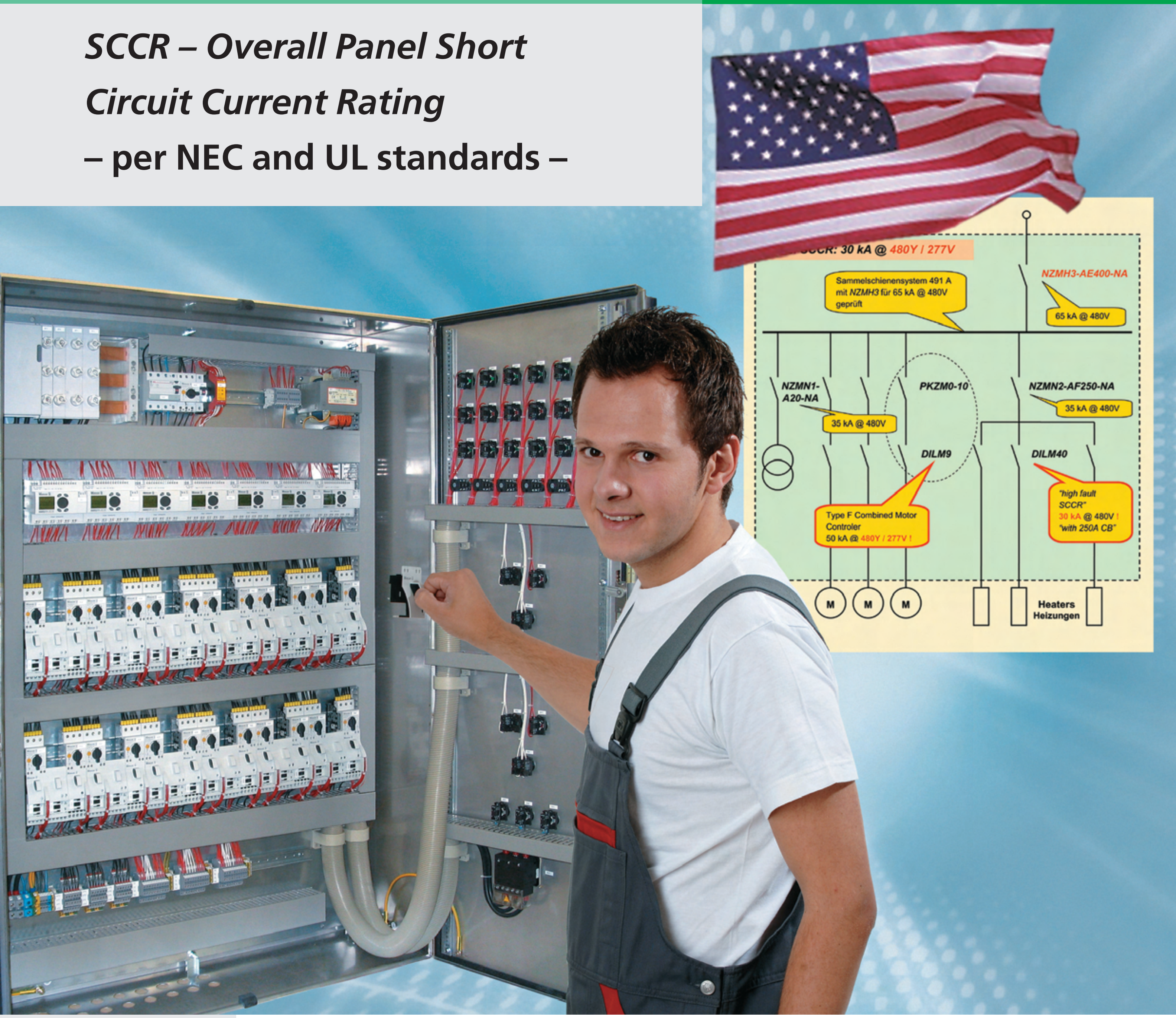
SCCR – Overall Panel Short Circuit Current Rating
– per NEC and UL standards –



Xtra Combinations

Xtra Combinations from Moeller offers a range of products and services, enabling the best possible combination options for switching, protection and control in power distribution and automation.

xStart

xEnergy

Xpole

Technical Paper

Dipl-Ing. Wolfgang Esser

MOELLER

We keep power under control.

SCCR - Overall Panel Short Circuit Current Rating
– per NEC and UL standards –

- a distinguishing feature of North American Industrial Control Panels -

Introduction

Under short circuit conditions, does the entire power circuit hold up for the time it takes the overcurrent protective device to clear the fault? Does one know how high the available fault at the installation site can reach? Important questions indeed, and ones which a panel builder needs to properly address in order to verify that the maximum overall *short circuit rating* of an industrial control panel will be suitable and adequate for the application. The end-user would also need to be assured that this withstand value is equal to, or higher than, what could be encountered at the installation site. Prior knowledge of the end use location would be useful as well, so that proper attention can be taken during the engineering phase to insure that both parties are in sync with the local requirements. Unfortunately, that's not always possible, particularly in the case of serially made machinery destined for multiple, and geographically varied, locations.

Machine manufacturers in North America and the IEC - world, as well as their suppliers of electrical equipment, have an urgent need to familiarize themselves with the concept of short circuit withstand capabilities for their installations, now that *Short Circuit Current Ratings* for all power circuits, including the primary supply of control circuits, have become part of the marking requirement on the rating labels of all *industrial control panels (ICP)* in the US. Power circuits make up the main electrical supply and distribution circuits within a panel and ultimately serve to energize and control all connected loads, including all motors and non-motor loads. *Industrial Control Panels* are commonly used on a general basis for commercial as well as industrial applications. Special versions, for which a short circuit current rating is also necessary, include *Control Panels for Industrial Machinery*, and *Control Panels for Elevator Duty*, just to name a few. This current situation confronting experts throughout North America relative to control panels is relatively recent, and was brought on by changes in the standards pertinent to those assemblies.

During standard UL/CSA testing, power circuit component manufacturers have to insure that short circuit current ratings are verified and can be applied to their equipment. Ideally then, *industrial control panels* would include only those power components which have been listed by a NRTL[2] such as UL, and marked with short circuit ratings. This would represent the simplest basis by which to achieve a viable and reliable determination of an overall control panel panel short circuit rating. Control circuits do not figure in the calculation nearly as much, since they are normally derived from the secondaries of control transformers which are considered electrically apart from the primary circuit (see **Diagram, Photo 1**).

The topic of *Short Circuit Current Ratings* as described in this paper is in line with current marking requirements in the US. There is presently no direct equivalent to UL 508A in the Canadian standards. It stands to reason, however, that the NEC and CEC[3] will come to harmonize closely in this regard, and that similar requirements will become clearly defined and equally applicable in both countries.

Throughout the paper the term "Short Circuit Withstand", relative to Control Panels, is purposely avoided and the standard itself makes a point of highlighting that a *Short Circuit Current Rating (SCCR)* is not to be confused with the *Short Circuit Interrupting Rating* of an overcurrent protective device, i.e. it is not meant to indicate in any way a panel's ability to interrupt or clear a fault. Rather, it forms the basis to establish an inherent performance and safety expectation level for all the power circuit components contained within a panel, should the assembly be subject to short circuit conditions. Important criteria to consider include the trip characteristics of the protective device, as well as its clearing time and peak let-through current and energy values. In this manner, the use of a current limiting molded case circuit breaker in the feeder supply circuit can be used to raise the overall short circuit rating of a panel or assembly. (see **Photo 7**). If the current limiting breaker, by virtue of sufficiently low let-through values, proves capable of providing protection to the weakest of components included in the panel, the overall short circuit rating of the panel can conceivably be raised to match the interrupting level of the circuit breaker, provided all the additional constraints stipulated in the standard for that particular case would have been met. It may be entirely worthwhile, therefore, to install a high performance device in the supply circuit (e.g. a current limiting circuit breaker instead of a *switch-disconnector* or a *molded case switch*), even if it is initially more costly, in order to permit the installation of more economical components downstream. The word "Rating", referenced in the in *SCCR* abbreviation, is more closely associated to the effects of dynamic forces resulting from an abnormally high fault current, which make it inherently difficult to pinpoint with accuracy the exact magnitude of the short circuit current flow. In actual practice, short circuit levels are, for the most part, lower than calculated values. That aspect is mostly related to a varying amount of resistance present in the short circuit path at any given moment. Thus, the word "withstand", if it were assigned to a panel power circuit component in this case, could be construed as misleading, since in actual fact, the level of short circuit current flowing through the component is effectively lower in most cases than the marked rating would imply.

It's always been the case in North America that individual components in a motor starter combination can't just be arbitrarily put together for end

[1] IEC = International Electrical Commission
[2] NRTL = Nationally Recognized Testing Laboratory
[3] CEC = Canadian Electrical Code

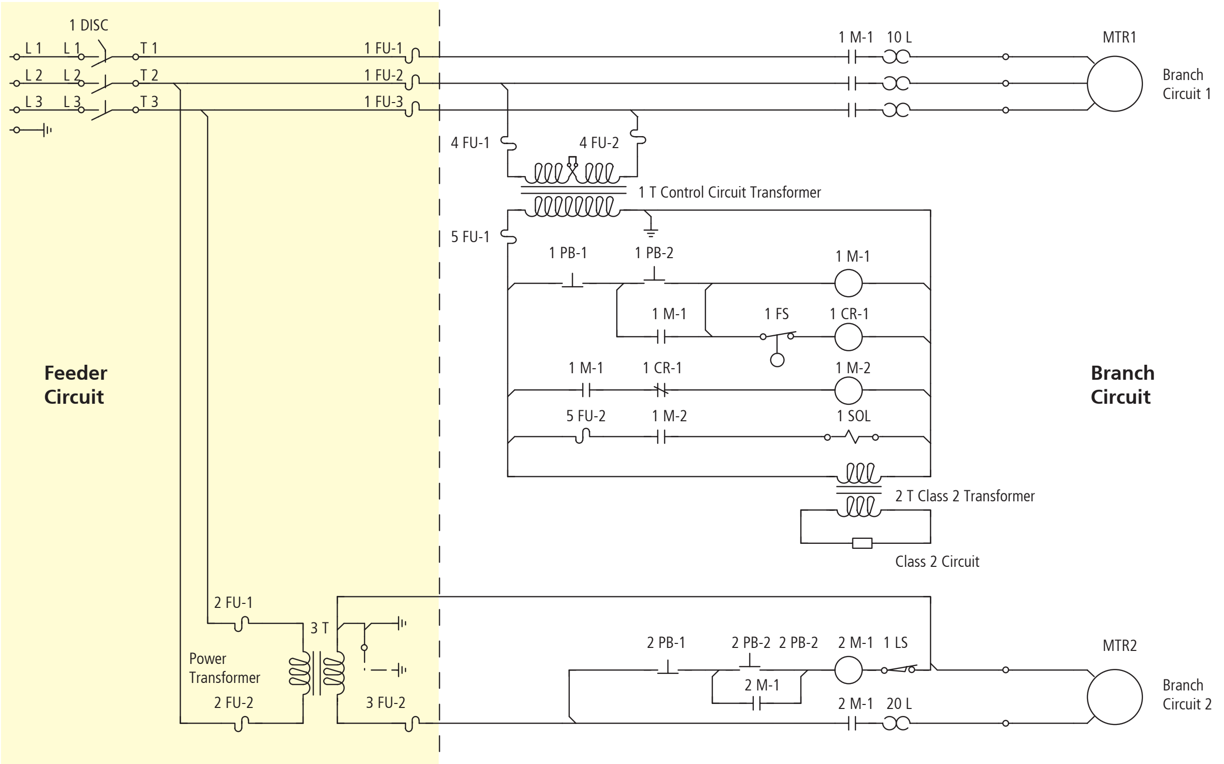


Photo 1: Typical North American wiring diagram showing power and control circuit layout. The control circuit is galvanically separated from the main power circuit via a control circuit transformer. Only the power circuit portion is assigned a *short circuit rating*. The *feeder circuit*, with its more stringent requirements concerning electrical clearances, is marked off in yellow to the left of the dotted line.

use (as is typically done in the IEC world under somewhat less constraining fashion). Rather, specific components are always tested together as a combination, and the ensuing results are tabulated in the manufacturer's *third party listing* (UL) or *certification (CSA)* report. The ratings achieved thus provide a useful and independently verified data base of information to help coordinate the proper application of combination motor starters relative to short circuit conditions and available faults in installations. [1] If, on the other hand, the components are not tested together, then the general rule will continue to apply, namely, that the short circuit rating of the entire combination will be predicated by the lowest rated component used in the motor starter assembly.

