

Selecting Protective Devices

SPD

Electrical protection handbook

Based on the 2014 NEC®

Bussmann
by **EATON**

This comprehensive guide
to electrical overcurrent
protection and electrical

design considerations is
based on the 2014 NEC®.

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** Does not include current limiting circuit breakers or current limiting fuses. Protection determined by comparing published values for let-through for Class CC, J, R, and T fuses versus a symmetrical RMS waveform at 200KA.

*** Test results are based on weighted sales volume of FUSETRON and Ferraz Shawmut (Mersen) fuses by selected amp and volt rating combination. Next leading brand refers to Ferraz Shawmut based on third-party fuse market share data for a twenty-seven month period (July 2008 through September 2010).

Selecting Protective Devices Handbook (SPD)

Based on the 2014 NEC®

Welcome to the Bussmann Selecting Protective Devices Handbook (SPD). This is a comprehensive guide to electrical overcurrent protection and electrical design considerations. Information is presented on numerous applications as well as the requirements of codes and standards for a variety of electrical equipment and distribution systems.

How to Use:

The SPD is comprised of major sections which are arranged by topic. There are three methods for locating specific information contained within:

1. Table of Contents: The table of contents sequentially presents the major sections and their contents. New or revised sections are noted in red text.
2. Index: The index, found on page 265, is more detailed than the table of contents and is organized alphabetically by topic with corresponding page number references.
3. 2014 NEC® Section Index: The NEC® Section Index, found on page 264, makes it easy to find information associated with specific National Electrical Code® section references.

For other technical resources and product information visit www.cooperbussmann.com.

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Benefits Offered by Current-Limiting Fuses

High Interrupting Rating of 200,000 Amps or More

Modern current-limiting fuses have high interrupting ratings at no extra cost. Whether for the initial installation or system updates, a fusible system can maintain a sufficient interrupting rating. This helps with achieving high assembly short-circuit current ratings. See Fuseology – Interrupting Rating details.

Type 2 Protection

Type 2 "No Damage" protection of motor starters when applied properly. See Motor Starter Protection – Type 1 versus Type 2 protection.

High SCCR

High assembly short-circuit current ratings can be achieved. See Industrial Control Panels – SCCR.

Rejection Features

Modern current-limiting fuses have rejection features which, when used with rejection fuse clips, assure replacement with a device of the same voltage rating and equal or greater interrupting rating. In addition, rejection features restrict the fuses used for replacement to ones of the same class or type.

Flexibility

Increased flexibility in panel use and installation. Valuable time that was spent gathering information for proper application is drastically reduced with fuses since:

- Fuses can be installed in systems with available fault currents up to 200kA or 300kA covering the majority of installations that exist.
- Fuses can handle line-to-ground fault currents up to their marked interrupting rating.
- Fuses have a straight voltage rating instead of a slash voltage rating. A device with a slash voltage rating is limited to installation in ONLY a solidly grounded wye type system. Fuses can be installed in any type of installation independent of the grounding scheme used.

Reliability

Fuses provide reliable protection throughout the life of the installation. After a fault occurs, fuses are replaced with new factory calibrated fuses assuring the same level of protection that existed previous to the fault.

No Venting

Fuses do not VENT. Therefore fuses will not affect other components in the panel while clearing a fault. Additional guards or barriers are not required.

Helps Regulation Compliance

Resetting or replacing fuses in a circuit without investigating the cause is prohibited in OSHA CFR29:1910-334. Fuses are not resettable and eliminate the invitation to reset.

Workplace Safety

Superior current limitation provides enhanced workplace safety. See Electrical Safety.

Component Protection Via Current Limitation

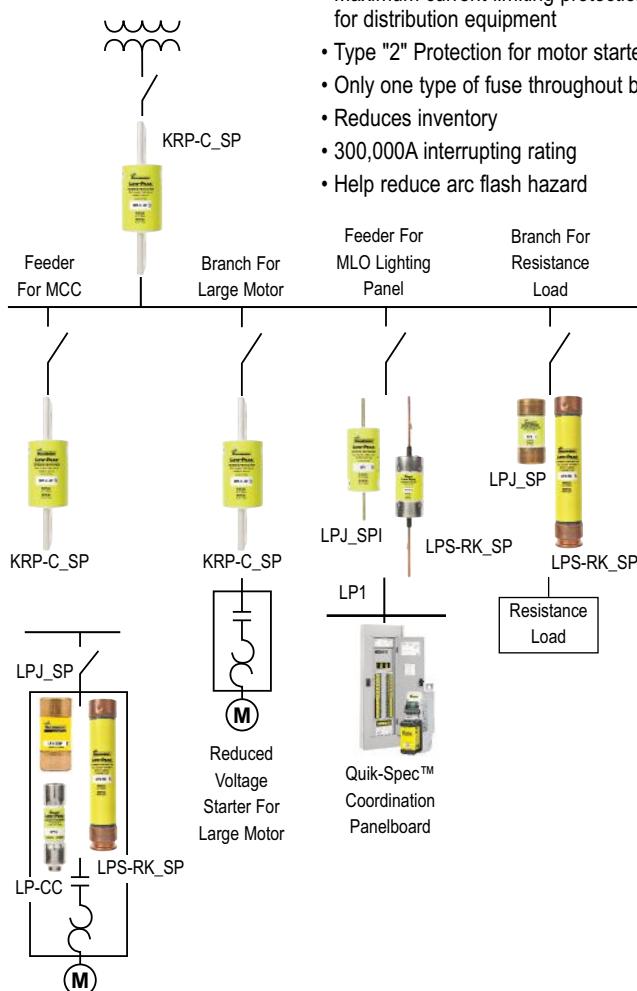
Current limitation provides protection of circuit components for even the most susceptible components such as equipment grounding conductors. See Component Protection and Industrial Control Panels – SCCR.

Selective Coordination

Achieving selective coordination is simple. Typically selective coordination can be achieved between current-limiting fuses by simply maintaining a minimum amp ratio between upstream and downstream fuses. This can aid in diagnostics within the building electrical system or machine panel as only the affected circuit is isolated. Selective coordination helps isolate faulted circuits from the rest of the system and prevents unnecessary power loss to portions of a building. See Selective Coordination.

Specify the Bussmann Low-Peak™ System

- Safety Built-in rejection features
- Selective coordination with a minimum 2:1 ratio
- Maximum current-limiting protection for distribution equipment
- Type "2" Protection for motor starters
- Only one type of fuse throughout building
- Reduces inventory
- 300,000A interrupting rating
- Help reduce arc flash hazard



Overcurrents and Voltage Ratings

Electrical distribution systems are often quite complicated. They cannot be absolutely fail-safe. Circuits are subject to destructive overcurrents. Harsh environments, general deterioration, accidental damage or damage from natural causes, excessive expansion or overloading of the electrical distribution system are factors which contribute to the occurrence of such overcurrents. Reliable protective devices prevent or minimize costly damage to transformers, conductors, motors, and the other many components and loads that make up the complete distribution system. Reliable circuit protection is essential to avoid the severe monetary losses which can result from power blackouts and prolonged downtime of facilities. It is the need for reliable protection, safety, and freedom from fire hazards that has made the fuse a widely used protective device.



Fuses are constructed in an almost endless variety of configurations. These photos depict Bussmann Low-Peak, Dual-Element, Class RK1 and Low-Peak Class L fuses.

Overcurrents

An overcurrent is either an overload current or a short-circuit current. The overload current is an excessive current relative to normal operating current, but one which is confined to the normal conductive paths provided by the conductors and other components and loads of the distribution system. As the name implies, a short-circuit current is one which flows outside the normal conducting paths.

Overloads

Overloads are most often between one and six times the normal current level. Usually, they are caused by harmless temporary surge currents that occur when motors start up or transformers are energized. Such overload currents, or transients, are normal occurrences. Since they are of brief duration, any temperature rise is trivial and has no harmful effect on the circuit components. (It is important that protective devices do not react to them.)

Continuous overloads can result from defective motors (such as worn motor bearings), overloaded equipment, or too many loads on one circuit. Such sustained overloads are destructive and must be cut off by protective devices before they damage the distribution system or system loads. However, since they are of relatively low magnitude compared to short-circuit currents, removal of the overload current within a few seconds to many minutes will generally prevent equipment damage. A sustained overload current results in overheating of conductors and other components and will cause deterioration of insulation, which may eventually result in severe damage and short-circuits if not interrupted.

Short-Circuits

Whereas overload currents occur at rather modest levels, the short-circuit or fault current can be many hundred times larger than the normal operating current. A high level fault may be 50,000A (or larger). If not cut off within a matter of a few thousandths of a second, damage and destruction can become rampant—there can be severe insulation damage, melting of conductors, vaporization of metal, ionization of gases, arcing, and fires. Simultaneously, high level short-circuit currents can develop huge

magnetic-field stresses. The magnetic forces between bus bars and other conductors can be many hundreds of pounds per linear foot; even heavy bracing may not be adequate to keep them from being warped or distorted beyond repair.

Fuses

The fuse is a reliable overcurrent protective device. A "fusible" link or links encapsulated in a tube and connected to contact terminals comprise the fundamental elements of the basic fuse. Electrical resistance of the link is so low that it simply acts as a conductor. However, when destructive currents occur, the link very quickly melts and opens the circuit to help protect conductors and other circuit components and loads. Modern fuses have stable characteristics. Fuses typically do not require periodic maintenance or testing. Fuses have three unique performance characteristics:

1. Modern fuses have an extremely "high interrupting" rating—can open very high fault currents without rupturing.
2. Properly applied, fuses prevent "blackouts." Only the fuse nearest a fault opens without upstream fuses (feeders or mains) being affected—fuses thus provide "selective coordination." (These terms are precisely defined in subsequent pages.)
3. Modern fuses provide optimum component protection by keeping fault currents to a low value...They are "current-limiting."



Major industrial assembly line circuits are protected with Bussmann Low-Peak fuses.

Voltage Rating - General

This is an extremely important rating for overcurrent protective devices (OCPDs). The proper application of an overcurrent protective device according to its voltage rating requires that the voltage rating of the device be equal to or greater than the system voltage. When an overcurrent protective device is applied beyond its voltage rating, there may not be any initial indicators. Adverse consequences typically result when an improperly voltage rated device attempts to interrupt an overcurrent, at which point it may self-destruct in an unsafe manner. There are two types of OCPD voltage ratings: straight voltage rated and slash voltage rated.

The proper application is straightforward for overcurrent protective devices with a straight voltage rating (i.e.: 600V, 480V, 240V) which have been evaluated for proper performance with full phase-to-phase voltage used during the testing, listing and marking. For instance, all fuses are straight voltage rated and there is no need to be concerned about slash ratings for fuses. Slash voltage rated devices are limited in their applications and extra evaluation is required when they are being considered for use. The next section covers fuse voltage ratings followed by a section on slash voltage ratings for other type devices.

Voltage Ratings and Slash Voltage Ratings



Fuses are a universal protective device. They are used in power distribution systems, electronic apparatus, and vehicles. Renewable energy systems such as solar and wind, utilize fuses to protect vital equipment and circuits.

Voltage Rating-Fuses

Most low voltage power distribution fuses have 250V or 600V ratings (other ratings are 125, 300, and 480 volts). The voltage rating of a fuse must be at least equal to or greater than the circuit voltage. It can be higher but never lower. For instance, a 600V fuse can be used in a 208V circuit. The voltage rating of a fuse is a function of its capability to open a circuit under an overcurrent condition. Specifically, the voltage rating determines the ability of the fuse to suppress the internal arcing that occurs after a fuse link melts and an arc is produced. If a fuse is used with a voltage rating lower than the circuit voltage, arc suppression will be impaired and, under some overcurrent conditions, the fuse may not clear the overcurrent safely. 300V rated fuses can be used to protect single-phase line-to-neutral loads when supplied from three-phase, solidly grounded, 480/277V circuits, where the single-phase line-to-neutral voltage is 277V. This is permissible because in this application, a 300V fuse will not have to interrupt a voltage greater than its 300V rating.

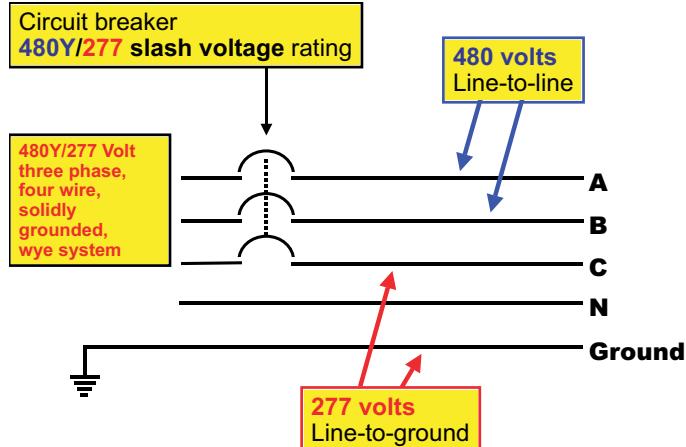
Slash Voltage Ratings

Some multiple-pole, mechanical overcurrent protective devices, such as circuit breakers, self-protected starters, and manual motor controllers, have a slash voltage rating rather than a straight voltage rating. A slash voltage rated overcurrent protective device is one with two voltage ratings separated by a slash and is marked such as 480Y/277V or 480/277V. Contrast this to a straight voltage rated overcurrent protective device that does not have a slash voltage rating limitation, such as 480V. With a slash rated device, the lower of the two ratings is for overcurrents at line-to-ground voltages, intended to be cleared by one pole of the device. The higher of the two ratings is for overcurrents at line-to-line voltages, intended to be cleared by two or three poles of the device.

Slash voltage rated devices are not intended to open phase-to-phase voltages across only one pole. Where it is possible for full phase-to-phase voltage to appear across only one pole, a full or straight rated overcurrent protective device must be utilized. For example, a 480V circuit breaker may have to open an overcurrent at 480V with only one pole, such as might occur when Phase A goes to ground on a 480V, B-phase, corner grounded delta system.

The NEC® addresses slash voltage ratings for circuit breakers in 240.85 restricting their use to solidly grounded systems where the line to ground voltage does not exceed the lower of the two values and the line voltage does not exceed the higher value.

430.83(E) was revised for the 2005 NEC® to address the proper application of motor controllers marked with a slash voltage rating. The words "solidly grounded" were added to emphasize that slash voltage rated devices are not



Proper application of slash rated OCPD.

appropriate for use on corner grounded delta, resistance grounded and ungrounded systems.

Slash voltage rated OCPDs must be utilized only on solidly grounded systems. This automatically eliminates their usage on impedance-grounded and ungrounded systems. They can be properly utilized on solidly grounded, wye systems, where the voltage to ground does not exceed the device's lower voltage rating and the voltage between any two conductors does not exceed the device's higher voltage rating. Slash voltage rated devices cannot be used on corner-grounded delta systems whenever the voltage to ground exceeds the lower of the two ratings. Where slash voltage rated devices will not meet these requirements, straight voltage rated overcurrent protective devices are required.

Overcurrent protective devices that may be slashed rated include, but are not limited to:

- Molded case circuit breakers – UL489
- Manual motor controllers – UL508
- Self protected Type E combination starters – UL508
- Supplementary protectors – UL1077 (Looks like a small circuit breaker and sometimes referred to as mini-breaker. However, these devices are not a circuit breaker, they are not rated for branch circuit protection and can not be a substitute where branch circuit protection is required.)

What about fuses, do they have slash voltage ratings? No, fuses do not have this limitation. Fuses by their design are full voltage rated devices; therefore slash voltage rating concerns are not an issue when using fuses. For instance, Bussmann Low-Peak™ LPJ (Class J) fuses are rated at 600V. These fuses could be utilized on systems of 600V or less, whether the system is solidly grounded, ungrounded, impedance grounded, or corner grounded delta.

If a device has a slash voltage rating limitation, product standards require these devices, to be marked with the rating such as 480Y/277V. If a machine or equipment electrical panel utilizes a slash voltage rated device inside, it is recommended that the equipment nameplate or label designate this slash voltage rating as the equipment voltage rating. UL508A industrial control panels requires the electrical panel voltage marking to be slash rated if one or more devices in the panel are slash voltage rated.

Amp Rating

Every fuse has a specific amp rating. In selecting the amp rating of a fuse, consideration must be given to the type of load and code requirements. The amp rating of a fuse normally should not exceed the current carrying capacity of the circuit. For instance, if a conductor is rated to carry 20A, a 20A fuse is the largest that should be used. However, there are some specific circumstances in which the amp rating is permitted to be greater than the current carrying capacity of the circuit. A typical example is motor circuits; dual-element fuses generally are permitted to be sized up to 175% and non-time-delay fuses up to 300% of the motor full-load amps. As a rule, the amp rating of a fuse and switch combination should be selected at 125% of the continuous load current (this usually corresponds to the circuit capacity, which is also selected at 125% of the load current). There are exceptions, such as when the fuse-switch combination is approved for continuous operation at 100% of its rating.

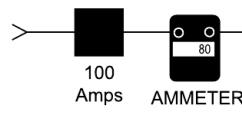
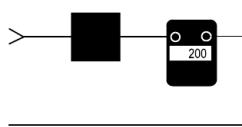
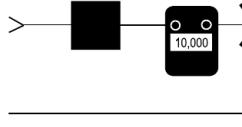
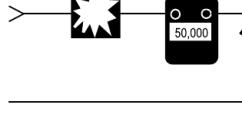


This photograph vividly illustrates the effects of overcurrents on electrical components when protective devices are not sized to the amp rating of the component.

Interrupting Rating

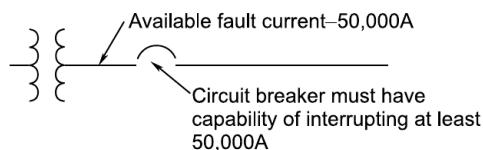
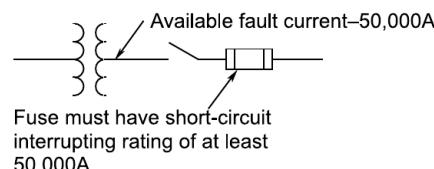
A protective device must be able to withstand the destructive energy of short-circuit currents. If a fault current exceeds a level beyond the capability of the protective device, the device may actually rupture, causing additional damage. Thus, it is important when applying a fuse or circuit breaker to use one which can safely interrupt the largest potential short-circuit currents. The rating which defines the capacity of a protective device to maintain its integrity when reacting to fault currents is termed its "interrupting rating". Most modern, current-limiting fuses have an interrupting rating of 200,000 or 300,000A. The National Electrical Code® 110.9, requires equipment intended to break current at fault levels to have an interrupting rating sufficient for the current that must be interrupted.

The table below depicts four different situations involving an overcurrent device with a normal current rating of 100A and an interrupting rating of 10,000A.

Circuit with Overcurrent Protective Device Current Rating = 100A and Interrupting Rating = 10,000A	Circuit Conditions	Application And Action of Protective Device
OVERCURRENT PROTECTION DEVICE 	Normal	Proper
	Overload Current Greater Than Device's Amp Rating	Proper-Safe Interruption of Current
	Short-Circuit Current Within Device Interrupting Rating	Proper-Safe Interruption of Current
	Short-Circuit Current Exceeds Device Interrupting Rating	Improper: Explosion or Rupture Could Result

In the first three instances above, the circuit current condition is within the safe operating capabilities of the overcurrent protective device. However, the fourth case involves a misapplication of the overcurrent device. A short-circuit on the load side of the device has resulted in a fault current of 50,000A flowing through the overcurrent device. Because the fault current is well above the interrupting rating of the device, a violent rupture of the protective device and resulting damage to equipment or injury to personnel is possible. The use of high interrupting rated fuses (typically rated at 200,000 or 300,000A) would prevent this potentially dangerous situation.

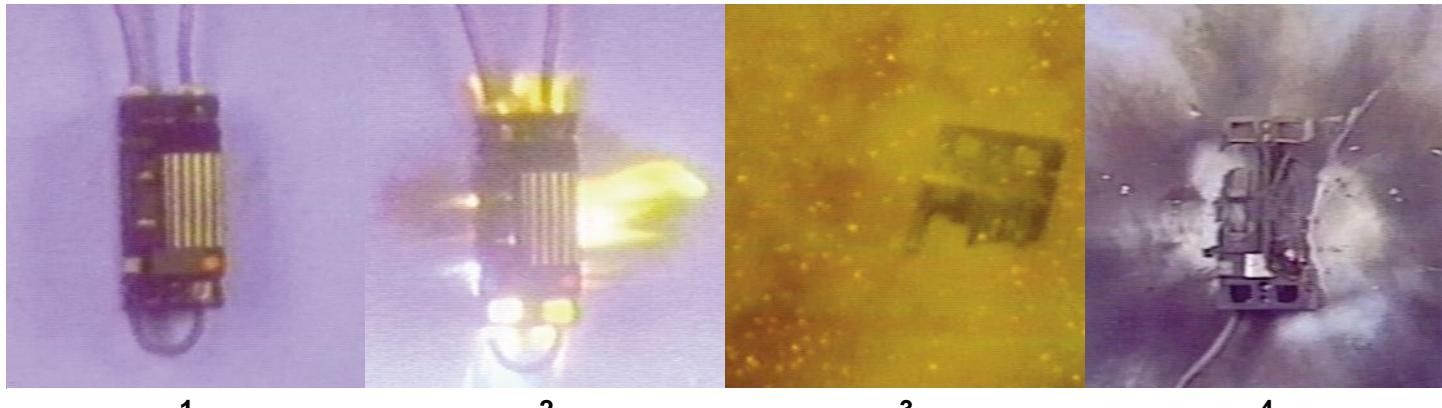
The first paragraph of NEC® 110.9 requires that the overcurrent protective device be capable of interrupting the available fault current at its line terminals.



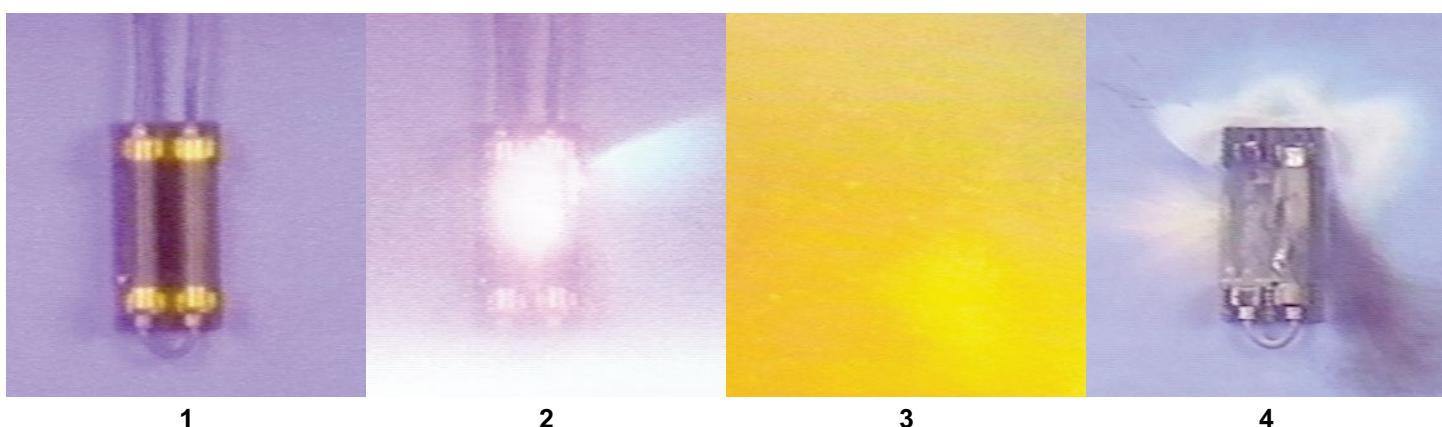
Interrupting Rating

The following series of images from high-speed film demonstrate the destructive power associated with short-circuit currents.

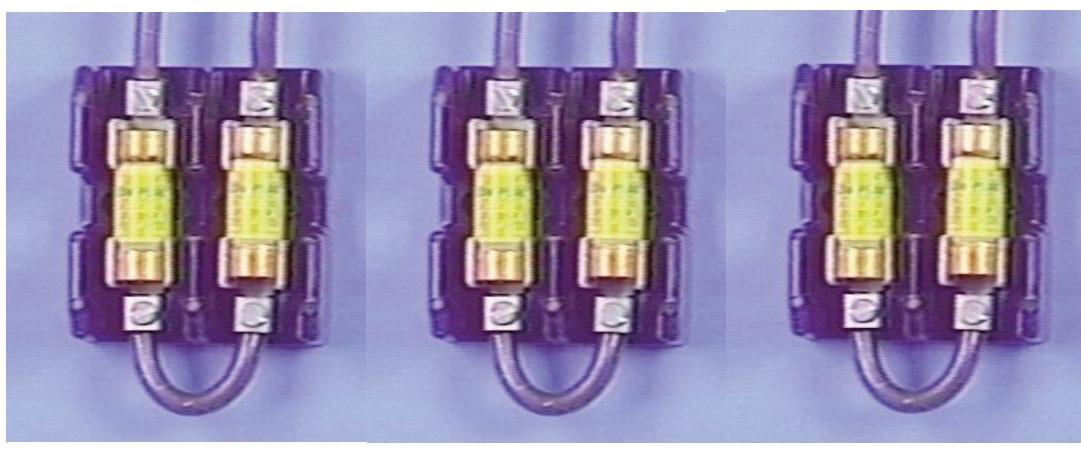
Test 1: This group of photos depicts a test conducted on a 480V circuit breaker. The breaker has an interrupting rating of 14,000A, however, the test circuit was capable of delivering 50,000A of short-circuit current at 480V. The results can be seen below.



Test 2: This group of photos uses the same test circuit as the previous test, however, the test subjects are a pair of 600V, one-time fuses with an interrupting rating of 10,000A. Notice in this test, as well as the circuit breaker test, the large amount of destructive energy released by these devices. Misapplying overcurrent protective devices in this manner is a serious safety hazard as shrapnel and molten metal could strike electricians or maintenance personnel working on equipment, or anyone who happens to be nearby.



Test 3: This group depicts the same test circuit as the previous two tests, which is 50,000A available at 480V. This time the test was performed with modern current-limiting fuses. These happen to be Bussmann Low-Peak fuses with a 300,000A interrupting rating. Notice that the fault was cleared without violence.



Test 1



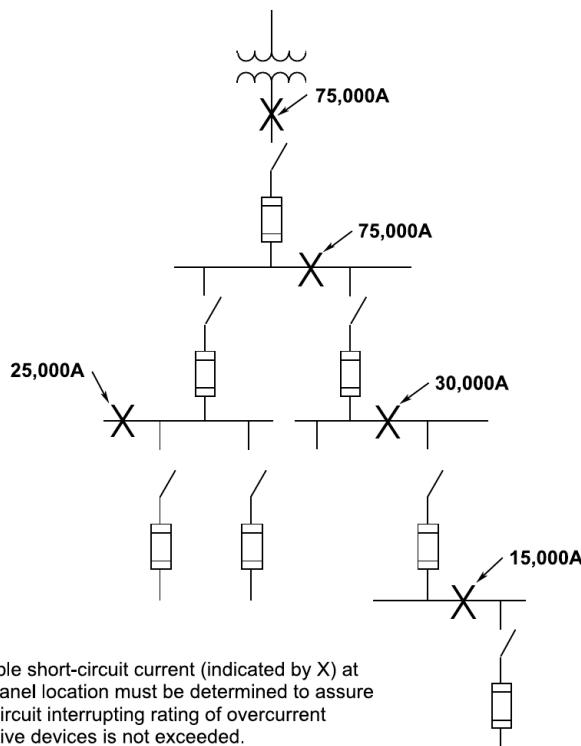
Test 2



Test 3

Interrupting Rating

As depicted in the diagram that follows, it becomes necessary to determine the available short-circuit currents at each location of a protective device. The fault currents in an electrical system can be easily calculated if sufficient information about the electrical system is known. See Short-Circuit Current Calculations – Point-to-Point Calculation Procedure. With modern fuses, these calculations normally are not necessary since the 200,000A or 300,000A interrupting rating is sufficient for most applications.



Interrupting Rating

It is the maximum short-circuit current that an overcurrent protective device can safely interrupt under standard test conditions. The phrase "under standard test conditions" means it is important to know how the overcurrent protective device is tested in order to assure it is properly applied.

Standard Test Conditions - Fuses

Branch circuit fuses are tested without any additional conductor in the test circuit. For instance, if a fuse has an interrupting rating of 300,000A, the test circuit is calibrated to have at least 300,000A at the rated fuse voltage. During the test circuit calibration, a bus bar is used in place of the fuse to verify the proper short-circuit current. Then the bus bar is removed and the fuse is inserted; the test is then conducted. If the fuse passes the test, the fuse is marked with this interrupting rating (300,000A). In the procedures just outlined for fuses, there are no extra conductors inserted into the test circuit after the short-circuit current is calibrated. A major point is that the fuse interrupts an available short-circuit current at least equal to or greater than its marked interrupting rating.

General Fuse Application Data For Compliance With NEC® 110.9

	Guideline	Features	Benefits	Commonly Used Cooper Bussmann Fuse Types
New Installations	1. Use modern, high interrupting rated fuses throughout electrical system.	300,000A interrupting rating, on Low-Peak fuses. 200,000 ampere interrupting rating on other classes of modern current-limiting fuses.	Assures proper interrupting rating compliance currently and future. Usually a short-circuit current calculation study is unnecessary.	All modern current-limiting fuses (most have 200,000A interrupting rating) Low-Peak, Class R, J and L fuses have a 300,000A interrupting rating.
	2. Use current-limiting fuses to protect low withstand rated components.	Correct type and size current-limiting fuse can protect low withstand rated equipment against high short-circuit currents. (See fuse protection of circuit breakers).	Compliance with NEC® 110.10 and 240.86.	Low-Peak Dual-Element T-Tron Fast-Acting Limitorch Fast-Acting CUBEFuse
System Up-Grading	3. Where available fault current has increased or is questionable, replace old style fuses such as One-Time and Renewable with modern high interrupting rated fuses.	200,000A or 300,000A interrupting rating.	Assures compliance with interrupting rating requirements with simple direct retrofit. Easily achieved since older style fuses can physically be replaced with modern fuses with no system modification.	Low-Peak Dual-Element Fusetron Dual-Element Limitorch Fast-Acting
	4. Where existing equipment may have questionable withstand rating due to deterioration, or the available fault current has increased, install modern current-limiting fuses.	Correct type and size current-limiting fuses can be put in switch, cut-in system or sometimes fuses can be cut in bus structure.	Improves the level of short-circuit protection. Small size of CUBEFuse or T-Tron fuse permits easy cut-in strategy.	CUBEFuse, T-Tron Fast-Acting, Low-Peak Dual-Element, Limitorch Fast-Acting, Low-Peak Time-Delay

Single-Pole Interrupting Capability

An overcurrent protective device must have an interrupting rating equal to or greater than the fault current available at its line terminals for both three-phase bolted faults and for one or more phase-to-ground faults (110.9). Although most electrical systems are designed with overcurrent devices having adequate three-phase interrupting ratings, the single-pole interrupting capabilities are easily overlooked. This section will examine single-pole interrupting capability (also referred to as individual pole interrupting capability).

What Are Single-Pole Interrupting Capabilities For Fuses?

By their inherent design a fuse's marked interrupting rating is its single-pole interrupting rating. Per UL/CSA/ANCE 248 Fuse Standards, fuses are tested and evaluated as single-pole devices. Therefore, a fuse's marked interrupting rating is its single-pole interrupting rating. So it is simple, fuses can be applied on single phase or three phase circuits without extra concern for single-pole interrupting capabilities. There is no need to perform any special calculations because of the grounding system utilized. Just be sure the fuses' interrupting ratings are equal to or greater than the available short-circuit currents. Modern current-limiting fuses are available with tested and marked single-pole interrupting ratings of 200,000 or 300,000A. Low-Peak LPJ_SP, KRP-C_SP, LPS-RK_SP and LPN-RK_SP fuses all have UL Listed 300,000A single-pole interrupting ratings. This is a simple solution to assure adequate interrupting ratings for present and future systems no matter what the grounding scheme. Review the three drawings for a fusible, high impedance grounded system.

High Impedance Grounded System

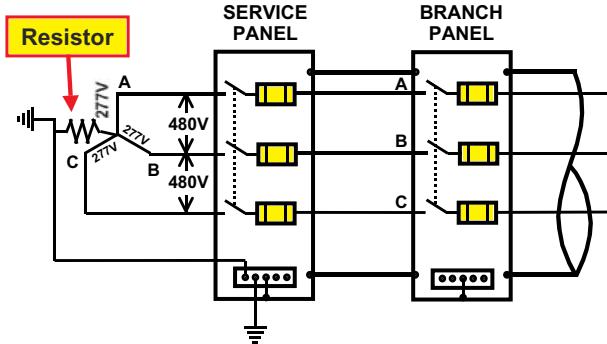


Figure 1. Fusible high impedance grounded system.

High Impedance Grounded System

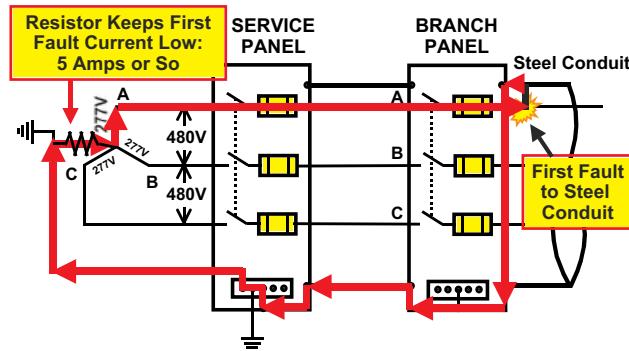


Figure 2. Upon first fault, the fault current is low due to resistor. As intended the fuse does not open.

High Impedance Grounded System

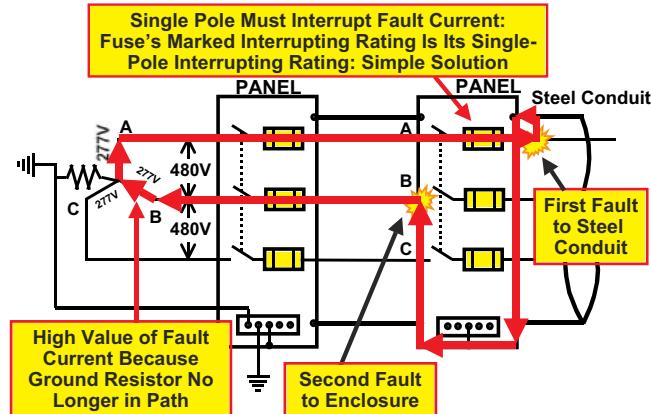


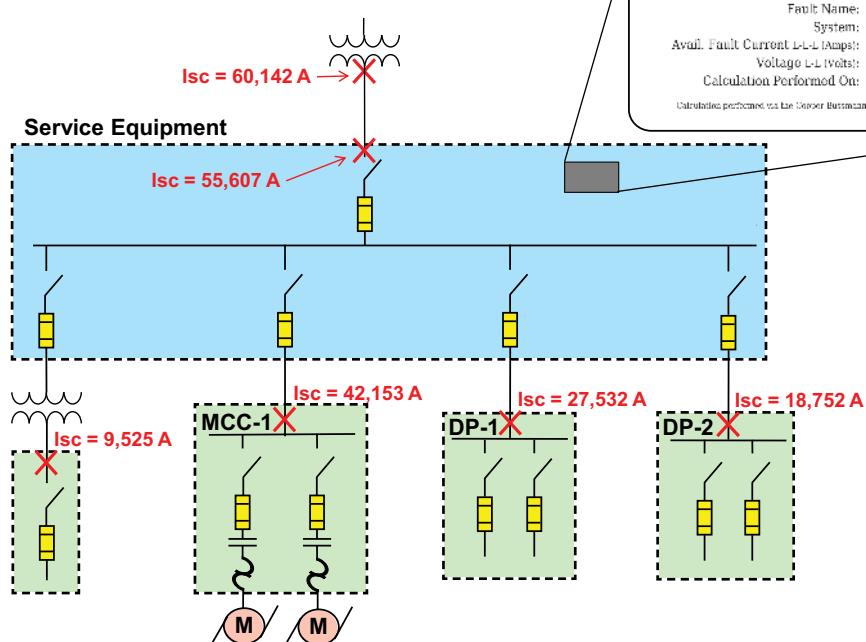
Figure 3. Upon the second fault, the fault is essentially a line-line fault with the impedance of the conductors and the ground path. The fuse must interrupt this fault. Since a fuse's interrupting rating is the same as its single-pole interrupting capability, modern fuses with 200,000A or 300,000A interrupting rating can be applied without further analysis for single pole interrupting capabilities.

110.24 Field Marking Available Fault Current

Section 110.24 requires that service equipment, in other than dwelling units, be field marked with the maximum available short-circuit current and the date that the calculation was performed or determined, and in addition, it is required that updates be made to the marking whenever modifications are made to the system that result in changes to the maximum available short-circuit current. This requirement was added to assure compliance with interrupting rating (110.9) and short-circuit current ratings (110.10) and in addition, for situations where the maximum available short-circuit current increases due to an increase in the size of the service transformer or where the impedance of the service transformer is reduced. All too frequently, a service transformer is "changed out" without attention being paid to changes in the maximum available short-circuit current. Assuming the service equipment is installed originally with adequate interrupting rating (110.9) and short-circuit current rating (110.10), a change to the service transformer often means that the equipment is no longer adequately rated, violating one of, or both, 110.9 and 110.10. At that point, it is a serious safety hazard.

The one-line diagram below shows a transformer capable of delivering a maximum of 60,142 amperes at its terminals and 55,607 amperes at the service equipment terminals. A field marking, showing the 55,607 maximum available short-circuit amperes and the date determined (9/25/2013) is then attached to meet the 110.24 requirement.

Note that the required label is for equipment interrupting rating and short-circuit current rating purposes (110.9 & 110.10). Equipment that is tested and marked with short-circuit current ratings that is adequate for the maximum available short-circuit current will still work properly at lower available short-circuit current.



For 110.24 calculations and labeling, use FC² Available Fault Current Calculator for three-phase and single-phase systems. This is a quick, easy method to determine available fault current at one or multiple points in an electrical distribution system. Scan QR Code to download app for Apple and Android mobile devices. Access a web-based version at HYPERLINK "<http://www.cooperbussmann.com/fc2>" www.cooperbussmann.com/fc2.

For complying with 110.9 and 110.10, the maximum available short-circuit current can be calculated conservatively such as using infinite available for the primary of the service transformer or omitting the service conductor impedance. As long as the overcurrent protective devices and service equipment have sufficient interrupting rating and short-circuit current rating, respectively, a conservative calculation is permitted.

For NFPA 70E 130.5 Arc Flash Hazard Analysis a conservative method of calculating the maximum available short-circuit current is permissible when verifying whether the available short-circuit current does not exceed the parameter value in Table 130.7(C)(15)(a), if desiring to use the HRC or "Table Method". However, if using the incident energy calculation method to comply with NFPA 70E 130.5 Arc Flash Hazard Analysis, the available short-circuit calculation should be determined as accurately as possible.

The exception to 110.24 means that the marking requirements do not apply to industrial installations where conditions of maintenance and supervision assure that only qualified personnel work on the equipment.

Finally, even though 110.24 only requires marking of the available fault current for the service equipment, all the equipment shown in the one-line diagram must meet the requirements of 110.9 and 110.10, at all times. So, for example, the interrupting ratings and short-circuit current ratings of the equipment in MCC-1 must be at least 42,153 amperes, while the interrupting ratings and short-circuit current ratings of the equipment in DP-2 must be at least 18,752 amperes.

Field Mark per NEC® 110.24

FC ² available fault current calculator	
Project Name:	Rastgate
Fault Name:	Service Equipment
System:	Three-Phase
Aval. Fault Current L-L-L (Amps):	55,607
Voltage L-L (Volts):	480
Calculation Performed On:	Sep 25, 2013 @ 11:02am
Calculated performed via the Cooper Bussmann Available Fault Current Calculator v1.0	

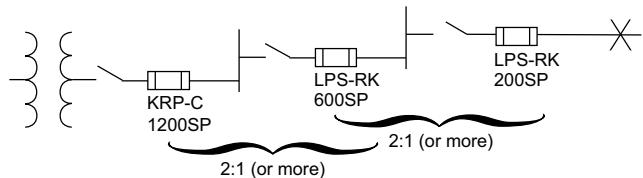


FC² | available fault current calculator

Selective Coordination & Current Limitation

Selective Coordination — Prevention of Blackouts

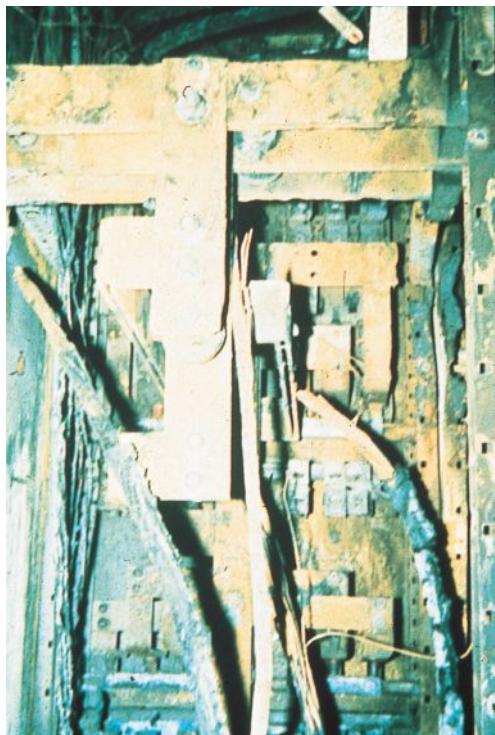
The coordination of protective devices prevents system power outages or blackouts caused by overcurrent conditions. When only the protective device nearest a faulted circuit opens and larger upstream fuses remain closed, the protective devices are "selectively" coordinated (they discriminate). The word "selective" is used to denote total coordination...isolation of a faulted circuit by the opening of only the localized protective device.



This diagram shows the minimum ratios of amp ratings of Low-Peak fuses that are required to provide "selective coordination" (discrimination) of upstream and downstream fuses.

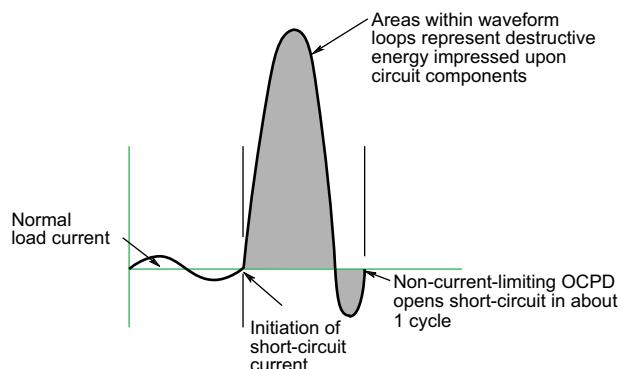
It's a simple matter to selectively coordinate fuses of modern design. By maintaining a minimum ratio of fuse-amp ratings between an upstream and downstream fuse, selective coordination is achieved. Minimum selectivity ratios for Bussmann fuses are presented in the Fuse Selectivity Ratio Guide in Selective Coordination.

This book has an indepth discussion on coordination. See Selective Coordination.

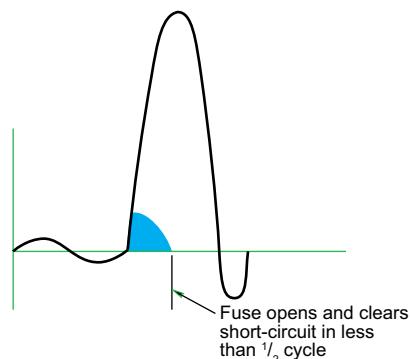


This burnt-out switchboard represents the staggering monetary losses in equipment and facility downtime that can result from inadequate or deteriorated protective devices. It emphasizes the need for reliable protective devices that properly function without progressive deterioration over time.

Current-Limitation — Component Protection



A non-current-limiting protective device, by permitting a short-circuit current to build up to its full value, can let an immense amount of destructive short-circuit heat and magnetic energy through before opening the circuit.



In its current-limiting range, a current-limiting fuse has such a high speed of response that it cuts off a short-circuit long before it can build up to its full peak value.

If a protective device cuts off a short-circuit current in less than one-half cycle, before it reaches its total available (and highly destructive) value, the device limits the current. Many modern fuses are current-limiting. They restrict fault currents to such low values that a high degree of protection is given to circuit components against even very high short-circuit currents. They can reduce bracing of bus structures. They minimize the need of other components to have high short-circuit current "withstand" ratings. If not limited, short-circuit currents can reach levels of 30,000 or 40,000A or higher (even above 200,000A) in the first half cycle (0.008 seconds, 60Hz) after the start of a short-circuit. The heat that can be produced in circuit components by the immense energy of short-circuit currents can cause insulation damage or violent explosion of conductors. At the same time, huge magnetic forces developed between conductors can crack insulators and distort and destroy bracing structures. Thus, it is important that a protective device limit fault currents before they reach their full potential level.

See Component Protection – Introduction and Current Limitation and How to Use Current Limitation Charts.

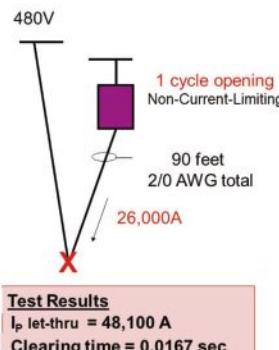
Current-Limitation Lab Tests Demonstrations

Short-circuit current flowing through wires and electrical equipment can create magnetic fields that result in powerful mechanical forces being exerted. During high fault conditions these mechanical forces can damage electrical equipment. If the mechanical forces exceed an electrical component's withstand, the electrical component can violently rupture. Current-limitation can reduce the mechanical forces exerted on electrical equipment and prevent damage. The maximum mechanical force exerted on the electrical equipment is proportional to the square of the instantaneous peak current (I_p^2) due to the fault current flow.

Test A and B are the same except Test B utilizes a 200-A current-limiting OCPD. Both tests are at 480 volts, with a total of 90' of 2/0 AWG conductor placed on the test lab floor. The fault current that flowed through the 2/0 conductor during a calibration test was an asymmetrical current with an approximately 26,000 symmetrical RMS ampere component. View the test videos utilizing the QR tags.

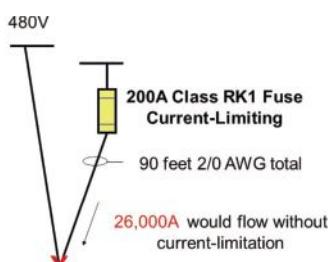


Test A: One Cycle Interrupting Time – Non-Current-Limiting



Video of Test A

Test B: 200-A Current-Limiting OCPD



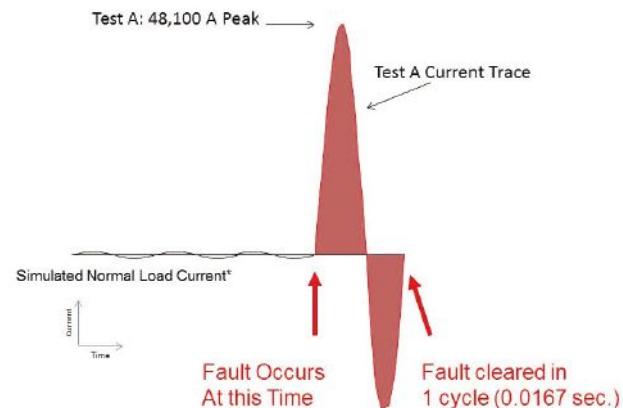
Video of Test B

Conductor whip results for Test A vs. Test B: reduction in energy let-thru by 200A current-limiting fuse vs. one-cycle non-current-limitation. **Reduction of the maximum mechanical force exerted on electrical equipment** is directly proportional to the instantaneous peak current squared (I_p^2) let-through.

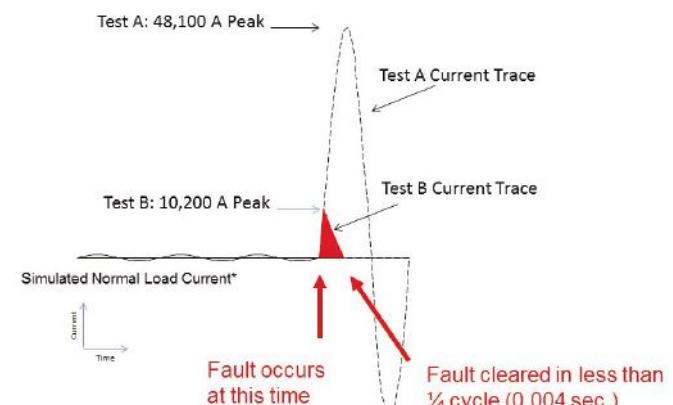
Current-limitation reduces the maximum mechanical force let-thru:

$$(10,200 / 48,100)^2 \approx 1/22$$

This is over a 95% reduction in mechanical force exerted on the conductor.



Test A current trace illustrates normal current until the fault occurs and then the fault current attains a peak let-through of 48,100 A and flows for one cycle.



Test B current trace illustrates normal current until the fault occurs and then the fault current is limited by the current-limiting operation of the LPS-RK200SP fuse. The fuse limits the instantaneous peak current to only 10,200A and clears in approximately 1/4 of a cycle.

Thermal Energy

RMS current flow creates thermal energy in electrical conductive parts and equipment. Excessively high short-circuit current flow for an excessive time duration can degrade the electrical insulation properties or the conductive metal can be annealed, melted, or explosively vaporized. For simplicity, this section does not provide the measurement parameter to assess the thermal energy let-through for these tests. However, the recording instrumentation documented that Test B let-through 1/123 the thermal energy compared to the let-through conditions of Test B.

Non Time-Delay Fuse Operation

The principles of operation of the modern, current-limiting Bussmann fuses are covered in the following paragraphs.

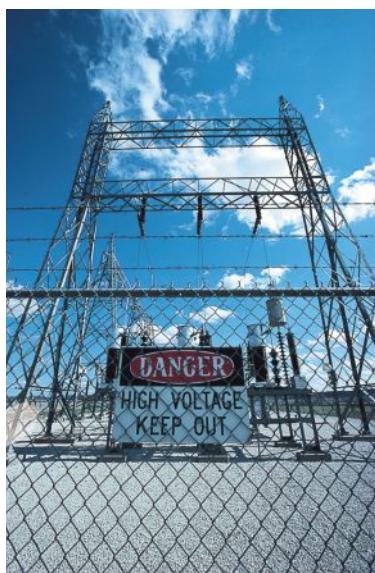
Non-Time-Delay Fuses

The basic component of a fuse is the link. Depending upon the amp rating of the fuse, the single-element fuse may have one or more links. They are electrically connected to the end blades (or ferrules) (see Figure 1) and enclosed in a tube or cartridge surrounded by an arc quenching filler material. Bussmann Limitron™ and T-Tron™ fuses are both single-element fuses.

Under normal operation, when the fuse is operating at or near its amp rating, it simply functions as a conductor. However, as illustrated in Figure 2, if an overload current occurs and persists for more than a short interval of time, the temperature of the link eventually reaches a level that causes a restricted segment of the link to melt. As a result, a gap is formed and an electric arc is established. However, as the arc causes the link metal to burn back, the gap becomes progressively larger. Electrical resistance of the arc eventually reaches such a high level that the arc cannot be sustained and is extinguished. The fuse will have then completely cut off all current flow in the circuit. Suppression or quenching of the arc is accelerated by the filler material.

