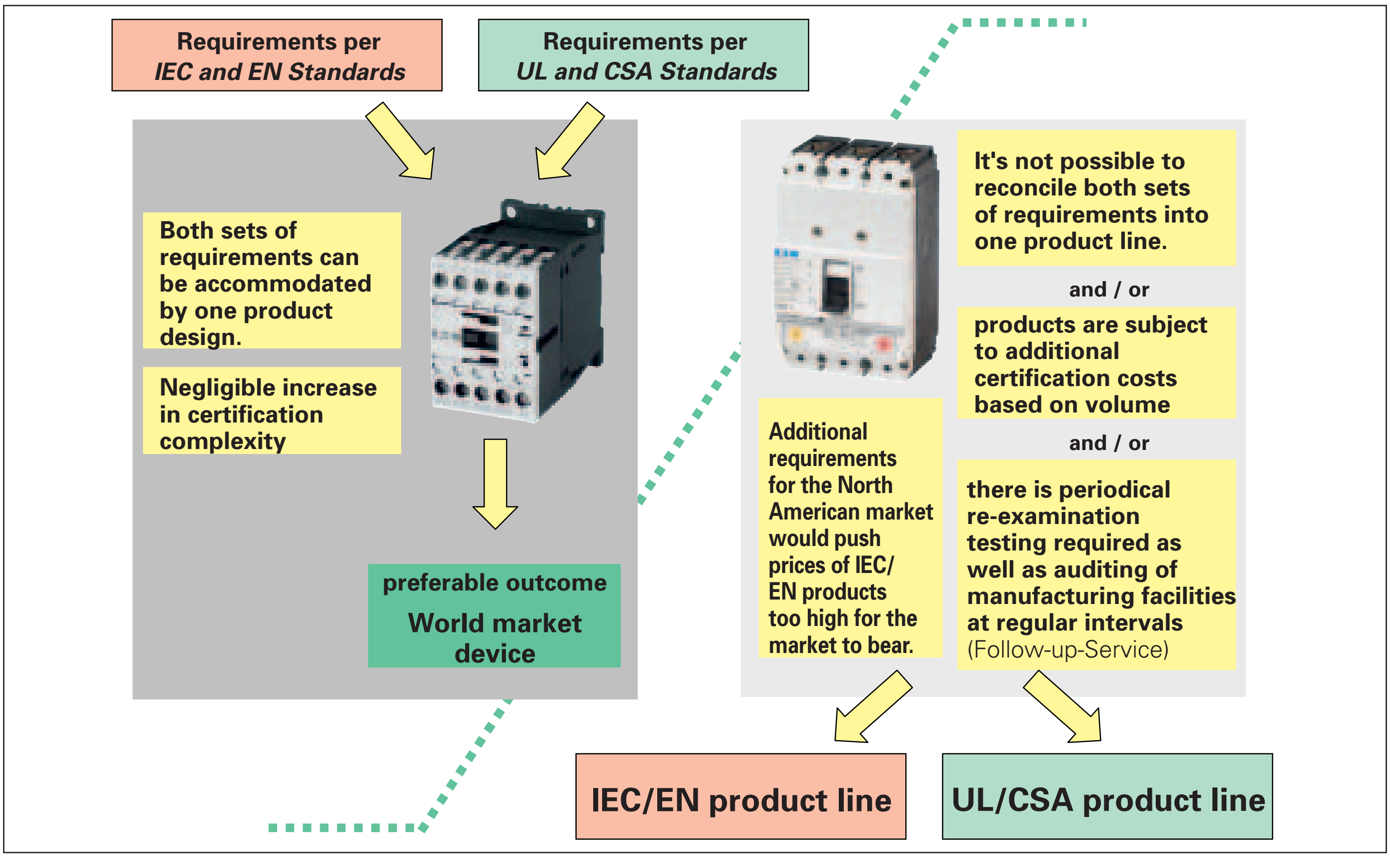


Figure 1: In the interest of manageability from a logistics point of view, Eaton prefers, wherever possible, to offer a single version of a product which carries all necessary certification markings for the global market place. Eaton refers to these components as World Market devices. For certain products, such as circuit breakers, it's not always technically possible to do so, or, certification testing per certain agencies would unnecessarily raise equipment prices for those markets not requiring that particular certification. In those cases, Eaton deems separate product ranges to be the better overall solution for customers. Manufacturers of high volume, serial production machinery will often standardize on products which bear North American certification marks for global usage. That is certainly a viable option as long as the equipment is also in conformity with IEC standards, and bears a CE mark.

Eaton equipment specifically certified for the North American market is identified with the suffix "***-NA***" or "***-CNA***" in the equipment part number. The differences between both types will be described in more detail in a later section entitled „North American certification categories". In Eaton parlance, the „*-NA*" and "*-CNA*", suffixes in the part numbers relate to their suitability for installation in both US and Canadian assemblies.

Also important: IEC rating data and the CE mark on equipment for North America.

The paper is primarily concerned with discussions of export related issues for equipment destined for North America. Naturally, a re-export of equipment back towards the IEC world can also occur. Smaller IEC designs have, in the meantime, gained better acceptance amongst North American firms and the general feeling is that it is better for UL and CSA certified equipment to also bear IEC rating data and the CE mark whenever possible in order to allow their movement back into the European Community and the IEC world at large. Eaton has fulfilled that need with this generation of circuit breakers. Generally speaking, North American users and modern machine manufacturers are very positively inclined towards the advantages that many products which meet the requirements of the international machinery standard IEC/ EN 60 204-1 [7] can offer, case in point the circuit breakers and disconnect switches presented in this paper.

IEC data will thus appear on NA versions of equipment to the extent that the product meets the certification criteria of both standards. Certain NA certified switches also carry worldwide ship approvals, and comply with the certification requirements of Chinese and Russian test agencies. **The IEC rating data, however, only has limited applicability in North American installations and usually serves best as reference information.**

There is also a growing trend amongst larger European serial machine manufacturers, for their world-wide production, to lean towards circuit breakers which also comply with the North American certification requirements. They simply want to avoid stocking two variations of the same switch. It's a sensible cost cutting decision on the part of management to reduce unnecessary inventories, i.e. the IEC switch can't be installed in North America, whereas they are free to globally apply the North American version additionally marked with IEC ratings. In a previous chapter we had described IEC components which met North American requirements as "world-market" devices. Now the trend for circuit breakers seems to be similar, this

<table>
<tr><th colspan="2">Product Groupings in North America</th></tr>
<tr><th>Components for energy distribution
(Distribution Equipment)</th><th>Components for motor control
(Industrial Control Equipment)</th></tr>
<tr><td>e.g. UL 489, 98, 248, and CSA-C22.2 No. 4, 5-09, 248</td><td>UL 508/UL 60947 and CSA-C22.2 No.14</td></tr>
<tr><td>• Molded Case Circuit Breakers (UL 489)
• Molded Case Switches (UL 489)
• Enclosed and dead-front switches (UL 98)
• (Non-)Fusible Disconnect Switches (UL 98)
• Fuses (UL 248)
UL:CSA equivalent standards:
UL 98 : CSA-C22.2 No. 4
UL 248: CSA-C22.2 No. 248</td><td>• Magnetic controllers (contactors)
• Control Relays
• Overload Relays
• Manual Motor Controllers (protectors)
• Rotary Cam Switches
• Pushbuttons and Pilot Devices
• Solid State controls and systems
• Programmable Controllers</td></tr>
<tr><td>Special requirements:</td><td>Special requirements:</td></tr>
<tr><td>• These devices need to be particularly robust in their construction and incorporate larger electrical clearances than standard industrial control equipment:
• (for 301...600 V: 1 Inch through air, 2 Inches over surface).
• Lower permissible temperature rise (50 instead of 70 °C).
• Product designs generally larger in size than IEC equivalent.
• Incoming and outgoing feeder components for energy distribution assemblies (Switchboards, Panelboards) must conform to these standards.
• Main disconnect and protective switches in conformity with these standards are also used in industrial control panel assemblies.
• Safety testing standards for these products are strictly maintained, and factory production quality is closely monitored through regular auditing by each certification agency.
• Quarterly re-examination testing of the production is also conducted by the approval authorities.
• UL/CSA Molded Case Circuit Breaker safety standards are amongst the most stringent in the industry world-wide.</td><td>• These components are constructionally smaller and electrical clearance sizing requirements are not as large as those for 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. in a motor branch circuit together with a circuit breaker used for main disconnect and protective functions.
• Factory production is also monitored by the certification agencies, but not to the same extent as is generally applicable to molded case circuit breakers.
• Generally speaking, more compatible with conventional IEC-designs.</td></tr>
</table>

Table 3: Differences in North American product groupings, based on product safety standards such as UL 489 und CSA-C22.2 No. 5-09 for molded case circuit breakers, and UL 508 und CSA-C22.2 No.14. for industrial control. „UL ..." standards apply primarily in the US, with comparable „CSA..." standards applicable in Canada. UL 98 = [8], UL 248-1 = [9]

time with North American rated breakers and switches bearing IEC ratings and being able to fulfill the definition of a „world-market“ component.

Applications of power components per differing North American standards

As shown in greater detail in **Table 3** a notable differentiation is made in the US and Canada between equipment that is designed primarily for use in supply or feeder circuits (***Distribution equipment***, like molded case circuit breakers per UL 489 [1]) versus that which is more commonly encountered in branch circuits, such as ***Industrial control equipment***, per standards like UL 508 [2]. A list of commonly encountered standards applicable to both product categories is shown in the table. Each places varying sets of requirements on components, depending on which category they fall under. Typically, components will be evaluated per one of the applicable standards. In a later section of the paper we’ll discuss how additional evaluations can sometimes be done to different standards in order to broaden the scope of application for that product, as well as help streamline component selection. An example of this would be UL 489 certification for a circuit breaker and additional calibration tests per UL 508 to permit the breaker to offer motor overload protective capabilities.

The most stringent requirements (such as electrical clearances, interrupting capabilities, robustness, ongoing re-examination testing) are applied to products in the energy distribution category, which also includes circuit breakers. The sequence of tests conducted by UL and CSA for circuit breakers belong to some of the most demanding performance requirements found in standards today. The line drawn between these various product categories is also important to keep in mind when discussing design aspects of products such as circuit breakers and motor controllers as well as understanding the manner in which these various products are properly applied per North American installation requirements.

Certification categories per North American standards

In North America, electrical equipment is subject to third party certification testing and marking. **Table 4** shows various certification categories which are commonly encountered. The type of certification ultimately impacts the selection and manner in which the equipment can be applied in various end-uses. A certification report and marking is the official confirmation that a piece of equipment has met the safety, construction and performance criteria of a given standard. Many of the UL standards in the US have been officially adopted by ANSI as American National Standards.

Eaton chooses to certify its equipment with UL in the US, and CSA in Canada. Along with certification, proper understanding of the regulations is considered key since most of the equipment will be installed in North America. The certification process can also be accomplished through their international agencies and, theoretically, with competitive agencies as well. It’s also possible for UL and CSA to certify equipment for both countries.

In the US, differentiation is made between equipment that is fully UL listed, and can be field installed, versus UL recognized, which is considered to be incomplete and subject to additional application related contingencies before it can be deemed to be acceptable in an end-use product or assembly. This type of certification can be encountered in both **energy distribution** (such as circuit breakers per UL 489 [1]) as well as **industrial control** (per UL 508 [2] / UL 60947) equipment. The certification marks for both categories are different. As mentioned, „listed“ equipment (Part number suffix „***-NA***“ on Eaton circuit breakers and switches) is not subject to any particular application restrictions, whereas „recognized“ (Part number suffix „***-CNA***“) would involve satisfying additional acceptability conditions, such as combining the product with additional components, before it could be deemed suitable for application per the North American electrical installation codes.

The certification agency places higher demands on the proper selection of recognized components, and how these may need to combined with additional equipment in order to complete an end-use product, normally assembled in a certified manufacturing location. Certified manufacturing locations are subject to regular field inspections through agency follow-up service activities (*Follow-up-Service*). Certification reports (*Procedures*) in these locations become an integral part of the manufacturing process and describe the essential marking and constructional aspects of the certified product or assembly. The certified manufacturing location is the only production facility able to assemble and label certified equipment. Products which are listed have been suitably evaluated for field wiring and could be directly installed by an end-user.

Eaton **Type suffix** added to the part number	**Type of certification**	**Certification marks** USA *„Listing“*	Canada *„Certifcation Marks“*
-NA	The device is fully UL listed or CSA certified as a stand-alone component, and suitable for field installation.		
		„Component Recognition“	
-CNA	The device is component recognized by UL, not field installable, and its proper application is subject to conditions of acceptability. (Table 5) The device is CSA certified as a component but may also be subject to specific application conditions.	(application of the mark is optional)	

Table 4: Commonly encountered certification variations and corresponding agency marks, as well as suffixes used in Eaton part number nomenclature. The yellow shaded areas refer to unrestricted application for components so marked, whereas the blue coloring denotes certification marks and suffixes for which specific conditions of acceptability would apply. Refer to Table 5 in this respect for more detailed info on the significance of the respective marks in the US.

Figure 2: Additional UL and CSA certification marks available for producers. Currently, Eaton only makes limited use of a portion of these more specialized marks. The marks from ETL-Intertek represent yet another Nationally Recognized Testing Laboratory in North America, under which components and assemblies could be certified. The additional letters "C" and "US" seen to the left and right of each agency's respective certification marks signify conformity with Canadian and/or US safety requirements respectively.

The situation in Canada and CSA, with respect to products with conditional application capabilities, is very similar, although not as readily discernable through the use of marks as is the case with UL. CSA has begun, relatively recently, to introduce a small yellow triangle mark as a means to alert inspection authorities to products which have demonstrated a history of mis-application per the local electrical codes.

As a general rule, the paper will often make sole reference to the UL standards when discussing a topic. This is done strictly for brevity purposes. CSA does have a number of product standards comparable to UL standards, as referenced in **Table 3** (Page 8), and which are applicable for CSA product certification in Canada. Certain differences do exist between comparable UL- and CSA-Standards, but these will be mentioned whenever they are relevant to the topic at hand. **Figure** 2 also shows additional marks available from UL and CSA but currently, Eaton only makes limited use of these more specialized certifications.

Note: A full UL listing or CSA certification for a product **does not necessarily mean** that the product can be applied in the same manner, or with the same performance capabilities, as is the case in the IEC world. A listed product does not have the same type of restrictions applicable to Recognized components (as highlighted in **Table 5**) but it must still be applied in accordance with the intent of its certification per the North American standards and electrical installation codes. In addition, the electrical ratings which have been established for the product during the certification process will need to be relevant to the manner in which the product is applied (energy distribution or machine control, individual motor starters, elevator controls etc.). The appearance of a listing or certification mark alone does not always guarantee that the product will be suitable for the requirement. It is simply an important step in establishing a basis for the approval mandated in the NEC and CEC electrical codes. Compliance with the requirements of the electrical codes is ultimately the decision of local authorities having jurisdiction (electrical inspectors). In certain jurisdictions, and some large cities *(City Codes)*, locally adopted amendments to these codes could also be a factor in determining the overall approval of the equipment.

As shown in **Tables 6** and **7,** Eaton circuit breakers type *NZM..-...-(C)NA* are offered under three various types of certification. The third is somewhat of a departure from the norm in that the circuit breaker (**Switch style E →** *NZM..-ME..-NA*) is certified as a listed product under UL 489, and as such, can be applied as a normal feeder and branch protective switch, but it also has been additionally evaluated under the UL 508 standard as a motor overload protective device. When it is applied in this manner, i.e. as part of a combination motor starter in branch circuits, it is typically combined with a listed motor contactor. Please refer to the Eaton Main Catalog under the "Circuit Breaker" chapter for additional information on permissible motor starter combinations using this circuit breaker.

Listed equipment **No restrictions when applied per their certification**	***Component Recognized Equipment*** **Application based on conditions of acceptability**
• 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.	• As components, products are suitable for „factory wiring" only. – Components are considered incomplete and could require combinations with other equipment in end-use assemblies – 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 Mark:	Certification Mark:

Table 5: In the US differentiation is made between UL „listed" and „recognized" equipment. CSA does not differentiate certified equipment in the same manner.

Type of certification and application possibilites for UL 489 and UL 508 equipment						
Switch style	**Type**	**Type suffix**	Switch	Test standard certification	Additional evaluation	Special acceptability conditions per UL 508
A	***NS..-...-NA***	***-NA***	*Molded Case Switch**	UL 489	-	-
B.1	***NZM..-S..-CNA***	***-CNA***	*Instantaneous Trip Circuit Breaker*	UL 489	-	**Use together with additional contactor and overload relay****
B.2	***NZM..-SE..-CNA***	***-CNA***		UL 489	-	
C.1	***NZM..-AF..-NA***	***-NA***	*Inverse Time Circuit Breaker*	UL 489	-	-
C.2	***NZM..-AEF..-NA***	***-NA***		UL 489	-	-
C.3	***NZM..-VEF..-NA***	***-NA***		UL 489	-	-
D.1	***NZM..-A..-NA***	***-NA***	*Inverse Time Circuit Breaker*	UL 489	-	-
D.2	***NZM..-AE..-NA***	***-NA***		UL 489	-	-
D.3	***NZM..-VE..-NA***	***-NA***		UL 489	-	-
E	***NZM..-ME..-NA***	***-NA***	*Motor Protective Circuit Breaker*	UL 489	Calibration test per UL 508 for motor overload protection certification	**Typically combined with contactor for motor branch circuits.*****

Type suffix indicates certification
-NA = Listed component ***-CNA*** = Recognized component
* Molded case switches have an integrated trip mechanism for self-protection.
** The instantaneous trip breaker, contactor and overload relay are part of a listed combination motor controller
*** The breaker is part of a listed combination motor controller with Eaton contactors

Application possibilites:
- As a UL 508 combination starter
- As per UL 489 and UL 508

Table 6: Application possibilities for UL 489 and/or UL 508 certified equipment per the North American electrical codes. Certain conditions of acceptability may apply.

Interaction of panel builders and users of certified components

In Europe there are a number of so-called installation standards, e.g. IEC/EN 60 204-1 [7] (Electrical apparatus for industrial machinery) which contain requirements for particular applications that go beyond what an equipment manufacturer alone can provide in terms of conformity. Responsibility for full compliance is also shared by project engineers, panel builders, contractors and/or end-users alike.

A similar situation also exists in North America with respect to compliance with the regulations. A circuit breaker, as a stand-alone component, is normally UL listed and CSA certified. That is certainly an important element, but not necessarily the only prerequisite which guarantees a compliant assembly per North American requirements. Circuit breakers, like those used in motor starter branch circuits, need to be additionally evaluated with motor starter components as complete and stand-alone assemblies (combination motor controllers). The combination ratings are then documented in certification reports and can be used to establish optimal ratings for the assemblies into which they are installed. An example of that would be short circuit current rating (SCCR) requirements for industrial control panels per the NEC and UL 508A standard. This requirement almost nullifies the practice of combining components from various manufacturers which have not been tested as an assembly, since the overall rating of the panel always defaults to the power device with the lowest rating. A drastic reduction in the overall short circuit rating of a panel could thus ensue, and lead to potential safety and approval problems if the suitability of the panel cannot be resolved with the prevalent circuit conditions at the installation site.

A panel builder can also obtain information on certified short circuit rated combination motor starters from various makes directly from UL's on-line resource of information on UL 508A industrial control panel assemblies (http://www.ul.com/controlequipment/shortcircuit.html). Another easy method is to consult individual manufacturer catalogs. For Eaton, that would be the Main Catalogue „Industrial switchgear products", which contains relevant certification data directly on the component selection pages. Additional information can be obtained from the Eaton web site (http://www.eaton.com/moellerproducts).

Equipment certification is always an ongoing process so it's always advisable to keep in touch with Eaton sales engineers for the latest news. They would have access to the most recent updates with respect to product introductions, as well as the latest developments on the standards front to benefit application related solutions for equipment and assemblies. This is especially true for Eaton's line of molded case circuit breakers presented here, since newly updated ratings and adaptations to the product line resulting from changes in the standards can also occur from time to time.

Eaton offers a comprehensive array of accessories for its breaker line, including various operators that are customized for particular applications. The requirements from the industrial machinery standard NFPA 79, and UL 508A, are especially noteworthy in this respect. It's important to re-state that a product certification alone is not sufficient. The equipment must also meet the installation guidelines of the electrical codes (NEC and CEC).

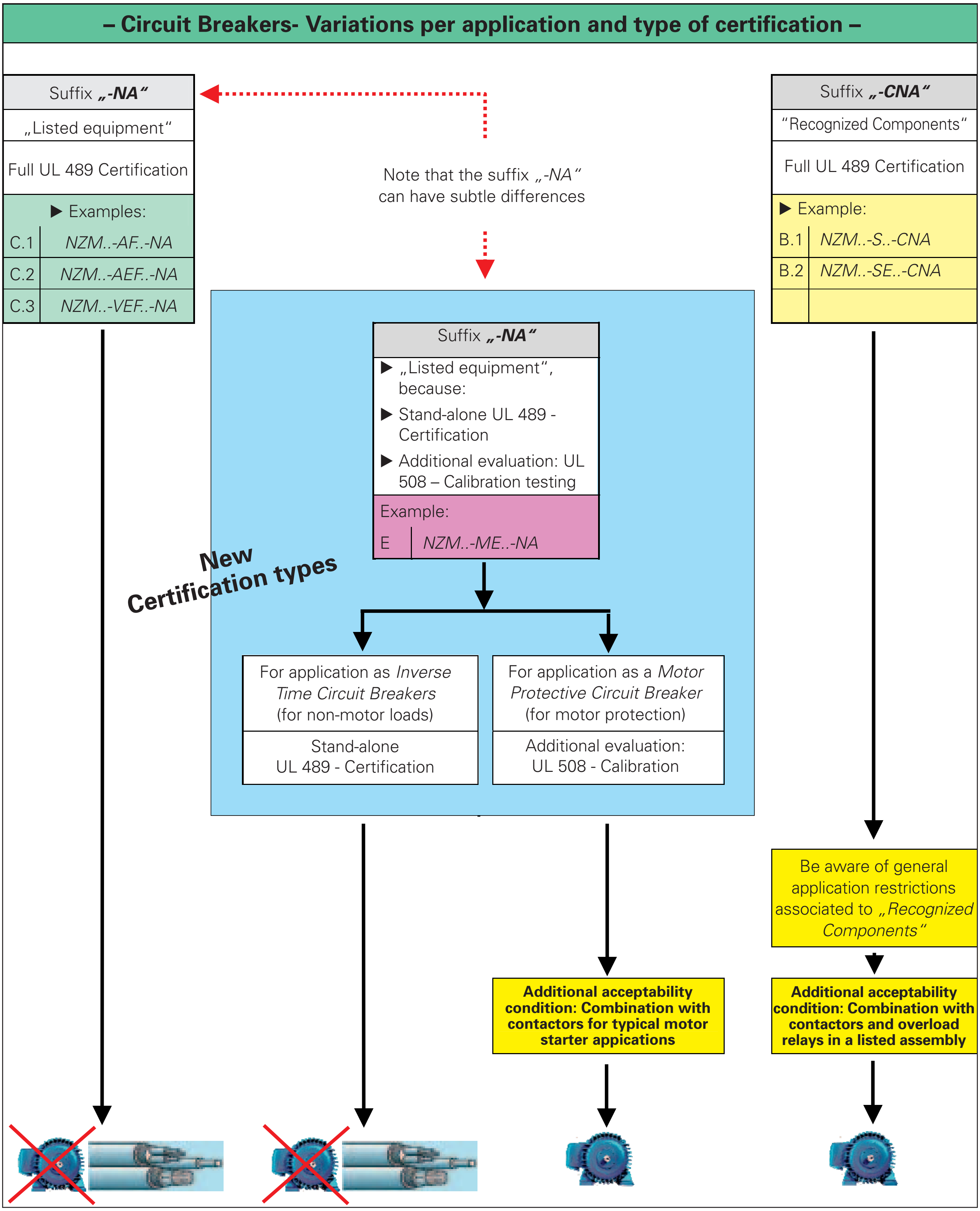
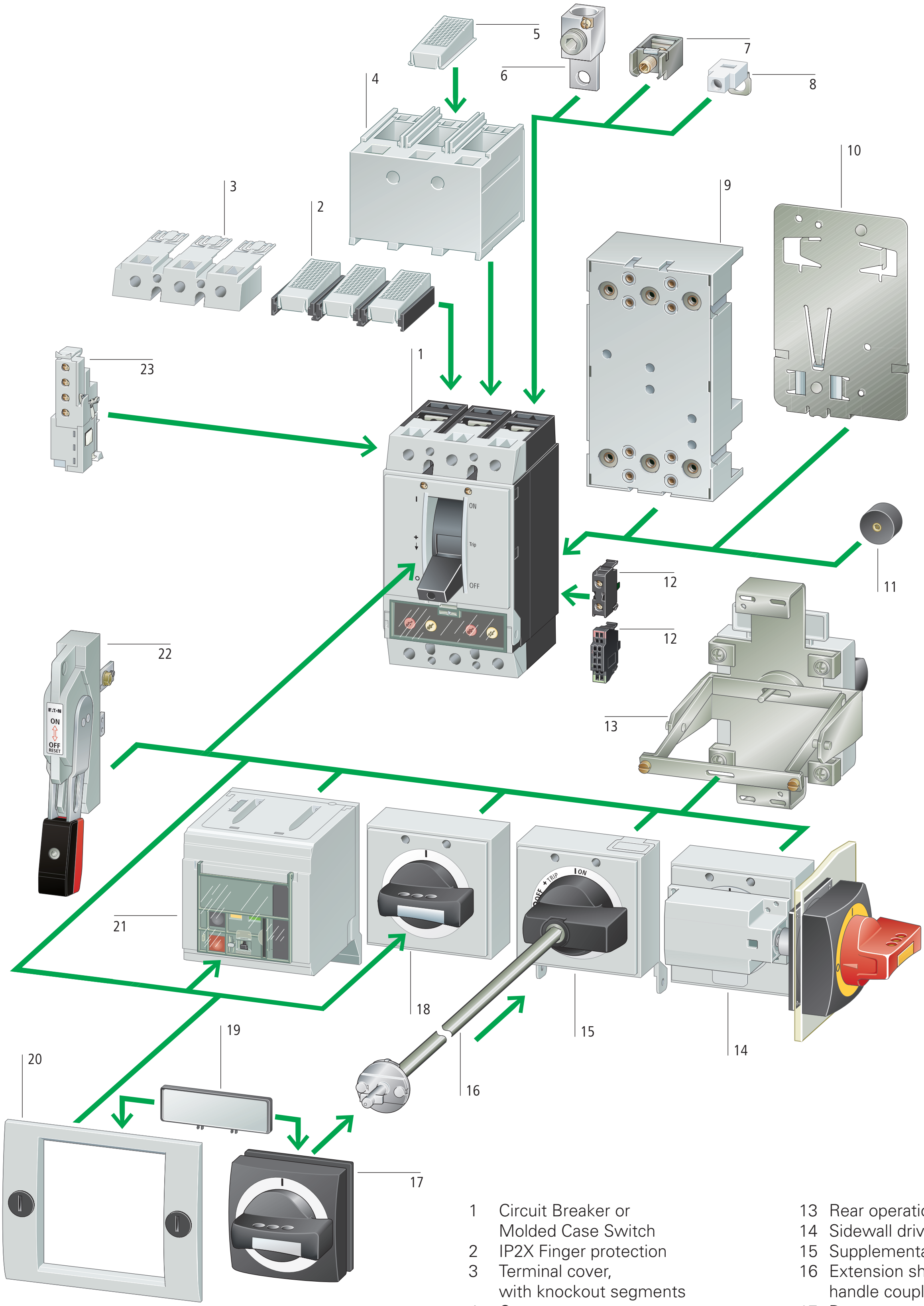


Table 7: Variations in certification categories and application possibilities. Both certification categories on the left hand side of the Table would allow for protection of cables and systems. As described in this paper, such breakers could also be used for generator protection and be suitable for selectivity functions in energy distribution networks.

Overview of the North American product line: Molded Case Circuit Breakers, Switch-Disconnectors and *Molded Case Switches*

As in North America, the rest of the world refers to the type of product covered in this paper under the general heading of "*Molded Case Circuit Breakers*", primarily for their unitized and enclosed construction, as well as their compact design. (**Photo 3**). In the US and Canada, depending on



1 Circuit Breaker or Molded Case Switch
2 IP2X Finger protection
3 Terminal cover, with knockout segments
4 Cover
5 IP2X Finger protection for cover
6 Barrel type termination lugs
7 Box type termination lugs
8 Control circuit terminations
9 Component busbar adapters
10 Clip plate
11 Spacer
12 Single or double auxiliary contacts
13 Rear operation mechanism
14 Sidewall drive mechanism
15 Supplementary handle for NA
16 Extension shaft with door handle coupler
17 Door mounted rotary handle
18 Switch mounted rotary handle
19 Identification label
20 Cutout frame
21 Remote control drive
22 Vertical motion handle for NA
23 Undervoltage and shunt trips

Figure 3: Pictorial overview of the compact molded case circuit breaker line, types NZM1 through NZM4. The range also includes Molded Case Switches, types NS1 through NS4. The diagram shows the essential elements which make up this universally applicable circuit breaker product range. The North American versions feature a 3 pole construction (for 4 pole NA versions, refer to Table 13c), whereas the IEC portion of the line includes 4 pole models as standard, in order to fully accommodate all supply network requirements for that market. Plug-in and withdrawable units are not certified for use on the North American market.

the type of trips they contain, they are also often referred to as „*Inverse Time Circuit Breakers*" (i.e. circuit breakers whose trip response times are inversely proportional to the magnitude of the fault current) or „*Instantaneous Trip Circuit Breakers*" (circuit breakers without any overload trip function, commonly found in motor starter circuits.) There are noteworthy differences in the constructional approach of non-automatic switches (switches with no protective functions), in particular between the Type N, IEC style "Switch-Disconnectors", and UL/CSA certified type NS *Molded Case Switches*, which the paper will describe in more detail in a separate chapter.

Table 8 shows the line-up of *NZM 1*, *NZM 2*, *NZM 3* und *NZM 4* circuit breakers along with certified current ratings for each respective frame size. The **Table** also differentiates between breakers with conventional electro-mechanical trips versus those with electronic tripping means. Circuit breakers with full inverse time tripping capabilities can be used for *cable and systems* protection. The following breakdowns apply:

- **Switch style B** – Circuit breakers **without** overload trips
- **Switch style C** – Circuit breakers **with fixed** overload trips and
- **Switch style D** – Circuit breakers **with adjustable** overload trips

Switch style B (*NZM..-**S**..-CNA, NZM..-**SE**-CNA*) without overload trips, are very seldom used in the IEC world, and **Switch style C** (*NZM..-**AF**..-NA, NZM..-**AEF**..-NA, NZM..-**VEF**..-NA*), with fixed overload trips, are almost never encountered. **Table 8** also refers to a number of circuit breaker nominal current ratings which are not being offered in the IEC range. Although production volumes for Eaton's IEC devices outnumber the quantities of product manufactured for the North American market, the assortment selection of UL/CSA certified devices is quite a bit more diverse.

Each additional version can trigger additional costs, e.g. for the global logistical picture, and can complicate planning from the user's point of view, since there are more types to deal with and potentially more inventories to carry. The variety in North American product offerings is certainly justified from an application point of view, even though the rest of the IEC world seems to get by fine and without being unduly restricted by the lesser amount of variety. On the other hand, the North American market, and especially the indirect export business originating from the EU, is so strategically important that Eaton fully justifies the need to offer a more complete line and cater to the special requirements of that market. The paper should help clarify the assortment of models and simplify the selection process.

Table 9 follows by providing additional information on breakers with undelayed and delayed short circuit trips. **Switch styles B**, **C** and **D** are further differenti-

Rated nominal currents In of North American molded case circuit breaker versions

Suitable for systems- and cable protection, 3 pole, with short circuit trips *("-NA" versions only, with overload trips).* Certified per UL 489 and CSA -C22.2 No. 5-09

	Breakers with thermal-magnetic trips			
	Without overload trips For these switch types, I_u relates only to the adjustable instantaneous trip setting ranges $I_n = I_u$ [A]	**Fixed** overload trip settings $I_n = I_u$ [A]	**Adjustable** overload trip settings $I_n = I_u$ [A]	Adjustable overload trip setting ranges I_r
NZM 1 ...- (C)NA	1.2, 2, 3, 5, 8, 12, 18, 26, 33, 40, 50, 63, 80, **100**	20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, **125**	20, 25, 32, 40, 50, 63, 80, 100, **125**	0,8 ... 1 x I_u
NZM 2 ...-(C)NA	1.6, 2.4, 5, 8, 12, 18, 26, 33, 40, 50, 63, 80, 100, 125, 160, 200, **250**	15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175 200, 225, **250**	20, 25, 32, 40, 50, 63, 80, 100, 125,160, 200, **250**	0,8 ... 1 x I_u
	Breakers with electronic trips			
	Without overload trips For these switch types, I_u relates only to the adjustable instantaneous trip setting ranges $I_n = I_u$ [A]	**Fixed** overload trip settings $I_n = I_u$ [A]	**Adjustable** overload trip settings $I_n = I_u$ [A]	Adjustable overload trip setting ranges I_r
NZM 2 ...-(C)NA	90, 140, **220**	150, 175, 200, 225, **250**	100, 160, **250**	0,5 ... 1 x I_u
NZM 3 ...-(C)NA	220, 350, **450**	250, 300, 350, 400, 450, 500, 550, **600**	250, 400, **600**	0,5 ... 1 x I_u
NZM 4 ...-NA	-	600, 700, 800, 900, 1000, **1200**	800, 1000, **1200**	0,5 ... 1 x I_u
Switch type:	**Style B**	**Style C**	**Style D**	

Table 8: UL 489 and CSA -C22.2 No. 5-09 certified molded case circuit breakers for the North American market are offered in a third variation consisting of fixed overload or long time response trip settings. „NA" switches, which are also in conformity with IEC standards, also bear ratings in accordance with the relevant IEC/EN 60947 component standard. This greatly simplifies the export from North America into the IEC world.