Power circuit components typically found in control panels, and fulfilling different functions, will often be associated with various levels and types of short circuit ratings. For example, a contactor doesn't have to feature a short circuit interrupting rating, since that is the prescribed domain of the overcurrent protective device, such as a fuse or a circuit breaker. From the point of view of high fault clearing capabilities, the contactor would actually represent the weakest link in the chain of power circuit components. On the other hand, it's also the most dependable performer, from the operational viewpoint of switching both motor and non-motor loads reliably, as well as achieving long life under normal service conditions. In order to be assigned a short circuit current rating, a test is performed in which the contactor must be able to withstand a fault current for the time it takes the protective device to clear without creating a shock or fire hazard in its immediate vicinity. Working in coordinated fashion with the protective device can thus lead to significant short circuit current rating levels for the contactor. The quicker the protective device can clear the fault, the greater the chance of being able to achieve a very high rating.

The magnitude of a short circuit current, which a contactor can safely withstand, is certainly not unlimited. A critical aspect of the device's construction in this respect involves the level at which the dynamic forces produced by the fault current are able to separate the main contact surfaces apart. Much of that is tied to relevant aspects of its design as well as to its physical size. As soon the fault level drops down to the value below the current lift-off point of the contactor, the main contacts re-close automatically. During that time, and under particularly unfavorable conditions, the burning-off of material through the arcing process can more or less lead to welding of the contact surfaces. To this effect, the IEC world has established Types 1, 2 and CPS levels of short circuit co-ordination as a means to better define allowable damages under fault conditions. These co-ordination levels are not yet officially part of the current North American motor starter testing standards, however, it is possible for UL to test and evaluate per these IEC definitions and classify equipment accordingly.

North American companies, particularly large concerns involved multinationally, are now coming across these requirements more frequently, both as requirements for projects abroad but also increasingly at home in applications for which the IEC definitions have begun to make inroads. Many safety aspects of IEC standards, in particular the Machinery Directive standard for electrical equipment IEC 60 204-1 [2], have evolved beyond the current accepted norm in North American standards, and have thus received a very positive response from many end-users in the US.

No matter the location around the world, the occurrence of a sizeable fault in an installation will require a thorough evaluation on the part of an expert and may, depending on the severity, lead to a need for extensive repairs. When testing for *short circuit ratings*, it is permissible for certain power components such as contactors to undergo extensive damage and for main contacts to weld. These devices can then no longer be brought back into service and need to be replaced.
In accordance with NEC 2005, Article 409.110 [3], and UL 508A [4] a determination of the *overall Short Circuit Rating* for an industrial control panel is now mandatory, and the resultant value must be displayed as part of the electrical rating information on the *panel's nameplate*. The panel nameplate, usually constructed out of durable material, bears the manufacturer's name as well as a summary of the panel's main electrical ratings. It is normally affixed to the panel's door or cover so that it is visible from the exterior. The electrical ratings are key to insure proper connection of the panel to its incoming supply power source. In addition, the panel should bear a set of serialized UL- Industrial control panel and panel enclosure labels, which are normally affixed on the inside of the cover or door after completion of a final evaluation by the authorized UL *panel shop* which performed the assembly.

A crucial requirement in properly fulfilling the new regulations involves the availability of qualified component and motor starter data from a manufacturer. It is always advantageous for a panel builder to purchase components from a manufacturer such as Moeller, who can offer both a broad and appropriate component selection while at the same time eliminate potential mix and match product compatibility issues in the determination of an overall rating for the control panel assembly.

Industrial Control Panels per NEC 2005

The latest edition of the NEC[4] (NFPA[5] 70) went into effect on Jan 1st, 2005. That doesn't necessarily mean that it was enabled across the US on that date. There are still regional differences with respect to its adoption, not only from state to state, but also from region to region within individual state borders, down to counties, cities, local municipalities and townships. Thus, changes in the NEC can be hard to come by on a full scale national basis. As of March 2006, only about half of the states had enabled the 2005 Code, with 13 others still recognizing the 2002 version. Four are still operating on the 1999 Code, while the rest of the nation has yet older versions of the NEC offically on the books. The delay in implementation of these new codes and standards can often lead to the following claim commonly heard amongst exporters: "We supplied equipment to North America and didn't have a single problem, even though we must have clearly been in violation of at least a few of the major rules. The only appropriate reply to that should be: "How lucky you were". At the same time, this slow integration process on a regional basis can lead to acceptance problems for electrical innovations, even when they are applied per newly implemented regulations, because the equipment might not be recognized locally as truly representing the latest developments in technology. Worse yet, it may not even be accepted. The recognition of UL 508A, on the other hand, seems broader and appears to have undergone a much more rapid acceptance process. The newly introduced regulations on short circuit marking requirements described herein should not only alleviate the burden of responsibility placed upon local electrical inspection authorities but also accelerate implementation of the new requirements on a national basis.

Apart from regional differences in the adoption of newly introduced regulations, the final approval by local electrical inspectors (AHJ[6]) still remains an unpredictable risk in many respects. In the US alone there are literally thousands of *jurisdictions* subject to local rulings and interpretations. Differing viewpoints are bound to emerge in view of the sheer number of regulations deemed to be pertinent and applicable. For this reason, it is imperative that strict adherence to the national equipment standards be maintained, since mandated changes in electrical installations otherwise deemed ready for commissioning can be both difficult and expensive. In extreme cases, fully scrapping the non-compliant assembly and replacing it with an entirely new system may end up as the only viable solution. The approval process of electrical equipment, conducted by the manufacturer in the country of export origin, automatically guarantees a high degree of acceptability. Each *UL listing* label helps to relieve the local electrical inspector's personal burden of responsibility with respect to approval of electrical equipment. An absolute promise of a trouble-free acceptance process in North America may be hard to come by, but taking the necessary steps to properly select and apply electrical equipment per local rules is the next best thing to securing a guarantee for a smooth and timely outcome.

This paper deals principally with assemblies falling under the *General Use* category and which are built in listed factories (*factory assembled*) (**Photo 2**). Specialized custom controls which are part of, or subsequently added to, a *field assembly*, such as for on-site lighting or air-conditioning, are not part of this general overview and may be subject in any case to additional requirements located in specific Articles throughout the electrical codes. Likewise, there are *custom controls* that address specific loads or types of equipment (specific use Industrial Control Panels), and which must be designed and installed per Code with particular attention to requirements pertaining to the application. Examples of these include con-

[4] NEC = National Electrical Code®
[5] NFPA = National Fire Protection Association, www.nfpa.org
[6] AHJ = Authority Having Jurisdiction

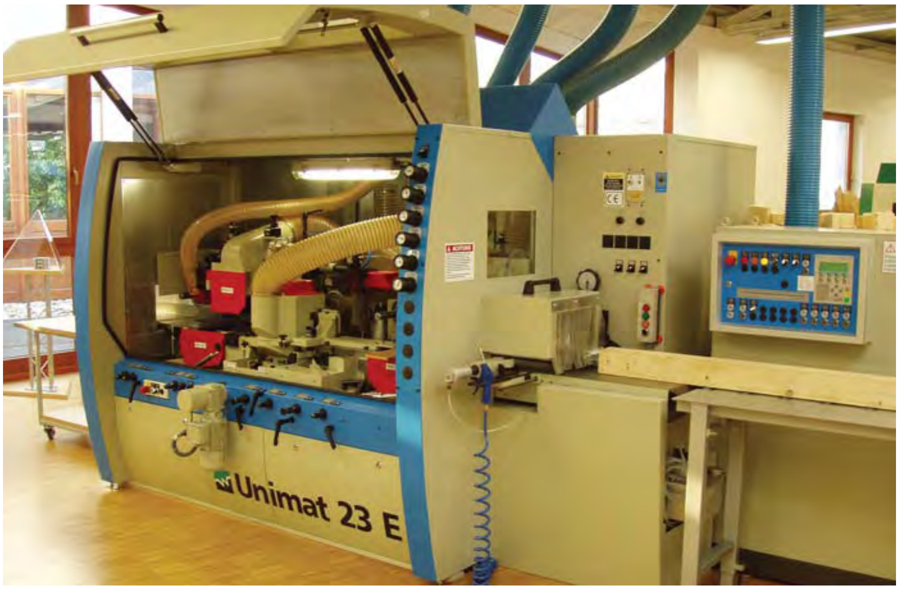


Photo 2: Example of a machine equipped with an *industrial control panel*. There are additional standards related to the above pictured machine which are relevant to the entire assembly, but these are beyond the scope of the topic addressed in this paper.

trol panels for *Industrial Machinery, Crane control, Elevator control* etc... Table 409.3 of the NEC describes the most important ones, along with the relevant article associated to the application.

A definition of *Industrial Control Panels* (identical with the one found in UL 508A) is provided in Article 409.2 of the NEC. In connection with the definition, the Code also mentions the need to consult other applicable requirements specific to certain loads and specialized custom control assemblies (refer also to [5]). The majority of control panels, in which typical Moeller components would be installed, would fall under the aforementioned definition. Individually customized *industrial control panels*, especially those with a highly automated control circuitry content, certainly represent a different breed of assembly than arguably more solidly built, and short circuit rated, constructions like conventional *Motor Control Centers* MCCs, on the other hand, mainly feature power circuit components, and typically include comparatively little in the way of intricate control circuit functionality [6]. MCCs are built and designed in the US to UL 845.

There exists a number of *listing* possibilites for *industrial control panels*. It is possible to obtain approvals for:

- Empty *industrial control panel enclosures* with various environmental ratings.
- *Enclosed industrial control panels*.
- *Open industrial control panels*, which become housed in suitably rated enclosures at a later stage of assembly.

Industrial Control Panels are defined as an assembly of standard and/or custom arrangement of two or more components in the power circuit, such as:

- Motor starters, contactors, overload relays, circuit breakers, motor protective switches, drives,
- and the associated control circuitry portion, which commonly include selector switches, operating and signaling devices, timers and control relays.
- Associated wiring and terminal blocks are also considered part of the panel per the definition.
- Industrial Control Panels under this Article operate at 600V or less.
- They do not include the controlled equipment or machinery.

Requirements of NEC 2005, Article 409 *(Industrial Control Panels)*

The latest Article 409 is divided into the following sections: "General", "Installation" and Construction Specifications". The Article makes installation recommendations in order to insure that listed equipment can be combined and installed into an enclosure in such a way as to provide a safe and Code compliant assembly for a variety of industrial and commercial applications. The scope of *Industrial Control Panels* can range from very elementary single motor starter and control apparatus to highly complex process automation assemblies.

In addition to providing the above mentioned definition of an industrial control panel, Code Article 409 goes on to describe general requirements for the proper calculation of panel cable ampacities. A properly selected supply conductor cross-section for a control panel takes into account the sum of all connected loads and features an overall ampacity not less than:

- 125 % of the full load current rating of all resistance heating loads, plus:
- 125 % of the full load current rating of the largest motor in the group, plus:
- the sum of the full load current ratings of all other motors and the rest of the loads that may be in operation at the same time based on their duty cycle.

The factor of 1.25 is based on the actual load which is connected and supplied. Future expansions which are either planned or may be implemented at a later date are not addressed by the additional reserves provided using this calculation. Additional loads would also be subject to the 1.25 factor and may necessitate a re-sizing of the supply conductor. Once the minimum ampacity requirements for the supply conductor have been established, a suitable feeder overcurrent protective is selected accordingly.

Control panels for industrial machinery in the US, per NEC Art. 670 and UL508A, would require the provision of a supply circuit *disconnecting means*, as is the case with electrical controls for industrial machinery per the IEC/EN standard EN 60 204-1 [2]. Article 409 further describes requirements for enclosures and bus bar systems, as well as the need to provide adequate wire bending space, particularly in the area of the main incoming supply terminals. *Control panels* can also be installed at the point of entry of an electrical supply circuit, in which case they would need to be deemed additionally suitable as *Service-Entrance Equipment*. In the area of industrial machinery, the need for industrial control panels marked suitable for service-entrance is less likely to occur.

Marking per NEC 2005, Article 409.110

Article 409.110 of the NEC deals in more specific terms with the thematic elements covered in this paper. One significant aspect of *Short Circuit Current Ratings* involves the interaction of various components in the power circuit under actual short circuit conditions. Even with the availability of extensive technical data on individual components as well as the expertise, either on the part of an inspector or professional engineer, to evaluate the information, it is important to realize that the tremendous dynamic and thermal forces unleashed by a large overcurrent can still often yield unpredictable results.