Single-element fuses of present day design have a very high speed of response to overcurrents. They provide excellent short-circuit component protection. However, temporary, harmless overloads or surge currents may cause nuisance openings unless these fuses are oversized. They are best used, therefore, in circuits not subject to heavy transient surge currents and the temporary overload of circuits with inductive loads such as motors, transformers, solenoids, etc.

Whereas an overload current normally falls between one and six times normal current, short-circuit currents are quite high. The fuse may be subjected to short-circuit currents of 30,000 or 40,000A or higher. Response of current-limiting fuses to such currents is extremely fast. The restricted sections of the fuse link will simultaneously melt (within a matter of two or three-thousandths of a second in the event of a high-level fault current).



With continued growth in electrical power generation, the higher levels of short-circuit currents made available at points of consumption by electrical utilities have greatly increased the need for protective devices with high short-circuit interrupting ratings. The trend is lower impedance transformers due to better efficiencies, lower costs, and improved voltage regulation. Utilities routinely replace transformers serving customers. These transformers can have larger kVA ratings and/or lower impedance, which results in higher available short-circuit currents. Devices that can interrupt only moderate levels of short-circuit currents are being replaced by modern fuses having the ability to cut-off short-circuit currents at levels up to 300,000 amps.

The high total resistance of the multiple arcs, together with the quenching effects of the filler particles, results in rapid arc suppression and clearing of the circuit. (Refer to Figures 4 & 5) Short-circuit current is cut off in less than a quarter-cycle, long before the short-circuit current can reach its full value (fuse operating in its current-limiting range).



Figure 1. Cutaway view of typical single-element fuse.



Figure 2. Under sustained overload, a section of the link melts and an arc is established.



Figure 3. The "open" single-element fuse after opening a circuit overload.



Figure 4. When subjected to a short-circuit current, several sections of the fuse link melt almost instantly.



Figure 5. The "open" single-element fuse after opening a shorted circuit.

Dual-Element, Time-Delay Fuse Operation

There are many advantages to using these fuses. Unlike single-element fuses, the Bussmann dual-element, time-delay fuses can be sized closer to provide both high performance short-circuit protection and reliable overload protection in circuits subject to temporary overloads and surge currents. For AC motor loads, a single-element fuse may need to be sized at 300% of an AC motor current in order to hold the starting current. However, dual-element, time-delay fuses can be sized much closer to motor loads. For instance, it is generally possible to size Fusetron dual-element fuses, FRS-R and FRN-R and Low-Peak dual-element fuses, LPS-RK_SP and LPN-RK_SP, at 125% and 130% of motor full load current, respectively. Generally, the Low-Peak dual-element fuses, LPJ_SP, and CUBEFuse™, TCF, can be sized at 150% of motor full load amps. This closer fuse sizing may provide many advantages such as: (1) smaller fuse and block, holder or disconnect amp rating and physical size, (2) lower cost due to lower amp rated devices and possibly smaller required panel space, (3) better short-circuit protection – less short-circuit current let-through energy, and (4) potential reduction in the arc flash hazard.

When the short-circuit current is in the current-limiting range of a fuse, it is not possible for the full available short-circuit current to flow through the fuse – it's a matter of physics. The small restricted portions of the short-circuit element quickly vaporize and the filler material assists in forcing the current to zero. The fuse is able to "limit" the short-circuit current.

Overcurrent protection must be reliable and sure. Whether it is the first day of the electrical system or years later, it is important that overcurrent protective devices perform under overload or short-circuit conditions as intended. Modern current-limiting fuses operate by very simple, reliable principles.



Figure 6. This is the LPS-RK100SP, a 100A, 600V Low-Peak, Class RK1, dual-element fuse that has excellent time-delay, excellent current-limitation and a 300,000A interrupting rating. Artistic liberty is taken to illustrate the internal portion of this fuse. The real fuse has a non-transparent tube and special small granular, arc-quenching material completely filling the internal space.

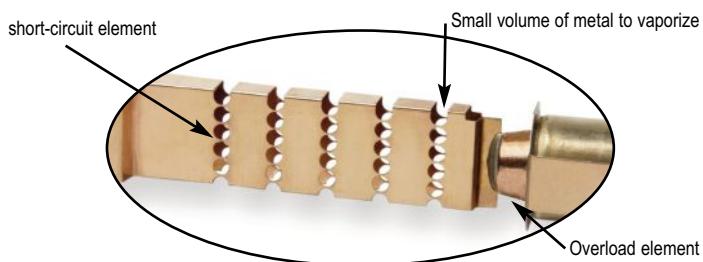


Figure 7. The true dual-element fuse has a distinct and separate overload element and short-circuit element.

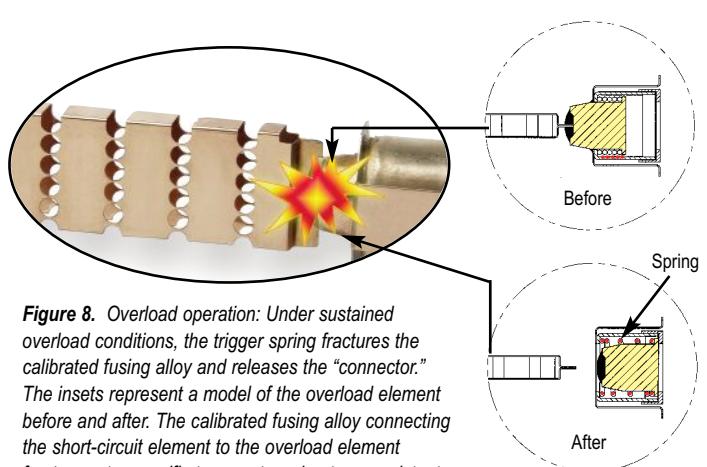


Figure 8. Overload operation: Under sustained overload conditions, the trigger spring fractures the calibrated fusing alloy and releases the "connector." The insets represent a model of the overload element before and after. The calibrated fusing alloy connecting the short-circuit element to the overload element fractures at a specific temperature due to a persistent overload current. The coiled spring pushes the connector from the short-circuit element and the circuit is interrupted.

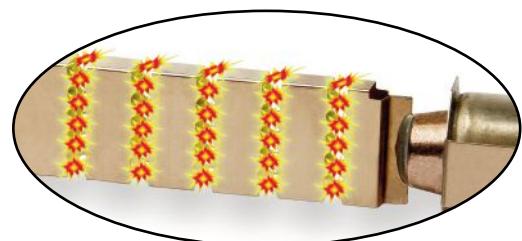


Figure 9. short-circuit operation: Modern fuses are designed with minimum metal in the restricted portions which greatly enhance their ability to have excellent current-limiting characteristics – minimizing the short-circuit let-through current. A short-circuit current causes the restricted portions of the short-circuit element to vaporize and arcing commences. The arcs burn back the element at the points of the arcing. Longer arcs result, which assist in reducing the current. Also, the special arc quenching filler material contributes to extinguishing the arcing current. Modern fuses have many restricted portions, which results in many small arclets – all working together to force the current to zero.

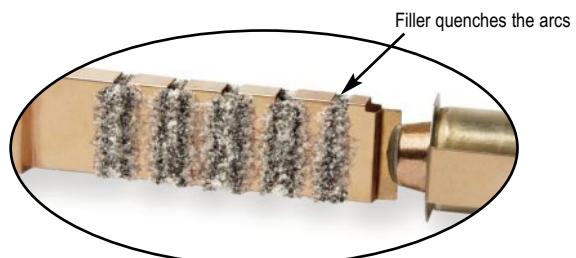


Figure 10. short-circuit operation: The special small granular, arc-quenching material plays an important part in the interruption process. The filler assists in quenching the arcs; the filler material absorbs the thermal energy of the arcs, fuses together and creates an insulating barrier. This process helps in forcing the current to zero. Modern current-limiting fuses, under short-circuit conditions, can force the current to zero and complete the interruption within a few thousandths of a second.

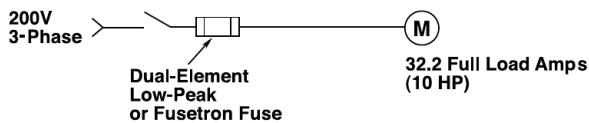
Dual-Element Fuse Benefits



Advantages of Bussmann Dual-Element, Time-Delay Fuses

Bussmann dual-element, time-delay fuses have four distinct advantages over single-element, non-time-delay fuses:

1. Provide motor overload or back-up overload, ground fault and short-circuit protection.
2. Permit the use of smaller and less costly switches.
3. Give a higher degree of short-circuit protection (greater current limitation) in circuits in which surge currents or temporary overloads occur.
4. Simplify and improve blackout prevention (selective coordination).



Motor Overload and short-circuit Protection

When used in circuits with surge currents such as those caused by motors, transformers, and other inductive components, the Bussmann Low-Peak and Fusetron dual-element, time-delay fuses can be sized close to full-load amps to give maximum overcurrent protection. Sized properly, they will hold until surges and normal, temporary overloads subside. Take, for example, a 10 HP, 200 volt, 1.15 service factor, three-phase motor with a full-load current rating of 32.2A.

Fuse and Switch Sizing for 10 HP Motor (200V, 3Ø, 32.2 FLA)

*Fuse Type	Maximum Fuse Size (Amps)	Required Switch Size (Amps)
Dual-Element, Time-Delay Fusetron FRS-R or FRN-R	40A*	60A
Single-Element, Non-Time-Delay (Limitor)	100A†	100A

*Per NEC® 430.32.

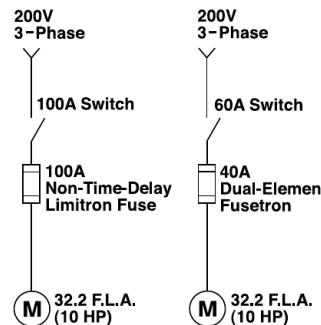
†Per NEC® 430.52.

The preceding table shows that a 40A, dual-element fuse will protect the 32.2A motor, compared to the much larger, 100A, single-element fuse that would be necessary. It is apparent that if a sustained, harmful overload of 200% occurred in the motor circuit, the 100A, single-element fuse would never open and the motor could be damaged. The non-time-delay fuse, thus, only provides ground fault and short-circuit protection, requiring separate overload

protection per the NEC®. In contrast, the 40A dual-element fuse provides ground fault, short-circuit and overload protection. The motor would be protected against overloads due to stalling, overloading, worn bearings, improper voltage, single-phasing, etc.

In normal installations, Bussmann dual-element fuses of motor-running, overload protection size, provide better short-circuit protection plus a high degree of back up protection against motor burnout from overload or single-phasing should other overload protective devices fail. If thermal overloads, relays, or contacts should fail to operate, the dual-element fuses will act independently and thus provide "back-up" protection for the motor.

When secondary single-phasing occurs, the current in the remaining phases increases to a value of 173% to 200% of rated full-load current. When primary single-phasing occurs, unbalanced voltages that occur in the motor circuit also cause excessive current. Dual-element fuses sized for motor overload protection can help protect motors against the overload damage caused by single-phasing. See the section "Motor Protection–Voltage Unbalance/Single-Phasing" for discussion of motor operation during single-phasing.



Permit the Use of Smaller and Less Costly Switches

Aside from only providing short-circuit protection, the single-element fuse also makes it necessary to use larger size switches since a switch rating must be equal to or larger than the amp rating of the fuse. As a result, the larger switch may cost two or three times more than would be necessary were a dual-element Low-Peak or Fusetron fuse used. The larger, single-element fuse itself could generate an additional cost. Again, the smaller size switch that can be used with a dual-element fuse saves space and money. (Note: where larger switches already are installed, fuse reducers can be used so that fuses can be sized for motor overload or back-up protection.)

Better short-circuit Component Protection (Current-Limitation)

The non-time-delay, fast-acting fuse must be oversized in circuits in which surge or temporary overload currents occur. Response of the oversized fuse to short-circuit currents is slower than the smaller time-delay fuse. Current builds up to a higher level before the fuse opens...the current-limiting action of the oversized fuse is thus less than a fuse whose amp rating is closer to the normal full-load current of the circuit. Therefore, oversizing sacrifices component protection.

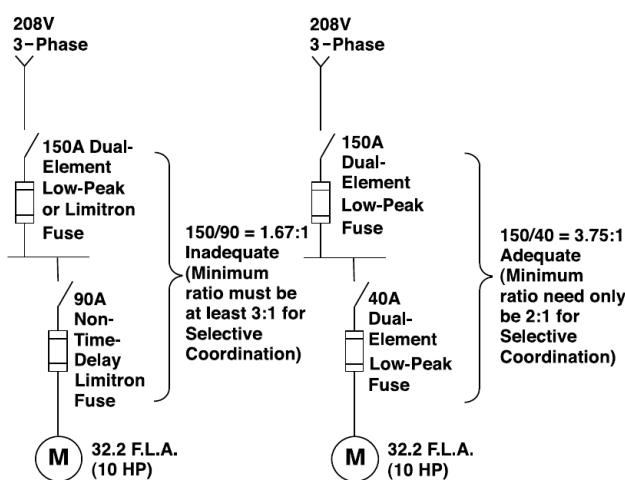
Dual-Element Fuse Benefits

Current-Limitation of Dual-Element Fuses Versus Non-Time-Delay Fuses Used to Protect 10 HP Motor (32.2 FLA).

Fuse Type	Fuse	Let-Through Current Versus Prospective Short-Circuit Currents (RMS Symmetrical)		
		25,000A	50,000A	100,000A
Dual-Element (40A)	Fusetron	2000A	3300A	4400A
	Low-Peak	1800A	2200A	3000A
Non-Time-Delay (100A)	Limitron	3100A	4100A	5000A

Better Selective Coordination (Blackout Prevention)

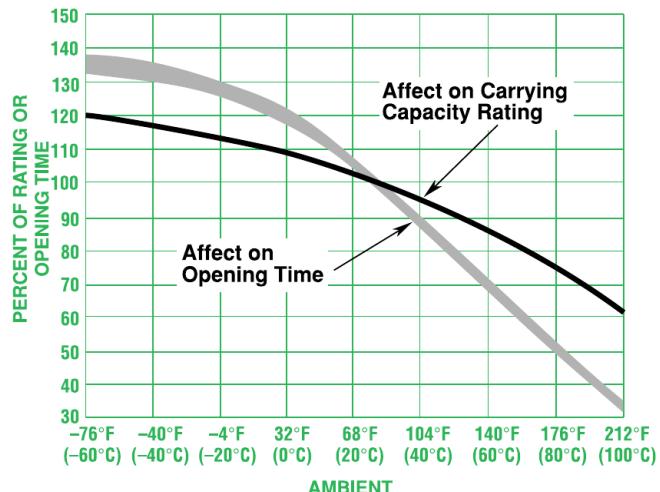
The larger an upstream fuse is relative to a downstream fuse (for example, feeder to branch), the less possibility there is of an overcurrent in the downstream circuit causing both fuses to open (lack of selective coordination). Fast-acting, non-time-delay fuses require at least a 3:1 ratio between the amp rating of a large upstream, line-side Low-Peak time-delay fuse and that of the downstream, loadside Limitron fuse in order to be selectively coordinated. In contrast, the minimum selective coordination ratio necessary for Low-Peak dual-element fuses is only 2:1 when used with Low-Peak loadside fuses.



The use of time-delay, dual-element fuses affords easy selective coordination—coordination hardly requires anything more than a routine check of a tabulation of required selectivity ratios. As shown in the preceding illustration, close sizing of Bussmann dual-element fuses in the branch circuit for motor overload protection provides a large difference (ratio) in the amp ratings between the feeder fuse and the branch fuse, compared to the single-element, non-time-delay Limitron fuse.

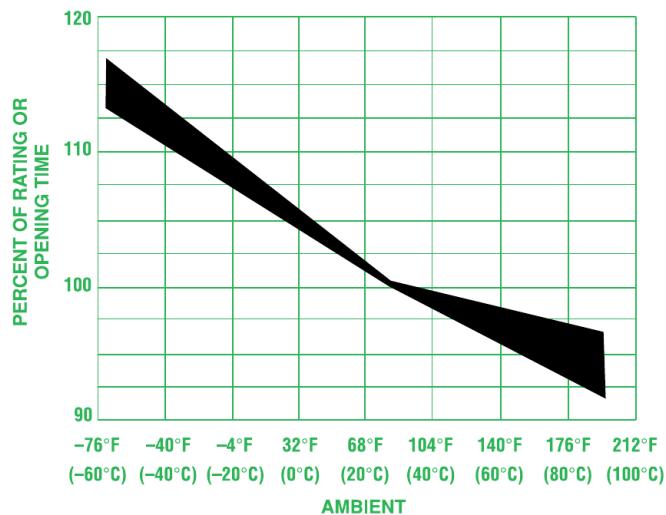
Better Motor Protection in Elevated Ambients

The derating of dual-element fuses based on increased ambient temperatures closely parallels the derating curve of motors in an elevated ambient. This unique feature allows for optimum protection of motors, even in high temperatures.



Affect of ambient temperature on operating characteristics of Fusetron and Low-Peak dual-element fuses.

Below is a rerating chart for single element fuses or non dual element fuses.



Ambient affect chart for non-dual-element fuses.

Branch-Circuit & Application Limited OCPDs

Branch-Circuit OCPDs & Application Limited OCPDs

In most cases, branch circuit overcurrent protective devices (OCPD) are the only type of overcurrent protective devices permitted to be used to protect electrical building system mains, feeders and branch circuits, and in utilization equipment mains, feeders and branch circuits. Yet, too often OCPDs which are not branch circuit rated are misapplied where a branch circuit rated OCPD is required. However, the "branch circuit overcurrent protective device" term can be difficult to grasp due to the multiple ways the electrical industry uses the phrase "branch circuit", and since most manufacturers do not identify their overcurrent protective devices with the specific wording "branch circuit overcurrent protective device."

Not using a branch circuit OCPD where required could result in potentially serious electrical safety hazards to people or damage to property. In addition National Electrical Code violations could be tagged by the authority having jurisdiction (AHJ), resulting in project delays and unplanned costs.

There are three types of overcurrent protective devices discussed in this section:

1. **Branch circuit overcurrent protective devices:** can be used for protection of the entire circuit on a main, feeder or branch of an electrical system
2. Application limited: the **device is suitable for specific branch circuit applications under limited conditions per the NEC®** (often listed or recognized for the specific use)
3. Application limited: **supplementary protective device** (cannot be used for branch circuit applications under most circumstances)

NEC® Article 100 offers the following definition for a branch circuit overcurrent device:

Overcurrent Protective Device, Branch-Circuit. A device capable of providing protection for service, feeder, and branch-circuits and equipment over the full-range of overcurrents between its rated current and its interrupting rating. Such devices are provided with interrupting ratings appropriate for the intended use but no less than 5,000 amperes.

With the definition, it becomes clear that a branch circuit overcurrent protective device is suitable for use at any point in the electrical system to protect branch circuits, as well as feeder circuits and mains. The definition also illustrates that a branch circuit overcurrent device must be capable of protecting against the

full range of overcurrents which includes overloads and short-circuits as well as have an interrupting rating sufficient for the application (this reflects the interrupting rating requirements of 110.9). In addition to the traits described in the definition, branch circuit overcurrent devices meet minimum common standardized requirements for spacings and operating time-current characteristics.

Table 1
Acceptable Branch Circuit Overcurrent Protective Device Types

Device Type	Acceptable Devices	Bussmann Branch Circuit Fuses
UL 248 Fuses	Class J Fuse	LPJ, SP, JKS, DFJ
	Class CF Fuse	TCF, PVCF, FCF
	Class RK1 Fuse	LPN-RK_SP, LPS-RK_SP KTN-R, KTS-R
	Class RK5 Fuse	FRN-R, FRS-R
	Class T Fuse	JJN, JJS
	Class CC Fuse	LP-CC, KTK-R, FNQ-R
	Class L Fuse	KRP-C_SP, KLU, KTU
	Class G Fuse	SC
	Class K5 Fuse	NON, NOS (0-60A)
	Class H Fuse	NON, NOS (61-600A)
UL 489	Molded Case CBs	
Circuit Breakers UL 1066 Circuit Breakers	Insulated Case CBs Low Voltage Power CBs	

Table 2

Fuse Safety System					
Fuse Safety System per Product Standards	Equipment Has Fuse Mounting for UL Fuse Class Below	Rejects Replacement of Other UL Fuse Fuse Classes*	Rejects Replacement of Lower Voltage Rated Fuses	Rejects Replacement of Fuses with Lower Interrupting Rating (200kA or Less)	Rejects Replacement of Fuse Classes with Greater Short-Circuit Energy Let Through
L, J, CC, T, G, CF	Yes	Yes	Yes	Yes	Yes
Class R (RK1 and RK5)	Yes	Yes	Yes	Yes	Yes

*For instance, only Class J fuses can be inserted in Class J fuse mounting.

Branch-Circuit & Application Limited OCPDs

Listed Branch Circuit Fuses: Current-Limiting

UL248 Standards cover distinct classes of low-voltage (600 volts or less) fuses. Of these, modern current-limiting fuse Classes J, CC, L, R, T, CF and G are the most important. The rejection feature of current-limiting fuses ensures a safety system for the life of the electrical system. Listed current-limiting fuses have physical size rejection features that help prevent installation of fuses that cannot provide a comparable minimum level of protection for critical ratings and performance. This is inherent in all current-limiting fuse classes. Each fuse class found in Table 1 on page 20 has certain criteria that must be met. These include

1. Maximum let-through limits (I_p and I^2t) during fault conditions
2. Minimum voltage ratings
3. Minimum interrupting ratings (200kA for Class J, T, R, CC and L) (300kA for Class CF)
4. Physical rejection of larger fuse amperages*
5. Physical rejection of non-current limiting fuses

*Amperages greater than fuse holder rating (i.e. 30A fuse holder will not accept 35A fuse)

By meeting these product standard requirements, the fuse industry provides branch circuit fuses that ensure a minimum specific level of circuit protection, when current-limiting fuses and equipment are used. Using a given fuse class will secure the voltage rating, interrupting rating and degree of current limitation for the life of the electrical system. This can be thought of as a "safety system" since the physical mounting configuration only permits the same specific fuse class to be installed. Each class of current-limiting fuses has its own unique physical dimensions so that fuses of a different class are not interchangeable. For instance, Class R fuses cannot be installed in Class J fuse equipment. Modern Class J, CC, L, R, T, CF, and G fuse equipment rejects the installation of any other fuse class. Class R has two categories: Class RK5 and RK1 which are interchangeable, but no other fuse class can be installed. Class H, an older style fuse class, is not considered current-limiting and is not recommended for new installations. Class R fuses can be installed in Class H fuse equipment as an upgrade. However, Class H fuses cannot be installed in Class R fuse equipment. Class R equipment physically rejects the installation of Class H fuses.



The illustration above shows Class R type fuse rejection clips, which accept only the Class R rejection type fuses.

Here is an example of how simple it is: use Class J fuses and equipment, and only Class J fuses can be installed. This ensures the voltage rating is 600V (whether the system is 120, 208, 480, or 575V), the interrupting rating is at least 200kA, and the short-circuit protection is provided by the current-limiting let-through characteristics of the Class J. If the fuse has to be replaced, only a Class J fuse physically fits into the equipment.



Branch-Circuit & Application Limited OCPDs

Application Limited OCPDs

The preceding paragraphs covered branch circuit fuses. There are two other categories to be considered:

(1) Permitted for specific branch circuit applications under limited conditions per the specific reference in the NEC®: These OCPDs have some limitation(s) and are not true branch circuit devices, but may be permitted, if qualified for the use in question. For example, most high speed fuses are not branch circuit OCPDs, however high speed fuses are allowed to be used for short-circuit protection on motor circuits utilizing power electronic devices by 430.52(C)(5). Motor Circuit Protectors (MCPs) are recognized devices (not listed) and can be used to provide short-circuit protection for motor branch circuits, if used in combination with a listed combination starter with which the MCP has been tested and found acceptable [per 430.52(C)(3)]. Self protected starters are another application limited OCPD; they are listed only for use as protection of motor branch circuits. These examples are only suitable for use on motor branch circuits; they cannot be used on other branch circuit types or for main or feeder protection. When considering the use of application specific devices, special attention must be paid to the circuit type/application, NEC® requirements, and the device's product listing or recognition. In other words, these types of overcurrent devices are only acceptable for use under special conditions.

(2) Supplementary overcurrent protective devices: These devices have limited applications and must always be in compliance with 240.10

240.10 Supplementary Overcurrent Protection. Where supplementary overcurrent protection is used for luminaires, appliances, and other equipment...it shall not be used as a substitute for required branch-circuit overcurrent devices or in place of the required branch-circuit protection...

The NEC® definition for a supplementary overcurrent protective device is shown below. Supplementary protective devices can only be used as additional protection when installed on the load side of a branch circuit overcurrent device. Supplementary devices must not be applied where branch circuit overcurrent protective devices are required; unfortunately this unsafe misapplication is prevalent in the industry. Supplementary devices are properly used in appliance applications and for additional, or supplementary protection where branch circuit overcurrent protection is already provided. In appliance applications, the supplementary devices inside the appliance provide protection for internal circuits and supplement the protection provided by the branch circuit protective devices.

The use of supplementary overcurrent protective devices allowed by 240.10 is for applications such as lighting and appliances shown in Figure 1. The supplementary protection is in addition to the branch circuit overcurrent protection provided by the device protecting the branch circuit (located in the lighting panel in Figure 1).

NEC® Article 100

Overcurrent Protective Device, Supplementary.

A device intended to provide limited overcurrent protection for specific applications and utilization equipment such as luminaires (lighting fixtures) and appliances. This limited protection is in addition to the protection provided in the branch circuit by the required branch-circuit overcurrent protective device.

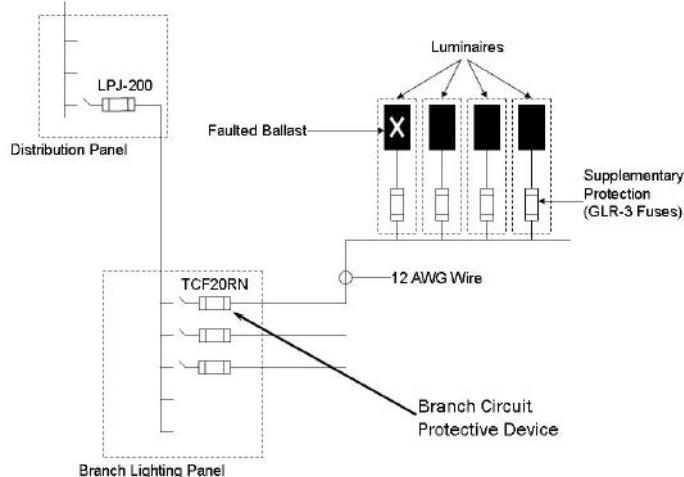


Figure 1

Branch circuit overcurrent protective devices can also be used to provide the additional protection that a supplementary overcurrent protective device provides: see Figure 2. Rather than using a supplementary overcurrent protective device for supplementary protection of the luminaire, a branch-circuit overcurrent protective device is used. The fact that a branch-circuit overcurrent device (KTK-R-3) is used where a supplementary device is permitted does not turn the circuit between the lighting panel and the fixture from a branch-circuit to a feeder. In the case of Figure 2, the branch circuit starts on the loadside of the 20A fuse in the lighting panel.

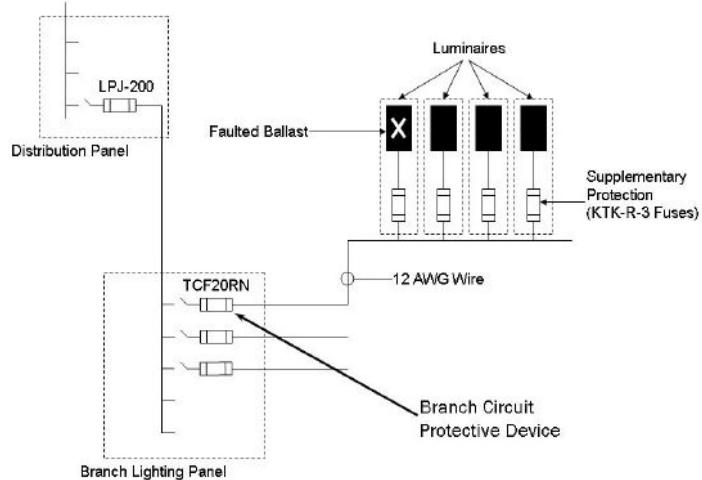


Figure 2

Branch-Circuit & Application Limited OCPDs

Supplementary overcurrent protective devices are not general use devices, as are branch-circuit overcurrent devices, and must be evaluated for appropriate application in every instance where they are used. Supplementary overcurrent protective devices are extremely application oriented and prior to applying the devices, the differences and limitations for these devices must be investigated and found acceptable. Examples of supplementary overcurrent protective devices include, but are not limited to the following:



**UL248-14
Supplemental Fuses**



**UL1077 Supplemental
Protectors (Mini Circuit Breakers)**

One example of the difference and limitations is that a supplementary overcurrent protective device may have creepage and clearance spacings that are considerably less than that of a branch circuit overcurrent protective device.

Example:

- A supplementary protector, recognized to UL1077, has spacings that are $\frac{1}{8}$ inch through air and $\frac{1}{2}$ inch over surface at 480V.
- A branch circuit rated UL489 molded case circuit breaker has spacings that are 1 inch through air and 2 inches over surface at 480V.

Another example of differences and limitations of supplementary protective devices is that branch circuit overcurrent protective devices have standard overload characteristics to protect branch circuit, feeder, and service entrance conductors. Supplementary overcurrent protective devices do not have standard overload (time-current) characteristics and may differ from the standard branch circuit overload characteristics. Also, supplementary overcurrent protective devices have interrupting ratings that can range from 32 amps to 100,000 amps. When supplementary overcurrent protective devices are considered for proper use, it is important to be sure that the device's interrupting rating equals or exceeds the available short-circuit current and that the device has the proper voltage rating for the installation (including compliance with slash voltage rating requirements, if applicable).

Reasons Why Supplementary Protectors (UL1077 Devices) cannot be used to Provide Branch Circuit Protection

1. Supplementary protectors are not intended to be used or evaluated for branch circuit protection in UL1077.
2. Supplementary protectors have drastically reduced spacings, compared to branch circuit protective devices, and often depend upon the aid of a separate branch circuit protective device upstream.
3. Supplementary protectors do not have standard calibration limits or over load characteristic performance levels and cannot assure proper protection of branch circuits.
4. Multi-pole supplementary protectors for use in 3 phase systems are not evaluated for protection against all types of overcurrents. Supplementary protectors are not tested to protect circuits from all types of fault conditions (for example line-ground faults on B-phase grounded systems.)
5. Most supplementary protectors are short-circuit tested with a branch circuit overcurrent device ahead of them and rely upon this device for proper performance.
6. Supplementary protectors are not required to be tested for closing into a fault.
7. Recalibration of a supplementary protector is not required and depends upon the manufacturer's preference. There is no assurance of performance following a fault or resetability of the device. The product standard does not require supplementary devices to be recalibrated and operational after interrupting a fault.
8. Considerable damage to a supplemental protector is allowed following short-circuit testing.
9. Supplementary protectors are not intended to be used as a disconnecting means.
10. Supplementary protectors are not evaluated for short-circuit performance criteria, such as energy let-through limits or protection of test circuit conductors.

Branch Circuit Fuse Selection Chart (600V or less)

Circuit	Load	Ampere Rating	Fuse Type	Symbol****	Voltage Rating (AC)	Class	Interrupting Rating (kA)	Remarks
Conventional Dimensions—Class RK1, RK5 (0-600A), L (601-6000A)								
Main, Feeder and Branch	All type loads (optimum overcurrent protection).	0 to 600A	Low-Peak™ (dual-element, time-delay)	LPN-RK_SP LPS-RK_SP	250V 600V	RK1††	300	All purpose fuses. Unequaled for combined short-circuit and overload protection. (Specification grade product)
		601 to 6000A	Low-Peak (time-delay)	KRP-C_SP	600V	L	300	
	Motors, welders, transformers, capacitor banks (circuits with heavy inrush currents).	0 to 600A	Fusetron™ (dual-element, time-delay)	FRN-R FRS-R	250V 600V	RK5††	200	Moderate degree of current-limitation. Time-delay passes surge-currents.
		601 to 4000A	Limitron™ (time-delay)	KLU	600V	L	200	All purpose fuse. Time delay passes surge-currents.
	Non-motor loads (circuits with no heavy inrush currents). Limitron fuses particularly suited for circuit breaker protection.	0 to 600A		KTN-R KTS-R	250V 600V	RK1††	200	Same short-circuit protection as Low-Peak fuses but - must be sized larger for circuits with surge-currents; i.e., up to 300%.
		601 to 6000A	Limitron (fast-acting)	KTU	600V	L	200	A fast-acting, high performance fuse
Reduced Dimensions For Installation in Restricted Space—CUBEFuse™ (0-100A), Class J (0-600A), T (0-1200A), CC (0-30A), G (0-60A)								
Branch	All type loads (optimum overcurrent protection).	0 to 100A	CUBEFuse™ (finger-safe, dual-element, time-delay)	TCF	600V	CF (J***)	300	Finger-safe. All purpose fuses. Unequaled for combined short-circuit and overload protection. (Specification grade product)
	All type loads (optimum overcurrent protection).	0	Low-Peak (dual-element, time-delay)	LPJ_SP	600V	J	300	All purpose fuses. Unequaled for combined short-circuit and overload protection. (Specification grade product)
	Power electronics applications such as drives and SSRs	to 600A	Drive Fuse (High Speed, Class J)	DFJ	600V	J	200	Where branch protection is needed with high speed fuse characteristics
	Non-motor loads (circuits with no heavy inrush currents).		Limitron (quick-acting)	JKS	600V	J	200	Very similar to KTS-R Limitron, but smaller.
		0 to 1200A	T-Tron (fast-acting)	JJN JJS	300V 600V	T	200	The space saver ($\frac{1}{2}$ the size of KTN-R/KTS-R).
	Motor loads (circuits with heavy inrush currents.)	0 to 30A	Low-Peak (time-delay)	LP-CC	600V	CC	200	Very compact ($\frac{1}{32}$ " x $1\frac{1}{2}$ "); rejection feature. Excellent for motor circuit protection.
	Non-motor loads (circuits with no heavy inrush currents.)	0 to 30A	Limitron (fast-acting)	KTK-R	600V	CC	200	Very compact ($\frac{1}{32}$ " x $1\frac{1}{2}$ "); rejection feature. Excellent for outdoor highway lighting.
	Control transformer circuits and lighting ballasts; etc.	0 to 30A	Tron™ (time-delay)	FNQ-R	600V	CC	200	Very compact ($\frac{1}{32}$ " x $1\frac{1}{2}$ "); rejection feature. Excellent for control transformer protection.
	General purpose; i.e., lighting panelboards.	0 to 60A	SC	SC	0-20A 600V 21-60A 480V	G	100	Current-limiting; $1\frac{1}{2}$ " dia. x varying lengths per amp rating.
	Miscellaneous	0 to 600A	One-Time	NON NOS	250V 600V	H or K5†	10	Forerunners of the modern cartridge fuse.
General Purpose (non- current limiting fuses)	Plug fuses can be used for branch circuits and small component protection.	0 to 30A	Fustat (dual-element, time-delay) Fusetron (dual-element, time-delay)	S T	125V	S	10	Base threads of Type S differ with amp ratings (size rejecting). T and W have Edison® base. T & S fuses recommended for motor circuits. W not recommended for circuits with motor loads.
		$\frac{1}{2}$ to 12A	Type W	W	125V	**	10	

** UL Listed as Edison Base Plug Fuse.

† Some ampere ratings are available as UL Class K5 with a 50,000A interrupting rating.

†† RK1 and RK5 fuses fit standard switches, equipped for non-rejection fuses (K1, K5 and H) fuse blocks and holders; however, the rejection feature of Class R switches and fuse blocks designed specifically for rejection type fuses (RK1 and RK5) prevent the insertion of the non-rejection fuses (K1, K5, and H).

*** Class J performance, special finger-safe dimensions.

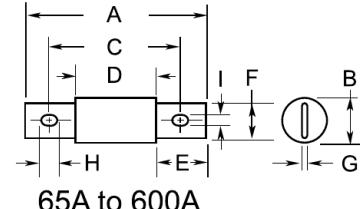
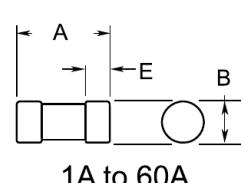
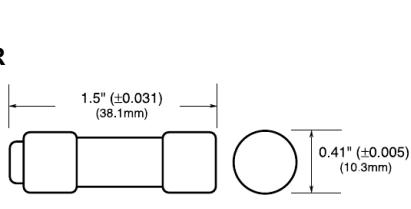
**** For many of these fuse types, there are indicating and non-indicating versions, each with different symbols.

Branch Circuit Fuse Dimensions

Class CC - in (mm)

LP-CC, FNQ-R & KTK-R

600V, 1-30A



Class J Dimensions - in (mm)

Low-Peak™, Limitron™ and Drive Fuses

LPJ, JK5 & DFJ — 600V

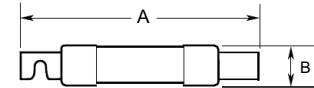
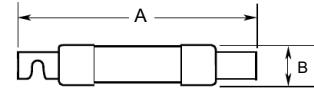
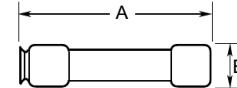
Amp Range	A	B	C	D	E	F	G	H	I
1-30	2.25 (57.2)	0.81 (20.6)	—	—	0.50 (12.7)	—	—	—	—
35-60	2.38 (60.3)	1.06 (27.0)	—	—	0.63 (15.9)	—	—	—	—
65-100	4.63 (117.5)	1.13 (28.6)	3.63 (92.1)	2.63 (66.7)	1.00 (25.4)	0.75 (28.6)	0.13 (3.2)	0.41 (10.4)	0.28 (7.1)
110-200	5.75 (146.1)	1.63 (41.4)	4.38 (111.1)	3.00 (76.2)	1.38 (34.9)	1.13 (28.6)	0.19 (4.8)	0.38 (9.5)	0.28 (7.1)
225-400	7.12 (181.0)	2.11 (53.6)	5.25 (133.3)	1.51 (38.3)	1.87 (47.6)	1.62 (41.2)	0.25 (6.4)	0.56 (14.2)	0.40 (10.3)
450-600	8.00 (203.2)	2.60 (66.0)	6.00 (152.4)	1.52 (38.6)	2.12 (54.0)	2.00 (50.8)	0.53 (13.5)	0.72 (18.3)	0.53 (13.5)

Class RK1 & RK5 - in (mm)

Basic dimensions are same as Class H (formerly NEC) One-Time (NON & NOS) and Superlag Renewable RES & REN fuses. NOTE: These fuses can be used to replace existing Class H, K1, K5 and K9 fuses relating to dimensional compatibility.

Ferrule Styles

Amp Range	250V		600V	
	A	B	A	B
1/10-30	2 (50.8)	0.56 (14.3)	5.0 (127.0)	0.81 (20.6)
35-60	3 (76.2)	0.81 (20.6)	5.5 (139.7)	1.06 (27.0)



Fusetron™ — (FRN-R & FRS-R) & Limitron™ — (KTN-R & KTS-R)

Amp Range	250V		600V	
	A	B	A	B
70-100	5.88 (149.2)	1.06 (26.9)	7.88 (200.0)	1.34 (34.0)
110-200	7.13 (181.0)	1.56 (39.6)	9.63 (244.5)	1.84 (46.7)
225-400	8.63 (219.1)	2.06 (52.3)	11.63 (295.3)	2.59 (65.8)
450-600	10.38 (263.5)	2.59 (65.8)	13.38 (339.7)	3.13 (79.5)

Low-Peak™ — (LPN-RK & LPS-RK)

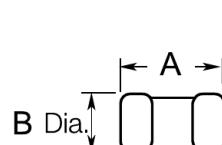
Amp Range	250V		600V	
	A	B	A	B
70-100	5.88 (149.2)	1.16 (29.5)	7.88 (200.0)	1.16 (29.5)
110-200	7.13 (181.0)	1.66 (42.2)	9.63 (244.5)	1.66 (42.2)
225-400	8.63 (219.1)	2.38 (60.5)	11.63 (295.3)	2.38 (60.5)
450-600	10.38 (263.5)	2.88 (73.2)	13.38 (339.7)	2.88 (73.2)

Class T - in (mm)

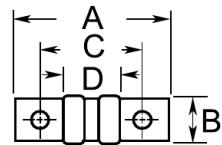
T-Tron™ Fuses

JJN — 300V

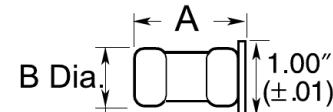
Amp Range	A		B		C		D	
	A	B	A	B	A	B	A	B
1-30	0.88 (22.2)	0.41 (10.3)	—	—	—	—	—	—
35-60	0.88 (22.2)	0.56 (14.3)	—	—	—	—	—	—
70-100	2.16 (54.8)	0.75 (19.1)	1.56 (39.7)	0.84 (21.4)	—	—	—	—
110-200	2.44 (61.9)	0.88 (22.2)	1.69 (42.9)	0.84 (21.4)	—	—	—	—
225-400	2.75 (69.9)	1.00 (25.4)	1.84 (46.8)	0.86 (21.8)	—	—	—	—
450-600	3.06 (77.8)	1.25 (31.8)	2.03 (51.6)	0.88 (22.2)	—	—	—	—
601-800	3.38 (85.7)	1.75 (44.5)	2.22 (56.4)	0.89 (22.6)	—	—	—	—
801-1200	4.00 (101.6)	2.00 (50.8)	2.53 (64.3)	1.08 (27.4)	—	—	—	—



JJN 1A to 60A
JJS 1A to 30A



JJN 70A to 1200A
JJS 70A to 800A



JJS 35A to 60A

JJS — 600V

Amp Range	A		B		C		D	
	A	B	A	B	A	B	A	B
1-30	1.50 (14.3)	0.56 (38.1)	—	—	—	—	—	—
35-60	1.56 (20.6)	0.81 (39.7)	—	—	—	—	—	—
70-100	2.95 (19.1)	0.75 (75.0)	2.36 (59.9)	1.64 (41.7)	—	—	—	—
110-200	3.25 (22.2)	0.88 (82.6)	2.50 (63.5)	1.66 (42.1)	—	—	—	—
225-400	3.63 (25.4)	1.00 (92.1)	2.72 (69.1)	1.73 (44.1)	—	—	—	—
450-600	3.98 (31.8)	1.25 (101.2)	2.96 (75.0)	1.78 (45.2)	—	—	—	—
601-800	4.33 (44.5)	1.75 (109.9)	3.17 (80.6)	1.88 (47.6)	—	—	—	—

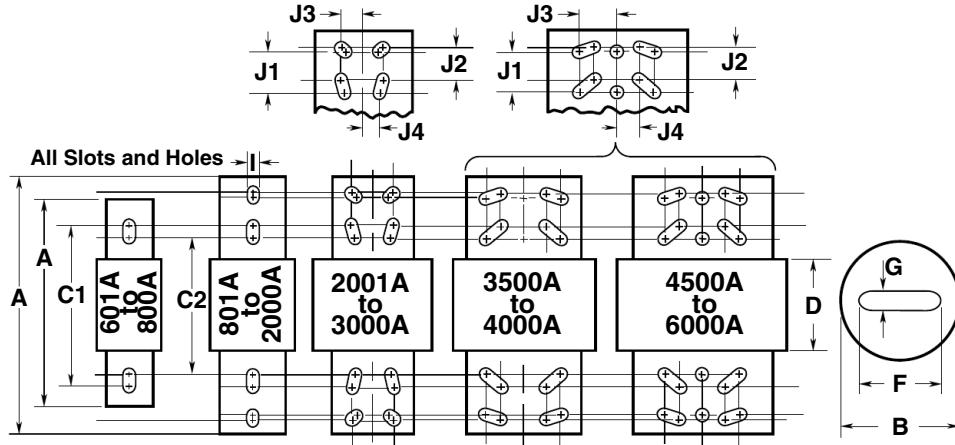
Branch Circuit Fuse Dimensions

Class L - in (mm)

Low-Peak™ – (KRP-C_SP) and Limitron™ – (KTU & KLU) Fuses, 600V

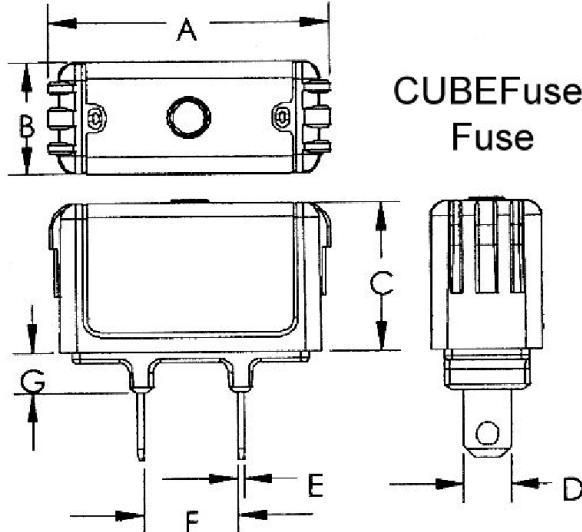
Amp Range	A	B	C1	C2	D	F	G	I	J1	J2	J3	J4
601-800	8.63 (219.1)	2.40 (61.0)	6.75 (171.5)	5.75 (146.1)	3.75 (95.3)	2.00 (50.8)	0.38 (9.5)	0.63 (15.9)	—	—	—	—
801-1200	10.75 (273.1)	2.40 (61.0)	6.75 (171.5)	5.75 (146.1)	3.75 (95.3)	2.00 (50.8)	0.38 (9.5)	0.63 (15.9)	—	—	—	—
1350-1600	10.75 (273.1)	3.00 (76.2)	6.75 (171.5)	5.75 (146.1)	3.75 (95.3)	2.38 (60.3)	0.44 (11.1)	0.63 (15.9)	—	—	—	—
1800-2000	10.75 (273.1)	3.50 (88.9)	6.75 (171.5)	5.75 (146.1)	3.75 (95.3)	2.75 (69.9)	0.50 (12.7)	0.63 (15.9)	—	—	—	—
2001-2500	10.75 (273.1)	4.80 (122.0)	6.75 (171.5)	5.75 (146.1)	3.75 (95.3)	3.50 (88.9)	0.75 (19.1)	0.63 (15.9)	1.75 (44.5)	1.38 (34.9)	0.88 (22.2)	0.81 (20.6)
3000	10.75 (273.1)	5.00 (127.0)	6.75 (171.5)	5.75 (146.1)	3.75 (95.3)	4.00 (101.6)	0.75 (19.1)	0.63 (15.9)	1.75 (44.5)	1.38 (34.9)	0.88 (22.2)	0.81 (20.6)
3500-4000	10.75 (273.1)	5.75 (146.1)	6.75 (171.5)	5.75 (146.1)	3.75 (95.3)	4.75 (120.7)	0.75 (19.1)	0.63 (15.9)	1.75 (44.5)	1.38 (34.9)	1.63 (41.3)	0.88 (22.2)
4500-5000	10.75 (273.1)	6.25 (158.8)	6.75 (171.5)	5.75 (146.1)	3.75 (95.3)	5.25 (133.4)	1.00 (25.4)	0.63 (15.9)	1.75 (44.5)	1.38 (34.9)	1.63 (41.3)	0.88 (22.2)
6000	10.75 (273.1)	7.13 (181.0)	6.75 (171.5)	5.75 (146.1)	3.75 (95.3)	5.75 (146.1)	1.00 (25.4)	0.63 (15.9)	1.75 (44.5)	1.38 (34.9)	1.63 (41.3)	0.88 (22.2)

NOTE: KRP-CL (150A to 600A) fuses have same dimensions as 601-800A case size. KTU (200-600A) have same dimensions, except tube 3" length x 2" diameter (76.2 x 50.8mm); terminal 1" width x 1/8" thick (41.3 x 31.8mm).



CUBEFuse™ Fuses: (TCF, FCF, PVCF and WCF) - in (mm), 600V

Fuse Amps	Dimensions - in (mm)						
	A	B	C	D	E	F	G
1-15	1.88 (47.75)	0.75 (19.05)	1.00 (25.40)	0.23 (5.84)	0.04 (1.02)	0.63 (15.93)	0.28 (7.11)
17 1/2	1.88 (47.75)	0.75 (19.05)	1.00 (25.40)	0.31 (7.87)	0.04 (1.02)	0.63 (15.93)	0.28 (7.11)
20	1.88 (47.75)	0.75 (19.05)	1.00 (25.40)	0.31 (7.87)	0.04 (1.02)	0.63 (15.93)	0.28 (7.11)
25-30	1.88 (47.75)	0.75 (19.05)	1.00 (25.40)	0.31 (7.87)	0.04 (1.02)	0.63 (15.93)	0.28 (7.11)
35-40	2.13 (54.10)	1.00 (25.40)	1.13 (28.58)	0.36 (9.10)	0.04 (1.02)	0.63 (15.93)	0.38 (9.65)
45-50	2.13 (54.10)	1.00 (25.40)	1.13 (28.58)	0.44 (11.13)	0.04 (1.02)	0.63 (15.93)	0.38 (9.65)
60	2.13 (54.10)	1.00 (25.40)	1.13 (28.58)	0.44 (11.13)	0.04 (1.02)	0.63 (15.93)	0.38 (9.65)
70	3.01 (76.45)	1.00 (25.40)	1.26 (32.00)	0.49 (12.45)	0.06 (1.60)	0.58 (14.78)	0.38 (9.65)
80-90	3.01 (76.45)	1.00 (25.40)	1.26 (32.00)	0.49 (12.45)	0.06 (1.60)	0.58 (14.78)	0.38 (9.65)
100	3.01 (76.45)	1.00 (25.40)	1.26 (32.00)	0.57 (14.48)	0.06 (1.60)	0.58 (14.78)	0.38 (9.65)



Bussmann Branch Circuit, Power Distribution Fuses



Good

Low-Peak Fuses* Now Offer Indication That's As Clear As Black And White

Low-Peak current-limiting fuses offer optional permanent replacement fuse indication. The indicator is either black or white; no in between coloring so no second-guessing whether to replace the fuse or not.



Replace

Proven Technology

Low-Peak fuses offer the same replacement fuse indication technology that's proven itself on the Bussmann CUBEFuse fuse and fuse holder system. It's the most reliable technology on the market today.

* Indication available on Bussmann LPJ_SPI, LPN-RK_SPI (250V) and LPS-RK_SPI (600V).



CUBEFuse, Dual-Element: TCF - (Time-Delay), FCF - (Fast-Acting)

TCF and FCF (600Vac), 1 to 100A, Current-Limiting, UL Listed Class CF, STD 248-8 Class J Performance

UL Guide # JFHR, UL File # E56412, 300,000AIR AC, (300Vdc – 100,000AIR), CSA Class #1422-02, CSA File #53787, 200,000AIR AC, (300VDC – 100,000AIR)

TCF and FCF fuses meet UL Class J time-delay electrical performance requirements. It is the world's first finger-safe fuse with the smallest installed footprint of any power class fuse including Class J, CC, T and R fuses. Satisfies requirements of IEC 60529 for IP20 finger safe-rating and provides Type 2 "No Damage" protection for motor starters when sized properly. Provide optional open fuse indication and is 35mm DIN-Rail and panel mountable.