240 V 60 Hz		Rated current I_n [A]																	
		20 …	50	125	…	…	250	300	350	400	450	500	550	600	700	800	900	1000	1200
Basic	35 kA	NZM B1																	
	35 kA	NZM B2																	
Normal	85 kA	NZM N1																	
	85 kA	NZM N2						NZM N3							NZM N4				
High	125 kA														NZM H4				
	150 kA	NZM H2						NZM H3											
	200 kA	NZM H2 1)																	
480 Y/277 V 60 Hz																			
Basic	25 kA	NZM B1																	
	25 kA	NZM B2																	
Normal	35 kA	NZM N1																	
	35 kA	NZM N2																	
	42 kA							NZM N3							NZM N4				
High	85 kA														NZM H4				
	100 kA	NZM H2						NZM H3											
	150 kA	NZM H2 1)																	
480 V 60 Hz																			
Basic	25 kA	NZM B2																	
Normal	35 kA	NZM N2																	
	42 kA							NZM N3							NZM N4				
High	85 kA														NZM H4				
	100 kA	NZM H2						NZM H3											
	150 kA	NZM H2 1)																	
600 Y/347 V 60 Hz																			
Basic	18 kA	NZM B2																	
Normal	25 kA	NZM N2																	
	35 kA							NZM N3							NZM N4				
High	50 kA	NZM H2						NZM H3							NZM H4				
	65 kA	NZM H2 1)																	
600 V 60 Hz																			
Normal	35 kA							NZM N3							NZM N4				
High	50 kA							NZM H3							NZM H4				

1) *NZMH2-A15-NA ... NZMH2-A125-NA, NZMH2-AF15-NA ... NZMH2-AF125-NA*

Figure 4: Interrupting capacity of various circuit breaker frame sizes at standard North American supply voltage ratings and per UL and CSA (NEMA) test procedures. The values correspond to the assigned Short Circuit Current Ratings (SCCR) of individual breakers.

ated in **B.1**, **B.2**, **C.1**, **C.2**, **C.3**, **D.1**, **D.2** and **D.3** variations.

Table 9 also provides more details on the line of switch-disconnectors/molded case switches, **Switch style A** (***NS***..- ..-*NA*). All Eaton circuit breakers and switches fulfill the requirements the IEC/EN 60 947-3 [11] standard for switch and load disconnectors, in addition to all applicable portions of the basic circuit breaker product norm IEC/EN 60 947-2 [10]. **Table 9** (page 16) also includes application related information for the products shown.

UL 489 **listed and** CSA-C22.2 No. 5-09 certified circuit breakers shown in **Table 9** meet the constructional (large electrical clearances) and interrupting rating requirements of distribution equipment and can be used as protective switches in those assemblies *(typically switchboards, panelboards, busways etc…,)*. In addition, **Switch style E** *(NZM..-**ME**..-NA)***,** has been additionally evaluated per UL 508 and CSA-C22.2 No. 14 to provide the motor overload protective capability in motor branch circuits. The **Table** does not include information on the necessity of additional power circuit components required for certain applications. (to be elaborated on later in the paper).

Various interrupting rating levels available for North American breakers further expand the line, just as is the case with

Selection criteria for molded case circuit breakers and switches for the North American market.							
Style	**Type**	Certification for the US	Certification for Canada	Additional application related evaluations for the US and Canada	Overload protection	Short Circuit protection undelayed	delayed
A	***NS..-...-NA***	UL 489	CSA-C22.2 No 5-09	-	-	Internally self-protected	-
B.1	***NZM..-S..-CNA***	UL 489	CSA-C22.2 No 5-09	-	-	EM	-
B.2	***NZM..-SE..-CNA***	UL 489	CSA-C22.2 No 5-09	-	-	EL	-
C.1	***NZM..-AF..-NA***	UL 489	CSA-C22.2 No 5-09	-	EM, fixed	EM	-
C.2	***NZM..-AEF..-NA***	UL 489	CSA-C22.2 No 5-09	-	EL, fixed	EL	-
C.3	***NZM..-VEF..-NA***	UL 489	CSA-C22.2 No 5-09	-	EL, fixed	EL	EL
D.1	***NZM..-A..-NA***	UL 489	CSA-C22.2 No 5-09	-	EM, adjustable	EM	-
D.2	***NZM..-AE..-NA***	UL 489	CSA-C22.2 No 5-09	-	EL, adjustable	EL	-
D.3	***NZM..-VE..-NA***	UL 489	CSA-C22.2 No 5-09	-	EL, adjustable	EL	EL
E	***NZM..-ME..-NA***	UL 489	CSA-C22.2 No 5-09	Calibration test per UL 508 and CSA-C22.2 No.14	EL, adjustable	EL	-

EM = Electro-Magnetic EL = Electronic

Table 9: Various differences in Eaton circuit breaker and switch offerings for the North American market with respect to design, type of certification and range of application. All switch variations are suitable for energy distribution systems, with the exception of Instantaneous-only circuit breaker styles B.1 and B.2 which are for individual motor circuits only. Switch style „E" are suitable for motor circuits as well, and are typically combined with a motor contactor for combination motor controller branch circuit application purposes.

IEC rated devices. Interrupting rating refers to the highest current rating at rated voltage that the breaker is able to clear under short circuit conditions. Interrupting level capabilities are determined to a large extent by constructional features of the design, and will also influence price levels. Different levels of interrupting capability will provide the panel builder with additional flexibility in matching the breaker to the technical requirements of the application as well as help keep pricing better in line with the need. Interrupting ratings for North America and the IEC world are done per different standards and at different voltage levels. Thus the differences seen in values attained for both markets.

Table 10 presents the interrupting levels of the breaker line for both IEC and North American markets. Interrupting ratings are always a function of the distribution voltage level at which they are determined. This relationship is highlighted in **Figure 4** for the North American values. The interrupting rating of the breaker corresponds to its short circuit current rating *(SCCR)*. The SCCR values for the combination of a breaker and an additional power circuit component, such as a contactor, can be higher simply due to the additional sets of contacts in the circuit which can contribute to help clear a fault.

Table 11 presents the rating data for the new, North American style molded case switches (**Switch syle A**) (*NS..-..-NA*) (refer also to chapter „Switch-disconnector *N* or *Molded Case Switches NS*"). **Table 12** is more or less a compilation of the information from **tables 8 through 11** (8: page 14, 9: page 16, 10: page 17, 11: page 18) with specific reference to nominal current ratings.

"Typical North American" circuit breakers in energy distribution circuits

- **for non-motor loads**

„Typical North American" circuit breakers for energy distribution circuits have either fixed overload and fixed instantaneous thermal-magnetic trip systems, fixed overload and adjustable instantaneous thermal-magnetic trip systems, or adjustable electronic trip systems. Circuit breakers of this variety are fully listed per **UL 489 or certified per CSA-C22.2 No. 5-09,** and typically provide both overload and instantaneous short circuit protection of non-motor circuits. **Eaton** also offers a ***fixed overload electronic*** trip response breaker for the North american market.

The fixed overload trip response versions are offered under the part numbers ***NZM...AF..-NA*** (thermal-magnetic) und ***NZM... AEF..-NA*** (electronic) . Breakers with fixed overload trips are not commonly used in the IEC world. This version appears in the tables throughout the paper as **Switch styles C.1** and **C.2** A third version of this variety, **Switch style C.3** (*NZM..-**VEF**..-NA*) features additional short circuit trip responses to make them more suitable in circuits with selective co-ordination.

Circuit breakers with fixed overload trip responses can be found in energy distribution assemblies as either incoming or outgoing protective switches in feeder and branch circuits. As circuit breakers, they also fulfill the function of a main disconnect switch per the electrical codes. They are also commonly used as alternatives to fuses in the protection of industrial control equipment falling under the North American UL 508 and CSA-C22.2 No.14 product standards and as protective switches in industrial control assemblies such as *Industrial Control Panels* and *Motor Control Centers*. They provide feeder protection

Main application	Supplementary applications
Molded Case Switch	Main and Emergency-OFF disconnect
Short circuit protection	Main and Emergency-OFF disconnect, for **individual** motor starters only
Short circuit protection	Main and Emergency-OFF disconnect, for **individual** motor starters only
Cable and systems protection	Main and Emergency-OFF disconnect
Cable and systems protection	Main and Emergency-OFF disconnect
Cable, systems and generator protection, selectivity	Main and Emergency-OFF disconnect
Cable and systems protection	Main and Emergency-OFF disconnect
Cable and systems protection	Main and Emergency-OFF disconnect
Cable, systems and generator protection, selectivity	Main and Emergency-OFF disconnect
Cable and systems protection, motor protection	Main and Emergency-OFF disconnect

as well as branch circuit protection for various loads. (**Figure 5**) [12].

- **Motor loads**

North Americans use fixed trip circuit breakers fairly commonly. Because the breaker fixed overload trip response[2] is not calibrated for overload protection, there is a need to add a separate motor overload relay, along with a motor contactor, to form the basis for a combination motor starter (UL/CSA *Construction Type C, Combination Motor Starters)* The fixed trip breaker provides conductor overload and short circuit protection whereas the separately mounted overload relay provides the motor overload

2 UL 489 certified circuit breakers in the US, whether equipped with fixed or adjustable long time (overload) response trips, are considered the same. The adjustable overload trip feature of a breaker does not necessarily offer a protective advantage. Both types are not considered suitable as stand-alone devices for the overload protection of motors

Molded Case Circuit Breakers for North America
Short circuit interrupting ratings per UL/CSA/NEMA and IEC test procedures

Switch Type	UL / CSA / NEMA Test Procedure					Breaking capacity I_{cu} per IEC 60 947		
	240 V 60 Hz sym. rms [kA]	480 Y/277 V 60 Hz sym. rms [kA]	480 V 60 Hz sym. rms [kA]	600 Y/347 V 60 Hz sym. rms [kA]	600 V 60 Hz sym. rms [kA]	400/415 V 50/60 Hz [kA] / cos φ	440 V 50/60 Hz [kA] / cos φ	690 V 50/60 Hz [kA] / cos φ
Basic Interrupting Rating B								
NZMB1-...-NA	35	25	-	-	-	25 / 0.25	25 / 0.25	-
NZMB2-...-NA	35	25	25	18	-	25 / 0.25	25 / 0.25	-
Normal Interrupting Rating N								
NZMN1-...-NA	85	35	-	-	-	50 / 0.25	35 / 0.25	10 / 0.50
NZMN2-...-NA	85	35	35	25	-	50 / 0.25	35 / 0.25	20 / 0.30
NZMN2-...E...-NA	85	35	35	25	-	50 / 0.25	35 / 0.25	20 / 0.30
NZMN3-...E...-NA	85	42	42	35	35	50 / 0.25	35 / 0.25	20 / 0.30
NZMN4-...E...-NA	85	42	42	35	35	50 / 0.25	35 / 0.25	20 / 0.30
High Interrupting Rating H								
NZMH2-...-NA	150	100	100	50	-	150 / 0.20	130 / 0.20	20 / 0.30
NZMH2-A…-NA[1)]	200	150	150	65	-	150 / 0.20	130 / 0.20	20 / 0.30
NZMH2-AF…-NA[1)]	200	150	150	65	-	150 / 0.20	130 / 0.20	20 / 0.30
NZMH2-...E...-NA	150	100	100	50	-	150 / 0.20	130 / 0.20	20 / 0.30
NZMH3-...E...-NA	150	100	100	50	50	150 / 0.20	130 / 0.20	35 / 0.30
NZMH4-...E...-NA	125	100	100	50	50	150 / 0.20	130 / 0.20	50 / 0.25

Ratings in the latest main catalog are binding!

1) NZMH2-A15-NA through NZMH2-A125-NA and NZMH2-AF15-NA through NZMH2-AF125-NA

Table 10: Comparison of short circuit interrupting ratings of various molded case circuit breaker frame sizes and switch types per comparable North American and IEC circuit breaker standards. The North American ratings are not identical to the IEC ratings. Breakers with 480Y/277VAC and 600Y/347V slash voltage ratings are suitable for installations in solidly grounded wye networks only. The short circuit interrupting ratings of each circuit breaker type corresponds to the device's overall short circuit current rating (SCCR). Short circuit ratings of instantaneous trip circuit breakers (without overload trips) are assigned only to the overall combination of a breaker, contactor and overload relay in a listed combination motor controller assembly.

Switch-Disconnectors for North America								
Switch-Disconnectors for North America with internal self-protective trips **Molded Case Switches** Certified per UL 489 and CSA-C22.2 No. 5-09							**Switch style A**	
Nominal current = Rated continuous current	Switch internally self-protects up to its maximum rated short circuit rating SCCR *					Internal self-protective instantaneous trip response current	**Type**
$I_n = I_u$ [A]	240 V [kA]	480 Y/277 V [kA]	480 V [kA]	600 Y/347 V [kA]	600 V [kA]	[A]	
63	85	35	-	-	-	1250	*NS1-63-NA*
100	85	35	-	-	-	1250	*NS1-100-NA*
125	85	35	-	-	-	1250	*NS1-125-NA*
160	150	100	100	50	-	2500	*NS2-160-NA*
200	150	100	100	50	-	2500	*NS2-200-NA*
250	150	100	100	50	-	2500	*NS2-250-NA*
400	150	100	100	50	50	6600	*NS3-400-NA*
600	150	100	100	50	50	6600	*NS3-600-NA*
800	85	65	65	42	42	25000	*NS4-800-NA*
1000	85	65	65	42	42	25000	*NS4-1000-NA*
1200	85	65	65	42	42	25000	*NS4-1200-NA*

Ratings in the latest main catalog are binding!

* **SCCR = Short Circuit Current Rating per UL 508A**

Table 11: North American molded case switches per UL 489 and CSA-C22.2 No. 5-09 have an internal instantaneous trip for self-protection. This is the most commonly encountered design in North America for these switch types. They can be equipped with undervoltage or shunt trips accessories to help trip them open electrically from a remote location. Molded case switches are used mainly as supply circuit and emergency-off disconnect switches. Type NS2-…-BT-NA switches are available with factory supplied line and load box terminals. Type NS1-...-NA switches come standard with line and load box terminals.

protection with trip responses not exceeding those mandated by the electrical codes (certain correction factors may also apply). This type of solution, i.e. with 2 overload protective devices in the circuit, would be difficult to defend in the IEC world from both an economical viewpoint, as well as from a technical perspective in view of the supplementary heat losses provided by the additional component. Furthermore, the required space for the starter is greater, as well as the assembly and wiring time. The solution does not lend itself well for export purposes in applications with motor currents up to 200A. Above 200A, a 3 component solution featuring a fixed trip inverse time breaker may be more justifiable technically.

Eaton offers the fixed trip breakers per **Table 12** in current ranges from 20A through 1200A, and at various short circuit interrupting rating levels commonly encountered in North America. Tables **13a, 13b** and **13c, resp. 14** show all available variations of these breakers. They are selected per their nominal current and interrupting rating. If they are equipped with auxiliary contacts, appropriate rating data (such as Pilot Duty [3]) is also provided on the breaker.

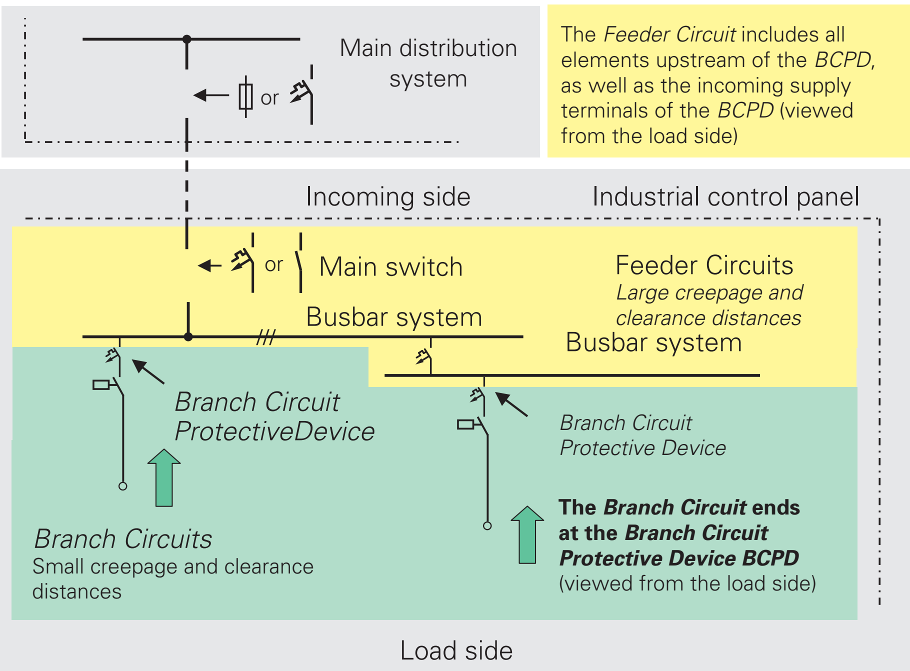


Figure 5: There is a differentiation made in North America between Feeder Circuits and Branch Circuits. The Figure shows a portion of the electrical controls for an industrial machine assembly (Industrial Control Panel for Machinery). The best way to properly assess the line between both circuits is to look at it from the load side, back towards the power source. The branch circuit terminates at the protective device, which is appropriately referred to as the Branch Circuit Protective Device (BCPD). Branch Circuit Protective Devices consist mostly of molded case case circuit breakers and fuses, but in certain cases, like individual motor circuits for example, the branch circuit protective function could be fulfilled by a UL 508 Type E Self-Protected combination motor controller, or a Type F combination motor controller.

Circuit breakers with adjustable overload trips

In addition to fixed overload trip response breakers, a variation with adjustable overload trips (as is typical in the IEC world), is offered as an alternative. These breakers are similarly listed and certified in North America as protective switches for cable and systems. They are referenced in the paper as **Switch style D.1** (*NZM..-* ***A****..-NA*) and **D.2** (*NZM..-****AE****..-NA*) (**Tables 15 and 16).** These circuit breakers are also not suitable for motor overload protection since they have not been additionally evaluated per UL 508 for that capability. **Switch style D.3** (*NZM..-****VE****..-NA*), have additional trip response functions that make them ideally suited per **Table 9** (page 16) for applications like generators, transformers and circuits with selective co-ordination. (refer to chapter **„Circuit breakers for special applications on the North American market"**)

Motor protection/Systems protection

Eaton refers to its PKZM... compact line of circuit protective devices for currents up to 65A as „Motor Circuit Protectors". These motor protective devices have a built-in single phasing differential trip feature in compliance with the IEC/EN 60947-4-1 standard. This single phasing sensitivity can be a problem when the devices are used as protective switches in non-motor load circuits, because an asymmetrical loading of phases, which can commonly occur in such circuits when phases are being individually tapped, could cause nuisance tripping. For this reason, Eaton offers so-called "systems protection" devices in that product line, e.g. PKZ2 switches which, as is typical of circuit breakers, do not carry that feature. The special *motor protective circuit breakers* discussed and presented in this paper, however, *do* have a built-in characteristic feature that makes them sensitive to single phasing conditions in motor circuits.

Additional requirements for circuit breakers in motor protective applications

Without the addition of a contactor and overload relay, the afore-mentioned certified circuit breaker types ***NZM...A(E) F..-NA*** (**Switch style C.1** and **C.2)** are used primarily as protective devices in feeder and non-motor load branch circuits. These breakers are not as readily suited for direct motor overload protective functions since they have a fixed setting and cannot be set exactly to the motor full load current. Furthermore, their overload trip function has not been additionally evaluated for protection of motors. Independent of the overload trip adjustability factor, there is somewhat of a parallel between North American and IEC standards as it relates to motor protection, since there would also be a need in the IEC world to pull in performance requirements from additional standards in order to verify the capability of a circuit breaker for the application. The circuit breaker standard IEC/EN 60 947-2 [10] alone does not include any provisions to verify a breaker's suitability for motor overload protection. Thus, in the IEC world, specific requirements from the motor starter standard IEC/ EN 60 947-4-1 [13] would need to be introduced for this purpose. That standard specifically describes actual trip curve calibration requirements for motor overload protection, which are not addressed in the circuit breaker standard, and also specifies trip class designations. The optional inclusion of the differential single phasing sensitivity protection function is also part of the IEC/EN 60 947-4-1 motor starter standard. The standard further includes provisions for verifying „Type 1" and „Type 2" protection co-ordination values for combination motor starters. These same co-ordination values have also now been incorporated into the newly introduced UL 60947 [14] standard as part of the ongoing harmonization effort. Although not part of North American standards up to that point, Type 2 co-ordination taken from the IEC standard had been the focus of special requests made to electrical equipment manufacturers by large North American firms as a way to improve motor starter protection levels in their own facilities. Testing agencies in North America, such as UL, had been able to accommodate requests for third party verification of these starters solely through their classification program, which usually involved the issuance of a letter report as opposed to a listing mark. With the introduction of the UL 60947 standard, UL will now be able to grant the more preferred listing mark for such assemblies. Single phasing sensitivity per the IEC definition has also been increasingly requested in motor protective component specifications by large end-users.

In order to be performance verified for the direct overload protection of motors, circuit breakers in North America must first be fully certified as stand-alone circuit breakers per the relevant product standards (such as UL 489) and then be additionally evaluated per the calibration requirements of the industrial control standard (such as UL 508 and CSA-C22.2No.14). Per these North American standards a 3 phase overlod protective device (such as the one discussed here) would have to demonstrate, among other tests, acceptable tripping responses when loaded on 2 phases at 600% and 200% of a given motor load current. This test is very broadly comparable to the IEC single phasing sensitivity verification. North American calibration tests also involve differentiation between various trip classes (Class 10, 20 or 30).

Note: Consideration must be made for the fact that, at higher trip classes, a larger current will be expected to flow for a longer time. This will produce greater thermal stresses for the entire circuit, including cables and switching devices, which need to be sized for the increased burden accordingly.

In the IEC world, circuit breakers with motor protective and (IEC) switching capabilities are deemed suitable for occasional and intentional switching of motors directly on line. In North America, the electrical codes also permit this function for listed and certified inverse time circuit breakers, as well as for molded case switches. Typically, however, circuit breakers in North America are used with separate components in motor branch circuits, such as contactors and overload relays. And, as previously mentioned, circuit breakers that would provide the motor overload protection function must also be additionally evaluated for that purpose per the industrial control standards (refer to next section).

Requirements for motor starters on the North American market

At this point, additional information on the topic of motor starters is presented in order to help provide a clearer overview. In North America, the electrical codes require the motor branch circuit to fulfill 4 essential functions: (**Figure 6**)

- Isolation (Main disconnect),
- Short circuit protection,
- Motor switching or controller (with controller or e.g. with motor contactor/ inverter)
- Overload protection

These 4 functions can be accomplished in the IEC world with a single circuit breaker or motor protector, assuming the equip-

Style	Trip types	Overload	without	fixed	adjustable	Short circuit	undelayed	delayed	Interrupting rating	NZM .. – .. :	1.2	1.6	2	2.4	3	5	8	12	15	18	20	25	26	30	32	33	35	40
A						*	*			1																		
						*	*			2																		
						*	*			3																		
						*	*			4																		
B.1	EM		x				x		**B,N**	1	x	-	x	-	x	x	x	x	-	x	-	-	x	-	-	x	-	x
	EM		x				x		**B,N,H**	2	-	x	-	x	-	x	x	x	-	x	-	-	x	-	-	x	-	x
B.2	EL		x				x		**N,H**	2																		
	EL		x				x		**N,H**	3																		
C.1	EM			x			x		**B,N**	1											x	x	-	x	-	-	x	x
	EM			x			x		**B,N,H**	2									x	-	x	x	-	x	-	-	x	x
C.2	EL			x			x		**N,H**	3																		
	EL			x			x		**N,H**	4																		
C.3	EL			x			x	x	**N,H**	2																		
	EL			x			x	x	**N,H**	3																		
	EL			x			x	x	**N,H**	4																		
D.1	EM				x		x		**B,N**	1											x	x	-	-	x	-	-	x
	EM				x		x		**B,N,H**	2											x	x	-	-	x	-	-	x
D.2	EL				x		x		**N,H**	3																		
	EL				x		x		**N,H**	4																		
D.3	EL				x		x	x	**N,H**	2																		
	EL				x		x	x	**N,H**	3																		
	EL				x		x	x	**N,H**	4																		
E	EL				x		x		**N,H**	2																		

Style = Switch style, refer to Table 6 (Page 11)
* = Internal instantaneous trip for switch self-protection
Trip types: EM = Electro-magnetic , TM = Thermal-magnetic, EL = Electronic

Interrupting Rating:
B = Basic
N = Normal
H = High

= Molded case switch

For specific interrupting ratings refer to Table 10 (Page 17)

Table 12: Exact correlation of breaker styles with respect to rated currents, interrupting rating levels and trip types.

ment in question has met the additional conformity provisions of the IEC/EN 60 947-4-1 motor starter standard. The addition of a contactor is made solely and freely upon need, i.e. in cases where a high degree of switching frequency is required for the application, or longer life for the equipment is desired.

The electrical codes do permit the use of a certified inverse time circuit breaker for the controller function so that all Eaton circuit breakers listed and certified for the North American market (Type suffix "-NA") would fulfill the requirement. Typically though, the majority of circuit breakers used in motor branch circuits in North America are combined with contactors and separate overload relays and certified as complete combination motor starter assemblies with their own assigned short circuit rating (SCCR). As is the case for both North America and the IEC world, the use of a separate motor contactor for motor loads represents the most advantageous solution in most applications, especially for high motor switching frequency requirements and certainly whenever motor starter operation needs to be fully automated.

The following info applies to the smaller frame Type PKZM motor protectors and similar designs from other makes, which have current ratings falling below those of the *NZM 1 … NZM 4* circuit breaker line [3]:

Note: Per North American standards, the typical European style manual motor protector is commonly certified in North America as a UL 508 listed, HP rated "**manual motor controller**" capable of providing motor overload protection only. They are not recognized as having a stand-alone short circuit protective capability. Unlike the IEC world, these components require an additional upstream protective device per the electrical codes. Protective devices consist of listed fuses or inverse time molded case circuit breakers. The electrical codes allow the possibility of grouping the controllers under a single back-up protective device if they are certified accordingly. All Eaton motor protectors fulfill this

45	50	60	63	70	80	90	100	110	125	140	150	160	175	200	220	225	250	300	350	400	450	500	550	600	700	800	900	1000	1200
			x	-	-	-	x	-	x																				
												x	-	x	-	-	x												
																				x	-	-	-	x					
																										x	-	x	x
-	x	-	x	-	x	-	x																						
-	x	-	x	-	x	-	x	-	x	-	-	x	-	x	-	-	x												
						x	-	-	-	x	-	-	-	-	x														
															x	-	-	-	x	-	x								
x	x	x	-	x	x	x	x	x	x																				
x	x	x	-	x	x	x	x	x	x	-	x	-	x	x	-	x	x												
																	x	x	x	x	x	x	x	x					
																								x	x	x	x	x	x
											x	-	x	x	-	x	x												
																	x	x	x	x	x	x	x	x					
																								x	x	x	x	x	x
-	x	-	x	-	x	-	x	-	x																				
-	x	-	x	-	x	-	x	-	x	-	-	x	-	x	-	-	x												
																	x	-	-	x	-	-	-	x					
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							x	-	-	-	-	x	-	-	-	-	x												
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						x	-	-	-	x	-	-	-	x															

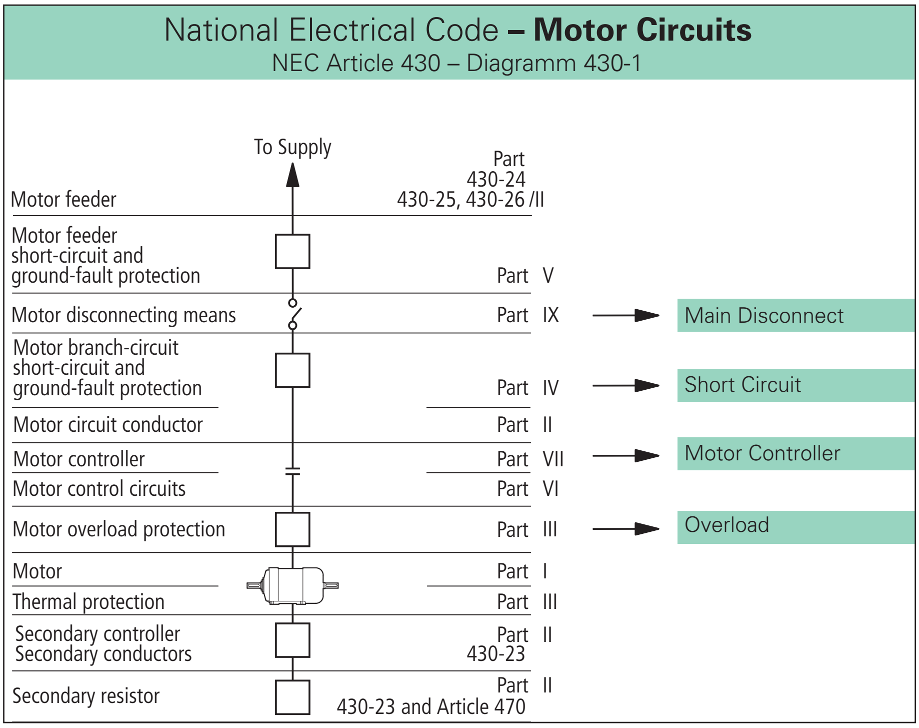


Figure 6: Diagram 430-1 of the National Electrical Code shows the essential elements of a motor branch circuit. Differences in the international and North American definitions of these terms are often the source of misunderstandings and problems encountered with North American electrical inspectors during installation and commissioning work. A comparable diagram is also found in the Canadian code (CEC). In the latest editions of the NEC, individual sections in Article 430 have been assigned roman numerals, Parts I through XIV. In previous editions, capital letters were used to denote same.

requirement and are listed for *„group installation"*. Additionally, they have been evaluated as *„tap conductor protectors"* to further enhance their capability in group installations. There are additional certifications beyond that which will be described and which allow the devices to function as stand-alone protective devices in individual motor branch circuits (i.e. UL 508 Type E and F combination motor starters).

The paper [3] also describes application possibilities for these compact controllers which permit their usage as protective devices in motor circuits without the need for upstream fuses or circuit breakers. The North American standards introduced *„Self-Protected Combination Starters"* (Construction Type E-Motorstarters) some years ago for this purpose. These stand-alone, individual motor branch circuit protective devices need to have large distribution clearances on their incoming supply side and typically feature high short circuit current ratings (SCCR). The large clearances on the supply side can be easily accommodated with the use of a supplementary terminal block fitted

Molded Case Circuit Breakers for North America, (Inverse Time Circuit Breakers)

Circuit breakers with fixed, thermal overload trips
and adjustable, magnetic instantaneous short circuit trips.
Systems and Cable protection certified per UL 489 and CSA-C22.2 No. 5-09

Switch style C.1

	Setting range			Circuit breakers with **B**asic Interrupting rating **Type**	Circuit breakers with **N**ormal Interrupting rating **Type**
	Overload trip (fixed)	Instantaneous short circuit trip		SCCR	SCCR
$I_n = I_u$ [A]	I_r [A]	I_i [A]	I_i	35 kA 240 V 25 kA 480 Y/277 V	85 kA 240 V 35 kA 480 Y/277 V
20	20	350	fest	*NZM**B**1-AF20-**NA***	*NZM**N**1-AF20-**NA***
25	25	350	fest	*NZM**B**1-AF25-**NA***	*NZM**N**1-AF25-**NA***
30	30	350	fest	*NZM**B**1-AF30-**NA***	*NZM**N**1-AF30-**NA***
35	35	320-400	8 ... 10 x I_n	*NZM**B**1-AF35-**NA***	*NZM**N**1-AF35-**NA***
40	40	320-400	8 ... 10 x I_n	*NZM**B**1-AF40-**NA***	*NZM**N**1-AF40-**NA***
45	45	300-500	6 ... 10 x I_n	*NZM**B**1-AF45-**NA***	*NZM**N**1-AF45-**NA***
50	50	300-500	6 ... 10 x I_n	*NZM**B**1-AF50-**NA***	*NZM**N**1-AF50-**NA***
60	60	380-630	6 ... 10 x I_n	*NZM**B**1-AF60-**NA***	*NZM**N**1-AF60-**NA***
70	70	480-800	6 ... 10 x I_n	*NZM**B**1-AF70-**NA***	*NZM**N**1-AF70-**NA***
80	80	480-800	6 ... 10 x I_n	*NZM**B**1-AF80-**NA***	*NZM**N**1-AF80-**NA***
90	90	600-1000	6 ... 10 x I_n	*NZM**B**1-AF90-**NA***	*NZM**N**1-AF90-**NA***
100	100	600-1000	6 ... 10 x I_n	*NZM**B**1-AF100-**NA***	*NZM**N**1-AF100-**NA***
110	110	750-1250	6 ... 10 x I_n	*NZM**B**1-AF110-**NA***	*NZM**N**1-AF110-**NA***
125	125	750-1250	6 ... 10 x I_n	*NZM**B**1-AF125-**NA***	*NZM**N**1-AF125-**NA***

Ratings in the latest main catalog are binding!

Table 13 a: Circuit breakers with fixed thermal overload trips and adjustable instantaneous short circuit trips for system and cable protection (Rated currents up to 125A). These breakers are not suitably rated in North America for motor overload protection. They may not be as advantageous as thermally adjustable breakers for export purposes. They can be used in North America as part of a 3 component solution for motor starter circuits (Circuit breaker- Contactor-Overload relay). Breakers with 480Y/277VAC ratings are suitable for solidly grounded wye systems only.