For example, a motor protective switch and a contactor in a motor starter branch circuit will both combine with each other to clear a fault. There exist today, particularly for high fault conditions, switching and protective devices that have been especially optimized for the purpose. Current limiting circuit breakers (**Photo 3**), safely clear a short circuit current within the first half cycle of the initiated fault. This quick reaction time insures that only a small portion of the damaging energy associated to the overcurrent will be let through. A very good thing, since the full brunt of the let-through energy associated to the prospective fault current would otherwise be highly destructive. Moeller also purposely incorporates fuseless current limiting designs, which feature extremely quick-acting break apart contacts, into certain control components such as contactors in

Photo 3: Modern current limiting Molded Case Circuit Breakers Type *NZM* with short circuit interrupting ratings established per the North American norms at levels up to 100 kA rms sym @ 480VAC and 50 kA rms sym @ 600VAC.

order to produce a high performance motor switching controller. A small magnetic trip coil is also included to further enhance the opening action of the fast acting contact assembly (**Photo 4**). This type of switching device can thus be installed in circuits with much higher available fault levels and will noticably limit the let-through energy under short circuit conditions, thus greatly minimizing potential damage to assemblies and loads downstream (**Photo 5**).

This type of dynamic co-dependence between components under fault conditions cannot be readily ascertained by comparing rating labels, or making paper calculations. As a rule, Moeller does perform highly complex computer simulations during the design stages in order to support its development planning. Nevertheless, it is still every bit as necessary to do extensive testing, some of it intentionally destructive, in our high power lab facility to assist these design efforts, as well as provide the necessary documentation which will become part of the approval process. In testing, as well as in practice, the nominal voltage plays a very crucial role in the amount of energy imparted to the arc. Higher fault levels encountered at installation sites, combined with relatively high voltage levels, such as in Canada with 600 V, 60 Hz, put a tremendous burden on the design of modern switching and protective devices. Everyone involved with electricity should have the opportunity at least once in their lifetime to witness a live high fault short circuit test in a lab, followed by a viewing of the event on a high speed cam recorder, in order to fully experience first hand the tremendous forces produced by magnetic fields associated to fault currents. These are powerful enough to easily rattle and bend

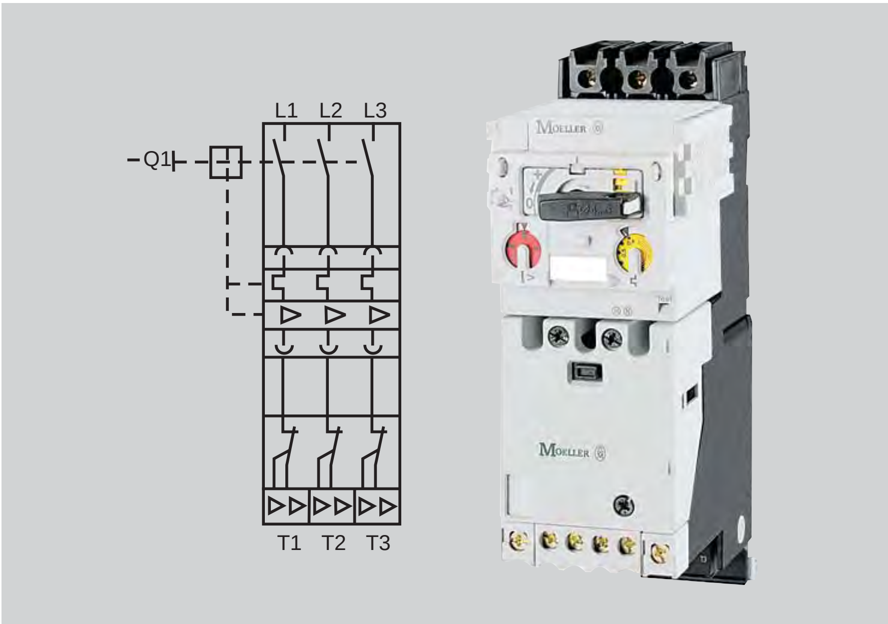


Photo 4: Motor and cable protective switch *PKZ2/ZM-..* mounted directly to its custom contoured current limiting module *CL-PKZ2*. The exterior housing of the current limiting module is essentially identical to the contactor module, which is similarly mounted directly to the switch.

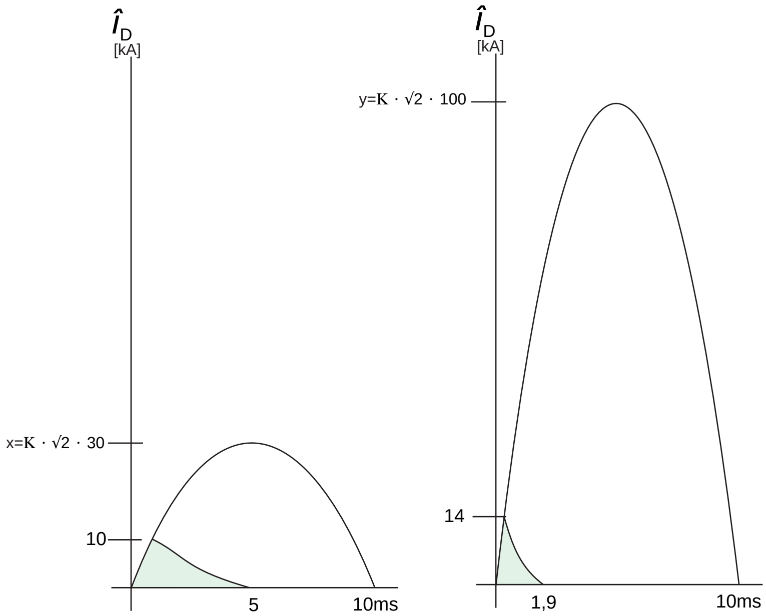


Photo 5: Without a current limiter, the motor and cable protective *PKZ 2* switch would only be suitable for circuits with a potential available fault of up to 30kA (photo at left). Use of the current limiting module enables the switch to be installed in circuits with potential faults of up to 100kA. In spite of this higher fault current, the let-through energy associated to the fault, which subjects the assembly to highly destructive forces in a short circuit, would be less. (photo at right). The shaded areas under the curves reflect the actual I^2t values. In addition, all the power circuit elements in the faulted circuit, e.g. conductors, motor, would be spared. The above reflects IEC data, although similar results are also achievable under North American testing conditions.

solid copper bus bars as thick as a man's arm.
This shows that it is not only correct, but essential to provide local electrical inspectors (*AHJ*) with nameplate data on the overall short circuit ratings of control panels so that they can make better informed decisions on the overall suitability of these assemblies in electrical installations. It's also vital information to have on record in the event of future changes which may impact the ratings established at the time of original commissioning. This is especially true should the panel and machine have to be physically relocated and/or when there are changes in the supply feed to the assembly. At the root of these ratings are series of complex and comprehensive tests. It's advantageous, therefore, if the majority of components in the panel can be derived from the same source since the manufacturer will likely be able to provide the necessary ratings documentation pertaining to individual components as well as those related to motor starter and assembly combinations. For example, in the case of more modern control panel designs in which motor starters are assembled onto busbar adapters and fed via bus bar systems, the entire assembly, including the bus system, would have to undergo a comprehensive testing verification process. On principle, any power circuit component in the chain could potentially be the weak link. The bottom line with respect to *Short Circuit Current Ratings* for *Industrial Control Panels* is to essentially verify that a potential fault in the panel will be properly cleared and not cause a hazardous condition in its vicinity. This would especially include the risk of fire and potential harm to personnel working in close proximity to the equipment. The majority of approval tests must be performed in enclosures. Other than Code imposed allowable wire bending space there are no limitations on minimum enclosure size requirements for starters and assemblies used in testing, but the overall volume has to be published and taken into consideration during the control panel engineering design stages. Enclosures of equal or greater volume and comparable quality must figure into the planning. It's neither necessary nor appropriate to add individual component volume requirements, but in the end it's required to provide adequate free room to insure that proper wiring space, pressure relief and temperature rise are kept within permissible values as allowed by the standards. Generally speaking, the amount of free space required in North American control panels for wiring and servicing purposes is greater than comparative panels in the IEC world.

During the course of evaluation to establish *short circuit ratings* there is a natural tendency to focus solely on the maximum available fault current at the installation site. Although that is certainly a major consideration, it's also important in an overall assessment to consider the impact of lesser magnitude fault currents, which one can argue would be more prevalent, and the likelihood that they may cause a protective device to react more slowly and not be sufficiently responsive. Low level overcurrents could potentially lead to the presence of hazardous touch voltages on affected circuit components and enclosures, should the fault be allowed to linger and not be cleared quickly enough. Typical ground fault current provisions on protective devices are generally more prevalent in North America than in Europe as a means to minimize fire and shock hazards in this respect. In spite of the relatively higher settings of equipment ground fault detective means, which can reach into the hundreds of amperes depending on the nominal frame size rating of the protective device, these values can still lie quite below the response currents of typical thermal and magnetic trip mechanisms, which would normally not respond at these relatively lower levels of fault currents. This represents a practical way of enhancing protection at levels lower than the protective device's normal trip response time.

Per UL508A, Par 52.1 (*General Use*), and 67.1 (*Industrial Machinery*), a visible and properly positioned Industrial Control *Panel nameplate* needs to include essential information on the panel such as:

The nameplate rating label now needs to also include the following

Panel nameplate

- The manufacturer's name or authorized designation and the particular factory's identification tag. (This can also be a good form of advertising for the manufacturer's qualified assembly locations).
- Panel Type marking if appropriate, e.g. "*Control panel for Industrial Machinery*".
- For each supply source: Nominal voltage (*slash ratings*, e.g. 480Y / 277 V, if appropriate). Nominal frequency, number of phases and total full-load amperes.
- Full Load Ampere rating of the largest motor.
- Rated current of the largest resistive load (*Industrial Machinery*).
- *Short Circuit Current Rating* of the control panel.
- Short Circuit Rating of the main overcurrent protective device if provided (NFPA 79, UL508A 67.1.2).
- If the overcurrent protective device associated to a *high fault* control panel *SCCR* is not provided, and is to be installed locally, a marking on the nameplate must show the type of overcurrent protective device necessary for the high fault rating.
- If applicable, a marking indicating suitability as "*Service Equipment*" (point of incoming energy supply, with main Disconnect Switch)
- Electrical wiring diagram number, or the index number to the electrical drawings.
- If applicable, the index number to the installation drawings.
- Enclosure environmental Type rating (e.g. Type 12, 4X, 3R etc...)

The enclosure must be marked with a North American *environmental rating*. If an enclosure is not marked with a recognizable environmental rating, it will always default to the lowest rating possible, i.e. Type 1.

text, or an equivalent wording:

"Short circuit current:
... kA rms[7] symmetrical,
... V maximum".

If a *High Fault Short Circuit Rating* is provided, the size and type of the protective device needed to achieve the rating is also required to be marked on the nameplate (per UL 508A, SB 5.1) in the event that the protective device is not provided in the panel, and is intended to be mounted in the field. In this respect, it may also be necessary to add an additional Warning marking to the panel.

When the main overcurrent protection in a control panel for *Industrial Machinery* is intended to provide protection for the supply conductors and the machine, the panel needs additionally to be marked as follows:

"Supply conductor and machine overcurrent protection provided at main supply terminals"

The *short circuit interrupting rating* of a built-in incoming protective device will no longer appear on the panel nameplate because it can often lead to the misconception that it represents the rating of the overall control panel. This change will also apply to *Industrial Machinery panel nameplates* per NEC Article 670.3. Contactors, Drives, Motor protective switches and *Motorstarter-Combinations* all have to be marked with their own *short circuit ratings* per NEC 430.8, either on their own rating labels (which is often the most convenient way, especially for individual components) or elsewhere as permitted by the NEC.

Determination of the control panel short circuit rating

NEC article 409.110 indicates that the short circuit rating of an industrial control panel is based on either of the following:

- The short-circuit current rating of a listed[8] and labeled[9] assembly (similar in many respects to a "Type-tested' combination), or:
- The short-circuit current rating established using an approved method.