Data Sheet No. 9000 (TCF)
Data Sheet No. 2147 (FCF)

See available blocks, switches, and panelboards



Drive Fuse (High Speed, Branch Protection)

DFJ (600Vac, 450Vdc) 1-600A, Current-Limiting, STD 248-8 Class J

UL Guide #JDDZ, UL File #E4273, 200,000AIR AC, 100,000AIR dc, CSA Class #1422-02, CSA File #53787, 200,000AIR ac

Now with one fuse, it is possible to meet NEC® and UL branch circuit protection requirements and provide high speed fuse protection characteristics. The DFJ is designed specifically for the protection of drives, soft starters, solid state relays and other power electronics. Capable of limiting fault energies like a semiconductor protection fuse, the DFJ fits into all standard Class J fuse mountings. The DFJ is ideal for circuits utilizing Solid State Relays (SSR) for control of heating loads where branch circuit protection is required, but high speed protection is also needed to achieve protection of semiconductor devices.

Data Sheet No. 1048



Low-Peak (Dual-Element, Time-Delay)

LPJ_SP (600Vac), 1 to 600A, Current-Limiting, STD 248-8 Class J

UL Guide #JFHR, UL File #E56412, 300,000AIR ac, 1 to 600A (300Vdc 100,000AIR), CSA Class #1422-02, CSA File #53787, 200,000AIR AC

Space saving LPJ fuses have the advantage of time-delay, permitting them to pass temporary overloads, offering back-up overload, and short-circuit protection. Ideal for IEC starter protection.

Data Sheet No. 1006, 1007



Limitron (Fast-Acting)

JKS (600Vac), 1 to 600A, 200,000AIR AC Current-Limiting STD 248-8 Class J

UL Guide #JDDZ, UL File #E4273, CSA Class #1422-02, CSA File #53787

JKS Limitron fuses are basically the same as RK1 Limitron fuses but smaller in physical size. JKS fuses are single-element units with no intentional time-delay and are thus best applied in circuits free of the temporary overloads of motor and transformer surges. The smaller dimensions of Class J fuses prevent their replacement with conventional fuses.

Data Sheet No. 1026, 1027



Low-Peak (Time-Delay)

LP-CC (600Vac), $\frac{1}{2}$ to 30A Current-Limiting 200,000AIR AC,

STD 248-4 Class CC

UL Guide #JDDZ, UL File #E4273, $\frac{1}{2}$ -2.25A (300Vdc 20,000AIR), 3-15A (150Vdc 20,000AIR), 20-30A (300Vdc 20,000AIR), CSA Class #1422-02, CSA File #53787

The Bussmann Low-Peak Class CC fuse (LP-CC) was developed specifically for a growing need in the industry - a compact, space saving branch circuit fuse for motor circuits.

Data Sheet No. 1023



CC-Tron (Time-Delay)

FNQ-R (600Vac), $\frac{1}{2}$ to 30A, 200,000AIR AC Current-Limiting STD 248-4 Class CC

UL Guide #JDDZ, UL File #E4273, CSA Class #1422-01, CSA File #53787

Ideal for control transformer protection. Can be sized to meet requirements of NEC® 430.72 and UL 508. Its miniature design and branch circuit rating allow it to be used for motor branch circuit and short-circuit protection required by NEC® 430.52.

Data Sheet No. 1014



Limitron (Fast-Acting)

KTK-R (600Vac), $\frac{1}{2}$ to 30A, 200,000AIR AC, Current-Limiting STD 248-4 Class CC

UL Guide #JDDZ, UL File #E4273, CSA Class #1422-02, CSA File #53787,

A very small, high performance, fast-acting, single-element fuse for protection of branch circuits, motor control circuits, lighting ballasts and street lighting fixtures. A diameter of only $\frac{1}{2}$ and a length of $1 \frac{1}{2}$ inch give cost and space savings. A grooved ferrule permits mounting in "rejection" type fuse holders as well as standard non-rejection type holders.

Data Sheet No. 1015

Bussmann Branch Circuit, Power Distribution Fuses

Low-Peak (Dual-Element, Time-Delay)



LPS-RK_SP (600Vac), LPN-RK_SP (250Vac), $\frac{1}{2}$ to 600A, Current-Limiting, STD 248-12 Class RK1
LPN-RK_SP 0-60A (125Vdc, 50,000AIR), 65-600A (250Vdc, 50,000AIR), LPS-RK_SP 0-600A (300Vdc, 50,000AIR)
UL Guide #JFHR, UL File #E56412, 300,000AIR AC, CSA Class #1422-02, CSA File #53787, 200,000AIR AC

High performance, all purpose fuses. Provide the very high degree of short-circuit limitation of Limitron fuses plus the overload protection of Fusetron™ fuses in all types of circuits and loads. Can be closely sized to full-load motor currents for reliable backup protection. Close sizing permits the use of smaller and more economical switches (and fuses); better selective coordination against blackouts; and a greater degree of current limitation (component protection). Low-Peak fuses are rejection type but also fit non-rejection type fuse holders. Thus, can be used to replace Class H, K1, K5, RK5 or other RK1 fuses.

Data Sheet No. 1001, 1002, 1003, 1004

Fusetron (Dual-Element, Time-Delay)



FRS-R (600Vac), FRN-R (250Vac), $\frac{1}{2}$ to 600A, 200,000AIR AC, FRN-R 0-600A (125Vdc, 20,000AIR), FRS-R 0-600A (300Vdc, 20,000AIR), Current-Limiting STD 248-12 Class RK5

UL Guide #JDDZ, UL File #E4273, CSA Class #1422-02, CSA File #53787

Time-delay affords excellent overload protection of motors and other type loads and circuits having temporary inrush currents such as those caused by transformers and solenoids. (In such circuits, Limitron fuses can only provide short-circuit protection). Fusetron fuses are not as fast-acting on short-circuits as Low-Peak fuses and therefore cannot give as high a degree of component short-circuit protection. Like the Low-Peak fuse, Fusetron fuses permit the use of smaller size and less costly switches. Fusetron fuses fit rejection type fuse holders and can also be installed in holders for Class H fuses. They can physically and electrically replace Class H, K5, and other Class RK5 fuses.

Data Sheet No. 1017, 1018, 1019, 1020

Limitron (Fast-Acting)



KTS-R (600Vac), KTN-R (250Vac), 1 to 600A, 200,000AIR AC Current-Limiting STD 248-12 Class RK1

UL Guide #JDDZ, UL File #E4273, CSA Class #1422-02, CSA File #53787

Single-element, fast-acting fuses with no intentional time-delay. Provide a high degree of short-circuit current limitation (component protection). Particularly suited for circuits and loads with no heavy surge currents of motors, transformers, solenoids and welders. Incorporate Class R rejection feature. Can be inserted in non-rejection type fuse holders. Thus, can physically and electrically replace fast-acting Class H, K1, K5, RK5, and other RK1 fuses.

Data Sheet No. 1044, 1043

T-Tron (Fast-Acting)

JJS (600Vac) 1-800A, JJN (300Vac) 1-1200A, 200,000AIR AC Current-Limiting STD 248-15 Class T
UL Guide #JDDZ, UL File #E4273, JJN 15-600A (160Vdc, 20,000AIR), JJN 601-1200A (170Vdc 100,000AIR)
CSA Class #1422-02, CSA File #53787

The space-savers. Counterpart of the KTN-R/KTS-R Limitron™ fuses, but only one-third the size; thus, particularly suited for critically restricted space. A single-element fuse; extremely fast-acting. Provides a high degree of current limitation on short-circuits for excellent component protection. Must be oversized in circuits with inrush currents common to motors, transformers and other inductive components (will give only short-circuit protection).

Data Sheet No. 1029, 1025

Type SC (½-6A Fast-Acting, 8-60A Time-Delay)



SC 100,000AIR ac, $\frac{1}{2}$ -20A (600Vac), 25-60A (480Vac) STD 248-5 Class G

UL Guide #JDDZ, UL File #E4273 0-20A (170Vdc 10,000AIR), 25-30A (300Vdc 10,000AIR), 35-60A (300Vdc 10,000AIR)
CSA Class #1422-01, CSA File #53787

A high performance general-purpose branch circuit fuse for lighting, appliance and motor branch circuits. Fuse diameter is $\frac{1}{16}$; lengths vary with amp rating from $\frac{1}{2}$ to $2\frac{1}{2}$ inches (serves as rejection feature and, thus, helps prevent oversizing).

Data Sheet No. 1024

Low-Peak (Time-Delay)

KRP-C_SP (600Vac), 601 to 6000A, Current-Limiting STD 248-10 Class L

UL Guide #JFHR, UL File #E56412, 300,000AIR AC, 601-2000A (300Vdc 100,000AIR), CSA Class #1422-02, CSA File #53787, 200,000AIR AC



The all purpose fuse for both overload and short-circuit protection of high capacity systems (mains and large feeders). Time-delay (minimum of four seconds at five times amp rating) for close sizing. The combination use of $\frac{1}{2}$ to 600A Low-Peak dual-element time-delay fuses and 601 to 6000A KRP-C Low-Peak fuses is recommended as a total system specification. Easily selectively coordinated for blackout protection. Size of upstream fuse need only be twice that of downstream Low-Peak fuses (2:1 ratio). Low-Peak fuses can reduce bus bracing; as well as provide excellent overall protection of circuits and loads.

Data Sheet No. 1008, 1009

Limitron (Fast-Acting)

KTU (600Vac), 601 to 6000A, 200,000AIR AC, Current-Limiting STD 248-10 Class L

UL Guide #JDDZ, UL File #E4273, CSA Class #1422-02, CSA File #53787



Single-element fuses with no intentional time-delay. Very fast-acting with a high degree of current limitation; provide excellent component protection. In motor circuits, is sized at approximately 300% of motor full-load current.

Data Sheet No. 1010

Limitron (Time-Delay)

KLU (600Vac), 601 to 4000A, 200,000AIR AC, Current-Limiting STD 248-10 Class L

UL Guide #JDDZ, UL File #E4273, CSA Class #1422-02, CSA File #53787

5 second delay (minimum) at 500% of rated current. Not as current-limiting as KRP-C_SP or KTU fuses.

Data Sheet No. 1013

Disconnects, Panelboards & One-Time Fuses



One-Time (General Purpose)

NOS (600Vac) NON (250Vac), Non-Current-Limiting, (NON 1-60A) 50,000AIR AC, (NOS 1-60A) 50,000AIR AC STD 248-9 Class K5

UL Guide #JDDZ, UL File #E4273, CSA Class #1421-01, CSA File #53787 (NON 65-600A) 10,000AIR AC, (NOS 70-600A) 10,000AIR Acc STD 248-6 Class H.

With an interrupting rating of 10,000 amps, and generally not considered current-limiting, Class H one-time fuses are used in circuits with low available short-circuit currents. Single-element one-time fuses do not incorporate intentional time-delay.

[Data Sheet No. 1030](#)



CCP-Class CC



CCP-CUBEFuse



CCP-CUBEFuse
(bolt-on)

Compact Circuit Protector (CCP)

The revolutionary Bussmann CCP is designed as a fused branch circuit disconnect with a footprint 1/3 that of equivalent rated circuit breakers. Available Class CC fuse and CUBEFuse versions have short-circuit current ratings (SCCR) at 600V up to three times greater than a molded-case circuit breaker. These higher ratings and compact design make the CCP ideal for industrial control panel, industrial machinery and HVAC applications. The bolt-on style CUBEFuse integrated in the Quik-Spec™ Coordination Panelboard (see below) provides a branch circuit panel with the inherent benefits of fuse protection. The CCP is a smaller, simpler, better solution.

Features

- High short-circuit current ratings (SCCR) up to 200kA
- Full voltage rated at 600Vac
- 1-, 2-, and 3-pole versions available
- Compact design
- UL98 Listed and suitable for branch circuit disconnect and branch circuit protection
- Permanent lockout/tagout provisions
- Switch/Fuse interlock prevents energized fuse removal
- Open fuse indication

[Data Sheet No. 1157 and 1161, Application Note No. 7038](#)
online at bussmann.com/ccp

Quik-Spec™ Coordination Panelboard



The new Bussmann Quik-Spec™ Coordination Panelboard Makes Selective Coordination Easy...with More Features, More Application Flexibility and...More Value!

Features

- Addresses NEC® selective coordination requirements
- Flexible configurations — up to 600Vac / 400 Amp
- Same size footprint as traditional circuit breaker panelboards
- Finger safe
- Saves time
- Easy-to-spec
- Size rejecting
- Storage for spares

[Data Sheet No. 1160 and Application Note 3148](#) online at bussmann.com/quik-spec

CUBEFuse™ Safety Switch

Bussmann CUBEFuse™ Safety Switch Provides Extra Measure of Protection

Features

- Enhanced finger-safe design
- Current-limiting fuses reduce arc flash hazard
- Easy interface with viewing window option
- Up to 100 Amps

For details,
see Data Sheet 1156 online at
www.bussmann.com



Quik-Spec Power Module™ Switch and Panel

The Bussmann Quik-Spec™ Power Module For Elevator Applications Offers the Superior All-In-One Solution

Features

- Easy-to-specify
- Easy-to-install
- Provides easy selective coordination
- UL98 Listed

The Quik-Spec™ Power Module™
Switch (PS)



Quik-Spec™ Power Module™
Panel (PMP)

Quik-Spec™ Power Module™ Panel for Multi-Elevator Applications

- Features multiple switches in a single panel
- Offers significant space savings
- Like the switch, the Power Module Panel is easy to specify and factory configured
- Meets prevailing ANSI/ASME, NEC® and NFPA 72 elevator circuit requirements and is UL 67 Listed
- To order, just call your Bussmann representative with all relevant electrical and circuit information, and we do the rest

For details, see Data Sheet 1145 (PS - switch) and Data Sheet 1146 (PMP - panel) online at www.bussmann.com

Rotary Disconnect Switches

Open Disconnect Switches

Flexibility and convenience make point-of-use configuration easy.



Full range of open disconnect switches with versatile options and accessories that ship within 24 hours.

Enclosed Disconnect Switches

Exceptional breadth and availability for your application.

Full range of application specific enclosed disconnect switches with most common configurations that ship



For more information visit: www.cooperbussmann.com/Disconnects

Fuse Holders, Fuse Blocks, Power Distribution Blocks and Surge SPDs

Modular Fuse Blocks



New snap-together Class R, H(K) & J knifeblade fuse blocks make installation easy and increase flexibility and electrical safety.

- Modular snap-together design permits assembly of required poles at point-of-use
- All fuse blocks meet UL creep and clearance requirements for industrial control circuits. Blocks rated 200A and above also meet industrial power distribution standards
- Optional high-clarity, see-through finger-safe covers improve safety and reduce maintenance time by allowing wire termination inspection without opening the cover
- Built-in lockout/tagout feature improves safety

CH Series Global Modular Fuse Holder



Compact Modular Fuse Holders With the Industry's Best Ratings. Finger-Safe DIN-Rail Mount Fuse Holders & Simplify Installation.

Key Features and Benefits:

- Easy color coding for use: yellow for PV, red for IEC, and black for UL applications
- Finger-safe, high SCCR rated, Class CC and midget holders with indicator options. Also for Class J and IEC size fuses.
- Agency ratings up to 1000Vdc for use with solar PV fuses
- Available remote PLC indication with the CH-PLC module
- Terminals rated for use with 75°C or 90°C wire, fine stranded wire, spade terminals and with comb-bus bars. Use any higher temperature rated wire with appropriate derating
- Complete range of UL Listed and high SCCR rated 1-phase and 3-phase finger-safe comb-bus bars and power feed lugs

For additional information see reorder #3185

Safety J™ Fuse Holder for Class J Fuses



Compact and finger-safe design that meets IP20 requirements. Fuse is removed/installed external to circuit. Open fuse indication available. Integral 35mm DIN-Rail adapter.

Data Sheet No. 1152

SAMI™ Fuse Covers with Open Fuse Indication



Dead front protection, optional open fuse indication. The SAMI fuse covers fit most fuses and fuse blocks. Covers snap on in seconds - no special wiring required.

Data Sheet No. 1204

For Data Sheets: www.cooperbussmann.com

Power Distribution Fuse Blocks



Save space, time and money with the new power distribution fuse block.

Innovative power distribution fuse block uses 50% less panel space and reduces installation time and labor by 33%.

For more information visit: www.cooperbussmann.com/Disconnects



Several PDB types are offered for industrial control panels, HVAC, wireways and other applications. Available in 1-, 2-, or 3-pole versions and a wide range of input/output terminations. Bussmann line includes UL 1059 recognized terminal blocks as well as UL 1953 listed PDBs. The listed versions are available in standard, High SCCR, and Finger-Safe High SCCR options. See below data sheets for more information.

Data Sheet No. 1049, 1148, 1117

UL Surge Protective Devices



For more product information see page 261

Panel-Mount Fuse Holders



Shown here is a typical Bussmann panel-mount fuse holder. This HPS-RR holder is a rejection type which accepts rejection type branch circuit fuses such as the Bussmann LP-CC, KTK-R and FNQ-R.

Data Sheet No. 2113

Optima Fuse Holders & Overcurrent Protection Modules



Optima Fuse Holder Without Switch Data Sheet No. 1102

Optima Fuse Holder With Switch Data Sheet No. 1103

Compact, full-featured modules that deliver "Type 2" coordinated protection, with properly sized fuses. Available in a broad range of combinations for process control panel applications. Hold Class CC and midget fuses.



Optima Overcurrent Protection Module Data Sheet No. 1109

Bussmann Photovoltaic Fuses

PVM Solar Fuse

A range of UL 2579 fast-acting 600Vdc Midget fuses specifically designed to protect solar power systems in extreme ambient temperature, high cycling and low level fault current conditions (reverse current, multi-array fault).

Features

- Specifically designed to protect solar power systems in extreme ambient temperature per UL 2579
- Capable of withstanding high cycling and low level fault current conditions

[Data Sheet No. 2153](#)



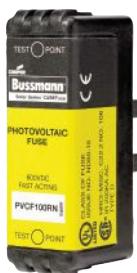
PVCF Class CF Fuse

Application Specific CUBEFuse Delivers Superior Photovoltaic Protection with up to a 70% Smaller Footprint

Features

- Fast-acting protection specifically designed for low-fault current conditions that occur in PV systems
- Finger-safe feature minimizes exposure to live parts, reducing hazard to personnel
- UL 2579 Listed for use in 600Vdc photovoltaic systems
- Demonstrated performance in extreme temperature cycling conditions, ranging from -40°C through 90°C
- Integral use with the CUBEFuse holder minimizes panel space by up to 70%

[Data Sheet No. 2155](#)



PVS-R (600Vac/dc) Class RK5

Fast-acting, current-limiting fuse, designed for the protection of both AC and DC systems.

Features

- List to UL 2579 – The industry's only Class R photovoltaic fuse
- Specially designed to protect in lower-level overload regions where common time-delay fuses do not
- Demonstrated performance in extreme temperatures, ranging from -40°C through 90°C
- Proven application in constantly changing PV environmental conditions
- Easily applied in readily available Class R fuse blocks and disconnects

[Data Sheet No. 4203](#)



10x38mm PV Solar Fuse

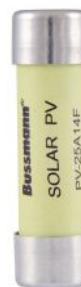
A range of fuses specifically designed for the protection and isolation of photovoltaic strings.

Ratings: 1000Vdc, Amps: 1-20A

Features

- Low level fault protection
- Superior cycling withstand - for conditions associated with solar panel system operation and environmental influences
- Solar PV fuses are IEC gPV rated and listed to UL 2579 for 1000Vdc
- Globally accepted 10x38mm dimension - available with standard ferrule, bolt and versatile PCB mount options
- Use with Bussmann standard combiner boxes

[Data Sheet No. 720110](#)



14x51mm PV Solar Fuse

A range of 14x51mm package fuse links specifically designed for protecting and isolating photovoltaic strings. These fuse links are capable of interrupting low overcurrents associated with faulted PV systems (reverse current, multi-array fault).

Ratings: 1000Vdc, Amps: 25 & 32A
1100Vdc, Amps: 15 & 20A

Features

- Specifically designed to provide fast-acting protection under low fault current conditions associated with PV systems
- High DC voltage rating
- Demonstrated performance in extreme temperature cycling conditions

[Data Sheet No. 720110](#)



NH1 Photovoltaic Fuses

A range of NH fuse links specifically designed for protecting and isolating photovoltaic array combiners and disconnects. These fuse links are capable of interrupting low overcurrents associated with faulted PV systems (reverse current, multi-array fault).

Ratings: 1000Vdc, Amps: 32-160A

Features

- Specifically designed to provide fast-acting protection under low fault current conditions associated with PV systems
- High DC voltage rating
- Variety of mounting options for flexibility
- Demonstrated performance in extreme temperature cycling conditions

[Data Sheet No. 720133](#)



1000 & 1500Vdc XL Style Photovoltaic Fuses

A range of XL package fuses specifically designed for protecting and isolating photovoltaic array combiners and disconnects. These fuse links are capable of interrupting low overcurrents associated with faulted PV systems (reverse current, multi-array fault).

Ratings: 1000Vdc, Amps: 63-630A

Features

- Specifically designed to provide fast-acting protection under low fault current conditions associated with PV systems
- High DC voltage rating
- Variety of mounting options for flexibility
- Demonstrated performance in extreme temperature cycling conditions

[Data Sheet No. 720134](#)



14x65mm Photovoltaic Fuse

A range of 14x65mm package fuse links specifically designed for protecting and isolating photovoltaic strings. These fuse links are capable of interrupting low overcurrents associated with faulted PV systems (reverse current, multi-array fault).

Ratings: 1300Vdc, Amps: 25 & 32A
1500Vdc, Amps: 15 & 20A

Features

- Specifically designed to provide fast-acting protection under low fault current conditions associated with PV systems
- High DC voltage rating
- Demonstrated performance in extreme temperature cycling conditions

[Data Sheet No. 720139](#)

High Speed Fuses

The protection needs for solid-state power equipment often differ from electrical equipment; hence, the high speed fuse evolved. The protection of power diodes and SCRs requires ultra current-limiting short-circuit fuses; semiconductor devices cannot withstand heavy short-circuit current. The circuits in which fuses are installed place certain requirements upon high speed fuses. These requirements are generally more stringent than the fuse requirements for typical 60 cycle AC power distribution systems in commercial buildings or industrial plants.

The diodes or SCRs are at the heart of the solid-state power equipment. These semiconductor devices have relatively low short-circuit current withstand capabilities. The thin silicon chip imbedded in the semiconductor device package has a very low transient thermal capacity. The heating effect produced by low, moderate and high fault currents can quickly cause permanent damage to the device. Damage to a semiconductor device can occur in a very short time period; the current-limiting fuse protection is one of the fastest protection means available. Under fault conditions, restricting the short-circuit energy by a high speed fuse is essential to the protection of SCRs, diodes, and other semiconductor devices in the system.

NEC® 430.52 recognizes the use of these types of fuses in motor applications; see the section on motor circuits with adjustable speed drives in this bulletin.

There are several criteria that can be used to judge the performance of high speed fuses (also referred to as semiconductor fuses). Among these are the current-limiting short-circuit capability and DC interrupting capability. From a design standpoint, I^2t is most often used to evaluate the current-limiting short-circuit performance. I^2t (RMS amps- squared seconds) is a parameter that indicates the heating effect associated with a current pulse. Typically the

semiconductor data sheet specifies a maximum I^2t withstand for a semiconductor device. To offer short-circuit protection to the semiconductor device, the fuse selected should have an I^2t let-through less than the I^2t withstand rating of the semiconductor device. High speed fuses have excellent current-limiting ability, as indicated by their low I^2t let-through and peak current let-through.

High speed fuses are often applied where DC interrupting capabilities are required. Some high speed fuses have been designed and rigorously tested in developing their excellent DC characteristics.

The type circuits often employed require specialized knowledge. Included in the following data are the current and voltage relationships for many of the common circuits on the next page.

Ratios of Circuit Currents (Diagrams on next page)

Circuit Diagram*	Relative Circuit Currents			
	$I_{1,RMS}$ $I_{1,average}$	$I_{2,RMS}$ $I_{1,average}$	$I_{3,RMS}$ $I_{1,average}$	$I_{4,RMS}$ $I_{1,RMS}$
1	1.57	—	—	—
2	1.11	0.79	—	0.71
3	1.11	0.79	1.11	0.71
4	1.02	0.59	—	0.58
5	1.00	0.58	0.82	0.58
6	1.00	0.41	—	0.41
7	—	—	—	0.71
8	—	—	—	0.71

*For example, in Diagram No. 1: $\frac{I_{1,RMS}}{I_{1,average}} = 1.57$



North American

FWA, FWX, FWH, KAC, KBC, FWP, FWJ
1 to 4000A, 130V to 1000V, 200,000AIR AC, UL Recognized

Bussmann offers a complete range of North American blade and flush-end style high-speed fuses and accessories. Their design and construction were optimized to provide:

- Low energy let-through (I^2t)
- Low watts loss
- Superior cycling capability
- Low Arc Voltage
- Excellent DC performance

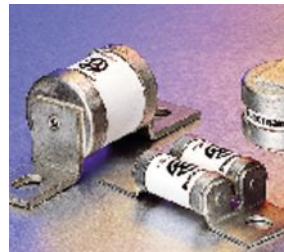
Medium power applications. While there are currently no published standards for these fuses, the industry has standardized on mounting centers that accept Bussmann fuses.

British Style BS 88

LET, LMMT, CT, FE, FM, MT
6 to 900A, 240V to 690V, 200,000AIR AC, UL Recognized
Designed and tested to BS 88:Part 4 & IEC 60269:Part 4
Wideest range of British style semiconductor fuses and accessories. Use innovative arc quenching techniques and high grade materials to provide:

- Minimal energy let-through (I^2t)
- Excellent DC performance
- Good surge withstand profile

Found in equipment manufactured in the United Kingdom or British Commonwealth countries. North American manufacturers have begun to specify British style fuses - particularly in UPS applications at 240 volts or less - to take advantage of their size, performance and cost benefits.



Square-Body

170M####
10 to 7500A, 690V to 1250V, 200,000AIR AC, UL Recognized, Designed and tested to IEC 60269:Part 4
Complete range of Square Body style high-speed fuses and accessories. Easy to provide custom products.

High power applications which require a compact design with superior performance. Different end fittings options include:

- DIN 43 653
- DIN 43 620
- Flush End (Metric/U.S.)
- French Style
- US Style



Ferrule

FWA, FWX, FWH, FWC, FWP, FWK, FWJ, FWL, FWS
1 to 100A, 150V to 2000V, 200,000AIR AC, UL Recognized

Designed and tested to IEC 60269:Part 4

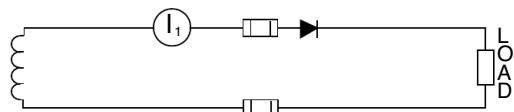
Bussmann offers a full line of ferrule style (cylindrical and clip-mounted) high-speed fuses, designed and tested to meet standards and requirements in various locations around the world. Their unique design and construction provide:

- Superior cycling
- Low energy let-through (I^2t)

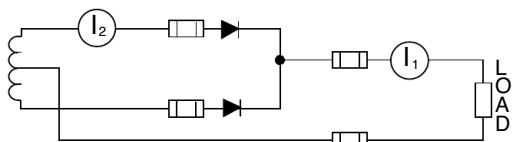
Ferrule high-speed fuses provide an excellent solution for small UPS, small AC drives and other low power applications where space is at a premium.

High Speed Fuses

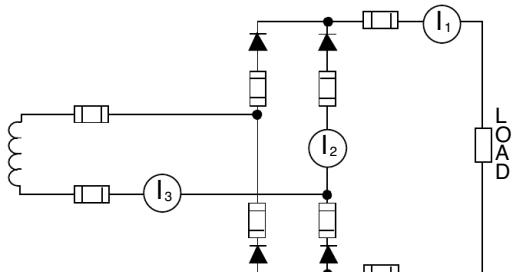
Typical Circuits



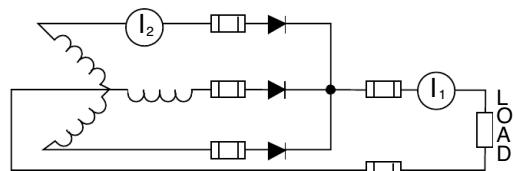
1. Single-Phase, Half-Wave.



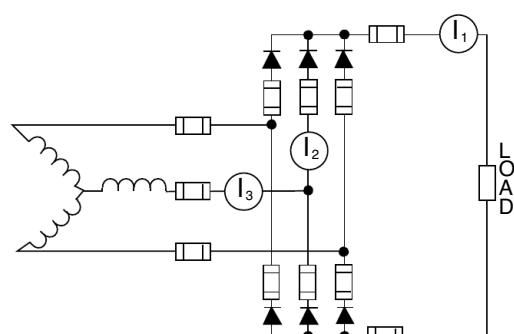
2. Single-Phase, Full-Wave, Center-Tap.



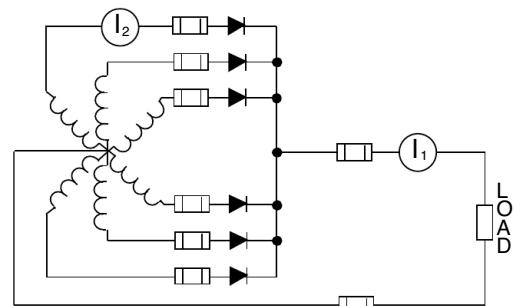
3. Single-Phase, Full-Wave, Bridge.



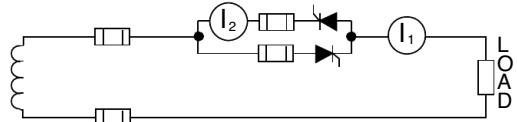
4. Three-Phase, Half-Wave.



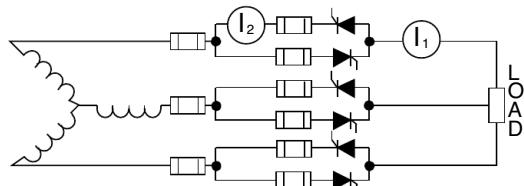
5. Three-Phase, Full-Wave.



6. Six Phase, Single Wave



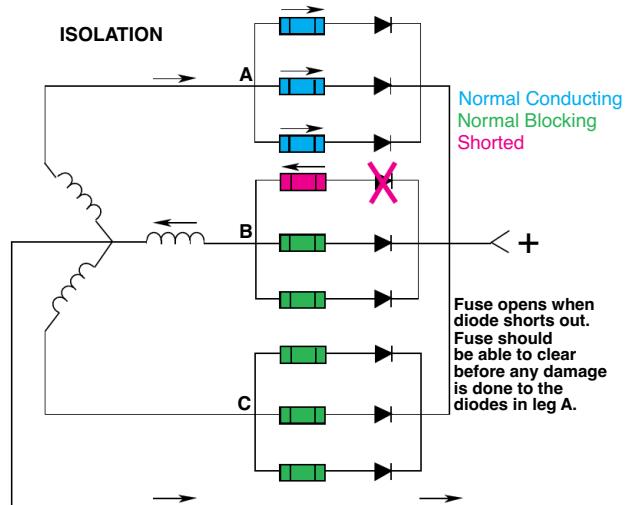
7. Single-Phase, Anti-Parallel, AC Control.



8. Three-Phase, Anti-Parallel, AC Control.

Not all systems are designed to have the fuse provide full protection for a diode or SCR. There are several degrees of protection:

1. Prevent Device Rupture—Fuse merely needs to interrupt current before SCR or diode ruptures.
2. Isolate Failed Device—Typically, used only where three or more diodes or SCRs (devices) are used per conduction path. An individual fuse is not intended to protect an individual device. Rather, the purpose of the fuse is to remove the diode or SCR after it shorts out and permit the overall circuit to continue operating. At this level, the fuse must be able to protect the diodes or SCRs that are splitting the fault current in another leg, as illustrated in the following diagram.



3. Protect The Device (short-circuits)—In this case the fuse is selected to protect the diode or SCR against short-circuits external to the SCR or diode. Typically, the fuse has to be selected to give a much lower let-through current than that required in applications (1) or (2) above.

For more information on high speed fuses, see Motor Circuits With Power Electronic Devices section.

Medium Voltage Fuses

General

Fuses above 600V are classified under one of three classifications as defined in ANSI/IEEE C37.40.

1. General Purpose Current-Limiting Fuse: A fuse capable of interrupting all currents from the rated interrupting current down to the current that causes melting of the fusible element in one hour.
2. Back-up Current-Limiting Fuse: A fuse capable of interrupting all currents from the maximum rated interrupting current down to the rated minimum interrupting current.
3. Expulsion Fuse: A vented fuse in which the expulsion effect of gasses produced by the arc and lining of the fuse holder, either alone or aided by a spring, extinguishes the arc.

One should note that in the definitions above, the fuses are defined as either expulsion or current-limiting. A current-limiting fuse is a sealed, non-venting fuse that, when melted by a current within its interrupting rating, produces arc voltages exceeding the system voltage, which in turn forces the current to zero. The arc voltages are produced by introducing a series of high resistance arcs within the fuse. The result is a fuse that typically interrupts high fault currents within the first $\frac{1}{2}$ cycle of the fault. In contrast, an expulsion fuse depends on one arc to initiate the interruption process. The arc acts as a catalyst, causing the generation of de-ionizing gas from its housing. The arc is then elongated, either by the force of the gasses created or a spring. At some point, the arc elongates far enough to prevent a restrike after passing through a current zero. Therefore, an expulsion fuse may take many cycles to clear.

Construction

Current-limiting fuses have four parts common to all designs: tube, end ferrules, element, and arc quenching filler.

The tube must have a high burst strength to withstand the pressures generated during interruption. The most common materials used are fiberglass reinforced epoxy and melamine tubing. End ferrule designs are usually dictated by the application. For example, a clip mounted fuse would have a silver-plated ferrule with a large surface area to insure good contact. In contrast, a stud mounted fuse may be cast bronze with very little surface area. In both designs it is very important that a good seal be provided between the tube and end ferrules. This is most commonly done with a gasket and magna-forming process, or with epoxy and screws. Fuse elements are typically made from silver. Silver is the most common material used for high voltage fuse elements because of its predictable melting properties. To achieve this low current operation, it is necessary to either add a series element of different material or reduce the melting temperature of the silver by adding an "M" spot. Finally, an arc quenching filler is added to aid in the interruption process. During interruption the arc quenching filler is changed into an insulating material called a fulgurite.

Application

Many of the rules for applying expulsion fuses and current-limiting fuses are the same, but because the current-limiting fuse operates much faster on high fault currents, some additional rules must be applied. Three basic factors must be considered when applying any fuse. These are: 1) Voltage, 2) Continuous Current Carrying Capacity, and 3) Interrupting Rating.

Voltage

The fuse must have a voltage rating equal to or greater than the normal frequency recovery voltage which will be seen across the fuse under all conditions. On three-phase systems, the voltage rating of the fuse must be greater than or equal to the line-to-line voltage of the system.

Continuous Current-Carrying Capacity

Continuous current values that are shown on the fuse represent the level of current the fuse can carry continuously without exceeding the temperature rises as specified in ANSI C37.46. An application that exposes the fuse to a current slightly above its continuous rating but below its minimum interrupting rating, may damage the fuse due to excessive heat. This is the main reason overload relays are used in series with back-up current-limiting fuses for motor circuit protection.

Interrupting Rating

All fuses are given a maximum interrupting rating. This rating is the maximum level of fault current that the fuse has been tested to safely interrupt. Back-up current-limiting fuses are also given a minimum interrupting rating. When using back-up current-limiting fuses, it is important that other protective devices are used to interrupt currents below this level.

Additional Rules

Expulsion Fuses: When choosing a fuse, it is important that the fuse be properly coordinated with other protective devices located upstream and downstream. To accomplish this, one must consider the melting and clearing characteristics of the devices. Two curves, the minimum melting curve and the total clearing curve, provide this information. To insure proper coordination, the following rules should be used.

1. The total clearing curve of any downstream protective device must be below a curve representing 75% of the minimum melting curve of the fuse being applied.
2. The total clearing curve of the fuse being applied must lie below a curve representing 75% of the minimum melting curve for any upstream protective device.

Current-Limiting Fuses

To insure proper application of a current-limiting fuse it is important that the following additional rules be applied.

1. As stated earlier, current-limiting fuses produce arc voltages that exceed the system voltage. Care must be taken to make sure that the peak voltages do not exceed the insulation level of the system. If the fuse voltage rating is not permitted to exceed 140% of the system voltage, there should not be a problem. This does not mean that a higher rated fuse cannot be used, but points out that one must be assured that the system insulation level (BIL) will handle the peak arc voltage produced.
2. As with the expulsion fuse, current-limiting fuses must be properly coordinated with other protective devices on the system. For this to happen the rules for applying an expulsion fuse must be used at all currents that cause the fuse to interrupt in 0.01 seconds or greater.

When other current-limiting protective devices are on the system it becomes necessary to use I^2t values for coordination at currents causing the fuse to interrupt in less than 0.01 seconds. These values may be supplied as minimum and maximum values or minimum melting and total clearing I^2t curves. In either case, the following rules should be followed.

1. The minimum melting I^2t of the fuse should be greater than the total clearing I^2t of the downstream current-limiting device.
2. The total clearing I^2t of the fuse should be less than the minimum melting I^2t of the upstream current-limiting device.

For fusing medium voltage motor branch circuits, see Medium Voltage Motor Circuits section.

Medium Voltage Fuses



R-Rated (Motor Circuit)

JCK, JCK-A, JCK-B, JCH, JCL, JCL-A, JCL-B, JCG, JCR-A, JCR-B
2R to 24R, 2400V: JCK & JCH, 4800V: JCL & JCG, 7200V: JCR-A & JCR-B, IR: 50,000AIR AC

R-Rated medium voltage fuses are back-up current-limiting fuses used in conjunction with medium voltage motors and motor controllers.

Current-limiting fuses may be designated as R-Rated if they meet the following requirements:

- The fuse will safely interrupt all currents between its minimum and maximum interrupting ratings.
- The fuse will melt in a range of 15 to 35 seconds at a value of 100 times the "R" number (ANSI C37.46).

Bussmann R-Rated current-limiting fuses are designed for use with medium voltage starters to provide short-circuit protection for the motor and motor controller. These fuses offer a high level of fault current interruption in a self-contained, non-venting package which can be mounted indoors or in an enclosure.

Available styles are: Standard, Ampgard Hookeye, Haz. Location, Bolt-in

Open fuse indication is on all fuses.

Data Sheet No. 6001



E-Rated (Potential & Small Transformers)

JCD: 2400V, ½-5E, JCW: 5500V, ½-5E, JCQ: 4800V, ½-10E, JCI: 7200V, ½-10E
JCT: 14.4kV, ½-10E

IR: 80,000AIR ac

Low amperage, E-Rated medium voltage fuses are general purpose current-limiting fuses. The E-rating defines the melting-time-current characteristic of the fuse and permits electrical interchangeability of fuses with the same E-Rating. For a general purpose fuse to have an E-Rating, the following condition must be met:

- The current responsive element shall melt in 300 seconds at a RMS current within the range of 200% to 240% of the continuous current rating of the fuse, fuse refill, or link. (For fuses rated 100E or less)(ANSI C37.46).

Bussmann low amperage, E-Rated fuses are designed to provide primary protection for potential, small service, and control transformers. These fuses offer a high level of fault current interruption in a self-contained non-venting package which can be mounted indoors or in an enclosure.

Data Sheet No. 6002



E-Rated (Transformer & Feeder Protection)

JCX: 2400V (½-250E), JCY: 4800V (½-450E), JCU: 4800V (10-750E), JDZ: 7200V (20-350E), JCZ: 7200V (15-200E), JDN: 14.4kV (15-250E), JCN: 14.4kV (20-300E), IR: 63,000AIR AC

Bussmann E-Rated medium voltage fuses are general purpose current-limiting fuses. The E-rating defines the melting-time-current characteristic of the fuse. The ratings are used to allow electrical interchangeability among different manufacturers. For a general purpose fuse to have an E-Rating, the following conditions must be met:

- The current responsive element shall melt in 300 seconds at a RMS current within the range of 200% to 240% of the continuous current rating of the fuse unit (ANSI C37.46).
- The current responsive element above 100 amps shall melt in 600 seconds at a RMS current within the range of 220% to 264% of the continuous current rating of the fuse unit (ANSI C37.46).

Bussmann E-Rated fuses are designed to provide primary protection of transformers, feeders, and branch circuits. They are non-venting fuses which must be mounted indoors or in an enclosure. Their current-limiting ability reduces the short-circuit energy (I^2t) that the system components must withstand.



CL-14 (Clip Lock)

ECL055: 10E-600E, ECL155: 10E-300E

5.5kV & 15.5kV

Interrupting Ratings: ECL055: 63kA, ECL155: 63kA (10-200A) & 50kA (250-300A)

See description for E-Rated "Transformer & Feeder Protection" fuses.

Data Sheet Nos. 9002, 9004



Medium Voltage Fuse Links - 27kV

FL11H: 1 to 8

FL11K: 1 to 200

FL11T: 1 to 200

FL3K: 1 to 200

FL3T: 1 to 200



E-Rated (Full Range)

MV055: 5E-450E, MV155: 5E-200E
5.5kV & 15.5kV, IR: 50,000AIR AC

See description for "E-Rated Transformer & Feeder Protection" fuses.

Satisfies additional ANSI C37.40 for full-range protection fuse.

A full-range fuse is capable of interrupting all currents from the rated interrupting rating down to the minimum continuous current that causes melting of the fusible element.

Data Sheet No. 6700 6701

OCPD Servicing and Maintenance

Overcurrent protection is similar to auto insurance. When a person buys auto insurance, they hope they never have to submit an accident claim. But if they have a major accident they are grateful the insurance company protects them financially. The insurance for electrical systems and equipment is the overcurrent protective devices (OCPDs), which are intended to protect from overload and short-circuit (fault) conditions that may arise. People install OCPDs hoping there will never be an overcurrent condition when the OCPDs are required to open, especially due to a fault. But if an overcurrent does occur, they need the OCPD to operate as originally specified. If the OCPD does not operate as fast as it should or fails to operate, the investment of installing the OCPD is nullified and property damage, lost business time/production and possible harm to property and people can occur.

Reliability may be the most important criteria for OCPD type evaluation and selection. What good is an OCPD that may not function or may not function properly when needed? For a particular circuit, an overcurrent event that must be cleared by the OCPD can occur in a range from the installation commissioning day, to decades later, or never. Whether a 1000A or a 20A circuit, the reliability of the OCPD is important for fire safety, life safety, and worker safety.

Modern current-limiting fuses are inherently reliable in terms of overcurrent interruption for the life of the product. The life cycle maintenance requirements are a primary consideration in the decision process whether to use fuses.

The NEC® is predominantly an installation standard and has few OCPD maintenance requirements. However, the NEC recognizes that proper installation alone is not adequate for safety; maintenance during the system life is necessary.

NEC 90.1(B) Adequacy. This Code contains provisions that are considered necessary for safety. Compliance therewith and proper maintenance results in an installation that is essentially free from hazard but not necessarily efficient, convenient, or adequate for good service or future expansion of electrical use.

NFPA 70E-2012 Standard for Electrical Safety in the Workplace does have OCPD maintenance requirements. A few important requirements:

130.5 Arc Flash Hazard Analysis (partial quote)

The arc flash hazard analysis shall take into consideration the design of the overcurrent protective device and its opening time, including its condition of maintenance...

IN No. 1: Improper or inadequate maintenance can result in increased opening time of the overcurrent protective device, thus increasing the incident energy.

205.4 General Maintenance Requirements.

Overcurrent protective devices shall be maintained in accordance with the manufacturers' instructions or industry consensus standards. Maintenance, tests, and inspections shall be documented.

210.5 Protective Devices.

Protective devices shall be maintained to adequately withstand or interrupt available fault current..

IN: Failure to properly maintain protective devices can have an adverse effect on the arc flash hazard analysis incident energy values.

Frequency of Maintenance and Maintenance

Procedures

Important OCPD decision factors include reliability, frequency of maintenance, maintenance procedures, and maintenance cost (including downtime) required to retain the original specified level of protection.

The best sources for OCPD maintenance frequency, necessary tests, and specific methods include OCPD manufacturer's instructions, NFPA 70B-2010 Recommended Practice for Electrical Equipment Maintenance, and ANSI/NETA MTS-2011, Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems.

NFPA 70B provides frequency of maintenance guidelines as well as guidelines for setting up an electrical preventative maintenance (EPM) program, including sample forms and requirements for electrical system maintenance. ANSI/NETA MTS-2011 is more prescriptive about what maintenance and testing is required for electrical power system devices and equipment. Visual, mechanical, and electrical inspections and tests are specified by equipment type, as well as what results are acceptable. This standard includes guidelines for frequency of maintenance required for electrical system power equipment in Appendix B, Frequency of Maintenance Tests.

2013 NFPA 70B OCPD Frequency of Maintenance

The complete NFPA 70B text has more comprehensive practices and annex information than shown here. This is merely a representation of what is provided by NFPA 70B. NFPA 70B stresses that for specific situations the frequency of maintenance is dependent upon many variables such as environment conditions and operating conditions.

11.4 Frequency of Tests. Most routine testing can best be performed concurrently with routine preventive maintenance, because a single outage will serve to allow both procedures. For that reason, the frequency of testing generally coincides with the frequency of maintenance. The optimum cycle depends on the use to which the equipment is put and the operating and environmental conditions of the equipment. In general, this cycle can range from 6 months to 3 years, depending on conditions and equipment use. The difficulty of obtaining an outage should never be a factor in determining the frequency of testing and maintenance. Equipment for which an outage is difficult to obtain is usually the equipment that is most vital in the operation of the electrical system. Consequently, a failure of this equipment would most likely create the most problems relative to the continued successful operation of the system. In addition to routine testing, tests should be performed any time equipment has been subjected to conditions that possibly could have caused it to be unable to continue to perform its design function properly.

Below are considerations for low-voltage fuses.

Annex L Maintenance Intervals (partial extract)

Item/Equipment	Task/Function	Interval	Reference
Fuses, 1000V or less			
Fuse terminals and fuseclips	Visual inspection/clean Clip contact pressure Cleaning of contact surfaces	3 years 3 years 3-5 years	18.1.2 18.1.3 18.1.3
Fuses	Visual inspection for discoloration and damage	3 years	18.1.3

18.1.2 Inspection. Fuse terminals and fuseclips should be examined for discoloration caused by heat from poor contact or corrosion. Early detection of overheating is possible through the use of infrared examination. If evidence of overheating exists, the cause should be determined.

18.1.3 Cleaning and Servicing. The power source to fuseholders should be disconnected before servicing. All Fuseholder connections should be tightened. All connections to specifications should be torqued where available. Fuseclips should be checked to ascertain that they exert sufficient pressure to maintain good contact. Clips making poor contact should be replaced or clip clamps used. Contact surfaces of fuse terminals and clips that have become corroded or oxidized should be cleaned. Silver-plated surfaces should not be abraded. Contact surfaces should be wiped with a noncorrosive cleaning agent. Fuses showing signs of deterioration, such as discolored or damaged casings or loose terminals, should be replaced.



Clip clamps can be used to improve fuse contact to poor clips.

OCPD Servicing and Maintenance

NFPA 70B-2010 has guidelines for testing fuses:

21.18.1 Fuses can be tested with a continuity tester to verify that the fuse is not open. Resistance readings can be taken using a sensitive 4-wire instrument such as a Kelvin bridge or micro-ohmmeter. Fuse resistance values should be compared against values recommended by the manufacturer.

21.18.2 Where manufacturer's data is not readily available, resistance deviations of more than 15 percent for identical fuses in the same circuit should be investigated.

Normally on low voltage systems, a simple continuity testing of fuses is sufficient. Low resistance denotes a fuse is good and extremely high resistance indicates a fuse is open. For some applications such as high speed fuses used in large power electronic applications and medium voltage fuse applications, maintenance contractors performing periodic shut down maintenance often will check the fuse resistance. This requires using sensitive resistance measurement instruments such as a Kelvin bridge or micro-ohmmeter.

Testing Knife-Blade Fuses

Contrary to popular belief, fuse manufacturers do not generally design their knife-blade fuses to have electrically energized fuse caps during normal fuse operation. Electrical inclusion of the caps into the circuit occurs as a result of the coincidental mechanical contact between the fuse cap and terminal extending through it. In most brands of knife-blade fuses, this mechanical contact is not guaranteed; therefore, electrical contact is not guaranteed. Thus, a resistance reading or voltage measurement taken across the fuse caps is not indicative of whether or not the fuse is open.

In a continuing effort to promote safer work environments, Bussmann has introduced newly designed versions of knife-blade Fusetron fuses (Class RK5) and knife-blade Low-Peak fuses (Class RK1). The improvement is that the end caps are insulated to reduce the possibility of accidental contact with a live part. With these improved fuses, the informed electrician knows that the end caps are isolated. With older style non-insulated end caps, the electrician doesn't really know if the fuse is energized or not.



After an OCPD Opens

Another important criterion for considering the type of OCPD is servicing and trouble shooting. This is an area where there is misinformation and often a lack of proper safe work practices.

When an OCPD device opens due to a fault, OSHA and NFPA 70E do not permit circuit breakers to be reclosed or fuses to be replaced, until it is safe to do so.

2012 NFPA 70E 130.6(L) & OSHA 1910.334(b)(2)* Reclosing Circuits After Protective Device Operation.

After a circuit is de-energized by the automatic operation of a circuit protective device, the circuit shall not be manually reenergized until it has been determined that the equipment and circuit can be safely energized. The repetitive manual reclosing of circuit breakers or reenergizing circuits through replaced fuses shall be prohibited. When it is determined that the automatic operation of a device was caused by an overload rather than a fault condition, examination of the circuit or connected equipment shall not be required before the circuit is reenergized.

*Shown is wording from 2012 NFPA 70E. The OSHA wording is different, but has the same meaning.

This is an important safety practice. If an overcurrent protective device opened under fault conditions, damage at the point of the fault may have resulted. If the fault is not

located and rectified, re-energizing the circuit into the fault again might result in an even more severe fault than the first fault.

What constitutes "can be safely energized"? First, ensuring the fault condition has been properly repaired. But that is not sufficient. When fault current is flowing through the distribution system to the point of a fault, damage to the circuit components carrying the fault can occur. Inspect and test the circuit to ensure that the fault current did not damage circuit components that now will be or soon could be a source of another fault. If all the components check out as in good condition, the circuit may still not be safe to reenergize. The OCPD(s) must be verified as safe to re-energize. New fuses of the proper type and ampere rating must be inserted and the circuit re-energized by closing the disconnect.

Calibration Decal on Equipment

A best practice after conducting periodic maintenance or maintenance after fault interruption on overcurrent protective devices is to apply a decal on the outside of the equipment. The decal is color coded and can be an aid for hazard identification and risk assessment for electrical safety. NFPA 70B *Recommended Practice for Electrical Equipment Maintenance* makes this recommendation in 11.27 Test or Calibration Decal System.