Molded Case Circuit Breakers for North America, (Inverse Time Circuit Breakers)

Circuit breakers with fixed, thermal overload trips
and adjustable instantaneous short circuit trips.
Special version: 4-pole Switch, with line and load box lug cable terminations
Systems and Cable protection, certified per UL 489 and CSA-C22.2 No. 5-09

Switch style C.1

	Setting range			Circuit breakers with **B**asic Interrupting rating **Type**	Circuit breakers with **N**ormal Interrupting rating **Type**	Circuit breakers with **H**igh Interrupting rating **Type**
	Overload trip (fixed)	Instantaneous short circuit trip		SCCR	SCCR	SCCR
$I_n = I_u$ [A]	I_r [A]	I_i [A]	I_i	35 kA 240 V 25 kA 480 V	85 kA 240 V 35 kA 480 V	200 kA 240 V 150 kA 480 V
125	125	750-1250	6 ... 10 x I_n	*NZM**B**2-4-AF125-**B**T-**NA***	*NZM**N**2-4-AF125-BT-**NA***	*NZM**H**2-4-AF125-BT-**NA*** *150 kA 240 V* *100 kA 480 V*
150	150	960-1600	6 ... 10 x I_n	*NZM**B**2-4-AF150-**B**T-**NA***	*NZM**N**2-4-AF150-BT-**NA***	*NZM**H**2-4-AF150-BT-**NA***
175	175	1200-2000	6 ... 10 x I_n	*NZM**B**2-4-AF175-**B**T-**NA***	*NZM**N**2-4-AF175-BT-**NA***	*NZM**H**2-4-AF175-BT-**NA***
200	200	1200-2000	6 ... 10 x I_n	*NZM**B**2-4-AF200-**B**T-**NA***	*NZM**N**2-4-AF200-BT-**NA***	*NZM**H**2-4-AF200-BT-**NA***
225	225	1500-2500	6 ... 11 x I_n	*NZM**B**2-4-AF225-**B**T-**NA***	*NZM**N**2-4-AF225-BT-**NA***	*NZM**H**2-4-AF225-BT-**NA***
250	250	1500-2500	6 ... 10 x I_n	*NZM**B**2-4-AF250-**B**T-**NA***	*NZM**N**2-4-AF250-BT-**NA***	*NZM**H**2-4-AF250-BT-**NA***

Ratings in the latest main catalog are binding!

Table 13 c: Table 13c lists a special version of switch style C.1: a 4 pole circuit breaker, currently for US based applications. These are not typical for this market but are being increasingly requested for special applications, e.g. by utilities and some manufacturers of high technology equipment. They are UL listed up to 480VAC. The suffix „-BT" (Box Terminal) refers to factory equipped line and load box terminations which are being supplied standard with this version.

Molded Case Circuit Breakers for North America, (Inverse Time Circuit Breakers)

Circuit breakers with fixed, thermal overload trips and adjustable, magnetic instantaneous short circuit trips
Systems and Cable protection, certified per UL 489 and CSA-C22.2 No. 5-09

Switch style C.1

	Setting range			Circuit breakers with **B**asic Interrupting rating **Type**	Circuit breakers with **N**ormal Interrupting rating **Type**	Circuit breakers with **H**igh Interrupting rating **Type**
	Overload trip (fixed))	Instantaneous short circuit trip		SCCR	SCCR	SCCR
$I_n = I_u$ [A]	I_r [A]	I_i [A]	I_i	35 kA 240 V 25 kA 480 V 18 kA 600 Y/347 V	85 kA 240 V 35 kA 480 V 25 kA 600 Y/347 V	200 kA 240 V 150 kA 480 V 65 kA 600 Y/347 V
15	15	350	fest	NZM**B**2-AF15-**NA**	NZM**N**2-AF15-**NA**	NZM**H**2-AF15-**NA**
20	20	350	fest	NZM**B**2-AF20-**NA**	NZM**N**2-AF20-**NA**	NZM**H**2-AF20-**NA**
25	25	350	fest	NZM**B**2-AF25-**NA**	NZM**N**2-AF25-**NA**	NZM**H**2-AF25-**NA**
30	30	350	fest	NZM**B**2-AF30-**NA**	NZM**N**2-AF30-**NA**	NZM**H**2-AF30-**NA**
35	35	320-400	8 ... 10 x I_n	NZM**B**2-AF35-**NA**	NZM**N**2-AF35-**NA**	NZM**H**2-AF35-**NA**
40	40	320-400	8 ... 10 x I_n	NZM**B**2-AF40-**NA**	NZM**N**2-AF40-**NA**	NZM**H**2-AF40-**NA**
45	45	300-500	6 ... 10 x I_n	NZM**B**2-AF45-**NA**	NZM**N**2-AF45-**NA**	NZM**H**2-AF45-**NA**
50	50	300-500	6 ... 10 x I_n	NZM**B**2-AF50-**NA**	NZM**N**2-AF50-**NA**	NZM**H**2-AF50-**NA**
60	60	380-630	6 ... 10 x I_n	NZM**B**2-AF60-**NA**	NZM**N**2-AF60-**NA**	NZM**H**2-AF60-**NA**
70	70	480-800	6 ... 10 x I_n	NZM**B**2-AF70-**NA**	NZM**N**2-AF70-**NA**	NZM**H**2-AF70-**NA**
80	80	480-800	6 ... 10 x I_n	NZM**B**2-AF80-**NA**	NZM**N**2-AF80-**NA**	NZM**H**2-AF80-**NA**
90	90	600-1000	6 ... 10 x I_n	NZM**B**2-AF90-**NA**	NZM**N**2-AF90-**NA**	NZM**H**2-AF90-**NA**
100	100	600-1000	6 ... 10 x I_n	NZM**B**2-AF100-**NA**	NZM**N**2-AF100-**NA**	NZM**H**2-AF100-**NA**
110	110	750-1250	6 ... 10 x I_n	NZM**B**2-AF110-**NA**	NZM**N**2-AF110-**NA**	NZM**H**2-AF110-**NA**
125	125	750-1250	6 ... 10 x I_n	NZM**B**2-AF125-**NA**	NZM**N**2-AF125-**NA**	NZM**H**2-AF125-**NA**
						150 kA 240 V 100 kA 480 V 50 kA 600Y/347 V
150	150	960-1600	6 ... 10 x I_n	NZM**B**2-AF150-**NA**	NZM**N**2-AF150-**NA**	NZM**H**2-AF150-**NA**
175	175	1200-2000	6 ... 10 x I_n	NZM**B**2-AF175-**NA**	NZM**N**2-AF175-**NA**	NZM**H**2-AF175-**NA**
200	200	1200-2000	6 ... 10 x I_n	NZM**B**2-AF200-**NA**	NZM**N**2-AF200-**NA**	NZM**H**2-AF200-**NA**
225	225	1500-2500	6 ... 11 x I_n	NZM**B**2-AF225-**NA**	NZM**N**2-AF225-**NA**	NZM**H**2-AF225-**NA**
250	250	1500-2500	6 ... 10 x I_n	NZM**B**2-AF250-**NA**	NZM**N**2-AF250-**NA**	NZM**H**2-AF250-**NA**

Ratings in the latest main catalog are binding!

Table 13 b: Circuit breakers with fixed thermal overload trips and adjustable instantaneous short circuit trips for system and cable protection. (Rated currents up to 250 A). A portion of the range is already covered by the 125A NZM1 frame device. The NZM2 offers rating up to 600Y/347V, a higher interrupting rating level, and a host of additional accessories. They can be used in North America as part of a 3 component solution for motor starter circuits (Circuit breaker- Contactor-Overload relay). The breakers would be better suited for export purposes in motor starter circuits above 200A. (Although instantaneous trip circuit breakers are more conventional for that application.) Types NZM..2-AF...-BT-NA are available with factory supplied line and load box terminals.

to the device on its incoming side. With this additional terminal, which can also be combined with bus connector links to feed a number of controllers, the switch takes on more or less the same form or appearance as in the IEC world. This may be significant to a panel builder who exports assemblies to North America and would ideally prefer to standardize on the same general panel layout for both markets. *Manual self-protected „UL 508 Type E“ Motor Controllers* are combined with standard magnetic contactors to build UL 508 Type F“- Combination motor starters. The terms „UL 508 Type E“ and „UL 508 Type F“ are not Eaton references. These are *„Combination Motor Starter Construction Types“* with letter identification taken from the North American standards. Eaton type PKZM0 and PKZM4 motor protectors combined with DILM contactors provide advantageous 2 component combination motor starter solutions for the North American market in motor currents up to 52A. Starting at 52A, the 2 component solution can be realized with the use of a molded case circuit breaker Type *NZM*.

The new generation of *NZM 1 … 4* products presented here (and shown in **Table** 9) are fully listed and certified as molded case circuit breakers and do not have the same application constraints for users as the previously described motor controllers. As circuit breakers, they can

Molded Case Circuit Breakers for North America, (Inverse Time Circuit Breakers)					
Circuit breakers with electronic trip. Fixed long time (overload), and adjustable undelayed short circuit trip response. **Systems and Cable protection** certified per UL 489 and CSA-C22.2 No. 5-09					**Switch style C.2**
	Setting range			Circuit breakers with **N**ormal Interrupting rating **Type**	Circuit breakers with **H**igh Interrupting rating **Type**
	Overload trip (fixed)	Instantaneous short circuit trip		SCCR	SCCR
$I_n = I_u$ [A]	I_r [A]	I_i [A]	I_i	85 kA 240 V 42 kA 480 V 35 kA 600 V	150 kA 240 V 100 kA 480 V 50 kA 600 V
250	250	500-2750	2 ... 11 x I_n	*NZM**N**3-AEF250-**NA***	*NZM**H**3-AEF250-**NA***
300	300	600-3300	2 ... 11 x I_n	*NZM**N**3-AEF300-**NA***	*NZM**H**3-AEF300-**NA***
350	350	700-3850	2 ... 11 x I_n	*NZM**N**3-AEF350-**NA***	*NZM**H**3-AEF350-**NA***
400	400	800-4400	2 ... 11 x I_n	*NZM**N**3-AEF400-**NA***	*NZM**H**3-AEF400-**NA***
450	450	900-3600	2 ... 8 x I_n	*NZM**N**3-AEF450-**NA***	*NZM**H**3-AEF450-**NA***
500	500	1000-4000	2 ... 8 x I_n	*NZM**N**3-AEF500-**NA***	*NZM**H**3-AEF500-**NA***
550	550	1100-4400	2 ... 8 x I_n	*NZM**N**3-AEF550-**NA***	*NZM**H**3-AEF550-**NA***
600	600	1200-4800	2 ... 8 x I_n	*NZM**N**3-AEF600-**NA***	*NZM**H**3-AEF600-**NA***
				85 kA 240 V 42 kA 480 V 35 kA 600 V	125 kA 240 V 85 kA 480 V 50 kA 600 V
600	600	1200-7200	2 ... 12 x I_n	*NZM**N**4-AEF600-**NA***	*NZM**H**4-AEF600-**NA***
700	700	1400-8400	2 ... 12 x I_n	*NZM**N**4-AEF700-**NA***	*NZM**H**4-AEF700-**NA***
800	800	1600-9600	2 ... 12 x I_n	*NZM**N**4-AEF800-**NA***	*NZM**H**4-AEF800-**NA***
900	900	1800-10800	2 ... 12 x I_n	*NZM**N**4-AEF900-**NA***	*NZM**H**4-AEF900-**NA***
1000	1000	2000-12000	2 ... 12 x I_n	*NZM**N**4-AEF1000-**NA***	*NZM**H**4-AEF1000-**NA***
1200	1200	2400-14400	2 ... 12 x I_n	*NZM**N**4-AEF1200-**NA***	*NZM**H**4-AEF1200-**NA***

Ratings in the latest main catalog are binding!

Table 14: Circuit breakers with fixed, long time response and adjustable, undelayed electronic trips for systems and cable protection up to 1200A. These breakers cannot be used in North America for motor overload protection. They can be used as part of a 3 component solution for motor starter circuits (Circuit breaker- Contactor-Overload relay) The breakers would be better suited for export purposes in motor starter circuits above 200A. (Although instantaneous trip circuit breakers are more conventional for that application.)

be installed as full, stand alone protective devices and disconnect switches in both feeder and branch circuits per the North American electrical codes.

The newly introduced motor protective circuit breaker **Switch style E** (r *NZM..-**ME**..-NA*) is combined with magnetic contactors to form advantageous 2 component combination motor starters in motor current ranges from 45 A through 200 A. (refer to section "Motor protective circuit breaker *NZM* – and more –). In 3 component motor starter solutions per **Table 7** featuring **Switch styles B.1** or **B.2** (→ *NZM..-**S**..-CNA*, *NZM..-**SE**..-CNA*) with contactors and motor overload relays, the disconnect and short circuit protective functions are provided by the Instantaneous-Trip Only circuit breaker. These circuit breakers are *„Recognized Components"* and are subject to additional conditions of acceptability. Per the electrical codes they must be used with contactors and overload relays to form an individual motor branch circuit, and be additionally listed for the purpose.

Combination motor starter testing in North America is typically done in an enclosure. Pass/failure test criteria for the assemblies are such that a short circuit may not expose people in the vicinity to a hazardous condition and the short circuit is not allowed to cause any appreciable damage to the enclosure nor to its surroundings. Eaton typically uses North American style enclosures and housings for high fault short circuit testing, such as Motor Control Centers (Type MCC 3000). Starters are normally tested in the smallest volume unit possible, the results of which are tabulated and documented. Panel builders that design and house these starters in short circuit rated control panels later on must insure that the volume of the enclosure selected is at least equal to or greater than the volume assigned to that particular combination by the manufacturer.

Instantaneous Trip circuit breakers (without overload trips): A crucial component of North American combination motor starters

This variety of circuit breaker (*NZM...-**S(E)**..-CNA)* is used in the most common breaker type combination motor starter found in North America, and represents the most popular alternative to fused based starters. These circuit breakers are referred to as *"Instantaneous Trip Circuit Breakers"* or *„Magnetic Only Circuit Breakers"* in North America. "Motor Circuit Protector" is another commonly

Molded Case Circuit Breakers for North America, (Inverse Time Circuit Breakers)

Circuit breakers with adjustable thermal overload trips,
and magnetic instantaneous short circuit trips, fixed and adjustable
certified per UL 489 and CSA -C22.2 No. 5-09

Switch style D.1

	Setting range			Circuit breakers with **B**asic Interrupting rating **Type**	Circuit breakers with **N**ormal Interrupting rating **Type**	Circuit breakers with **H**igh Interrupting rating **Type**
	Overload trip	Instantaneous short circuit trip		SCCR	SCCR	SCCR
$I_n = I_u$ [A]	I_r [A]	I_i [A]	I_i	35 kA 240 V 25 kA 480 Y/277 V	85 kA 240 V 35 kA 480 Y/277 V	
20	15-20	350	fixed	*NZM**B**1-A20-**NA***	*NZM**N**1-A20-**NA***	-
25	20-25	350	fixed	*NZM**B**1-A25-**NA***	*NZM**N**1-A25-**NA***	-
32	25-32	350	fixed	*NZM**B**1-A32-**NA***	*NZM**N**1-A32-**NA***	-
40	32-40	320-400	8 ... 10 x I_n	*NZM**B**1-A40-**NA***	*NZM**N**1-A40-**NA***	-
50	40-50	300-500	6 ... 10 x I_n	*NZM**B**1-A50-**NA***	*NZM**N**1-A50-**NA***	-
63	50-63	380-630	6 ... 10 x I_n	*NZM**B**1-A63-**NA***	*NZM**N**1-A63-**NA***	-
80	63-80	480-800	6 ... 10 x I_n	*NZM**B**1-A80-**NA***	*NZM**N**1-A80-**NA***	-
100	80-100	600-1000	6 ... 10 x I_n	*NZM**B**1-A100-**NA***	*NZM**N**1-A100-**NA***	-
125	100-125	750-1250	6 ... 10 x I_n	*NZM**B**1-A125-**NA***	*NZM**N**1-A125-**NA***	-
				35 kA 240 V 25 kA 480 V 18 kA 600 Y/347 V	85 kA 240 V 35 kA 480 V 25 kA 600 Y/347 V	200 kA 240 V 150 kA 480 V 65 kA 600 Y/347 V
20	15-20	350	fixed	*NZM**B**2-A20-**NA***	*NZM**N**2-A20-**NA***	*NZM**H**2-A20-**NA***
25	20-25	350	fixed	*NZM**B**2-A25-**NA***	*NZM**N**2-A25-**NA***	*NZM**H**2-A25-**NA***
32	25-32	350	fixed	*NZM**B**2-A32-**NA***	*NZM**N**2-A32-**NA***	*NZM**H**2-A32-**NA***
40	32-40	320-400	8 ... 10 x I_n	*NZM**B**2-A40-**NA***	*NZM**N**2-A40-**NA***	*NZM**H**2-A40-**NA***
50	40-50	300-500	6 ... 10 x I_n	*NZM**B**2-A50-**NA***	*NZM**N**2-A50-**NA***	*NZM**H**2-A50-**NA***
63	50-63	380-630	6 ... 10 x I_n	*NZM**B**2-A63-**NA***	*NZM**N**2-A63-**NA***	*NZM**H**2-A63-**NA***
80	63-80	480-800	6 ... 10 x I_n	*NZM**B**2-A80-**NA***	*NZM**N**2-A80-**NA***	*NZM**H**2-A80-**NA***
100	80-100	600-1000	6 ... 10 x I_n	*NZM**B**2-A100-**NA***	*NZM**N**2-A100-**NA***	*NZM**H**2-A100-**NA***
125	100-125	750-1250	6 ... 10 x I_n	*NZM**B**2-A125-**NA***	*NZM**N**2-A125-**NA***	*NZM**H**2-A125-**NA***
						150 kA 240 V 100 kA 480 V 50 kA 600 Y/347 V
160	125-160	960-1600	6 ... 10 x I_n	*NZM**B**2-A160-**NA***	*NZM**N**2-A160-**NA***	*NZM**H**2-A160-**NA***
200	160-200	1200-2000	6 ... 10 x I_n	*NZM**B**2-A200-**NA***	*NZM**N**2-A200-**NA***	*NZM**H**2-A200-**NA***
250	200-250	1500-2500	6 ... 10 x I_n	*NZM**B**2-A250-**NA***	*NZM**N**2-A250-**NA***	*NZM**H**2-A250-**NA***

Ratings in the latest main catalog are binding!

Table 15: Circuit breakers with adjustable overload trips. These breakers are not suitable for motor overload protection (no calibration per UL 508) , but rated for systems and cable protection. Breaker types NZM..2-AF…-BT-NA are available with factory supplied line and load box terminals.

encountered term for these devices. These breakers are referenced as **Switch style B.1** and **B.2** in the tables. The assortment is presented in **Tables 17 a, b** and **Table 18**. The breakers incorporate adjustable, instantaneous magnetic or electronic short circuit trips for overcurrent protection of the motor and do not have any built-in **overload** trips.

This special circuit breaker version *must always be combined with a separately mounted motor contactor and overload relay* to form an individual combination motor starter branch circuit. This conditional aspect is the reason for which the certification agencies assign a "Recognized Component" tag to the circuit breaker. Moeller uses the suffix "-CNA" as a means to identify equipment with a recognized component only certification.

The US and Canadian electrical codes require the application of such breakers in listed or certified combination motor starters only. Certified combination motor starters are assemblies of components which have been tested and evaluated as a unit for applications in individual motor branch circuits. They are typically described in manufacturer catalogs as well as in manufacturer test reports issued by the certification agencies.

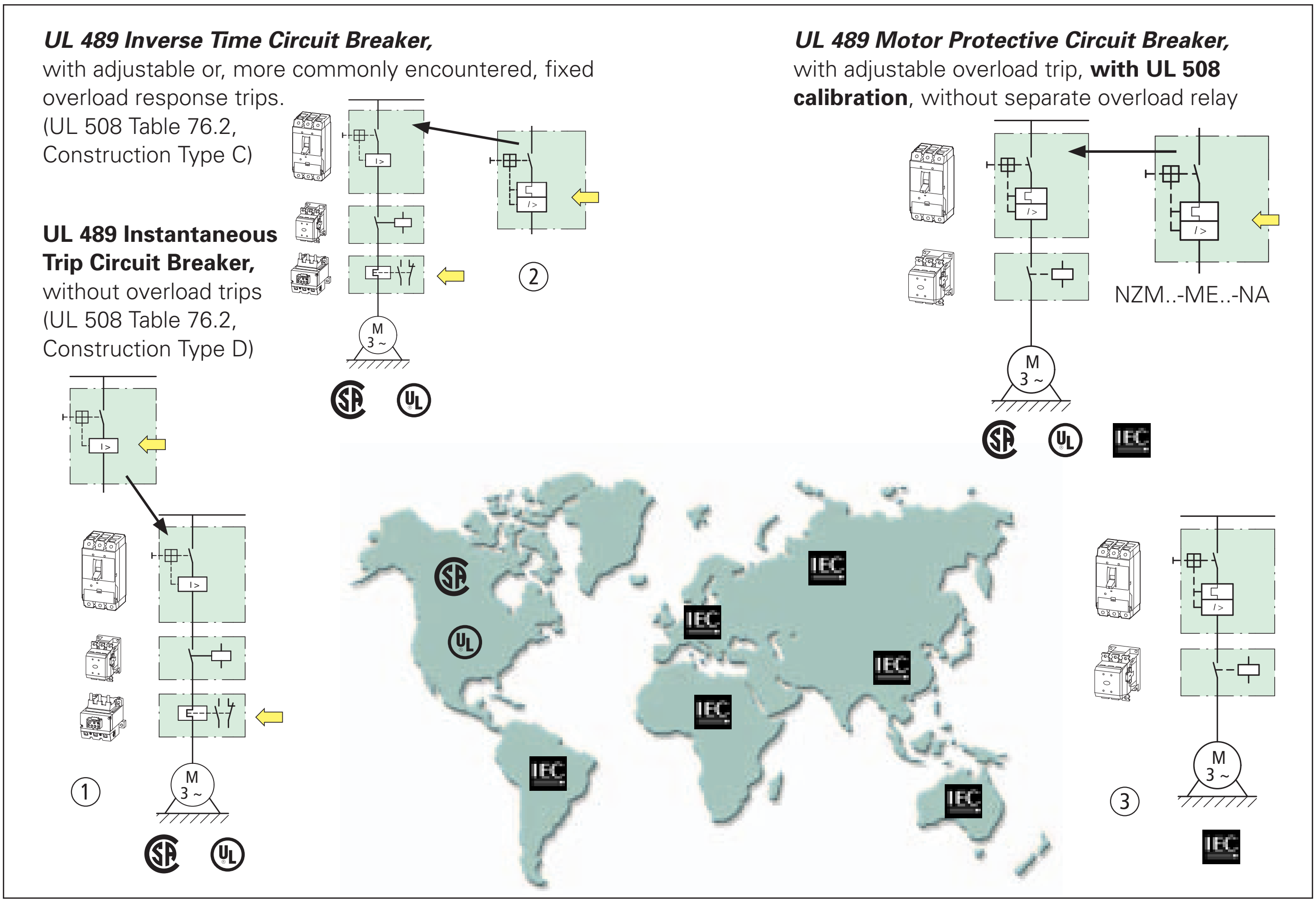


Figure 7: Most combination motor starters in North America are made up of at least three components, e.g. circuit breaker, contactor and motor overload relay, whereas in the IEC world, equivalent starters usually feature only two, a circuit breaker or motor protective switch and a contactor. The two component combination motor starter solution is projected to gain more acceptance in North America with the availability of equipment such as the NZM..2-ME…-NA motor protective circuit breaker.

Molded Case Circuit Breakers for North America, (Inverse Time Circuit Breakers)

Circuit breakers with electronic trip. Adjustable long time (overload), and adjustable undelayed short circuit trip response. Certified per UL 489 and CSA -C22.2 No. 5-09

Switch style D.2

	Setting range			Circuit breakers with **N**ormal Interrupting rating **Type**	Circuit breakers with **H**igh Interrupting rating **Type**
	Overload trip	Instantaneous short circuit trip		SCCR	SCCR
$I_n = I_u$ [A]	I_r [A]	I_i [A]	I_i	85 kA 240 V 42 kA 480 V 35 kA 600 V	150 kA 240 V 100 kA 480 V 50 kA 600 V
250	125-250	500-2750	2 ... 11 x I_n	*NZM**N**3-AE250-**NA***	*NZM**H**3-AE250-**NA***
400	200-400	800-4400	2 ... 11 x I_n	*NZM**N**3-AE400-**NA***	*NZM**H**3-AE400-**NA***
600	300-600	1200-4800	2 ... 8 x I_n	*NZM**N**3-AE600-**NA***	*NZM**H**3-AE600-**NA***
				85 kA 240 V 42 kA 480 V 35 kA 600 V	125 kA 240 V 85 kA 480 V 50 kA 600 V
800	400-800	1600-9600	2 ... 12 x I_n	*NZM**N**4-AE800-**NA***	*NZM**H**4-AE800-**NA***
1000	500-1000	2000-12000	2 ... 12 x I_n	*NZM**N**4-AE1000-**NA***	*NZM**H**4-AE1000-**NA***
1200	600-1200	2400-14400	2 ... 12 x I_n	*NZM**N**4-AE1200-**NA***	*NZM**H**4-AE1200-**NA***

Ratings in the latest main catalog are binding!

Table 16: Circuit breakers with adjustable, long time response and adjustable, undelayed electronic trips for systems and cable protection up to 1200A. These breakers cannot be used in North America for motor overload protection (no calibration per UL 508) but as protective devices for feeder and branch circuits.

Molded Case Circuit Breakers for North America, (Instantaneous Trip Circuit Breakers)

Circuit breakers without overload trips,
with adjustable, magnetic instantaneous short circuit trips
Short circuit protection for individual motor starter circuits
Certified per UL 489 ("Component Recognized") and CSA-C22.2 No. 5-09

Switch style B.1

$I_n = I_u$ [A]	Setting range: Overload trip (none provided) I_r [A]	Setting range: Instantaneous short circuit trip I_i [A]	I_i	Circuit breakers with **B**asic Interrupting rating	Circuit breakers with **N**ormal Interrupting rating
				The applicable short circuit rating value is the one assigned to the overall motor starter combination consisting of the circuit breaker, contactor and overload relay.	
				Type 240 V 480 Y/277 V	**Type** 240 V 480 Y/277 V
1,2	-	8-14	8 ... 14 x I_n	*NZM**B**1-S1.2-**CNA***	*NZM**N**1-S1.2-**CNA***
2	-	12,8-22,4	8 ... 14 x I_n	*NZM**B**1-S2-**CNA***	*NZM**N**1-S2-**CNA***
3	-	19,2-33,6	8 ... 14 x I_n	*NZM**B**1-S3-**CNA***	*NZM**N**1-S3-**CNA***
5	-	32-56	8 ... 14 x I_n	*NZM**B**1-S5-**CNA***	*NZM**N**1-S5-**CNA***
8	-	48-84	8 ... 14 x I_n	*NZM**B**1-S8-**CNA***	*NZM**N**1-S8-**CNA***
12	-	80-140	8 ... 14 x I_n	*NZM**B**1-S12-**CNA***	*NZM**N**1-S12-**CNA***
18	-	128-224	8 ... 14 x I_n	*NZM**B**1-S18-**CNA***	*NZM**N**1-S18-**CNA***
26	-	200-350	8 ... 14 x I_n	*NZM**B**1-S26-**CNA***	*NZM**N**1-S26-**CNA***
33	-	256-448	8 ... 14 x I_n	*NZM**B**1-S33-**CNA***	*NZM**N**1-S33-**CNA***
40	-	320-560	8 ... 14 x I_n	*NZM**B**1-S40-**CNA***	*NZM**N**1-S40-**CNA***
50	-	400-700	8 ... 14 x I_n	*NZM**B**1-S50-**CNA***	*NZM**N**1-S50-**CNA***
63	-	504-882	8 ... 14 x I_n	*NZM**B**1-S63-**CNA***	*NZM**N**1-S63-**CNA***
80	-	640-1120	8 ... 14 x I_n	*NZM**B**1-S80-**CNA***	*NZM**N**1-S80-**CNA***
100	-	800-1250	8 ... 12,5 x I_n	*NZM**B**1-S100-**CNA***	*NZM**N**1-S100-**CNA***

Ratings in the latest main catalog are binding!

The -CNA suffix means that the UL certification has some restrictions and proper application depends on satisfying additional conditions of acceptability. The circuit breakers shown in this table must be combined with appropriate contactors and overload relays to form combination motor starters for individual motor branch circuits. The breakers are individually CSA certified but are nevertheless applied the same way per the Canadian electrical codes.

Table 17 a: The use of instantaneous trip circuit breakers is quite common in North America. The breaker assumes the function of both disconnect and short circuit protective device in a motor branch circuit. These breakers are certified by UL as "Recognized Components" in the US. They are applied solely with contactors and overload relays as combination motor starters for individual motor branch circuits. The entire assembly is then assigned a short circuit rating through third party certification testing. Breakers with 480Y/277VAC ratings are suitable for solidly grounded wye systems only.

The breakers are selected per their nominal current rating in amperes (**Table 19**). The UL and CSA standards do not allow any references to interrupting ratings on the device's rating label. The reference to a short circuit rating is only permitted as it relates to the complete combination motor starter assembly (refer to next section). If the breakers are equipped with auxiliary circuit contacts, the ratings (usually in Pilot Duties) will be provided accordingly as part of the breaker markings.

As previously described, the instantaneous trip only circuit breakers *NZM...-S(E)..-CNA (without overload trips)* are not installed individually but rather, always combined with contactors and overload relays as part of a combination motor starter assembly. The motor contactor's main function in the starter is for direct switching of the motor and the overload relay protects the motor and cable against overloads. The circuit breaker's function is to provide short circuit protection and serve as the main disconnect for the individual motor branch circuit. As an added benefit from this particular starter configuration, auxiliary circuit contacts from the separately provided overload device and circuit breaker easily enable differentiated overload and short circuit trip signalization for trouble-shooting and diagnostic purposes. The desirability of the trip differentiation signal is one reason why this particular type of starter is also occasionally encountered in the IEC world. Motors with longer starting times would be yet another application where the use of these breakers may represent the most viable option. They could be combined with electronic overload relays featuring adjustable trip class settings (Class 5…40) in order to accommodate the longer starting times. For these types of applications, the overall thermal withstand rating of the circuit would need to be taken into consideration. We recommend these 3 component motor starter solutions for export to North America for motor circuits greater than 200A, or whenever the breakers presented in the section „Motor protective circuit breakers NZM- and more-„ cannot fulfil the requirement.

In North America, combination motor controllers are usually applied as units in MCCs (Motor Control Centers), and as combination starters in individual enclosures or in control panels, such

Molded Case Circuit Breakers for North America, (Instantaneous Trip Circuit Breakers)

Circuit breakers without overload trips,
with adjustable, magnetic instantaneous short circuit trips
Short circuit protection for individual motor starter circuits
Certified per UL 489 ("Component Recognized") and CSA-C22.2 No. 5-09

Switch style B.1

	Setting range			Circuit breakers with **B**asic Interrupting rating	Circuit breakers with **N**ormal Interrupting rating	Circuit breakers with **H**igh Interrupting rating
	Overload trip (none provided)	Instantaneous short circuit trip		The applicable short circuit rating value is the one assigned to the overall motor starter combination consisting of the circuit breaker, contactor and overload relay.		
				Type 240 V 480 V 600 Y/347 V	**Type** 240 V 480 V 600 Y/347 V	**Type** 240 V 480 V 600 Y/347 V
$I_n = I_u$ [A]	I_r [A]	I_i [A]	I_i			
1,6	-	12,8-22,4	8 ... 14 x I_n	NZM**B**2-S1.6-**CNA**	NZM**N**2-S1.6-**CNA**	NZM**H**2-S1.6-**CNA**
2,4	-	19,2-33,6	8 ... 14 x I_n	NZM**B**2-S2.4-**CNA**	NZM**N**2-S2.4-**CNA**	NZM**H**2-S2.4-**CNA**
5	-	32-56	8 ... 14 x I_n	NZM**B**2-S5-**CNA**	NZM**N**2-S5-**CNA**	NZM**H**2-S5-**CNA**
8	-	48-84	8 ... 14 x I_n	NZM**B**2-S8-**CNA**	NZM**N**2-S8-**CNA**	NZM**H**2-S8-**CNA**
12	-	80-140	8 ... 14 x I_n	NZM**B**2-S12-**CNA**	NZM**N**2-S12-**CNA**	NZM**H**2-S12-**CNA**
18	-	128-224	8 ... 14 x I_n	NZM**B**2-S18-**CNA**	NZM**N**2-S18-**CNA**	NZM**H**2-S18-**CNA**
26	-	200-350	8 ... 14 x I_n	NZM**B**2-S26-**CNA**	NZM**N**2-S26-**CNA**	NZM**H**2-S26-**CNA**
33	-	256-448	8 ... 14 x I_n	NZM**B**2-S33-**CNA**	NZM**N**2-S33-**CNA**	NZM**H**2-S33-**CNA**
40	-	320-560	8 ... 14 x I_n	NZM**B**2-S40-**CNA**	NZM**N**2-S40-**CNA**	NZM**H**2-S40-**CNA**
50	-	400-700	8 ... 14 x I_n	NZM**B**2-S50-**CNA**	NZM**N**2-S50-**CNA**	NZM**H**2-S50-**CNA**
63	-	504-882	8 ... 14 x I_n	NZM**B**2-S63-**CNA**	NZM**N**2-S63-**CNA**	NZM**H**2-S63-**CNA**
80	-	640-1120	8 ... 14 x I_n	NZM**B**2-S80-**CNA**	NZM**N**2-S80-**CNA**	NZM**H**2-S80-**CNA**
100	-	800-1400	8 ... 14 x I_n	NZM**B**2-S100-**CNA**	NZM**N**2-S100-**CNA**	NZM**H**2-S100-**CNA**
125	-	1000-1750	8 ... 14 x I_n	NZM**B**2-S125-**CNA**	NZM**N**2-S125-**CNA**	NZM**H**2-S125-**CNA**
160	-	1280-2240	8 ... 14 x I_n	NZM**B**2-S160-**CNA**	NZM**N**2-S160-**CNA**	NZM**H**2-S160-**CNA**
200	-	1600-2500	8 ... 12,5 x I_n	NZM**B**2-S200-**CNA**	NZM**N**2-S200-**CNA**	NZM**H**2-S200-**CNA**
250	-	2000-2500	8 ... 10 x I_n	NZM**B**2-S250-**CNA**	NZM**N**2-S250-**CNA**	NZM**H**2-S250-**CNA**

Ratings in the latest main catalog are binding!