The NEC explicitely mentions Supplement SB of UL 508A (1st edition-2001) "*Short Circuit Current Ratings for Industrial Control Panels*" as an example of an approved method. The supplement has been recently updated, and a newer version dated September 2005 is now in place. Marking requirements for UL listed short-circuit current rated control panels became effective as of April 25, 2006. The UL 508A standard for Industrial *Control Panels* enjoys the broadest from of acceptance and recognition amongst panel builders throughout the US. The important aspect remains that the short-circuit rating of the panel and/or the assembly be equal to, or greater than, the maximum available fault current which the installation site power source can deliver. The ability to make this determination at the point of connection is often beyond the capabilites of the panel builder and the electrical manufacturer of components and motor starter assemblies. The ultimate responsibilty for proper application of the equipment and for verifying the suitability of the installation with respect to the panel nameplate rating remains in the hands of the property owner and the end-user. Of course, the local electrical authorities (AHJs) are also part of this process by helping to establish and validate overall compliance with the NEC and local code requirements.
Generally speaking, a calculation of the short circuit power available at the secondary terminals of the distribution transformer (**Table 1**) will yield an overall conservative value. The actual levels available downstream would diminish somewhat because of damping in the electrical feeder pathways.

7 rms = root mean square is analogous to the term Effective Value used in the IEC world

8 *LISTED* = Equipment, published in a list by an organization that is acceptable to AHJs, that maintains periodic evaluations and whose listing states that appropriate product standards have been met and are deemed suitable for the purpose.

9 *Labeled* = Equipment, to which a label or a mark by an organization that is acceptable to AHJs has been attached, and which verifies its compliance with the appropriate product standards for which it has been Listed.

Short circuit ratings of typical North American 3 phase power transformers							
		240 V, 60 Hz		480 V, 60 Hz		600 V, 60 Hz	
3 Phase Power Rating kVA	Impedance rating Uk %	Continuous Current Rating A	Short Circuit Rating "I_k" kA	Continuous Current A	Short Circuit Rating "I_k" kA	Continuous Current A	Short Circuit Rating "I_k" kA
300	5	722	14,4	381	7,2	289	5,8
500	5	1203	24,1	601	12,0	481	9,6
750	5,75	1804	31,4	902	15,7	722	12,6
1000	5,75	2406	41,8	1203	20,9	962	16,7
1500	5,75	3609	62,8	1804	31,4	1444	25,1
2000	5,75	-	-	2406	41,8	1924	33,5
2500	5,75	-	-	3008	52,3	2405	41,8
3000	5,75	-	-	3609	62,8	2886	50,2

Table 1: **Continuous current and and short circuit current ratings of typical North American power transformers.**
I_k'' = Initial transformer short circuit current when connected to a system with unrestricted short circuit capacity.

The provision of a control panel short circuit rating can also represent a form of legal protective function for the OEM[10], the machine manufacturer and the panel builder, in the event that local installation requirements are not made known during the engineering stage or at the time of commissioning. The rating, clearly visible and displayed on the panel nameplate, acts as verification of the maximum short circuit rating for which the assembly is suitable. The *SCCR* can also become a prominent part of the quotation presented to the end-user at the time of bidding.

Supplement SB of UL 508A

The UL 508A Standard for Safety entitled "*Industrial Control Panels*" was released in 2001 by the Northbrook office of Underwriters Laboratories Inc., in Northbrook, IL, USA. It is the de-facto authoritative safety standard on the design and engineering of control panels in the US. The current edition contains all the updates and revisions issued in September 2005. This would include the most recent changes to the afore-mentioned supplement SB specifically dealing with short circuit ratings for control panels which became effective April 25th of 2006. The September 2005 set of revision includes at least 40 additional requirement changes which are scheduled to take effect in March of 2007.
In the 2005 NEC the Supplement SB is the only document to be singled out as an approved method for establishing "*Short Circuit Current Ratings for Industrial Control Panels*" **(refer to Tables 2a/b** through **2e/f)**. Such a mention in the NEC naturally provides the Supplement with pre-eminence over other comparable methods.

A design engineer has certainly always needed to take into consideration potential fault currents when properly selecting and applying power circuit components in an installation. As such, not much has changed from this basic task and requirement. There is now, however, an additional need to make an even more thorough design analysis of the circuit so that all the weakest elements can be properly identified and incorporated into the overall calculation. In order to make a meaningful comparison between the available fault and the suitability of the component or components in question, a design engineer can rely on:

- The SCCR marked on listed (e.g. UL-Listed) and properly labeled components and assemblies, or
- An approved method to reliably establish the SCCR of the engineered assembly or panel in question.

- As a general rule, the short-circuit rating (*SCCR*, in kA) of all power circuit components in the panel, as well as of the control circuit supply, shall be equal to or greater than the maximum available fault current [in kA] which can be present on the incoming supply terminals of the panel at the point of installation.

When using a **current limiting** protective device the short circuit burden is greater on its supply side than it is on its load side. A good indicator of the current limiting effect is the let-through current of the protective device. The use of current limiting devices greatly reduces the requirements placed upon components under fault conditions in the power circuit downstream. Components don't need to deal with a magnitude of current quite as high as in the supply side circuit.

[10] OEM = *Original Equipment Manufacturer*

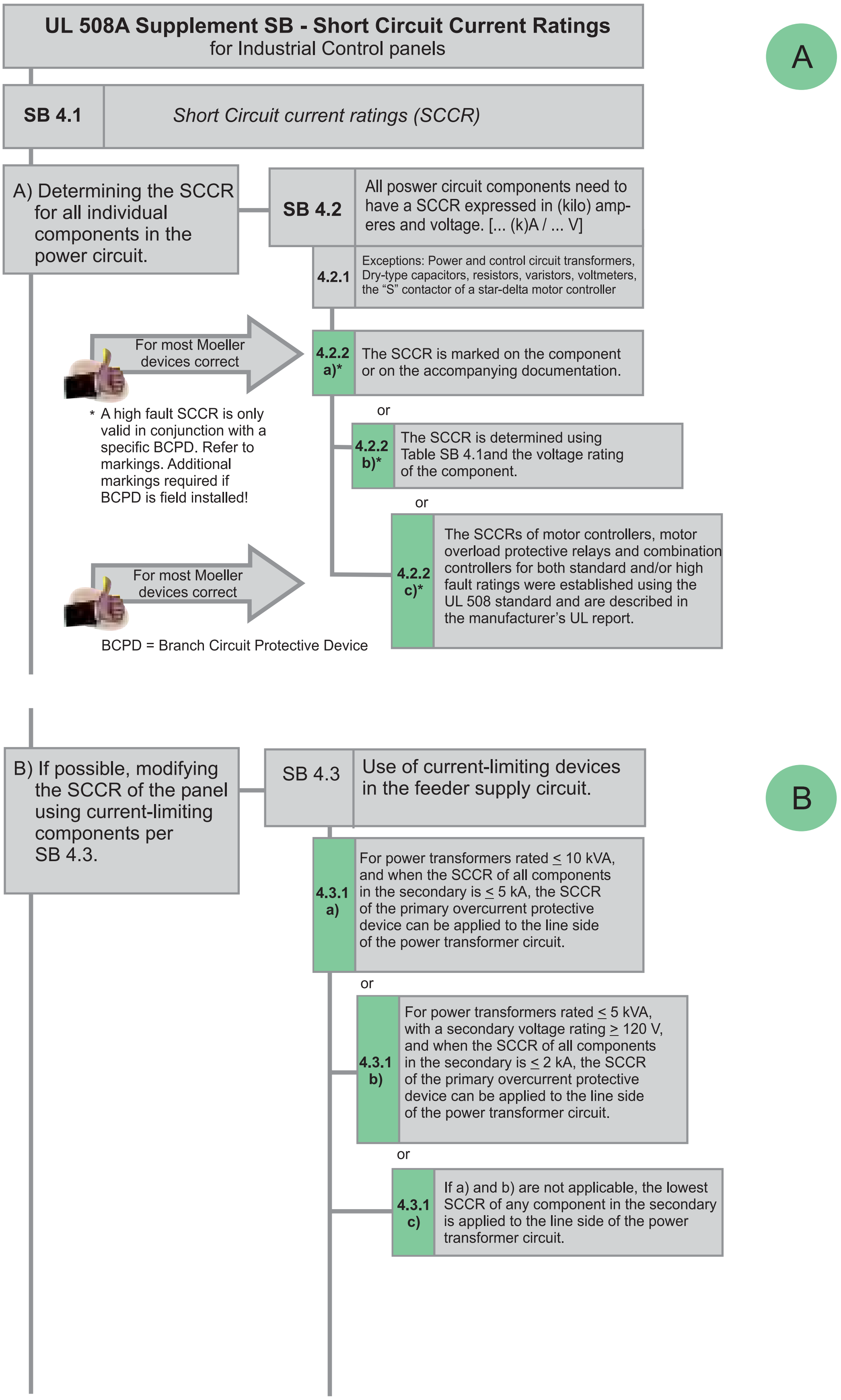


Table 2 a/b: Determination of the Short Circuit Current Rating according to UL 508A Supplement SB

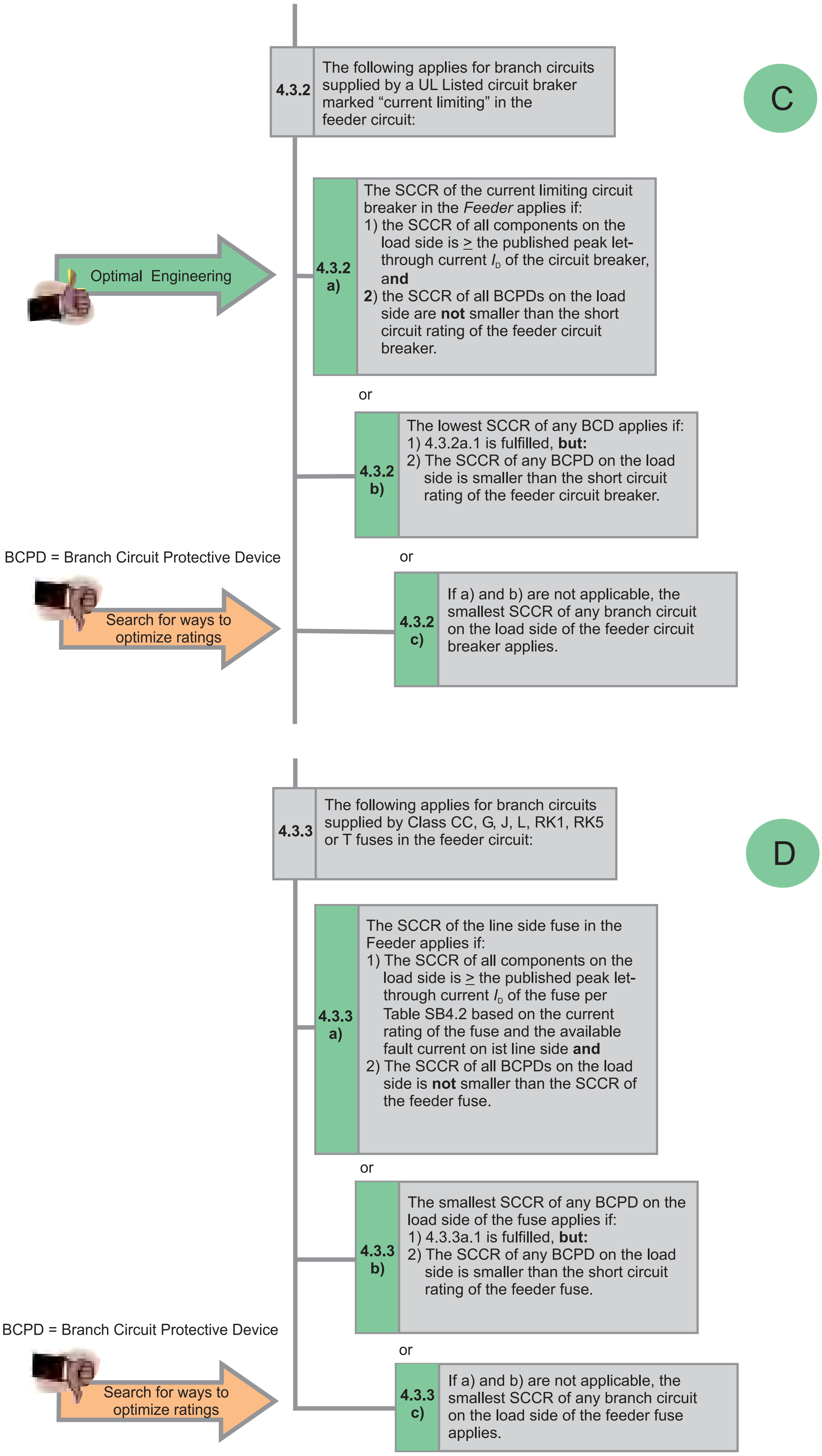


Table 2 c/d: Determination of the Short Circuit Current Rating according to UL 508A Supplement SB

C) Determination of the overall SCCR of the panel as described in SB 4.4.