See Figures 4A, 4B, and 4C for example of a decal system Courtesy of Shermco Industries, a NETA member company. This maintenance decay system complies with NFPA 70B 11.27. After the technician performs inspections and tests and if necessary, remedial measures, one of three color coded decals is affixed to the equipment.

The decal and test records can communicate the condition of maintenance of the overcurrent protective device. This is especially important for arc flash hazard analysis. For instance, NFPA 70E 130.5 Arc Flash Hazard Analysis requires the overcurrent protective device's design, opening time, and condition of maintenance to be taken into consideration. When an OCPD is not maintained properly, if an arcing fault occurs, the resulting arc flash incident energy may be much greater than calculated due to the OCPD not clearing the arcing current in the time indicated by the published data for the OCPD. The possible result: a worker is wearing PPE with a certain arc rating based on an incident energy calculation but the arc flash incident energy actually is much greater than calculated.

TESTED	
Project No.:	_____
Test Date:	_____
Tested By:	(Technician) (Company)

Figure 4A White decal communicates the overcurrent protective device is electrically and mechanically acceptable. I.e., it should perform to the original specification of the manufacturer.

LIMITED SERVICE	
Project No.:	_____
Test Date:	_____
Tested By:	(Technician) (Company)

Figure 4B Yellow decal communicates the overcurrent protective device may have minor deficiencies, but is electrically and mechanically acceptable. A trip indicator (upon operation indicates whether the overcurrent interrupted was an overload or fault) that does not function properly is an example of such a minor deficiency.

DEFECTIVE	
Project No.:	_____
Test Date:	_____
Tested By:	(Technician) (Company)

Figure 4C Red decal communicates the overcurrent protective device has not passed one or more inspections or tests and the device is not suitable to be in service. Example deficiencies are failure to trip on calibration test or unacceptable high values during contact resistance test.

General

All conductors must be protected against overcurrents in accordance with their ampacities, as set forth in NEC® 240.4. They must also be protected against short-circuit current damage, as required by 240.1 (IN) and 110.10. The safest, most economical way to meet these requirements is through the use of current-limiting fuses.

Fuse amp ratings must not be greater than the ampacity of the conductor. 240.4(B) states that if such conductor rating does not correspond to a standard size fuse, the next larger size fuse may be used, provided its rating does not exceed 800A and the conductor is not part of a multi-outlet branch circuit supplying receptacles for cord and plug connected portable loads.

Standard fuse sizes per NEC® 240.6 are: 1, 3, 6, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 601, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, and 6000A.

Note: The small fuse amp ratings of 1, 3, 6, and 10 were added to provide more effective short-circuit and ground-fault protection for motor circuits, in accordance with 430.40 and 430.52 and listing agency requirements for protecting the overload relays in controllers for very small motors.

For fuse amp ratings over 800A, per 240.4(C), the ampacity of the conductor must be equal to or greater than the rating of the fuse as required in 240.6. For supervised industrial installations, see 240.91.

Protection of Small Conductors

240.4(D) determines protection of small conductors. The overcurrent protective device is required to not exceed the following, unless specifically permitted by 240.4(E) for tap conductors or 240.4(G) for specific conductor applications:

18 AWG Copper – 7 amps or less provided continuous loads do not exceed 5.6 amps and overcurrent protection is provided by one of the following:

- Class CC, Class J, or Class T fuses
- Branch circuit-rated fuses or circuit breakers listed and marked for use with 18 AWG copper wire

16 AWG Copper – 10 amps or less provided continuous loads do not exceed 8 amps and overcurrent protection is provided by one of the following:

- Class CC, Class J, or Class T fuses
- Branch circuit-rated fuses or circuit breakers listed and marked for use with 16 AWG copper wire

14 AWG Copper or 12 AWG aluminum and copper-clad aluminum – 15 amps or less

- 12 AWG Copper - 20 amps or less
- 10 AWG Aluminum and Copper-Clad Aluminum - 25 amps or less
- 10 AWG Copper - 30 amps or less

It is important to note that 310.106 (and Table 310.106(A)) lists the minimum size conductor as 14 AWG. 16 AWG and 18 AWG conductors can only be used provided they are permitted elsewhere in the Code. In addition to allowances for small motors per 430.22(G) 16 AWG and 18 AWG conductors are permitted for power circuits in industrial machinery per NFPA 79 and UL 508A. However, there are strict limitations on the overcurrent protection. See NFPA 79 for more information.

Protection of Flexible Cords

Per NEC® 240.5 flexible cords and extension cords shall have overcurrent protection rated at their ampacities. Supplementary fuse protection is an acceptable method of protection. For 18 AWG fixture wire of 50 feet or more, a 6 amp fuse would provide the necessary protection. For 16 AWG fixture wire of 100 feet or more, an 8 amp fuse would provide the necessary protection.

For 18 AWG extension cords, a 10 amp fuse would provide the necessary protection for a cord where only two conductors are carrying current, and a 7 amp fuse would provide the necessary protection for a cord where only three conductors are carrying current.

Location of Fuses in Circuit (NEC® 240.21)

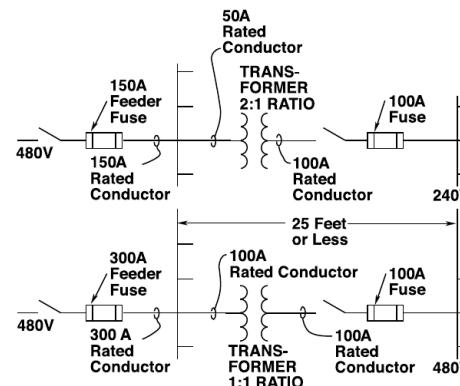
Fuses must be installed at the point where the conductor receives its supply, i.e., at the beginning or lineside of a branch circuit or feeder (240.21).

(B)(1) Fuses are not required at the conductor supply if a feeder tap conductor is not over ten feet long; is enclosed in raceway; does not extend beyond the switch board, panelboard or control device which it supplies; and has an ampacity not less than the combined computed loads supplied, and not less than the rating of the equipment containing an overcurrent device(s) supplied, unless the tap conductors are terminated in a fuse not exceeding the tap conductor ampacity. For field installed taps, the ampacity of the tap conductor must be at least 10% of the overcurrent device protecting the feeder conductors [240.21(B)(1)].

(B)(2) Fuses are not required at the conductor supply if a feeder tap conductor is not over 25 feet long; is suitably protected from physical damage by being enclosed in an approved raceway or other approved means; has an ampacity not less than $\frac{1}{2}$ that of the device protecting the feeder conductors and terminate in a single set of fuses sized not more than the tap conductor ampacity [240.21(B)(2)].

(B)(3) Fuses are not required at the conductor supply if a transformer feeder tap has primary conductors at least $\frac{1}{2}$ the ampacity of the overcurrent device protecting the feeder, and secondary conductors are at least $\frac{1}{2}$ the ampacity of the overcurrent device protecting the feeder, when multiplied by the transformer turns ratio. The total length of one primary plus one secondary conductor (excluding any portion of the primary conductor that is protected at its ampacity) is not over 25 feet in length; the secondary conductors terminate in a set of fuses rated at the ampacity of the tap conductors; and if the primary and secondary conductors are suitably protected from physical damage [240.21(B)(3)].

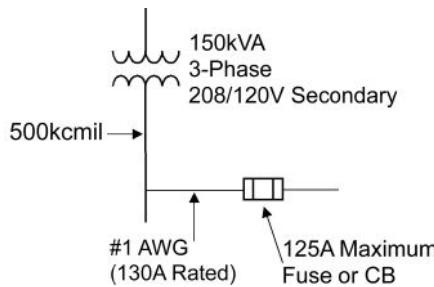
(B)(4) Fuses are not required at the conductor supply if a feeder tap is not over 25 feet long horizontally and not over 100 feet long total length in high bay manufacturing buildings where only qualified persons will service such a system. Also, the ampacity of the tap conductors is not less than $\frac{1}{2}$ of the fuse rating from which they are supplied. The size of the tap conductors must be at least 6 AWG copper or 4 AWG aluminum. They may not penetrate walls, floors, or ceilings, and the taps are made no less than 30 feet from the floor. The tap conductors terminate in a single set of fuses that limit the load to the ampacity of the tap conductors. They are physically protected by being enclosed in an approved raceway or other approved means and contain no splices.[240.21(B)(4)].



Note: Smaller conductors tapped to larger conductors can be a serious hazard. If not adequately protected against short-circuit conditions (as required in NEC® 110.10 and 240.1(FPN)), these unprotected conductors can vaporize or incur severe insulation damage. Molten metal and ionized gas created by a vaporized conductor can envelop other conductors (such as bare bus), causing equipment burndown. Adequate short-circuit protection is recommended for all conductors. When a tap is made to a switchboard bus for an adjacent panel, such as an emergency panel, the use of Bussmann cable limiters is recommended for protection of the tapped conductor. These current-limiting cable limiters are available in sizes designed for short-circuit protection of conductors from 12 AWG to 1000 kcmil. Bussmann cable limiters are available in a variety of terminations to make adaption to bus structures or conductors relatively simple.

(B)(5) Fuses are not required at the supply for an outside tap of unlimited length where all of the following are met:

1. The conductors are outdoors except at the point of load termination.
2. The conductors are protected from physical damage in an approved manner.
3. The conductors terminate in a single set of fuses that limit the load to the ampacity of the conductors.
4. The fuses are a part of or immediately adjacent to the disconnecting means.
5. The disconnecting means is readily accessible and is installed outside or inside nearest the point of entrance or where installed inside per 230.6 nearest the point of conductor entrance [240.21(B)(5)]. See the following Figure.



(C)(1) Fuses are not required on the secondary of a single-phase two-wire or three-phase, three-wire, delta-delta transformer to provide conductor protection where all of the following are met:

1. The transformer is protected in accordance with 450.3.
2. The overcurrent protective device on the primary of the transformer does not exceed the ampacity of the secondary conductor multiplied by the secondary to primary voltage ratio. [240.21(C)(1)]. Selecting the next higher standard size overcurrent protective device is NOT allowed.

(C)(2) Fuses are not required on the secondary of a transformer to provide conductor protection where all of the following are met:

1. The secondary conductors are not over 10 feet long.
2. The secondary conductors' ampacity is not less than the combined computed loads.
3. The secondary conductor ampacity is not less than the rating of the device they supply or the rating of the overcurrent device at their termination. Selecting the next higher standard size overcurrent protective device is NOT allowed.
4. The secondary conductors do not extend beyond the enclosure(s) of the equipment they supply and they are enclosed in a raceway.

5. For field installations where the secondary conductors leave the enclosure or vault where they receive their supply, the secondary conductor ampacity is not less than $\frac{1}{2}$ of the rating of the over-current device protecting the primary of the transformer multiplied by the turns ratio. [240.21(C)(2)]

(C)(3) Transformer secondary conductors do not require fuses at the transformer terminals when all of the following conditions are met:

1. Must be an industrial location.
2. The conditions of maintenance and supervision in a given industrial location ensure that only qualified personnel service the system
3. Secondary conductors must not be more than 25 feet long.
4. Secondary conductor ampacity must be at least equal to the secondary full-load current of transformer and sum of terminating, grouped, overcurrent devices. Selecting the next higher standard size overcurrent protective device is NOT allowed.
5. Secondary conductors must be protected from physical damage in an approved raceway or other approved means. [240.21(C)(3)]

Note: Switchboard and panelboard protection (408.36) and transformer protection (450.3) must still be observed.

(C)(4) Outside conductors that are tapped to a feeder or connected to the secondary terminals of a transformer do not require fuse protection when all of the following are met:

1. The conductors are protected from physical damage in an approved means.
2. The conductors terminate in a single set of fuses, no larger than the ampacity of the conductors.
3. The conductors are outside, except for point of load termination.
4. The overcurrent device is near or a part of the disconnecting means.
5. The disconnecting means is readily accessible outdoors or, if indoors, nearest the point of the entrance of the conductors or where installed inside per 230.6 nearest the point of conductor entrance [240.21(C)(4)].

Tap Conductor Exception for Listed Surge Protective Devices

Exceptions to 240.21(B)(1)(1)b. and 240.21(C)(2)(1)b. permits sizing of tap conductors for listed surge protective devices and other listed non-energy consuming devices to be based on the manufacturer's instructions.



This surge protective device is prewired with specific conductors that are shown in the device's instructions. Surge protective devices are non-energy consuming devices that do not have a calculated load as referenced by 240.21(B)(1)(1)b and 240.21(C)(2)(1)b. For surge protective devices see "<http://www.cooperbussmann.com/surge>" www.cooperbussmann.com/surge.

Other Conductors Protection

Battery Conductors

Conductors connected to storage battery systems shall be protected in accordance with their ampacity per 240.4. For non-hazardous environments the location of the overcurrent protective device shall be as close as practicable to the storage battery terminals in accordance with 240.21(H). The installation of overcurrent protective devices on battery systems in hazardous locations is permitted. However, the additional requirements for hazardous locations must be followed.

Branch Circuits – Lighting And/Or Appliance Load (No Motor Load)

The branch circuit rating shall be classified in accordance with the rating of the overcurrent protective device. Classifications for those branch circuits other than individual loads shall be: 15, 20, 30, 40, and 50A (210.3).

Branch circuit conductors must have an ampacity of the rating of the branch circuit and not less than the load to be served (210.19).

The minimum size branch circuit conductor that can be used is 14 AWG (210.19). For exceptions to minimum conductor size, see 210.19.

Branch circuit conductors and equipment must be protected by a fuse with an amp rating which conforms to 210.20. Basically, the branch circuit conductor ampacity and fuse amp rating minimum size must be at least the larger of two calculations (a) or (b): (a) the sum of non-continuous load plus 125% of the continuous load or (b) maximum load to be served after applying adjustment or correction factors (as calculated per Article 220). An example calculation is shown in NEC® Information Annex D, Example D3(a). The fuse size must not be greater than the conductor ampacity (for exceptions, see 210.20). Branch circuits rated 15, 20, 30, 40, and 50A with two or more outlets (other than receptacle circuits of 210.11(C)(1) and (C)(2) must be fused at their rating and the branch circuit conductor sized according to Table 210.24 (see 210.24).

Feeder Circuits (No Motor Load)

The feeder fuse amp rating and feeder conductor ampacity minimum size must be at least the larger of two calculations (a) or (b): (a) the sum of non-continuous load plus 125% of the continuous load or (b) maximum load to be served after applying adjustment or correction factors (as calculated per Article 220). An example calculation is shown in NEC® Information Annex D, Example D3(a). The feeder conductor must be protected by a fuse not greater than the conductor ampacity (for exceptions, see 240.3). Motor loads shall be computed in accordance with Article 430; see subsection on Motor Feeder Protection. For combination motor loads and other loads on feeders, see subsection on feeder combination motor, power and lighting loads.

Service Equipment

Each ungrounded service entrance conductor shall have a fuse in series with an amp rating not higher than the ampacity of the conductor (for exceptions, see 230.90(A)). The service fuses shall be part of the service disconnecting means or be located immediately adjacent thereto (230.91).

Service disconnecting means can consist of one to six switches for each service (230.71) or for each set of service entrance conductors permitted in 230.2. When more than one switch is used, the switches must be grouped together (230.71).

Service equipment must have adequate short-circuit ratings for the short-circuit currents available.

110.24 requires the maximum available fault current and date of calculation to be field marked on the service equipment. This is to ensure that the overcurrent protective devices have sufficient interrupting rating and that the service equipment short-circuit current rating are equal to or exceed the available short-circuit current. If electrical installation modifications are made the maximum available fault current should be recalculated and new field marking for the service equipment. It should be verified that the service equipment short-circuit current rating and overcurrent protective devices' interrupting ratings are adequate for the new available fault current. 110.24 is not required, for dwelling units or certain industrial installations.

Transformer Secondary Conductors

Secondary conductors need to be protected from damage by the proper overcurrent protective device. Although 240.4(F) provides an exception for conductors supplied by a single-phase transformer with a two-wire secondary, or a three-phase delta-delta transformer with a three-wire, single voltage secondary, it is recommended that these conductors be protected by fuses on the secondary sized at the secondary conductor ampacity. Due to transformer primary energization inrush current, overcurrent protective devices on the primary may not be able to be sized low enough to meet the requirements of 450.3 and provide protection to the secondary conductors.

Motor Circuit Conductor Protection

Motors and motor circuits have unique operating characteristics and circuit components, and therefore must be dealt with differently than other type loads. Generally, two levels of overcurrent protection are required for motor branch circuits:

1. Overload protection – Motor running overload protection is intended to protect the system components and motor from damaging overload currents.
2. Short-circuit protection (includes ground fault protection) – Short-circuit protection is intended to protect the motor circuit components such as the conductors, switches, controllers, overload relays, etc., against short-circuit currents or grounds. This level of protection is commonly referred to as motor branch circuit protection.

Frequently, due to inherent limitations in various types of overcurrent device for motor application, two or more separate protective devices are used to provide overload protection and short-circuit protection. An exception is the dual-element fuse. For most motor applications, the beneficial features of dual-element fuse characteristic allow sizing of the Fusetron™ Class RK5 fuses to provide both protection functions for motor circuits.

Application Considerations



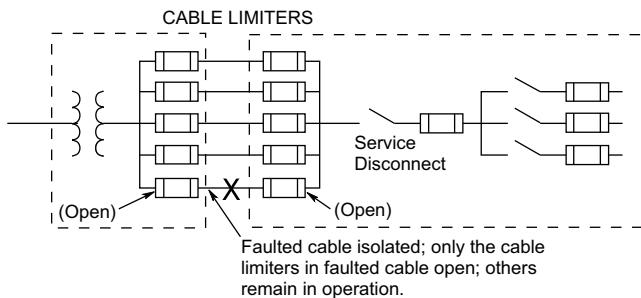
Cable Limiters

Cable limiters are distinguished from fuses by their intended purpose of providing only short-circuit response; they are not designed to provide overload protection. Typically, cable limiters are selected based on conductor size. They are available in a wide range of types to accommodate the many conductor sizes, copper or aluminum conductors and a variety of termination methods. There are two broad categories of cable limiters:

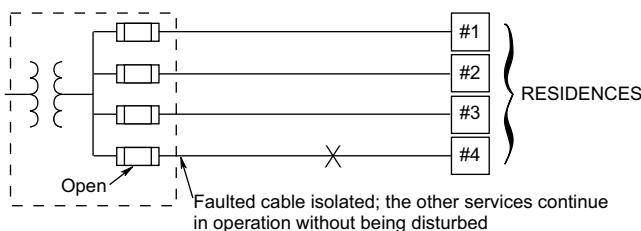
1. 600V or less rated - for large commercial, institutional and industrial applications.
2. 250V or less rated - for residential and light commercial applications.

In institutional, commercial and industrial systems, cable limiters are used at both ends of each cable on three or more cables per phase applications between the transformer and switchboard, as illustrated in the diagram and photographs.

Commercial/Industrial Service Entrance With Multiple Cables Per Phase



In residential systems, the cable limiters are normally installed on a single cable per phase basis at the source end of the lateral feeder to each residence.



Residential Service Entrance With Single Cables Per Phase

Cable limiters may be located on the supply side of the service disconnecting means. The advantages of using cable limiters on the supply side of the service disconnect are multi-fold:

1. Isolation of one or more faulted cables. Only the affected cable(s) are removed from service by the cable limiters at each end opening, (assuming three or more cables per phase, with cable limiters on each end).
2. The isolation of a faulted cable permits the convenient scheduling of repair service.
3. The hazard of equipment burnout due to a fault on the lineside of the main overcurrent protective device is greatly reduced. Typically, without cable limiters, a fault between the transformer and service switchboard is given little or no protection.
4. Their current-limiting feature can be used to minimize arc flash hazards by reducing the magnitude of the arc flash current and the time of the arc flash exposure. There are many different cable limiters available for cables from 12 AWG to 1000 kcmil and many different type terminations. Below is the listing of those most commonly used.

Copper Cable Limiter — 600V

Catalog Symbol	Cable Size	Catalog Symbol	Cable Size
KCY	4 AWG	KCF	4/0 AWG
KCZ	3 AWG	KCH	250 kcmil
KCA	2 AWG	KCJ	350 kcmil
KCB	1 AWG	KCM	500 kcmil
KCC	1/0 AWG	KCV	600 kcmil
KCD	2/0 AWG	KCR	750 kcmil
KCE	3/0 AWG	KCS	1000 kcmil

Tubular Terminal and Offset Bolt-Type Terminal

KQV	12 AWG	KDD	2/0 AWG
KQT	10 AWG	KDE	3/0 AWG
KFZ	8 AWG	KDF	4/0 AWG
KIG	6 AWG	KDH	250 kcmil
KDY	4 AWG	KDJ	350 kcmil
KDA	2 AWG	KDM	500 kcmil
KDB	1 AWG	KDU	600 kcmil
KDC	1/0 AWG	KDR	750 kcmil

Compression Connector Rod Terminal and Tubular Terminal

KEX	4/0 AWG	KQO	350 kcmil
KFH-A	250 kcmil	KDT	500 kcmil
*Center Bolt-Type Terminal and Off-Set Bolt-Type Terminal			
KPF	4/0 AWG	KDP	500 kcmil
KFT	250 kcmil	KFM	750 kcmil
KEW	350 kcmil		

*Copper or aluminum cable; sizes of all other limiters pertain to copper only.

Cable Limiter Data Sheet No. 1042

Application Considerations



The middle, lineside conductor to this disconnect became loose. The loose connection created an excessive thermal condition that caused excessive damage to the device termination, the middle conductor and the adjacent conductors.

Conductor & Termination Considerations

A fuse, as well as a circuit breaker, is part of a system where there are electrical, mechanical and thermal considerations. All three of these are interrelated. If there is too much electrical current for the circuit, the components can overheat. If a conductor termination is not properly torqued, the termination can be a "hot spot" and contribute excess heat. This additional heat is detrimental to the integrity of the termination, conductor insulation and even the overcurrent protective device. If the conductor size is too small for the circuit load or for the fuse/termination or circuit breaker/termination rating, the undersized conductor will be a source of excess heat, which can damage the device.

How important is the proper conductor size and proper termination methods? Both are critical! Many so called "nuisance" openings of overcurrent protective devices or device failures can be traced to the root causes of improper termination methods or improper conductor sizing. Poorly made or improper electrical connections can result in fire or other damage to property, and can cause injury and death. If there are loose terminal connections, then:

- The conductor overheats and the conductor insulation may break down. This can lead to a fault; typically line-to-ground. If conductors of different potential are touching, the insulation of both may deteriorate and a phase-to-neutral or phase-to-phase fault occurs.



- Arcing can occur between the conductor and lug. Since a poor connection is not an overload or a short-circuit, the overcurrent protective device does not operate.
- The excessive heat generated at the conductor termination increases the temperature beyond the thermal rating of the fuse clip material. The result is that the fuse clip can lose its spring tension, which can result in a hot spot at the interface surface of the fuse and clip.

- These excessive thermal conditions described above may cause the device (block, switch, fuse, circuit breaker, etc.) insulating system to deteriorate, which may result in a mechanical and/or electrical breakdown. For instance, the excessive thermal condition of a conductor termination at a circuit breaker can degrade the insulating case material or fuse block material may carbonize due to the excessive thermal conditions over a long time.

Normally, a fuse is mounted in a fuse clip or bolted to a metal surface. It is important that the two metal surfaces (such as fuse to clip) are clean and mechanically tight so that there is minimal electrical resistance at this interface. If not, this interface will be a high resistance connection, which can lead to a hot spot. With a fuse clip application, the temperature rise from a poor clip can cause even further deterioration of the clip tension. This results in the hot spot condition getting worse.



The fuse clip on the right has excellent tension that provides a good mechanical and electrical interface (low resistance) between the fuse and clip. The clip on the left experienced excessive thermal conditions due to an improper conductor termination or undersized conductor. As a result, the clip lost its tension. Consequently, the mechanical and electrical interface between the fuse and clip was inadequate which further accelerated the unfavorable thermal condition.

Some Causes of Loose Terminal Connections

Below are some possible causes of loose terminal connections for various termination methods and possible causes of excessive heating of the overcurrent protective device / termination / conductor system:

1. The conductor gauge and type of conductor, copper or aluminum, must be within the connector's specifications. Terminals are rated to accept specific conductor type(s) and size(s). A conductor that is too large or too small for the connector will result in, a poor connection. Additionally, it must be verified that the terminal is suitable for aluminum conductor, copper conductor or both. Usually the termination means is rated for acceptable conductor type(s) and range of conductor sizes; these ratings may be marked on the device (block, switch, circuit breaker, etc.) or specified on the data sheet.
2. The connector is not torqued to the manufacturer's recommendation. Conductors expand and contract with changes in temperature due to load. If the connections are not torqued appropriately, loose connections may result after a number of expansion/contraction cycles. For a mechanical screw, nut, bolt or box lug type connection, follow the manufacturer's recommended torque. Typically the specified torque for a connector is marked on the device. For a specific connector, the specified torque may be different for different wire sizes. At the end of this section see more information on torquing terminations.
3. The conductor is not crimped appropriately. A poor crimp could be between the conductor and a ring terminal. It could be between the conductor and the quick-connect terminal. Or, it could be between the conductor and an in-line device. If using a compression connection, use the manufacturer's recommended crimp tool with the proper location and number of crimps.

Application Considerations

4. The quick-connect terminal is not seated properly. If the male-female connections are not fully seated, a hot spot may be created.
5. The quick-connect terminal is being used beyond its amp rating. Quick-connects typically have limited continuous current ratings that must not be exceeded. Typical maximum ratings possible for a quick-connect are 16 or 20A (some are less); this is also based on a proper conductor size, too. If the quick-connect is used beyond its amp rating, excessive temperature will result which can degrade the quick-connect's tension properties, leading to ever increasing temperatures until the device fails.
6. The conductor is not properly soldered to a solder terminal. Again, if there is not a good connection between the two, a hot spot will be created.
7. The terminal is only rated to accept one conductor, but multiple conductors are being used. Again, the product specifications must be checked to see if the terminal is rated for dual conductors. If the product is not marked suitable for dual conductors, then only one conductor can be used for this termination. Inserting too many conductors will cause a poor connection, which can result in overheating at the connector.
8. The terminal is not rated for the type finely stranded conductor used. The common electrical connectors and terminals for electrical equipment are rated to accept conductors with the number of strands not exceeding Class B and Class C stranding. If conductors with finer stranding are used, the connectors and terminals must be suitable and identified for the specific stranded conductor class(es). See NEC® 110.14 for the requirement and NEC® Chapter 9 Table 10 for the number of strands for Class B and Class C stranded conductors.

Properly Torque Terminations

Proper conductor termination installation and maintenance practices are to properly torque during conductor initial installation and then to periodically conduct visual and thermal inspections (such as infrared scan).

When installing a conductor into a termination, applying the device manufacturer's specified torque for the type and size conductor is critical. The specified torque value ensures the proper force is being applied on the conductor in the termination resulting in a low contact resistance. Applying a torque value below the manufacturer's specified value can result in a higher resistance at the conductor termination. A higher resistance may result in excessive heat at the conductor termination when conducting current, which causes damage to the conductor and device. Applying a torque value in excess of that specified can result in damage to the termination device and/or the conductor.

Therefore, when installing conductors it is important to use a calibrated torque tool and torque to the device manufacturer's specification. A device's conductor termination specified torque values typically are on the device label – see example label below. However, these specifications may be in the instructions or datasheet. The conductor termination torque values are part of the testing and listing procedures when a manufacturer's device is evaluated for compliance to product standards by a nationally recognized testing laboratory. NEC 110.3(B) requires installing the equipment to the torque values that were used in the listing or labeling of the product.

18-10AWG(1-2.5mm) Single & Dual 20lbin (2.26Nm)
8-6AWG(3.15-4mm) Single & Dual 35lbin (3.95Nm)
4AWG(5mm) single 35lbin (3.95Nm)
75C, CU ONLY, SAME AWG & TYPE FOR DUAL

If all connections were properly torqued, many electrical device failures would not occur. The installer needs to ensure a proper conductor termination.

Without using a calibrated torque measurement tool and the device manufacturer's specified torque value for the type and gauge conductor, how can a reliable installation be assured? Through recent surveys conducted at various electrical industry events, it was found that approximately 75% of the terminations performed without a torque measuring tool do not come within plus or minus 20% of the manufacturer's recommendations. With this knowledge, it becomes apparent that there is a need to concentrate on ensuring proper termination methods by using installation tools that measure torque.

What about periodically checking the conductor termination by checking the torque or just retightening? Look to the 2011 NEC® Informative Annex I: "Because it is normal for some relaxation to occur in service, checking torque values sometime after installation is not a reliable means of determining the values of torque applied at installation."

It is often assumed that terminations inevitably become loose after extended cycling of a system or just through time in service. After all, it is a physical property of all metals that they have a certain amount of relaxation, and it is perceived that this relaxation is a cause of concern. However, manufacturers have taken these physical properties into account through their testing and design. If equipment, conductors, and terminations are used in applications for which they are designed and listed and if the termination is tightened to the proper torque value during installation, then the connection will remain within its required values. However, note that conductor termination devices must be suitable for the application. For instance, many common conductor termination devices are not suitable for applications with vibrations, such as at the terminals of a generator.

When a loose conductor termination has resulted in thermal damage to the conductor at and near the termination, remove the conductor from the terminal. First determine if the terminal is suitable for further use. Stripped threads are not suitable for use and terminal discoloration may be an indication the terminal is not suitable for further use. If terminal is suitable for further use, cut the damaged portion from the conductor, and reinstall the conductor using a calibrated torque tool set to the proper torque value.

Improper overcurrent protection can be a root cause of conductor termination damage. Conductors can become loose under screws or lugs if they have carried excessive amounts of short-circuit current. High fault current can result in high mechanical forces causing conductor movement which degrades the contact points between the conductors and terminal devices. In addition, the excessive heat generated caused by the fault current flowing through the conductor/termination contact points contributes to the problem. Since the conductor is deformed at the time of conductor termination, the portion of the conductor at the termination that is damaged due to a short-circuit current needs to be cut off and the conductor properly re-terminated in order to allow for the creation of new contact points. Unfortunately, terminated conductor damage due to fault current may not manifest as a problem condition until long after the fault has been repaired. Current-limiting fuses, properly applied, prevent terminated conductor damage due to fault currents.

Terminal and Conductor Temperature Ratings

There are several important factors in the electrical and thermal relationship for circuit components, including the conductor size, conductor rated ampacity, conductor insulation temperature rating and the permissible connector, device, and equipment temperature limits. Conductors have specified maximum ampacities that are based on many variables including the size of the conductor and its insulation temperature rating. The NEC® establishes the allowable ampacity of conductors for various variables and applications. In

Application Considerations

addition, there are some overriding requirements in the NEC® and product standards that dictate the ampacity of conductors when connected to terminals. For instance, the ampacity for a conductor with 90°C insulation is generally greater than the ampacity of a conductor of the same size but with 60°C insulation. However, the greater ampacity of a conductor with 90°C insulation is usually not permitted to be used due to limitations of the terminal temperature rating and/or the requirements of the NEC®. (Reference 110.14 in the NEC® for specific requirements.) However, there are some simple rules to follow for circuits of 100A and less. These simple rules usually apply because these are the norms for the device component product standards and performance evaluation to these standards for fuses, blocks, disconnects, holders, circuit breakers, etc.

Simple rules for 100 amps and less:

1. Use 60°C rated conductors [110.14(C)(1)(a)(1)]. This assumes all terminations are rated for 60°C rated conductors.
2. Higher temperature rated conductors can be used, but the ampacity of these conductors is limited to the value in the 60°C column because the termination temperature is only 60°C. [110.14(C)(1)(a)(2)]. For instance, assume an ampacity of 60A is needed in a circuit that has terminations that are rated for 60°C conductors. If a 90°C copper conductor is used, what is the minimum conductor size required?

Wire Size (Copper)	60°C Ampacity	90°C Ampacity
6 AWG	55	75
4 AWG	70	95

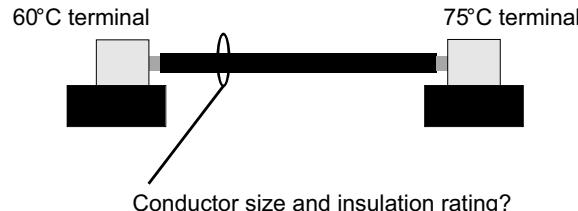
The answer is 4 AWG. A 6 AWG, 90°C conductor has an ampacity of 75 amps per (NEC® Table 310.15(B)(16)); but this ampacity can not be used for a 60°C termination. For the example circuit above, if a 90°C, 6 AWG conductor is evaluated, the ampacity of the conductor would be limited to the 60°C conductor ampacity, which is 55A. (Ampacities are from NEC® Table 310.15(B)(16).)
3. Conductors with higher temperature ratings can be used at their rated ampacities if the connectors, circuit devices and equipment are all rated for the higher temperature rated conductor [110.14(C)(1)(a)(3)]. However, the industry norm is that most devices rated 100A or less, such as blocks, disconnects and circuit breakers, have 60°C or 75°C rated terminations. Panelboards are typically listed at 75°C rated terminations.
4. For motors with design letters B, C or D, conductors with insulation rating of 75°C or higher are permitted as long as the ampacity of the conductors is not greater than the 75°C rating [110.14(C)(1)(a)(4)]. Note that in order to use the 75°C ampacity, the termination at the other end at the conductor must also be rated 75°C.
5. If a conductor is run between two devices that have terminals rated at two different temperatures, the rules above must be observed that correlate to the terminal with the lowest temperature rating.

For circuits greater than 100A, use conductors with at least a 75°C insulation rating at their 75°C ampacity rating.

So why would anyone ever want to use a conductor with a 90°C or a 105°C rating if they can't be applied at their ampacity ratings for those temperatures? The answer lies in the fact that those higher ampacity ratings can be utilized when derating due to ambient conditions or due to exceeding more than three current carrying conductors in a raceway.

Example (ampacity and derating tables next page)

Circuit ampacity required: 60 amps
Ambient: 45°C



Assume that an ampacity of 60A is needed in a circuit with a 75°C termination at one end and a 60°C termination at the other end, where the ambient is 45°C. First, since one termination temperature rating is higher than the other, the lowest one must be used to determine ampacity, which is 60°C. The first choice might be a 4 AWG TW conductor with an ampacity of 70A at 60°C. However, the NEC® the Correction Factors Table 310.15(B)(2)(a) reveals that the 70A ampacity must be derated, due to the 45°C ambient, by a factor of 0.71. This yields a new ampacity of 49.7A, which is less than the required 60A. This is where a conductor with a higher temperature rating becomes useful. A 4 AWG THHN conductor has a 90°C ampacity of 95A. Again, looking at Table 310.15(B)(2)(a), a factor of .87 must be used, due to the 45°C ambient. This yields a new ampacity of 82.65, which is adequate for the required 60A ampacity.

Could a 6 AWG THHN conductor be used in this application? Its 90°C ampacity is 75A. Using the factor of 0.87 for the 45°C ambient gives a new ampacity of 65.25, which seems adequate for a required ampacity of 60A. However, a 6 AWG conductor of any insulation rating could never be used in this application because the 60°C terminal requires that the smallest conductor size is a 4 AWG for a 60A ampacity (simple rule 2 in previous paragraphs). The use of smaller conductor would not conduct enough heat away from the terminal, and therefore overheating problems could result.

Application Considerations

Allowable Ampacities

The table below shows the allowable ampacities of insulated copper conductors rated 0 through 2000 volts, 60°C through 90°C, not more than three current-carrying conductors in a raceway, cable, or earth (directly buried), based on ambient of 30°C (86°F) (data taken from NEC® Table 310.15(B)(16)). The note for 14, 12 and 10 AWG conductors is a very important note that limits the protection of these conductors.

Conductor Size AWG	Ampacity For Temperature Rated Copper Conductors (NEC® Table 310.16)		
	60 C	75 C	90 C
14*	20*	20*	25*
12*	25*	25*	30*
10*	30*	35*	40*
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	110
2	95	115	130
1	110	130	150

*See NEC® 240.4(D) which essentially limits (with several exceptions) the overcurrent protection of copper conductors to the following ratings after any correction factors have been applied for ambient temperature or number of conductors: 18 AWG - 7A, 16 AWG - 10A, 14 AWG - 15A, 12 AWG - 20A, 10 AWG - 30A. Depending on the circumstances of a specific application, the ampacity determined due to the correction factors may be less than the values in Table 310.15(B)(16). In those cases, the lower value is the ampacity that must be observed. For instance, a 75°C, 10AWG in 50°C ambient would have a derating factor of 0.75, which results an ampacity of 26.25 (35A x 0.75). So in this case, the ampacity would be 26.25. Since 26.25 is not a standard size fuse per NEC® 240.6, NEC® 240.4(B) would allow the next standard fuse, which is a 30A fuse. The 30A fuse is in compliance with 240.4(D). In a 35°C ambient, the correcting factor for this same conductor is 0.94, so the new ampacity is 32.9A (35A x 0.94). However, a 35A fuse can not be utilized because NEC® 240.4(D) limits the protection to 30A.

Note on 18 & 16 AWG Conductors

The 2008 National Electrical Code® added provisions for protection of 18 and 16 AWG conductors in 240.4(D). The 2011 National Electrical Code® then recognized these smaller conductors for the protection of certain motor circuits in 430.22(G). Although these actions themselves do not permit the use of these smaller conductors for power circuits in all applications they do provide criteria for proper overcurrent protection should future articles include their use in other applications. *NFPA-79 Electrical Standard for Industrial Machinery* does permit the use of 18 and 16 AWG conductors for industrial machinery, and that was the basis for the changes to Articles 240 and 430. For more detail on the application of small conductors see Component Protection-Wire & Cable-16 and 18 AWG Conductors For Industrial Machinery Power Circuits.

Ambient Derating

The general rule is that conductor allowable ampacities based on Tables 310.15(B)(16) or 310.15(B)(17) must be derated when a conductor is in temperature ambient greater than 30°C. In this case, the correction factors are in Table 310.15(B)(2)(a), which is shown after this paragraph. Conductor

allowable ampacities based on Tables 310.15(B)(18), 310.15(B)(19), 310.15(B)(20), and 310.15(B)(21) must be derated when a conductor is in temperature ambient greater than 40°C and Table 310.15(B)(2)(b) provides these correction factors.

Conductor Ampacity Correction Factors For Ambient Temperatures Based on 30°C.

Ambient Temp. C	For ambient other than 30 C, multiply conductor allowable ampacities by factors below (NEC® Table 310.16)			Ambient Temp. F
	60 C	75 C	90 C	
21-25	1.08	1.05	1.04	70-77
26-30	1.00	1.00	1.00	78-86
31-35	0.91	0.94	0.96	87-95
36-40	0.82	0.88	0.91	96-104
41-45	0.71	0.82	0.87	105-113
46-50	0.58	0.75	0.82	114-122
51-55	0.41	0.67	0.76	123-131
56-60	—	0.58	0.71	132-140
61-70	—	0.33	0.58	141-158
71-80	—	—	0.41	159-176

From NEC® Table 310.15(B)(2)(a)

Conduit Fill Derating

Also, conductor ampacity must be derated when there are more than three current-carrying conductors in a raceway or cable per NEC® 310.15(B)(3). There are several exceptions; the derating factors are:

# Of Current-Carrying Conductors	% Values in NEC® Ampacity Tables 310.15(B)(16) to 310.15(B)(19) As Adjusted for Ambient Temperature if Necessary
4 - 6	80
7 - 9	70
10 - 20	50
21 - 30	45
31 - 40	40
41 & greater	35

Termination Ratings

As discussed above, terminations have a temperature rating that must be observed and this has implications on permissible conductor temperature rating and ampacity. Shown below are three common termination ratings and the rules. Remember, from the example above, the conductor ampacity may also have to be derated due to ambient, conduit fill or other reasons.

60°C	Can use 60°C, 75°C, 90°C or higher temperature rated conductor, but the ampacity of the conductor must be based on 60°C column.
75°C	Can use 75°C, 90°C or higher temperature rated conductor, but the ampacity of the conductor must be based on 75°C column. A 60°C conductor is not permitted to be used.
60°C/75°C	Dual temperature rated termination. Can use either 60°C conductors at 60°C ampacity or 75°C conductors at 75°C ampacity. If 90°C or higher temperature rated conductor is used, the ampacity of the conductor must be determined as if conductor is rated 75°C.

Listed or Labeled Equipment

Listed or labeled equipment must be installed in accordance with instructions included in the listing or labeling [110.3(B)]. Be sure to observe maximum branch circuit fuse size labels. When the equipment label is marked with a maximum fuse amp rating rather than marked with maximum overcurrent device amp rating, only fuses can be used for protection of this equipment.

Panelboards

Each panelboard must be individually protected within the panelboard or on the supply side by an overcurrent protective device having a amp rating not greater than the panelboard (408.36). Exception No. 1: Individual protection is not required when the panelboard is used as service equipment in accordance with 230.71, where the panelboard is protected by three or more sets of fuses, those fuses shall not supply a second bus structure within the panelboard assembly. Exception No. 2: individual protection is not required when the panelboard is protected on its supply side by two main sets of fuses which have a combined rating not greater than the panelboard. Panelboards wired under this exception shall contain a maximum of 42 overcurrent protective devices. Exception No. 3: For existing panelboards used as service equipment on individual residential occupancies, individual protection is not required.

Panels with snap switches rated at 30A or less must be protected by fuses not larger than 200A [408.36(A)]. Fusible panelboards are available with heavy duty toggle switches rated more than 30A; these panelboards are not restricted by this 200A requirement. If the panelboard is supplied through a transformer, the fuses for the protection of the panelboard must be located on the transformer secondary [408.36(B)] except where the fuse on the primary complies with 240.21(C)(1). [408.36(B) Exception]

Quik-Spec™ Coordination Panelboard

The Bussmann Quik-Spec™ Coordination Panelboard which is a fusible branch circuit lighting panel offers the benefits inherent with fuse protection for building electrical systems. This innovative panel offers numerous advantages over other commercially available panelboards including simplified selective coordination with upstream fuses when the published Fuse Selectivity Ratios are followed. For more information see the Bussmann website at www.cooperbussmann.com/quik-spec.



Appliances

Appliance branch circuits shall be protected in accordance with 240.5. If a fuse rating is marked on an appliance, the branch circuit fuse rating cannot exceed that rating marked on the appliance [422.11(A)]. See 430.6(A)(1) exception

No.3 for situations where the appliance is marked with both a horsepower rating and an amp rating.

For branch circuits which supply a single non-motor operated appliance rated more than 13.3A, the fuse rating shall not exceed 150% of the appliance rating [422.11(E)(3)].

Electric heating appliances using resistance heating elements rated more than 48A shall have the heating elements subdivided such that each subdivision does not exceed 48 amps and each subdivision shall be protected by a branch circuit listed fuse not to exceed 60A in rating. These fuses shall be factory installed by the heater manufacturer, be accessible and be suitable for branch circuit protection [422.11(F)(1)].

Fixed appliances are considered protected when supplied from 15, 20, 25, or 30A branch circuits. Fixed cooking appliances are permitted to be protected by 40 or 50A branch circuits (210.23(C)). Household appliances with surface heating elements that have a maximum rating greater than 60A must be divided into two or more circuits, each of which is protected by a fuse of no greater than 50A [422.11(B)].

Portable appliances are considered as protected when supplied from a 15, 20A, or 30A branch circuit (210.23).

Supplementary Protection

Supplementary overcurrent protection is permitted by the National Electrical Code® for specific uses such as in lighting fixtures, appliances and other equipment or for certain internal control circuits, and components of equipment. This type of protection must not be used as a substitute for branch circuit protection as described in Article 210. This type of protection is not required to be readily accessible as are branch circuit devices. There are a wide variety of supplementary fuses and fuse holders, which have small physical dimensions and are easily installed in or on equipment, appliances or fixtures. The advantages of supplementary protection are closer fuse sizing for better individual protection, isolation of equipment on overcurrents so that the branch circuit fuse is not disturbed, ease in locating troubled equipment and generally direct access to the fuse at the location of the equipment. For instance, the in-line fuse and holder combination, such as the Type HLR fuse holder with Type GLR or GMF fuses, protects and isolates fluorescent lighting fixtures in the event of an overcurrent.

The Tri-National Standard for supplementary fuses is UL/CSA/ANCE 248-14. When supplementary overcurrent protective devices are considered for proper use, it is important (1) not to use these devices as a substitute for branch circuit protection and (2) to be sure that the device's interrupting rating equals or exceeds the available short-circuit current (see the discussion for 110.9 in this publication).

Industrial Control Panels

Article 409 covers the installation requirements for industrial control panels. As noted in 409.1, UL 508A is the product safety standard for industrial control panels.

The NEC® defines an industrial control panel per 409.2 as an assembly of two or more components consisting of one of the following:

- Power circuit components only
- Control circuit components only
- Combination of power and control circuit components

The components and associated wiring and terminals are mounted on a subpanel or contained in an enclosure. Industrial control panels do not include the controlled equipment.

Power circuit components carry main power current to loads such as motors, lighting, heating, appliances and general use receptacles. Control circuits, as defined per 409.2, carry the electric signals directing the performance of the controller but do not carry the main power current.

Overcurrent protection is required to be provided per 409.21 ahead of the industrial control panel or by a single main overcurrent protective device within the panel.

409.110 requires the industrial control panel to be marked with the following:

- Manufacturer
- Voltage, number of phases, frequency and full-load current for each supply circuit
- Short-circuit current rating based on listing and labeling of the assembly or an approved method such as UL 508A, Supplement SB. If the panel only contains control circuit components (i.e., no power circuit components), a short-circuit current rating marking is not required.

See the Industrial Control Panel - SCCR section in this publication.

Industrial Machinery

Article 670 covers the installation requirements for industrial machinery. As noted in 670.1, NFPA 79 is the electrical standard for industrial machinery.

670.2 defines industrial machinery as a power driven machine (or group of machines), not portable by hand while working, which is used to process material. It can include associated equipment used to transfer material or tooling, to assemble/disassemble, to inspect or test, or to package. The associated electrical equipment is considered as part of the industrial machine.

670.3(A) requires the industrial machinery to be marked with the following:

- Voltage, number of phases, frequency and full-load current for each supply circuit
- Maximum amp rating of the short-circuit and ground-fault protective device
- Amp rating of the largest motor
- Short-circuit current rating based on listing and labeling of the assembly or an approved method such as UL 508A, Supplement SB.

670.4(B) requires a disconnecting means. If overcurrent protection is included with the disconnecting means, it is required to be marked as such per 670.3(B). Overcurrent protection is required to be provided and sized in accordance with 670.4(C) ahead of the industrial control panel or by a single main overcurrent protective device within the panel.

To determine the SCCR of an industrial machine control panel, see Industrial Control Panel - SCCR in this publication.

Air Conditioning and Refrigeration

Air conditioning and refrigeration equipment requirements are covered in Article 440 of the National Electrical Code®. Hermetic motor-compressors are not rated in "full load amps" as are standard motors. Instead, different terms are used, such as rated load current, branch circuit selection current, maximum continuous current, minimum circuit ampacity, and maximum overcurrent protection. This equipment has overcurrent protection requirements that differ from that for ordinary motors covered in Article 430. Some highlights are presented here.

Branch Circuit Protection HVAC

Individual Motor-Compressor(s) and HVAC Equipment Having Motor-Compressor(s) and Other Loads (Such as fan motors, electric heaters, coils, etc.).

Fuses sized for branch circuit protection only must not exceed 175% of the hermetic motor-compressor rated load current or branch circuit selection current (whichever is larger). If this size fuse cannot withstand the motor starting current, a higher amp rating is permitted, but in no case can the fuse size exceed 225% [440.22(A)].

Low-Peak™ dual-element and Fusetron™ dual-element fuses are recommended for branch circuit protection of air conditioning and refrigeration hermetic motor-compressors because these fuses have an adequate time-delay for motor starting surges.

Refer to the nameplate on the equipment. The sizing (amp rating) for the overcurrent protection has been determined by the manufacturer of the equipment. It is not necessary to apply any further multipliers to arrive at the proper size. This has already been done by the manufacturer.

The marked protective device rating is the maximum protective device rating for which the equipment has been investigated and found acceptable by nationally recognized testing laboratories.

See "Listed or Labeled Equipment" for requirement when nameplate states Maximum Size Fuse. This is a critical requirement, and must be followed without exception to be in compliance with 110.3(B) of the Code. NEC® 110.3(B) requires that listed or labeled equipment must be installed in accordance with any instructions included in the listing or labeling.

Disconnecting Means

(Individual hermetic motor compressor)

The amp rating of the disconnect shall be at least 115% of the compressors rated load current or branch circuit selection current, whichever is greater [440.12(A)(1)]. 440.12(A)(1) Exception permits a nonfused disconnect rated less than 115% of the specified current if this disconnect has a horsepower rating not less than the equivalent horsepower rating per 440.12(A)(2).

The equivalent horsepower rating to comply with 430.109 can be obtained by taking the larger horsepower value from: (1) NEC® Tables 430.248, 430.249 or 430.250 using the greater of either the rated load current or the branch circuit selection current to select the corresponding horsepower rating, or (2) horsepower rating from Tables 430.251(A) and 430.251(B) corresponding to the locked-rotor current. For both preceding (1) and (2), if the value falls between two horsepower ratings in a table, the equivalent horsepower rating to use is the larger of the two; i.e., round up to the larger Hp. [440.12(A)(2)].

Disconnecting Means

(Equipment that has hermetic motor-compressor and other loads)

The amp rating of the disconnecting means must be at least 115% of the sum of all of the individual loads within the equipment at rated load conditions [440.12(B)(2)]. 440.12(B)(2) Exception permits a nonfused disconnect rated less than 115% of the sum of all the individual loads if the disconnect has a horsepower rating not less than the equivalent horsepower rating per 440.12(B)(1).

The horsepower rating of the disconnecting means must be at least equal to the equivalent horsepower determined per 440.12(B)(1) which accounts for all the individual loads with the equipment at rated load conditions.

Controller

The controller for a hermetic motor-compressor must have a continuous duty full load current rating not less than the nameplate rated current or branch circuit selection current (whichever is larger) [440.41] and the controller must also have a locked rotor current rating equal to or greater than the locked rotor current of the compressor [440.41(A)]. Where the controller serves a hermetic motor-compressor(s) plus other loads, the controller rating is determined according to 440.12(B), in much the same manner as determining the disconnecting means rating. It may be necessary to refer to Tables 430.251(A) and (B) to convert locked rotor current values to horsepower.

The branch circuit protective device rating shall not exceed the maximum protective device rating shown on a manufacturer's heater table for use with a given motor controller [440.22(C)]. Where the equipment is marked Maximum Size Fuse amp rating rather than stating Maximum Overcurrent Device amp rating, only fuses can be used for the branch circuit protection.