The -CNA suffix means that the UL certification has some restrictions and proper application depends on satisfying additional conditions of acceptability. The circuit breakers shown in this table must be combined with appropriate contactors and overload relays to form combination motor starters for individual motor branch circuits. The breakers are individually CSA certified but are nevertheless applied the same way per the Canadian electrical codes.

Table 17 b: Continuation of Table 17 a. A portion of the range is already covered by the 125A NZM1 frame device. Frame size NZM 2 provides for additional accessories and a higher short circuit rating capability. Above 200A, i.e. above Eaton's offering of a 2 component motor starter solution, 3 component combination motor starters can be realized with these circuit breakers. Types NZM..2-S...-BT-CNA are available with factory supplied line and load box terminals.

as those for industrial machinery. They can be installed in circuits up to their maximum short circuit rating. As previously mentioned, the ratings are verified through third party testing by certification agencies and the results are tabulated in the manufacturer's certification report or available directly from the certification agency through on-line resources. The starters can then be referred to as "listed" or "certified" combination motor starters with short circuit ratings (SCCR) per the intent of the North American electrical codes.

Motor protective circuit breakers type *NZM* – and more –

The motor protective circuit breakers described in this section are identified throughout this paper as **Switch style E** (*NZM..-ME..-NA*) circuit breakers. (Refer also to clarifications provided in section „ Motor starter requirements for the North American market"). These breakers are sometimes referred to as "Motor protective circuit breakers" in North America even though this designation is not presently described in the current edition of the UL 489 standard. In the long run, it would seem inevitable that motor starter combinations featuring a protective device combining both the motor overload and short circuit protection function will also eventually win out in North America over the conventional 3 component approach featuring an instantaneous only breaker and a separate overload device. Alone the savings in materials, reduction in space, as well as wiring and mounting time, will provide strong enough incentive to eliminate a third component from the motor starter assembly. In the IEC world, it would be difficult to justify any other solution.

Molded Case Circuit Breakers for North America, (Instantaneous Trip Circuit Breakers)					
Circuit breakers without overload trips, with adjustable, electronic instantaneous short circuit trips **Short circuit protection for individual motor starter circuits** Certified per UL 489 ("Component Recognized") and CSA-C22.2 No. 5-09					**Switch style B.2**
	Setting range			Circuit breakers with **N**ormal Interrupting rating	Circuit breakers with **H**igh Interrupting rating
	Overload trip (none provided)	Instantaneous short circuit trip		The applicable short circuit rating value is the one assigned to the overall motor starter combination consisting of the circuit breaker, contactor and overload relay.	
				Type	**Type**
$I_n = I_u$ [A]	I_r [A]	I_i [A]	I_i	240 V 480 V	240 V 480 V
90	-	90-1260	2 ... 14 x I_n	*NZM**N2**-SE90-**CNA***	*NZM**H2**-SE90-**CNA***
140	-	140-1960	2 ... 14 x I_n	*NZM**N2**-SE140-**CNA***	*NZM**H2**-SE140-**CNA***
220	-	220-3080	2 ... 14 x I_n	*NZM**N2**-SE220-**CNA***	*NZM**H2**-SE220-**CNA***
				240 V 480 V 600 V	240 V 480 V 600 V
220	-	220-3080	2 ... 14 x I_n	*NZM**N3**-SE220-**CNA***	*NZM**H3**-SE220-**CNA***
350	-	350-4900	2 ... 14 x I_n	*NZM**N3**-SE350-**CNA***	*NZM**H3**-SE350-**CNA***
500	-	450-6300	2 ... 14 x I_n	*NZM**N3**-SE450-**CNA***	*NZM**H3**-SE450-**CNA***

Ratings in the latest main catalog are binding!

The -CNA suffix means that the UL certification has some restrictions and proper application depends on satisfying additional conditions of acceptability. The circuit breakers shown in this table must be combined with appropriate contactors and overload relays to form combination motor starters for individual motor branch circuits. The breakers are individually CSA certified but are nevertheless applied the same way per the Canadian electrical codes.

Table 18: As a continuation of Tables 17 a and b the above tabulation lists similar instantaneous type circuit breakers without overload trips, but with electronic short circuit tripping means. These breakers are subject to the same conditions of acceptability given in Table 17 a with respect to application. Types NZM..2-SE…-BT-CNA are available with factory supplied line and load box terminals.

The *Motor Protective Circuit Breakers* ***NZM...-ME..-NA*** are in many ways similar to the adjustable circuit breakers used for motor protection in the IEC world. This type of circuit breaker has never been part of any previous generation of Eaton circuit breakers. What's new with this certification is the combination of a UL 489 listing for the breaker as a stand-alone protective device for feeder and branch circuits, and the additional evaluation of its calibration per the industrial control UL 508 standard, which normally covers motor overload protective devices. This type of protective device is brand new on the North American market. They are seen as a rapproachment of sorts with designs more commonly seen in the IEC world and have been acknowledged for the first time by the North American certification agencies. Eaton recommends these world market rated devices especially for North American export applications requiring motor starter circuit assemblies.

So-called „thermal-magnetic motor disconnect switches" had been part of previous generations of molded case circuit breakers, but these devices were only certified under the UL 508 industrial control standard. Although this new variation of circuit breaker is ideally suited for motor overload protection, and in the process adequately substitutes the function of a separately mounted overload relay, the device is still listed as a full fledged UL 489 protective device suitable for the more conventional protection of cables and systems in feeder and branch circuits. The **Switch style E** assortment is presented in **Table 20**. Standard circuit breakers in the US are rated to protect loads not exceeding

Instantaneous-trip circuit breaker sizing for individual motor branch circuits	**Conditions**	**Motor to be protected**
The breaker continuous rated current	Must be *equal* or *greater*	than **115 %** of the motor full load current
• The instantaneous trip settings on the breaker must be adjustable • The trip current setting of the breaker	is *not allowed to be set higher* in the field	than **1300 %** of the motor full load current • Exception allowed for high efficiency motors: **1700 %** instead of **1300 %**

Table 19: Sizing of instantaneous trip circuit breakers without overload function (NZM...-S(E)..-CNA) per NEC and CEC installation requirements.

Motor Protective Circuit Breakers for North America, (Inverse Time Circuit Breakers) ***Motor Protective Circuit Breakers***										
Circuit breakers with adjustable, electronic overload and short circuit trips **With motor inrush override setting for overload trip** certified per UL 489 and CSA-C22.2 No. 5-09 **additional motor overload protective function** (calibration) **per UL 508 and CSA-C22.2 No.14** The overload trip characteristic for the motor inrush override function can be incremented in steps between 2 and 20 sec. at 6 x I_r. **Special feature: 100 % rating**										
	Setting range			3 phase motor ratings		Matched contactor **Type**	Circuit breakers with **N**ormal Interrupting rating **Type**		Circuit breakers with **H**igh Interrupting rating **Type**	
	Overload trip	Instantaneous short circuit trip					SCCR		SCCR	
$I_n = I_u$ [A]	I_r [A]	I_i [A]	I_i	230 V 240 V HP	460 V 480 V HP		without contactor 85 kA 240 V 35 kA 480 V	with contactor 65 kA/240 V 35 kA/480 V	without contactor 150 kA 240 V 100 kA 480 V	with contactor 65 kA/240 V 65 kA/480 V
90	45-90	90- 1260	2 ... 14 x I_n	20 – 25 30	40 50 60 –	*DILM50* *DILM65* *DILM80* *DILM80*	*NZM**N**2-ME90-**NA***		*NZM**H**2-ME90-**NA***	
140	70-140	140- 1960	2 ... 14 x I_n	40 50	75 100	*DILM95* *DILM115*	*NZM**N**2-ME140-**NA***		*NZM**H**2-ME140-**NA***	
200	100- 200	200- 2800	2 ... 14 x I_n	– 60 75	125 – 150	*DILM150* *DILM185* *DILM225*	*NZM**N**2-ME200-**NA***		*NZM**H**2-ME200-**NA***	

Ratings in the latest main catalog are binding!

Table 20: UL 489 certified inverse time circuit breakers with additional motor protective calibration per UL 508 and CSA-C22.2 No.14, are relatively new in North America. The market may come to accept these devices as simply larger versions of commonly used "motor protectors". These circuit breakers are ideally matched up with motor contactors for application in motor starter branch circuits. The breakers are 100% rated, i.e. the entire current range of the device is available for setting to the motor full load current.

80% of the circuit breaker's current rating. The motor protective ***NZM..-ME...-NA*** circuit breakers, on the other hand, have been certified and marked for full 100% rating, meaning that the full setting range of the circuit breaker can be used to match the load rating. This added feature lends itself particularly well to the motor protective application. *80 %-rated* breakers are the most commonly encountered version of circuit breakers in North America and are not required to be marked as such, as are the 100% rated devices.

A ***NZM..-ME...-NA*** circuit breaker with a rated current of 200A can thus be set to a motor full load current of up to 200A. As mentioned, 100% rated circuit breakers on the North American market are not the norm so they must be tested and marked accordingly in order to be applied as such. These circuit breakers have an electronic trip with a wide setting range of 0.5 – 1 x Rated current. ***NZM..-ME..-NA*** circuit breakers also have an additional dial which can be set to shift the overload portion of the curve and allow motors with long run-up times to start without nuisance tripping. The breakers are available to cover

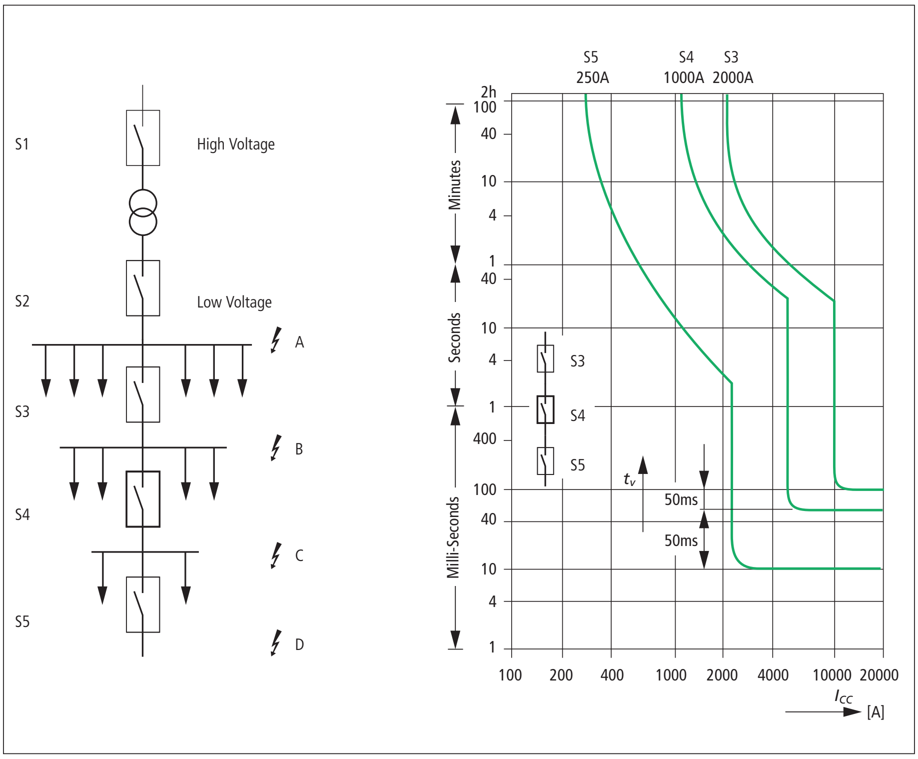


Figure 8: Example of a cascading supply system network. The breakers in each respective sub-division must operate selectively with one another. This can be accomplished using time delay trip settings on circuit breakers for selectivity purposes. The devices at the lowest level and closest to the load (S5 in the example) would be equipped with instantaneous trips. In the levels above, the trip settings of the upstream breakers would be intentionally delayed, in increments of 50ms, 100ms, etc…

current ranges of between 45 and 200A. The combination of the breaker with a magnetic contactor and certification as a combination motor starter effectively expands, for motor full load currents 52A and up, the concept of a 2 component UL 508 Type F combination starter covered by the PKZM0 and PKZM4 motor protectors in the lower ranges. The breakers are available in various interrupting capacity levels, and as 2 component combination motor starters offer the possibility of short circuit current rated (*SCCR)* motor starters in industrial control panels to accommodate different levels of available fault current at the installation site.

A listed circuit breaker is permitted to fulfill the function of a motor controller (contactor) per the North American electrical codes. For practical purposes, however, circuit breakers are typically always combined with motor contactors in motor starter applications to permit electro-magnetic actuation of the motor. Furthermore, as a power circuit component, a contactor is ideally suited to handle the higher motor switching frequency and longer electrical life requirements of motors encountered in modern industrial applications. For practical reasons, therefore, a motor protective circuit breaker will also be typically combined with a motor contactor for certification as a combination motor starter. In addition, the combination lends itself well to achieve the higher short circuit current levels which are so much in demand in today's industrial control environment.

Circuit breakers for various applications on the North American market

When discussing short circuit currents the natural tendency is to automatically focus solely on protective aspects at the highest of fault levels. There are many applications, however, where a design engineer would need to consider the potential circuit and protective ramifications of low level fault currents whose magnitude may not be sufficiently high to trigger an adequately quick tripping response of the circuit breaker. Adjustable short circuit trip settings on circuit breakers are very useful in this case as a means to better address protective requirements at all potential fault current levels. Circuits fed from generators with relatively low available fault currents, or short circuit current levels that have been dampened by the higher resistance and voltage drops from long cable runs, can obviously also occur in North American supply networks.

The statement on low available fault currents in generator fed circuits doesn't necessarily apply to all generators. Generators on board today's super tankers, for example, have by design very little impedance and thus can produce very high faults, even in the neighborhood of 150kA. In power transfer equipment, potential fault levels can vary quite a bit depending on the power source. Circuit breakers in **Switch style C.3** (*NZM..-**VEF**..-NA*) and **D.3** (*NZM..- **VE**..-NA*) have additional short circuit trip adjustments for lower level fault currents which makes them ideally suited for generator and transformer protective requirements.

Circuit breaker types ***NZM..-VEF...-NA*** (with fixed electronic overload trips) and ***NZM..-VE...-NA*** (with adjustable electronic overload trips) are particularly adaptable for a broad range of applications. Selective co-ordination performance, which is a more specialized form of an energy distribution system configuration, is more easily achieved by these circuit breakers through the addition of short-time delayed short circuit trips, which permit the design of time based selectivity protective networks. In a cascading supply system network, with circuit breakers present at various levels of the energy distribution chain (**Figure 8**), the use of time delayed trip settings in different time incremental settings can be very advantageous in setting up a selective network which insures that the device closest to the faulted circuit trips ahead of any other protective device upstream. (*Coordinated Overcurrent Protection*).

Circuit breakers with short time delayed trips are also helpful in circuits where momentary current spikes from certain loads, e.g. transformers under no load conditions, could otherwise cause nuisance tripping. Generally speaking, circuit breakers solely equipped with undelayed short circuit trips would be typically installed in supply network locations closest to the load. For that reason it's not considered necessary for all circuit breakers in an energy distribution network to be equipped with an intentionally delayed short circuit trip capability. Motor protective switches like the PKZM line of devices, which have lower current ratings matched exactly to the load, or circuit breakers with thermal-magnetic trips, which are more common in the lower current ranges, do

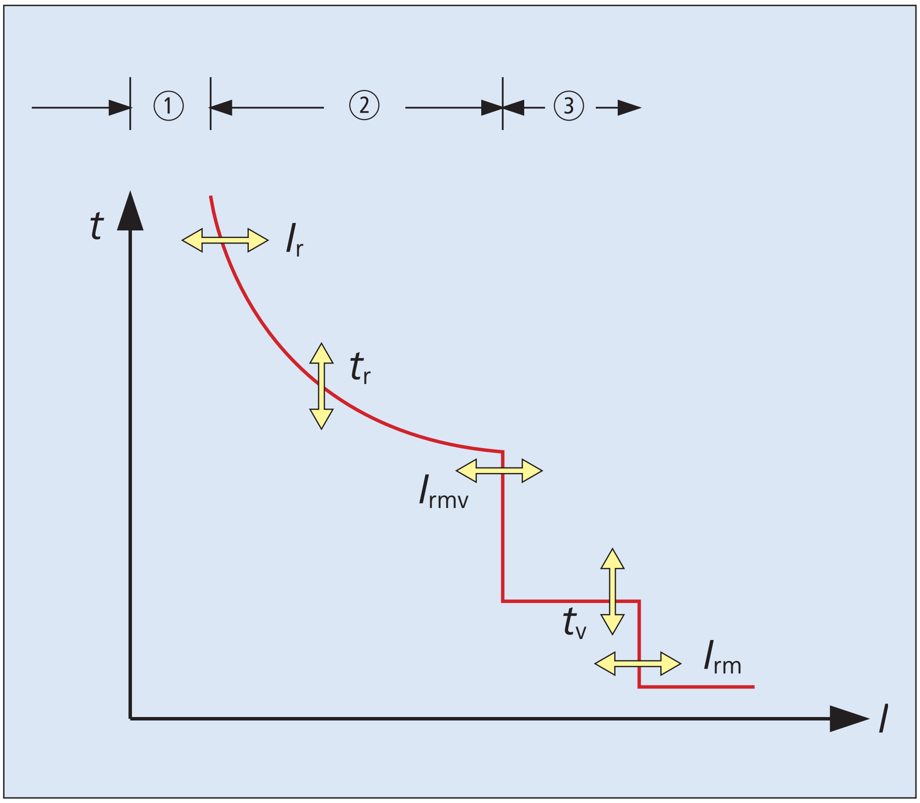


Figure 9: The figure shows a typical breaker trip curve with various functional characteristics.
1. Non-tripping range, found both to the left and under the red trip curve line.
2. Overload or long time response trip range, where brief duration overloads are possible
3. Overcurrent or short circuit trip range.
The figure additionally shows the variable parameters per Table 4 (Page 9), which are used to customize and fine tune the trip curve to better suit the application at hand.

Molded Case Circuit Breakers for North America, (Inverse Time Circuit Breakers)					
Circuit breakers with electronic trip. Fixed long time (overload), and adjustable undelayed, and short-time delayed, short circuit trip response. **Systems, Cable, Selectivity and Generator protection** certified per UL 489 and CSA-C22.2 No. 5-09					**Switch style C.3**
	Setting range			Circuit breakers with **N**ormal Interrupting rating **Type**	Circuit breakers with **H**igh Interrupting rating **Type**
	Overload trip (fixed)	Short circuit trip		SCCR	SCCR
$I_n = I_u$ [A]	I_r [A]	Undelayed I_i [A]	Short-time delayed I_{sd} [A]	85 kA 240 V 35 kA 480 V 25 kA 600 Y/347 V	150 kA 240 V 100 kA 480 V 50 kA 600 Y/347 V
150	150	1800	300-1500	*NZM**N**2-VEF150-**NA***	*NZM**H**2-VEF150-**NA***
175	175	2100	350-1750	*NZM**N**2-VEF175-**NA***	*NZM**H**2-VEF175-**NA***
200	200	2400	400-2000	*NZM**N**2-VEF200-**NA***	*NZM**H**2-VEF200-**NA***
225	225	2700	450-2250	*NZM**N**2-VEF225-**NA***	*NZM**H**2-VEF225-**NA***
250	250	3000	500-2500	*NZM**N**2-VEF250-**NA***	*NZM**H**2-VEF250-**NA***
				85 kA 240 V 42 kA 480 V 35 kA 600 V	150 kA 240 V 100 kA 480 V 50 kA 600 V
250	250	500-2750	500-2500	*NZM**N**3-VEF250-**NA***	*NZM**H**3-VEF250-**NA***
300	300	600-3300	600-3000	*NZM**N**3-VEF300-**NA***	*NZM**H**3-VEF300-**NA***
350	350	700-3850	700-3500	*NZM**N**3-VEF350-**NA***	*NZM**H**3-VEF350-**NA***
400	400	800-4400	800-4000	*NZM**N**3-VEF400-**NA***	*NZM**H**3-VEF400-**NA***
450	450	900-3600	675-3150	*NZM**N**3-VEF450-**NA***	*NZM**H**3-VEF450-**NA***
500	500	1000-4000	750-3500	*NZM**N**3-VEF500-**NA***	*NZM**H**3-VEF500-**NA***
550	550	1100-4400	835-3850	*NZM**N**3-VEF550-**NA***	*NZM**H**3-VEF550-**NA***
600	600	1200-4800	900-4200	*NZM**N**3-VEF600-**NA***	*NZM**H**3-VEF600-**NA***
				85 kA 240 V 42 kA 480 V 35 kA 600 V	125 kA 240 V 85 kA 480 V 50 kA 600 V
600	600	1200-7200	1200-6000	*NZM**N**4-VEF600-**NA***	*NZM**H**4-VEF600-**NA***
700	700	1400-8400	1400-7000	*NZM**N**4-VEF700-**NA***	*NZM**H**4-VEF700-**NA***
800	800	1600-9600	1600-8000	*NZM**N**4-VEF800-**NA***	*NZM**H**4-VEF800-**NA***
900	900	1800-10800	1800-9000	*NZM**N**4-VEF900-**NA***	*NZM**H**4-VEF900-**NA***
1000	1000	2000-12000	2000-10000	*NZM**N**4-VEF1000-**NA***	*NZM**H**4-VEF1000-**NA***
1200	1200	2400-14400	2400-12000	*NZM**N**4-VEF1200-**NA***	*NZM**H**4-VEF1200-**NA***

Ratings in the latest main catalog are binding!

Table 21: Universally applied circuit breakers for systems, cable, selectivity and generator protection with fixed overload and adjustable undelayed and short-time delayed electronic trips. These breakers are not suitable for motor overload protection. Types NZM..2-VEF… -BT-NA are available with factory supplied line and load box terminals.

not typically feature any intentional trip delay function. As a general rule, therefore, protective devices with undelayed trips are nearly always found at load levels in selectively designed distribution networks. The assortment of breakers available under **Switch styles C.3** and **D.3** are shown in **Tables 21 and 22.** **Table 23** presents various configurations and typical application ranges for **Switch styles C.3** and **D.3.**

Circuit breaker trip curves (and trip setting guidelines)

Figure 9 shows a typical trip curve of a circuit breaker equipped with multiple trip function characteristics. The topic is described in greater detail in [15]. Not all circuit breakers, amongst both the thermal-magnetic and electronic trip varieties, are equipped with all the settings options displayed in **Figure 9.** Refer also to **Table 24**. The Moeller series of electronic trip circuit breakers from Eaton also include as a special feature an electronic data bank which can store and display the 10 most recent operational events of the circuit breaker, as well as circuit related data and additional diagnostical information. The data content for IEC rated circuit breakers can be additionally sent over a network using the Data Management Interface *DMI* unit (**Figure 10**). A laptop can also easily be hooked up to the circuit breaker in order to obtain useful trip characteristic curve displays which take into consideration all the trip function settings available on that particular breaker.

Free *CurveSelect* software from Eaton can be used to combine and display trip characteristics from multiple protective devices in a circuit. This is particularly useful, for example, in evaluating selective co-ordination in a network (**Figure 11**). As a rule, the greater the number of available adjustments on a circuit breaker trip unit, the more difficult it becomes to optimally dial in and co-ordinate all of its functionality. **Figure 12,** along with **Tables 25** and **26,** should be helpful in making proper breaker trip adjustment choices. The tables also point out the potential ramifications of an improper setting, which is also important information to take into account. The *CurveSelect* software does not yet currently contain the trip characteristics for specific North American breaker

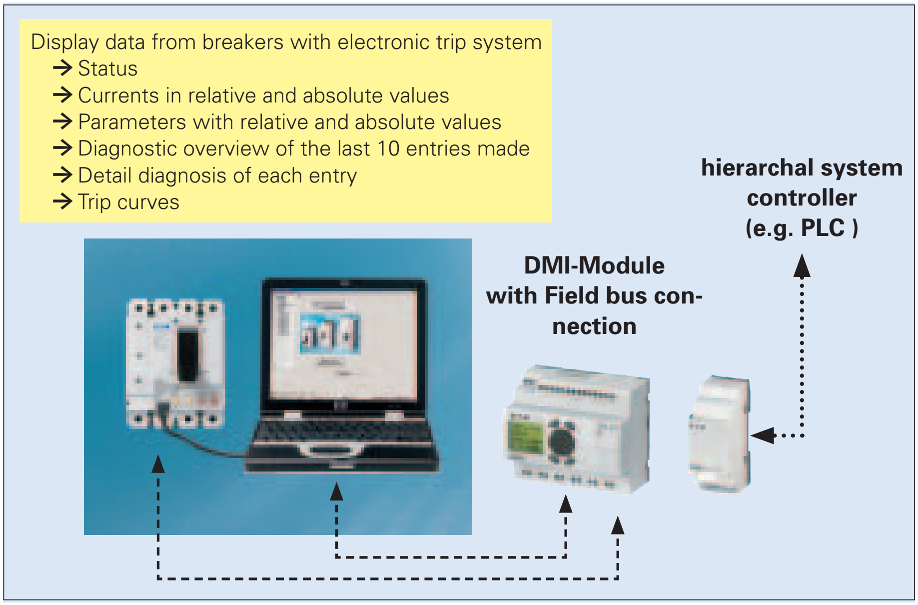


Figure 10: Comprehensive data stored in the memory chips of NZM circuit breakers with electronic trips can be readily accessed with a laptop. This capability is also available on all comparable North American versions. The Data Management Interface DMI unit is currently used in the IEC world as a gateway to transfer the information onto a network.

Molded Case Circuit Breakers for North America, (Inverse Time Circuit Breakers)

Circuit breakers with electronic trip. Adjustable long time (overload),
and adjustable undelayed, and short-time delayed, short circuit trip response.
Systems, Cable, Selectivity and Generator protection
certified per UL 489 and CSA -C22.2 No. 5-09

Switch style D.3

	Setting range			Circuit breakers with **N**ormal Interrupting rating **Type**	Circuit breakers with **H**igh Interrupting rating **Type**
	Overload trip	Short circuit trip		SCCR	SCCR
$I_n = I_u$ [A]	I_r [A]	Undelayed I_i [A]	Short-time delayed I_{sd} [A]	85 kA 240 V 35 kA 480 V 25 kA 600 Y/347 V	150 kA 240 V 100 kA 480 V 50 kA 600 Y/347 V
100	50-100	1200	100-1000	NZM**N**2-VE100-**NA**	NZM**H**2-VE100-**NA**
160	80-160	1920	160-1600	NZM**N**2-VE160-**NA**	NZM**H**2-VE160-**NA**
250	125-250	3000	250-2500	NZM**N**2-VE250-**NA**	NZM**H**2-VE250-**NA**
				85 kA 240 V 42 kA 480 V 35 kA 600 V	150 kA 240 V 100 kA 480 V 50 kA 600 V
250	125-250	500-2750	250-2500	NZM**N**3-VE250-**NA**	NZM**H**3-VE250-**NA**
400	200-400	800-4400	400-4000	NZM**N**3-VE400-**NA**	NZM**H**3-VE400-**NA**
600	300-600	1200-4800	450-4200	NZM**N**3-VE600-**NA**	NZM**H**3-VE600-**NA**
				85 kA 240 V 42 kA 480 V 35 kA 600 V	125 kA 240 V 85 kA 480 V 50 kA 600 V
800	400-800	1600-9600	800-8000	NZM**N**4-VE800-**NA**	NZM**H**4-VE800-**NA**
1000	500-1000	2000-12000	1000-10000	NZM**N**4-VE1000-**NA**	NZM**H**4-VE1000-**NA**
1200	600-1200	2400-14400	1260-12000	NZM**N**4-VE1200-**NA**	NZM**H**4-VE1200-**NA**

Ratings in the latest main catalog are binding!

Table 22: Universally applied circuit breakers for systems, cable, selectivity and generator protection with adjustable overload and adjustable undelayed and short-time delayed electronic trips. These breakers are not suitable for motor overload protection. Types NZM..2-VE…-BT-NA are available with factory supplied line and load box terminals.

Molded Case Circuit Breakers for North America, (Inverse Time Circuit Breakers)				
Maximum configuration of current dependent tripping features, universal application range				
certified per UL 489 and CSA -C22.2 No. 5-09				**Switch style C.3**
Circuit Breaker **Type**	Product features	Application range	Setting range	Factory supplied settings
NZM..-VEF..-NA	Overload trips, **fixed**	Systems and cable protection	-	Type dependent
	Undelayed short circuit trips, adjustable	Systems and cable protection	Frame size dependent 2 ... 8 x I_r 2 ... 11 x I_r 2 ... 12 x I_r	Type dependent 8 x I_r 11 x I_r 12 x I_r
	Short time delayed short circuit trips, adjustable	Selective protection, Time based selectivity implementation	Frame size dependent 2 ... 10 x I_r 2 ... 11 x I_r Frame size 2: fixed: 12 x I_r	6 x I_r
	Short time delay trip time setting tsd t_{sd}	Incremental time delay gradation setup for multiple distribution network levels	in increments of 0, 20, 60, 100, 200, 300, 500, 750, 1000 ms	0 ms
	Adjustable long time response delay settings	Shift of long time response (overload) characteristic curve	2 ... 20 s at 6 x I_r	10 s
	I^2t selectivity function switch	Improves selectivity with upstream fuses		off, not available on frame size 2
certified per UL 489 and CSA -C22.2 No. 5-09				**Switch style D.3**
Circuit Breaker **Type**	Product features	Application range	Setting range	Factory supplied settings
NZM..-VE..-NA	Overload trips, **adjustable**	Systems and cable protection	0,5 ... 1 x I_n	0,5 x I_n
	Undelayed short circuit trips, adjustable	Systems and cable protection Broad setting range makes them particularly suitable for generator protection	Frame size dependent 2 ... 8 x I_r 2 ... 11 x I_r 2 ... 12 x I_r	Type dependent 8 x I_r 11 x I_r 12 x I_r
	Short time delayed short circuit trips, adjustable	Time based selectivity implementation Suppresses effects from current spikes	Frame size dependent 2 ... 10 x I_r Frame size 2: fixed: 12 x I_r	6 x I_r
	Short time delay trip time setting t_{sd}	Incremental time delay gradation setup for multiple distribution network levels	in increments of 0, 20, 60, 100, 200, 300, 500, 750, 1000 ms	0 ms
	Adjustable long time response delay settings	Shift of long time response (overload) characteristic curve	2 ... 20 s at 6 x I_r	10 s
	I^2t selectivity function switch	Improves selectivity with upstream fuses		off, not available on frame size 2

Table 23: Additional features of NZM..-VEF..-NA and NZM..-VE..-NA circuit breakers which can be used to broaden their application range. (Configuration: similar to equivalent IEC rated circuit breakers)

versions, but since both UL/CSA and IEC versions are very similar in design, indeed, most of the North American versions also carry IEC ratings, the trip curves generated by the software can arguably be applied on a broad basis to all types in the circuit breaker line.

Current interrupting designs of molded case circuit breakers

– Zero point clearing, or devices which can limit the short circuit current –

The contact systems of modern circuit breakers can be optimized to handle varying switching requirements. In the previous section we described the use of selective co-ordination in supply networks, and how that can be useful in better managing the energy demands of modern distribution systems. Circuit breakers for these applications, particularly in larger current sizes and further up in the distribution chain, are best designed with contact systems that are able to withstand relatively high levels of short circuit current flow without premature contact lift-off from the effects of electro-dynamic forces generated by the fault current, and in the process leave adequate time for the smaller and quicker acting devices downstream to clear the faulted circuit. The contact spring forces (which keep the contacts closed) must therefore be sufficiently strong to resist the dynamic push in the opposite direction from the repulsive effects of magnetic fields generated in the vicinity of the contact area (**Figure 13)** which are trying to force open the contacts. One can see from **Figure 13**, that the parallel runs of the contact circuit paths are very short. On the other hand, the repulsive forces generated in that particular portion of the contact paths during a high fault condition are extremely high since they rise as a function of the square of the current. If the circuit breaker is called on to clear the fault after this initial delay, the contacts would open and the current, along with the arc generated, would be extinguished during the next zero passage of the AC current waveform. Thus the term "zero point clearing" associated to circuit breakers of this particular design. The associated test criteria for these circuit breakers per IEC varies by frame size and is referred to as the "rated shorttime withstand current" I_{cw} or the one second current. One of the drawbacks of this construction is that the full fault current would be allowed to flow through the contacts for a maximum of a half-wave. From this respect, all downstream power circuit components, loads, feeders and cables would come under heavy loading for that duration. Typical representatives of this contact design in Eaton's breaker line are the Type *IZM* insulated case power circuit breakers, which are currently being offered for IEC markets only. Eaton's Type *NZM4* molded case circuit breaker is also a zero point switch by design, since breakers in that current range are typically found upstream in selectively co-ordinated energy distribution systems and feeder circuits rather than providing branch circuit protection requirements for motors and other loads. That is the main reason why the circuit breaker models in this frame size are not certified as current limiting. The use of current limiting circuit breakers and their impact on the overall *Short Circuit Current Rating (SCCR)* of an assembly, such as an industrial control panel, will be discussed in greater detail in an upcoming section.