SB 4.4 Determination of the overall SCCR for the panel

E

4.4.1 For each branch circuit provided with branch circuit protection in the panel, the smallest short circuit rating of all power components on the load side of a branch circuit protective device and the control circuit overcurrent protection in SB3.2.1 is to be determined and compared with the SCCR of the branch circuit protective device. The smaller of the two ratings shall be assigned to the line side of the branch circuit protective device.

4.4.2 Deleted

4.4.3 Deleted

4.4.4 The overall SCCR of the panel shall be one of the following:

BCPD = Branch Circuit Protective Device

4.4.4 a) For panels consisting of a single branch circuit, **without branch circuit protection within the panel,** the overall panel SCCR shall be the lowest SCCR of all power circuit components and the control circuit overcurrent protection per SB3.2.1.

or

4.4.4 b) For panels consisting of a single branch circuit, ***with*** **branch circuit protection and power circuit components within the panel,** the overall panel SCCR shall be in accordance with SB4.4.1.

F

or

4.4.4 c) for *Panels* consisting of multiple branch circuits, and feeder components such as disconnect switches, bus bars, terminal blocks and feeder overcurrent protective devices within the panel, the panel SCCR shall be the lowest of the following:

1) the lowest value of any branch circuit determined in accordance with 4.4.1, which was not modified by the use of current limiting components (4.3.1 bis 4.3.3),
2) the lowest SCCR of any feeder component not covered by SB 4.4.4(c)(3) and any control circuit overcurrent protection connected to the feeder as in SB3.2.1, or:
3) the lowest SCCR determined from SB4.3.1-SB4.3.3 for each branch circuit supplied by the associated feeder component.

Paragraph SB3.2.1 differentiates between:

1) common control circuits and the primary of control transformers and power supplies ***tapped from the feeder circuit***, for which the overcurrent protective must be a BCPD having a short circuit current rating not less than the overall panel SCCR as per SB4.4.4.

and

2) common control circuits and the primary of control transformers and power supplies ***tapped from the load side of a motor branch circuit protective device***, for which the short circuit rating of the overcurrent protection needs to be included in the determination of the branch circuit short circuit current rating per SB 4.4.1 and SB4.4.4(a).

Table 2 e/f: Determination of the Short Circuit Current Rating according to UL 508A Supplement SB

In the past, such a comparison would have often been done solely with the protective devices in mind, and less in consideration of industrial control equipment and miscellaneous elements located downstream in the panel. In all likelihood, the rating appearing on the nameplate would have simply reflected the interrupting or short circuit rating of the main disconnecting means. From that standpoint, the engineering design requirements have certainly become more comprehensive. It follows that the process by which ratings are determined should also be properly documented by the design engineer in order to facilitate the eventual commisioning and approval of the control panel at the installation site. It is thus highly recommended, either in ledger or block form, to create an *SCCR* register of all the power circuit components as well as the control circuit supply rating (**Photo 6**)) in order to facilitate the overall determination of the panel short circuit rating. **Table 3** attempts to help the process by providing a checklist of sorts to arrive at ratings. These design steps are also a necessary part of the engineering associated to *Control Panels for Industrial Machinery*.

This evaluation process is certainly helped by the fact that NEC Article 430.8 actually requires short circuit markings on power circuit components and motor starter assemblies. These would include mostly contactors, motor starters, drives etc...essentially all the power components suitable for switching and controlling motor branch circuits.

It's worth noting initially that the Supplement differentiates between a "*Standard SCCR*" and a "*High Fault SCCR*" with respect to *Motor controllers*. A "*High Fault SCCR*" applies whenever the *short circuit rating* value assigned to the component or assembly is greater than the "*Standard SCCR*" shown in Table SB 4.1 the standard. The table also assigns assumed maximum short circuit ratings to *listed* or *recognized components* which are otherwise umarked. Those values are rather conservatively assigned and thus tend to be on the low side. (Refer to **Table 4** of this paper for excerpts out of Supplement Table SB4.1)**.** With respect to internal wiring connections, the standard points out the need to follow manufacturer's specified instructions for torquing or crimping all terminals of power circuit wiring connectors and components.

There are additional references to the overcurrent protection requirement for control circuits which are directly tapped from the *feeder* or from the *branch circuit.* Specifically, the standard differentiates between:

- A control circuit which is connected directly to the *Feeder* via a *BCPD*[11], either with or without a control circuit transformer or power supply, or:
- A control circuit which is directly tapped from the load side of a *Motor Branch Circuit Protective Device*.

In the former, the *short circuit rating* of the branch circuit protective device must not be less than the overall panel SCCR. In the latter, the short circuit rating of the branch circuit protective device needs to be included in the determination of the branch circuit *short circuit rating* (SB 4.4.1 und SB 4.4.4 a).

The Supplement SB defines several steps to follow in the determination of the overall short circuit rating (*SCCR*) of the control panel:

1.) The first thing to do is to establish the *short circuit ratings* of individual power circuit components. This will be a value in kiloamps at a particular voltage, and is applicable to all power components aside from a few minor exceptions.

    To accomplish this, the following 3 alternative methods are presented:

    a.) Finding the *SCCR* information on the component rating label, or on the accompanying product documentation provided by the manufacturer.

    b.) Using the assumed *short circuit rating* of the component taken from Table SB 4.1 along with the voltage rating of the component.

    c.) Obtaining from the manufacturer an overriding *short circuit rating* of the component or assembly which was tested per UL 508 and is documented in the manufacturer's UL procedure.

2.) The short circuit current rating can be modified due to the presence of current limiting protective devices in the circuit. Per SB 4.3, these can be
    - A defined type and size of power transformer in the supply circuit.
    - A listed molded case circuit breaker additionally evaluated and marked "**Current Limiting**", or
    - Fuses from a defined group of characteristics.

3.) The determination of the overall panel *SCCR* is done per SB 4.4

    a.) For each *branch circuit*, the smallest *short circuit rating* (*SCCR*) of all power circuit components and the control circuit overcurrent protection must be determined and compared with the *short circuit rating* of the *branch circuit protective device* (*BCPD*). The smaller of the two ratings then becomes the assigned rating for that branch circuit.

    b.) In isolated secondaries of power transformers which are rated up to 10kVA and used as components to limit the available *short circuit rating*, the *short circuit rating* assigned to the line side of the power transformer circuit will be the same as the rating of the primary overcurrent device, as long as the components in the secondary meet minimum *short circuit rating* requirements per the standard.
    For transformers rated above 10kVA, the lowest *short circuit rating* of any of the components in the secondary

[11] BCPD = Branch Circuit Protective Device

Checklist: **Overall Short Circuit Current Rating** (SCCR) **for Industrial Control Panels** (ICP)
per *UL 508A, Supplement SB*, Sept. 2005

Project:		Name:		Date:	
Circuit:		Sheet:			

SB 4.2.1	*SCCR*s of all components SB 4.2.3 BCPD notwendig	vorhanden	CL	per SB 4.2.2 a) Rating label b) Table SB 4.1 c) Test data per UL 508	a, b, c	kA	Modifications per SB 4.3.1 kA	SB 4.3.2 kA	SB 4.3.3 kA	Data source Company:
				Disconnect						
				Branch Circuit Protective Device						
				Contactors						
				Overload Relays						
				Terminals						
				Bus bars						
	Lowest *SCCR* in the Branch Circuit									

SB 3.2.1	Overcurrent Protection of the Control Circuit	applicable	kA	Comments
	Control supply tapped from the feeder *SCCR* as per SB 4.4.4			
	Control supply tapped from the load side of a *Branch Circuit Current Protective Device*			

SB 4.4.4	Results for individual Branch or partial result for panel with multiple branch circuits	applicable	kA	Comments
	Case a) Individual Branch without a protective device in the panel, control circuit per SB 3.2.1			
	Case b) Individual Branch with a protective device in the panel, *SCCR* per SB 4.4.1			
	Case c) Multiple branches, feeder components within the panel, with feeder overcurrent protective devices.			

The panel is covered with sheets 1 through ____

Overall result: *SCCR* = ____ kA Verified: Name, Date ____

Table 3: Checklist to detemine the *SCCR*s of individual power circuits

Abbreviated version of Table SB4.1 of UL 508A, Supplement SB

Assumed maximum *short circuit current rating* for unmarked components

Component				***SCCR* in kA**
Bus bars				10
Circuit breaker (including *GFCI * type*)				5
Current meters				[a])
Current shunt				10
Fuseholder				10
Industrial control equipment:				
	a. Auxiliary devices (overload relay)			5
	b.			
	c.			
Motor controller rated in: HP resp. kW				
	a.	0 - 50 HP	0 - 37,3 kW	5 [c])
	b.	51 - 200 HP	38 - 149 kW	10 [c])
	c.	201 - 400 HP	150 - 298 kW	18 [c])
	d.	401 - 600 HP	299 - 447 kW	30 [c])
	e.	601 - 900 HP	448 - 671 kW	42 [c])
	f.	901 - 1500 HP	672 - 1193 kW	85 [c])
Supplementary protector				0.2
Switch unit				5
Terminal Block or power distribution block				10
and miscellaneous devices				

[a]) not required when connected via a current transformer or shunt. A directly connected current meter needs to have a marked short circuit current rating.

[c]) *Standard fault current rating* for motor controllers rated within that specified horsepower range.

* *GFCI* = US style ground fault circuit interrupter.

Table 4: Examples of *Standard Short Circuit Current Ratings* for unmarked components.

becomes the short circuit rating assigned to the line side of the power transformer. (These transformers are not considered to be current limiting.)

c.) For the *Feeder Circuit* the *short circuit rating* assigned will be the lowest rating determined from comparing all of the branch circuit ratings connected to the feeder as well as any additional feeder components located in the panel. Miscellaneous feeder components can include for example:

- Disconnect switches
- Feeder overcurrent protective devices
- Bus bar systems, or
- Terminal blocks

Generally speaking, the final SCCR appearing on the nameplate of the control panel, and which could not otherwise be modifed in any permissible manner as described by the standard, is not allowed to exceed the assigned rating of the lowest rated circuit or component in the panel.

Photos 6 and 7 provide pictorial examples of how various Moeller components can be used to determine an overall panel *SCCR*, and how the values achieved can be modified using proper and approved component selection techniques to improve ratings.

As a final step, the overall result of the determination is entered on the nameplate rating label of the industrial control panel with the following marking:

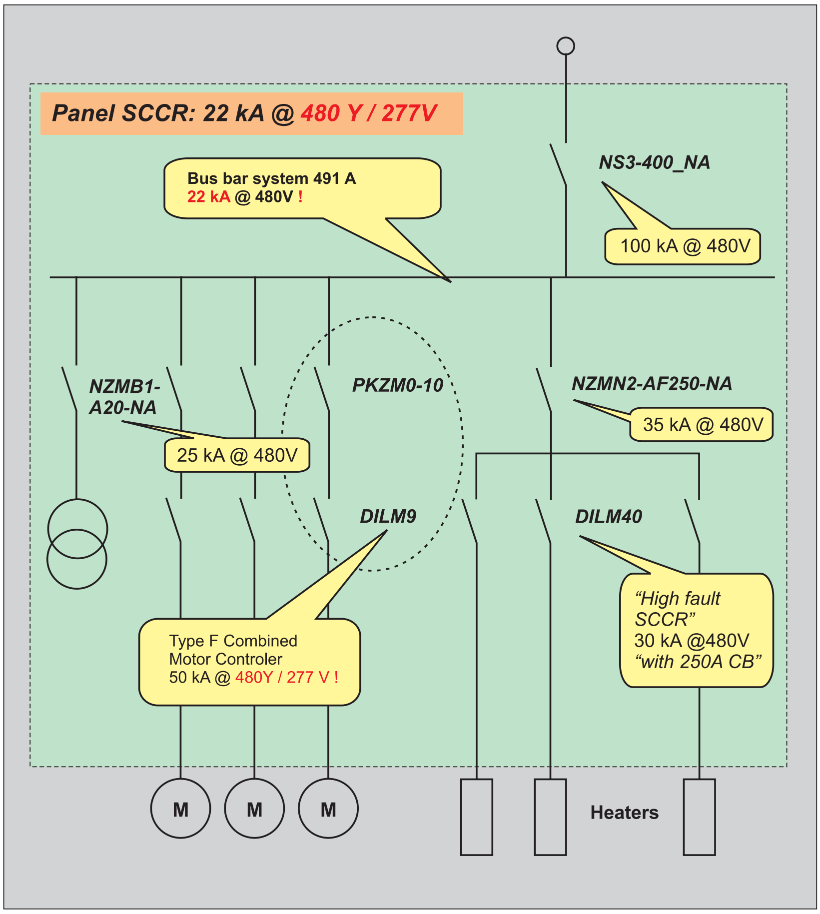


Photo 6: It's advisable, once the component selection process for an industrial control panel begins, to specify in a layout plan or in a block diagram the *short circuit rating* of all power circuit elements, components, primary circuits of transformers and individually tested combination assemblies included in the panel. The *SCCR*s will either be marked on the components or on accompanying documentation, or can be obtained from the manufacturer. This method will help to more quickly identify the lowest rated elements in the power circuit which will be essential in the proper determination of the overall *short circuit rating* of the panel. In the example above, the bus bar assembly has been flagged as having the lowest short circuit current rating.