Marked Short-Circuit Current Rating - New Air Conditioning and Refrigeration Equipment with Multimotor and Combination-Loads

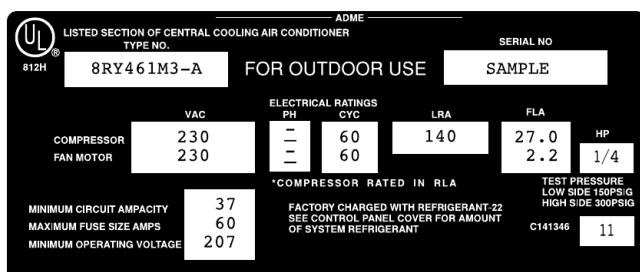
440.4(B) Requires the nameplate of this equipment to be marked with its short-circuit current rating. There are exceptions for which this requirement does not apply to this equipment:

- One and two family dwellings
- Cord and attachment-plug connected equipment
- Or equipment on a 60A or less branch circuit

So for most commercial and industrial applications, air conditioning and refrigeration equipment with multimotor and combination loads must have the short-circuit current rating marked on the nameplate. This facilitates the inspection and approval process. Inspectors need this information to ensure that NEC® 110.10 is met. A potential hazard exists where the available short-circuit current exceeds the short-circuit current rating. For more information, see the Assembly Short-Circuit Current Rating section in this publication or Short-Circuit Current Rating web page on www.cooperbussmann.com.

Room Air Conditioners

Room air conditioners (hermetic refrigerant motor-compressor) installed in the conditioned room are considered as single-motor units when the conditions of 440.62 are met. This condition also applies to conditioners containing a heating unit. Branch circuit requirements are determined by nameplate rating [440.62].



Because of all the fires caused by mistreated cords, single-phase cord-and-plug connected room air conditioners are now required to have either an AFCI (arc-fault circuit interrupter) or a LCDI (leakage current detection and interruption) attached to the plug.

Electric Heat

Electric space heating equipment employing resistance type heating elements, rated more than 48A, must have heating elements subdivided. Each subdivided load must not exceed 48A, and the fuse for each load should not exceed 60A [424.22(B)]. If a subdivided load is less than 48A, the fuse rating should be 125% of that load.

Exception: Boilers employing resistance type immersion electric heating elements in an ASME rated and stamped vessel may be subdivided into circuits not exceeding 120A, and protected by a fuse at not more than 150A [424.22(B) and 424.72(A)]. If a subdivided load is less than 120A, the fuse rating should be 125% of that load.

Fusetron™ dual-element fuses in the sizes required above provide protection for electric heat applications (their lower internal resistance offers cooler operation than ordinary fuses).

T-Tron fast-acting fuses (JJN and JJS) in the sizes required above provide protection for electric heat applications and offer small physical size to reduce space and material cost.

Capacitors

The purpose of fusing capacitors is for short-circuit protection. When a capacitor fails, it shorts out. Proper fusing is intended to remove the shorted capacitor from the circuit, prevent the shorted capacitor from rupturing and protect the conductors from damage due to short-circuit current. However, proper fusing must also be sized such that the capacitor can operate normally; that is the fuse should not open due to the normal steady state current or the inrush current when voltage is applied. For example, when the circuit is switched on, a capacitor in the circuit can draw a very high inrush current for a very brief time. Therefore, a capacitor fuse must have the characteristics to not open due to the initial inrush current. Also, the steady state current of a capacitor is directly proportional to the applied voltage; when the voltage increases the capacitor current increases.

A fuse must be provided in each ungrounded conductor (no protection is required for a capacitor connected on the loadside of a motor running overcurrent device). The fuse rating must be as low as practical [460.8(B)]. Generally, size dual-element, current-limiting fuses at 150% to 175% of the capacitor rated current and size non-time delay, fast-acting, current-limiting fuses at 250% to 300% of the capacitor rated current.

Conductor ampacity must be at least 135% of the capacitor rated current [460.8(A)]. The ampacity of conductors for a capacitor connected to a motor circuit must be at least $\frac{1}{2}$ the ampacity of the motor circuit conductors [460.8(A)].

Welders

Arc Welders must be protected by a fuse rated at not more than 200% of the rated primary current. The fuse protecting the supply conductor can serve as the welder protection, if the fuse is rated at not more than 200% of $I_{1\max}$ or the welder rated primary current [630.12(A)]. Conductors supplying one or more welders must be protected by a fuse rated at not more than 200% of the conductor rating [630.12(B)].

Resistance Welders must be protected by a fuse rated at not more than 300% of the rated primary current of the welder. The fuse protecting the supply conductor can serve as the welder protection if the fuse is rated at not more than 200% of the welder rated primary current [630.32(A)]. Conductors supplying one or more welders must be protected by a fuse rated at not more than 300% of the conductor rating [630.32(B)].

Transformers — 1000V or Less

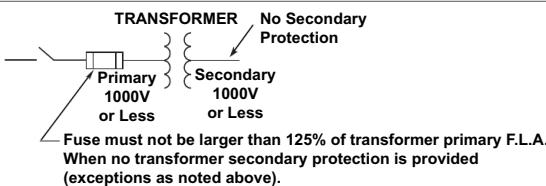
The requirements of 450.3 cover only transformer protection. In practice, other components must be considered in applying circuit overcurrent protection. For circuits with transformers, requirements for conductor protection per Articles 240 and 310 and for panelboards per Article 408, must be observed. Refer to 240.4(F), 240.21(B)(3), 240.21(C), 408.36(B).

Primary Fuse Protection Only [450.3(B)] (see Figure below) If secondary fuse protection is not provided (as discussed in the next Section) then the primary fuses must not be sized larger than as shown below.

Individual transformer primary fuses are not necessary where the primary circuit fuse provides this protection.

Primary Fuse Only

Primary Current	Primary Fuse Rating
9 amps or more	125% or next higher standard rating if 125% does not correspond to a standard fuse size.
2 amps to 9 amps	167% maximum
Less than 2 amps	300% maximum

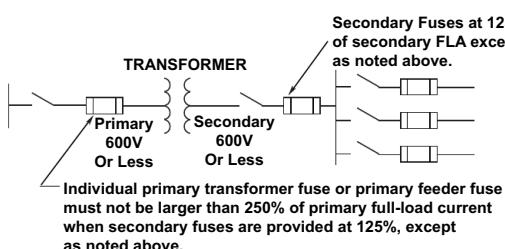


Note: Section 450.3 requirements pertain only to transformer protection. Additional circuit overcurrent protection for conductors or panelboards may be required per Articles 240, 310, 408, 430.72.

* Primary Fuse (600V or less) and Secondary Fuse (600V or less). If secondary (600V or less) fuses are sized not greater than 125% of transformer secondary current, individual transformer fuses are not required in the primary (600V or less) provided the primary feeder fuses are not larger than 250% of the transformer rated primary current. (see Note 3 of Table 450.3(B) for overcurrent protection requirements of thermally protected transformers).

Primary and Secondary Fuses

Secondary Current	Primary Fuse Rating	Secondary Fuse Rating
9 amps or more	250% max.	125% or next higher standard rating if 125% does not correspond to a standard fuse size
Less than 9 amps	250% max.	167% max.



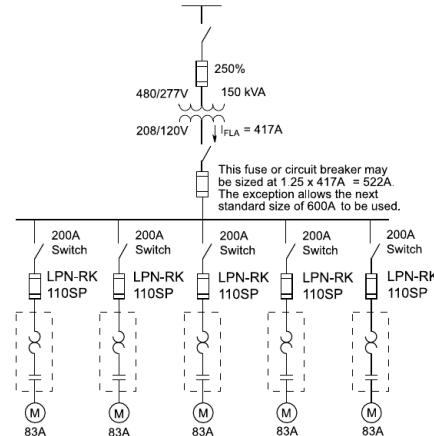
Note: Transformer overload protection will be sacrificed by using overcurrent protective devices sized much greater than the transformer FLA. The limits of 150%, 167%, 250% and 300% may not adequately protect transformers. It is suggested that for the highest degree of transformer overload protection the fuse size should be within 125% of the transformer full load amps.

Normal magnetizing inrush currents for power transformers can range from 10 times to 12 times the transformer full load current, for up to 6 cycles, and as high as 25 times transformer full load current at 0.01 seconds. Some transformers may have inrush magnitudes substantially greater. Severe inrush should be compared with fuse melting times to assure that unnecessary opening of the device does not occur.

There is a wide fuse amp rating range available to properly protect transformers. Fusetron™ Class RK5 and Low-Peak™ Class RK1 dual-element fuses can be sized on the transformer primary and/or secondary rated at 125% of the transformer FLA. These dual-element fuses have sufficient time-delay to withstand the high magnetizing inrush currents of transformers. There is a wide amp rating selection in the 0 to 15A range for these dual-element fuses to provide protection for even small control transformers.

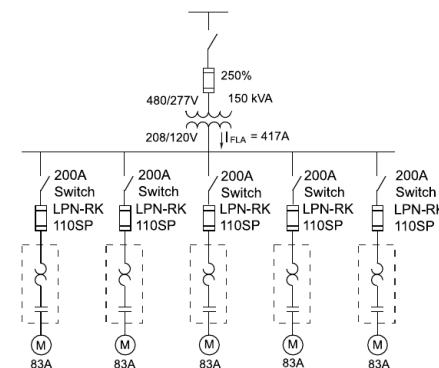
The required secondary protection may be satisfied with multiple overcurrent devices that protect feeders fed from the transformer secondary. The total amp rating of these multiple devices may not exceed the allowed value of a single secondary overcurrent device. If this method is chosen, dual-element, time-delay fuse protection offers much greater flexibility. Note the following examples:

Design 1 Single Secondary Device



Design 1 utilizes a single secondary overcurrent device. It provides the greatest degree of selective coordination, transformer protection, secondary cable protection and switchboard/panelboard/load center protection. The transformer cannot be overloaded to a significant degree if future loads are added (improperly). With this arrangement the transformer's full capacity is utilized.

Design 2 No Single Secondary Device



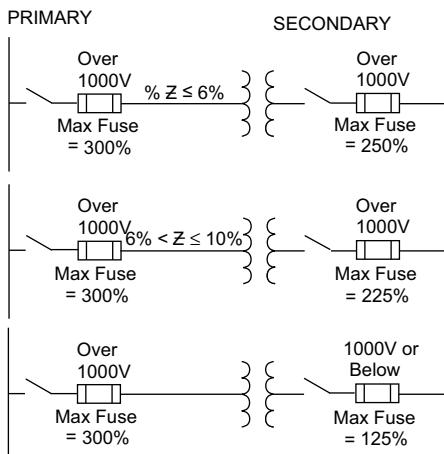
Design 2 In this case the single secondary overcurrent device is eliminated, much of the protection described in Design 1 will be reduced. If dual-element fuses are utilized as branch circuit protection, the transformer can continue to be loaded with the five 83A motors because $5 \times 110 = 550A$, (less than the maximum 600A). If additional loads are improperly added in the future, overload protection will be lost because the primary device can be sized at 250%.

Transformers — Over 1000V

Primary and Secondary Protection

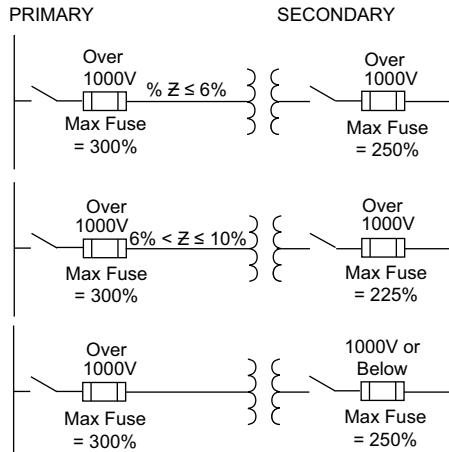
In unsupervised locations, with primary over 1000V, the primary fuse can be sized at a maximum of 300%. If the secondary is also over 1000V, the secondary fuses can be sized at a maximum of 250% for transformers with impedances not greater than 6% or 225% for transformers with impedances greater than 6% and not more than 10%. If the secondary is 1000V or below, the secondary fuses can be sized at a maximum of 125%. Where these ratings do not correspond to a standard fuse size, the next higher standard size is permitted.

Unsupervised Locations



In supervised locations, the maximum ratings are as shown in the next diagram. These are the same maximum settings as the unsupervised locations except for secondary voltages of 1000V or less, where the secondary fuses can be sized at maximum of 250%.

Supervised Locations



Primary Protection Only

In supervised locations, the primary fuses can be sized at a maximum of 250%, or the next larger standard size if 250% does not correspond to a standard fuse size.

Note: The use of "Primary Protection Only" does not remove the requirements for compliance with Articles 240 and 408. See (FPN) in Section 450.3, which references 240.4, 240.21, 240.100 and 240.101 for proper protection for secondary conductors.

E-Rated Fuses for Medium Voltage Potential & Small Power Transformers

Low amperage, E-Rated medium voltage fuses are general purpose current-limiting fuses. A general purpose current-limiting fuse is capable of interrupting all current from the rated interrupting current down to the current that causes melting of the fusible element in 1 hour (ANSI C37.40). The "E" rating defines the melting time-current characteristic of the fuse and permits electrical interchangeability of fuses with the same E-Rating. For a general purpose fuse to have an E-Rating the following condition must be met:

The current responsive element shall melt in 300 seconds at an RMS current within the range of 200% to 240% of the continuous current rating of the fuse, fuse refill or link (ANSI C37.46).

Bussmann low amperage, E-Rated fuses are designed to provide primary protection for potential, small service and control transformers. These fuses offer a high level of fault current interruption in a self-contained non-venting package which can be mounted indoors or in an enclosure.

Application

As for all current-limiting fuses, the basic application rules found in the fuseology section of this publication should be adhered to. In addition, potential transformer fuses must have sufficient inrush capacity to successfully pass through the magnetizing inrush current of the transformer. If the fuse is not sized properly, it will open before the load is energized. The maximum magnetizing inrush currents to the transformer at system voltage and the duration of this inrush current varies with the transformer design. Magnetizing inrush currents are usually denoted as a percentage of the transformer full load current, i.e., 10x, 12x, 15x, etc. The inrush current duration is usually given in seconds. Where this information is available, an easy check can be made on the appropriate Bussmann minimum melting curve to verify proper fuse selection. In lieu of transformer inrush data, the rule of thumb is to select a fuse size rated at 300% of the primary full load current and round up to the next larger standard size.

Example:

The transformer manufacturer states that an 800VA 2400V, single-phase potential transformer has a magnetizing inrush current of 12x lasting for 0.1 second.

$$A. I_{FL} = 800\text{VA}/2400\text{V} = 0.333\text{A}$$

$$\text{Inrush Current} = 12 \times 0.333 = 4\text{A}$$

Since the voltage is 2400 volts we can use either a JCW-1E or JCD-1E.

$$B. \text{Using the rule of thumb--}300\% \text{ of } 0.333\text{A is } 0.999\text{A.}$$

Therefore we would choose a JCW-1E or JCD-1E.

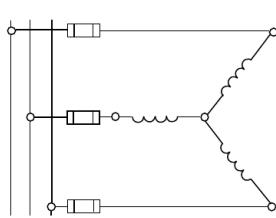
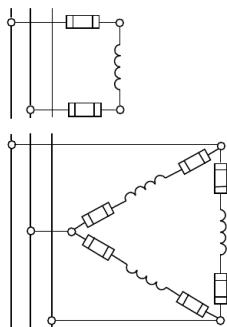
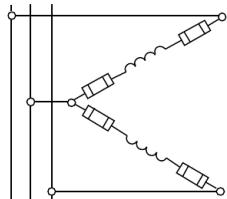
Transformers — Over 1000V

Typical Potential Transformer Connections

The typical potential transformer connections encountered in industry can be grouped into two categories:

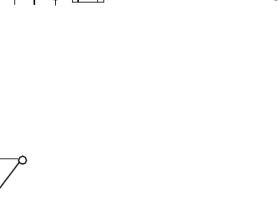
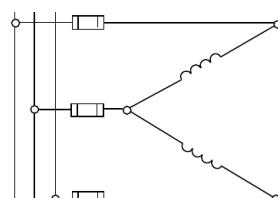
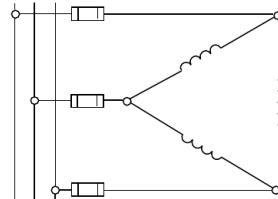
Category 1

1. Those connections which require the fuse to pass only the magnetizing inrush of one potential transformer



Category 2

2. Those connections which must pass the magnetizing inrush of more than one potential transformer



E-Rated Fuses for Medium Voltage Transformers & Feeders

Bussmann E-Rated medium voltage fuses are general purpose current-limiting fuses. A general purpose current-limiting fuse is capable of interrupting all currents from the rated interrupted current down to the current that causes melting of the fusible element in 1 hour (ANSI C37.40). The fuses carry either an 'E' or an 'X' rating which defines the melting time-current characteristic of the fuse. The ratings are used to allow electrical interchangeability among different manufacturers' fuses.

For a general purpose fuse to have an "E" rating, the following conditions must be met:

1. 100E and below - the fuse element must melt in 300 seconds at 200% to 240% of its rating (ANSI C37.46).
2. Above 100E - the fuse element must melt in 600 seconds at 220% to 264% of its rating (ANSI C37.46).



Bussmann E-Rated Medium Voltage Fuse.

A fuse with an 'X' rating does not meet the electrical interchangeability for an "E" rated fuse, but offers the user other ratings that may provide better protection for a particular application.

Application

Transformer protection is the most popular application of E-Rated fuses. The fuse is applied to the primary of the transformer and is used solely to prevent rupture of the transformer due to short-circuits. It is important, therefore, to size the fuse so that it does not clear on system inrush or permissible overload currents. See section on transformers over 600V for applicable sizing recommendations. Magnetizing inrush must also be considered when sizing a fuse. In general, power transformers have a magnetizing inrush current of 12x the full load rating for a duration of $\frac{1}{6}$ second.

Three-Phase Transformers (Or Transformer Bank)

Transformer kVA Rating	System Voltage	4.16kV		4.8kV	
		2.4kV	Full Load Fuse Amps	Full Load Fuse Amps	Full Load Fuse Amps
9	2.17	JCX-7E	1.25	JCY-5E	1.08
15	3.6	JCX-10E	2.08	JCY-7E	1.8
30	7.3	JCX-20E	4.2	JCY-15E	3.6
45	10.8	JCX-25E	6.2	JCY-15E	5.4
75	18.0	JCX-40E	10.4	JCY-25E	9.0
112.5	27.0	JCX-65E	15.6	JCY-40E	13.5
150	36.0	JCX-65E	20.8	JCY-40E	18.0
225	54.0	JCX-100E	31.2	JCY-65E	27.0
300	72.0	JCX-125E	41.6	JCY-80E	36.0
500	120.0	JCX-200E	69.4	JCY-125E	60.0
750	—	—	104.0	JCY-150E	90.0
1000	—	—	139.0	JCY-200E	120.0

Single-Phase Transformers

3	1.25	JCX-5E	0.72	JCY-3E	0.63	JCY-3E
5	2.08	JCX-7E	1.20	JCY-5E	1.04	JCY-5E
10	4.17	JCX-15E	2.40	JCY-7E	2.08	JCY-7E
15	6.25	JCX-15E	3.61	JCY-10E	3.13	JCY-10E
25	10.4	JCX-25E	6.01	JCY-15E	5.21	JCY-15E
37.5	15.6	JCX-40E	9.01	JCY-20E	7.81	JCY-20E
50	20.8	JCX-40E	12.0	JCY-25E	10.4	JCY-25E
75	31.3	JCX-65E	18.0	JCY-40E	15.6	JCY-30E
100	41.7	JCX-80E	24.0	JCY-80E	20.8	JCY-40E
167	70.0	JCX-100E	40.0	JCY-100E	35.0	JCY-65E
250	104.0	JCX-150E	60.0	JCY-125E	52.0	JCY-100E
333	139.0	JCX-200E	80.0	JCY-125E	69.5	JCY-100E
500	—	—	120.0	JCY-200E	104.0	JCY-150E
667	—	—	—	—	139.0	JCY-200E

Introduction and Current-Limitation

This issue analyzes the protection of electrical system components from fault currents. It gives the specifier the necessary information regarding the short-circuit current or withstand rating of electrical circuit components, such as wire, bus, motor starters, etc. Proper protection of circuits will improve reliability and reduce the possibility of injury. Electrical systems can be destroyed if the overcurrent devices do not limit the short-circuit current to within the withstand rating of the system's components. Merely matching the amp rating of a component with the amp rating of a protective device will not assure component protection under short circuit conditions.

The National Electrical Code® covers Component Protection in several sections. The first section to note is 110.10.

Component Protection and The National Electrical Code®

110.10 Circuit Impedance Short-Circuit Current Ratings, and Other Characteristics: The overcurrent protective devices, the total impedance, the equipment short-circuit current ratings, and other characteristics of the circuit to be protected shall be selected and coordinated to permit the circuit-protective devices used to clear a fault to do so without extensive damage to the electrical equipment of the circuit. This fault shall be assumed to be either between two or more of the circuit conductors or between any circuit conductor and the equipment grounding conductor(s) permitted in 250.118. Listed equipment applied in accordance with their listing shall be considered to meet the requirements of this section.

This requires that overcurrent protective devices, such as fuses and circuit breakers be selected in such a manner that the short-circuit current (withstand) ratings of the system components will not be exceeded should a short circuit occur.

The "short-circuit withstand rating" is the maximum short-circuit current that a component can safely withstand. Failure to provide adequate protection may result in component destruction under short circuit conditions.

After calculating the fault levels throughout the electrical system, the next step is to check the withstand rating of wire and cable, circuit breakers, transfer switches, starters, etc., under short circuit conditions.

Note: The let-through energy of the protective device must be equal to or less than the short-circuit withstand rating of the component being protected.

CAUTION: Choosing overcurrent protective devices strictly on the basis of voltage, current, and interrupting rating alone will not assure component protection from short-circuit currents. The interrupting rating of a protective device is only a self-protection rating for that OCPD evaluated to its respective product standard's evaluation criteria under specific test procedures.

Before proceeding with the study of component withstandability, the technology concerning "current-limitation" will be reviewed.

Current-Limitation Defined

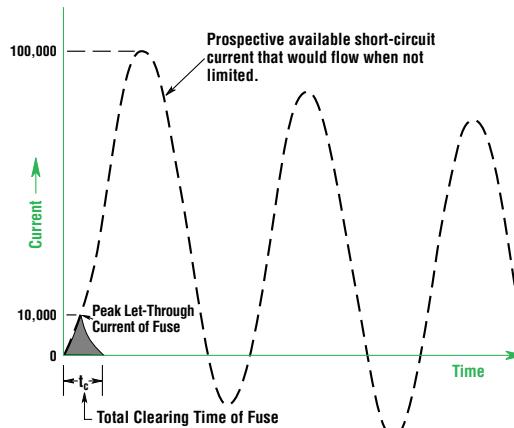
Today, most electrical distribution systems are capable of delivering very high short-circuit currents, some in excess of 200,000A. Many circuit components have relatively low short circuit withstandability of a few thousand amps. If the components are not capable of handling these short-circuit currents, they could easily be damaged or destroyed. The current-limiting ability of today's modern fuses allows components with low short-circuit withstand ratings to be specified in spite of high available fault currents.

NEC® 240.2 offers the following definition of a current-limiting device:

Current-Limiting Overcurrent Protective Device: A device that, when interrupting currents in its current-limiting range, reduces the current flowing in the faulted circuit to a magnitude substantially less than that obtainable in the same circuit if the device were replaced with a solid conductor having comparable impedance.

The concept of current-limitation is pointed out in the following graph, where the prospective available fault current is shown in conjunction with the limited current resulting when a current-limiting fuse clears. The area under the current curve is representative of the amount of short circuit energy being dissipated in the circuit. Since both magnetic forces and thermal energy are directly proportional to the square of the current, it is important to limit the short-circuit current to as small a value as possible. The maximum magnetic forces vary as the square of the "PEAK" current and thermal energy varies as the square of the "RMS" current.

Current-Limiting Effect of Fuses



Thus, the current-limiting fuse in this example (above waveform) would limit the let-through energy to a fraction of the value which is available from the system. In the first major loop of fault current, a non-current-limiting device would let-through approximately 100 times* as much destructive energy as the fuse would let-through.

$$*\left(\frac{100,000}{10,000}\right)^2 = 100$$

How To Use Current-Limitation Charts

Analysis of Current-Limiting Fuse Let-Through Charts

The degree of current-limitation of a given size and type of fuse depends, in general, upon the available short-circuit current that can be delivered by the electrical system. Current-limitation of fuses is best described in the form of a let-through chart that, when applied from a practical point of view, is useful to determine the let-through currents when a fuse opens.

Fuse let-through charts are plotted from actual test data. The test circuit that establishes line A-B corresponds to a short circuit power factor of 15%, that is associated with an X/R ratio of 6.6. The fuse curves represent the cutoff value of the prospective available short-circuit current under the given circuit conditions. Each type or class of fuse has its own family of let-through curves.

The let-through data has been generated by actual short-circuit tests of current-limiting fuses. It is important to understand how the curves are generated, and what circuit parameters affect the let-through curve data.

Typically, there are three circuit parameters that can affect fuse let-through performance for a given available short-circuit current. These are:

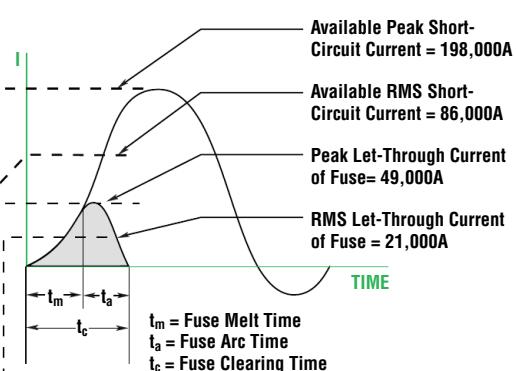
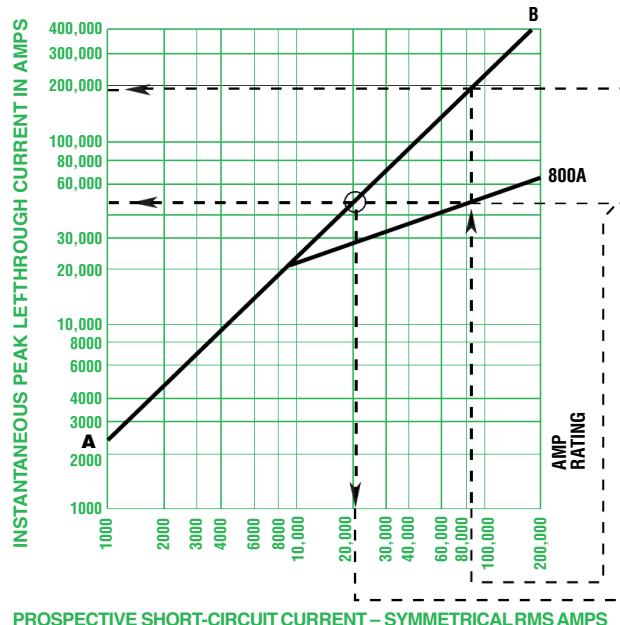
1. Short-circuit power factor
2. Short-circuit closing angle
3. Applied voltage

Current-limiting fuse let-through curves are generated under worst case conditions, based on these three variable parameters. The benefit to the user is a conservative resultant let-through current (both I_p and I_{RMS}). Under actual field conditions, changing any one or a combination of these will result in lower let-through currents. This provides for an additional degree of reliability when applying fuses for equipment protection.

Current-Limiting Let-Through Charts for Bussmann fuses are near the back of this book.

See section **Fuseology: Current-Limitation Lab Tests Demonstrations** for actual test results and QR test videos.

Analysis of a Current-Limiting Fuse



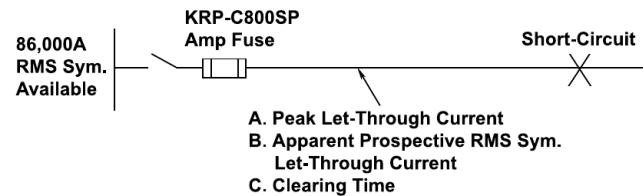
Prior to using the Fuse Let-Through Charts, it must be determined what let-through data is pertinent to equipment withstand ratings.

Equipment withstand ratings can be described as: How Much Fault Current can the equipment handle, and for How Long? Based on standards presently available, the most important data that can be obtained from the Fuse Let-Through Charts and their physical effects are the following:

- A. Peak let-through current: mechanical forces
- B. Apparent prospective RMS symmetrical let-through current: heating effect
- C. Clearing time: less than $\frac{1}{2}$ cycle when fuse is in its current-limiting range (beyond where fuse curve intersects A-B line).

This is a typical example showing the short-circuit current available to an 800A circuit, an 800A Low-Peak current-limiting time-delay fuse, and the let-through data of interest.

800 Amp Low-Peak™ Current-Limiting Time-Delay Fuse and Associated Let-Through Data



How To Use Current-Limitation Charts

How to Use the Let-Through Charts

Using the example given, one can determine the pertinent let-through data for the KRP-C-800SP amp Low-Peak fuse. The Let-Through Chart pertaining to the 800A Low-Peak fuse is illustrated.

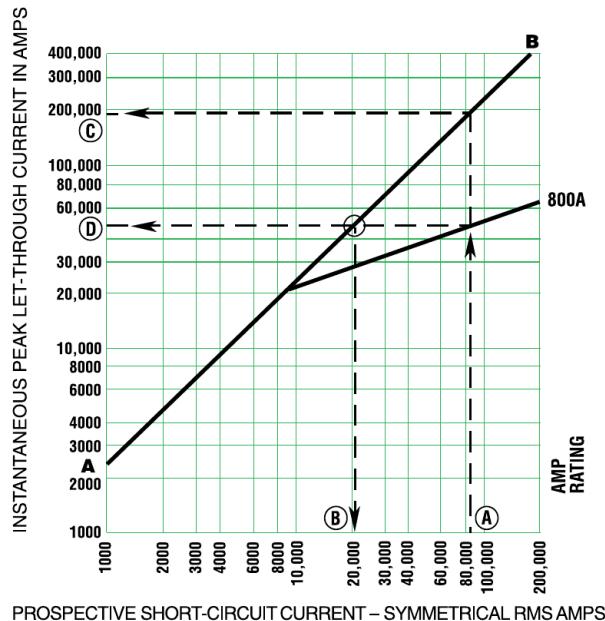
A. Determine the PEAK let-through CURRENT.

- Step 1. Enter the chart on the Prospective Short-Circuit current scale at 86,000 amps and proceed vertically until the 800A fuse curve is intersected.
- Step 2. Follow horizontally until the Instantaneous Peak Let-Through Current scale is intersected.
- Step 3. Read the PEAK let-through CURRENT as 49,000A. (If a fuse had not been used, the peak current would have been 198,000A.)

B. Determine the APPARENT PROSPECTIVE RMS SYMMETRICAL let-through CURRENT.

- Step 1. Enter the chart on the Prospective Short-Circuit current scale at 86,000A and proceed vertically until the 800A fuse curve is intersected.
- Step 2. Follow horizontally until line A-B is intersected.
- Step 3. Proceed vertically down to the Prospective Short-Circuit Current.
- Step 4. Read the APPARENT PROSPECTIVE RMS SYMMETRICAL let-through CURRENT as 21,000A. (The RMS SYMMETRICAL let-through CURRENT would be 86,000A if there were no fuse in the circuit.)

Current-Limitation Curves — Bussmann



- (A) I_{RMS} Available = 86,000 Amps
- (B) I_{RMS} Let-Through = 21,000 Amps
- (C) I_p Available = 198,000 Amps
- (D) I_p Let-Through = 49,000 Amps

Low-Peak Time-Delay Fuse KRP-C-800SP

Most electrical equipment has a withstand rating that is defined in terms of an RMS symmetrical-short-circuit current, and in some cases, peak let-through current. These values have been established through short circuit testing of that equipment according to an accepted industry standard. Or, as is the case with conductors, the withstand rating is based on a mathematical calculation and is also expressed in an RMS short-circuit current.

If both the let-through currents (I_{RMS} and I_p) of the current-limiting fuse and the time it takes to clear the fault are less than the withstand rating of the electrical component, then that component will be protected from short circuit damage.

Typical Short-Circuit Current Ratings For Unmarked Components*

Component	Short-Circuit Rating, kA
Industrial Control Equipment:	
a. Auxiliary Devices	5
b. Switches (other than Mercury Tube Type)	5
c. Mercury Tube Switches	
Rated over 60 amperes or over 250 volts	5
Rated 250 volts or less, 60 amperes or less, and over 2kVA	3.5
Rated 250 volts or less and 2kVA or less	1
Meter Socket Base	10
Photoelectric Switches	5
Receptacle (GFCI Type)	10
Receptacle (other than GFCI Type)	2
Snap Switch	5
Terminal Block	10
Thermostat	5

*Based upon information in UL 891 (Dead-Front Switchboards)

The following Table shows typical assumed short-circuit current ratings for various unmarked components.

The following components will be analyzed by establishing the short-circuit withstand data of each component and then selecting the proper current-limiting fuses for protection:

- Wire and Cable
- Bus (Busway, Switchboards, Motor Control Centers and Panelboards)
- Transfer Switches
- HVAC Equipment
- Ballasts

A detailed analysis of motor circuit component protection is provided later in the section on motor circuits.

C. Determine the clearing time

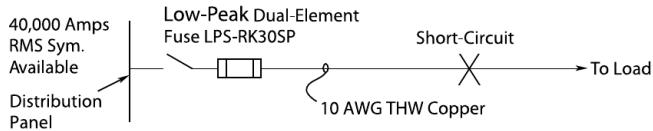
If the RMS Symmetrical available is greater than the point where the fuse characteristic curve intersects with the diagonal A-B line, then the fuse clearing time is $\frac{1}{2}$ cycle or less. In this example, the intersection is approximately 9500A; so for short-circuit currents above approximately 9500A, this KRP-C-800SP fuse is current-limiting.

The current-limiting charts and tables for Bussmann fuses are in the rear of this book under "Current-Limiting Let-Through Charts." Refer to these tables when analyzing component protection in the following sections.

Wire & Cable

The circuit shown originates at a distribution panel where 40,000 amps RMS symmetrical is available. To determine the proper fuse, first establish the short-circuit withstand data for the 10 AWG THW copper cable shown in the diagram.

Short-Circuit Protection of Wire and Cable



The following table shows the short-circuit withstand of copper cable with 75°C thermoplastic insulation based on Insulated Cable Engineers Association (ICEA) formulae.

The short-circuit withstand of the 10 AWG THW copper conductor is 4300A for one cycle (0.0167 seconds). Short-circuit protection of this conductor requires the selection of an overcurrent device which will limit the 40,000A RMS symmetrical available to a value less than 4300A, and clear the fault in one cycle or less.

The Low-Peak dual-element fuse let-through chart shows that the LPS-RK30SP Low-Peak dual-element fuse will let-through an apparent prospective RMS current of less than 1800A, when 40,000A is available (and would clear the fault in less than ½ cycle). See current-limiting fuse let-through data to obtain LPS-RK fuse data.

Short-Circuit Currents for Insulated Cables

The increase in kVA capacity of power distribution systems has resulted in possible short-circuit currents of extremely high magnitude. Conductor insulation may be seriously damaged by fault induced, high conductor temperatures. As a guide in preventing such serious damage, maximum allowable short circuit temperatures, which begin to damage the insulation have been established for various insulation as follows:

- Paper, rubber and varnished cloth 200°C
- Thermoplastic 150°C

The chart at the top of next column shows the currents which, after flowing for the times indicated, will produce these maximum temperatures for each conductor size. The system short circuit capacity, the conductor cross-sectional area and the overcurrent protective device opening time should be such that these maximum allowable short-circuit currents are not exceeded.

Using the formula shown on the ICEA protection table will allow calculating withstand ratings of conductors. It may be advantageous to calculate withstand ratings below one cycle, when the opening time of the current-limiting device is known; see table below. See Bussmann current-limiting fuse let-through data to obtain LPS-RK data.

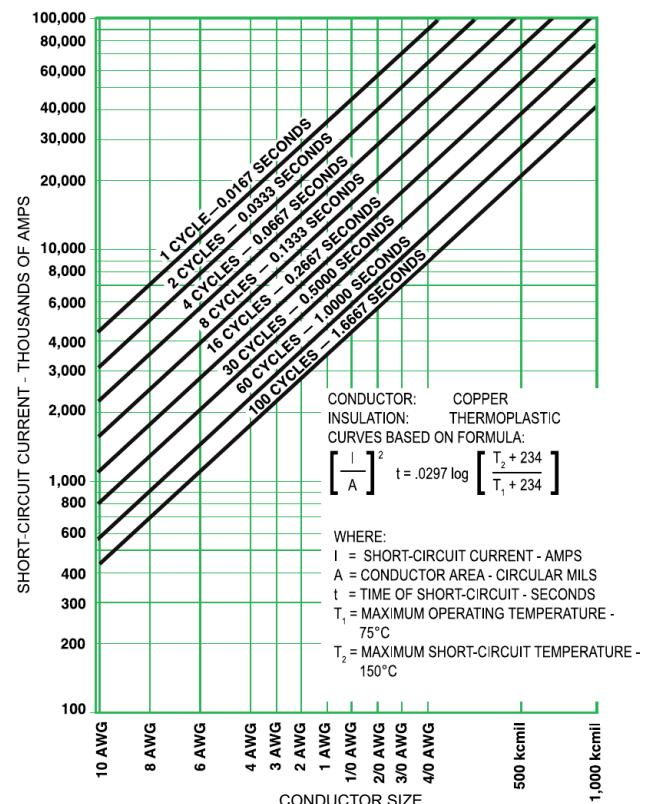
Copper, 75° Thermoplastic Insulated Cable Damage (based on 60 Hz)

Copper Wire Size	Maximum Short-Circuit Withstand Current in Amps					
	75°C Thermoplastic	1/8 Cycles*	1/4 Cycles*	1/2 Cycles*	1 Cycle	2 Cycles
18*	1850	1300	900	700	500	400
16*	3000	2100	1500	1100	700	600
14*	4800	3400	2400	1700	1200	1000
12*	7600	5400	3800	2700	1900	1550
10	12,000	8500	6020	4300	3000	2450
8	19,200	13,500	9600	6800	4800	3900
6	30,400	21,500	16,200	10,800	7600	6200
4	48,400	34,200	24,200	17,100	12,100	9900

* Extrapolated data.

Short-Circuit Current Withstand Chart for Copper Cables with Thermoplastic Insulation

Allowable Short-Circuit Currents for Insulated Copper Conductors*



*Copyright 1969 (reaffirmed March, 1992) by the Insulated Cable Engineers Association (ICEA). Permission has been given by ICEA to reprint this chart

Protecting Equipment Grounding Conductors

Safety issues arise when the analysis of equipment grounding conductors (EGC) is discussed. Table 250.122 of the NEC® offers minimum sizing for equipment grounding conductors.

Equipment grounding conductors are much more difficult to protect than phase conductors because the overcurrent protective device is most often several sizes larger than the ampacity of equipment grounding conductor.

The problem of protecting equipment grounding conductors was recognized more than 30 years ago when Eustace Soares, wrote his famous grounding book "Grounding Electrical Distribution Systems for Safety." In his book he states that the "validity" rating corresponds to the amount of energy required to cause the copper to become loose under a lug after the conductor has had a chance to cool back down. This validity rating is based upon raising the copper temperature from 75°C to 250°C.

In addition to this and the ICEA charts, a third method promoted by Onderdonk allows the calculation of the energy necessary to cause the conductor to melt (75°C to 1083°C).

The table on the next page offers a summary of these values associated with various size copper conductors.

Protection of Equipment Grounding Conductor

It becomes obvious that the word "Minimum" in the heading of NEC® Table 250.122 means just that - the values in the table are a minimum - they may have to be increased due to the available short-circuit current and the current-limiting, or non-current-limiting ability of the overcurrent protective device. 250.4(A)(5) and 250.4(B)(4) require grounding conductors sized adequately for the short-circuit current that could be let-through. This means that based on the available short-circuit current, the overcurrent protective device characteristics (it's let-through current), the grounding conductor may have to be sized larger than the minimum size in Table 250.122.

Good engineering practice requires the calculation of the available short-circuit currents (3-phase and phase-to-ground values) wherever equipment grounding conductors are used. Overcurrent protective device (fuse or circuit breaker) manufacturers' literature must be consulted. Let-through energies for these devices should be compared with the short circuit ratings of the equipment grounding conductors. Wherever let-through energies exceed the "minimum" equipment grounding conductor withstand ratings, the equipment grounding conductor size must be increased until the withstand ratings are not exceeded.

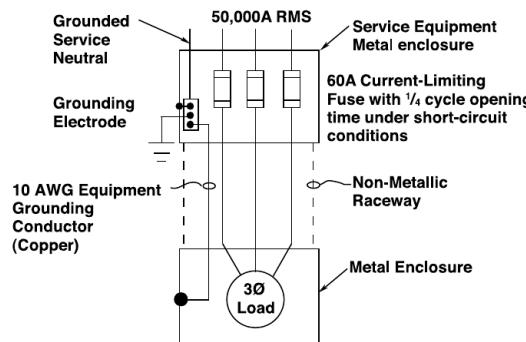
Comparison of Equipment Grounding Conductor Short-Circuit Withstand Ratings

Conductor Size	5 Sec. Rating (Amps)			I ² t Rating x10 ⁶ (Amp Squared Seconds)		
	ICEA P32-382 Insulation Damage 150°C	Soares 1 Amp/30 cm Validity	Onderdonk Melting Point 250°C	ICEA P32-382 Insulation Damage 150°C	Soares 1 Amp/30 cm Validity	Onderdonk Melting Point 250°C
18	38	55	99	0.007	0.015	0.049
16	61	88	158	0.019	0.039	0.124
14	97	137	253	0.047	0.094	0.320
12	155	218	401	0.120	0.238	0.804
10	246	346	638	0.303	0.599	2.03
8	391	550	1015	0.764	1.51	5.15
6	621	875	1613	1.93	3.83	13.0
4	988	1391	2565	4.88	9.67	32.9
3	1246	1754	3234	7.76	15.4	52.3
2	1571	2212	4078	12.3	24.5	83.1
1	1981	2790	5144	19.6	38.9	132.0
1/0	2500	3520	6490	31.2	61.9	210.0
2/0	3150	4437	8180	49.6	98.4	331.0
3/0	3972	5593	10,313	78.9	156.0	532.0
4/0	5009	7053	13,005	125.0	248.0	845.0
250	5918	8333	15,365	175.0	347.0	1180.0
300	7101	10,000	18,438	252.0	500.0	1700.0
350	8285	11,667	21,511	343.0	680.0	2314.0
400	9468	13,333	24,584	448.0	889.0	3022.0
500	11,835	16,667	30,730	700.0	1389.0	4721.0
600	14,202	20,000	36,876	1008.0	2000.0	6799.0
700	16,569	23,333	43,022	1372.0	2722.0	9254.0
750	17,753	25,000	46,095	1576.0	3125.0	10,623.0
800	18,936	26,667	49,168	1793.0	3556.0	12,087.0
900	21,303	30,000	55,314	2269.0	4500.0	15,298.0
1000	23,670	33,333	61,460	2801.0	5555.0	18,867.0

Take the example below. The EGC must be protected from damage. It can withstand 4300A of current for 1 cycle. A current-limiting fuse will limit the

current to within the withstand rating of the EGC. An LPS-RK60SP will limit the line to ground current to approximately 3300A, providing protection.

COMPLIANCE



Conforms to 110.10, Table 250.122,
and 250.4(A)(5) or 250.4(B)(4)

Tap Conductor Sizing by Engineering Method

The NEC® has additional sizing latitude for feeder tap conductors used in Supervised Industrial Installations. Tap conductors are now considered protected under short-circuit current conditions by using an engineering method to select the conductor size based on the proper characteristics of the feeder overcurrent protective device. This allowance can only be used in Supervised Industrial Installations.

Three conditions must be met to be qualified as a Supervised Industrial Installation (240.2):

- The maintenance crew must be qualified and under engineering supervision.
- The premises wiring system load (based on industrial process(es) and manufacturing activities) must be 2500 KVA or greater as calculated in accordance with Article 220.
- There must be at least one service at 277/480 or 480 volts or higher.

The physics formulas shown in Table 240.92(B) are the same as in the ICEA protection table and can be used to find the maximum short-circuit current and time for proper protection of the conductor under short-circuit conditions.

Table 240.92(B) Tap Conductor Short-Circuit Current Ratings.

Tap conductors are considered to be protected under short-circuit conditions when their short-circuit temperature limit is not exceeded. Conductor heating under short-circuit conditions is determined by (1) or (2):

(1) Short-Circuit Formula for Copper Conductors

$$(I^2/A^2)t = 0.0297 \log_{10} [(T_2 + 234)/(T_1 + 234)]$$

(2) Short-Circuit Formula for Aluminum Conductors

$$(I^2/A^2)t = 0.0125 \log_{10} [(T_2 + 228)/(T_1 + 228)]$$

where:

I = short-circuit current in amperes

A = conductor area in circular mils

t = time of short-circuit in seconds (for times less than or equal to 10 seconds)

T1 = initial conductor temperature in degrees Celsius (conductor insulation rating)

T2 = final conductor temperature in degrees Celsius (threshold for insulation damage)

Copper conductor with paper, rubber, varnished cloth insulation, T2 = 200

Copper conductor with thermoplastic insulation, T2 = 150

Copper conductor with cross-linked polyethylene insulation, T2 = 250

Copper conductor with ethylene propylene rubber insulation, T2 = 250

Aluminum conductor with paper, rubber, varnished cloth insulation, T2 = 200

Aluminum conductor with thermoplastic insulation, T2 = 150

Aluminum conductor with cross-linked polyethylene insulation, T2 = 250

Aluminum conductor with ethylene propylene rubber insulation, T2 = 250

The change in 240.92(B) allows supervised industrial installations increased flexibility for feeder tap conductor protection in lieu of simple ratios in 240.21(B)(2), (B)(3) and (B)(4) where protection can be proven by physics formulas. Thus, the sizing of feeder tap conductors can be accomplished using accepted physics formulas for the selection of overcurrent protective devices based on conductor insulation thermal damage levels and the let-through energy of the overcurrent protective device under short-circuit conditions. Previous tap conductor sizing did not take into consideration any fault current or current-limiting characteristics of the overcurrent device, only the ampere rating ratios that may result in overly conservative sizing of tap conductors.

16 and 18 AWG Conductors

For Industrial Machinery Power Circuits

Typically 14 AWG conductors or larger are required for use in power circuits. However, 16 AWG and 18 AWG conductors are permitted for motor and non-motor circuits under specified conditions per 430.22(G), 240.4(D), NFPA 79 (12.6.1.1 and 12.6.1.2) and UL508A (66.5.4 Exception and Table 66.1A). The use of 16 AWG and 18 AWG conductors reduces wiring costs in industrial machinery. The Table below illustrates where Class J, CC, and T fuses can be utilized for protection of 16 AWG and 18 AWG conductors in power circuits per NFPA 79 and UL 508A.

Sizing Chart for LP-CC (Class CC), JJN/JJS (Class T), and LPJ (Class J - Time-Delay) Fuse Protection of 16 AWG and 18 AWG Conductors in Power Circuits of Industrial Machinery per 430.22(G), 240.4(D) NFPA 79 and UL 508A

Conductor Size	Max Load Ampacity	Load Type	Max LP-CC Fuse Size	Max LPJ or TCF Fuse Size	Motor Overload Relay Trip Class
16 AWG	8	Non-motor	10A	10A	—
	8	Motor	300% of motor FLA or next standard size*	175% of motor FLA or next standard size*	Class 10
	5.5	Motor	300% of motor FLA or next standard size*	175% of motor FLA or next standard size*	Class 20
18 AWG	5.6	Non-motor	7A	7A	—
	5	Motor	300% of motor FLA or next standard size*	175% of motor FLA or next standard size*	Class 10
	3.5	Motor	300% of motor FLA or next standard size*	175% of motor FLA or next standard size*	Class 20

*Standard size for fuses are 1, 3, 6, 10, 15, 20, 25 and 30. Where the starting current of the motor opens the fuse, the maximum setting can be increased, but not exceed 400% for LP-CC or 225% for LPJ or CUBEFuse.

16 AWG and 18 AWG conductors are easily damaged due to fault currents. Many overcurrent protective devices are unable to protect these small conductors. However, the Small Wire Working Group of the NFPA 79 technical committee performed tests and evaluated criteria to demonstrate that Class CC, J or T fuses are among those able to provide protection. Other branch-circuit rated fuses or circuit breakers can only be used if marked for protection of 16 AWG and 18 AWG conductors.

UL issued a Special Service Investigation, An Investigation of the Use of 16AWG and 18AWG Conductors for Power Branch Circuits in Industrial Machinery Applications file number E4273 to verify the test results. The analysis, test program, and results can be viewed in an IEEE paper presented at the 2002 IEEE Industrial and Commercial Power Systems Technical Conference titled, An Investigation of the Use of 16AWG and 18AWG Conductors for Branch Circuits in Industrial Machinery Built to NFPA 79 2002. The report and paper can be found on www.cooperbussmann.com.

Busway

Bus Short-Circuit Rating Requirements

When Protected by Current-Limiting Fuses

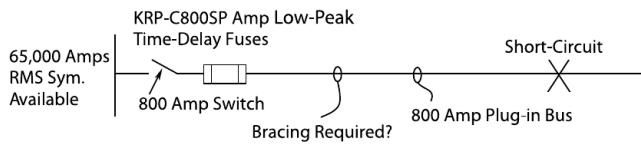
NEMA Standards require that busways have a symmetrical short-circuit withstand rating at least as great as the average available symmetrical short-circuit current.

Since the short circuit ratings of busways are established on the basis of minimum three-cycle duration tests, these ratings will not apply unless the protective device used will remove the fault within three cycles or less.

BUSWAYS MAY BE USED ON CIRCUITS HAVING AVAILABLE SHORT-CIRCUIT CURRENTS GREATER THAN THE THREE CYCLE RATING OF THE BUSWAY RATING WHEN PROPERLY COORDINATED WITH CURRENT-LIMITING DEVICES. (NEMA Pub. No. BU1)

If a busway has been listed or labeled for a maximum short-circuit current with a specific overcurrent device, it cannot be used where greater fault currents are available without violating the listing or labeling. If a busway has been listed or labeled for a maximum short-circuit current without a specific overcurrent device (i.e., for three cycles), current-limiting fuses can be used to reduce the available short-circuit current to within the withstand rating of the busway.

Refer to Figure below for an analysis of the short circuit rating requirements for the 800A plug-in bus.



Determining the Short-Circuit Ratings of Busway

The 800A plug-in bus could be subjected to 65,000 amps at its line side; however, the KRP-C800SP amp Low-Peak™ time-delay fuse would limit this available current. When protected by KRP-C800SP amp Low-Peak time-delay fuses, the 800A bus need only be braced for 19,000A RMS symmetrical. This is derived by using the KRP-C_SP fuse Let-Through Chart (found in another section). The table in the adjacent column can also be used; it shows the minimum required bracing to be 20,000A RMS symmetrical when protected by KRP-C 800SP fuses with 75,000A available short-circuit current. This would allow a standard 22,000A RMS symmetrical (three-cycle) rated bus to be specified, whereas, if a non-current-limiting type protective device were specified, the bracing requirements would have been 65,000A for three cycles.

CURRENT-LIMITING FUSES GENERALLY REDUCE BUS BRACING REQUIREMENTS TO ALLOW A STANDARD SHORT-CIRCUIT RATED BUSWAY TO BE SPECIFIED.

The busway short circuit short-time rating has a mechanical limit. Exceeding this limit invites mechanical damage due to the high magnetic forces associated with the peak current of the fault. The mechanical limit typically applies for high faults near and below the busway short circuit rating. Allowable durations of short-circuit current, longer than the three-cycles at 60Hz (0.05 seconds) required at the maximum short circuit rating, are obtained from a constant I^2t "mechanical damage limit" curve.