Trip current setting possibilites for various types of protective switches

		Certain trip functions may be optional on some models, or the information shown may only be valid for certain models within a given product range. Refer to current Eaton main catalog					
		Electro-mechanical Trips				Electronic Trips	
Parameters which can impact the trip characteristic	Type Frame size	*ZB... 12, 32, 75, 175*	*PKZM... 01, 0, 4*	*PKZ... 2*	*NZM... 1, 2*	*NZM... 2, 3, 4*	*IZM... 20..63*
Setting value I_r for overload trip		Adj.	Adj.	Adj.	Adj. -	Adj.	Adj.
Response value I_{rm} for instantaneous short circuit trip		-	Fixed	Adj.	Fixed Adj.	-	-
Response value I_i for undelayed short circuit trip		-	-	-	-	Fixed Adj.	- Adj.
Response value I_{sd} for short time delayed short circuit trip		-	-	-	-	Adj.	Adj. -
Motor overload protective trip class		Fixed	Fixed	Fixed	Fixed	Adj.	-
Inrush time delay setting t_r for overload trip		-	-	-	-	Fixed Adj.	Fixed Adj.
Time delay setting t_{sd} for short time delayed short circuit trip		-	-	-	-	Adj.	Adj.
I^2t-selectivity function switch		-	-	-	-	Fixed Adj.	Fixed Adj.
Single phasing sensitivity		Fixed	Fixed	- Fixed	- Fixed	- Fixed	- Fixed
Rated differential current $I_{\Delta n}$		-	-	-	-	Adj.	-
Time delay setting t_v for differential trip		-	-	-	-	Adj.	-
Response value I_g for earth (ground) fault trip		-	-	-	-	Adj.	Adj.
Time delay setting t_g for earth (ground) fault trip		-	-	-	-	Adj.	Adj.

Table 24: Fixed and adjustable parameters of current dependent trip functions for various power circuit protective devices.

Information on trip setting adjustments for NZM circuit breakers in IEC version – Type dependent rating and setting values –								
Posi-tion in Dia-gram	**Para-meter**	**Range**	**Factory setting**	**Type of adjustment**	**For Types**	**Influence on trip characteristic curve**	**Purpose of value for breaker setting**	**Potential selection errors**
			Adhere to factory pre-set dial increments!					**→ Caution!** **→ Danger!!!**
	$I_n = I_u$	Refer to device rating label; non-adjustable rating, based on frame size.			All	No influence Base frame size rating to help switch selection process	Establishes maximum rating of breaker per the application	Breaker is oversized or **undersized**
1	I_r	0.5-1 x I_n	0.8 x I_n	Incremental dial	All, except breakers without I_r setting	Shifts the upper portion of the curve to the right.	e.g. Motor rated current or allowable cable ampacity	Nuisance or **late trip** of breaker
2	t_r	2-20 s and ∞ (∞ = no overload trip)	10 s	Incremental dial	NZM2..4 -ME and -VE	Trip time applies to 6 x I_r . Pushing the trip curve upward will lenghten the trip time and minimize potential nuisance tripping, but the trip time should not be set longer than necessary. The thermal capacity of the load and of the entire circuit must be taken into consideration.	Allows fine tuning of breaker to override (necessary) motor inrush starting period	Nuisance or **late trip** of breaker, **potential oversizing of power switching components and cables necessary,** **Maximum table values per trip class in Main catalog must be strictly observed!**
3	I_{sd}	2-10 x I_r	6 x I_r	Incremental dial	NZM2..4 -VE	Breaker will trip once the fault current reaches trip setting levels and preset time delay value has expired.	For time delayed selective tripping in a network: undelayed trip setting closest to the load (e.g. PKZM), followed by per level incremental time delay setting adjustments upstream.	**Absence of selective breaker performance due to insufficiently long time delay increments.**
4	t_{sd}	0–1000 ms	0 ms	Incremental dial				
5	I_i	2-14 x I_n or not adjustable	12 x I_n	Incremental dial	All	Has to protect the weakest element in the circuit against destruction due to short circuit fault currents (Emergency-brake)	Setting is dependent on available short circuit current fault levels and in accordance with normal operational inrush peak currents expected in the circuit. Protective earthing installation conditions must be observed (IEC 60364)	**Motor starting current is not allowed to cause nuisance tripping.** **Conversely, if set too high, breaker will not trip when it should.**
6	I^2t	on / off	off	on / off	NZM3..4 -VE	Trip time is lengthened as a function of the breaker's maximum allowable let-through I^2t-value.	Circuit evaluation consideration in establishing selectivity with fuse	**Absence of selectivity with fuse in circuit**
7	I_g	0.3-1 x I_u		Incremental dial	optional for: NZM3..4 -AE,-ME, -VE	No effect	Situational requirement, evaluation of acceptable levels for fire prevention, incremental time delay settings enable a selective earth fault trip capability	**Settings can be susceptible for nuisance tripping if set too fine, absence of selective performance,** **fire danger in certain cases if values are set too high**
8	t_g	0-1000 ms		Incremental dial				
9	Overload warning LED „Alarm" light (light is continuous at 70 % of I_r, slow blinking begins at 100 %, at 120% light begins to blink rapidly)				NZM2..4 -AE,-ME, -VE	No effect	–	**Early warning visual clues for imminent trip on overload fail to be observed.**
10	Data communication interface for Laptop or Data Management Interface DMI				NZM2..4 -AE,-ME, -VE	Enables additional parametric functions	Refer to additional info above for parametric values	Refer to additional info above **on parametric values**

Table 25: Clarifications to Figure 12. Effects of adjustments made on circuit breaker current and trip setting parameters.

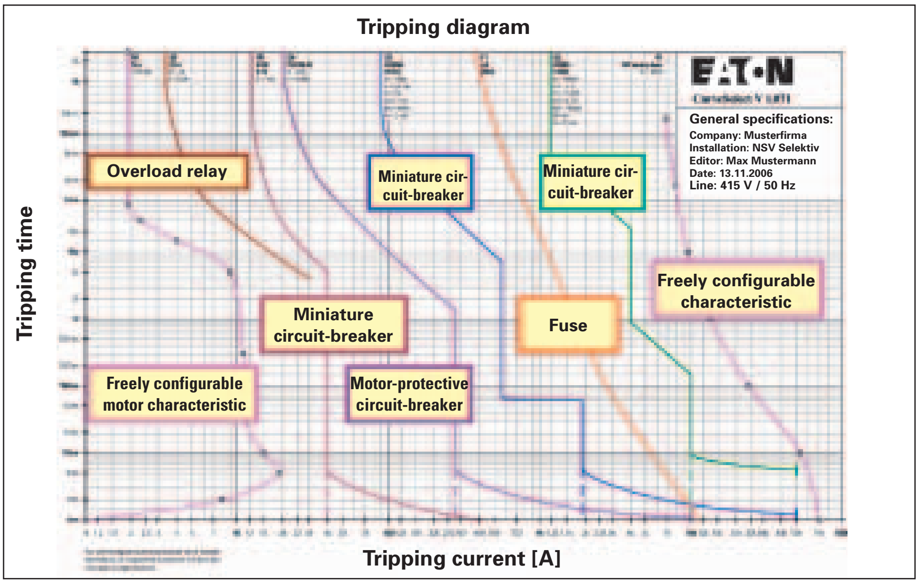


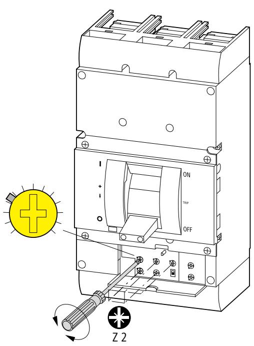
Figure 11: The Curve Select software from Eaton can be used to display trip curves from various protective devices for comparison and evaluation purposes. Individual breaker curves will reflect any particular trip setting currently selected on the device. For clarifications on breaker trip setting adjustments and the Curve Select software please refer to [14].

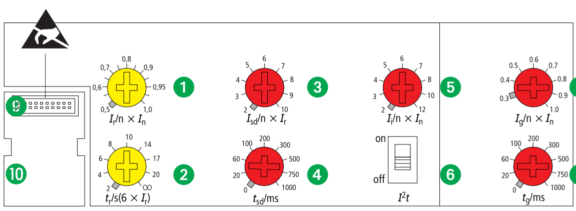
The alternative to zero point switches are circuit breakers equipped with a current limiting contact design, which is specifically optimized for very quick contact opening sequences and clearing times. The high quality materials of the contact assembly are purposely kept as light as possible, and with relatively low contact forces, in order to insure the quickest of dynamic separation under pre-determined levels of fault current present. This opening action of the contacts takes place automatically, independent of a trip signal, and ideally at the same time as the short circuit trip mechanism has been set in motion. The process of finding the right balance between these forces is a specialized task indeed, and requires in-depth knowledge on the part of the product designer.

Of late, meeting these design requirements has been made easier through the use of rotational contacts as depicted in **Figure 14.** As alluded to in the previous section, circuit breakers with current limiting features in a selectively co-ordinated energy distribution network are best utilized in zones closest to the loads. At higher levels in the distribution chain the use of zero point switches or short time delayed trips is recommended in order to more effectively achieve a time based selectivity co-ordination. The switches are then typically offset in increments of 50ms per distribution level. Using a time delay approach will also more easily enable the use of current limiting circuit breakers within the network. In the IEC world, and especially at Eaton, the use of the term "current limiting" is normally associated to particular design features incorporated into the product.

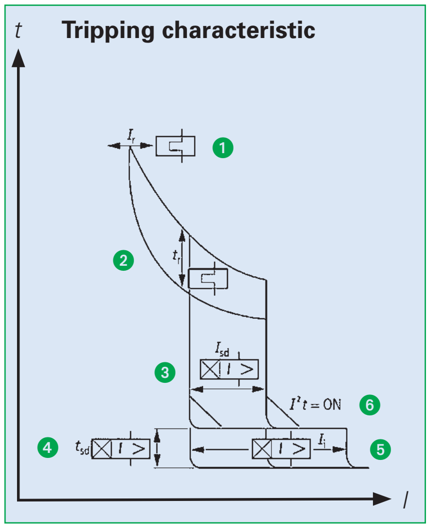
The North American standards take a different approach and associate the term current limiting *(Current Limiting)* exclusively to protective devices such as fuses and circuit breakers. The definition does not specify any particular constructional requirement, and is based solely on performance verification through testing. The current limiting performance of a tested component is evaluated on the basis of test results evaluated at three magnitude levels of fault: *Threshold Current, Intermediate Current, High Interrupting Capacity*. The device is said to be current limiting if, when operating within its current limiting range, it limits the let-through *I2t* to a value less than the *I2t* of a M-cycle wave of the symmetrical prospective current. A half-

Small setting aid
– notes for avoiding faults –





Note: Not all parameters are available or adjustable on simpler protective devices.



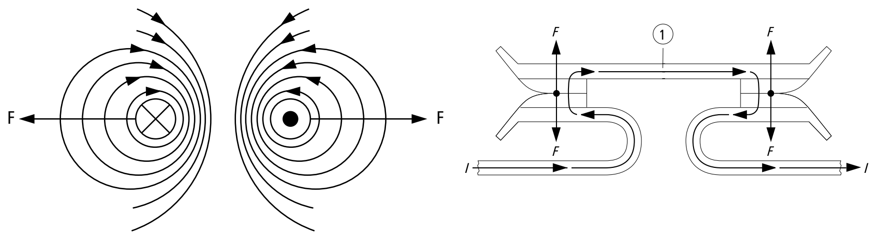
The diagram shows the directional effect of dial setting adjustments on the overall trip characteristic.

Adjustable Parameters:

1. Long time pick-up (overload) current I_r
2. Overload trip Inrush time delay setting t_r
3. Short time delayed short circuit trip I_{sd}
4. Short time delay setting t_{sd} (based on I_{sd})
5. Undelayed short circuit trip I_i
6. I^2t- On/Off selectivity function switch
7. Earth (ground) fault trip I_g (optional)
8. Time delay setting for earth (ground) fault trip t_g
9. LED Overload signal alarm light I_r 70 / 100 / 120%
10. Data communication interface

Figure 12: Description of trip setting parameters for circuit breakers, in this case a Type NZM4 with solid state trips. Not all breaker frame sizes and variations offer the same type or quantity of available trip setting possibilities. Trip setting parameter adjustments and their overall effect on breaker response are detailed in Tables 25 and 26.

Circuit breakers with current limiting properties. How is current limitation achieved?



Current flow in adjacent opposing conductors will generate magnetic fields around each conductor that will repel each other. This dynamic and physical repulsion effect forms the basis of the circuit breaker's current limiting design.

The principle behind a current limiting contact system. The magnitude of the repulsive force can be approximated by the formula $F \sim I^2$.
① = Movable contact

Figure 13: Current flow in adjacent opposing conductors will generate magnetic fields which repel each other. At high fault current levels the associated force leads to a dynamic lift-off of the contact surfaces. (Direct opening of contacts without the assistance of a trip mechanism).

wave represents a relatively long period of time for a good current limiting device. The Eaton circuit breakers also rely on a sound design approach to yield excellent current limitation results.

As an historical note, Eaton/Moeller was the first manufacturer, back in 1971, to introduce a fuseless, current limiting circuit breaker in North America: The 250A frame NZMH9 model, a circuit breaker that also featured a blow apart contact mechanism, which is the prevalent technology still in use today.

Although the breaker was UL/CSA certified, UL at that time had not yet introduced a definition for "current limiting" circuit breakers. That came later, in the late 70s.

Eaton can thus be considered a pioneer of sorts in North America with respect to current limiting circuit breakers.

The let-through energy is the total amount of energy which passes through the breaker during the time it takes for the breaker to trip and clear the arc. The corresponding let-through current $\hat{I}_D$ (**Figure 15**) is also reduced. The let-through energy (**Figure 16**) and the let-through current values for each frame size as a function of voltage and interrupting rating are published in the form of diagrams and tables in the Eaton Main Industrial Catalog (HPL0211).The test results are based on 3 phase rms sym short circuit current values. Symmetrical, 3 phase full bolted faults, however, are seldom encountered in the real world. Bolted faults originate at points in a circuit with very negligible impedance. More common are single and two pole faults with a greater resistance component, like arcs for example.

The actual magnitude of short circuit current which can flow in practice is thus often much smaller than the calculated theoretical value. Additional damping from the inductance of transformers, feeders and cables also help reduce fault current levels. One could say, therefore, that the practical world does have a built-in margin of safety, although it would be difficult to quantify it. Due to differing test criteria and voltage levels in both markets, resultant values for IEC and North American switches tend to also vary.

Current limiting circuit breakers and fuses play a special role in the determination of the overall short circuit rating of an industrial control panel (UL 508A) by limiting the amount of let-through current that downstream components in power circuits would be subject to [16]. The use of current limiting devices is an approved method 41 under UL 508A by which to modify and improve the panel's overall short circuit rating. As will later be seen, however, there are some limitations in how the standard allows the physical aspect of the current limiting effect to impact the overall determination of the panel rating. **Table 27** shows which circuit breakers are currently certified as current limiting. Per North American requirements, a marking *(Current Limiting)* must appear on the circuit breaker to indicate its current limiting status, and manufacturers must publish corresponding let-through values.

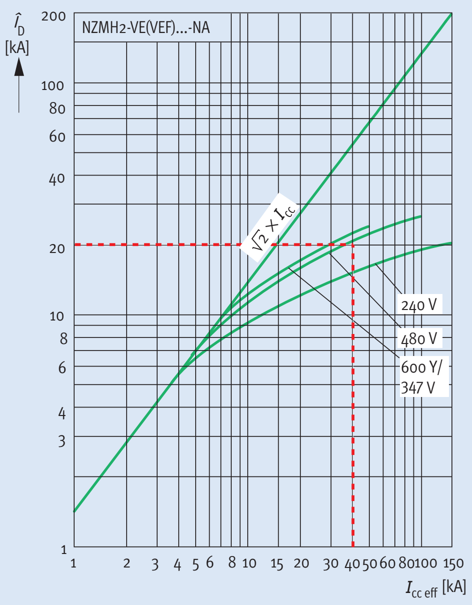
Switch mechanism with current limiting properties. Design aspects of switches with rotational contact mechanisms (e.g. circuit breaker type NZM 2)

Figure 14: Rotational contact mechanisms use the repulsive magnetic field forces in such a way as to greatly accelerate the switch's opening time in order to achieve a higher degree of current limitation.

Current limiting circuit breakers for use in *Industrial Control Panels* per UL 508A

As denoted in the preceding section, the use of current limiting circuit breakers and fuses plays a special role in the determination of the overall short circuit current rating *(SCCR)* of an industrial control panel as determined per the standard for industrial control panels, UL 508A. Industrial control panels for industrial machinery are, for example, amongst the many versions of *Industrial Control Panels* covered by the UL 508A standard. It is worth noting in this respect that the definition of a machine per North American standards is very nearly identical to the one found in the European Union machinery directive standard IEC/EN 60 204-1 (electrical equipment for machines).

There are two aspects to consider. The first, and very positive aspect, is that power circuit components downstream of the current limiting protective device in the supply circuit will only be subject to the allowable let-though current from that device. That principle is physically correct. As an example: a current limiting circuit breaker, e.g. used as a main disconnect switch, reduces an available fault current from 30kA down to 10kA, which enables power circuit components with a short circuit rating of at least 10kA to be safely installed. The second aspect to consider is somewhat more restrictive, and potentially more costly, as was alluded to earlier. In spite of the reduction in let-through current afforded to branch circuit power components by the upstream current limiting feeder switch, the interrupting rating of all downstream branch circuit protective devices *(BCPDs)* would also have to match the rating of



Characteristic let-through current curves of circuit breaker type *NZM2* with breaking capacity H = High.

The maximum available fault I_{cc} selected for this particular example is 40 kA rms sym.

The associated let-through current in a 480V distribution network would then be 20 kA, peak value.

All power circuit components downstream from this breaker would have to have a short circuit rating of 20 kA or better in order to be considered suitable for use.

Figure 15: The let-through current characteristic curve shows the effect of the current limiting design. Based on an available fault Icc of 40 kA at the installation site, the associated peak value let-through current would not exceed 20 kA. Please note: I_{cc} is given as an rms sym value, whereas ÎD is a peak value. The current limiting effect is also dependent on the magnitude of the network supply voltage.

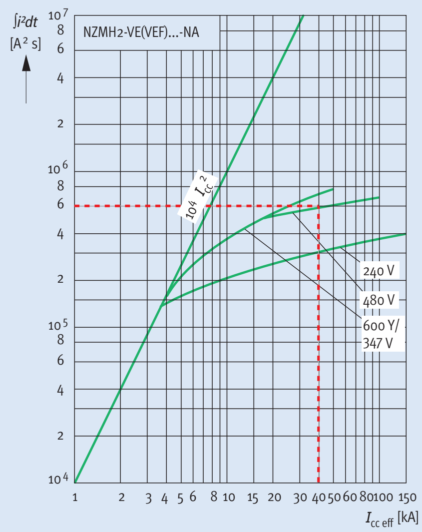


Figure 16: The Figure shows the corresponding let-through energy characteristic curve of the current limting circuit breaker from Figure 15. At an available I_{CC} fault of 40 kA rms sym current, the associated let-through energy would max out at 6 x 10^5 A^2s. (ampere-square seconds).

the feeder switch in order to achieve a matching overall short circuit current rating for the assembly.

The individual *BCPDs* themselves are not sized in accordance with the lower let-through current values and thus could be deemed to be oversized in terms of their interrupting ratings. Admittedly, the technical merits behind this particular aspect of the standard could stand some scrutiny and perhaps should be subject to re-evaluation in upcoming editions. If the BCPDs' interrupting rating does not match the rating of the upstream current limiting device, an analysis of each branch circuit must be conducted in order to identify the lowest rated branch circuit in the group. The use of a current limiting device in the feeder circuit of an industrial control panel is

„Current Limiting" certification in North America for molded case circuit breakers Useful, for example, in determining overall SCCR „Short Circuit Current Rating" of industrial control panels per supplement SB of UL 508A.

Interrupting rating levels	*NZM..1-NA*	*NZM..2-NA **	*NZM..3-NA ***	*NZM..4-NA*
B	*Current Limiting ✓*	*Thermal-magnetic trip Current Limiting ✓* *Electronic trip Current Limiting ✓*	Interrupting level B not currently part of this frame size offering.	Interrupting level B not currently part of this frame size offering.
C	Not certified	Not certified	Not certified	Not certified
N	*Current Limiting ✓*	*Thermal-magnetic trip Current Limiting ✓* *Electronic trip Current Limiting ✓*	*Current Limiting ✓*	Current Limiting certification not possible because of non-current limiting circuit breaker design used in this frame size.
H	Interrupting level H not currently part of this frame size offering.	*Current Limiting ✓*	*Current Limiting ✓*	Current Limiting certification not possible because of non-current limiting circuit breaker design used in this frame size.

* Exception: NZM..2-ME..-NA are not certified as Current Limiting.
** Breakers with thermal-magnetic trips not currently certified.
Instantaneous Trip Only circuit breakers do not carry individual interrupting ratings and cannot be certified as current limiting.
Current Limiting ✓ = The Current Limiting-status of the breaker is verified in the report.

Table 26: Current limiting circuit breakers can play a special role in the determination of Short Circuit Current Ratings (SCCR) for Industrial Control Panels per the UL 508A standard. The Table shows the current certification status of Eaton circuit breakers as of January 2008. The larger frame size NZM4 will often be closest to the power source in a selective energy distribution network. Those breakers perform best in a selective network when they remain closed for as long as it takes the downstream breaker in the affected circuit to clear the fault, and they are not generally designed to be current limiting. Spring forces required to keep breakers of this frame size closed under these conditions need to be especially strong to avoid any possibility of undesired lift-off.

thus not always the most viable solution. If there is a motor contactor located on the load side of a *BCPD* (Circuit breaker or UL 508 manual Type E device) forming a motor starter, chances are the short circuit rating of the combination will be much greater than that of the individual contactor. That stems in part from the fact that both sets of contacts contribute to clear the fault and help break up the arc caused by the interruption of the short circuit current. Every combination motor starter must be so tested in order to confirm optimal ratings. In this regard, the maximum values reached for these types of motor starter assemblies are inevitably those that combine components from the same make.

Another important aspect to consider when using the UL 508A method for determining overall industrial control panel short circuit ratings is the lack of recognition for any form of series ratings performance capability between protective devices, such as is the case in other types of assemblies. The standard does not allow an increase in overall ratings from the interactive combination of two unlike rated protective devices. As an example, it wouldn't be possible to use a UL 489 listed miniature circuit breaker (*FAZ…-NA)* with an interrupting rating of 10kA in a circuit downstream from a current limiting breaker or fuse, both of which with let-through values less than 10kA, and push the overall rating of the combination to, let's say, beyond 10kA to 20kA. Such an overall outcome is certainly theoretically possible, but nevertheless, the FAZ-NA's SCCR rating of 10kA would remain unaffected, and would have to be used as a basis of the panel's overall short circuit determination. People outside North America have a difficult time accepting this viewpoint, since a similar series rating approach with the use of appropriate back-up protective devices is a practice applied successfully in the IEC world. Furthermore, the series concept is recognized by the North American electrical codes in energy distribution systems such as switchboards and panelboards. The idea to exclude it for industrial control panels, therefore, would seem rather unjustified and arbitrary.

Switch-disconnectors *N* or *Molded Case Switches NS*

Switch-disconnectors fulfill in the open position all the requirements of an isolating function. They are installed as a mains or circuit disconnect means to provide proper galvanic separation between a source of supply and an electrical panel or assembly. Molded case switches Type *NS* were designed and certified per the UL 489 standard. Under certain conditions, with corresponding markings and appropriate configuration, they can either simultaneously or exclusively fulfill the function of an Emergency-Off supply circuit switch in accordance with IEC/EN 60 204-1 [7].

Note: It is worth mentioning at this venue that, in the event of a hazardous situation arising, the opening of the main disconnect switch need not always be considered the safest course of action to take, since the complete loss of supply power in and of itself could create additional dangers. The standard specifically states that undertaking an Emergency-off measure is not allowed to create additional hazards. It could be necessary to bring certain drives to a controlled stop or reverse them, or, for example, the process to match or fuse certain parts together would need to be maintained through to completion. For this reason, emergency-off operations are often best carried out in the control circuit. In a priority order of safety related measures, emergency-off actually ranks last, and is considered solely as an additional measure on top of everything else. Solving safety related issues through design measures is always the best approach. The establishment of proper Stop-Category levels must be taken into consideration, as is the need for an overall Emergency Switching-Off function depending on the circumstances.

Even if undervoltage or shunt trip accessories in the disconnect switch are used as part of the control panel door electrical interlocking/monitoring scheme, the afore-mentioned design based safety related measures take overall precedence in minimizing potential hazards. Safety related aspects per IEC/EN 60 204-1 have received very positive reception in North America and the North American industrial machinery standard NFPA 79 in its current 2007 edition often refers to the international norm. The high degree of safety throughout the IEC/EN 60 204-1 standard combined with the precision of

Requirements for multiple disconnect switches in a North American industrial control panel

Main disconnect functions:
1 = For supply circuit
2 = For panel lighting circuits needed for lighting and maintenance purposes
3 = For circuits that are required to remain energized for proper operation of equipment such as measuring and electronic program storage devices.

Requirements of individual disconnect switches:

Switch	Layout of switches in panels	Interlocking of disconnect switches with each other	Electrical and/or mechanical interlocking of switch with control panel doors	Comments
1, 2, 3	Grouped together in one location	Not required		
1			Required	Warning/caution and safety labels are required *)
2, 3			Not required	

Circuits which are not disconnected by the supply circuit disconnect need to be properly separated from other internal conductors and be appropriately marked with safety signs or be identified by color.

*) e.g.: „Warning, live circuits inside when supply circuit disconnecting means is in the OFF position"

Table 27: The table shows multiple disconnect switch requirements in a control panel using 3 typical disconnect switch functions as an example.

the machinery are important reasons why so many European machinery and assemblies are exported to North America.

IEC Switch-disconnectors have for many years been built, designed and tested to the IEC/EN 60 947 Part 3 standard [11]. That particular standard does not allow products to contain any sort of current dependent tripping means. Switch-disconnectors as a result do not have any kind short circuit breaking capacity. They must always be protected against the destructive effects of short circuit currents by an upstream overcurrent protective device. It's typical for switch-disconnectors to have a short time withstand current I_{cw} rating of at least 12 x I_u for 1 second.

The switch-disconnectors differ from the simpler interrupters by the fact that they have a definite making and breaking capacity (motor switching capacity) and that, depending on the utilization category, they can safely switch motors up to their maximum stated switching capacity rating. They have a rated short-circuit making capacity which provides them the capability of closing directly onto a fault, and they can be loaded up to their full rated uninterrupted current I_u. The demands placed on these switches in the IEC world prove that they can easily fit the description of a premium product.

The descriptions provided with respect to scope of application for these switches are also valid in North America, even though motor switching utilization categories in that market are not as well defined as in the IEC world. As a supply circuit disconnecting means for control panels, the switches are usually fed from upstream switchboards or panelboards containing protective devices like molded case circuit breakers and fuses for the protection of the feeder conductors and the switch itself. Additional current limiting means installed between the supply source and the incoming panel switch are always a possibility in order to limit the available fault to a value in line with the panel's overall short circuit rating. Such measures would be required in order to effectively bridge the gap between the circuit's potential fault level on the one hand, and the downstream panel's rating on the other.

In North America, molded case switches are ampere rated devices and applied primarily as disconnect switches for all types of circuits, both in feeder and in branch circuit applications. They retain many design features from circuit breakers, which makes them ideally suited as a supply circuit disconnecting means for engineered assemblies like industrial control panels. They are suitable for both non-motor *and* motor loads, since they have the ability to manually make and break motor locked rotor currents. Since they do share a circuit breaker like construction, they usually feature a high short circuit rating in order to match the relatively higher fault currents available at their point of installation. As manual, non-automatic switches they do not provide any protective trip function for a circuit. However, they do have a distinctive feature which sets them apart from corresponding IEC products: North American molded case switches, such as Eaton NS line, incorporate an internal short circuit trip assembly, which is solely used to provide the switch with self-protection in the event of a high fault. As we shall see, European exporters of equipment to North America should be very pleased indeed that such a feature is included in North American molded case switches. Why? For the following main reasons:

- The internal self-protective feature provides the switch with very high short circuit ratings (SCCR), which, as we have discussed, is a crucial aspect for today's North American installation requirement.
- The internal self-protective trip guarantees a successful short circuit test per the product standard (UL 489), regardless of the type of protective device in the circuit, i.e. fuse or circuit breaker. This means that the exporter need not concern himself with any restrictive "FUSE OR BREAKER ONLY" markings on the switch, nor with the type of protective device in the equipment upstream protecting the feed to the control panel in which the switch is installed.

It's a win-win combination for exporters, which makes the NS switch the product of choice for their export requirements.

As mentioned, the IEC and EN norms for switch-disconnectors neither recognize nor allow the use of a similar, current based, internal trip [17], so this feature remains a very distinctive difference between these comparable types of switches in both markets.

One option of providing the ***NS..-..-NA*** (**Switch style A**) *Molded Case Switches* with some coverage under the IEC standards, since IEC/EN 60 947-3 no longer was an option, came in the form of the recently updated Appendix L of the IEC/EN 60 947-2 circuit breaker standard [10], entitled „Circuit breakers without overload trips *CBI-X"*. Applying this standard to the ***NS..-..-NA*** *Molded Case Switches* had the advantage of allowing the switches to more or less function in the IEC world as a specialized form of switch-disconnector, while at the same time adhering closely to the IEC convention, which strives to maintain all devices with built-in overcurrent trips under the circuit breaker standard. In the end, it was a good compromise to achieve the best of both worlds.

The *Molded Case Switches* are thus able to self-protect up to their maximum short circuit rating (Refer to **Table 11** (page 18). The internal trips, however, are there solely to protect the switch, so that molded case switches per North American standards do not provide any form of circuit protection. Per the IEC standards, on the other hand, they would be considered more like circuit breakers without overload protection, so the IEC would recognize the internal trip as providing some form of protection for the connected circuitry.

The high short circuit ratings of the North American switches as shown in **Table** 11 (page 18), and their lack of any restrictive markings with respect to upstream protective switches, certainly provide them with a great deal of flexibility when it comes to circuit design and installation. As mentioned earlier, the planning engineer no longer has the burden of worrying about any type of limitations imposed on the switch by the circuit conditions upstream. Typically, if the molded case switch is fulfilling the function of a control panel disconnect, the control panel feed will be protected by the upstream power source, either a switchboard or a panelboard, and the European design engineer has no way of knowing what lies upstream. Any type of restrictive marking on the switch, such as "fuses only", or very low short circuit ratings, or both, could prove to be a real problem for the exported assembly in resolving local installation conditions. The use of suitably rated and certified ***NS..-..-NA*** *Molded Case Switches* from Eaton solves all those issues.

Indeed, a more problematic aspect for the design engineer to consider, based on a general consensus of the current situation with respect to short circuit rated control panels, may be the overall short circuit rating of the control panel itself, since often times the panel's calculated rating will result in a much lower value than what the switch alone carries.

The overall *SCCR* of the panel needs to be shown on the panel's nameplate.

The panel designer has various options to consider when evaluating the best rated switch to use for the control panel assembly:

- He can find out from local sources how high the available fault is at the installation site, and then consult **Table 11** (page 18) to select the most appropriately rated molded case switch for the job.
- If the available fault cannot be determined, or if the machine enduser is not known, or if the design engineer wants to work with some built-in reserves, there's always the possibility of choosing a higher rated switch with the same current rating, let's say a NS2 (100kA@480V) versus the NS1 (35kA@480Y/277V). Chances are the NS2's 100kA rating would be able to cover all possible applications. It would be very rare for the available fault at the incoming terminals of a control panel to be a higher value, given that, as a general rule, control panels are located relatively far from the power source and consequently, the number of additional impedances from feeders and cables located between the supply and the panel would likely dampen the fault current even further.

The North American electrical contractor, who is tasked with connecting the machine, makes sure that the protective device and feeder from the up-stream supply to the panel are matched to the current rating of the panel and the incoming switch. The interrupting rating of the protective device, e.g. 50 kA@480 V, must also be sized in accordance with the maximum fault current that the circuit can generate.

Industrial control panels could also conceivably experience an increase in the usage of NZM type current limiting circuit breakers as disconnect switches, rather than NS molded case switches, simply to take better advantage of the current limiting breaker's ability to modify the overall short circuit current rating of the panel by limiting available let-through currents under fault conditions. This practice is allowed under Supplement SB of the UL 508A industrial control panel standard.

Note: Like the molded case switch, the *Instantaneous Trip Circuit Breaker* is also a member of the molded case circuit breaker family. It does not include an overload trip, but it does feature an adjustable instantaneous trip to provide short circuit protection for an individual motor starter circuit. As such, it is a recognized component only, and must **always** be combined with a motor contactor and a separately mounted overload relay for full motor branch circuit protection requirements per the electrical codes.

Advantages of circuit breakers over fuses in North American feeder and branch circuits

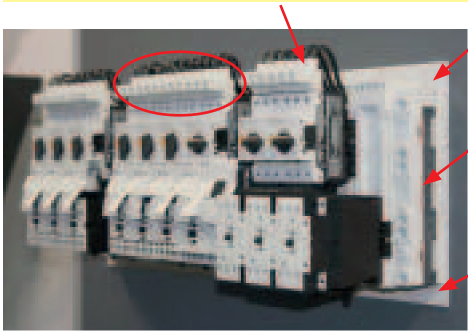
In North America, the protection of multiple types of loads in feeder and branch circuits is predominantly the domain of listed fuses (UL 248 series) and molded case circuit breakers (UL 489). Typical IEC protective devices, like manual motor protectors or common miniature circuit breakers, are often considered unsuitable for the purpose. The use of fuses in North America is quite widespread. On the other hand, the application of fuseless design solutions featuring Type PKZM motor protective switches (as UL 508 Type E or UL 508 Type F) for motor circuits, as well as molded case circuit breakers Type NZM, offer many technical and economical advantages:

- Space saving. Many North American fuse classes have become quite small, but certain older versions continue to be popular, and these can be relatively large and often take up as much room as the combination of a contactor and overload relay, sometimes more.
- Molded case circuit breakers *NZM… -NA* and motor protective switches *PKZM..-..+ BK..(UL 508 Type E)* combine many functions under a unitized construction, such as isolation (including padlocking off), short circuit and overload protection, as well as that of a motor controller. And even so, they can be much more economical and smaller than the combination of fuse base + fuse + contactor + overload relay. Circuit breakers interrupt in all 3 poles and are generally quicker at getting back into service after a fault.
- With the addition of various auxiliary contacts or with electronic trips, Eaton circuit breakers can easily provide trip signal differentiation between short circuit and overload fault conditions. Circuit breakers can accommodate additional functions, like Emergency-Off and automatic restart prevention, fairly economically and without much addtional space by the use of accessories like voltage trips.
- Circuit breakers can be set more accurately to match circuit loading conditions, and short duration inrush peaks can be easily and safely bridged without causing any nuisance tripping.