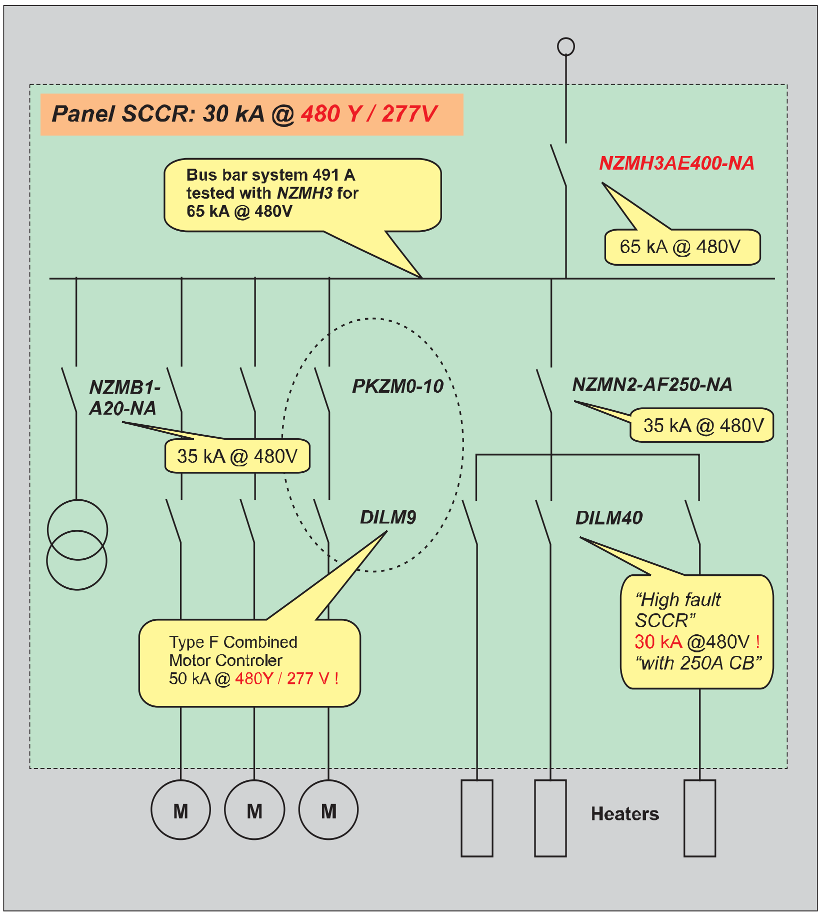


Photo 7: Substitution of the incoming switch from **Photo 6** with a UL listed "current limiting" circuit breaker raises the overall *short circuit rating* of the panel from 18kA to 30 kA. Note that the short circuit rating of the transformer primary protective switch also had to be increased in order to match or exceed the rating of the panel main incoming switch. The peak let-through current of the main incoming current limiting circuit breaker is sufficiently low to protect the bus bar system.

"Short circuit current: ... kA rms symmetrical, ... V maximum".

If the *Industrial Control Panel SCCR* is based on a *High Fault rating*, and the panel is not provided with the required *branch circuit protective devices* (because they were meant to be installed in the field and/or supplied separately), the marking above would also have to specify the type and size of the required *branch circuit protective devices* to be provided.

In addition, whenever the overall *SCCR* assigned to the *Industrial control Panel* is based on a *High Fault rating*, the panel is required to bear an additional caution marking (in English) with the following wording:

Warning
Risk of Fire or Electric Shock - The opening of the branch-circuit protective device may be an indication that a fault current has been interrupted. All current-carrying parts and other components protected by this device should be examined and replaced if damaged. If burnout of a current element of an overload relay occurs, the complete overload relay must be replaced.

The following exceptions apply:

1. An *Instantaneous trip circuit breaker*, used as branch circuit protection for a *combination motor controller*, needs to be marked per UL 508A, 55.6, and a
2. *Self-protected combination motor controller* needs to be marked per UL 508A, 55.7.

UL 508 A also has additional supplements worthy of mention. Supplement SA provides information on the application of equipment which complies with specific component requirements of UL 508A, but which may require additional description in the manufacturer's procedure file. This is often the case with "*Recognized*" only equipment but may also be required for *listed equipment* which does not specifically appear in the supplement. Appendix A provides a summary of all pertinent equipment standards referenced in UL 508A. Appendix B details the restrictions under which ***unevaluated** components* (i.e. ones which are neither *listed* nor *recognized*) can be used in *industrial control panels*. Note that power circuit components must always carry a UL listing or recognition. *Unevaluated components* are thus not permitted to provide any protective functions such as short circuit, overload or ground fault tripping. They are, in actual fact, not even permitted to have any connection to the power circuit. Accordingly, they are found in control circuits only, and would still be subject to specific application criteria in order to fulfill the intent of the standard.

Determining *Short Circuit Ratings* for individual components

It's been previously mentioned that it is both necessary and useful to determine the *Short Circuit Current Ratings* of individual components in the power circuit. The UL 508A standard also assigns ratings to devices and elements of the power circuit which may be unmarked and/or for which rating information may not be generally available. As far as Moeller components are concerned, these values can be found in the Moeller Main Catalog as well on individual component rating labels, which makes it more convenient for the inspection authorities. **Photos 8** and **9** provide examples of typical ratings found on Moeller contactors and motor protective switches. Additional selection assistance will be posted on Moeller Internet web sites.

It will be necessary to determine actual peak let-through currents I_D as well as interrupting ratings when using circuit breakers which have been additionally evaluated and listed as "*Current Limiting*". Since these values are a function of more than just 2 parameters it's difficult to provide the data in table and text form on rating labels. The conventional method is for the manufacturer to provide representative curves in catalogs or accompanying documentation. (**Photo 10**). The photo shows curves at nominal voltage levels of 415, 525 and 690V. It's evident from the curves, however, that the values are only slightly affected by the voltage and thus the typical IEC 525V and 690V data can be used to adequately determine let-through values at 480V and 600V for the US and Canada respectively. Similarly, the 415V curve can be used to determine let-through I_D values at lower nominal voltage levels.

It is also worth noting that approval authorities such as UL and CSA require manufacturers of current limiting circuit breakers to publish actual let-through current and energy values at specific fault current and voltage levels achieved through testing. These are referred to by the standard as *Threshold*, *Intermediate* and *High-Fault values*, and are usually provided by the manufacturer as technical data in catalogs or in accompanying component documentation. Occasionally, the information will appear directly on the product rating label.

If the maximum available fault at the supply side terminals of an installation is known, the value can be applied to the I_{cc} axis of the diagram in order to ultimately select the proper circuit breaker for the application and determine its let-through values at that fault level using the appropriate voltage curve. If the maximum available fault cannot be determined accurately, one has to take a conservative approach and rely on the incoming circuit breaker's maximum interrupting rating (take note of interrupting rating part number code letters B, N, and H for Moeller circuit breakers), since it represents a value which cannot be exceeded during an actual fault condition.

It may be necessary for the designer in this case to select a breaker with a higher interrupting capability than what is perhaps needed for the installation, in order to err on the safe side. As previously alluded to, one way to narrow it down conservatively would be to base the value on the maximum fault current which the upstream power distribution transformer can deliver, should its secondary be short

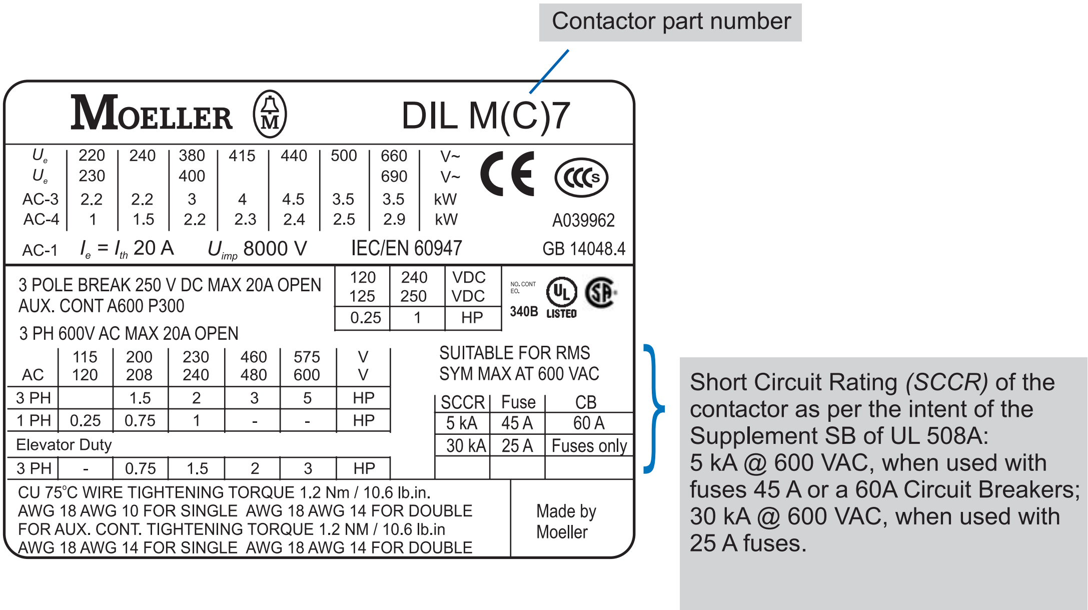


Photo 8: Nameplate rating label of a contactor, with its *short circuit rating* (*SCCR*) as an individual component.