Typically, for currents below one-half of the short-circuit current rating, where mechanical stresses are reduced to one-quarter of those at the maximum rating, the mechanical capabilities become less important than the thermal capability. The lower limit duration at one-half the busway rating is determined by the busway thermal (I^2t) capabilities.

The following example shows busway short circuit overcurrent protection by current-limiting fuses. This study looks at the development of the busway mechanical withstand curves and the time-current curves of the fuses.

In this example, the 800A plug-in busway has a 65kA short circuit rating for three cycles.

A plot of the busway mechanical limit characteristic on log-log paper passes through the short circuit rating at (65kA, 0.05 seconds) and is a constant I^2t down to 32.5kA (one-half the short circuit rating of 65kA).

Assume the available short-circuit current at the busway is equal to the 65kA rating. The overcurrent device is assumed to have the proper interrupting rating.

A plot of the system utilizing Low-Peak Class L and Class RK1 fuses is shown. Current-limitation by the KRP-C800SP will offer short circuit protection for the busway, as it lets through 19,000A in less than $\frac{1}{2}$ cycle.

Note: The busway is protected by the fast speed of response in the high short circuit region. Protection is achieved, as is selective coordination, with the downstream LPS-RK400SP fuse.

Minimum Bracing Required for Bus Structures at 480V (Amps RMS Symmetrical)

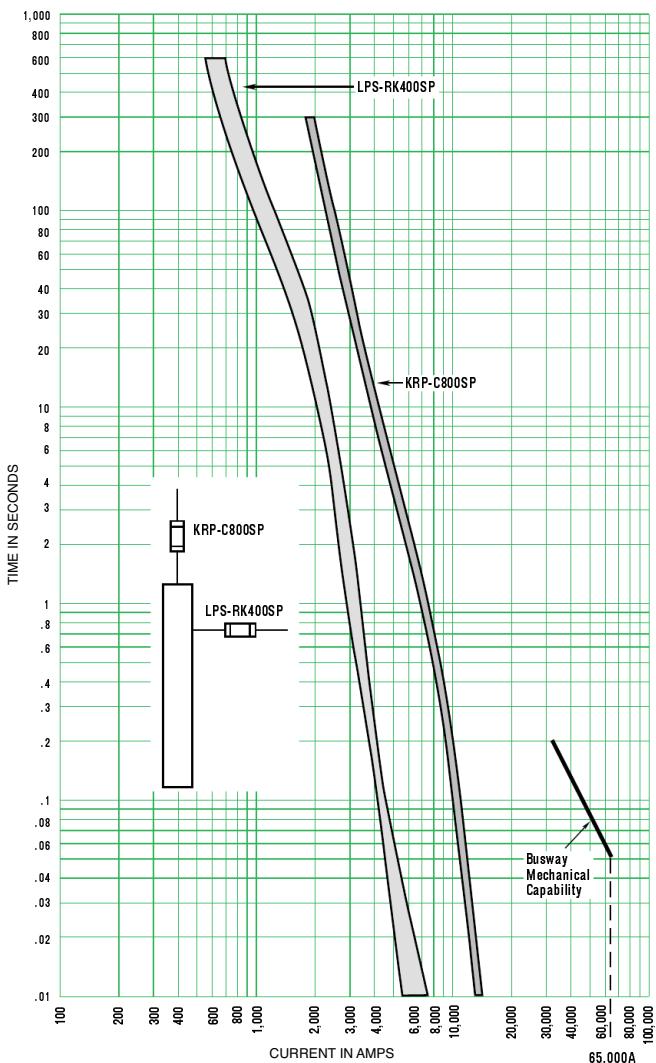
Rating*

Busway	Fuse	Available Short-Circuit Amps RMS Sym.				
		25,000	50,000	75,000	100,000	200,000
100	100	3400	4200	4800	5200	6500
225	225	6000	7000	8000	9000	12 000
400	400	9 200	11,000	13,000	14,000	17,000
600	600	12,000	15,000	17,000	19,000	24,000
601	601	11,000	14,500	17,000	18,000	24,000
800	800	14,200	17,500	20,000	23,000	29,000
1200	1200	16,000	22,500	26,000	28,000	39,000
1600	1600	22,500	28,500	33,000	36,000	46,000
2000	2000	25,000	32,000	37,000	40,000	52,000
3000	3000	25,000	43,000	50,000	58,000	73,000
4000	4000	25,000	48,000	58,000	68,000	94,000

*Fuses are: 100-600 Amp—Low-Peak Dual-Element Fuses—LPS-RK_SP (Class RK1) or LPJ_SP (Class J); 800-4000 Amp—Low-Peak Time-Delay Fuses — KRP-C_SP (Class L). (Low-Peak fuses are current-limiting fuses.)

UL Standard 891 details short circuit durations for busway within switchboards for a minimum of three cycles, unless the main overcurrent device clears the short in less than three cycles.

Bus Short Circuit Rating & Bracing Requirements



HVAC and Refrigeration Equipment

Air Conditioning and Refrigeration Equipment With Multimotor and Combination-Loads

NEC® 440.4(B) requires the nameplate of this equipment to be marked with its short-circuit current rating and UL1995 provides the means for the HVAC manufacturer to do so. There are exceptions for which this requirement does not apply to this equipment:

- One and two family dwellings
- Cord and attachment-plug connected equipment
- Or equipment on a 60A or less branch circuit

So for most commercial and industrial applications, air conditioning and refrigeration equipment with multimotor and combination loads must have the short-circuit current rating marked on the nameplate. For proper protection and compliance with NEC® 110.10, the short-circuit current rating for equipment shall be equal to or greater than the available short-circuit current where the equipment is being installed in the system.

HVAC equipment must be properly installed to "Meet Code." To connect HVAC equipment in locations where the available fault current exceeds the listed short-circuit current levels could present a real hazard to property as well as personnel trouble-shooting the equipment. That is why the new Short-Circuit Current Rating marking requirement is so important.

The short-circuit current rating of the HVAC unit, which is on the nameplate, shall be equal to or greater than the available short-circuit current at the terminals of the HVAC unit. If the HVAC unit nameplate specifies a specific type and size overcurrent protective device (not supplied integral with the unit), then that specific size (as a maximum) and type overcurrent protective device shall be in the building distribution system that supplies the unit.

Nameplate Specifies Overcurrent Protective Device

Per UL 1995, the HVAC nameplate can specify the type of overcurrent protective device that must be used. When the nameplate specifies "Maximum Overcurrent Protective Device", then either a circuit breaker or fuse is permitted. If the nameplate is marked "Maximum Fuse____", then fuse protection must be provided in accordance with the label. If the nameplate is marked "Maximum Circuit Breaker____", a circuit breaker must be provided in accordance with the label.

Ballast Protection

The National Electrical Code® requires integral thermal protection for ballasts in 410.130(E), except for egress lighting.

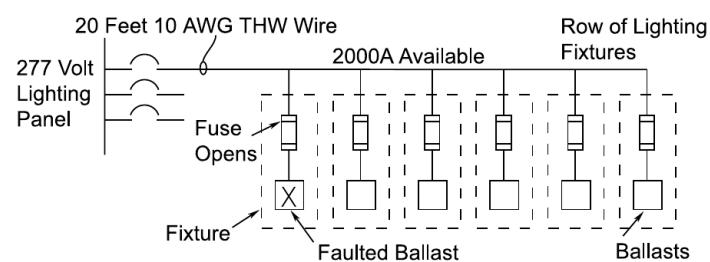
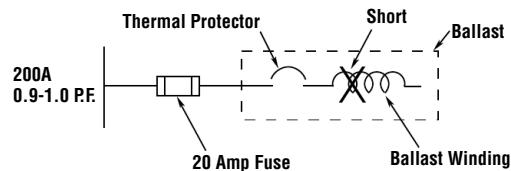
Testing agencies list ballasts for general use in lighting fixtures which pass specific thermal and short circuit tests. The ballast must incorporate a thermal protector to sense certain over-temperature conditions and must also be able to withstand 200A of short-circuit current when tested with a 20A fuse. See the figure below for a typical test for ballasts.

Most systems today will deliver more than 200A of short-circuit current to a row of fixtures. Based upon the last sentence of NEC® 110.10, it is imperative that the ballasts be applied in accordance with their listing and therefore the fixtures must be specified to incorporate individual ballast fusing within the fixture and external to the ballast.

Fusing each fixture will also provide isolation of the faulted ballast and reduce costly and dangerous blackouts. When a ballast does fail, only the fuse protecting that individual fixture opens - the remaining fixtures continue in normal operation. Without this individual ballast protection, a faulted ballast could cause the branch circuit protective device to open, thereby shutting off all the lights. With individual fusing, the maintenance electrician can trouble shoot the problem much more quickly because only one fixture is "out." And this trouble shooting can be performed as part of a scheduled maintenance procedure. It doesn't have to become an "emergency" because employees are left in the dark.

Note: Refer to fixture manufacturer for recommended fuse size. Bussmann has in-line holder/fuses specifically for light fixtures.

UL Short-Circuit Test for Ballast Protectors



Series Rating: Protecting Circuit Breakers

Generally, a circuit breaker should not be applied where the available short-circuit current at its lineside terminals exceeds the circuit breaker's interrupting rating. This is a requirement per 110.9. However, 240.86 has allowances for fuses or circuit breakers to protect downstream circuit breakers where the available short-circuit current exceeds the downstream circuit breaker's interrupting rating. The term given to this is a series rated combination, series rating, or series combination rating. The application of series ratings has many technical limitations and additional NEC® requirements that must be met for proper application. Series rated combinations allowed per 240.86 should be used sparingly. The series rating requirements are different for new installations versus existing installations. At the end of this section are tables of commercially available fuse/circuit breaker series rated combinations published by panelboard and switchboard manufacturers. These tables, along with a compliance check list for evaluating a series rated combination for a specific installation can be viewed or downloaded from www.cooperbussmann.com.

First, it is best to understand the definitions of fully rated and series rated. As far as interrupting ratings are concerned, fully rated systems are recommended and can be used everywhere, as long as individual interrupting ratings are in compliance with 110.9. On the other hand, series rated combinations have limited applications and have extra NEC® requirements that must be met.

Fully Rated

A fully rated system is one in which all of the overcurrent protective devices have an individual interrupting rating equal to or greater than the available short-circuit current at their line terminals per 110.9. Fully rated systems can consist of all fuses, all circuit breakers, or a combination of fuses and circuit breakers. The interrupting rating of a branch circuit fuse is required by 240.60(C) to be marked on the fuse (unless its interrupting rating is 10,000A). The interrupting rating of a branch circuit circuit breaker is required by 240.83(C) to be marked on the circuit breaker (unless its interrupting rating is 5000A). In this section, "individual" or "stand-alone" interrupting rating is used to denote the interrupting rating of a circuit breaker or fuse. It is the "individual" or "stand-alone" interrupting rating that is marked on a fuse or circuit breaker (see Figure 1). A major advantage with modern current-limiting fuses is that they have interrupting ratings of 200,000A or 300,000A.

Fully Rated Fuse System

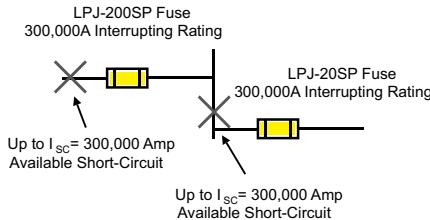


Figure 1

Series Rated Combinations

A series rated combination is a specific combination of circuit breakers or fuses and circuit breakers that can be applied at available short-circuit current levels above the interrupting rating of the loadside (protected) circuit breaker, but not above the interrupting rating of the lineside (protecting) device. A series rated combination can consist of fuses protecting circuit breakers, or circuit breakers protecting circuit breakers. Figure 2 illustrates a fuse/circuit breaker series rated combination. There are unique requirements for series rated combinations in new and existing installations, as well as common

requirements for both. The following addresses both the common and specific requirements for each.

Series Rated System Fuse/CB

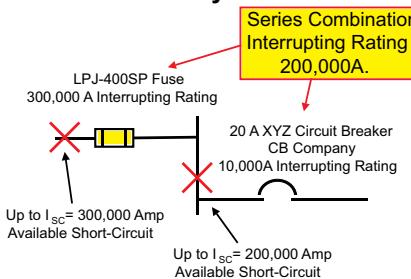


Figure 2

Series Rated Combinations – New Installations

For new installations, the series rated combinations shall be tested and marked on specific panelboards and switchboards [240.86(B)]. Testing determines the series combination interrupting rating, but this interrupting rating is not marked on circuit breakers or fuses. As will be shown in this section, the manufacturer of the panelboard, loadcenter, switchboard or other equipment in which the protected circuit breaker is installed must mark the equipment with the details of a tested series rated combination. In a later section, field labeling per NEC® 110.22 and motor contribution limitation requirements are discussed.

How Is A Tested Series Rated Combination Listed?

The industry has devised a method for a Nationally Recognized Testing Laboratory (NRTL) to test a combination of a manufacturer's specific type and size circuit breaker beyond its marked interrupting rating when protected by specific type lineside fuses or circuit breakers of a maximum amp rating. A Nationally Recognized Testing Laboratory (NRTL) does not list the fuse/circuit breaker combination by itself as a series rated combination. The series combination has to be evaluated and found suitable for a specific manufacturer's panelboard, loadcenter, switchboard or other equipment.

Section 240.86(B) requires that, when a series rating is used, the switchboard, panelboard, loadcenter, or other equipment be marked by the manufacturer for use with the series rated combinations to be utilized. This indicates that the appropriate switchboard, panelboard or loadcenter assembly has been investigated for such use with the specific series rated combination. For instance, the series rated combination shown in Figure 2 is tested and marked for use in a particular manufacturer's panelboard type as shown in Figure 3. Notice in these two figures that the loadside circuit breaker has an individual marked interrupting rating of 10,000A. However, with the series rated combination testing and marking, it may be possible to use it where 200,000A of available short-circuit current is available. Also, note that this rating applies to (1) a specific manufacturer's type and size circuit breaker, (2) when used in a specific manufacturer's type panelboard, switchboard, or other equipment, (3) when protected on the lineside by a specific maximum amp rating and class fuse or circuit breaker and (4) the panelboard is factory marked with the necessary series combination rating specifics. The lineside (protecting) fuse or circuit breaker can be installed in the same panelboard or a separate enclosure.

Series Rating: Protecting Circuit Breakers

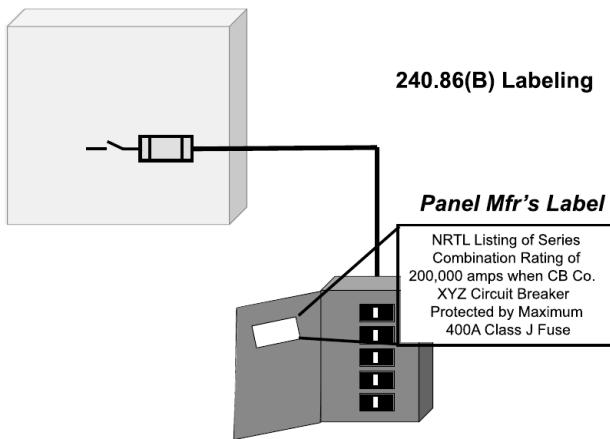


Figure 3

Because there is often not enough room in the equipment to show all of the legitimate series rated combinations, UL 67 (Panelboards) allows for a bulletin to be referenced and supplied with the panelboard. These bulletins typically provide all of the acceptable series rated combinations for that panelboard.

Bussmann has researched the major manufacturers' application literature and published the tables at the end of this section. These tables show, by manufacturer, the various series rated combinations of fuses and breakers that are acceptable by panelboard and switchboard type. Note that more combinations may be available for loadcenters and metercenters; refer to the equipment manufacturer's literature.

Although series rated combinations save a small percentage of the initial equipment costs, there are many issues about designing and utilizing series rated combinations. If series rated combinations are considered for use, there are other NEC® requirements that must be met! Since series rated combinations are evaluated by laboratory testing under specific conditions, these other requirements are extremely important to make sure a series rated combination is, in fact, applied per its testing, listing and marking [110.3(B)].

Series Rated Combinations – Existing Installations

For existing installations, NEC® 240.86(A) permits licensed professional engineers to select series rated combinations by other means than just the method of tested, listed and marked by a Nationally Recognized Testing Laboratory (NRTL).

When buildings undergo improvements, or when new transformers are installed, the new available short-circuit currents can exceed the existing circuit breakers' interrupting ratings. This is a serious safety hazard and does not comply with NEC® 110.9. In the past, an owner in this situation faced the possibility of removing and scrapping the existing circuit breaker panel, and installing a new circuit breaker or fusible switch panel with overcurrent devices that have sufficient interrupting ratings for the new available short-circuit currents. This could be very expensive and disruptive.

Now, for existing systems, a licensed professional engineer can determine if an upgrade of lineside fuses or circuit breakers can constitute a sufficient series rated combination with existing loadside breakers. This option may represent a significant cost savings versus replacing the existing gear.

The professional engineer must be qualified by primarily working in the design or maintenance of electrical installations. Documents on the selection shall be stamped and available to all necessary parties. The series rated combination

must also be labeled in the field, including identification of the upstream protecting device.

There may be several analysis options for a licensed professional engineer to comply with 110.9 where existing circuit breakers have inadequate interrupting ratings. In some cases, a suitable method may not be feasible. New methods may surface in the future.

Some Methods

1. Check to see if a new fused disconnect can be installed ahead of the existing circuit breakers utilizing a tested series rated combination. Even though the existing system may not take advantage of series ratings, if the existing circuit breakers are not too old, the panel may have a table or booklet that provides all the possible tested combinations of fuse-circuit breaker series ratings.
2. If the existing system used series ratings with Class R fuses, analyze whether a specific Bussmann Class RK1, J or T fuse may provide the protection at the higher short-circuit current level. The series ratings for panelboards that use lineside Class R fuses have been determined with special, commercially unavailable Class RK5 umbrella fuses. (Commercially unavailable umbrella fuses are only sold to electrical equipment manufacturers in order to perform equipment short-circuit testing.) Actual, commercially available Bussmann Class RK1, J or T fuses will have current-limiting let-through characteristics considerably better than the Class RK5 umbrella limits.
3. Supervise short-circuit testing of lineside current-limiting fuses to verify that protection is provided to circuit breakers that are identical to the installed, existing circuit breakers.
4. Perform an analysis to determine if a set of current-limiting fuses installed on the lineside of the existing circuit breakers provides adequate protection for the circuit breakers. For instance, if the existing equipment is passive during the interruption period, such as with low voltage power circuit breakers (approximately three cycle opening time), then the lineside fuse short-circuit let-through current (up, over and down method) must be less than the circuit breaker's interrupting rating.

Requirements In Applying Series Rated Combinations

A Series Rated Combination (for new installations) Compliance Checklist is available in the Inspection Checklist section of this publication.

Labeling Requirements:

New Installations (see Figure 4)

- Factory Labeling Requirement: the switchboard, panelboard or other equipment is required to be tested, listed and **factory marked** for use with series rated combination to be utilized per 240.86(B).
- Field Labeling Requirements: **installer** (electrical contractor) to **affix labels** on the equipment enclosures, which note the series combination interrupting rating and call out the specific replacement overcurrent protective devices to be utilized. If the upstream overcurrent protective device protecting the downstream circuit breaker is in a different enclosure, then both enclosures need to have field-installed labels affixed.

Existing Installations (see Figure 5)

- Field Labeling Requirements: for engineered series ratings, **affix labels** on the equipment enclosures, which note engineered series rating, the series combination interrupting rating and call out the specific replacement overcurrent protective devices to be utilized. If the upstream overcurrent protective device protecting the downstream circuit breaker is in a different enclosure, then both enclosures need to have field installed labels affixed. 240.86(A) and 110.22(B).

Series Rating: Protecting Circuit Breakers

240.86(B) & 110.22(C) New Installation

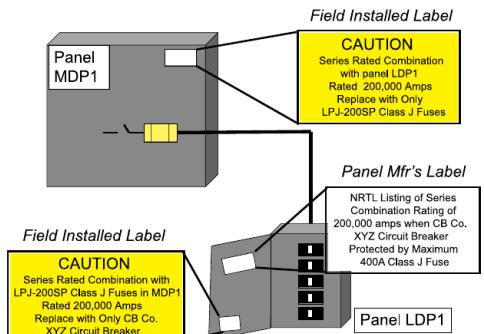


Figure 4

240.86(A) & 110.22(B) Existing Installation

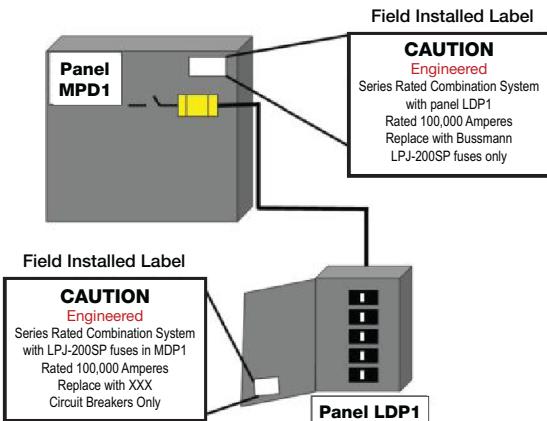


Figure 5

240.86(C) Motor Contribution Limitations

This is a major limitation. It is critical for initial installations, but in addition, future system changes can negate the series combination rating. Where motors are connected between the lineside (protecting) device and the loadside (protected) circuit breaker, 240.86(C) has a critical limitation on the use of series rated combinations. This section requires that a series rated combination shall not be used where the sum of **motor full load currents exceeds 1% of the loadside (protected) circuit breaker's individual interrupting rating**. See Figure 6. The reason is that when a fault occurs, running motors momentarily contribute current to the short-circuit (usually about four to six times their full load rating). This added motor contribution may result in short-circuit current in excess of what the loadside (protected) circuit breaker was tested to handle per the series rated combination testing. See Figure 7.

Series Rated Systems

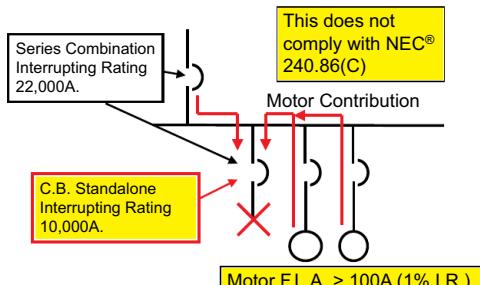


Figure 6

Test Set-Up Series Rated

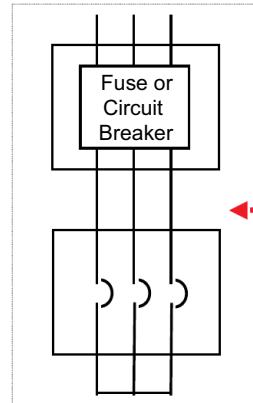
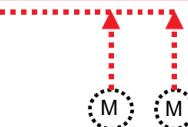


Figure 7

UL 489 testing circuit for series combination ratings does *not* include short-circuit contribution from system motors, which in practical applications can contribute fault current on the loadside of the series combination protecting device

Motor Contribution In Practical Applications Not Part of Series Rating Testing & Listing



When a short-circuit occurs in actual systems, motors contribute approximately 4 to 6 times their full load amps

This is one of the major reasons that series rated combinations are generally recommended only for lighting panel applications. Lighting panels typically do not have significant motor loads so the motor contribution between the feeder overcurrent device and lighting panel branch circuit circuit breakers is not an issue upon initial installation or in the future. However, series rated combinations used for power panel or main/feeder applications can often pose a problem upon initial installation or if the loads change in the future.

Example 1

As an example of the implications of 240.86(C) look at Figure 8. On an installation with a 1000A total load, 50% motor load (which is motor load of 500A), the motor contribution could be an issue in selecting a series rated combination. If a main/feeder series rating were to be considered, the feeder circuit breaker must have at least a 50,000A individual or stand-alone interrupting rating per 240.86(C) ($1\% \text{ of } 50,000 = 500$). If the protected circuit breaker has to have an individual interrupting rating of at least 50,000A, it negates the reason that series rated combinations are utilized for most applications.

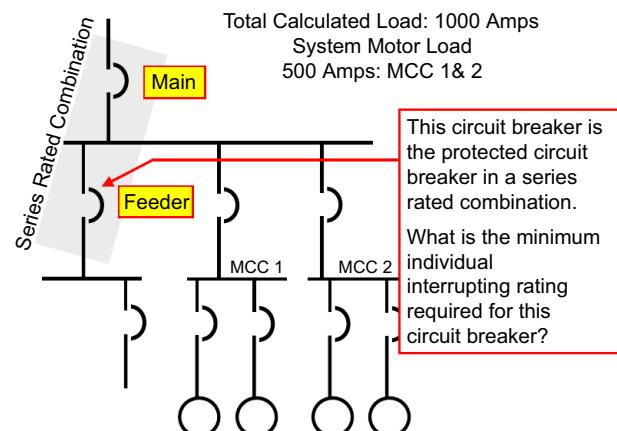


Figure 8

Series Rating: Protecting Circuit Breakers

Example 2

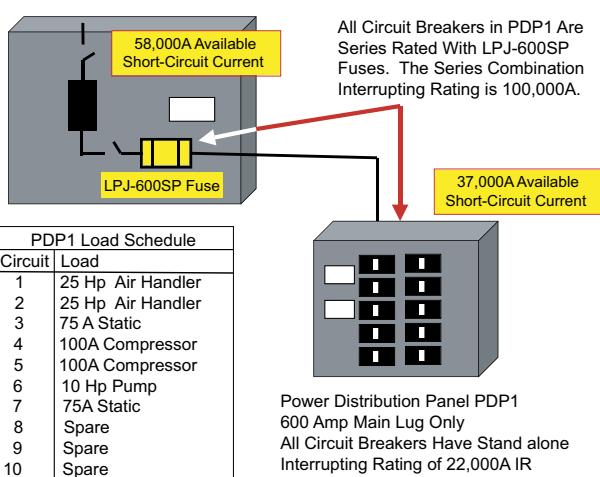
Below is an easy to use table to evaluate the “protected” (loadside) circuit breaker in a series rated combination for meeting the motor contribution limits in 240.86(C). In the Figure 8 example, the motors that are connected and could contribute current where the feeder circuit breaker (“protected” device of the series combination) would have to interrupt, but that the main circuit breaker (“protecting” device of the series combination) would not have to interrupt is represented by 500A of normal full load current. Reading the table below, it is seen that 500A full load motor current exceeds 420A in column A. Therefore, a series rating with a “protected” circuit breaker having a stand alone interrupting rating of 42,000 AIR is insufficient to meet 240.86(B). A series combination that uses a “protected” circuit breaker with a stand alone interrupting rating of at least 50,000A would be required to meet 240.86(C). Note: do not confuse the stand alone interrupting rating of the “protected” circuit breaker with the series combination interrupting rating. The series combination interrupting rating is the rating for both devices working together to interrupt short-circuit currents. The series combination interrupting rating is much greater than the stand alone interrupting rating of the “protected” circuit breaker.

Motor Full Load Amps Shall Not Exceed This Value, If Using Series Combination With “Protected” Circuit Breaker Having Standalone Interrupting Rating In Column B	“Protected” Circuit Breaker Standalone Interrupting Rated In Series Combination	Motor Full Load Amps Shall Not Exceed This Value If Using Series Combination With “Protected” Circuit Breaker Having Standalone Interrupting Rating In Column B	“Protected” Circuit Breaker Standalone Interrupting Rated In Series Combination
(A)	(B)*	(A)	(B)*
75A	7500 AIR	250A	25,000 AIR
100A	10,000 AIR	300A	30,000 AIR
140A	14,000 AIR	350A	35,000 AIR
180A	18,000 AIR	420A	42,000 AIR
200A	20,000 AIR	500A	50,000 AIR
220A	22,000 AIR	650A	65,000 AIR

*Some possible circuit breaker interrupting ratings per UL489, Table 8.1

Example 3

Assess the series combination rating for motor contribution limits in the following system.



Step 1: Motor Load

(2) 100A Compressors	200A
(2) 25Hp Motors @ 34A ea.	68A
(1) 10Hp Pump @ 14A	14A
Total Motor Load Connected Between Series Rated Devices	282A

Step 2: Is the Series Rated Combination Shown Acceptable?

No. The series combination shown has a series combination interrupting rating of 100,000A, which is sufficient for the 37,000A available short-circuit current at PDP1. The LPJ-600SP fuses have an interrupting rating of 300,000A, which is sufficient for the 58,000A available short-circuit current at the main switchboard. However, the “protected” circuit breakers of the series combination, which are located in PDP1, have a stand alone or individual rating of 22,000A. The motor load connected between the protecting and protected devices in the series rated combination can not exceed 1% of the protected circuit breaker’s stand alone interrupting rating. The motor load is 282A, which exceeds 1% of 22,000A (220A). So this series rated combination applied as shown does not comply with 240.86(C).

Then consider the uncertain future of building spaces. For instance, many building spaces, such as office buildings, manufacturing facilities, institutional buildings and commercial spaces, by their nature, incur future changes. A properly designed and initially installed series combination rating could be compromised if the building loads change to a larger percentage of motor loads.

As just illustrated, it is not enough to only check the available short-circuit current against the series combination interrupting rating. 240.86(C) also requires that the designer, contractor and AHJ investigate the individual or stand alone interrupting rating of the protected circuit breaker of a series combination. This is necessary for series rated combinations for new installations as well as existing series rated combinations when existing systems are refurbished or upgraded.

Selective Coordination Requirement Limitations

In most applications, series rated combinations cannot be selectively coordinated. In order to protect the loadside circuit breaker, the lineside (protecting) device must open in conjunction with the loadside (protected) circuit breaker. This means that the entire panel can lose power because the device feeding the panel must under short-circuit conditions.

With the application of series rated combinations, it is difficult to meet the selective coordination requirements for elevator circuits per 620.62, critical operations data systems per 645.27, emergency systems per 700.28, legally required standby systems per 701.27 and critical operations power systems per 708.54. The application of series rated combinations reduces emergency circuit overall system reliability because of their inherent lack of fault current coordination (see Figure 9).

Series Rating: Protecting Circuit Breakers

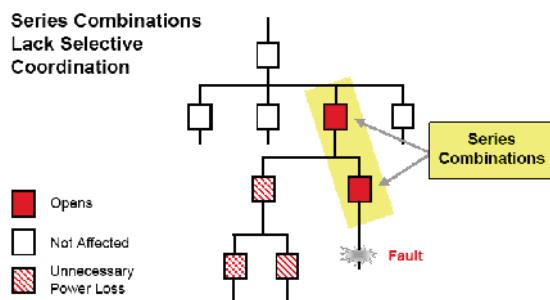


Figure 9

Component Protection

Using series rated combinations does not assure protection for the circuit components. The series rating only pertains to the overcurrent protective devices. Specifically, it means that the loadside circuit breaker of lower interrupting rating can be used in an application with higher available short-circuit currents. In practical applications, the other circuit components, such as conductors, busway, contactors, etc., should independently be assessed for protection under the worst-case short-circuit conditions.

Which Is Best: Fully Rated or Series Rated?

Fully rated systems are the preferred choice for many reasons. If fully rated fuses are used and the proper choices are made, the systems will not have any of the limitations described in the previous paragraphs. In addition, if a fully rated system uses modern current-limiting fuses with interrupting ratings of 200,000A and higher, the system will likely remain fully rated over the life of the system even if changes or additions occur that increase the available short-circuit current.

Series rated combinations should be used sparingly. The most suitable application for series rated combinations is for branch circuit, lighting panel circuit breaker protection. Lighting panels typically do not have significant motor loads so the motor contribution limitation [240.86(C)] is not an issue for series rated combinations in lighting panelboard applications. However, series rated combinations used for power panel or main/feeder applications can pose a problem upon initial installation or if the loads change in the future.

A recommendation is to use fully rated fuses for all lighting panelboards, power panelboards, distribution panelboards, motor control centers, motor branch circuits, emergency circuits, elevator circuits and switchboards.

Most series rated combinations can not be selectively coordinated. This is a major limitation that most building owners or tenants do not want to incur. To unnecessarily black out a portion of an electrical system in today's business environment, technology driven healthcare systems, or emergency circuits is unacceptable. Consider the consequences if there is a disaster to a portion of the building; it is important for safety egress to have as much of the electrical system in service as possible.

If Using Series Ratings, What Lineside Choice Considerations Are There?

Remember that with a series rated combination, the loadside circuit breaker is applied beyond its individual interrupting rating. Because of this, if a series rated combination is to be used, the designer and contractor should select the tested and marked lineside protection that will assure reliable performance over the lifetime of the electrical system. If the lineside (protecting) overcurrent protective device does not react as intended, due to lack of maintenance or loss of calibration, the loadside circuit breaker may be on its own to interrupt the short-circuit current.

For the reasons mentioned in the previous paragraph, if series rated combinations are going to be used, it is recommended to use fuses as the lineside (protecting) devices. Modern current-limiting fuses are the most reliable overcurrent protective devices available. Periodic maintenance of fuses is not required. It is recommended that disconnects and all conductor and fuse terminations be periodically assessed and maintained. However, whether it is the first day of service or years later, modern current-limiting fuses will respond to protect the circuit components as originally designed.

If and when fuses are called upon to open on an overcurrent, installing the same type and amp rated fuses provide the circuit with new factory-calibrated fuses. The original design integrity can be maintained throughout the life of the electrical system. With fuses there is typically no worry about putting an incorrect one in per the series rating. Modern current-limiting fuses have mountings that only accept the same class fuse. All the testing, listing and marking of series rated combinations that utilize fuses as the lineside (protecting) device are tested with the maximum amp rated fuse that fits into the fuse mounting. For instance, all the series ratings with lineside fuses are at the maximum amp ratings for standard fuse mounting of 100A, 200A, 400A and etc.

Series Rating: Protecting Circuit Breakers

The lineside fuses used for testing for series rated combinations are special "umbrella" fuses that intentionally exceed the maximum short-circuit current let-through values for specific fuse classes and amp ratings per UL/CSA/ANCE 248 Fuse Standards. This adds an extra safety factor; these special "umbrella" fuses insure that the short-circuit current let-through energy represents the worst case for all the commercially available fuses of that amp rating and class. (Umbrella fuses are not commercially available. They are sold only to electrical equipment manufacturers for testing purposes.) And as mentioned previously, it is an umbrella fuse of the largest amp rating that fits in a given amp rated fuse mounting. In addition, the commercially available fuses undergo periodic follow up testing witnessed by the listing agency to verify that the products continue to have short-circuit let-through values under the umbrella limits.

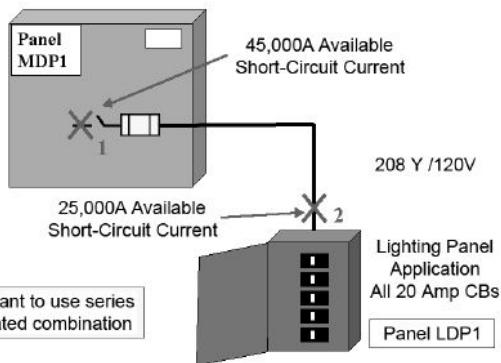


Figure 10

Example of Practical Application of Series Rated Combination

In Figure 10, the 208Y/120V, 200A lighting panel LDP1 has 25,000A available short-circuit current. The distribution panel MDP1 has 45,000A available. The lighting panel has all single-pole, 20A circuit breakers. The typical standard 20A lighting panel circuit breaker has a 10,000A interrupting rating, which is insufficient for the 25,000A available fault current. The options are (1) to use a higher interrupting rated circuit breaker for the lighting panel, which may cost more and require more space or (2) to use a series rated combination. The series rated combination option can be investigated by looking at the fuse/circuit breaker tables by panelboard manufacturer that follow at the end of this section.

Every major panelboard manufacturer has a suitable fuse/circuit breaker series rated solution. The example that follows uses Eaton equipment, so review their table at the end of this section. The following is selected: Eaton panelboard type PRL1A with BA single-pole, 20A, circuit breakers (which have an individual interrupting rating of 10,000A) protected by Bussmann LPJ-200SP fuses (which have a 300,000A interrupting rating). From the table it is seen that this series combination interrupting rating is 200,000A. That means if all the other requirements are met, the BA circuit breakers in this type panelboard can be applied in a system which has an available short-circuit current up to 200,000A at the point where the panelboard is installed. The requirements that must be met are:

1. The series combination interrupting rating must be equal to or greater than the available short-circuit current at the circuit breaker location, X_2 . Remember, the loadside circuit breaker in a series rated combination can be applied beyond its individual interrupting rating (a BA circuit breaker in this case has an individual interrupting rating of 10,000A).
2. In this example, the series rated combination interrupting rating is 200,000A and there is 25,000A available short-circuit current. The interrupting rating of the protecting overcurrent protective device must have an individual interrupting rating equal to or greater than the available short-circuit current at its point of application, X_1 . In this example, the LPJ-200SP fuses have an individual interrupting rating of 300,000A and there is 45,000A available short-circuit current available.
3. The loadside (protected) circuit breaker's individual interrupting rating must meet the minimum required in 240.86(C) due to motor contribution. In this case, it is a lighting panel application and there are no motor loads on the loadside of the LPJ-200SP fuses.
4. Selective coordination requirements. Selective coordination in this application is not required per the NEC® since this is neither a healthcare application, an elevator circuit, nor a part of an emergency legally required standby, or critical operations power system circuit. However, the owner and designer should consider the consequences of a lack of selective coordination. If selective coordination were considered to be necessary, another approach would have to be taken.
5. Labeling requirements. The panelboard must be marked by the manufacturer providing sufficient details about the tested series combination rating. The installer must field install a label on the panelboard and the distribution panelboard providing specific details of the installed series combination rating, the devices and their respective locations. These are critical for verifying the proper ratings for the initial installation and during the life of the system.

Tables by Manufacturer of Available Fuse/Circuit Breaker Series Combination Ratings are on the following pages:

Eaton	67 to 69
Square D	70 to 71
General Electric	72 to 75
Siemens	76 to 77

Eaton Series Rating Chart

Switchboards: PRL-C / PRL-i

Panelboards: PRL 5P, PRL 4, PRL 3A & Pow-R-Command Panelboards (See Notes on Page 45)

Max System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load Side		
				Circuit Breaker	Amps	Poles
120/240	100kA	LPN-RK	200	GB, GHB	ALL	1,2
		JJN, LPJ	400	BA, BAB, HQP, QBHW, QPHW	ALL	1,2
	200kA	LPN-RK	100	BA, BAB, HQP, QBHW, QPHW, GB, GHB	ALL	1,2
		JJN, LPJ	200	BA, BAB, HQP, QBHW, QPHW	ALL	1,2
		JJN, LPJ	400	GB, GHB	ALL	1,2
240	100kA	LPN-RK	200	GHB	ALL	1,2,3
				GB, CA	ALL	2,3
		JJN, LPJ	400	BAB_H, QBHW_H, HQP_H, QPHW_H	ALL	2,3
		JJN	600	CA, CAH, HCA	ALL	2,3
		KRP-C	4000	EHD, FD	ALL	1,2,3
	200kA	KRP-C	4000	FDB, ED, JDB, JD, DK, KDB, KD	ALL	2,3
		LPN-RK	100	GHB	ALL	1,2,3
				BAB_H, QBHW_H, HQP_H, QPHW_H, CAH, HCA, GB	ALL	2,3
		LPN-RK	200	GB, GHB	ALL	2,3
		JJN, LPJ	200	BAB_H, HQP_H, QBHW_H, QPHW_H, CA, CAH, HCA	ALL	2,3
		JJN, LPJ	400	GHB	ALL	1,2,3
				GB	ALL	2,3
480/277	65kA	JJS, LPJ	200	GHBS	ALL	1,2
	100kA	JJS, LPJ	100	GHBS	ALL	1,2
		LPS-RK	200	GHB	ALL	1,2,3
		LPJ	600	EHD, FD, HFD, FDC	ALL	2,3
	200kA	JJS	600	GHB, EHD, FD, HFD, FDC, JD, HJD, JDC	ALL	2,3
		LPS-RK	100	GHB	ALL	1,2,3
		JJS, LPJ	400			
480	100kA	LPS-RK	100	EHD	ALL	2,3
		JJS, LPJ	200	EHD, FD, HFD, FDC	ALL	2,3
		KRP-C	1200	MC, HMC, NC, HNC	ALL	2,3
		KRP-C	800	MC, HMC	ALL	2,3
	200kA	LPS-RK	100	FD, HFD	ALL	2,3
			200	FDC	ALL	2,3
			400	JD, HJD, JDC	ALL	2,3
			600	KD, HKD, KDC	ALL	2,3
600	100kA	JJS, LPJ	200	LC	ALL	2,3
			400	FD, HFD	ALL	2,3
			600	FDC	ALL	2,3
		KRP-C	1200	JD, HJD, JDC	ALL	2,3
	200kA	LPS-RK	400	LC	ALL	2,3
		JJS, LPJ	600	KD, HKD, KDC, LC	ALL	2,3

*Series Combination Interrupting Rating

Eaton Series Rating Chart

Panelboards: PRL 1A, PRL 2A, PRL 1A-LX, PRL 2A-LX

(See Notes Below & Page 45)

Max System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load Side		
				Circuit Breaker	Amps	Poles
120/240	100kA	LPN-RK	200	GB, GHB	ALL	1,2
		JJN, LPJ	400	BA, BAB, HQP, QBHW, QPHW	ALL	1,2
	200kA	LPN-RK	100	BA, BAB, HQP, QBHW, QPHW, GB, GHB	ALL	1,2
		JJN, LPJ	200	BA, BAB, HQP, QBHW, QPHW	ALL	1,2
		JJN, LPJ	400	GB, GHB	ALL	1,2
240	100kA	LPN-RK	200	GHB	ALL	1,2,3
				GB, CA	ALL	2,3
		JJN, LPJ	400	BAB_H, QBHW_H, HQP_H, QPHW_H	ALL	2,3
		JJN	600	CA, CAH, HCA	ALL	2,3
		KRP-C	4000	EHD, FD	ALL	1,2,3
		KRP-C	4000	FDB, ED, JDB, JD, DK, KDB, KD	ALL	2,3
	200kA	LPN-RK	100	GHB	ALL	1,2,3
				BAB_H, QBHW_H, HQP_H, QPHW_H, CAH, HCA, GB	ALL	2,3
		LPN-RK	200	GB, GHB	ALL	2,3
		JJN, LPJ	200	BAB_H, HQP_H, QBHW_H, QPHW_H, CA, CAH, HCA	ALL	2,3
		JJN, LPJ	400	GHB	ALL	1,2,3
				GB	ALL	2,3
480/277	65kA	JJS, LPJ	200	GHBS	ALL	1,2
	100kA	JJS, LPJ	100	GHBS	ALL	1,2
		LPS-RK	200	GHB	ALL	1,2,3
		LPJ	600	EHD, FD, HFD, FDC	ALL	2,3
		JJS	600	GHB, EHD, FD, HFD, FDC, JD, HJD, JDC	ALL	2,3
	200kA	LPS-RK	100	GHB	ALL	1,2,3
		JJS, LPJ	400			

*Series Combination Interrupting Rating

Notes for above Table:

1. The HQP & QPHW are not listed for use in the PRL1A-LX Panel.
2. PRL1A & PRL1A-LX are for use at 240V maximum
3. Branch breakers for maximum 120/240V systems include: BAB, HQP, QBHW & QPHW.
4. Branch breakers for maximum 240V systems include: BAB_H, HQP_H, QBHW_H & QPHW_H.
5. PRL2A & PRL2A-LX, branch breakers include: GHB, GHBS & GB.
6. PRL1A-LX & PRL2A-LX Main & Sub-feed breakers include: ED, FD, HFD, FDC.
7. PRL1A & PRL2A Main & Sub-feed breakers include: CA, CAH, HCA, ED, FD, HFD, FDC, JD, HJD, JDC, KD, HKD & KDC

Eaton Series Rating Chart**Triple Series Rating - Switchboards: PRL-C & PRL-i**

**Panelboard Types: PRL 5P, PRL 4, PRL 3A, PRL 2A, PRL 2A-LX, PRL 1A, PRL 1A-LX
& Pow-R-Command Panels**

(See Notes Below)

Max System Voltage	SCIR*	Line Side Fuse	Tenant Main Type	Branch Type		
				Circuit Breaker	Amps	Poles
120/240	100kA	KRP-C (Max Fuse Size - 6000A)	DK, KDB, KD	GB, GHB	ALL	1,2
			JD, JDB	GB, GHB	ALL	1,2
			FD	GB, GHB	ALL	1,2
			FD, FDB	HQP	15-70	1,2
				BA, BAB	ALL	1,2
			EHD	BA, BAB, HQP	ALL	1,2
240	100kA	KRP-C (Max Fuse Size - 6000A)	DK, KDB, KD	GHB	ALL	1,2,3
				GB, EHD	ALL	2,3
				CA, CAH, HCA	ALL	2,3
				FD, FDB	ALL	2,3
				JD, JDB	ALL	2,3
			JD, JDB	GHB	ALL	1,2,3
				GB	ALL	2,3
			FD	GHB	ALL	1,2,3
				GB	ALL	2,3
			FD, FDB	BAB_H, QBHW_H, HQP_H, QPHW_H	ALL	2,3
				BAB_H, HQP_H	ALL	2,3
			EHD			

*Series Combination Interrupting Rating

NOTE (1): The data in these charts was compiled from information in Eaton, Series Rating Information Manual, catalog reference number 1C96944H01 Rev. E, pages 18-24, and Eaton, Consulting Application Catalog 12th Edition, pages F1-11 - F1-12. Bussmann assumes no responsibility for the accuracy or reliability of the information. The information contained in the tables may change without notice due to equipment design modifications.

NOTE (2): The line-side fused switch may be in a separate enclosure or in the same enclosure as the load-side circuit breaker. A line-side fused switch may be integral or remote.

NOTE (3): Max fuse current rating denotes the largest amperage fuse that may be used for that series rated combination. A lower amperage fuse may be substituted for the listed fuse.

Eaton

Square D Series Rating Chart

I-Line Switchboard/Panelboard

(See Notes on Next Page)

Maximum System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load Side		
				Circuit Breaker	Amps	Poles
240Vac	100kA	LPN-RK	600	FH, KA, KH, LA, LH, MA, MH, MX	ALL	2, 3
		JJS	600	FA	ALL	2, 3
		JJS	800	FH, KA, KH, LA, LH, MA, MH, MX	ALL	2, 3
		LPJ	600	FA, FH, KA, KH, LA, LH, MA, MH, MX	ALL	2, 3
		KRP-C	800	KA	ALL	2, 3
		KRP-C	1200	FH, LA, LH	ALL	2, 3
		KRP-C	2000	KH, MA, MH, MX	ALL	2, 3
	200kA	LPN-RK	600	FH, FC, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA, NC, NX	ALL	2, 3
		JJS	600	FA	ALL	2, 3
		JJS	800	FH, FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA, NC, NX	ALL	2, 3
		LPJ	600	FA, FH, FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA, NC, NX	ALL	2, 3
		KRP-C	800	FH, LA, LH	ALL	2, 3
		KRP-C	1200	FC, KH, KC, LC, LX, MA, MH, MX	ALL	2, 3
		KRP-C	2000	NA, NC, NX	ALL	2, 3
480Vac	100kA	LPS-RK	600	FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA	ALL	2, 3
		JJS	600	FA, FH	ALL	2, 3
		JJS	800	FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA	ALL	2, 3
		LPJ	600	FA, FH, FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA	ALL	2, 3
		KRP-C	800	KA	ALL	2, 3
		KRP-C	1200	KH, LA, LH		
		KRP-C	1600	MA		
	200kA	LPS-RK	600	FC, KC, LA, LH, LC, LX, MA, MH, MX, NA, NC, NX	ALL	2, 3
		JJS	400	FA, FH	ALL	2, 3
		JJS	800	FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA, NC, NX	ALL	2, 3
		LPJ	400	FA, FH	ALL	2, 3
		LPJ	600	FC, KA, KH, KC, LA, LH, LC, LX, MA, MH, MX, NA, NC, NX	ALL	2, 3
		KRP-C	800	LA, LH	ALL	2, 3
		KRP-C	1200	FC, KC, LC, LX, MA, MH, MX	ALL	2, 3
		KRP-C	2000	NA, NC, NX	ALL	2, 3

*Series Combination Interrupting Rating

Square D Series Rating Chart**NQOD Panelboards**

(See Notes Below)

Maximum System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load Side		
				Circuit Breaker	Amps	Poles
240Vac	200kA	JJS, LPJ	200	QO, QOB	ALL	1, 2, 3
				QO, QOB (AS)	ALL	1, 2, 3
				QO, QOB (GF I)	ALL	1, 2, 3
	JJN	JJN	400	QO, QOB	ALL	1, 2, 3
				QO, QOB (AS)	ALL	1, 2, 3
				QO, QOB (GF I)	ALL	1, 2, 3

Note for NQOD Panelboards: 1P for use at 120V Only**NEHB Panelboards**

(See Notes Below)

Maximum System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load Side		
				Circuit Breaker	Amps	Poles
480Y/277Vac	100kA	JJS, LPJ	200	EH, EHB	ALL	1, 2, 3

Note for NEHB Panelboards: 1P for use at 277V Only**NF Panelboard**

(See Notes Below)

Maximum System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load Side		
				Circuit Breaker	Amps	Poles
480Y/277Vac	100kA	JJS, LPJ	400	EDB, EGB, EJB	ALL	1, 2, 3
	200kA	JJS, LPJ	200			

Note for NF Panelboards: 1P for use at 277V Only**SF Switchboards with I-Line or NQOD Distribution**

(See Notes Below)

Maximum System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load Side		
				Circuit Breaker	Amps	Poles
120/240Vac	42kA	JJS	400	QO-VH, QOB-VH	ALL	1 (120V)
240Vac	42kA	JJS	800	QO-VH, QOB-VH, FA, Q4	ALL	2, 3
				Q2-H	ALL	2
				FA, FH	ALL	2, 3
480Vac	50kA	JJS	800	KA, KH, LA, LH	ALL	
	65kA	JJS	800			

*Series Combination Interrupting Rating

NOTE (1): The data in these charts was compiled from information in Square D, Series Rating Data Bulletin No. 2700DB9901 and Square D Digest 171. Bussmann assumes no responsibility for the accuracy or reliability of the information. The information contained in the tables may change without notice due to equipment design modifications

NOTE (2): The line-side fused switch may be in a separate enclosure or in the same enclosure as the load-side circuit breaker. A line-side fused switch may be integral or remote.

NOTE (3): Max fuse current rating denotes the largest amperage fuse that may be used for that series rated combination. A lower amperage fuse may be substituted for the listed fuse.