Motor starters fed from busbar adapters located in the Feeder circuit

Whenever starters are mounted on busbars and fed from the **feeder**, the use of a supply side spacing terminal is required for **UL 508 Type F Combination Motor Controllers.**

Each *Type F Starter* constitutes its own *Branch Circuit*



Use evaluated/certified busbar holders only!

Be on the look-out for possible reductions in permissible busbar ampacity levels!

Bottom plate needed to maintain larger creepage and clearance distances to mtg. plate!

In this example, the incoming supply terminals of the *PKZM0* are considered to be in the *feeder circuit*.

Figure 17: With the SASY60i busbar system featuring motor starter equipped mounting adapters. The bus system is available with both flat and profiled copper busbars. The figure shows a motor starter array with an incoming feed from a feeder circuit, as evidenced by the large electrical clearance terminals on the supply side of the starters (UL 508 Type F combination motor starters). The bus system also features UL certifed bus holders and supports, as well as a bottom plate made of insulating material.

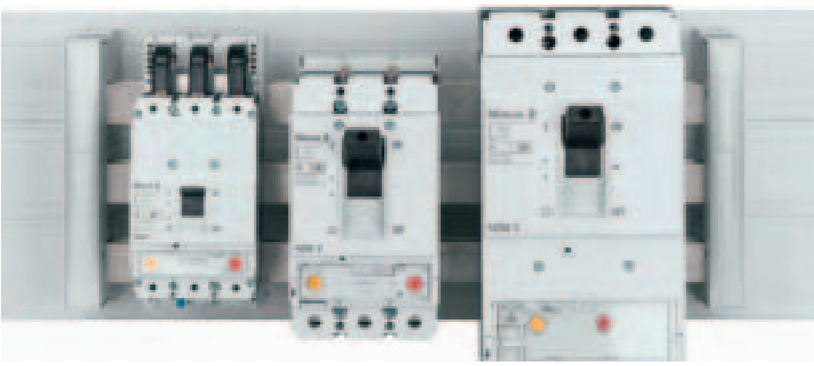


Figure 18: Panel busbar systems with bottom plates made of insulating material and equipped with bus component adapters for frame size 1, 2 and 3 circuit breakers and molded case switches. Frame size 4 breakers and switches are physically too heavy to be supported by busbar system adapters. The adapters can be field modified by users in such a way as to allow incoming supply side conductors to connect through the top or bottom of each switch.

- The US and Canada feature a multitude of available fuse characteristics and classes. The variety alone makes the selection process for machine and control panel manufacturers exporting from Europe that much more difficult to co-ordinate with respect to local installation conditions. IEC fuses are generally neither known nor accepted in North America.
- Fuseless design for the machine and assembly makes the process independent of fuse system selection. Spare part maintenance is not as difficult when fuses are excluded from the process.
- It is arguably safer for personnel working on live equipment to do so on modern fuseless equipment, in which the potential for arcing faults is considered less.
- Fuseless designs, depending on the type of fault, enable potential re-setting of the circuit without opening the control panel door.
- Exporting machine manufacturers from the IEC world tend to avoid the use of North American fuses in their assemblies, and are aware that IEC fuses in North America tend to have little acceptance. Conversely, North American fuses are not readily accepted in the IEC world. From that point of view, the use of fuses tends to make the design of a universally acceptable panel for both markets a more challenging task.

Use of certified accessories for the panel builder

The paper deals primarily with general aspects of the molded case circuit breaker line. Beyond that, however, are a number of associated parts and accessories (**Figure 3** (page 13), whose purpose it is to help fulfill a number of safety related requirements, accomplish more complex circuit functionality, and essentially allow the circuit breaker more flexibility in its end-use application. It's worth mentioning here that the accessory assortment for circuit breakers for the IEC market, and those for the North American market, are identical. The design goal for both lines remains the same. That is a definite competitive advantage. Other firms offer much different constructive approaches for both markets, often with accessory lines that have little commonality with each other, i.e. not even the auxiliary contacts are the same.

In addition to field installable standard auxiliary contacts used for various signalling and interlocking purposes, the main accessories for these Eaton circuit breakers include undervoltage and shunt trips, remote control drives and mechanical interlocks. Furthermore, there are many customized accessories for panel mounting, including busbar adapters, custom covers for shock hazard protection, special power terminations and a broad range of operating handles. Nearly all accessories are certified for the North American market. Plug-in and withdrawable units were intentionally left out of the certification process since the IEC design specifications for those particular accessories are quite a bit different than the North American standards require. These accessories are also primarily found in typical IEC energy distribution systems, which are very rarely exported to the North American market. There are also accessories which were specifically developed for the North American market. These include special barrel lug terminations for single or multiple cable connections, and vertical motion handles with Bowden cable connectors which allow the handle to remain in contact with the switch at all times. Supplementary handles, which mount to disconnect switch housings internally and allow operation of the device from inside the control panel when the door is open, were also developed to satisfy the requirements of the North American market, but can also just as easily be used in IEC applications. These handles have been available for years but a newly introduced requirement involving the need for a *„deliberate Action"* on the part of the operator made it necessary for a re-design of the handle [18]. These handles and the overall theme of door interlocking will be described in closer detail in an upcoming section.

This latest product offering, with its clear design structure and advantageous modular concept, made the certification process somewhat more laborious since all combination possibilities required thorough descriptions, and there were many markings necessary on the equipment as well as in the accompanying installation instruction (AWA) and Informational Leaflet (IL) documentation[19].

In North America, typical smaller frame circuit breakers are usually connection ready and don't offer much in the way of field modifications. But in cases where the breakers do offer modular and field installable accessories, it's very important to insure that the necessary electrical clearances are maintained at all times through all permissible variations of assembly.

This especially includes accessories like terminal covers and barriers, whose primary function may not be the provision of necessary clearances, but whose presence in the final assembly to that end is considered necessary. The manufacturer's set of installation instructions must be followed in all cases to insure proper assembly.

New busbar system *SASY 60i* opens up new possibilities in the assembly of control panels featuring circuit breakers

Power busbar adapters equipped with fuseless motor starters have long been established in the IEC world as an effective design tool for industrial machinery control panels (**Figure 17**). The method is considered state-of-the-art. One big reason for its popularity is that the space normally reserved for power wiring inside the panel can now be effectively used for the mounting

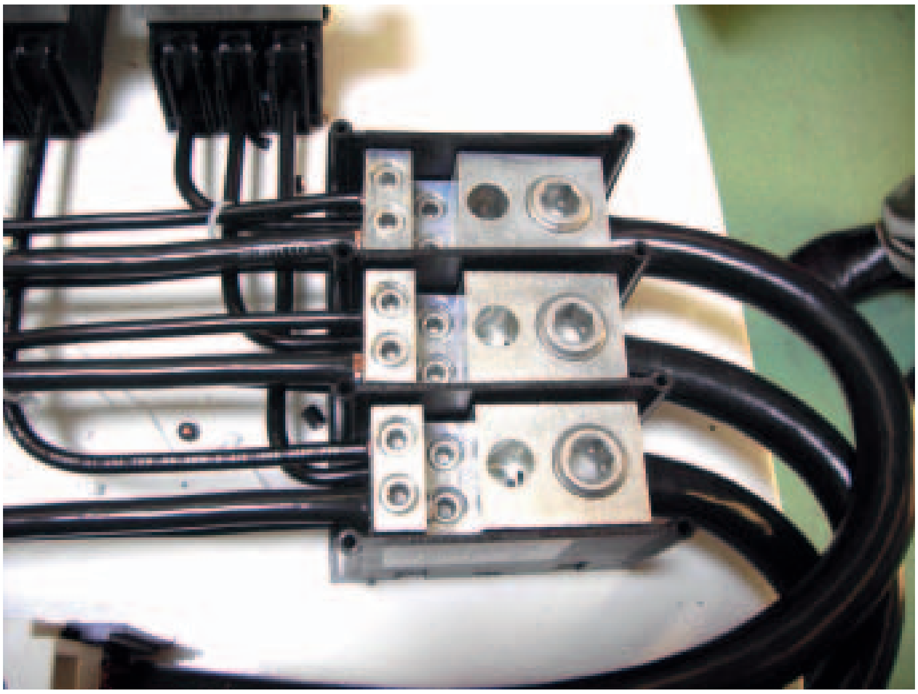


Figure 19: Power Distribution Blocks are still encountered frequently in feeder portions of North American control panels. They can accommodate large incoming supply conductors, which can then be tapped off into multiple outgoing conductors of smaller cross-sectional sizes.

of power circuit components. There is currently a growing trend to go beyond simple motor starters and to equip busbar adapters with complete combination motor starter assemblies, as well as molded case circuit breakers and switches (**Figure 18**), rather than just busbar mounted fuses, which had been previously the convention. In North America the use of *Power Distribution Blocks* (**Figure 19**) for energy distribution purposes within a control panel is still very popular. The main function of these power terminal blocks is to accommodate the incoming supply wiring on one side, and on the other, tap off into multiple circuits of smaller cross-sections in order to connect downstream power circuit components.

Tap rules must be observed, as to when and how the smaller cross-sections need to protected. The use of busbar systems makes that somewhat easier, since each busbar adapter is normally equipped with a branch circuit protective device *(BCPD)*, which, in the case of a motor starter, would then be wired to a motor contactor. Each branch is thus protected in accordance with its crosssection and per the load considerations of the branch circuit and protective device. In North America, the use of busbar systems in control panels is not as well established, so there is a large potential to tap in this respect. Part of its lack of popularity is due to the manner in which bus systems are traditionally utilized in that market, which typically doesn't include control panels. In motor control centers for example, each motor starter unit is compartmentalized, so the use of such control panel busbar systems is not really considered practical, even though the use of vertical and horizontal busbars in that particular type of assembly is a prominent feature of the design.

Generally speaking though, the advantages of bus systems are well known and recognized. Furthermore, exported machinery and assemblies to North America utilizing these busbar configurations have increased their exposure outside the IEC world, and greatly popularized their usage.

The bus itself, the bus holders, adapters and terminal connector block on the incoming side of motor protective switches lie mostly in the feeder circuit portion of industrial control panels (Figure 5, page 19). In North America, this particular area of the circuit (at least on the incoming side) generally requires larger distribution electrical clearances on component field terminations, i.e. distances of an 1" (1 Inch = 25.4 mm) through air and 2" (2 Inch = 50.8 mm) over surface between terminals and points of opposite polarity for circuits up to 600V (**Figure 20**). A clearance over surface of at least 1" would also be required between uninsulated live parts and any grounded metal surface such as a mounting plate or an enclosure wall. Those are the classical electrical clearance requirements of energy distribution systems in North America *(Distribution Equipment)*.

When one considers that European power circuit components, e.g. a *PKZM0* motor protective switch, can only be 45 mm in width, one can imagine how challenging it is to resolve these spacings requirements. Even on components of that size, the electrical clearances between phases and to housing sidewalls must be maintained. In many instances the only way to do that properly is to cleverly incorporate notches and ridges into the material molding. For applications in North America, or in cases where a single panel layout is to be made universally acceptable, the use of additional insulated bottom plates (**Figure 17**) next to the mounting plate on the supply side is often necessary to maintain these greater creepage and clearance distances. The use of spacers

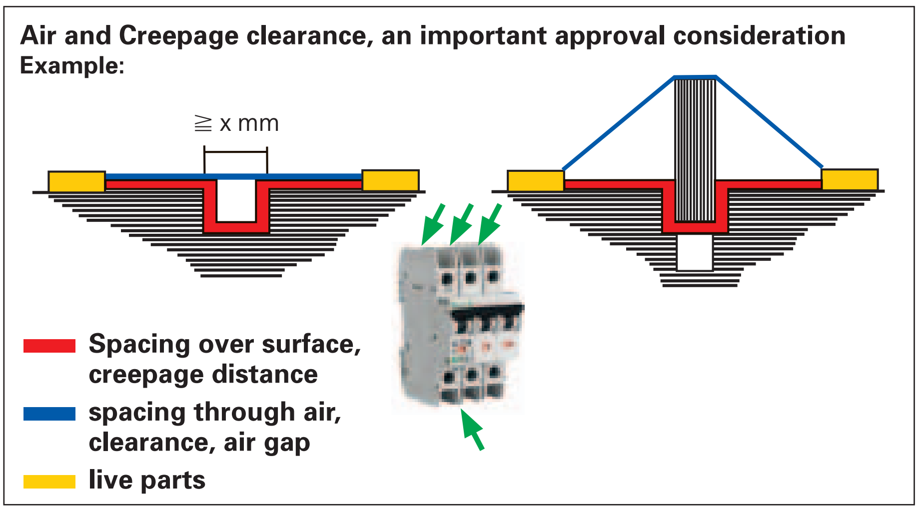
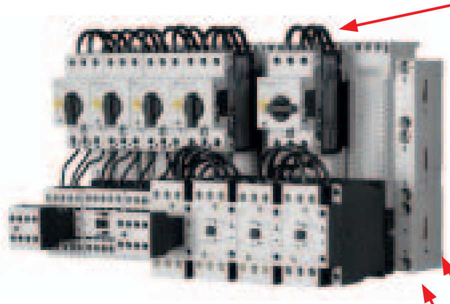


Figure 20: The basic principles underlying the concept of "creepage and clearance" distances (spacings). The barriers used to provide greater air and creepage clearances on the miniature UL 489 listed molded case circuit breaker Type FAZ..-NA are highlighted in the bottom right figure.

Motor starter on busbar adapters (under Group Protection rules)

The use of busbars in motor branch circuits is not as common. Industrial control spacings ("small" spacings) would be sufficient in this case. Application example: **Group protection** (the entire grouping makes up **only one individual Branch Circuit)**



No large spacing incoming terminal necessary. ***Group Protection listings/ certification required!*** **Group back-up branch circuit protective device also required! 1/3 rule** electrical Code wiring requirements apply! For *Tap Conductor Protectors*, 1/10 rule electrical Code wiring requirement apply. (for solidly grounded, Slash rated, networks) **Sizing of group back-up branch circuit protective** per electrical Code rules!

Certified versions of IEC busbar holders are sufficient spacings wise.

No additional bottom plate required between bus holder and mtg. plate.

These are not Type F- combination controllers, Back-up branch circuit protective device required!

Figure 21: SASY60i busbar system located in the branch circuit. This array is possible as long as each motor protective switch is additionally evaluated and listed for group protection per the electrical codes. A branch circuit protective device (such as a UL listed fuse or inverse time circuit breaker) must be provided ahead of the group. See Figure 18 (page 43). This application is becoming less common with the advent of Type E and Type F motor protective devices.

under the busbar holders, as a means of creating more clearance from the mounting plate, is not considered optimal since it may weaken the overall rigidity of the system and create concerns under fault conditions, particularly in view of weightier mounted components, such as circuit breakers and switches. The center of balance from the entire system would also be shifted away from the mounting plate. The larger electrical clearances must be maintained at least all the way through to the incoming terminals of the *Branch Circuit Protective Device.* Smaller industrial control spacings are found in the branch circuit itself, i.e. on the load side of the BCPD.

Bus bar hardware components in the *SASY60i* busbar system come in both UL and IEC versions but the adapters themselves are universally rated and can be applied in both markets. That means that all adapters are equipped with certified cables and wiring materials. Even though the system is often installed in the feeder portion of the circuit, there are certain cases, for example in group applications, where the entire bus system could be fed from the load side of a branch circuit protective device. In that case, the smaller spacings more typical of the IEC construction would apply, and there would no longer be a need for the special bottom plate. Furthermore, the additional spacing terminal block, which is normally found on motor protective switches when they are used as stand-alone protective devices in individual motor circuits, would not be considered necessary since the assembly would fall under the group application provisions of the electrical codes (**Figure 21, Figure 22**). Such group arrangements can also prove to be a useful design engineering option when the supply network would otherwise restrict the use of motor protective devices in stand-alone applications, such as would be the case in commonly encountered ungrounded delta distribution systems.

A broad range of accessories simplifies the way to connect the bus system and help cover live parts. The component adapters already cover the largest sections of the bus in a touch safe design construction. Sections left uncovered for future additions can be easily fitted with customized insulating material pieces to shield all exposed parts. It's also possible today, in addition to the use of busbar adapters for motor starters, to mount NZM molded case circuit breakers and NS molded case switches in similar fashion directly onto busbar systems. These can reach current levels up to 550A (Frame size 3) and can be used either as an incoming supply disconnecting means or for the protection and/ or isolation of outgoing circuits. Incoming terminals on supply circuit switches in North America are always equipped with line terminal shields, which are readily available as an add-on accessory for such purposes. The same would apply when the switch is mounted in this manner on busbar systems. It's also recommended in North American panel assemblies to provide adequate spacing between the supply disconnecting means and outgoing feeder and motor starter circuits, as a way to visually distinguish between incoming and outgoing power circuits. Markings and safety signs are additional ways in which to highlight the area between incoming supply and outgoing circuits. For additional details on System *SASY60i* please refer to the technical paper [12].

Molded case circuit breakers, when subjected to heavy fault currents, can blow out through their top and bottom end. Adequate blow-out space, in accordance with manufacturer specifications, must also be taken into consideration and strictly adhered to when devices are mounted directly onto a busbar system. In the case of a 500A breaker, for example, copper cross-sections will tend to be large to accommodate the loading. When bringing in supply conductors of that size it's especially important to leave sufficient room for cable entry and wire bending clearances. Busbar systems also **Figure** prominently in the determination of an overall short circuit current rating *(SCCR)* for a panel or an assembly. Comprehensive testing has shown that the combination of Eaton equipment on busbar adapters favorably raises the short circuit rating of the entire bus assembly system up to the rating of the mounted components. It was important to demonstrate that the large dynamic forces generated by the short circuit current did not pull apart vulnerable connection points between the adapters and the bus bar system assembly. (similar physical process to what was described earlier for the contact systems). The solid construction of the adapter contact system safely eliminates any chance of welding on those potentially critical locations. The tight connections keep contact resistances down and help minimize heat losses.

As mentioned, testing demonstrates that the short circuit withstand rating of the bus system can be raised to match the maximum value of the components mounted on adapters. If mounted components do not share the same rating, the overall rating of the bus system and the adapters will default to the lowest rated unit. From this point of view, it could make sense to break the

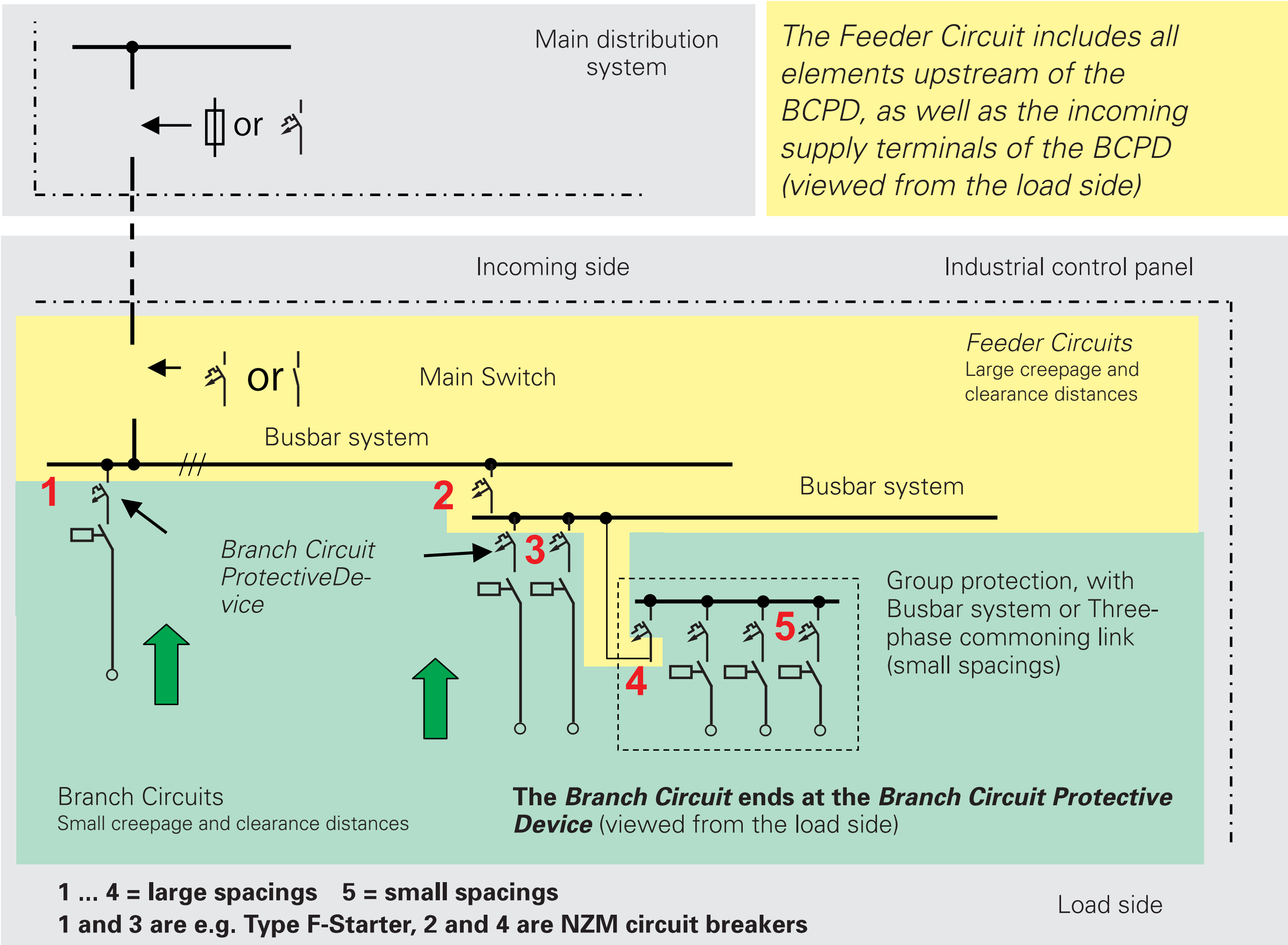


Figure 22: A motor starter grouping (5) consisting of PKZM0 motor protective switches and DILM contactors (not a Type E or F array) is located on the load side of a group branch circuit protective device in a branch circuit. In this case, the smaller industrial control electrical clearances on the load side of the branch circuit protective device would apply. The group protective device can either be placed and connected on the bus system together with the starters, or mounted separately.

assembly down into smaller segments of similarly rated components as part of an overall design approach. A selective grouping in this manner would also be helpful in group protection arrangements as a means to better rationalize the cross-section of outgoing conductors with the size of the back-up branch circuit protective switch. (keyword: 1/3 rule, 1/10 rule, refer to [3]). The use of adapters to mount components will be extremely effective at saving space in the panel and will enable a greater concentration of starters in a given volume. For this reason it is recommended to generously size the cross-section of the busbars, so that a good amount of heat transfer and dissipation throughout the panel can take place. At the very least, the busbars themselves should be sized to run as cool as possible and not be unduly contributing to unnecessary heat production in the panel. A combination of careful design planning and proper evaluation of diversity factors can be helpful in this respect.

3 phase bus links or connector pieces for smaller rated current devices are very commonly used in the IEC world as way to more effectively distribute electrical energy between components in control panels. These 3 phase commoning links, as they are often called, are customized wiring devices belonging to specific product lines such as *PKZM0*, *PKZ2*, *PKZM4* motor protective switches or *FAZ-NA* molded case circuit breakers, and usually come with a dedicated supply terminal block which feeds each grouping of product so linked. They are especially advantageous economically for lines like the FAZ-NA miniature molded case circuit breakers because they also come available in 1, 2 and 4 pole versions. 3 phase commoning links are also especially valuable as as a wiring aid in group protection arrangements and with components such as UL 508 Type E and F combination motor starters.

Special requirements on the use of circuit breakers and switches in North American engineered products and assemblies

North American colleagues often tell the story of their experiences during job start-ups when certain portions of newly arrived European equipment, usually the supply circuit disconnecting means, would be intentionally removed and replaced by more conventional North American products, simply because the European device did not meet typical North American operational conventions. This represents a particularly difficult aspect of the export market. Whereas it is relatively easy to learn about product certification requirements and read the contents the standard itself, local knowledge of North American mindsets and conventions is arguably a lot harder to come by. Often times, the problem is not in the equipment itself but rather, in the way it is operated, which may not be that familiar to local plant personnel. But since switch and operating handle go nearly always hand in hand, and are not so easily separated from each other, replacing the entire switch often becomes the only viable option. The machine manufacturer will, in most cases, never hear about the change, and will just go on assuming that the equipment supplied was acceptable in every respect.

Besides obvious dissatisfaction on the part of local customers, such situations can potentially always trigger additional costs and delays, and even create regulatory problems with local approval authorities. To be fair, it would also be pretty difficult for a European based panel builder to have to perform changes on a panel or assembly locally. On the one hand, field changes to a certified panel would in all likelihood be impossible without, at the very least, the local intervention of the certification agency. But even in spite of that, the hiring of local contractors to perform any kind of follow-up work could also be problematic since it may violate the local plant's labor practices and contractual obligations. The influence of strong unions in certain areas of the country may complicate matters even further, and whatever representation the machine manufacturer may have in place locally may not necessarily be of any use, other than perhaps to perform a supervisory capacity. The right way will always be to properly select certified equipment for the North American market ahead of time, i.e. during the design phase of the project. You can count on Eaton to have the right products available for the job, world-wide. Of special significance to European based exporters are aspects dealing with disconnect switch operators and in particular, the requirements of the supply circuit disconnecting means for applications such as industrial machinery:

- Most supply circuit disconnect switches are certified products per UL 489 or UL 98.
- Similar to IEC, supply circuit disconnect switches in North American assemblies are 2 or 3 (Trip) position switches.
- Supply circuit disconnect switches are allowed to be power operated electrically with the use of *NZM..-XR…* remote control drives, which are also padlockable.
- A supply circuit disconnect switch is required for each incoming source of energy, and must simultaneoulsy disconnect all ungrounded conductors from the supply.
- Supply circuit disconnect switches (in *Control Panels for industrial Machinery,* per UL 508A und NFPA 79) must be operable at all times independent of the door position, and without the use of a tool, and must be padlockable in the OFF position.
- Supply circuit disconnect switches in the afore-mentioned application must be interlocked with all panel doors. That means: opening the door is only possible if the power is off, or, put another way, the act of opening the door effectively needs to remove all power inside. Exceptions to this rule will be discussed later in the paper (permissible defeat of the interlocking mechanism by qualified persons under additional sets of conditions.).

In North America, it's possible to install the supply circuit disconnect switch *adjacent* to the main enclosure panel in its own enclosure. Panel builders from other countries, who normally work with IEC standards, seldom select that solution however, simply because they tend to prefer not straying too far from the solution they like to employ globally. In fact, the goal of most companies today is to ideally standardize on a single panel design layout which would find acceptance world-wide. Admittedly, most firms find that to be a most difficult goal to reach. As in the IEC world, a control panel should ideally have only one source of supply and one single supply circuit disconnecting means. If that is unavoidable and multiple supply circuits are necessary (AC and DC, higher frequency, different voltage levels) then the proper way is to group them together in a dedicated area of the panel. Warning signs on the exterior of the panel would need to be present to alert users that full removal of power would require switching off more than one circuit disconnect. Markings on panels warning of potential flash hazards would also be required for control panels per section 110.16 of the NEC and the intent of NFPA 70E.

Table 28 shows an example of a control panel with more than one incoming supply source. It should be possible for the user to readily identify multiple sources of incoming power into a panel, along with multiple disconnects, and it should be clear that all would need to taken off line in order to achieve full removal of power inside the panel. It is also allowed to feed circuits from the line side of the supply circuit disconnecting means, e.g. undervoltage protection circuits, lighting circuits used for maintenance, circuits supplying equipment that are required to remain energized etc.…

In order to do so, however, all the requirements spelled out in the standard to address these cases would have to be followed, including the use of additional disconnects, adequate separation of circuits, the use of special color identifiers for cables, permanent safety signs etc.… A suitable door interlocking and monitoring means must also be

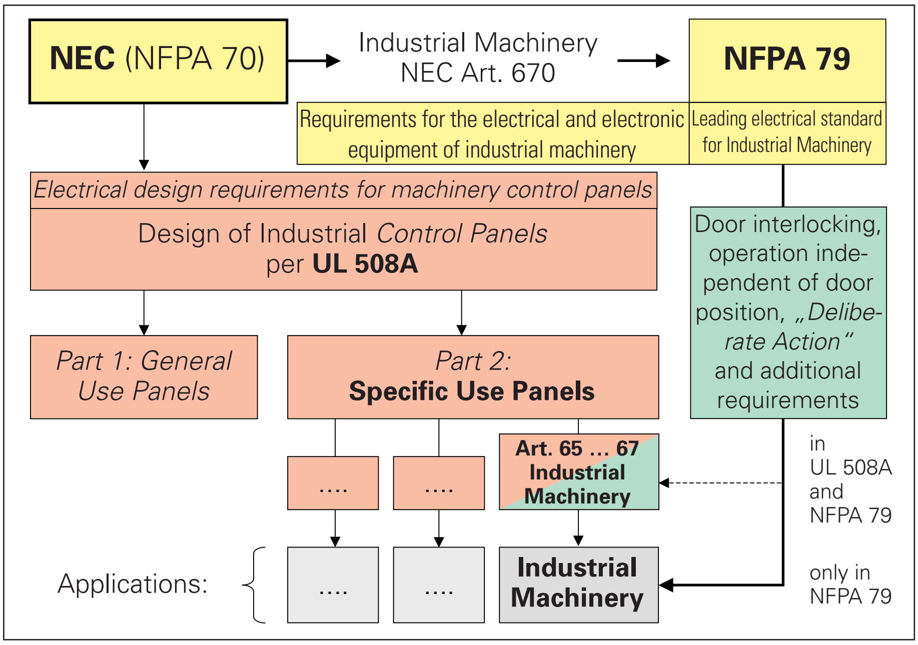


Figure 23: Relationship between the relevant standards NFPA 70 (NEC), NFPA 79 and UL 508A dealing with electrical control panels for industrial machinery. There are many different types of industrial control panels. Control panels for industrial machinery are usually afforded the most stringent requirements, including, for example, specific door interlocking provisions and permissible ways to secure operation of the supply circuit disconnecting means when the control panel door is open.

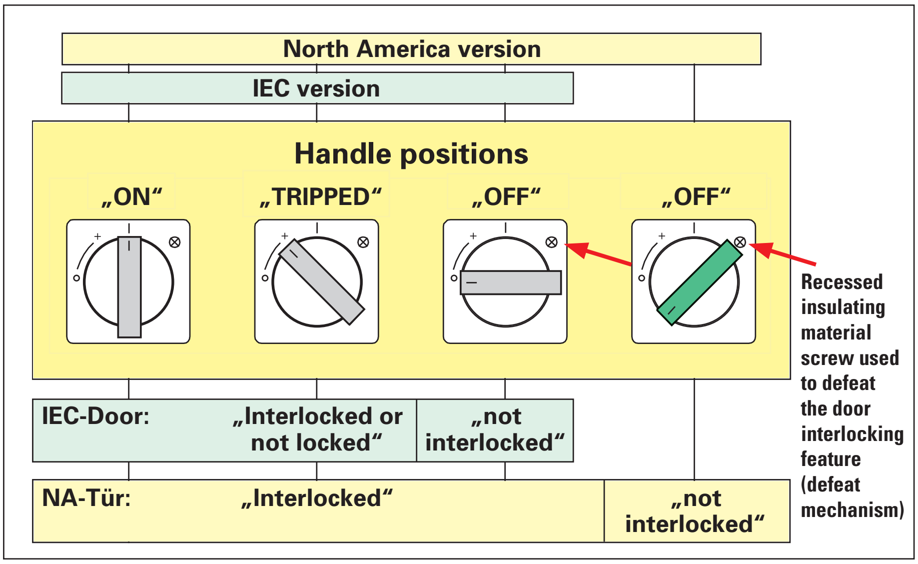


Figure 24: Description of various operating handle positions for main disconnect switches in North America. The three positions on the left are also representative of the IEC handles. In the OFF position, the control panel door can be opened. In the North American version, the handle in the OFF position remains interlocked with the panel door. A slight operational overtravel beyond the OFF position is necessary for the handle to release the interlock and allow the door to open. This is the preferred method in North America for these types of handles because it prevents the door from otherwise unintentionally opening on its own if the handle is in the OFF position. These handles are all equipped with a interlock defeater mechanism which can be accessed with a screwdriver by qualified persons.

in place for all control panel doors. A higher margin of safety in electrical door monitoring circuitry can be introduced with the use of transformers at voltages below shock hazard levels.

The standards in North America don't require any special form of mechanical interlocking between multiple disconnect switches, as is often the case in Europe for various applications (e.g. emergency supply of power transfer equipment). This mechanical IEC type accessory (*NZM..-XMV*) can still be used in North America, however, in order to achieve additional margins of safety.

Door Interlocking provisions

The UL 508A [4] standard for *Industrial Control Panels* is made up of two parts. Part 1 deals with „*General-Use-Panels*" and identifies basic requirement guidelines valid for all control panels. Part 2 of UL 508A deals with the requirements of „Specific Use" control panels and identifies special requirements specific to a range of applications which go beyond the guidelines spelled out under the General Use section. Control panels for industrial machinery would be a typical example of a specific use control panel found in Part 2 of UL 508A, and would include, for example, the same kind of control panel door interlocking requirements found in the electrical standard for industrial machinery NFPA 79 (**Figure 23**). Additional examples of "Specific Use" control panels include *Elevator Control Panels* or *Crane Control Panels,* each with their own set of special requirements.