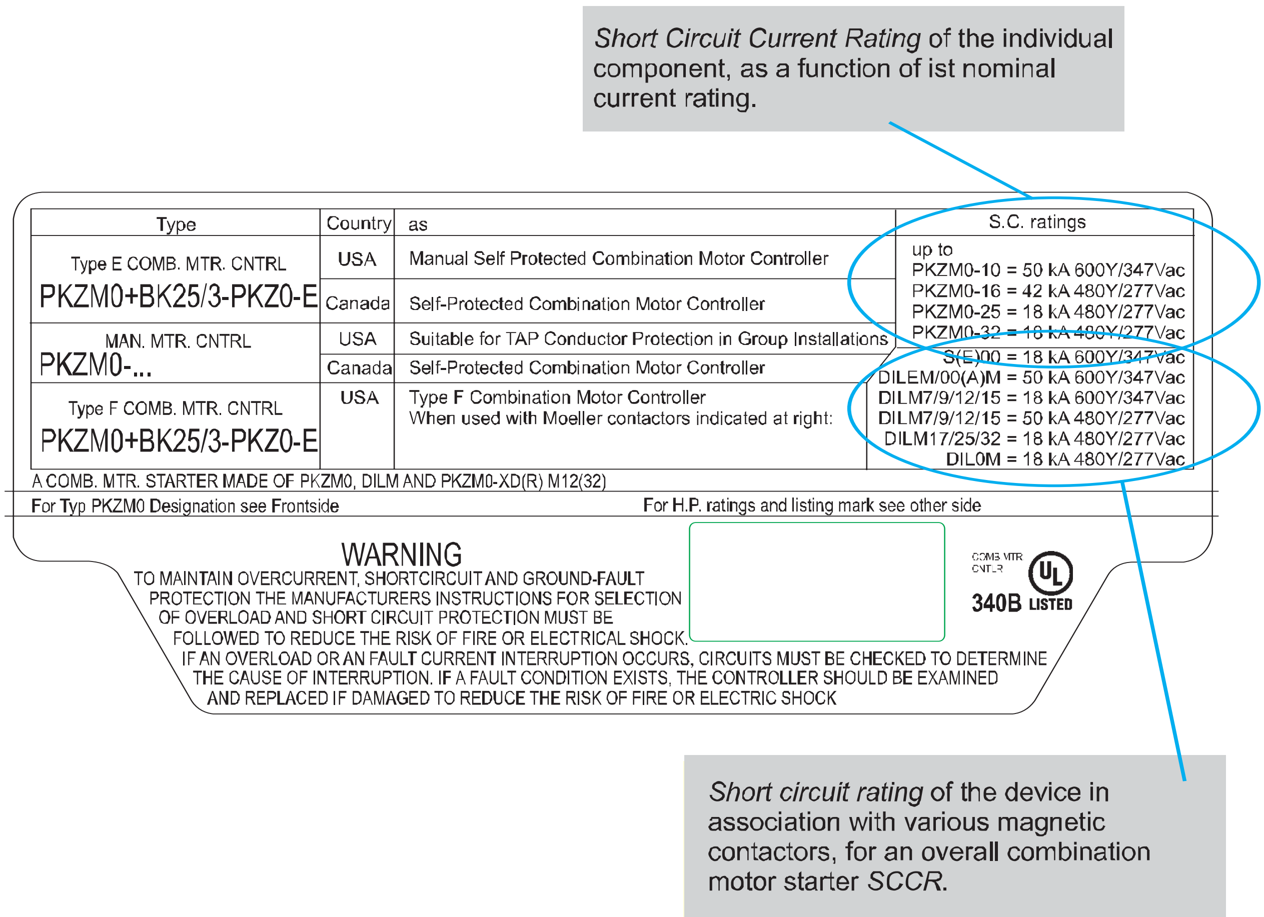


Photo 9: Nameplate rating label of a motor protective switch, Moeller Type ***PKZM0***. The label provides *short circuit rating* information for the device, both as an individual component and in association with Moeller magnetic contactors as a combination motor starter assembly.

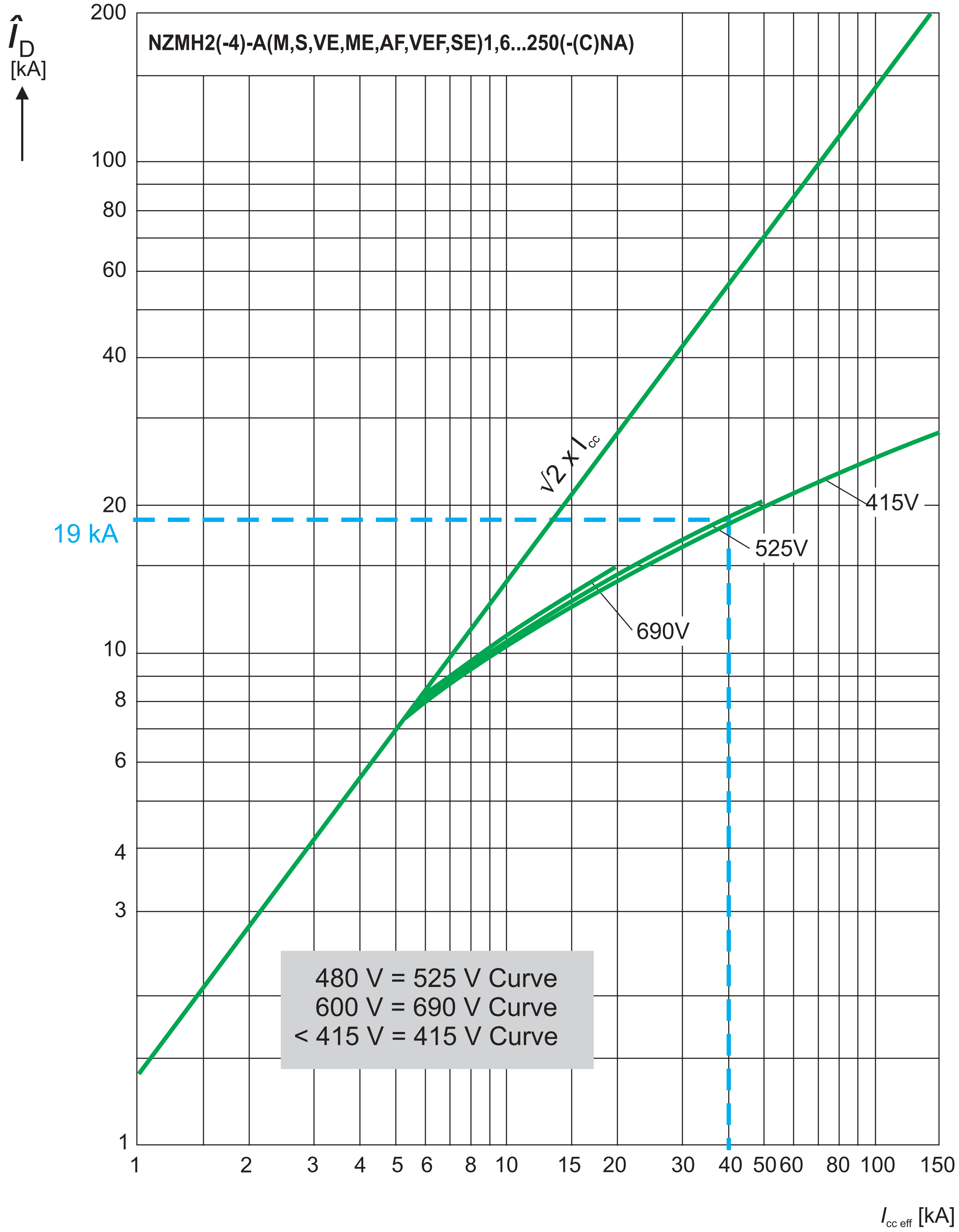


Photo 10: Typical curve to assist in determining the peal let-through current values of a listed current limiting circuit breaker, Moeller Type *NZM 2* "H" (H = high interrupting rating). If we take as an example an available fault of 40kA rms sym (I_{cc}) at the point of installation, the peak let-through current at 480V for the breaker, at that level of fault, can be seen to be 19kA. All components and assemblies mounted downstream from the breaker would have to be rated at only 19 kA or better in order to take full advantage of the circuit breaker's current limiting rating.

circuited at the transformer terminals. The power rating of the transformer, along with the secondary voltage and the transformer impedance rating, would provide enough information to yield a reasonably appropriate value of available fault for the power circuit downstream in this respect (see **Table 1**).

The breaker's interrupting rating in this case would equate to its *Short Circuit Current Rating*. Plotting this value on the I_{cc}-Axis and intersecting it with the appropriate voltage curve would provide the peak let-through values on the left hand side vertical axis.

How can one arrive at a more suitable *Overall Short Circuit Current Rating* for the control panel, given the magnitude of the available fault current and potential peak let-through values? One way to positively influence the outcome in terms of achieving better ratings could be the deliberate oversizing of switching components such as contactors, and/or optimization of the protective elements in the power circuit. For example, use of a current limiting circuit breaker, as opposed to a non-protective *Switch Disconnector* or *Molded Case Switch*, would provide immediate benefits in this respect. The selected circuit breaker's interrupting rating can also influence the overall outcome.

It was previously mentioned how individual component ratings are established and, in some cases, can be assigned from tables in standards. Component assemblies, on the other hand, such as fuseless combination motor starters from Moeller, can generally feature better overall ratings than what can be achieved individually, simply through the positive effect of dynamic interaction between components during short circuit conditions. However, it is crucial that these results always be achieved and independently validated through actual testing. Indeed, such *third party certification* by recognized agencies is a strict requirement throughout the North American electrical system of Codes and Standards.

Summary:

The recent enactment of NEC Article 409, together with the latest SB Supplement of UL 508A, seem at first glance, from both a domestic and exporting perspective, to have further complicated the already challenging task of properly applying electrical equipment in North America. This paper points out, however, that the provision of *short circuit ratings* on *control panels* is a not only a technically worthwhile endeavor, but one which may ultimately pave the way for a smoother approval process on the part of North American electrical inspection authorities. In the US, the new NEC Article brings much needed clarity and focus to the requirements of Industrial Control Panels, especially those which may not have been built and listed to UL 508A. For the panel builder, compliance with the requirements of the standard has meant a closer relationship and added dependency on the supplier and manufacturer of electrical components and assemblies. In order to achieve timely and cost effective solutions it will often be more advantageous to purchase the majority of parts from the same supplier. Finally, it is recommended to refrain from having to engineer each panel on an individual, customized basis. Rather, it is best, if at all possible, to standardize on the fewest number of possible solutions which, in spite of some slight variance, could still be fully accomplished within a similar and more narrowly defined component framework.

Through comprehensive and often complex testing, Moeller provides panel builders with truly useful and helpful results (e.g. **Tables 5** and **6**). for the most commonly encountered components and motor starter assemblies. The overall UL ratings achieved through component combination testing are often much better than those established for individual components. A good example of a system solution involves component mounted motor starter busbar adapters from Moeller, which are tested in combination with the bus systems onto which they are fastened and connected. [6].

The individual parts of such a system don't necessarily need to be purchased **completely** assembled from Moeller. It's entirely permissible for the panel builder to combine the parts on his own, provided he uses only those listed parts described in the manufacturer's procedure and, of course, doesn't exceed the overall assembly ratings as shown on respective rating labels. Additional application stipulations appearing in the manufacturer's procedure in this respect would naturally also require strict adherence on the part of the installer. Whenever necessary, Moeller also provides appropriate instructions in catalogs and/or on the product's accompanying documentation and set of installation instructions.

Because bus bar systems, constructionally speaking, are nearly always located in the more demanding *feeder circuit* (**Photo 11**), they figure to be a particularly important point of consideration when discussing succesful export of electrical equipment to North America. Moeller provides panel builders and end-users in North America, as well as exporting OEM customers from the IEC world, with practical selection tables geared towards facilitating a more precise and applicable determination of the *SCCR* (*Short Circuit Current Rating*) now required on the Industrial Control Panel rating nameplate. The panel builder should only be installing power circuit components with readily identifiable and marked short circuit current ratings, i.e. only those which can be safely and reliably be included in the overall SCCR determination.

It would be false to conclude that this new NEC Article affects only component manufacturers and panel builders, at the exclusion of all others in the chain. On the contrary, future end-users and/or buyers of electrical equipment alike should familiarize themselves with these changes, if anything, so that they may make better informed and more educated decisions on their purchases and invest-

UL 508 Type F Combination Motor Controllers										
Can be applied without a contactor as a *UL 508 Type E Self-Protected Combination Motor Controllers*										
Maximum HP Rating 3-phase, 60 Hz				Setting Range		***Short Circuit Current Rating SCCR***		Line side terminal always required	Motor Protective Switch	Contac-tor
208 V (200 V) HP	240 V (230 V) HP	480V[1] (460 V) HP	600 V[1] (575 V) HP	Adjustable Thermal A	Fixed Instantaneous Trip A	200 V 240 V 480 V[1] kA	600 V[1] kA	**Type**	**Type**	**Type**
				0,2 - 0,25	3,4	**50**	**50**	***BK25/3-PKZ0-E***	***PKZM0-0,25***	***DILM7***
				0,3 - 0,4	5,6	**50**	**50**		***PKZM0-0,4***	***DILM7***
				0,4 - 0,63	8,8	**50**	**50**		***PKZM0-0,63***	***DILM7***
		½	½	0,6 - 1	14	**50**	**50**		***PKZM0-1***	***DILM7***
		¾	1	1 - 1,6	22	**50**	**50**		***PKZM0-1,6***	***DILM7***
½	½	1	1½	1,6 - 2,5	35	**50**	**50**		***PKZM0-2,5***	***DILM7***
1	1	2	3	2,5 - 4	56	**50**	**50**		***PKZM0-4***	***DILM7***
1½	1½	3	5	4 - 6	88	**50**	**50**		***PKZM0-6,3***	***DILM7***
3	3	7½	10	6,3 - 11	140	**50**	**50**		***PKZM0-10***	***DILM9***
3	3	7½	-	8 - 12	168	**50**	**50**		***PKZM0-12***	***DILM12***
3	5	10	-	10 - 16	224	**18**	-		***PKZM0-16***	***DILM15***
5	5	10	-	16 - 20	280	**18**	-		***PKZM0-20***	***DILM25***
5	7½	15	-	20 - 25	350	**18**	-		***PKZM0-25***	***DILM25***
7½	10	20	-	25 - 32	448	**18**	-		***PKZM0-32***	***DILM32***
3	5	10	-	10 - 16	224	**50**	-	***BK50/3-PKZ4-E***	***PKZM4-16***	***DILM17***
7½	7½	20	-	20 - 25	350	**50**	-		***PKZM4-25***	***DILM25***
10	10	25	-	25 - 32	448	**50**	-		***PKZM4-32***	***DILM32***
10	10	30	-	32 - 40	560	**50**	-		***PKZM4-40***	***DILM40***

[1]) Suitable for grounded 480 Y / 277 V 60 Hz and 600 Y / 347 V 60 Hz networks only.