General Electric Series Rating Chart

Spectra Series

(See Notes on Page 49)

Maximum System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load Side		
				Circuit Breaker	Amps	Poles
240Vac	42kA	JJN, LPJ	600	TJD	250-400	2, 3
		KRP-C	2000	TJD	250-400	2, 3
	100kA	LPJ, JJN	400	TQD	125-225	2, 3
			600	THHQB	40-100	3
			600	TQD	100-225	2
		KRP-C	700	TQD	125-225	3
			800	TJD	250-400	2, 3
			1200	SFH	70-250	2, 3
			2000	TJD	250-400	2, 3
	200kA	LPN-RK	200	THJK	250-600	2, 3
			200	TEB, TED	15-100	1, 2, 3
			200	SFH, SFL	70-250	2, 3
		LPJ, JJN	400	SED, SEH, SEL	15-150	2, 3
			400	TEB	15-100	1, 2
			400	TEB, TED	15-100	2, 3
			400	TJD	250-400	2, 3
		KRP-C	600	SFH, SFL	70-250	2, 3
			2000	SED, SEH, SEL	15-150	2, 3
277Vac	100kA	LPS-RK	200	SGD, SGH, SGL	125-600	
			100	TED	15-50	1
			100	THED	15-30	1
			100	TEY	15-100	1
			200	SED, SEH, SEL	15-150	2, 3
		LPJ, JJS	200	TEY	15-100	1
			200	TED	15-50	1
			400	TED	15-50	1
			400	THED	15-30	1
			400	SED, SEH, SEL	15-150	2, 3
480Vac	100kA	LPS-RK	600	TEY	15-100	1
			600	SED, SEH, SEL	15-150	2, 3
			100	TED, THED6	15-100	2, 3
			100	TEY	15-100	2, 3
			200	SED, SEH, SEL	15-150	2, 3
		LPJ, JJS	200	TED	15-50	1
			400	TED, THED6	15-100	2, 3
			400	SFH, SFL	70-250	2, 3
			400	SGH, SGL	125-600	2, 3
			600	TEY	15-100	2, 3
		JJS	600	SED, SEH, SEL	15-150	2, 3
			800	SKH, SKL	300-1200	2, 3
			1200	THJK	125-600	2, 3
		KRP-C	2000	SKH, SKL	300-1200	2, 3
			2000	SGH, SGL	125-600	2, 3
			2000	TPV, THPV	800A FRAME (1)	3
		200kA	2500	TPV, THPV	2500A FRAME (1)	3
			2500	TPV, THPV	800A FRAME (1)	3
		200kA	2500	TPV, THPV	2500A FRAME (1)	3

*Series Combination Interrupting Rating

(1) Includes all sensor/rating plug or setting values within stated frame size.

General Electric Series Rating Chart

AL / AQ PANELBOARD

(See Notes on Page 49)

Maximum System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load Side		
				Circuit Breaker	Amps	Poles
240Vac	42kA	JJN	600	THQL-GF	15-30	1
				THQL	15-100 (2)	1, 2, 3
		JJN, LPJ	600	TJD	250-400	2, 3
	65kA	KRP-C	2000	TJD	250-400	2, 3
		JJN	600	THHQL	15-70	1
				THHQL	15-125	2
	100kA	JJN, LPJ, LPN-RK	600	TFJ	70-225	2, 3
		KRP-C	3000	TFJ	70-225	2, 3
		LPN-RK	200	THQL	15-100 (2)	1, 2, 3
	200kA	JJN	200	THQP	15-50	1, 2
			400	THQL	15-100 (2)	1, 2, 3
				TQD	125-225	2, 3
				THHQL, THHQB	40-100	3
			600	TFJ	70-225	2, 3
				TQD	100-225	2
				TQD	125-225	3
			800	TJD	250-400	2, 3
		KRP-C	1200	TFJ	70-225	2, 3
				SFH	70-250	2, 3
			2000	TJD	250-400	2, 3
	LPJ, JJN	LPN-RK	200	THQL	15-100 (2)	1, 2
				TFJ	70-200	2, 3
				SFH, SFL	70-250	2, 3
				SED, SEH, SEL	15-150	2, 3
		LPJ, JJN	400	THQL	15-100 (2)	1, 2
				TFJ	70-225	2, 3
				TJD	250-400	2, 3
	KRP-C		600	SFH, SFL	70-250	2, 3
				SED, SEH, SEL	15-150	2, 3
			2000	SGD, SGH, SGL	125-600	

(2) THQL 1 pole rating is 70 amperes maximum. Maximum system voltage is 120/240Vac.
 THQL 2 pole 110-125A ratings are also series rated on 120/240Vac maximum services.

ALC / AQC Panelboard

(See Notes on Page 49)

Maximum System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load Side		
				Circuit Breaker	Amps	Poles
240Vac	42kA	JJN	600	THQL-GF	15-30	1
				THQL	15-100 (2)	1, 2, 3
		JJN	600	THHQL	15-70	1
	65kA	JJN, LPJ, LPN-RK	600	TFJ	70-225	2, 3
		KRP-C	3000	TFJ	70-225	2, 3
		LPN-RK	200	THQL	15-100 (2)	1, 2, 3
	100kA	JJN	200	THQP	15-50	1, 2
			400	THQL	15-100 (2)	1, 2, 3
				TQD	125-225	2, 3
				THHQL, THHQB	40-100	3
			600	TFJ	70-225	2, 3
				TQD	100-225	2
				TQD	125-225	3
		KRP-C	1200	TFJ	70-225	2, 3
				SFH	70-250	2, 3
		LPJ, JJN	400	THQL	15-100 (2)	1, 2
	200kA	LPN-RK	200	TFJ	70-200	2, 3
				SFH, SFL	70-250	2, 3
				SED, SEH, SEL	15-150	2, 3
		LPJ, JJN	400	THQL	15-100 (2)	1, 2
				TFJ	70-225	2, 3
				SFH, SFL	70-250	2, 3
			600	SED, SEH, SEL	15-150	

*Series Combination Interrupting Rating

(2) THQL 1 pole rating is 70 amperes maximum. Maximum system voltage is 120/240Vac.
 THQL 2 pole 110-125A ratings are also series rated on 120/240Vac maximum services.

General Electric Series Rating Chart

AE / AD PANELBOARD

(See Notes on Page 49)

Maximum System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load Side		
				Circuit Breaker	Amps	Poles
277Vac	100kA	LPS-RK	100	TED	15-50	1
				THED	15-30	1
				TEY	15-100	1
		LPJ, JJS	200	SED, SEH, SEL	15-150	2, 3
				TEY	15-100	1
				TED	15-50	1
		400	400	TED	15-50	1
				THED	15-30	1
				SED, SEH, SEL	15-150	2, 3
		600	600	TEY	15-100	1
				SED, SEH, SEL	15-150	
480Vac	100kA	LPJ	600	TED, THED	15-150	2, 3
			100	TED, THED6	15-100	2, 3
		LPS-RK	200	TEY	15-100	2, 3
				SED, SEH, SEL	15-150	2, 3
				TED	15-50	1
		LPJ, JJS	400	TED, THED6	15-100	2, 3
				TFJ	70-225	2, 3
				TJJ	125-400	2, 3
				SFH, SFL	70-250	2, 3
				SGH, SGL	125-600	2, 3
		600	600	TEY	15-100	2, 3
				SED, SEH, SEL	15-150	2, 3
		JJS	800	SKH, SKL	300-1200	2, 3
		KRP-C	1200	TJJ	125-400	2, 3
			2000	SKH, SKL	300-1200	2, 3
			SGH, SGL	1		

*Series Combination Interrupting Rating

AEC PANELBOARD

(See Notes on Page 49)

Maximum System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load Side		
				Circuit Breaker	Amps	Poles
277Vac	100kA	LPS-RK	100	TED	15-50	1
				TEY	15-100	1
			200	SED, SEH, SEL	15-150	2, 3
		LPJ, JJS	400	TEY	15-100	1
				TED	15-50	1
			600	TED	15-50	1
			400	SED, SEH, SEL	15-150	2, 3
				TEY	15-100	1
		600	600	SED, SEH, SEL	15-150	
				TEY	15-100	1
480Vac	100kA	LPJ	600	TED	15-150	2, 3
			100	TED	15-100	2, 3
		LPS-RK	200	TEY	15-100	2, 3
				SED, SEH, SEL	15-150	2, 3
			400	TED	15-50	1
		LPJ, JJS	400	TEY	15-100	2, 3
				TFJ	70-225	2, 3
			600	SFH, SFL	70-250	2, 3
				SGH, SGL	125-600	2, 3
			600	TEY	15-100	2, 3
				SED, SEH, SEL	15-150	

*Series Combination Interrupting Rating

General Electric Series Rating Chart

Note: The following circuit breakers may be substituted for the circuit breakers shown in the series rating tabulations. Devices with MicroVersaTrip Plus and PM trip units may also be substituted, provided the short circuit rating is equal to or greater than series connected rating. Ref. GE publication DET-008A.

Breaker	Substitute Breaker(s)
THQL	THQB, THQC, THQE, THHQL, THHQB, THHQC
THHQL	THHQB, THHQC
THQL-GF	THQB-GF, THQC-GF
TED	THED
SED	SEH, SEL, SEP
SEH	SEL, SEP
SEL	SEP
TQD	THQD
TFJ	TFK, THFK
SFH	SFL, SFP
SFL	SFP
TJJ	TJK, THJK, TJ4V, THJ4V, THJ9V, TJH
THJK	THJ4V, THJ9V, TJH, TJL
SGD	SGH, SGL, SGP
SGH	SGL, SGP
SGL	SGP
SKH	SKL, SKP
SKL	SKP
TPV	SS, SH, TP, TC, TCV, THP, THC, THCV
THPV	SH, THP, THC, THCV

NOTE 1: The data in these charts was compiled from information in GE Electrical Distribution & Control publication, catalog reference number GEP-1100P and GE Electrical Distribution & Control publication - UL Component Recognized Series Ratings, publication reference number DET-008A. Bussmann assumes no responsibility for the accuracy or reliability of the information. The information contained in the tables may change without notice due to equipment design modifications.

NOTE 2: The line-side fused switch may be in a separate enclosure or in the same enclosure as the load-side circuit breaker. A line-side fused switch may be integral or remote.

NOTE 3: Max fuse current rating denotes the largest amperage fuse that may be used for that series rated combination. A lower amperage fuse may be substituted for the listed fuse.

Siemens Series Rating Chart

Switchboards SB1, SB2, SB3 Panelboard S1

(See Notes on Next Page)

Max System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load side		
				Circuit Breaker	Amps	Poles
120/240Vac	65kA	LPJ, LPN-RK	600	QPH, BQH, BLH	15-70	1 (120V)
		JJN (300V)	1200		15-125	2
		KRP-C	6000		15-100	3
	100kA	JJN (300V)	200	QP, BQ, BL	15-70	1 (120V)
					15-125	2
					15-100	3
				HQP, HBQ, HBL, QPH, BQH, BLH	15-100	3
			600	QPF, BQF, BLF, QE, BE, BLE, QEH, BLEH, BLHF, QPHF, BQHF	15-30	1 (120V)
				QEH, BLEH, QE, QPHF, BLHF, BLE, QPF, BLF	15-60	2
				QT	15-50	1 (120V),2
240Vac	100kA	LPJ, LPN-RK	600	QPH, BQH, BLH, HQP, HBQ, HBL	15-70	1 (120V)
				15-125	2	
				15-100	3	
			1200	ED4, HED4	15-100	1 (120V)
				ED4, ED6, HED4, HED6	15-125	2,3
				FD6-A, FXD6-A	70-250	2,3
				JD6-A, JXD6-A, JXD2-A, SJD6-A	200-400	2,3
	200kA	JJN (300V)	1200	LD6-A	200-600	2,3
				SLD6-A	300-600	3
				LXD6-A	450-600	2,3
				ED4, HED4	15-100	1 (120V)
				ED4, ED6, HED4, HED6	15-125	2,3
				FD6-A, FXD6-A	70-250	2,3
				JD6-A, JXD6-A, JXD2-A, SJD6-A	200-400	2,3
		KRP-C	6000	LD6-A	200-600	2,3
				SLD6-A	300-600	3
				LXD6-A	450-600	2,3
				SMD6	500-800	3
	200kA	LPN-RK	200	SND6	500-1200	3
				PD6, PXD6, SPD6	1200-1600	3
				RD6, RXD6	1600-2000	3
		JJN (300V)	400	QJH2, QJ2H, QJ2	125-200	2,3
				QJ2	125-225	2,3
				QJH2, QJ2H	125-225	2,3
				HFD6, HFxD6	70-250	2,3
		LPJ, LPN-RK	600	HFD6, HFxD6	70-250	2,3
				HFD6, HFxD6	70-250	2,3
				MD6, MXD6, HMD6, HMxD6	500-800	2,3
				ND6, NXD6, HND6, HNXD6	500-1200	2,3

*Series Combination Interrupting Rating

Siemens Series Rating Chart

Switchboards SB1, SB2, SB3
Panelboards S2, SE, S3, S4, S5

(See Notes Below)

Max System Voltage	SCIR*	Line Side Fuse	Max Fuse Current Rating	Load side		
				Circuit Breaker	Amps	Poles
480Vac	50kA	LPJ	400	ED4	60-100	1 (277V)
					15-100	2,3
	100kA	LPJ	400	ED4	15-50	1 (277V)
					70-250	2,3
		JJS, LPJ	600	FD6-A, FXD6-A	70-250	2,3
		LPJ, LPS-RK	600	HFD6, HFxD6	70-250	2,3
		JJS, LPJ, LPS-RK	600	JD6-A, JXD6-A, HJD6-A, HJxD6-A	200-400	2,3
				LD6-A, HLD6-A	200-600	2,3
				LxD6-A, HLxD6-A	450-600	2,3
		JJS	800	HFD6, HFxD6	70-250	2,3
		JJS, KRP-C	1200	JD6-A, JXD6-A, HJD6-A, HJxD6-A	200-400	2,3
				LD6-A, HLD6-A	200-600	2,3
				LxD6-A, HLxD6-A	450-600	2,3
	480/277V	KRP-C	6000	HFD6, HFxD6	70-250	2,3
				MD6, MXD6, HMD6, HMXD6	500-800	2,3
		LPS-RK	100	ND6, NxD6, HND6, HNxD6	500-1200	2,3
				BQD, CQD	15-100	1 (277V)
				BQD**, CQD **	20-30	2,3
		JJS, LPJ	200	BQD, CQD	15-100	1 (277V)
				BQD**, CQD **	20-30	2,3

*Series Combination Interrupting Rating

** BQD and CQD breakers are series rated from 15-100A for Series 7A, S2 and S3 panelboard applications only.

NOTE (1): The data in these charts was compiled from information in Siemens SpeedFax 2000 Electrical Products publication, catalog reference number GNPC-01000. Bussmann assumes no responsibility for the accuracy or reliability of the information. The information contained in the tables may change without notice due to equipment design modifications.

NOTE (2): The line-side fused switch may be in a separate enclosure or in the same enclosure as the load-side circuit breaker. A line-side fused switch may be integral or remote.

NOTE (3): Max fuse current rating denotes the largest amperage fuse that may be used for that series rated combination. A lower amperage fuse may be substituted for the listed fuse.

Automatic Transfer Switch Protection

Automatic transfer switches (ATSs) are a vital part of many life safety-related systems and mission critical systems where continuity of service is crucial. The NEC® requires 600V or less ATSs to be “listed for emergency system use” for emergency power systems [700.5(C)], legally required standby systems [701.5(C)], healthcare essential electrical systems (517.26), and critical operation power systems [708.24(C)(1)].

When designing a power system and specifying a transfer switch, two important design considerations must be evaluated:

- (1) An ATS’s Withstand and Closing (Close On) Ratings (WCR), which is analogous to its Short Circuit Current Rating.
- (2) How the overcurrent protective device protecting the ATS affects system selective coordination.

Both are related to the overcurrent protective device selection. A misapplication of the relationship between a transfer switch and its overcurrent protective device (OCPD) can have a severe impact on the integrity of the system and to the overall project cost. In addition, the characteristics of the transfer switch overcurrent protective device can impact whether selective coordination can be achieved for the full range of overcurrents. This section focuses on ATS short-circuit current protection and the common misconceptions and deficiencies of non-current limiting protection. Please see the SPD section on selective coordination for more information concerning system overcurrent protective device coordination.

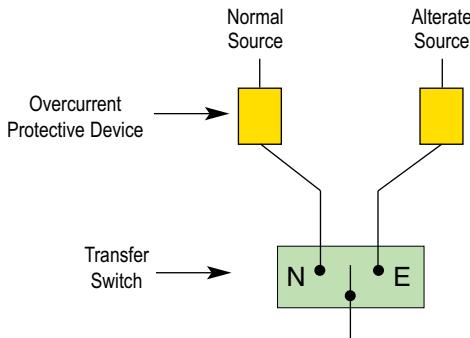


Figure 1

Automatic transfer switches must comply with the Withstand and Closing (Close On) Ratings (WCR)

Requirements of UL 1008 Transfer Switch Equipment.

A clear understanding of the relationship between a transfer switch’s short-circuit current withstand and closing rating and its protective device is imperative to assure a well designed installation. See Figure 1. An ATS must be properly protected for short-circuit currents from either source of power or in the case of closed transition ATSs, the combination of the fault current from each source. If a transfer switch is subjected to a fault current above its maximum short-circuit current withstand and closing rating, severe ATS damage (including a potential fire hazard and arc flash hazard), and severe injury or death may result.

Options for ATS Protection

Transfer switches are tested, listed, and labeled for use with either fuses or circuit breakers; each offering different levels of protection. UL 1008 Transfer Switch Equipment is the product standard for transfer switches. Within this standard there are two ATS short-circuit current withstand tests. First the transfer switch must withstand a short-circuit when the switch is in a closed position. During the second withstand test the ATS must transfer, close and withstand the short-circuit current until the current is cleared. ATSs must pass both of these tests at the same available short-circuit current magnitude and survive within specified acceptable damage levels. The term commonly used in the industry for this ATS short-circuit current rating is WCR for Withstand and Closing (Close On) Rating.

Figures 2 and 3 (at the end of the document) are aids for understanding the protection options and illustrate typical ATS manufacturers’ data available for proper specification and application. Figure 2 is an example label for a 400A ATS. The label is typically affixed on the outside of the enclosure or readily visible by opening a door or removing a cover. The label is useful during installation, inspection, and post installation alterations. Figure 3 is a WCR table for all the ampere ratings for a manufacturer’s specific ATS series. This would be useful during the specification/procurement process. The Figure 2 label and Figure 3 table are fictitious for illustrative purposes only. When interpreting actual manufacturer’s WCR tables and equipment labels, be sure to read all pertinent footnotes, referenced materials, etc.

Circuit Breaker Protection Options for ATS WCR

ATSS protected by circuit breakers can be classified by one of three different Withstand and Closing (Close On) ratings:

- (1) Specific circuit breaker rating
- (2) “Any Breaker” rating: 3 cycle short-circuit test rating applicable to any circuit breakers having an instantaneous trip
- (3) Short time rating (may be rated for 18-30 cycles)

These three ATS short-circuit protection options for circuit breaker are indicated in Figures 2 and 3 by the corresponding number (1), (2), or (3).

(1.) Specific Breaker WCR Rating

For a transfer switch to receive a “specific breaker” rating in accordance with UL 1008, it must be short-circuit current tested when protected by a specific circuit breaker (CB manufacturer, type designation, and ampere rating). ATS manufacturers typically will provide many specific circuit breaker choices that have been tested and listed for a particular transfer switch. ATS manufacturers provide documentation of these acceptable “specific breakers”. See Figure 2 option 1 for label example. Figure 3, Specific Breaker Rating column marked (1), provides the levels of protection, in amperes, achievable through the use of specific breakers for a particular transfer switch series. To view the list of specific breakers tested and accepted, it is necessary to contact the ATS manufacturer.

Certain issues may arise when specific breaker combinations are used. Specific breaker ratings are usually a hindrance on bid day, because in most circumstances, the vendor providing the circuit breaker and the transfer switch are not the same. This places extra responsibility on the contractor and consulting engineer to make sure the ATS/circuit breaker pair is a tested, listed combination. Specific breaker combinations are often highly scrutinized by the authority having jurisdiction during an inspection. Although a specific breaker may be properly short-circuit combination rated with the transfer switch at the time of the initial installation, it is very likely that over the life of a system the circuit breaker may need to be replaced. The person tasked with finding a replacement circuit breaker, may not fully understand the importance of the relationship between the circuit breaker and the ATS it is protecting. If a new circuit breaker is installed that differs in type and/or rating, it may not be listed to protect the transfer switch, and could be a potential hazard.

3 Cycle “Any Breaker” WCR Rating

The 3 cycle rating was introduced into UL 1008 in 1989. It allowed ATS manufacturers to provide their switches with another rating category for short-circuit current WCR. An ATS that passes this test is able to withstand a fault of a given magnitude for 3 cycles (1.5 cycles for switches 400A and less and tested for 10,000A WCR.) and not exceed certain damage criteria. See Figure 2 option 2 for label example. See Figure 3 “Any” Breaker Rating column marked (2).

The purpose of the test is to allow a transfer switch to be marked for use with any manufacturer’s circuit breaker that incorporates an “instantaneous trip” when the transfer switch and circuit breaker are applied within their ratings. The umbrella ratings provided by this test allow an engineer more flexibility when specifying circuit breaker protection for a transfer switch. This option does not have many of the procurement, installation, or replacement issues incurred when using the specific breaker option (1). It was for this reason the rating was referred to as the “any breaker” rating and was considered the best practice solution when using circuit breakers for ATS protection. This however has changed recently with the advancement and growing understanding of selective coordination; see circuit breaker option (3), which follows.

Automatic Transfer Switch Protection

(3.) Short time WCR Ratings with Circuit Breakers

New considerations for ATSs came to the forefront with the addition of selective coordination requirements for emergency systems, legally required standby systems and healthcare essential electrical systems into the 2005 NEC. (A similar requirement for critical operations power systems was included in the 2008 NEC). See the selective coordination section in Bussmann SPD publication for more information.

Designers desiring selective coordination with circuit breakers often use circuit breakers with short time delay tripping (CB without instantaneous trip) in vital systems. Circuit breakers with short-time delay and no instantaneous trip increase the time that an ATS must withstand a short-circuit current. Since the short-time delay opening time will exceed the three cycle time limit for the 3 cycle "any breaker", Option 2 of Figure 2 or Column 2 of Figure 3 cannot be utilized.

Because of the selective coordination requirements for the life safety-related loads, the 3 cycle, "Any Breaker" ratings that were previously the norm for ATS protection in circuit breaker designs, are no longer sufficient in many cases. Practical example: If the circuit breaker upstream protecting a transfer switch has an intentional short time delay of 0.1 seconds (6 cycles), a 3 cycle "any breaker" rating will not provide adequate protection for the ATS.

In recent years some ATS manufacturers have introduced short time rated ATSs to aid in circuit breaker designs requiring selective coordination. The short time test subjects an ATS to a given fault current for up to 30 cycles, for which the ATS cannot sustain extensive damage and must be operable afterwards. The options available for transfer switches with short time ratings are very limited and also usually carry a much higher price tag when compared to similar standard ATSs of the same amp size. See Figure 2 option 3 for short-time WCR and see Figure 3, "Short-Time" column (3).

Fuse Protection Option for ATS WCR

(4.) Fuse Protection Option for ATS WCR

The other option for ATS protection is the use of current limiting fuses. The current-limiting ability of fuses to limit let-through current and thereby reduce the damaging energy during a fault, assures the ATS will be protected even when exposed to very high fault levels; in almost all cases up to 200kA. (*See the Fuseology section for a better understanding of how a fuse operates and is able to limit fault current.*) The combination tested fuse class and maximum amp rating is given by ATS manufacturers along with the WCR protection level. See Figure 2, option 4 Fuse WCR, and Figure 3, ATS Protected by Current-Limiting Fuse Protection columns (4).

Simplicity in Achieving High WCRs

It is fast and easy to specify fuse protection and achieve high ATS WCR. In most cases, regardless of manufacturer, ATSs will have a 200kA WCR with current-limiting fuses. Compare Tables 1 and 2 which outline some of the ATS characteristics that must be evaluated to adequately specify fuse or circuit breaker protection for ATS WCR. When choosing circuit breaker protection, an ATS's WCR varies considerably based on the type circuit breaker used and the characteristics of the ATS; these considerations will have an impact on the design as well as the installation. When using fuse protection, the specifier, installer or facility owner does not have to be concerned with the specifics of the maximum available short-circuit current during the design/install process or whether the fault current may increase during the system life time, (because very few systems have available short-circuit currents above 200kA).

Table 1: What determines an ATS's WCR when protected by fuses:

- Only the switch amp rating and the fuse UL class/max. amp rating (Almost all ATSs, regardless of manufacturer, have a WCR of 200,000A when protected by current-limiting fuses. There are very few exceptions.)

Table 2: What determines an ATS's WCR when protected by a circuit breaker:

- ATS Manufacturer (ASCO, Russel, Zenith, Cummins, CAT/Eaton, Kohler, etc.)
- ATS Series (i.e. 300,4000,7000)
- Voltage (240,480,600)
- Frame size (amp rating)
- Bypass/Non Bypass Switch
- # of poles (2,3,4)
- Type of neutral (solid, switched, overlapping)
- Connection type (front/rear connect, mechanical/compression lugs)
- Type circuit breaker to be used: specific manufacturer, any breaker w/instantaneous trip, short-time delay without instantaneous trip (and for how long)

As you can see in Table 2, there are many factors that define the protection level provided by a circuit breaker. Following the ATS manufacturers' WCR chart, (similar to Figure 3) a specifier or installer cannot be assured that in all applications a circuit breaker will provide adequate protection. Common configurations such as using a 4 pole overlapping neutral will actually result an ATS with a lower WCR rating in certain cases. For one major ATS manufacturer, an ATS from 260 to 600A has a 42kA, 3 cycle WCR rating at 480V when protected by any circuit breaker. However, if a 260 to 600A ATS with a 4 pole overlapping neutral is used, the rating would only be 35kA for these switches when protected by any circuit breaker. These same ATSs protected by appropriate fuses have a 200kA WCR.

Another commonly overlooked design concern is the connection type chosen for the ATS. Certain ATSs have optional front, rear, or side connect versions to help accommodate sizing concerns and aid in installation. For instance, an ATS when designed as a rear connect switch is rated for 65kA WCR with any circuit breaker protection, but may only have a 50kA WCR if the front connect version is chosen with any circuit breaker protection. Similarly when protected by a circuit breaker, the WCR for an ATS may vary with the type of cable connections specified. While in most cases the standard connection type for ATS installation is mechanical screw type lugs, many projects request compression lugs for ATSs. This will in most cases also adversely affect the WCR given to an ATS when protected by a circuit breaker. If these ATSs are protected by fuses, these ATS characteristics are a non-issue and the WCR is typically 200kA.

Practical Examples

Cost Factor Example 1

Along with the superior current limiting protection and simplicity that fuses provide there is in most cases, a substantial cost savings. Let's take a look at a common automatic transfer switch example: The following pricing example has been taken from an actual transfer switch quote, and is a common occurrence across ATS manufacturers. The manufacturer name and part numbers have been omitted.

Requirement

A consulting engineer needs to specify the following for a hospital patient wing addition. In their design circuit breakers will be used upstream to protect the ATSs. Qty (5) Automatic Transfer Bypass Isolation Switches, 600A, 480V, 4 pole switched neutral, with a NEMA 1 enclosure

Initial ATS Cost Estimate

From ATS manufacturer:

The estimated cost per switch: \$15,000.00

Cost for Qty (5): \$75,000.00

Footprint dimensions per switch: 34"W x 28"D (Height not considered)

ATS Cost Modified due to Fault Current

However when the available fault current is calculated, it is determined that there is a 58kA RMS sym available short-circuit current at the ATS. The designer concludes that these transfer switches will require a 65kA 3 cycle, WCR. (This assumes instantaneous trip circuit breakers will be used.)

After reviewing the WCR chart provided by the ATS manufacturer (similar to Figure 3), the engineer discovers the transfer switch quoted above is only rated to withstand 42kA for 3 cycles. In order to assure the ATS can withstand a fault current of this magnitude it is necessary to move up to the next ATS frame size, and purchase an ATS with adequate WCR. The next frame size offered by this ATS manufacturer is their 800 to 1200A ATS. The engineer again goes back to the WCR chart and learns that a switch of this size is only rated for 50kA for 3 cycles. Again, this will require the move up to an even larger ATS. The next ATS frame size manufactured is 1600-2000A. After reviewing the WCR chart the consultant sees that these switches can withstand faults of 100kA depending on the required ATS characteristics. Either way, this switch will be able to withstand the 58kA available and meet the 65kA 3 cycle requirement. The consultant goes back to the ATS manufacturer for a new price.

Automatic Transfer Switch Protection

Requote of ATS Cost Estimate

From ATS manufacturer:

The new cost per switch: \$35,000.00

Cost for Qty (5): \$175,000.00

Footprint dimensions per switch: 38"W x 60"D

Additional cost =

\$20K per ATS x Qty (5) = **\$100,000.00 to Owner**

Additional floor space required = 20"W x 160"D in electrical room

This is a very common example. It may or may not be made clear during a bid or submittal review that these changes have occurred, but the added costs are real. These additional costs are in most cases figured in by the ATS manufacturer during the initial bid and never questioned. There can be a substantial price premium incurred when the system has higher available short-circuit currents. The larger ATSS will also take up more floor space in already crowded electrical rooms.

ATS Cost with Fuse Protection

Both of these situations could be avoided however with the use of fuses. If current limiting fuses are specified upstream of the ATS, the energy let through during a fault will be far below the withstand threshold of the ATS, allowing the original 600A (\$15,000) transfer switches to be protected from any fault up to 200kA. With fuse protection, the original ATS cost estimate would be applicable. This in turn would have saved the end user over \$100,000.00! In addition, floor space is conserved.

Practical Example 2

The following is another real transfer switch example. This illustrates issues that may arise after initial design. A consulting engineer specifies an ATS protected by circuit breakers. The engineer calculates the available fault current as designed at the ATS to be 48kA and labels the drawings accordingly. After reviewing the drawings the contractor purchases an ATS with a WCR of 50kA. When installing the conduit and pulling the cables the contractor finds a shorter path to run the cabling to the ATS than originally planned and is able to save on conductor material and installation costs. The ATS is manufactured, shipped, and installed at the job site. When the "as installed" short circuit and coordination study is conducted, it is determined that the available fault current at the ATS is now 52kA. The ATS however is only rated to withstand a fault of 50kA. Now what?

An inspector will not approve this ATS that is not rated for use with the maximum available fault current plus there is a liability if installed in this manner. If the contractor requests a return and purchase of a properly rated ATS from the manufacturer, there will surely be a change order and extra costs involved. Who pays? This is another real example that is common across the industry. The solution to this dilemma by some contractors is to run the cabling down a hallway and back again to reduce the available fault current to what was originally expected! Is that good practice? In most cases, current-limiting fuses provide a simple, no worry solution for transfer switches with available fault current up to 200kA.

400A Automatic Transfer Switch Label Example				
CB O P T I O N 1	When protected by type designated circuit breaker shown rated not more than _amps shown, this transfer switch is rated for use on a circuit capable of delivering not more than _rms symmetrical amps at _volts maximum shown.			
	RMS Sym Amps (kA)	Volts Max.	Circuit Breaker Manufacturer / Type	Amps Rating Max.
	50	480	Brand X Types A, B, C	400 500
	50	480	Brand Y Types D, E, F	400 800
	50	480	Brand Z Types G, H, I	400 800
CB O P T I O N 2	When protected by a circuit breaker without a short-time delay, this transfer switch is rated for use on a circuit capable of delivering not more than _rms symmetrical amps at the _volts maximum shown. (This is for circuit breakers with an instantaneous trip.)			
	RMS Sym Amps (kA)	Volts Max.	Circuit Breaker Manufacturer / Type	Amps Rating Max.
	65	240	Any	Per NEC®
	35	600	Any	Per NEC®
	This transfer switch is intended for use with an upstream circuit breaker having a short-time rating not exceeding 30,000A at 480V, for 24 cycles (0.40 seconds).			
CB O P T I O N 3	RMS Sym Amps (kA)	Volts Max.	Circuit Breaker Manufacturer / Type	Amps Rating Max.
Fuse O P T I O N 4	When protected by specified _amp maximum Class fuse shown, this transfer switch is rated for use on a circuit capable of delivering not more than _rms symmetrical amps and at _volts maximum shown.			
	RMS Sym Amps (kA)	Volts Max.	Fuse Class	Amps Rating Max.
	200	600	Class J	600
	200	600	Class L	800

Figure 2: Label example for a 400 Amp ATS providing the tested and listed short-circuit current withstand and closing ratings (WCR) for this specific device. The circuit breakers or fuses that supply this ATS must adhere to these types and ampere ratings. In addition, the available short-circuit current at the ATS installation point cannot exceed the RMS sym amps as shown for the corresponding circuit breaker or fuses option used. This information is presented in different formats on actual ATS labels. The terminology, wording, and formats can vary considerably.

Automatic Transfer Switch Protection

Figure 3: Example of short-circuit current WCR chart provided by ATS manufacturer

This chart and notes provide an example of the information ATS manufacturers provide as a starting point for specifying overcurrent protection for their transfer switches. Fuses provide WCR protection typically up to fault currents of 200kA. Circuit breaker protection on the other hand typically results in lower ATS WCRs and there may be many exceptions to this chart. See the **Simplicity in Achieving High WCRs** section for more details.

Notes:

ATS UL 1008 Withstand and Close-On Ratings (WCR) (Sym RMS Amp)											
Transfer Switch Amp Rating	ATS Protected by Circuit Breaker						ATS Protected by Current-Limiting Fuse				
	1	2	3			4					
	ATS Specific Circuit Breaker WCR Note 1	Max. Voltage	ATS Any Circuit Breaker WCR Note 2	Max. Voltage	ATS Short Time WCR (Circuit Breaker without instantaneous Trip)			ATS Fuse WCR	Fuse Max. Amp Rating	Fuse UL Class	Max. Voltage
40	NA	-	10,000	600	NA	-	-	200,000	60	J	600
70, 100	22,000	480	10,000	600	NA	-	-	200,000	200	J	600
125, 150, 200	22,000	480	10,000	480	NA	-	-	200,000	300	J	600
260, 400, 600	50,000	480	42,000	480	30,000	24	480	200,000	600 800	J L	600
800, 1000, 1200	65000	600	50,000	600	35,000	18	480	200,000	1600	L	600
1600, 2000	100,000	480	100,000	600	65,000	30	480	200,000	3000	L	600

1. WCR with specific circuit breaker: with this option the ATS manufacturer will provide a list of specific circuit breakers detailing the circuit breaker manufacturer, CB type or series, max. voltage, max. amp rating, and ATS WCR rating with that specific CB. Contact ATS manufacturer.

2. WCR with "Any" circuit breaker: the circuit breakers for this option must have an instantaneous trip and clear within 3 cycles (1.5 cycle clearing for switches 400A and less and tested for 10,000A WCR). The circuit breaker ampere rating would be based on NEC® requirements.

Short-Circuit Current Rating (SCCR)

The NEC® has a definition of "Short-Circuit Current Rating" (SCCR). Previous to the 2011 NEC® there was no definition of short-circuit current rating (sometimes referred to as "withstand rating"), although it was referenced in several sections on the marking and proper application of various types of equipment. Because the term is referenced in multiple locations of the Code, it was necessary to add a definition to Article 100 of the NEC®.

Article 100 Definitions

Short-Circuit Current Rating. The prospective symmetrical fault current at a nominal voltage to which an apparatus or system is able to be connected without sustaining damage exceeding defined acceptance criteria.

What is Short-Circuit Current Rating?

Short-Circuit Current Rating (SCCR) is the maximum short-circuit current a component or assembly can safely withstand when protected by a specific overcurrent protective device(s) or for a specified time. Adequate equipment short-circuit current rating is required per NEC® 110.10.



AWG Wire Range	Class J Fuse Max. Amp	Resulting SCCR
2-6	400A	200kA
2-14	200A	50kA
2-14	175A	100kA

This power distribution block, protected with Class J fuses, is rated for use on a circuit capable of delivering no more than the SCCR kA shown (kA rms sym. or DC amps 600V maximum).

Figure 1

Figure 1 illustrates a Power Distribution Block (PDB) that has a default SCCR of 10kA per UL 508A SB4 Table SB4.1. However, this PDB has been combination tested and UL Listed with higher SCCRs when in combination with specific types and maximum amp rating current-limiting fuses. The label is marked with a 200kA SCCR when protected by 400A or less Class J fuses and the conductors on the lineside and loadside are in the range of 2 to 6AWG.

"Short-circuit current rating" is not the same as "interrupting rating" and the two must not be confused. Interrupting rating is the highest current at rated voltage that a device is identified to interrupt under standard test conditions; it does not ensure protection of the circuit components or equipment. Adequate interrupting rating is required per NEC® 110.9. The fuse in Figure 2 has a UL Listed interrupting rating of 300kA @ 600Vac or less.

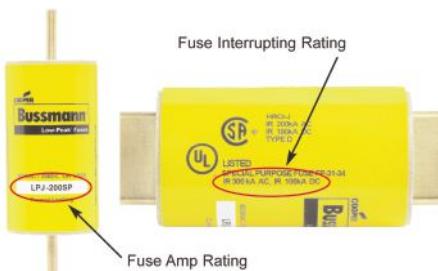


Figure 2

When analyzing assemblies for short-circuit current rating, the interrupting rating of overcurrent protective devices and the short-circuit current rating of all other components affect the overall equipment/assembly short-circuit current rating. For instance, the short-circuit current rating of an industrial control panel typically can not be greater than the lowest interrupting rating of any fuse or circuit breaker, or the lowest short-circuit current rating of all other components in the enclosure.

Why is Short-Circuit Current Rating Important?

Short-circuit current ratings provide the level of fault current that a component or piece of equipment can safely withstand (based on a shock hazard or a fire hazard external to the enclosure). Without knowing the available fault current and short-circuit current rating, it is impossible to determine if components or equipment can be safely installed.

Specification and installation of new equipment with higher short-circuit current ratings, such as 200,000 amps, makes it easy to meet the requirements of the NEC®. In addition, when equipment is later moved within a facility or from plant to plant, equipment with the highest ratings can be moved without worrying about unsafe situations that might arise from placing the equipment in a new location where the available short-circuit current is higher than the old location and now above the rating of the equipment.

Use of Current Limiting Fuses and Equipment SCCR.

The use of current-limiting fuses is frequently an effective tool that is used by original equipment manufacturers to increase their equipment SCCR. The question sometimes arises, however, as to the suitability of utilizing the let-through current of an externally mounted current-limiting fuse to reduce the available short-circuit current to within the SCCR of a piece of equipment that has a marked SCCR that is inadequate for the intended application. While you can take the reduction of the calculated available short-circuit current based on manufacturer published data "to the bank", independent of what is connected downstream (resulting short-circuit current will never exceed the published let-through current. It can't. If the current that the fuse sees is less, the let-through current will also be less.), it would not be appropriate to utilize the let-through current of the remotely mounted fuse since the equipment short-circuit current rating was likely determined in accordance with product standards such as UL 508A, and, usage of the manufacturer published let-through current of a remote current limiting fuse is not compatible with the methods in UL 508A. Two examples may help to explain. Example (1)-If the equipment SCCR were limited due to the low interrupting rating of an overcurrent protective device, such as a circuit breaker with a 10,000 ampere interrupting rating, UL 508A would not allow current limitation to increase that rating. Example (2)-If the equipment SCCR were limited due to the low combination rating of, for example, a combination motor controller that is already tested with and takes advantage of current- limitation provided by the device that was part of the combination testing, UL 508A, and the laws of physics, would not allow another device, upstream, to provide additional current limitation. That is because, if the overcurrent device that was part of the combination controller selectively coordinated with the larger upstream device, the upstream device would not open, and therefore would not provide any additional current limitation. For installations where the fault current exceeds the marked SCCR of industrial control panels and industrial machinery, other methods should be explored such as adding impedance to reduce the fault current or redesigning the existing equipment, or reevaluating, and remarking the SCCR based on field inspection by an NRTL. However, this does not mean that current-limiting fuses should not be installed upstream of equipment. That couldn't be further from the truth. The use of upstream current-limiting fuses (1) is an effective tool to reduce arc flash hazards at downstream equipment, (2) allows for simple selective coordination with upstream, larger, current limiting fuses in a feeder or main, (3) provides excellent and unsurpassed short-circuit protection for any load side-connected conductors/busway, and (4) retains its protection capabilities, independent of the preventative maintenance performed on it.

SCCR Marking Requirements & Compliance

What are the Short-Circuit Current Rating Requirements?

The NEC® has requirements for certain components and equipment to be marked with their short-circuit current rating. The important sections of the Code that require the marking of the short-circuit current rating include the following areas.

Industrial Control Panels: 409.110(4) requires that an industrial control panel be marked with its short-circuit current rating (see Figure 3).

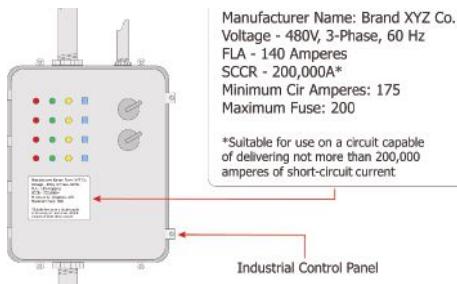


Figure 3 (Courtesy IAEI)

Per the 2011 NEC®, 409.22 prohibits the installation of industrial control panels where the available fault current exceeds the short-circuit current rating as marked in accordance with 409.110(4). This new change to the NEC® identifies the fact that the installer of industrial control panels must verify that the available fault current where the equipment is being installed does not exceed the marked SCCR of industrial control panels. Typically where fault currents exceed 5,000A, the designer and installer need to advise the manufacturer of the industrial control panel of the available fault current so industrial control panels with adequate SCCR can be designed/manufactured. This may require the use of current-limiting fuses to achieve an SCCR adequate for the installation.

Industrial Machinery Electrical Panel: 670.3(A)(4) requires the nameplate on industrial machinery to include the short-circuit current rating of the machine industrial control panel. In previous editions of the NEC® (2002 Edition) and NFPA 79 (2002 Edition), the industrial machine nameplate was required to include only the interrupting rating of the machine overcurrent protective device, if furnished. This marking was misleading as it did not represent the short-circuit current rating of the machine industrial control panel, but could be misinterpreted as such.



Interior of modern industrial machinery panel.

Per the 2011 NEC®, 670.5 prohibits the installation of industrial machinery where the available fault current exceeds the short-circuit current rating as marked in accordance with 670.3(A)(4). This new change to the NEC® identifies the fact that the installer of industrial machinery must verify that the available fault current where the equipment is being installed does not exceed the marked SCCR of industrial machinery. Typically where fault currents exceed 5,000A, the designer and installer need to advise the manufacturer of the industrial machinery of the available fault current so industrial machinery with adequate SCCR can be designed/manufactured. The use of current-limiting fuses may be required to achieve an SCCR adequate for the installation.

Air Conditioning and Refrigeration Equipment with Multimotor and Combination Loads: 440.4(B) requires the nameplate of this equipment to be

marked with its short-circuit current rating. There are three exceptions for which this requirement does not apply:

- One and two family dwellings
- Cord and attachment-plug connected equipment, or
- Equipment on a 60A or less branch circuit

So for most commercial and industrial applications, air conditioning and refrigeration equipment with multimotor and combination loads must have the short-circuit current rating marked on the nameplate.

Meter Disconnect Switches: 230.82(3) permits a meter disconnect switch (rated up to 1000V) ahead of the service disconnecting means, provided the meter disconnect switch has a short-circuit current rating adequate for the available short-circuit current.

Motor Controllers: 430.8 requires that motor controllers be marked with their short-circuit current rating. There are three exceptions:

- For fractional horsepower motor controllers
- Two horsepower or less general-purpose motor controllers, and
- Where the short-circuit current rating is marked on the assembly

Surge Protective Devices (SPD): 285.6 requires SPDs permanently installed on 1000V or less premise wiring systems to be SCCR marked and the marked SCCR must be equal or greater than the available short-circuit current.

How to Assure Compliance?

To assure proper application, the designer, installer and inspector must assure that the marked short-circuit current rating of a component or equipment is not exceeded by the calculated available fault current.

In order to assure compliance it is necessary to:

1. Determine the available short-circuit current or fault current at the point of installation of the component or equipment.
2. Assure the component or equipment marked short-circuit current rating (see Figure 3 for example) is equal to or greater than the available fault current.

Figure 4 illustrates compliance of short-circuit current ratings from a system perspective. Any installation where the equipment marked SCCR is less than the available fault current is a lack of compliance, a safety hazard, and violation of 110.10. In these cases, the equipment cannot be installed until the component or equipment SCCR is sufficient or the fault current is reduced to an acceptable level. An IR and SCCR Compliance Checklist is available in the Inspection Checklist section of this publication.

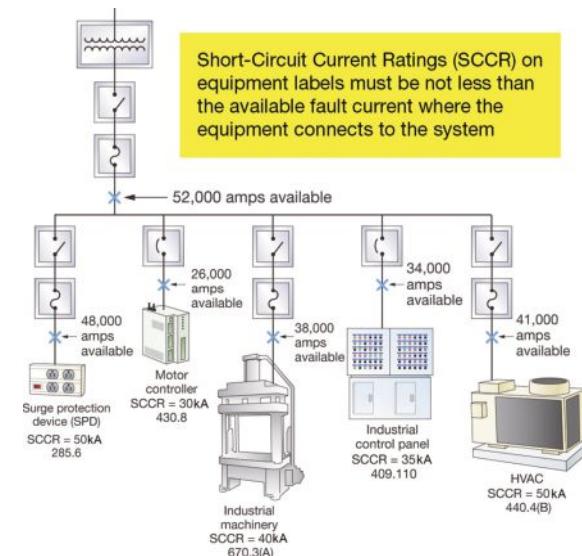


Figure 4 (Courtesy NJATC)

Determining Assembly SCCR: “Two Sweep” Method & Procedures

How to Determine Assembly SCCR

For **components**, the Short-Circuit Current Rating (SCCR) is typically determined by product testing. For **assemblies**, the SCCR can be determined through the equipment product listing standard or by an approved method. With the release of the UL 508A, *UL Standard for Safety for Industrial Control Panels*, an industry-approved method is now available. **UL 508A, Supplement SB**, provides an analytical method to determine the SCCR of an industrial control panel. This method is based upon the “weakest link” approach. In other words, the assembly marked SCCR is limited to the lowest rated component SCCR or the lowest rated overcurrent protective device interrupting rating. Since testing is not required with this method, it is typically the preferred method to use in determining the assembly SCCR.

There are two basic concepts that must be understood and identified before analyzing the assembly SCCR per UL 508A, Supplement SB. The first is power circuit vs. control circuit. The second is branch circuit vs. feeder circuit. The differences and importance of these concepts are detailed below:

- **Per UL 508A:** a **power circuit** is defined as the conductors and components of branch and feeder circuits. A branch and feeder circuit carries main line power current to loads such as motors, lighting, heating, appliances and general use receptacles. A **control circuit** is a circuit that carries the electric signals directing the performance of a controller, and which does not carry the main power current. **Only devices in power circuits and overcurrent devices protecting control circuits affect the assembly SCCR.**
- **Per UL 508A:** a **branch circuit** is defined as the conductors and components following the final branch circuit overcurrent protective device protecting a load. A **feeder circuit** is the conductors and circuitry on the supply side of the branch circuit overcurrent protective device(s). **In some cases, as will be discussed later; current-limiting devices in the feeder circuit can be used to increase the SCCR of branch circuit components.** In addition, larger spacings are required for components used in feeder circuits versus when used in branch circuits. This is especially important for power distribution and terminal blocks, if used in feeder circuits.

Using the “Two Sweep” Method Based on UL 508A

After all the power circuit components and overcurrent devices protecting control circuits have been identified, the “Two Sweep” method based on UL 508A can be used to determine the assembly Short-Circuit Current Rating (SCCR). The purpose of performing two sweeps in this method is to assure that the overcurrent protective device interrupting rating (or SCCR for some devices) are never increased by an upstream overcurrent protective device. UL 508A requirements strictly prohibit any overcurrent protective device interrupting rating (or SCCR for some devices) from being raised beyond the marked interrupting rating by an upstream overcurrent protective device. Hence series rating of overcurrent devices is prohibited.

Sweep 1: The Component Protection Sweep

The first sweep reviews all components in the branch, feeder, sub-feeder and supply circuits, and determines the component with the lowest SCCR.

Sweep 2: The Overcurrent Protection Sweep

The second sweep reviews all overcurrent protection devices in the branch, feeder and supply circuits, and determines the lowest interrupting rating (or SCCR for some devices).

The lowest rating from Sweep 1 and Sweep 2 identifies the assembly SCCR. Because this method determines the assembly SCCR, it may be referred to as the “**FIND IT**.”

Note: It is necessary to complete **both** Sweeps and **all** Steps to determine an assembly’s SCCR marking. If an assembly SCCR marking is inadequate, then see the “**FIX IT**” portion at the end of this section for suggestions on how to increase an assembly’s marked SCCR.

Procedures for the “Two Sweep” Method

Each sweep of this method is broken down into steps. Sweep 1 has five steps and Sweep 2 has three steps. The following shows the procedure for completing the steps of both sweeps.

Sweep 1: Verifying assembly component SCRRs

Step 1: Determine the component SCCR for each branch circuit:

- Identify all component SCRRs and any special conditions that exist to utilize the ratings by one of the following methods:
 1. The SCCR based on the default ratings per UL 508A Table SB4.1 (see Table SCCR1 - Default SCRR Ratings).
 2. The SCCR marked on the component or instruction sheet provided with the component.
 3. The SCCR based on testing with a specific overcurrent protective device and/or combination of components in accordance with product standards and documented by the manufacturer. Example: a motor controller may have a high Fault SCCR of 100kA with a 30A Class J fuse, but only 5kA with a 30A non-current-limiting over-current protective device.
- Take and apply the lowest SCCR of any component used in a branch circuit as the SCCR for that branch circuit. Repeat this for each branch circuit in the assembly.
- Note the lowest branch circuit SCCR for every branch circuit in the assembly or panel.

Step 2: Determine the component SCCR for each feeder circuit (includes supply, feeders and sub-feeders):

- Identify all component SCRRs and any special conditions that exist to utilize the ratings by one of the following methods:
 1. The SCCR based on the default ratings per UL 508A Table SB4.1 (see Table SCCR1 - Default SCRR Ratings).
 2. The SCCR marked on the component or instruction sheet provided with the component.
 3. The SCCR based on testing with a specific overcurrent protective device and/or combination of components in accordance with product standards and documented by the manufacturer. Example: a power distribution block may have a high fault SCCR of 100kA with a 200A Class J fuse, but only 10kA with a 200A non-current-limiting over-current protective device.
- Take and apply the lowest SCCR of any component used in the feeder circuit as the SCCR of the feeder circuit.
- Note the lowest feeder circuit SCCR.

Determining Assembly SCCR “Two Sweep” Method Procedures

Step 3: If using a **10kVA or less power transformer** in a feeder circuit, modify the transformer circuit SCCR, if possible, as follows:

- For **10kVA or less** power transformers that are in a feeder circuit, determine if the SCCR of the downstream circuits can be increased by applying the following procedure:
 - On the transformer secondary, verify the SCCR of each component and the interrupting ratings of all overcurrent protective devices.
 - Identify the lowest component SCCR or overcurrent protective device interrupting rating.
 - If the lowest component SCCR or overcurrent protective device interrupting rating is 5kA or greater, apply the transformer's primary overcurrent protective device interrupting rating to the entire transformer circuit. Otherwise apply the lowest downstream component SCCR or overcurrent protective device interrupting rating to the transformer circuit.
- For **5kVA or less** power transformers with **120V secondary** in the feeder circuit, determine if the SCCR of the downstream circuits can be increased by applying the following:
 - On the transformer secondary, verify the SCCR of each component and the interrupting ratings of all overcurrent protective devices.
 - Identify the lowest component SCCR or overcurrent protective device interrupting rating.
 - If the lowest component SCCR or overcurrent protective device interrupting rating is 2kA or greater, apply the transformer's primary overcurrent protective device interrupting rating to the entire transformer circuit. Otherwise apply the lowest downstream component SCCR or overcurrent protective device interrupting rating to the transformer circuit.