The electrical standard for industrial machinery NFPA 79 [5], (which covers all types of industrial machinery and is comparable to the Machinery Directive standard IEC/EN 60 204-1 [7])), stipulates the following:

- Each supply circuit disconnecting means, whether mounted within or adjacent to a control panel enclosure, shall be mechanically, or electrically, or mechanically and electrically, interlocked with the control panel doors in such a way that none of the doors can be opened unless the power is disconnected.

The topic of door interlocking in industrial applications brings together many conflicting views on the subject from across the globe. These include, on the one hand, the basic premise which would stipulate that work performed on electrical installations in the field, for personnel safety reasons, be done solely off line, or under removal of all power, and on the other, the practical realization that troubleshooting of an electrical assembly, or the performance of necessary adjustments to equipment, can and should only be done under live conditions.

In earlier times the most common way of shutting power off in the event of a panel door being opened involved the use of door mounted limit switches which were interlocked with the main disconnect switch (electrical interlocking). These days, a sudden removal of power (as in Emergency-Stop), could be problematic for the machinery from a safety point of view (and may cause its own sets of hazards, or there may be a need to take Stop category levels (Emergency Switching-OFF) into consideration) so that the use of special safety positioning switches to mechanically keep doors closed and prevent inadvertent opening is becoming more prevalent. A deliberate intent to open panel doors thus becomes necessary for the action to take place. As indicated later in the paper, the defeat of such a door monitoring/interlocking mechanism by qualified persons is permitted by the standards.

It's helpful that all adjustable elements and actuators (e.g. a potentiometer to adjust time delay settings on timers), which are not only serviced by qualified persons, can be integrated into the door, so that they can remain accessible when the control panels are closed. In many instances, however, adjustable controls are designed to purposely restrict access to those who are unqualified for the purpose. Accessories, such as special covers which can only be opened by qualified persons with the use of a tool, can be useful in achieving this type of protection. A number of enclosure designs on the North American market feature control panels with both outer and inner doors. Actuators mounted on the outer door would generally be accessible to everyone, whereas restricted elements and controls would be part of the inner panel door design and only an inadvertent opening of the inner door would trip open the main disconnect switch or the main switch would have to be first de-energized in order to allow opening of the inner door.

The North American standards do have provisions to allow trained and qualified persons access to live parts inside an electrical assembly such as a control panel. Door mounted rotary handles type *NZM..-XDTV(R)-NA,* with a door interlocking feature, provide qualified persons the ability of defeating the door interlock with the use of a screwdriver (defeat mechanism per UL 508A). The door interlocking feature can only be defeated, however, if the handle is not padlocked in the OFF position. The defeating feature cancels itself once the panel doors are re-closed, whether the

Operating handle features per IEC and NA standards for breakers and switches Type NZM, N, NS and PN					
Type	**Environmental Rating** IEC/EN – UL/CSA (NEMA) P 20 / 40 = IP 20 open / IP 40 with Door cut-out and frame		**Handle color**	**Interlocking / padlocking capability** Door interlocking provisions on handles in yellow shaded areas only	**Figure 25, Part…**
IEC-Door mounted rotary handles				**Door opening in OFF position*)**)**	
NZM..XTVD(-60)(-0)	IP66	UL/CSA **Type 12 + 4X**	black	Handle padlockable in OFF	A/B
NZM..XTVDV(-60)(-0)	IP66	UL/CSA **Type 12 + 4X**	black	Handle and switch padlockable in OFF[2]	C/D
NZM..XTVDVR(-60)(-0)	IP66	UL/CSA **Type 12 + 4X**	red	Handle and switch padlockable in OFF	C/D
IEC- rotary handles mounted directly on switch				**Door opening in OFF position*)**	
NZM..-XDVG	IP20/40	UL/CSA Type 1	black	Handle padlockable in OFF	E/F
NZM..-XDVGR	IP20/40	UL/CSA Type 1	red	Handle padlockable in OFF	E/F
NZM..-XDV	IP20/40	UL/CSA Type 1	black	Switch padlockable in OFF	K/L/M
NZM..-XDVR	IP20/40	UL/CSA Type 1	red	Switch padlockable in OFF	K/L/M
NZM..-XDTV	IP20/40	UL/CSA Type 1	black	Handle padlockable in OFF[1][2]	G/H
NZM..-XDTVR	IP20/40	UL/CSA Type 1	red	Handle padlockable in OFF[1]	G/H
NA-Door mounted rotary handles				**Door opening beyond OFF in Reset position*)**	
NZM..XTVDV(-60)(-0)-NA	IP66	UL/CSA **Type 12 + 4X**	black	Handle and switch padlockable in OFF	C/D
NZM..XTVDVR(-60)(-0)-NA	IP66	UL/CSA **Type 12 + 4X**	red	Handle and switch padlockable in OFF	C/D
NA-rotary handles mounted directly on switch				**Door opening beyond OFF in Reset position*)**	
NZM..XDTV-NA	IP20/40	UL/CSA Type 1	black	Handle padlockable in OFF[1][2]	G/H
NZM..XDTVR-NA	IP20/40	UL/CSA Type 1	red	Handle padlockable in OFF[1]	G/H
IEC-Main disconnect handle kit				**Door opening in OFF position*)**)**	
NZM..-XHB	IP66	UL/CSA **Type 12 + 4X**	black	Handle padlockable in OFF[2]	R
NZM..-XHBR	IP66	UL/CSA T**Type 12 + 4X**	red	Handle and switch padlockable in OFF	S
NZM..-XS(M)-L(R)	IP66	UL/CSA **Type 12 + 4X**	black	Handle padlockable in OFF	T/U
NZM..-XSR(M)-L(R)	IP66	UL/CSA **Type 12 + 4X**	red	Handle padlockable in OFF	T/U
IEC- Main disconnect handle set with internal supplementary handle, IEC-door mounted handle				**Door opening in OFF position*)**)**	
NZM..-XHB-DA	IP66	UL/CSA **Type 12 + 4X**	black	Handle and switch padlockable in OFF	S
NZM..-XHB-DAR	IP66	UL/CSA **Type 12 + 4X**	red	Handle and switch padlockable in OFF	S
NA- Main disconnect handle set with internal supplementary handle, NA-door mounted handle				**Door opening beyond OFF in Reset position*)**	
NZM..-XHB-DA-NA	IP66	UL/CSA **Type 12 + 4X**	black	Handle and switch padlockable in OFF	S
NZM..-XHB-DAR-NA	IP66	UL/CSA **Type 12 + 4X**	red	Handle and switch padlockable in OFF	S

*) in ON, the door interlock can be defeated with the use of a tool
**) the door interlock is factory supplied in de-activated form.
1) Interlock for small doors only, e.g. drawer units for MCCs (motor control centers)
2) modifiable, handle also padlockable in ON-position

Table 28: Switch operating handle variations with their associated North American environmental ratings. It is especially worth noting the interlocking and padlocking requirements of the North American versions of the handles. All handles carry UL and CSA certification, and the certified IEC versions of the handles would also be legitimate in export assemblies, although they have lesser appeal locally as individual components sold through distribution channels. Refer to text body for more information.

door interlocking provision is achieved mechanically or electrically. Conversely, the door interlocking provision re-activate automatically when all the doors are re-closed.

It is peculiar to North America that the rotary disconnect switch operator handle must be turned slightly past the OFF position in order to fully disengage the interlock and allow the door to open (**Figure 24, Table 28**). Without this over-travel, the door could open on its own, especially if the door is unlatched, as soon as the main switch operator handle would be brought to the OFF position. That's why the North American style rotary handles remain interlocked with the door until the handle is deliberately rotated slightly past the OFF position.

There are, therefore, 4 positions associated to the North American versions handles, as opposed to just 3 for the IEC versions. The handle doesn't lock into this 4th position, i.e. it springs back to the OFF position once you let it go. The North American version of the handle, with suffix *-NA*, should be the one used in export machinery and assembly projects. Admittedly, they take a bit of getting used to on the part of world-market machinery users not familiar with North American conventions. Also, all of the IEC versions of the handles have also been certified for the North American market. An overview of possible door interlocking functions and padlocking capabilities for the handles is provided in **Table 29**.

Circuit breakers or *Molded Case Switches*, when used as the supply circuit disconnecting means for control panels in North American industrial machinery applications, need to fulfil many requirements, some of which are:

- **They need to be operable independent of the control panel door position and without the need for special accessory tools or devices by qualified persons.**
- **They need to be provided with a permanent means allowing to be locked in the OFF position, also independent of the door position.**

Rotary mechanisms for switches are not as common in North America as they are in the IEC world. Some are not as readily accepted in the market place as the more conventional North American designs, in spite of their UL/CSA product certification, and are harder to market as components for that reason. Selection of the wrong type of operator can lead to definite approval problems for the assembly, depending on the location and the application. If possible, the type of operator used to actuate the supply circuit disconnecting means should be clarified during the early design stages with all parties involved, or it is recommended to simply use a design that is more conventionally accepted in North America. As mentioned, equipment requirements from industrial machinery standards such as NFPA 79 can be quite demanding, as are the actual specifications from large end-users such as the automotive industry. The only viable solution in some of these applications may consist of the *„Vertical Motion/ Flange Mounted Handle"*, which will be discussed in more detail in an upcoming section and which represents the most conventional type of operator used in North America. It is not only a regulatory issue, but one which must also factor in market familiarity and user acceptance.

Operating handles with North American environmental protection ratings

Molded case circuit breakers and switches from Eaton are known for their rugged design. The significance of the operating handles to the overall image of durability for the circuit breakers cannot be underestimated. In addition to the many styles and variations of operators available for the line there is one aspect which needs special mention: The high North American environmental degree ratings offered by the handles. As can be seen in **Table 29** (page 51) and **Figure 25** the door mounted handles are provided as standard with UL & CSA Type 12 and 4X ratings. These ratings will cover a large majority of the application requirements, including those of the industrial machinery standard NFPA 79. Field inspectors need to verify the environmental ratings of door mounted operators to make sure that the environmental rating of the enclosure into which they are mounted is not compromised. The handles are thus provided with stickers referencing UL/CSA and IP environmental ratings, which can be attached to the base plate of the handles. Each opening in an enclosure is a potential source of concern, because it could adversely affect the overall environmental rating of the enclosure. All door mounted operators and openings are thus closely screened by inspectors in view of the impact they could have on the overall environmental integrity of the assembly.

Figure **26** shows various operator padlocking solutions which are compliant with the norms. The handles can be locked off with multiple padlocks and versions „b" also feature a padlocking provision on the rotary mechanism attached to the switch housing. The molded case circuit breakers from Eaton described in this paper all have a toggle switch as a basic operator. The rotary mechanism is the accessory which translates the vertical motion of the toggle into the rotary motion of the door or switch mounted rotary handles (**Figure 27**). Devices equipped with rotary handles mounted directly on the switch are meant for installation in panels which are not meant to be accessed from the exterior.

Switches equipped with this open style handle can only be operated when the panel door is open. They can be used for motor starters, load switching or outgoing feeder applications. Without any door mounted operator the switches are not suitable for main disconnect switch applications, since a main disconnect must always be accessible from the exterior without having to open any doors. This requirement applies in all markets. **Figure 32** (page 54) shows a rotary mechanism with an integrated support piece for the extension shaft. The support piece extends sufficiently outward to prevent drooping on the part of the extension shaft. It also provides weight and torque relief for the extension shaft when the door is open and insures that the tip of the extension shaft properly engages the opening in back of the door mounted rotary handle when re-closing the door.

Type *NZM..-XBR* door cut-out frames are accessories especially designed to cleanly frame the openings made in doors (**Figure 28**) to accommodate operators. Doors with framed cut-outs allow direct access to toggle operated switches, switches with rotary handles, or switches equipped with remote control drives (**Figure 29**). These solutions insure that switches are always operable even when the door is open. The framed door cut-out designs shown in **Figure 28** are not that common in North America. They could conceivably be used in general use panels per UL 508A, although their open construction would not provide any type of environmental rating, other than possibly Type 1. The enclosure construction would also have to comply with the requirements of the standard. Unfortunately, there is no certified padlocking accessory for the toggle operator. The lack of such an accessory would not make it possible to use the switches as main disconnect switches, nor in any application for which a padlocking capability would be required. The general recommendation, therefore, in view of the reduced environmental ratings and potential enclosure construction issues, would be to avoid designs with door cut-outs in North American industrial control panel applications. Certain manufacturers claim that these designs help solve the need for additional supplementary handles on disconnect switches, but as we will see later, the use of supplementary handles in conjunction with door mounted handles is a much more involved issue, and one which goes beyond this more simplified design approach.

NZM circuit breakers, *N* switch-disconnectors and *NS Molded Case Switches* can be equipped with a sidewall mounted operator *NZM..-XS-L(R)* (**Figure 30**) which fulfills the North American requirement that the operator always

Operating handle modification possibilities for circuit breakers and switches Type NZM, N, NS and PN						
Type	**Door interlocking** The door interlocking feature is automatically activated. It cannot be defeated, if the door is padlocked closed.			**Padlockability** Padlocking of handle is only possible when panel door is closed. Padlocking on switch can also be done with the door open.		**Figure 25 Part ...**
	Door opening is possible			Padlocking is possible		
	also in ON	only in OFF	only > OFF	ON + OFF	only in OFF	
IEC-Door mounted rotary handle						
NZM..XTVD(-60)(-0)	wT	+	-	-	H	A/B
NZM..XTVDV(-60)(-0)	wT	+	-	mH	H + S	C/D
NZM..XTVDVR(-60)(-0)	wT	+	-	-	H + S	C/D
IEC-Rotary handle mounted on switch						
NZM..-XDVG	Not applicable, no door interlocking provision on switch mounted handles			-	H	E/F
NZM..-XDVGR				-	H	E/F
NZM..-XDV				-	S	K/L/M
NZM..-XDVR				-	S	K/L/M
NZM..-XDTV	wT	+ [1]	-	mH	H	G/H
NZM..-XDTVR	wT	+ [1]	-	-	H	G/H
NA- Door mounted rotary handle						
NZM..XTVDV(-60)(-0)-NA	wT	wT	+	-	H + S	C/D
NZM..XTVDVR(-60)(-0)-NA	wT	wT	+	-	H + S	C/D
NA- Rotary handle mounted on switch						
NZM..XDTV-NA	wT	wT	+ [1]	-	H	G/H
NZM..XDTVR-NA	wT	wT	+ [1]	-	H	G/H
IEC- Main disconnect handle kit						
NZM..-XHB	wT	+	-	mH	H	R
NZM..-XHBR	wT	+	-	-	H + S	S
NZM..-XS(M)-L(R)	Not applicable, no door interlocking provision			mH	H	T/U
NZM..-XSR(M)-L(R)				-	H	T/U
IEC- Main disconnect handle set with internal supplementary handle, IEC-door mounted handle						
NZM..-XHB-DA	wT	+	-	-	H + S	S
NZM..-XHB-DAR	wT	+	-	-	H + S	S
NA- Main disconnect handle set with internal supplementary handle, NA-door mounted handle						
NZM..-XHB-DA-NA	wT	-	+	-	H + S	S
NZM..-XHB-DAR-NA	wT	-	+	-	H + S	S

\+ = normal   - = not possible   S = on Switch   H = on Handle   mH = modifiable on Handle   wT = defeatable with a Tool
Only > OFF = Door opens once handle has traveled slightly beyond the OFF position
1) Interlock for small doors, e.g. drawer units in MCCs (motor control centers)

Table 29: The table shows factory supplied padlocking and interlocking features of the operators and additional field modification capabilities.

remain in contact with the switch, independent of the door position. The operator is mounted to either the left or right sidewall of the enclosure. The correct sidewall to choose would be the one opposite the hinged door side of the enclosure, in order to insure clear access to the operator when the door is open. A mounting bracket is also available as an accessory for more roomier mounting of the switch. The handle is joined to the switch via a mechanism attached to the housing which operates at a 90° angle to the handle. The operating handle is totally independent of the door position and is padlockable at all times. The fact that the operator is mounted on the side, rather than on the front, makes it less vulnerable than a comparable door mounted handle to inadvertent bumps and hits. For supply circuit disconnecting purposes in an industrial machinery application it's advisable to provide an electrical door interlocking provision, since the design of the switch makes it unsuitable for a mechanical interlocking solution.

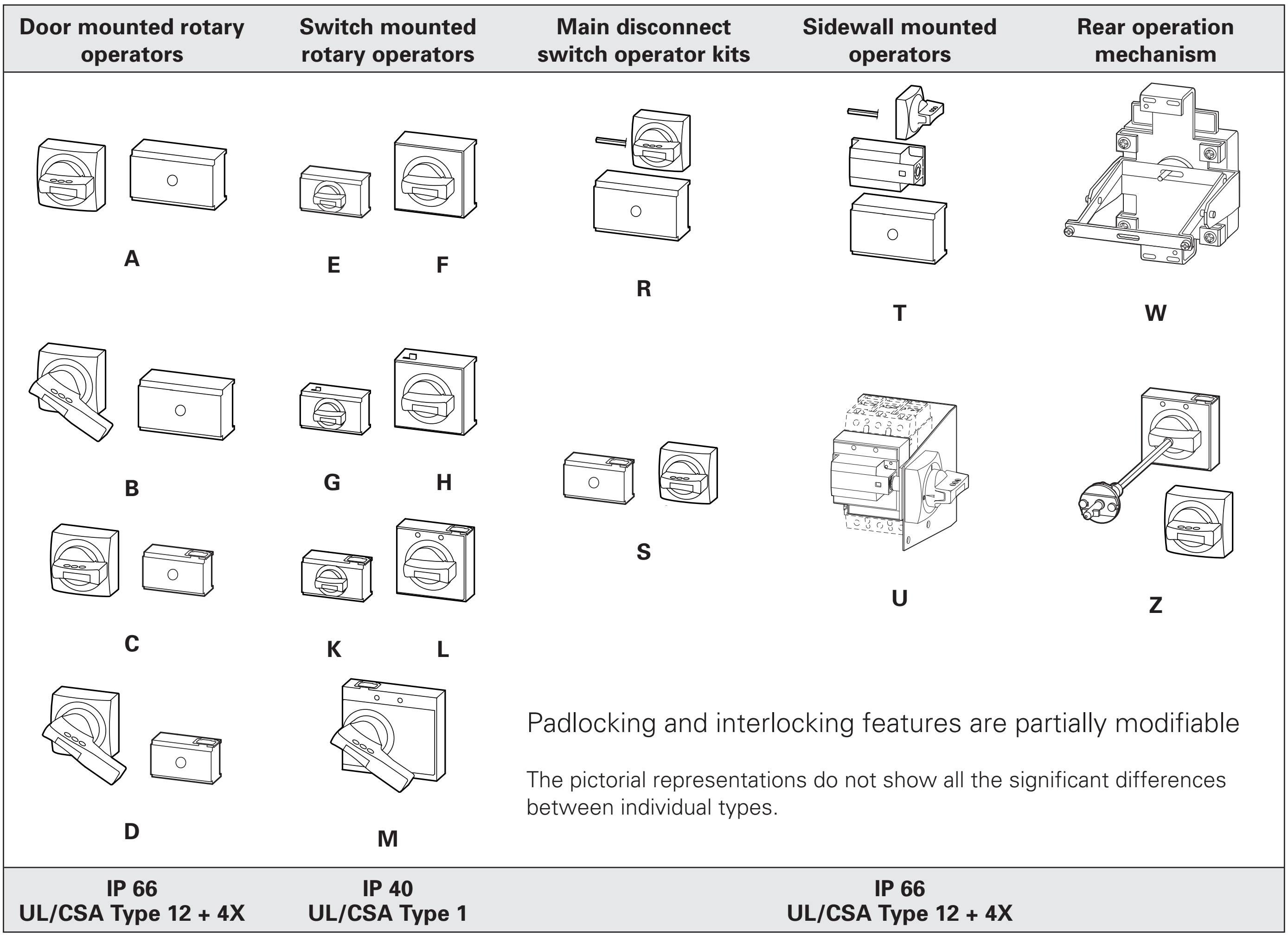
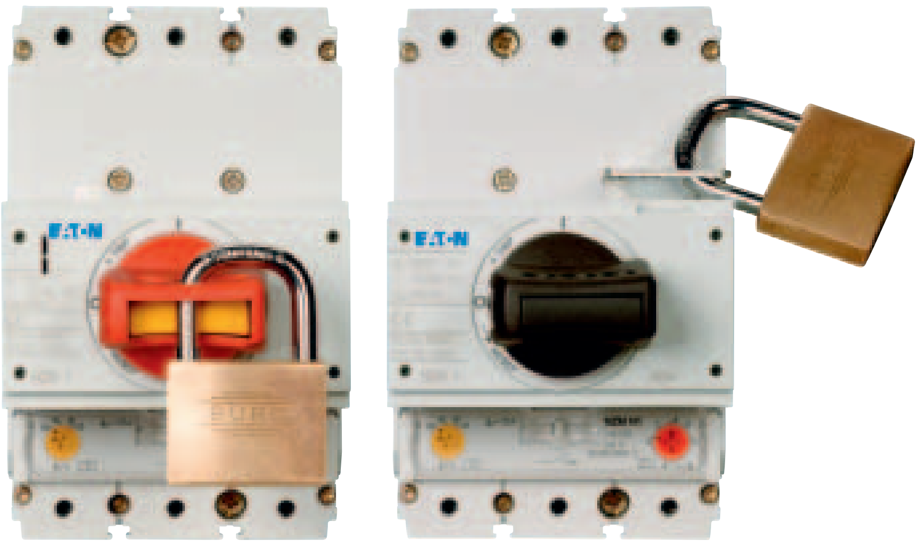


Figure 25: Pictorial representation of various handle operational methods to further illustrate the information provided in tables 28

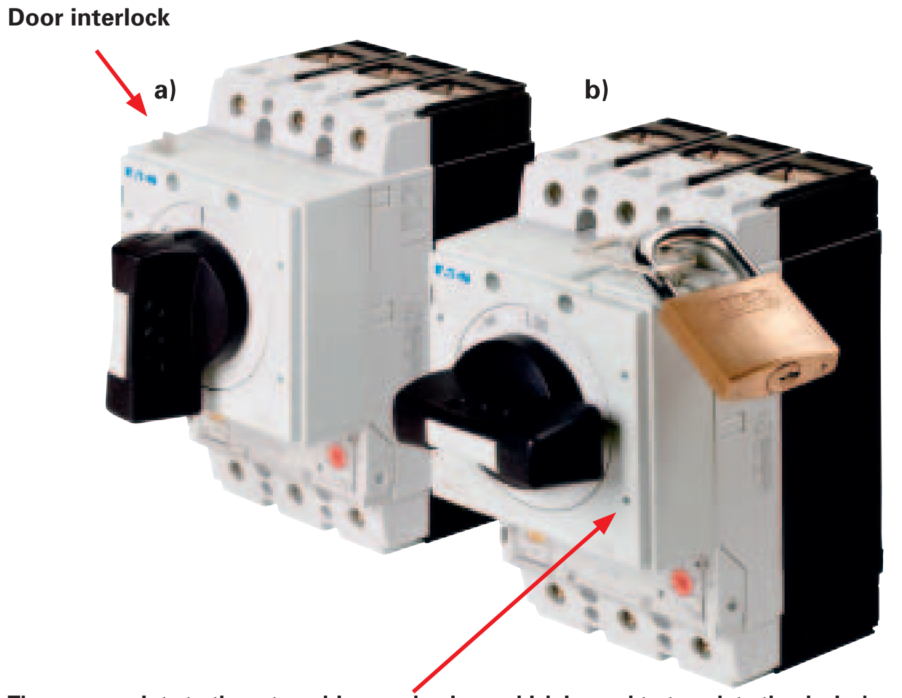
These types of operators are very well known in Europe, but the same can't really be said for their usage in North America. It would be difficult to find them in the more traditional industries, such as in an automotive plant, but they do manage to find their way, mostly through indirect export, in a number of other industrial applications. In spite of their certification with UL/ CSA standards, and of their compliance with important North American conventions, it would be highly advisable in applications like industrial machinery, which would fall under the NFPA 79 standard, to consult ahead of time, if at all possible, with the end-user in order to ascertain if this IEC type of operator would be acceptable in their plant. Otherwise, the risk is high that unfamiliarity with the operator could jeopardize its acceptance on a new machine, even if it does meet regulatory requirements.



a) b)

Figure 26: Switches with rotary drive mechanisms can either be locked off at the rotary handle with one or more padlocks as shown under a), or as depicted under b), directly on the rotary drive mechanism, which also features a padlocking provision. Refer also to Figure 27 (page 27).

The rear-operation mechanism *NZM..-XRAV* (**Figure 31**) is similar in function to the sidewall operator from the point of view that the padlockable black or red handle also remains in contact with



The arrow points to the rotary drive mechanism, which is used to translate the device's toggle operation into a rotary motion. The rotary drive mechanism is also padlockable

Figure 27: Example of a circuit breaker type NZM…equipped with a simple door interlocking provision normally best suited for smaller enclosures with door cut-outs, in applications where a more demanding environmental rating for the assembly is not required. Example of a circuit breaker type NZM…which, independent of the type of operating handle selected, can be padlocked in the OFF position, also with the control panel door open. (Type NZM..-XDV). As a slight departure from what is shown in the photo, a device equipped with a padlocking provision on its housing would normally be combined solely with a door mounted door interlocking and padlockable rotary handle. Equipment per solution "b" would require additional electrical interlocking provisions with control panel doors. That would also apply to equipment per solution "a" if the control panel enclosure has multiple doors.

the switch at all times independent of the door position. It too does not have a mechanical door interlocking feature, so an electrical door interlocking provision would have to be provided for separately. Both the sidewall and rear operated handles feature the highly desirable UL/CSA North American Type 4X and 12 environmental ratings. The rear operated mechanism can of course also be adapted for sidewall mounting if need be. Mounting of the accessory in the door, however, which a few clients have been known to do, should be discouraged in both IEC and North American markets, because of the problematic wiring issues it creates.

Even though the typical door mounted rotary handle has been used for many years, and in the millions, throughout the IEC world, the design is still very much viewed with a critical eye when it comes to North American industrial machinery applications per NFPA 79.

These handles represent a very prominent and distinctive aspect of Eaton molded case circuit breakers and switches. It is therefore Eaton's stated goal to push for their full acceptance on the North American market. The door mounted handles have a very high and desirable environmental rating and offer the feature of a direct interlocking capability with the door in which they are mounted. The major drawback to the design, as perceived by those who oppose it, lies in the fact that the handle is mounted directly into the door and thus, when the door is opened, it is no longer coupled to the switch (**Figure 32**). When the door is open, the handle no longer can operate the switch. However, in order to provide the user with the capability of operating the switch with the door open Eaton has been offering for many years a set of supplementary handles, *NZM1/2-XDZ* und *NZM3/4-XDZ,* which mount internally on the shaft between the switch and the door coupling piece. The supplementary handle has to be mounted securely, because the use of tools or objects, which an electrician would normally carry in a toolkit, is not allowed to operate it. These supplementary handles can thus to be used to operate the switch when the control panel is open and, as **Figure 27 b** (page 52) demonstrates, can also be locked off using the padlocking provision on the rotary switch mechanism.

Figure 28: Versions of operating handles which remain in contact with the switch. The handles can be operated through a cut-out in the door, which is suitably framed using the molded cut-out frame accessory (Type NZM..-XBR). The handles can be directly padlocked if desired. Currently, the padlockable accessory for the toggle operator is not certified for North American versions. These through-the-door operating handle versions are normally associated with additional electrical interlocking provisions. This type of mounting would not be generally considered acceptable for the supply circuit disconnecting means per the North American Industrial Machinery standard NFPA 79 simply because the environmental rating of the handle and molded frame assembly would not be sufficiently adequate for that application.

Figure 29: Electrically motorized drives allow ON-OFF operation of the switch from a remote location. The motor drives utilize a stored energy spring mechanism, which enables a quick closing of the switch at the application of an electrical signal. The opening and spring loading operations are carried out by the motor. The motor drives can also be mechanically actuated at the switch. In cases where the opening action of the switch via the motor would be considered too slow, usage of voltage trip accessories can be introduced to quickly trip open the switches.

These supplementary handles can, of course, be installed in IEC assemblies as well in order to permit access to the switch when the panel door is open. This topic is not being addressed as prominently by the IEC standards, but is the subject of occasional focus from the safety authorities such as TÜV/DEKRA or the BG in Germany (accident prevention and insurance association). Up until this point, the combination of the door mounted handle and the occasional use of this type of supplementary handle had been sufficient to meet the intent of most panels per the UL 508A and NFPA 79 standards. Relatively recent changes in those standards, however, have made it such that their usage is no longer considered in compliance with the current requirements. As will be described in the coming section, the changes required a design adaptation to the supplementary handle which is somewhat reminiscent of tamper-proof container tops found in the medicinal cabinet and used primarily for child protection. Regardless of anyone's position on the matter, Eaton simply went ahead and made sure that it implemented a viable solution to meet the new requirements.

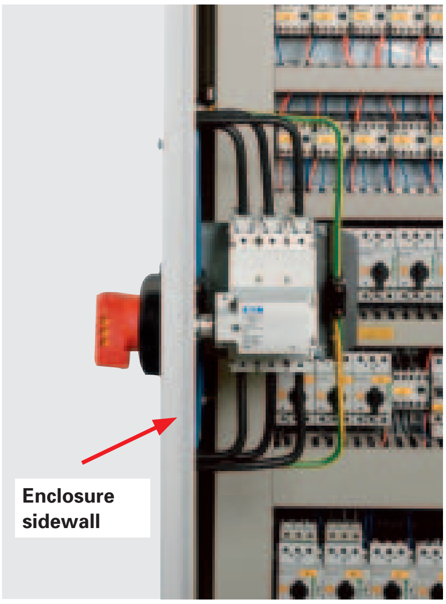


Figure 30: In circuit breakers equipped with a sidewall mounted operating handle, a Moeller innovation, the switch and handle remain permanently in contact with each other independent of the door position. They are also padlockable. From that point of view, the handles would meet the intent of the North American industrial machinery requirements for padlocking of the supply circuit disconnecting means. Additional electrical interlocking with control panel doors would have to be provided. In spite of fulfilling many of the requirements as an operating handle for a disconnecting means, and being certified for the North American market, it is not advisable to use this particular style of operator for the supply circuit disconnecting means of industrial machinery applications per NFPA 79 without prior clarification with the end-user and regulatory bodies. The risk of rejection would be otherwise too great.

The new supplementary handle with *„deliberate action"*

The event which triggered these latest developments really occurred back in 2002, when the NFPA 79 standard was issued containing a number of significant changes related to the operating handle of the supply circuit disconnecting means. Essentially, it became a requirement at that time that the operating handle of the supply circuit disconnecting means be readily accessible with control panel doors in the open and closed position. This meant, effectively, that it no longer was considered acceptable for the handle to physically separate from the switch mounted inside the panel. At the same time, it was also a requirement that the switch be provided with a permanent means permitting it to be locked in the OFF, or OPEN, position only, in order to prevent operation of the switch at all times independent of the door position. Still, it was possible to fulfil these particular requirements with the combination of the afore-mentioned supplementary handles *NZM1/2-XDZ* and *NZM3/4-XDZ*, and the door mounted *NZM..-XTVDV(R)* or *NZM..-XTVDV(R)-NA* rotary handles.

The changes described here affect mostly control panels used for industrial machinery. The UL safety standard for industrial control panels, UL 508A, was first issued in April 2001, and heavily revised in September 2005. A good deal of the changes introduced with the revisions in Sep 2005 first became effective in March of 2007. The changes which took place in the UL 508A standard now fully support the requirements of the NFPA 79 standard which stipulate that closing of the supply circuit disconnecting means be prevented at all times while the control panel door is open, unless an interlock is operated by a deliberate action. This requirement is now valid for all North American standards dealing with electrical equipment for industrial machinery. Note that the deliberate action requirement has been in place in the NFPA 79 standard for years, but it has always been more closely associated to an interlocking provision which had traditionally been a feature of the control panel enclosure itself, and not the switch. Only when the requirement began to relate more closely to the use of rotary handles did it take on the added significance being addressed by this latest change to the supplementary handle, as will be described shortly.

To summarize, the use of IEC style door mounted rotary handles for the supply circuit disconnecting switch means that the handle will separate from the switch whenever the enclosure door is open. The presence of a supplementary handle is thus necessary in order to fulfill the intent of the standard that the switch

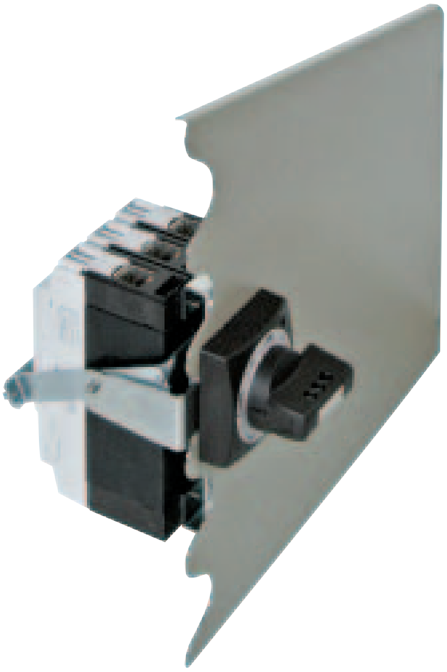


Figure 31: The rear operated mechanism is similar to the sidewall operator in terms of its application. Both fulfill the identical requirements from a North American viewpoint. However, application concerns for these IEC style accessories still currently remain. Removal or replacement of a sidewall operator, or rear-operated mechanism, from a panel locally could prove to be troublesome in cases where the use of these accessories is considered objectionable.

be operable by qualified persons when the enclosure door is also open, without the use of accessory tools or devices. Furthermore, the supplementary handle needs to incorporate a means by which closing of the switch when the door is open will be prevented, unless it is deliberately defeated.