Table 5: Short Circuit Rating of UL 508 Type F-Combination Motor Controllers mounted without bus bar adapters. The same ratings apply for Motor Starter Combinations Type MSC of similar HP ratings and featuring the innovative and time saving "toolless" plug wiring connectors. Also included are reversing combinations in those sizes, which have a set of mechanically and electrically interlocked contactors. (The mechanical interlock is always required for reversing starters in North America.)

ments. That's especially the case, given that these changes deal mostly with the safety and dependability of the equipment over the entire lifespan of the machine and its associated electrical equipment. Price differences from various manufacturer sources can ultimately have a crucial bearing on the overall reliability of the installation. A thorough attempt to consider the complete life cycle of the equipment when weighing a purchase decision will nearly always yield a decision offering the best value in the long run.

Validity:

The information provided in this paper represents a thoroughly and dutifully researched interpretation by the author of relevant portions of the NEC 2005 Code book and the UL 508A standard, valid as of June 2006. It does not purport to serve as a substitute for the informational content of current and pertinent North American standards, since more detailed information for both domestic panel builders and exporters of electrical machines and equipment destined to North America would be required for more comprehensive design and engineering purposes. In case of any doubt with respect to the proper interpretation of these norms, it is highly recommended to directly consult the assistance resources of these respective approval and standard making agencies. The paper does not attempt to make comment on the standards themselves. Rather, the informational content serves to highlight the compliance of Moeller products and assemblies with appropriate and pertinent excerpts taken from the afore-mentioned North American electrical standards.

UL 508 Type F Combination Motor Controllers*, complete sets mounted on bus bar adapters** **Short Circuit Rating of combinations mounted on bus bar adapters.** **Can be applied without a contactor as a *UL 508 Type E Self-Protected Combination Motor Controllers									
Maximum HP Rating 3-phasig, 60 Hz				Setting Range		*Short Circuit Current Rating SCCR*		Starters mounted on busbar adapters	Incoming terminal block, always required for UL versions
208 V (200 V) HP	240 V (230 V) HP	480V[1]) (460 V) HP	600 V[1]) (575 V) HP	Adjustable Thermal A	Fixed Instantaneous Trip A	200 V 240 V 480 V[1]) kA	600 V[1]) kA	(IEC-version, please note column at right) **Type**	**Type:** **BK25/3 -PKZ0-E**
				0,2 - 0,25	3,4	**50**	**50**	***MSC-D-0,25-M7(24VDC)/BBA***	
				0,3 - 0,4	5,6	**50**	**50**	***MSC-D-0,4-M7(24VDC)/BBA***	
				0,4 - 0,63	8,8	**50**	**50**	***MSC-D-0,63-M7(24VDC)/BBA***	
		½	½	0,6 - 1	14	**50**	**50**	***MSC-D-1-M7(24VDC)/BBA***	
		¾	1	1 - 1,6	22	**50**	**50**	***MSC-D-1,6-M7(24VDC)/BBA***	
½	½	1	1½	1,6 - 2,5	35	**50**	**50**	***MSC-D-2,5-M7(24VDC)/BBA***	
1	1	2	3	2,5 - 4	56	**50**	**50**	***MSC-D-4-M7(24VDC)/BBA***	
1½	1½	3	5	4 - 6,3	88	**50**	**50**	***MSC-D-6,3-M7(24VDC)/BBA***	
3	3	7½	10	6,3 - 11	140	**50**	**50**	***MSC-D-10-M9(24VDC)/BBA***	
3	3	7½	-	8 - 12	168	**50**	**50**	***MSC-D-12-M12(24VDC)/BBA***	
3	5	10	-	10 - 16	224	**18**	-	***MSC-D-16-M17(24VDC)/BBA***	
5	5	10	-	16 - 20	280	**18**	-	***MSC-D-20-M25(24VDC)/BBA***	
5	7½	15	-	20 - 25	350	**18**	-	***MSC-D-25-M25(24VDC)/BBA***	
7½	10	20	-	25 - 32	448	**18**	-	***MSC-D-32-M32(24VDC)/BBA***	

[1]) Suitable for grounded 480 Y / 277 V 60 Hz and 600 Y / 347 V 60 Hz networks only.

Table 6: *Short circuit rating* of motor starter combinations mounted on bus bar adapters. The ratings apply for fully equipped adapters or for customer assembly using the identical parts and configurations. As per Table 5, reversing combinations are also possible in those sizes, and always feature a set of mechanically and electrically interlocked contactors. (The mechanical interlock is always required for reversing starters in North America.)

An upcoming table, which is planned to be posted as a link at the UL web site for short circuit rated industrial control panels, will include references to the UL file, the starter ID numbers, minimum volume sizes per starter, the respective *Conditions of Acceptability* associated to each starter, the number of phases and HP ratings, the *component abbreviation tags* (e.g. CB, DS, F, MC etc...) as well as the type of combination starter it is per the UL nomenclature (e.g. Types A, D, E, F etc....). The table is currently in preparation.

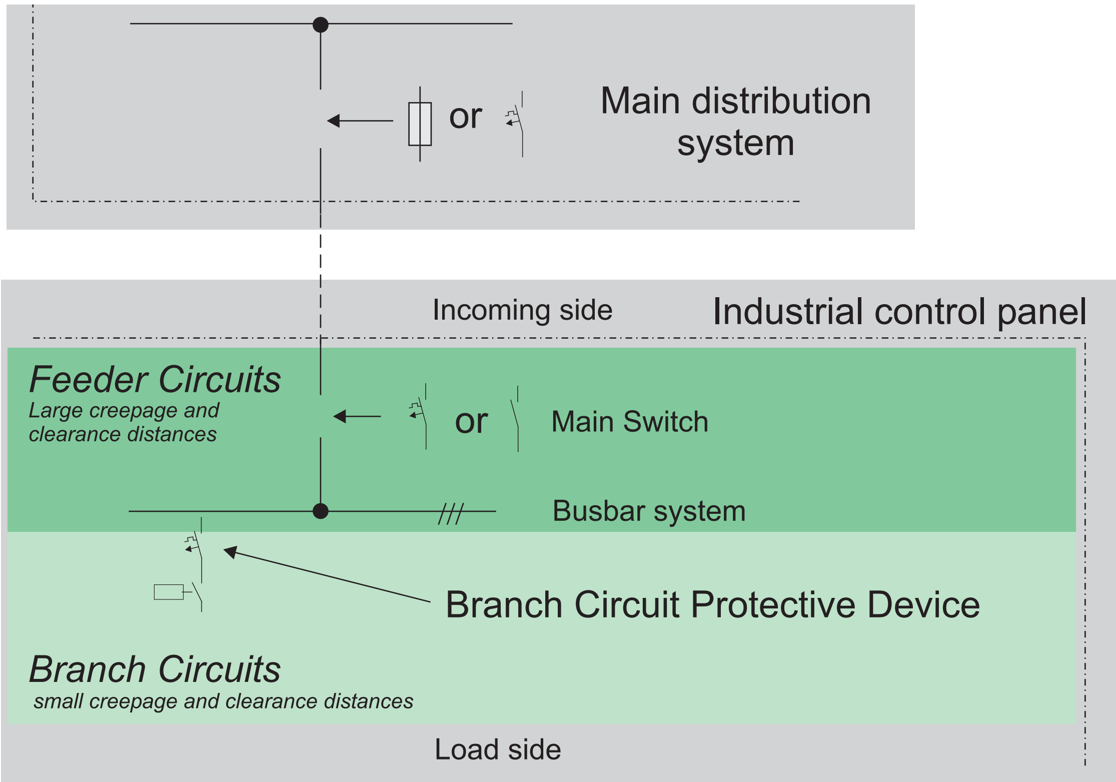


Photo 11: North American standards place a greater emphasis on maintaining adequate air and creepage clearances for components and circuit elements located In the incoming supply circuit (*Feeder Circuit*). These requirements will impact construction aspects of devices such as bus bar systems and bus component adapters, which are often part of the feeder circuit.

References:

[1] Wolfgang Esser
"Besondere Bedingungen für den Einsatz von Motorschutzschaltern und Motorstartern in Nordamerika"
Moeller GmbH, Bonn, 2004
VER1210-1280-928D
Article No.: 267951
Download: http://www.moeller.net/binary/ver_techpapers/ver928de.pdf

Wolfgang Esser
"Special considerations governing the application of Manual Motor Controllers and Motor Starters in North America"
Moeller GmbH, Bonn, 2004
VER1210-1280-928GB
Article No.: 267952
Download: http://www.moeller.net/binary/ver_techpapers/ver928en.pdf

[2] IEC / EN 60 204-1, DIN VDE 0113 Teil 1 "Sicherheit von Maschinen, Elektrische Ausrüstung von Maschinen, Teil 1: Allgemeine Anforderungen"
(IEC 204-1: 1997 + Corrigendum 1998)

[3] NEC 2005 Handbook
NFPA 70: National Electrical Code 2005, National Fire Protection Association, Inc.
Quincy, Massachusetts
02169-7471

[4] UL 508A, "Standard for Industrial Control Panels, 2001, May 1, 2003
Copyright: Underwriters Laboratories INC.

[5] Wolfgang Esser
"Motorstarter und Special Purpose Ratings für den nordamerikanischen Markt"
Moeller GmbH, Bonn, 2006
VER1200+2100-953D
Article No.: 106648

Wolfgang Esser
Moeller GmbH, Bonn, 2006
VER1200+2100-953GB
Article No.: 106649

[6] Wolfgang Esser
"Sammelschienenadapter für die rationelle Motorstartermontage auch auf dem nordamerikanischen Markt erfolgreich einsetzen"
Moeller GmbH, Bonn, 2006
VER4300-960D
Download: http://www.moeller.net/binary/ver_techpapers/ver960de.pdf

Wolfgang Esser
"Busbar Component Adapters - for modern industrial control panel assembly are now fully compliant with North American market requirements"
Moeller GmbH, Bonn, 2006
VER4300-960GB
Download: http://www.moeller.net/binary/ver_techpapers/ver960en.pdf

Author:
Dipl.-Ing. Wolfgang Esser
Leiter Produktsupport Industrieschaltgeräte
Geschäftsbereiche Leistungsschalter, Motorstarter und Drives
Moeller GmbH, Bonn

The essay has been produced with the kind support of:

Mr. BA Phys. Andre R. Fortin
Manager - Codes & Standards
International Corporate Advisor – Power Products
Moeller Electric Corporation,
Millbury, Massachusetts, USA
and
Mr. Dipl.-Ing. Dieter Reiß
Institute for International Product Safety GmbH, Bonn
and
Mr. Dipl.-Ing. Dirk Meyer
Moeller GmbH, Bonn

Moeller addresses worldwide:
www.moeller.net/address
E-Mail: info@moeller.net

VER0211-959GB MDS/Schrems 01/07
Printed in Austria (02/07)
Article No.: 110102

4 015081 096589

Xtra Combinations

Xtra Combinations from Moeller offers a range of products and services, enabling the best possible combination options for switching, protection and control in power distribution and automation.

Using Xtra Combinations enables you to find more efficient solutions for your tasks while optimising the economic viability of your machines and systems.

It provides:

- flexibility and simplicity
- great system availability
- the highest level of safety

All the products can be easily combined with one another mechanically, electrically and digitally, enabling you to arrive at flexible and stylish solutions tailored to your application – quickly, efficiently and cost-effectively.
The products are proven and of such excellent quality that they ensure a high level of operational continuity, allowing you to achieve optimum safety for your personnel, machinery, installations and buildings.

Thanks to our state-of-the-art logistics operation, our comprehensive dealer network and our highly motivated service personnel in 80 countries around the world, you can count on Moeller and our products every time. Challenge us!
We are looking forward to it!

MOELLER

We keep power under control.