Those are in essence the requirements facing the use of rotary handles for compliance with the standard. Although this requirement of the NFPA 79 standard directly impacts significant design aspects of the operating handle of a supply circuit disconnecting means used in electrical control panels for industrial machinery, particularly those involving IEC style door mounted rotary handles, its primary goal naturally is not to make component design more difficult, but rather to provide industry floor personnel with an extra measure of protection from electric shock through the use of suitable enclosures and equipment, specifically the need for adequate interlocking provisions with the supply disconnecting means whenever there is the potential for exposure to live equipment.

Eaton enjoys a relatively high share of the market for main disconnect switches and is presumably the first European manufacturer to now offer new supplementary handles (**Figure 33, Figure 34**) to meet these stricter requirements now in effect in both the UL 508A and NFPA 79 standards. The goal of the design sought to establish an actuation method which went beyond a simple ON and OFF operation, by introducing a non-instinctive and deliberate procedure to fully engage the handle. The principle is not unlike the safety guards found on the opening covers of child-proof or tamper-proof medicinal and prescription drug bottles.

The solution involves a motion implemented in multiple steps. The first consists of turning the supplementary handle clockwise approximately 20° towards the ON position. At that stage, the handle reaches a point at which it can be pushed in, and then rotated through to the ON position to engage the switch. Four models of the handle, varying in size, were introduced in order to adequately transfer the proper amount of force necessary to actuate the switch mechanism within different frame sizes of the circuit breaker and molded case switch family. The larger one features a more prominent, lever type grip design. If the handles, after reaching the 20° position, are not simultaneously pushed

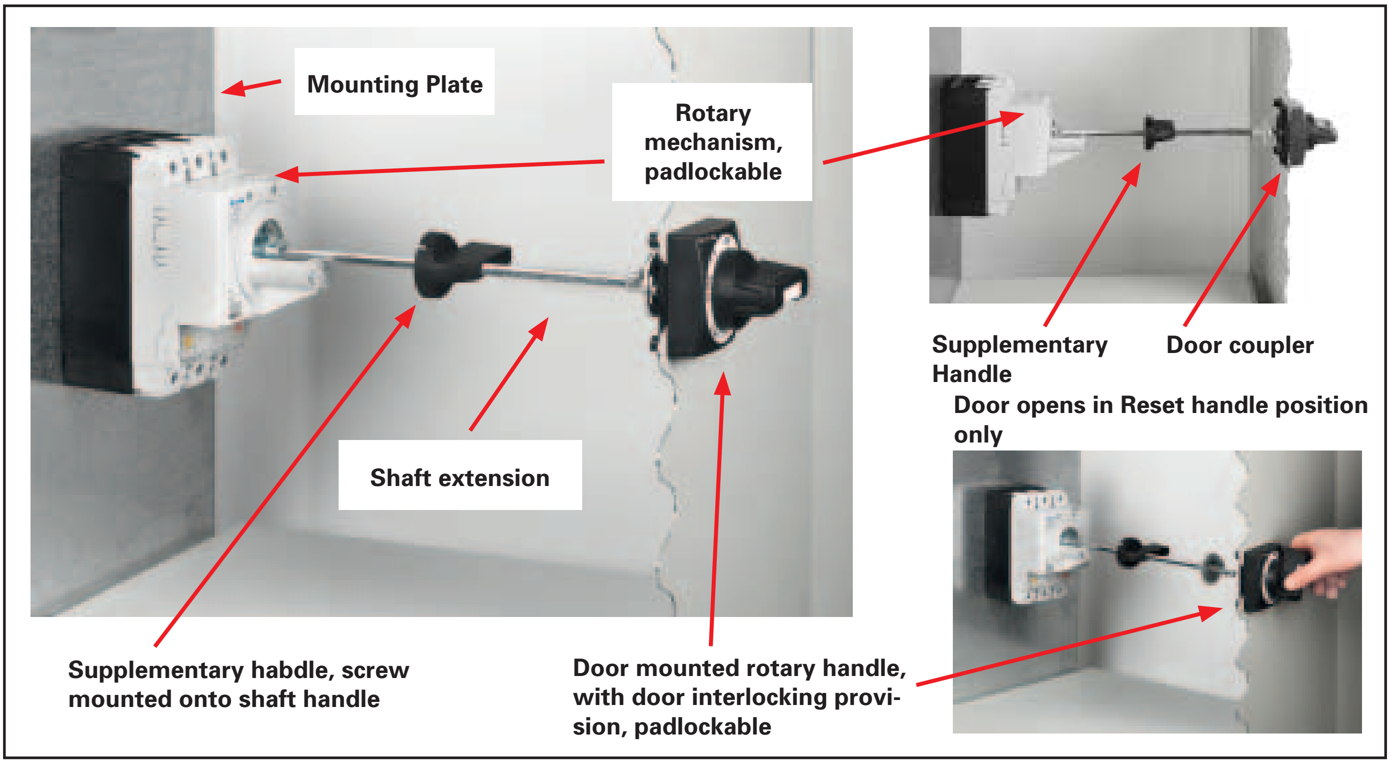


Figure 32: In the IEC world one would typically install door mounted rotary handles accessible from the exterior of the control panel. This type of actuation does not quite fall in line with typical North American convention and falls short of requirements in many cases. Up until recently, the use of an additional supplementary handle Type NZM..-XDZ, which could be attached to the shaft of the main disconnect switch and allow the switch to be actuated from inside the panel, was deemed acceptable. However, this is no longer the case for industrial machinery applications. IEC style door mounted rotary handles now need to be combined with more sophisticated internal supplementary handles which incorporate a deliberate action interlocking provision in order to allow internal actuation of the switch by qualified persons. Please refer also to Figure 33 (page 55) and 34 (page 56).

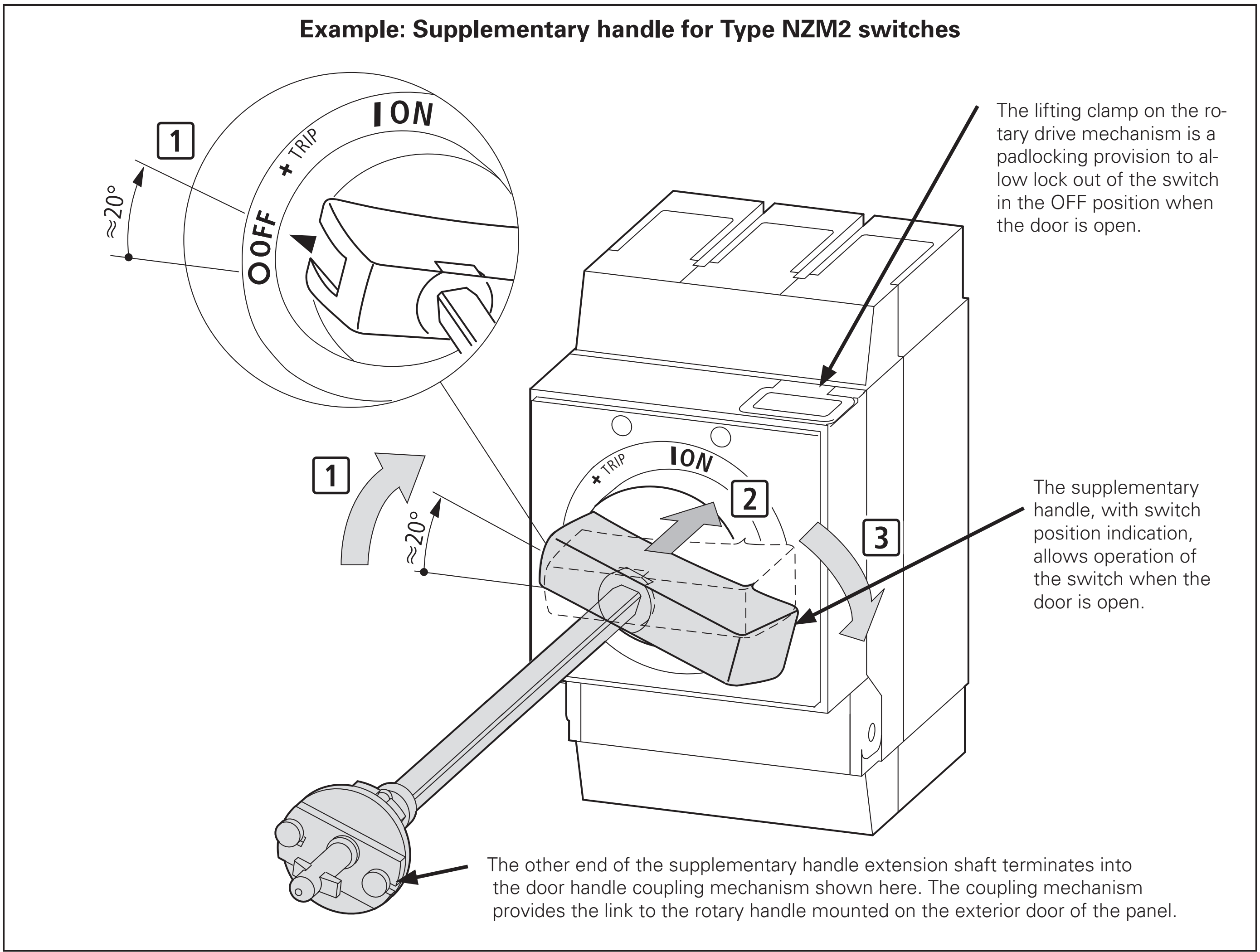


Figure 33: The new supplementary handle requires a deliberate action (by qualified persons) before it can be engaged to operate the switch to the ON position, should the control panel door be open (e.g. for maintenance purposes). The deliberate action consists of the following 3 operational movements:
1. The handle must first be turned clockwise appr. 20°.
2. At this 20° position the handle is pushed in to engage the shaft.
3. From this pushed-in position the handle can be turned all the way to ON to operate the switch.
From the ON position, the switch can be turned back to OFF directly, without any intermediary manipulation. The switch can be locked in the OFF position with up to 3 padlocks using the padlocking provision on the switch housing. If the handle is not turned and pushed in simultaneously during an attempted operation, it simply rotates unengaged up to the point at which its travel perceptibly reaches a preset stop point. The switch is not being operated in this case.

in and turned, they cannot engage the shaft and simply rotate through unlatched to an end-stop position. The handles feature a clear positional marking dial on the switch housing to help identify their position relative to the switch. The length of the extension shaft can be modified by the panel builder as a function of the panel depth and then installed into the final assembly (factory assembly). The certification also allows the handle to be field installed.

This present solution, as well as the former one, effectively provides the supply circuit disconnecting switch with two distinct rotary motion handles. The first handle is door mounted and operates the switch with the enclosure door closed, whereas the second

Figure 34: The photo on the left shows a supplementary handle (in the ON position) for a Frame Size 2 switch. The right portion of the photo shows the slightly larger handle required for Frame size 3 and 4 switches.

handle (supplementary handle) is used to actuate the switch with the enclosure door open. As was the case with the previous solution, Eaton requires with this latest supplementary handle the use of a rotary mechanism on the switch housing which is equipped with a padlocking provision. A padlocking feature is necessary to fulfill the intent of the standard that, independent of the door position, the switch always be permitted to be locked in the OFF position. In that manner, the switch can be locked off when the enclosure door is open and thus provide personnel with protection against inadvertent actuation of the switch. In line with the requirements of OSHA (Occupational Safety and Health Administration), switches with isolating functions in North America should also be equipped with appropriate tags *(LOTO, Lockout/Tagout)* which are used to provide personnel with additional warning that operation of the switch during maintenance periods or other down times is forbidden.

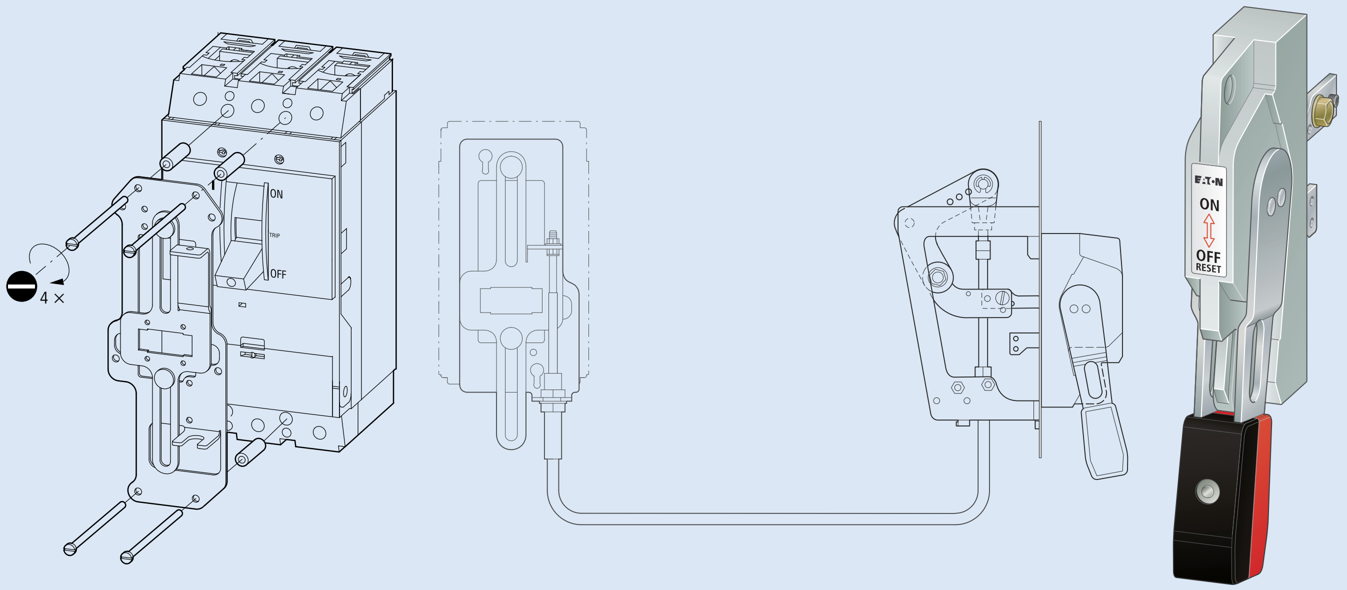
The modular rotary mechanism is usually an optional accessory with the switch. In order to simplify the ordering procedure for this particular assembly, the padlockable rotary mechanism, together with the handle and shaft, form a single unit which is factory assembled, and provided as a supply circuit disconnecting switch operating handle kit. The supplementary handle fulfills a safety function and is thus not allowed to be removed from the panel once installed. That is a safety requirement which is deemed necessary to meet the intent of the standards, and which the certification agencies feel particularly strong about.

An additional warning marking is placed on the supplementary handle to both alert people to the potential dangers arising from restoring power to a panel with the door open and to re-emphasize that the operation must only be undertaken by qualified persons. For additional safety reasons, and in order to make the interlock defeating procedure of the supplementary handle even more "deliberate", a description of it was purposely left off of the body of the handle. Qualified persons can learn about the proper way to operate the supplementary handle from instructions provided as part of the machinery documentation, which are always supplied to the end-user or operator of the assembly. The installation instructions also include detailed and descriptive text in English, which is more desirable in North America than a document with pictorial information only.

The North American handle with *„vertical motion"*

In the North American automotive industry the use of door mounted, IEC style rotary handles on supply circuit disconnect switches (**Figure 28**) (Page 53) in industrial control panels has traditionally never been accepted. The automotives, and many related branches, generally call for a *„Flange*

Typical North American operating handle design for the supply circuit disconnecting means of electrical equipment per the NFPA 79 industrial machinery standard.



The lockable actuator and the actuating mechnical operator remain connected to the switch at all times, even with an open panel door.

Figure 35: The figure shows a typical North American solution: The operating handle of a supply circuit disconnecting means preferred by a wide majority of users in that market. This type of operating handle is frequently encountered and commonly expected on electrical controls for industrial machinery built in accordance with the NFPA 79 standard. A vertical motion slide operating mechanism, pictured on the left, is fitted to the disconnect switch. The padlockable vertical motion handle (right) mounts on the control panel enclosure flange located on the exterior of the panel. In this particular example, the handle is connected to the switch sliding mechanism via a flexible Bowden cable and remains in contact with the switch at all times, independent of the door position. An interlocking feature is provided in conjunction with a suitable control panel enclosure (Refer to Figure 36). Handles of this design generally fall short of compliance with operator rigidity construction requirements per the European IEC/EN 60 947 set of component standards, and are thus considered suitable solely for applications within North America.

Mounted Handle" (Vertical Motion Handles, Side Mounted Handle3[3]*, Flexible Cable Operators)*, as per **Figure 35**, on disconnect switches as part of their overall specifications for electrical equipment. In spite of its unpopularity in the IEC world, Eaton also offers this type of operator (*NZM-XSH...-NA*) as part of its product offering in order to comply with North American requirements whenever that particular style of handle turns out to be the only acceptable option for the application. It's important to point out, however, that these typical North American style handles **do not comply** with the padlocking and operational durability performance tests of the IEC/EN 60947 product standards.

The handles are, therefore, only suitable in North American assemblies and installations. That was the main reason why Eaton hesitated for so long to incorporate them into its product offering, but finally decided to relent and address the need to fulfill North American demands and conventions in this respect. In the meantime, the outlook of the North American automotive industry in this regard is not as rigid as it once was, and it is anticipated that specifications for future assemblies will be more flexible in accommodating more globally accepted solutions. Besides the use of flexible Bowden type cables, flange monted handles can also be attached to the switch directly, via customized mechanical linkages. All these flange mounted, vertical motion operators require a specially designed enclosure featuring a flanged side on which the handle is mounted (**Figure 36**). When the door is open, the handle remains in its original position, physically connected to the switch at all times.

The handles, also those from Eaton, can be linked in these special enclosures with additional mechanical rods which run vertically and horizontally throughout each cabinet and provide the overall control panel assembly with a more elaborate mechanical interlocking function. Door mounted rotary handles and a number of other handle variations in North America must constantly compete with the well established vertical motion handle. These special enclosures with mechanical interlocking provisions are also available for export purposes from a few IEC enclosure manufacturers, but they are not considered typical in the IEC world. This type of solution is thus not very compatible with the wishes of European industrial machinery manufacturers and panel builders to establish once and for all a universally acceptable panel design layout.

Identification, warning markings and documentation

All product submittals to certification agencies are normally associated with extensive marking requirements. These include not only agency Listing Marks or Certification Marks, but also manufacturer identification logos, part number and production date and above all, a display of all relevant electrical ratings on nameplates and rating labels. There are also detailed requirements in the product standard on the placement of these markings and whether or not some of them need to be visible when the product is installed. Not all markings have to go on the product, and many are allowed to appear in manufacturer catalogs or on accompanying documentation sheets normally supplied with the product. Markings are required in English. The markings occasionally have reference to the manner in which the product is used, or provide certain warnings associated with the product's application. Markings, which normally appear in the IEC world in the form of symbols, are usually expressed in text to better comply with North American requirements and expectations.

Canada has two official languages, so certain markings are required to appear in both French and English. The use of the words „CAUTION" and „WARNING" on product or instructions are meant always to draw the attention to the user to special safety considerations related to the application and use of the product. The warning markings ideally appear close to the source of danger or hazard and must always be clearly indicated. Not all safety related markings need to, or are even able to, appear on product. As mentioned, a great deal of them end up on associated documentation supplied with the product and for that reason, the Eaton installation instructions „AWAs", or, Instruction Leaflets "IL", usually take on special significance for export related applications, since they may contain crucial information related to the application of the product in North America [19]. This product information forms an integral part of the overall technical documentation supplied with machinery, and it must always be supplied to the end-user. Safety and liability concerns may even be more of an issue for manufacturers in North America than they are in Europe so providing clear and proper documentation for the complete machinery and electrical installation also fulfills a crucial obligation on the part of the equipment supplier towards the end-user by making sure that the information is complete and reliable.

Additional requirements on the assembly of North American engineered products

In the introduction to the paper the point was made that all the necessary requirements for the proper engineering of assemblies for North America may not be adequately covered simply by the use of certified equipment and a general knowledge base of motor starter design aspects for that market. At various times in the paper it was also pointed out that components used in motor starter assemblies also need to be tested together as units in order to establish and maximize combination motor starter ratings and, futhermore, to have the results tabulated and listed in the manufacturer's certification report.

Typical North American engineered products take up quite a bit more room than comparable European assemblies. Part of that is due to the size of North American equipment, which traditionally

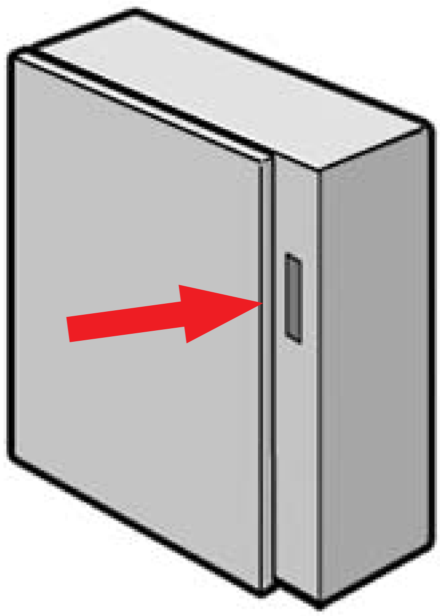
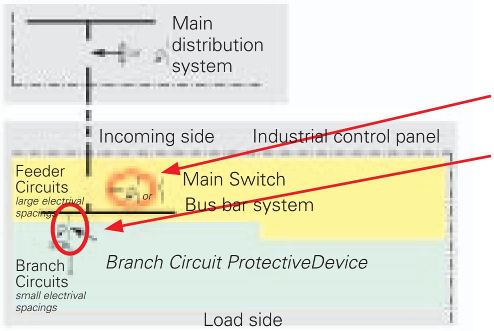


Figure 36: „Typical North American" industrial control panel enclosure with flange and cut-out on the side to accommodate mounting of vertical motion operating handles for supply circuit disconnect switches, as per Figure 35 (page 57).

3 Not to be confused with Eaton's sidewall handle accessory Type NZM..-XS-L(R)

Miniature Molded Case Circuit Breakers (MCCB), Standards

MCCB **for** ***Feeder- and Branch Circuit Protection***	***MCB*** **for** ***Supplementary Protection***
USA: **UL 489** Canada: **CSA C22.2 No. 5-09** Large electrical spacings ***LISTED Component*** ←	USA: **UL 1077** Canada: **CSA C22.2 No. 235** Small electrical spacings ***Recognized Component*** ←



High:
105 mm
Tide:
17.7 mm

High:
80 mm
Tide:
17.5 mm

IEC/EN 60 898

Caution!
An improper component selection in this area counts as one of the 10 most frequently made errors flagged by inspection authorities.

Figure 37: Miniature type molded case circuit breakers FAZ..-NA (left) listed to UL 489 represent an especially economical solution for fuseless protection of small loads in the range of 10A or less. They are not to be confused with comparable looking supplementary protector devices (shown at right), which are not suitable as as Branch Circuit Protective Devices per North American electrical code and installation standards.

has been larger than equivalent European designs; but the extra room generally required between components in a typical layout, along with greater need for wiring space in installations, have also been major factors contributing to this size differential. One could make a legitimate claim that these more tightly spaced European assemblies, which also tend to incorporate power circuit components that are much smaller in size, automatically invite much closer scrutiny on the part of electrical inspectors tasked with the responsibility of approving the electrical equipment. This situation makes it particularly important to follow North American requirements at all times, however difficult that may be in certain cases. Exporters should also be diligent in providing the right kind of documentation (e.g. wiring schematics, operation manuals etc...) Although the use of typical North American ANSI symbols, text and conventions (with typical ladder diagram electrical lines going left to right) is expected, the use of comparable IEC notation has been gaining in acceptance in recent years.

For a period of time, exporting machine manufacturers were providing both IEC and ANSI style documentation for their assemblies. The manufacturer's on site personell worked with the IEC documentation, whereas local inspectors and the end-users felt more comfortable using the ANSI based schematics and descriptions. Based on input from machine builders the use of IEC notation was quite a bit more helpful in reducing wiring time and errors during commissioning. It is thus recommended to provide on the first few pages of the accompanying documentation a comparison listing of IEC and ANSI wiring symbols. Particular attention to local fuse types in the selection process must also be observed whenever the use of fuses is an integral part of the overall electrical equipment. In spite of varying dimensions and rejection features, some North American based fuses with different ratings and characteristics are still interchangeable, so the use of specific fuses must be marked appropriately in the panel along with component identification markers to insure correct replacement of parts.

Of course, the use of certified wiring materials in appropriate AWG and kcmil cross-sections is a strict requirement. The insulation rating of all wires which can be bundled together at the same time must be equal to or greater than the highest voltage present in the wiring channel. Even the smallest plug or receptacle needs to be certified. The same applies for terminals, ventilation fans, panel lighting, outlets etc.... A mutually acceptable networking protocol must be declared and agreed to ahead of time in the event of networking requirements between power and automation equipment in any control panel assembly.

At this point of time it's worth mentioning again the engineering and production capabilities of SAE Schaltanlagenbau Erfurt GmbH, which is a certified manufacturing location of North American assemblies. The firm has amassed a lot of experience over the years in North American projects, and continues to enjoy the excellent reputation it established at the time it was a fully owned subsidiary of the Moeller Group. Eaton can also provide references for additional centers of competency in this sector, which provide certified assemblies to a number of other clients.

Engineered assemblies for North America can be, on the average, 10 to 60 % more expensive than comparable IEC versions (non-binding assessment). This is in part due to larger physical dimensions, higher processing costs and the occasional need to supply additional components to fulfill the electrical requirements of certain applications.
It is generally ineffective for exporting machine manufacturers and IEC panel builders to only peripherally busy themselves with the requirements of the North American market. The risk of approval problems and delays resulting from recent changes in the standards

should never be underestimated, just as a proper understanding between both continents can remain an elusive goal in spite of modern technological advances in communication, especially when issues raised are leading to hardened positions on both sides of the pond. These scenarios are always likely, since it is often difficult from a European technical viewpoint to properly assess positions taken by North American approval authorities. The issue is rarely technical in nature however, and is mostly due to a lack of a fundamental understanding of the regulations on which these positions are based.

Influence of supply network configurations on equipment selection

Some protective devices of modern European construction are rated exclusively for solidly grounded star network electrical distribution systems in North America, which makes them unsuitable for branch circuit protective duty in many ungrounded systems, both star and delta. The presence of any slash-rated protective device in an engineered assembly such as a control panel effectively establishes the slash voltage as the nameplate rated voltage marking for that control panel, usually 480Y/277VAC or 600Y/347VAC. The term slash-voltage is actually a reference to the oblique line separating both voltage ratings in the numerical designation. The larger number references the phase to phase voltage rating, whereas the lesser value indicates the maximum phase to ground voltage of the system. Typical slash-rated devices of modern European construction would include, for example, UL 508 Type E self-protected devices and Type F combination motor controllers, the smaller framed NZM1 and 2 molded case circuit breakers, and the FAZ...-NA miniature molded case circuit breaker described in an upcoming section.

A proper determination of the electrical distribution system available at the installation site can present problems for a potential exporter of electrical equipment. General statements on the suitability of equipment for grounded systems only can often be more confusing than helpful. This is especially the case when the enduser is not known, or when dealing with serial production machines whose end-use location can never be determined ahead of time. Some machine manufacturers have also been known to install power rated transformers, e.g. rated 480/400V in the incoming supply of their machines. The use of such transformers can then make it possible to establish grounded star networks on the transformer's secondary, and satisfactorily resolve the issue for the local authorities.

Full voltage rated devices are very nearly always a suitable alternative to the use of slash-rated devices. That would mean substituting an NZM circuit breaker for an FAZ-NA, or using the NZM2 circuit breaker instead of the NZM1 at 480V. Instead of UL 508 Type E or Type F controllers, a protective switch can be installed ahead of standard PKZM motor protective switches in group installation applications. The devices have the proper certification for this purpose, and have even been additionally certified as tap conductor protectors. The upstream protective device in this case would consist of a UL 489 listed inverse time circuit breaker or listed fuse. [3].

Listed (UL 489) circuit breakers type *FAZ..-NA* for small loads

Most non-motor electrical loads can only be protected with listed molded case circuit breakers or fuses per the North American electrical codes. These types of loads include small power conversion equipment, power transformers, lighting and heating loads. (Note: It is permissible to use a Type E device to provide branch circuit protection power conversion equipment, but the combination must be so tested. Usually, indication of the protective device are part of the power conversion equipment's marking requirements.) Some of the loads mentioned are rated for very small currents, usually between 1 and 10A. Currently, the smallest power circuit conductor suitable for branch circuits to connect such loads per the electrical codes is AWG 14 (15A). In recent years, however, the industrial machinery standard NFPA 79, as well as the NEC (NFPA 70), have begun to allow the use of smaller power branch circuit conductors for connection to smaller rated motor and non-motor loads. The sizes in question would be AWG 18 rated 7A, for continuous loads not exceeding 5.6A, and AWG 16 rated 10A, for continuous loads not exceeding 8A. This was done in order to better harmonize with international practices of using comparably small conductors for such loads. Wire sizes of 0.75 mm^2 and 1 mm^2 are commonly used in applications per the machinery directive standard IEC 60204-1. One of the requirements of the electrical codes for the protection of these smaller conductors is that the protective devices be listed and marked for the purpose. Eaton's line of *FAZ..-NA* miniature single and multi-pole molded case circuit breakers have been certified and marked for use with AWG 16 and AWG 18 conductors under the UL 489 standard, and thus provide an ideal alternative for fuseless protection of these smaller loads and conductors. This circuit breaker line is not to be confused with the similar range of FAZ supplementary protectors, which are recognized devices only, and not suitable for feeder or branch circuit protection per the North American electrical codes (**Figure 37**). The FAZ..-NA devices feature the larger electrical clearances of energy distribution equipment, and are certified as stand-alone branch circuit protective devices per the UL 489 and CSA 5- 09 molded case circuit breaker standards.

The line of *miniature molded case circuit breakers FAZ..-NA* is rated for use up to 25A in solidly grounded 480Y/277 VAC slash-rated electrical distribution systems. Their short-circuit rating, ranging from 10kA to 14kA, makes them suitable in UL 508A industrial control panels rated accordingly.

Compact molded case circuit breakers, Type PKZM4-..-CB

A new and compact molded case circuit breaker, fully tested and certified to the UL 489 standard, emerged after the PKZM4 manual motor protective switch underwent some constructional modifications consisting of increased electrical clearances on its line and load field wiring terminations. The new device does not have a supplementary handle with "deliberate action" as part of its accessory line, but is ideally designed and suited as a branch circuit protective device (BCPD) for smaller rated loads. The PKZM4-..-CB features a high short circuit interrupting rating (SCCR), up to 65kA @ 480Y/277VAC and an impressive 22kA rating at 600Y/347VAC. A comprehensive line of accessories complements the new breaker.

Validity

As previously indicated, product certification issues are subject to constant changes and updates, and these could always have a bearing on the informational content of this paper. Technical ratings in the most recent edition of the Eaton Main Industrial Switchgear Catalog (HPL0211), in catalog supplements, and in certification reports, are binding. The products covered in this paper are supplied with installation and operational instruction sheets, which in some cases include information specifically related to applications in North America. The informational content of this paper is based on certifications and standards valid as of mid-2011.

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Institute for International Product Safety GmbH, Bonn

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Glossar

ANSI = American National Standards Institute
AWG = American Wire Gauge
CEC = Canadian Electrical Code
CSA = Canadian Standards Association (http://www.csa.ca)
EVU = Elektrizitäts-Versorgungs-Unternehmen
Factory Assembling = Verarbeitung in der Werkstatt/Fabrik
Field Assembling = Verarbeitung auf der Baustelle
IEC = International Electrical Commission
kcmil = thousands circular mils
MCCB = Molded Case Circuit Breaker
NEC = National Electrical Code (USA)
NEMA = National Electrical Manufacturers Association (www.nema.org)
OEM = Original Equipment Manufacturer
OSHA = Occupational Safety and Health Act (http://www.osha.gov)
SCCR = Short Circuit Current Rating
UL = Underwriter's Laboratories (http://www.ul.com)

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 310.15(B)(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°)	75°C (167°F)	90°C (194°F)	
AWG kcmil	Types TW¹, UF¹	Types FEPW¹, RH¹, RHW¹ THHW¹, THW¹, THWN¹, XHHW¹ USE¹, ZW¹	Types TBS, SA SIS, FEP¹, FEPB¹, MI RHH¹, RHW-2, THHN¹, THHW¹, THW-2¹, THWN-2¹ USE-2, XHH, XHHW¹ XHHW-2, ZW-2	Types TW¹, UF¹	Types RH¹, RHW¹ THHW¹, THW¹, THWN¹, XHHW¹ USE¹	Types TBS, SA, SIS, THHN¹, THHW¹, THW-2¹, THWN-2¹ RHH¹ RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	AWG kcmil
	Copper			Aluminum or Copper-Clad Aluminum			
18	....	....	14	....	....	....	....
16	....	....	18	....	....	....	....
14**	15	20	25	....	....	....	....
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	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	195	230	260	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	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	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	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	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.

* Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F).

** Refer in 240.4(D) for conductor overcurrent protection limitations.

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.

	Induction Type Squirrel-cage and Wound-Rotor							Synchronous Type Unity Power Factor* Amperes			
HP	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 430-91. Motor Controller Enclosure Selection Table

For Outdoor Use

Provides a Degree of Protection Against the Following Environmental Conditions	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

For Indoor Use

Provides a Degree of Protection Against the Following Environmental Conditions	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	14	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

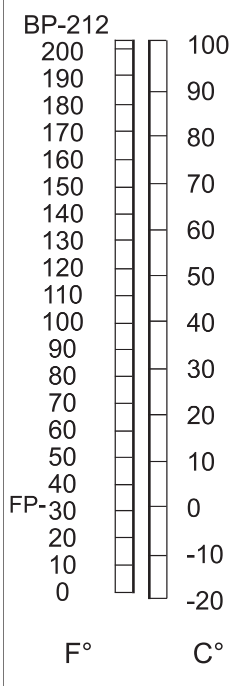
How to use conversion table A and B

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



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