Step 4: If using a **current-limiting overcurrent protective device** in the **feeder circuit**, modify **branch circuit component** SCRRs (other than the interrupting rating of branch circuit overcurrent protection devices such as fuses and circuit breakers or, the SCCR of instantaneous trip circuit breakers/motor circuit protectors (MCPs) and self-protected combination starters), if possible, as follows:

- If current-limiting overcurrent protective devices are used in the feeder circuit use the following procedure:
 - Determine the **peak let-through value** of the current-limiting overcurrent protective devices.
 - If the overcurrent protective device is a **current-limiting fuse**, determine the peak let-through umbrella value dictated by the product standard for the fuse class and amp rating utilized at the level of fault current desired (50, 100, 200kA). **See Table SCCR2 - UL Umbrella Limits at Rated Voltage** (based on UL 508A Table SB4.2).
 - If the overcurrent protective device is a **marked current-limiting circuit breaker, manufacturer's let-through curves** can be used to determine the peak let-through value.
 - Ensure that the peak let-through value is less than any of the SCRRs determined in Step 1.
 - If condition "2" above is met, apply a short-circuit current rating to branch circuits fed by the feeder based upon the value of fault current used to determine the peak let-through value of the current-limiting overcurrent protective device.

Step 5: Determine the assembly SCCR for Sweep 1

- Determine the Sweep 1 assembly SCCR by utilizing the lowest rated branch or feeder circuit SCCR.

End of Sweep 1

Sweep 2: Verify assembly SCCR based upon overcurrent protective device interrupting rating (or SCCR for some devices).

Step 1: Determine the interrupting ratings (or SCCR) of all the overcurrent protective devices used in feeder (includes supply, feeders and sub-feeders) and branch circuits, including those overcurrent protective devices protecting control circuits.

Step 2: Determine the lowest overcurrent protective device interrupting rating or SCCR.

Step 3: Compare the lowest **overcurrent protective device** interrupting rating or SCCR with the **component** SCRRs from Sweep 1, Step 5. The lowest rating encountered is the **assembly** SCCR.

This SCCR is then marked on the assembly. If this SCCR is not sufficiently high enough, there are "FIX IT" solutions at the end of this section that can be investigated to achieve a higher SCCR marking.

End of Sweep 2

Table: SCCR1 - Default SCCR Ratings (UL 508A Table SB4.1)

Component	Default SCCR (kA)
Bus bars 10	
Circuit breaker (including GFCI type)	5
Current meters	*
Current shunt	10
Fuseholder	10
Industrial control equipment	
a. Auxiliary devices (overload relay)	5
b. Switches (other than mercury tube type)	5
c. Mercury tube switches rated:	
• Over 60 amps or over 250 volts	5
• 250 volts or less, 60 amps or less and over 2kVA	3.5
• 250 volts or less and 2kVA or less	1
Motor controller, rated in horsepower (kW)***	
a. 0-50 (0-37.3)	5**
b. 51-200 (38-149)	10**
c. 201-400 (150-298)	18**
d. 401-600 (299-447)	20**
e. 601-900 (448-671)	42**
f. 901-1500 (672-1193)	85**
Meter socket base	10
Miniature or miscellaneous fuse	10***
Receptacle (GFCI type)	2
Receptacle (other than GFCI)	10
Supplementary protector	0.2
Switch unit	5
Terminal block or power distribution block	10
* A SCCR is not required when connected via a current transformer or current shunt. A directly connected current meter shall have a marked SCCR.	
** Standard fault current rating for motor controller rated within specified horsepower range.	
*** The use of a miniature fuse is limited to 125 volt circuits.	
**** Includes combination motor controllers, float and pressure operated motor controllers, power conversion equipment and solid state motor controllers.	

Verify Assembly Overcurrent Protective Devices

Table: SCCR2 - UL Umbrella Limits at Rated Voltage (UL 508A Table SB4.2)

Fuse Type	Fuse Amp Rating	Between threshold & 50kA		100kA		200kA		300kA**	
		I ² t x 10 ³	I _p x 10 ³ (kA)	I ² t x 10 ³	I _p x 10 ³ (kA)	I ² t x 10 ³	I _p x 10 ³ (kA)	I ² t x 10 ³	I _p x 10 ³ (kA)
Class CC	15	2	3	2	3	3	4	—	—
	20	2	3	3	4	3	5	—	—
	30	7	6	7	7.5	7	12	—	—
Class G	15	—	—	3.8	4	—	—	—	—
	20	—	—	5	5	—	—	—	—
	30	—	—	7	7	—	—	—	—
	60	—	—	25	10.5	—	—	—	—
Class RK1	30	10	6	10	8.7	11	12	13	16
	60	40	10	40	12	50	16	60	20
	100	100	14	100	16	100	20	120	24
	200	400	18	400	22	400	30	480	38
	400	1200	33	1200	35	1600	50	1920	79
	600	3000	45	3000	50	4000	70	4800	104
Class RK5	30	50	11	50	11	50	14	60	21
	60	200	20	200	21	200	26	240	35
	100	500	22	500	25	500	32	600	40
	200	1600	32	1600	40	2000	50	2400	62
	400	5200	50	5000	60	6000	75	7200	90
	600	10000	65	10000	80	12000	100	14400	124
Class T 300V*	1	—	—	0.4	0.8	—	—	—	—
	3	—	—	0.6	1.3	—	—	—	—
	6	—	—	1	2	—	—	—	—
	10	—	—	1.5	3	—	—	—	—
	15	—	—	2	4	—	—	—	—
	20	—	—	2.5	4.5	—	—	—	—
	25	—	—	2.7	5.5	—	—	—	—
	30	3.5	5.0	3.5	7	3.5	9	—	—
	35	—	—	6	7	—	—	—	—
	40	—	—	8.5	7.2	—	—	—	—
	45	—	—	9	7.6	—	—	—	—
	50	—	—	11	8	—	—	—	—
	60	15	7	15	9	15	12	—	—
	70	—	—	25	10	—	—	—	—
	80	—	—	30	10.7	—	—	—	—
	90	—	—	38	11.6	—	—	—	—
	100	40	9	40	12	40	15	—	—
	110	—	—	50	12	—	—	—	—
	125	—	—	75	13	—	—	—	—
	150	—	—	88	14	—	—	—	—
	175	—	—	115	15	—	—	—	—
	200	150	13	150	16	150	20	—	—
	225	—	—	175	21	—	—	—	—
	250	—	—	225	22	—	—	—	—
	300	—	—	300	24	—	—	—	—
	350	—	—	400	27	—	—	—	—
	400	550	22	550	28	550	35	—	—
	450	—	—	600	32	—	—	—	—
	500	—	—	800	37	—	—	—	—
	600	1,000	29	1,000	37	1,000	46	—	—
	700	—	—	1,200	45	—	—	—	—
	800	1,500	37	1,500	50	1,500	65	—	—
	1000	—	—	3,500	65	—	—	—	—
	1200	3,500	50	3,500	65	4,000	80	—	—

Note: These values are UL umbrella limits.

*When values at 50kA and 200kA are needed, the standard case size shall be used.

**300kA values are in 248 Standard, but are not yet in UL 508A Standard.

Verify Assembly Overcurrent Protective Devices

Table: SCCR2 - UL Umbrella Limits at Rated Voltage (UL 508A Table SB4.2) (continued)

Fuse Type	Fuse Amp Rating	Between threshold & 50kA		100kA		200kA		300kA† (Class J Only)	
		I ² t x 10 ³	I _p x 10 ³ (kA)	I ² t x 10 ³	I _p x 10 ³ (kA)	I ² t x 10 ³	I _p x 10 ³ (kA)	I ² t x 10 ³	I _p x 10 ³ (kA)
Class	1	—	—	0.8	1	—	—	—	—
CF, J & T	3	—	—	1.2	1.5	—	—	—	—
600V*	6	—	—	2	2.3	—	—	—	—
	10	—	—	3	3.3	—	—	—	—
	15	—	—	4	4	—	—	—	—
	20	—	—	5	5	—	—	—	—
	25	—	—	5.5	6	—	—	—	—
	30	7	6	7	7.5	7	12	8.4	18.5
	35	—	—	12	7.5	—	—	—	—
	40	—	—	17	8	—	—	—	—
	45	—	—	18	8.5	—	—	—	—
	50	—	—	22	9	—	—	—	—
	60	30	8	30	10	30	16	36	24.4
	70	—	—	50	11.5	—	—	—	—
	80	—	—	60	12.5	—	—	—	—
	90	—	—	75	12.5	—	—	—	—
	100	60	12	80	14	80	20	96	28.4
	110	—	—	100	14.5	—	—	—	—
	125	—	—	150	15.5	—	—	—	—
	150	—	—	175	17	—	—	—	—
	175	—	—	225	18.5	—	—	—	—
	200	200	16	300	20	300	30	360	42.4
	225	—	—	350	22.5	—	—	—	—
	250	—	—	450	24	—	—	—	—
	300	—	—	600	26	—	—	—	—
	350	—	—	800	29	—	—	—	—
	400	1,000	25	1,100	30	1,100	45	1320	66.4
	450	—	—	1,500	36	—	—	—	—
	500	—	—	2,000	42	—	—	—	—
	600	2,500	35	2,500	45	2,500	70	3000	101.4
	700**	—	—	3,500**	50**	—	—	—	—
	800**	4,000**	50**	4,000**	55**	4,000**	75**	—	—
Class L	800	10000	80	10000	80	10000	80	12000	79
	1200	12000	80	12000	80	15000	120	18000	108
	1600	22000	100	22000	100	30000	150	36000	143
	2000	35000	110	35000	120	40000	165	48000	158
	2500	—	—	75000	165	75000	180	90000	171
	3000	—	—	100000	175	100000	200	120000	226
	4000	—	—	150000	220	150000	250	180000	286
	5000	—	—	350000	—	350000	300	420000	286
	6000	—	—	350000	—	500000	350	600000	399

*When values at 50kA and 200kA are needed, the standard case size shall be used.

**Value applies to Clas T fuses. Values at 700A are included per UL 248, but have not been added to UL 508A Supplement 5B.

Note: These values are UL umbrella limits.

†300kA values are in 248 Standard, but are not yet in UL 508A Standard.

About Umbrella Limits

What is a Fuse Umbrella Limit?

UL / CSA / ANCE Fuse Standards set maximum I_p and I^2t let-through limits for short-circuit current performance of current-limiting fuses. The limits vary by fuse class, amp rating and available short-circuit current. To receive a listing, a commercially available current-limiting fuse must be tested and evaluated under short-circuit current tests per the applicable standard and witnessed by a National Recognized Testing Laboratory (NRTL). One evaluation criteria of the testing is that the fuse's I_p and I^2t let-through measured during the short-circuit tests can not exceed the Standard's "umbrella limits" for I_p and I^2t let-through established for that fuse class, amp rating, and available short-circuit current*. See Table: SCCR2 - UL Umbrella Limits at Rated Voltage on the preceding pages for the umbrella limits applicable to most of the current-limiting fuses.

***NOTE:** These tests are done at the fuse's rated voltage, with only one fuse in the circuit and by controlled closing of the test circuit so that the fuse "starts to arc" between 60 and 90 degrees on the voltage wave. These test conditions are the most severe for fuse interruption. In addition, current-limiting fuses are required to have periodic NRTL witnessed follow-up testing in the same manner. The fuses for NRTL witnessed follow-up testing are pulled from inventory.

What is an umbrella fuse?

An umbrella fuse is a special fuse that is designed to have short-circuit current I_p and I^2t let-through that are at least equal to or greater than the UL / CSA / ANCE Fuse Standard limit. Umbrella fuses are not intended as commercially available fuses.

UL has a specific standard for these devices, which is UL248-16 Test Limiters. UL uses the term "test limiters" for what we refer to as umbrella fuses. UL 248-16 states:

"...test limiters are calibrated to specific limits of peak let-through current and clearing I^2t at 250, 300, 480, or 600Vac. Test limiters are non-renewable and current-limiting, with test current ratings up to 200,000 A. They are calibrated to maximum peak let-through current and clearing I^2t limits for the fuses specified in this Standard and are used for withstand testing of equipment designed to accept those fuses."

Umbrella fuses are used for test purposes in qualifying a combination short-circuit current rating with a specific component. For instance, a controller manufacturer wants the controller to be marked with a 100,000A SCCR at 600V when protected by 60A Class J fuses. The NRTL witnessed tests would be with 60A Class J umbrella fuses in combination with the controller on a test circuit of 100,000A at 600V. If the results satisfy the UL 508 Industrial Control Standard evaluation criteria, the controller can be labeled with a 100,000A, 600V SCCR when protected by Class J fuses 60A (or less). Another use of umbrella fuses is for series rated fuse/circuit breaker panelboard and switchboard combinations per NEC® 240.86. For more information on series ratings see the section on Series Rating: Protecting Circuit Breakers. However, UL 508A Supplement SB4 does not permit series rated combinations for use in establishing the SCCR for industrial control panels. Therefore, the interrupting rating of overcurrent devices cannot be raised by another upstream overcurrent device.

Example Using the “Two Sweep” Method: “FIND IT”

“FIND IT”

The following example will illustrate the procedures previously outlined for the two sweep method to determine the assembly SCCR. It may be helpful to periodically refer back to the procedures for the two sweep method while going through this example. The example is based on the industrial control panel shown in Figure 5 and 6. Figure 5 shows the graphical representation of the industrial control panel while Figure 6 is the one-line diagram for the

industrial control panel. The ratings for each power circuit component are detailed in Figure 6. This example illustrates how each sweep and their steps are performed and documented in the tables. After both sweeps and all steps have been completed, the result identifies the assembly SCCR (“FIND IT”). Later, methods are outlined to increase the assembly SCCR (“FIX IT”).

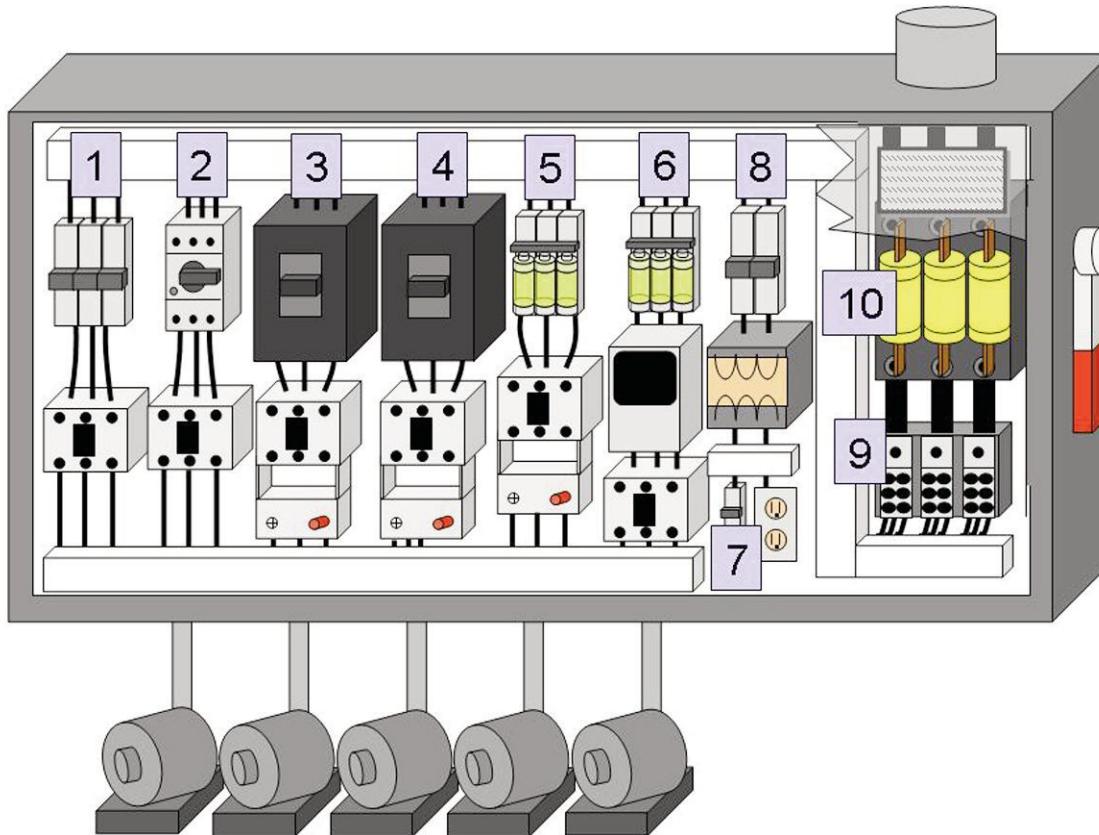


Figure 5

Industrial Control Panel Circuit and Device Descriptions

Circuit Number	Device Descriptions
1	Molded case circuit breaker protecting an IEC contactor
2	Self-protected starter protecting an IEC contactor (additional components may be required)
3	Instantaneous trip circuit breaker (MCP) protecting an IEC starter (special assembly conditions required)
4	Molded case circuit breaker protecting an IEC starter
5	Class CC fused switch protecting an IEC starter
6	Class CC fused switch protecting variable frequency drive and contactor
7	Molded case circuit breaker and GFCI receptacle
8	Molded case circuit breaker protecting power transformer
9	Power distribution block
10	Class J fused switch

Example Using the “Two Sweep” Method: “FIND IT”

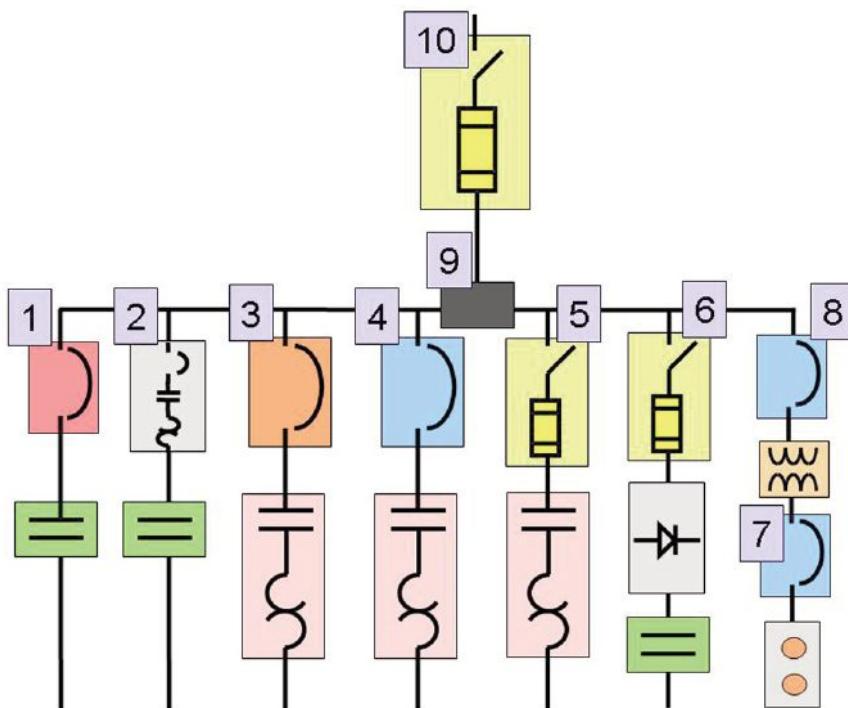


Figure 6 – One-line Diagram of Industrial Control Panel

Note: It is important to record the voltage ratings for all components and overcurrent protective devices. The assembly is marked based upon the lowest or most restrictive device voltage rating. If there are devices with slash voltage ratings (such as 480/277V), these are more limiting than straight or full voltage ratings (such as 480V). Assemblies with 480/277V devices are suitable for only 480/277V solidly grounded wye systems. These assemblies cannot be applied on 480V ungrounded, resistance grounded or corner grounded systems. (See the section on Slash Voltage Ratings for more information.)

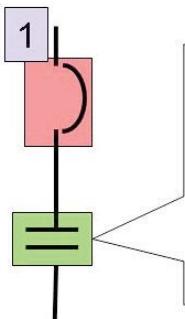
Industrial Control Panel Circuit Descriptions and Ratings

Circuit Number	Circuit Type	Device Descriptions
1	Branch	<ul style="list-style-type: none"> Molded case circuit breaker: IR = 14kA @ 480/277V IEC contactor: SCCR = 5kA @ 600V
2	Branch	<ul style="list-style-type: none"> Self-protected starter with lineside terminal kit: SCCR = 65kA @ 480/277V IEC contactor: SCCR = 5kA @ 600V
3	Branch	<ul style="list-style-type: none"> Instantaneous trip circuit breaker (MCP): unmarked IR IEC Starter: SCCR = 5kA @ 600V
4	Branch	<ul style="list-style-type: none"> Molded case circuit breaker: IR = 14kA @ 480V IEC starter: SCCR = 5kA @ 600V
5	Branch	<ul style="list-style-type: none"> Bussmann Class CC Compact Circuit Protector (CCP): SCCR = 200kA @ 600V Bussmann LP-CC Fuses: IR = 200kA @ 600V IEC starter: SCCR = 5kA @ 600V
6	Branch	<ul style="list-style-type: none"> Bussmann Class CC Compact Circuit Protector (CCP): SCCR = 200kA @ 600V Bussmann LP-CC Fuses: IR = 200kA @ 600V Variable Frequency Drive: SCCR = 5kA @ 480V IEC contactor: SCCR = 5kA @ 600V
7	Branch	<ul style="list-style-type: none"> Molded case circuit breaker: IR = 10kA @ 120V GFCI Receptacle: unmarked SCCR
8	Sub-Feeder	<ul style="list-style-type: none"> Molded case circuit breaker: IR = 14kA @ 480/277V 3kVA 480V-120V secondary power transformer (does not affect SCCR)
9	Feeder	<ul style="list-style-type: none"> Power distribution block: unmarked SCCR
10	Supply	<ul style="list-style-type: none"> Bussmann 100A Class J fused switch: SCCR = 200kA @ 600V Bussmann 100A LPJ fuses: IR = 300kA @ 600V

"Two Sweep" Method: Sweep 1, Step 1 - Branch Circuit Components**Sweep 1: Verifying assembly component SCCRs****Step1:** Determine lowest rated **component** in each branch circuit.

Note: Determine SCCR for components only.

Interrupting rating or SCCR of overcurrent protective devices is ignored in this step.



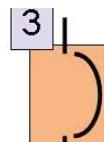
IEC Contactor- Listed motor controller
Combination SCCR = 5kA at 600V
when protected by circuit breaker



UL US LISTED
MAGNETIC MOTOR
CONTROLLER 600Vac
S.C. RATING, RMS, SYM:
5 kA, 600V

Branch Circuit 1

- IEC contactor: SCCR = 5kA @ 600V
- Higher combination rating with a circuit breaker does not exist
- **SCCR = 5kA @ 600V**



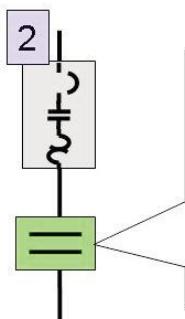
IEC Starter - Listed motor controller and overload relay
Combination SCCR = 65kA at 480V
when protected by MCP (same manufacturer)



UL US LISTED
MAGNETIC MOTOR
CONTROLLER 600Vac
S.C. RATING, RMS, SYM:
5 kA, 600V

Branch Circuit 3

- IEC Starter: SCCR = 5kA @ 600V
- Combination rating with MCP
(only with same manufacturer) = 65kA @ 480V



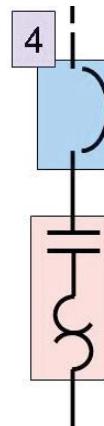
IEC Contactor- Listed motor controller
Combination SCCR = 65kA at 480/277V
when protected by self-protected starter (same manufacturer)



UL US LISTED
MAGNETIC MOTOR
CONTROLLER 600Vac
S.C. RATING, RMS, SYM:
5 kA, 600V

Branch Circuit 2

- IEC contactor: SCCR = 5kA @ 600V
- Combination rating with self-protected starter
(only with same manufacturer) = 65kA @ 480/277V
- **SCCR = 65kA @ 480/277V**



IEC Starter - Listed motor controller and overload relay
Combination SCCR = 25kA at 480V
when protected by circuit breaker (same manufacturer)



UL US LISTED
MAGNETIC MOTOR
CONTROLLER 600Vac
S.C. RATING, RMS, SYM:
5 kA, 600V

Branch Circuit 4

- IEC starter: SCCR = 5kA @ 600V
- Combination rating with circuit breaker
(only with same manufacturer) = 25kA @ 480V
- **SCCR = 25kA @ 480V**



Save space, time and money with Bussmann's power distribution fuse block



Innovative power distribution fuse block uses 50% less panel space and reduces installation time and labor by 33%.

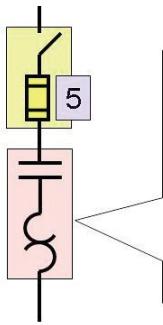
Bussmann's new Class J fuse block with power distribution capability uses up to 50% less panel space and reduces installation time and labor by 33% when compared with traditional solutions. This patented product is available with ratings of 100, 200 and 400 amps.

The power distribution fuse block represents an industry first, combining a power distribution block

with a Class J fuse block to help enhance overall system integrity. It utilizes innovative technology to help save valuable panel space and reduce overall installation cost.

For more information, please visit www.cooperbussmann.com/pdfb.

Bussmann
by **EATON**

"Two Sweep" Method: Sweep 1, Step 1 - Branch Circuit Components

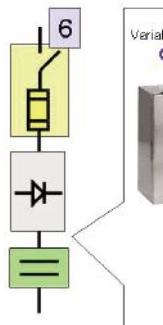
IEC Starter - Listed motor controller and overload relay
Combination SCCR = 100kA at 600V
when protected by Class CC fuses



cUL US LISTED
MAGNETIC MOTOR
CONTROLLER 600Vac
S.C. RATING, RMS, SYM:
5 kA, 600V

Branch Circuit 5

- IEC starter: SCCR = 5kA @ 600V
- Combination rating with Class CC fuses = 100kA @ 600V
- **SCCR = 100kA @ 600V**



IEC Contactor - Listed motor controller &
Variable Frequency Drive - Listed power conversion equipment
Combination SCCR = 100kA at 600V
when protected by Class CC fuses

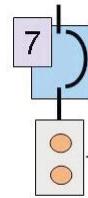


cUL US LISTED
POWER CONVERSION
EQUIPMENT 600Vac
S.C. RATING, RMS, SYM:
5 kA, 600V

cUL US LISTED
MAGNETIC MOTOR
CONTROLLER 600Vac
S.C. RATING, RMS, SYM:
5 kA, 600V

Branch Circuit 6

- Variable Frequency Drive: SCCR = 5kA @ 480V
- IEC contactor: SCCR = 5kA @ 600V
- Combination rating with Class CC fuses:
 - 200kA @ 600V for variable frequency drive
 - 100kA @ 600V for IEC contactor
- **SCCR = 100kA @ 600V**



GFCI Receptacle - Unmarked
SCCR = 2kA at 120V
when protected by circuit breaker

cUL US LISTED
GROUND-FAULT CIRCUIT
INTERRUPTER 120Vac

Branch Circuit 7

- GFCI Receptacle: unmarked SCCR (2kA per Table SCCR1-Default SCCR Ratings)
- Higher combination rating with circuit breaker does not exist
- **SCCR = 2kA @ 120V** (does not affect panel voltage rating)

Sweep 1 - Step 1 Summary

- Lowest SCCR of Step 1 is 2kA @ 480/277V

Results of Sweep 1, Step 1: SCCR = 2kA @ 480/277V

	Assessment				SCCR Revisions		Sweep 1 Results		Sweep 2-Steps 1 & 2 (Overcurrent Device)	
	Sweep 1-Step 1 (Branch)		Sweep 1-Step 2 (Feeder)		Sweep 1-Step 3 (Trans)	Sweep 1-Step 4 (C-L OCPDs)	Sweep 1-Step 5			
	SCCR	Voltage	SCCR	Voltage	SCCR	SCCR	SCCR	Voltage	IR/SCCR	Voltage
Branch Circuit 1	5kA	600V								
Branch Circuit 2	65kA	480/277V								
Branch Circuit 3	65kA	480V								
Branch Circuit 4	25kA	480V								
Branch Circuit 5	100kA	600V								
Branch Circuit 6	100kA	600V								
Branch Circuit 7	2kA	—								
Sub-Feeder Circuit 8	—	—								
Feeder Circuit 9	—	—								
Supply Circuit 10	—	—								

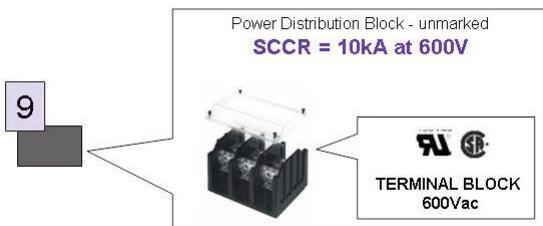
Note: Red cells in table denote limiting components and voltages for each step.

"Two Sweep" Method: Sweep 1, Step 2 - Feeder Circuit Components**Sweep 1: Verifying assembly component SCCRs**

Step 2: Determine the **component** SCCR for each **feeder, sub-feeder and supply circuit**.

Sub-Feeder Circuit 8

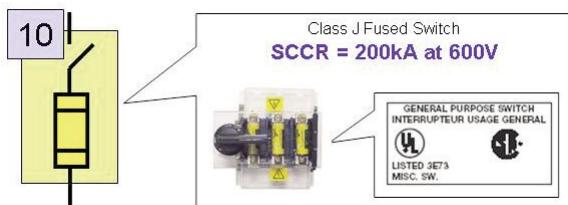
- This is a transformer circuit and is covered by Sweep 1, Step 3

**Feeder Circuit 9**

- Power distribution block (PDB): unmarked SCCR (10kA per Table SCCR1 - Default SCCR Ratings)

- SCCR = 10kA @ 600V**

Note: PDB must have proper spacings for feeder application per UL 508A.

**Supply Circuit 10**

- Bussmann 100A Class J fused switch: SCCR = 200kA @ 600V
- SCCR = 200kA @ 600V**

Sweep 1 - Step 2 Summary

- Lowest SCCR of Step 2 is 10kA @ 600V
- Lowest SCCR of Step 1 or Step 2 is 2kA @ 480/277V

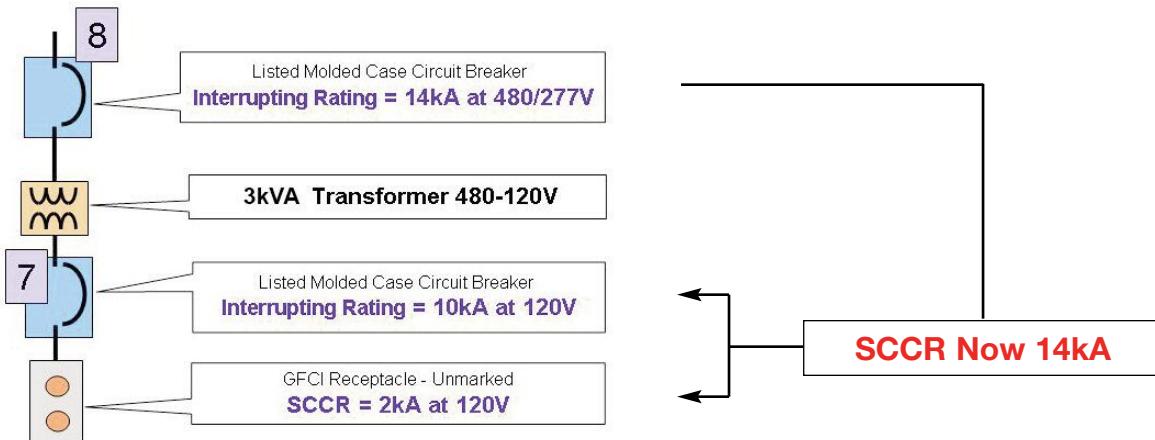
Results of Sweep 1, Step 2: SCCR = 2kA @ 480/277V

	Assessment				SCCR Revisions		Sweep 1 Results		Sweep 2-Steps 1& 2 (Overcurrent Device)	
	Sweep 1-Step 1 (Branch)		Sweep 1-Step 2 (Feeder)		Sweep 1-Step 3	Sweep 1-Step 4 (Trans)	Sweep 1-Step 5			
	SCCR	Voltage	SCCR	Voltage	SCCR	SCCR	SCCR	Voltage	IR/SCCR	Voltage
Branch Circuit 1	5kA	600V	–	–						
Branch Circuit 2	65kA	480/277V	–	–						
Branch Circuit 3	65kA	480V	–	–						
Branch Circuit 4	25kA	480V	–	–						
Branch Circuit 5	100kA	600V	–	–						
Branch Circuit 6	100kA	600V	–	–						
Branch Circuit 7	2kA	–	–	–						
Sub-Feeder Circuit 8	–	–	–	–						
Feeder Circuit 9	–	–	10kA	600V						
Supply Circuit 10	–	–	200kA	600V						

Note: Red cells in table denote limiting components and voltages for each step.

"Two Sweep" Method: Sweep 1, Step 3 - Components/Transformers**Sweep 1: Verifying assembly component SCCRs**

Step 3: Determine if **10kVA or smaller power transformers** in the feeder, sub-feeder or supply circuit are able to raise branch circuit component SCCRs (circuit breaker and GFCI receptacle):

**Sub-Feeder Circuit 8**

- Sub-feeder transformer is 3kVA with 120V secondary and can be used to raise the secondary components. Follow procedure for 5kVA or smaller transformers.
- Since all 120V secondary components have an interrupting rating/SCCR (circuit breaker IR = 10kA) or SCCR (GFCI receptacle SCCR = 2kA) of 2kA or higher, the interrupting rating rating of the transformer primary overcurrent protective device (Sub-Feeder Circuit 8) can be assigned to the entire Branch Circuit 7 (circuit breaker and GFCI receptacle).
- Revised Branch Circuit 7 **SCCR = 14kA**

Sweep 1 - Step 3 Summary

- Branch Circuit 7 was raised to 14kA
- However, Branch Circuit 1 is still the limiting SCCR factor

Results of Sweep 1, Step 3: SCCR = 5kA @ 480/277V

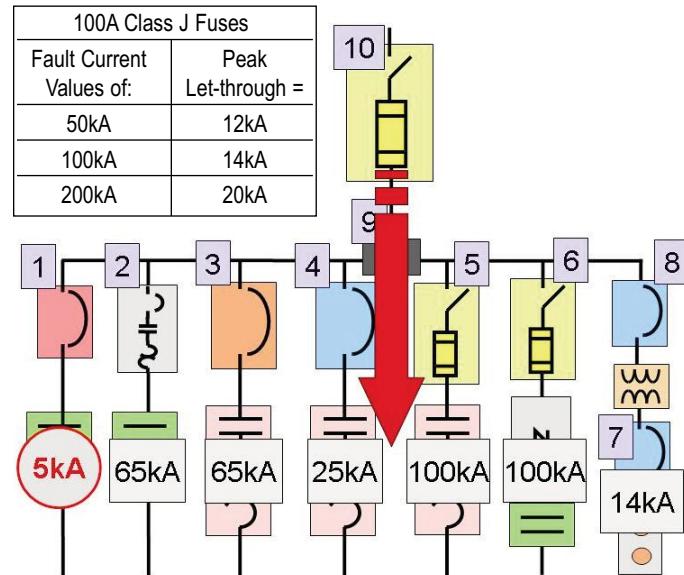
	Assessment				SCCR Revisions		Sweep 1 Results		Sweep 2-Steps 1 & 2 (Overcurrent Device)	
	Sweep 1-Step 1 (Branch)		Sweep 1-Step 2 (Feeder)		Sweep 1-Step 3 (Trans)	Sweep 1-Step 4 (C-L OCPDs)	Sweep 1-Step 5			
	SCCR	Voltage	SCCR	Voltage	SCCR	SCCR	SCCR	Voltage	IR/SCCR	Voltage
Branch Circuit 1	5kA	600V	—	—	—	—	—	—	—	—
Branch Circuit 2	65kA	480/277V	—	—	—	—	—	—	—	—
Branch Circuit 3	65kA	480V	—	—	—	—	—	—	—	—
Branch Circuit 4	25kA	480V	—	—	—	—	—	—	—	—
Branch Circuit 5	100kA	600V	—	—	—	—	—	—	—	—
Branch Circuit 6	100kA	600V	—	—	—	—	—	—	—	—
Branch Circuit 7	2kA	—	—	—	14kA	—	—	—	—	—
Sub-Feeder Circuit 8	—	—	—	—	—	—	—	—	—	—
Feeder Circuit 9	—	—	10kA	600V	—	—	—	—	—	—
Supply Circuit 10	—	—	200kA	600V	—	—	—	—	—	—

Note: Red cells in table denote limiting components and voltages for each step.

"Two Sweep" Method: Sweep 1, Step 4 - Current-Limiting Overcurrent Devices**Sweep 1:** Verifying assembly component SCCRs

Step 4: Determine if current-limiting overcurrent protective devices (C-L OCPDs) are used in the **feeder**, **sub-feeder** or **supply** circuit that can raise **branch circuit component ratings** (other than devices that provide branch circuit overcurrent protection).

100A Class J Fuses	
Fault Current Values of:	Peak Let-through =
50kA	12kA
100kA	14kA
200kA	20kA



Note: Since the 100A Class J fuse peak let-through of 20kA at a fault current of 200kA is less than the SCCR of Step 1 for Branch Circuits 2 through 6, the SCCR is raised to 200kA. The SCCR of components in Feeder Circuit 9, Sub-Feeder Circuit 8 or Supply Circuit 10 cannot be raised per UL 508A.

Supply Circuit 10

The 100A Class J fuse in Supply Circuit 10 is a current-limiting device. Use *Table SCCR2 - UL Umbrella Limits at Rated Voltage* to identify the peak let-through values:

- Compare the peak let-through values with result of Step 1 and increase branch circuit component ratings where possible.

Sweep 1 - Step 4 Summary

- Branch Circuit 1 SCCR cannot be raised
- Increased SCCR of Branch Circuits 2 through 6 to 200kA
- Branch Circuit 7 SCCR cannot be raised in this step because it was raised by Step 3
- Feeder circuit 9, sub-feeder circuit 8 or supply circuit 10 can not be raised in this step (only branch circuit components can be raised)

Results of Sweep 1, Step 4: SCCR = 5kA @ 480/277V

	Assessment				SCCR Revisions		Sweep 1 Results		Sweep 2-Steps 1 & 2 (Overcurrent Device)
	Sweep 1-Step 1 (Branch)		Sweep 1-Step 2 (Feeder)		Sweep 1-Step 3 (Trans)	Sweep 1-Step 4 (C-L OCPDs)	Sweep 1-Step 5		
	SCCR	Voltage	SCCR	Voltage	SCCR	SCCR	SCCR	Voltage	
Branch Circuit 1	5kA	600V	–	–	–	–	–	–	
Branch Circuit 2	65kA	480/277V	–	–	–	–	200kA	–	
Branch Circuit 3	65kA	480V	–	–	–	–	200kA	–	
Branch Circuit 4	25kA	480V	–	–	–	–	200kA	–	
Branch Circuit 5	100kA	600V	–	–	–	–	200kA	–	
Branch Circuit 6	100kA	600V	–	–	–	–	200kA	–	
Branch Circuit 7	2kA	–	–	–	14kA	–	–	–	
Sub-Feeder Circuit 8	–	–	–	–	–	–	–	–	
Feeder Circuit 9	–	–	10kA	600V	–	–	–	–	
Supply Circuit 10	–	–	200kA	600V	–	–	–	–	

Note: Red cells in table denote limiting components and voltages for each step.

"Two Sweep" Method: Sweep 1, Step 5 - Results of Entire Sweep 1**Sweep 1: Verifying assembly component SCCRs**

Step 5: Determine the lowest branch or feeder circuit component SCCR based on all steps in Sweep 1 and retain for Sweep 2.

- Lowest SCCR resulted from Branch Circuit 1 in Step 1
- Branch Circuit 2 limited voltage in Step 1
- **Sweep 1 Lowest SCCR = 5kA @ 480/277V**

Note: Sweep 2 must still be completed to determine SCCR marking.

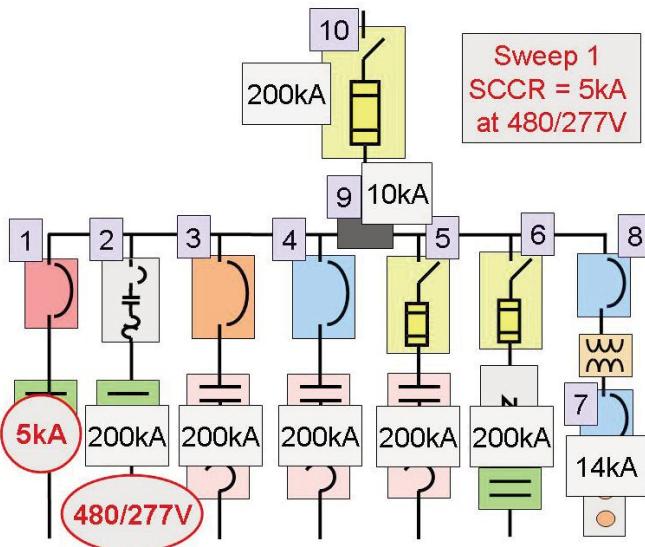


Figure 7 – Results of Sweep 1, Steps 1 through 5

Sweep 1 - Step 5 Summary

After completing all five steps in Sweep 1, the resulting SCCR based upon the components, remains at a low 5kA @ 480/277V because of the 5kA rated contactor in Branch Circuit 1 and the slash voltage rating of the contactor in Branch Circuit 2 (when protected by a slash voltage rated self protected motor starter). See figure 7.

Results of Sweep 1, Step 5: SCCR = 5kA @ 480/277V

	Assessment				SCCR Revisions		Sweep 1 Results		Sweep 2-Steps 1 & 2 (Overcurrent Device)	
	Sweep 1-Step 1 (Branch)		Sweep 1-Step 2 (Feeder)		Sweep 1-Step 3 (Trans)	Sweep 1-Step 4 (C-L OCPDs)	Sweep 1-Step 5			
	SCCR	Voltage	SCCR	Voltage	SCCR	SCCR	SCCR	Voltage		
Branch Circuit 1	5kA	600V	–	–	–	–	5kA	600V		
Branch Circuit 2	65kA	480/277V	–	–	–	200kA	200kA	480/277V		
Branch Circuit 3	65kA	480V	–	–	–	200kA	200kA	480V		
Branch Circuit 4	25kA	480V	–	–	–	200kA	200kA	480V		
Branch Circuit 5	100kA	600V	–	–	–	200kA	200kA	600V		
Branch Circuit 6	100kA	600V	–	–	–	200kA	200kA	600V		
Branch Circuit 7	2kA	–	–	–	14kA	–	14kA	–		
Sub-Feeder Circuit 8	–	–	–	–	–	–	–	–		
Feeder Circuit 9	–	–	10kA	600V	–	–	10kA	600V		
Supply Circuit 10	–	–	200kA	600V	–	–	200kA	600V		

Note: Red cells in table denote limiting components and voltages for each step

"Two Sweep" Method: Sweep 2, Step 1 - Overcurrent Protective Device IR or SCCR

Sweep 2: Verifying assembly SCCR based upon overcurrent protective device interrupting rating (or SCCR for some devices).

Step 1: Determine overcurrent protective device interrupting rating or SCCR*:



Branch Circuit 1

- Molded case circuit breaker
- IR = 14kA @ 480/277V**



Branch Circuit 4

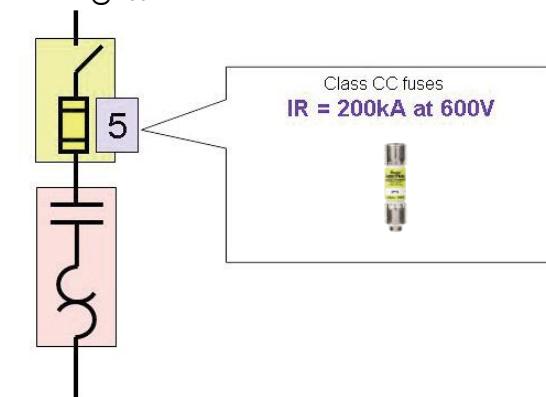
- Molded case circuit breaker
- IR = 14kA @ 480V**



Branch Circuit 2

- Self-protected starter (with line-side terminal kit)
- SCCR = 65kA @ 480/277V**

***Note:** Self-protected starters are not rated with an interrupting rating. So for this Step 1, its SCCR is used per UL 508A.



Branch Circuit 5

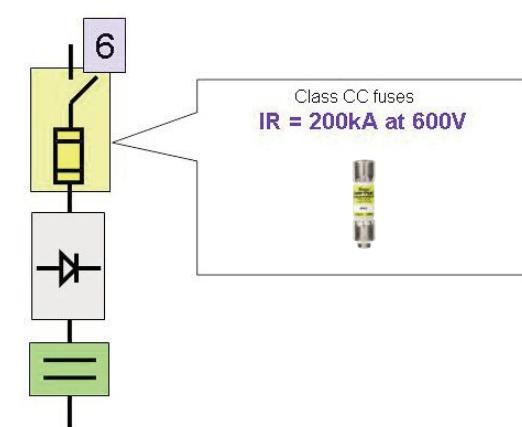
- Bussmann LP-CC fuses
- IR = 200kA @ 600V**



Branch Circuit 3

- MCP – Combination rating with IEC Starter (same manufacturer)
- SCCR = 65kA @ 480V**

***Note:** Per UL 508A, in order to assure proper application in industrial control panels, the MCP must be procedure described to verify use as part of a listed combination motor controller and the corresponding SCCR.



Branch Circuit 6

- Bussmann LP-CC fuses
- IR = 200kA @ 600V**

"Two Sweep" Method: Sweep 2, Step 2 - Lowest IR or SCCR

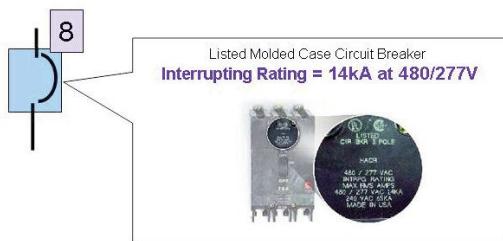
Sweep 2: Verifying assembly overcurrent protective device interrupting rating or SCCR.

Step 2: Determine lowest overcurrent protective device interrupting rating or SCCR.



Branch Circuit 7

- Molded case circuit breaker analyzed in Sweep1, Step 3
- IR = 10kA, but raised to 14kA due to **transformer** and interrupting rating of Sub-Feeder Circuit 8 molded case circuit breaker



Sub-Feeder Circuit 8

- Molded case circuit breaker
- IR = 14kA @ 480/277V

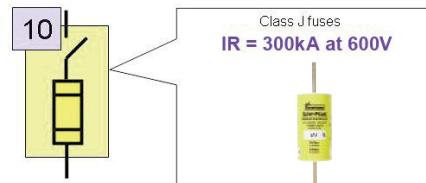
Sweep 2 - Step 2 Summary

- The lowest interrupting rating or SCCR of this Step is 14kA @ 480/277V based upon the interrupting rating of branch circuits 1, 2, 4 and sub-Feeder Circuit 8



Feeder Circuit 9

- No overcurrent protective device in this circuit



Supply Circuit 10

- Bussmann 100A LPJ fuses
- IR = 300kA @ 600V

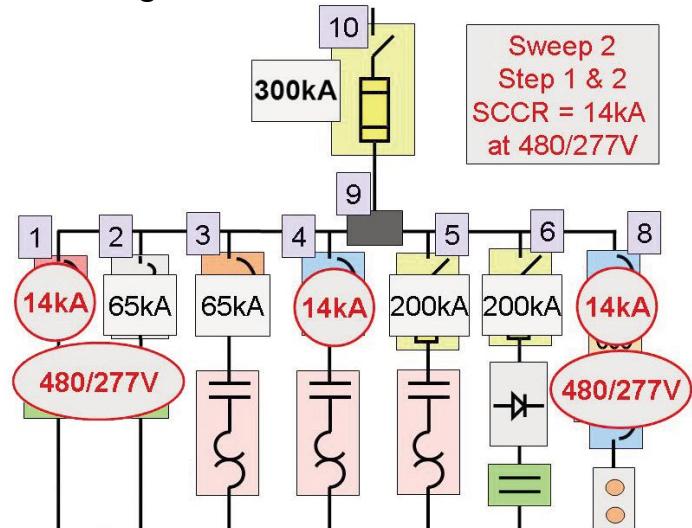


Figure 8 – Results of Sweep 2 – Steps 1 & 2

Results of Sweep 2, Steps 1 & 2: SCCR = 14kA @ 480/277V (Sweep 2, Step 2 Only)

	Assessment				SCCR Revisions		Sweep 1 Results			
	Sweep 1-Step 1 (Branch)		Sweep 1-Step 2 (Feeder)		Sweep 1-Step 3 (Trans)	Sweep 1-Step 4 (C-L OCPDs)	Sweep 1-Step 5		Sweep 2-Steps 1 & 2 (Overcurrent Device)	
	SCCR	Voltage	SCCR	Voltage	SCCR	SCCR	Voltage	IR/SCCR	Voltage	
Branch Circuit 1	5kA	600V	–	–	–	–	5kA	600V	14kA	480/277V
Branch Circuit 2	65kA	480/277V	–	–	–	200kA	200kA	480/277V	65kA	480/277V
Branch Circuit 3	65kA	480V	–	–	–	200kA	200kA	480V	65kA	480V
Branch Circuit 4	25kA	480V	–	–	–	200kA	200kA	480V	14kA	480V
Branch Circuit 5	100kA	600V	–	–	–	200kA	200kA	600V	200kA	600V
Branch Circuit 6	100kA	600V	–	–	–	200kA	200kA	600V	200kA	600V
Branch Circuit 7	2kA	–	–	–	14kA	–	14kA	–	–	–
Sub-Feeder Circuit 8	–	–	–	–	–	–	–	–	14kA	480/277V
Feeder Circuit 9	–	–	10kA	600V	–	–	10kA	600V	–	–
Supply Circuit 10	–	–	200kA	600V	–	–	200kA	600V	300kA	600V

Note: Red cells in table denote limiting components and voltages for each step.

"Two Sweep" Method: Sweep 2, Step 3 - Final Assembly SCCR

Sweep 2: Verifying assembly SCCR based upon overcurrent protective device interrupting rating (or SCCR for same devices).

Step 3: Determine final assembly SCCR based upon results of Sweep 1 (component SCCR) and Sweep 2 (overcurrent protective device interrupting rating or SCCR).

- Sweep 1 lowest SCCR = 5kA @ 480/277V
- Sweep 2 lowest IR or SCCR = 14kA @ 480/277V
- Resulting **assembly SCCR = 5kA @ 480/277** (see Figure 9)

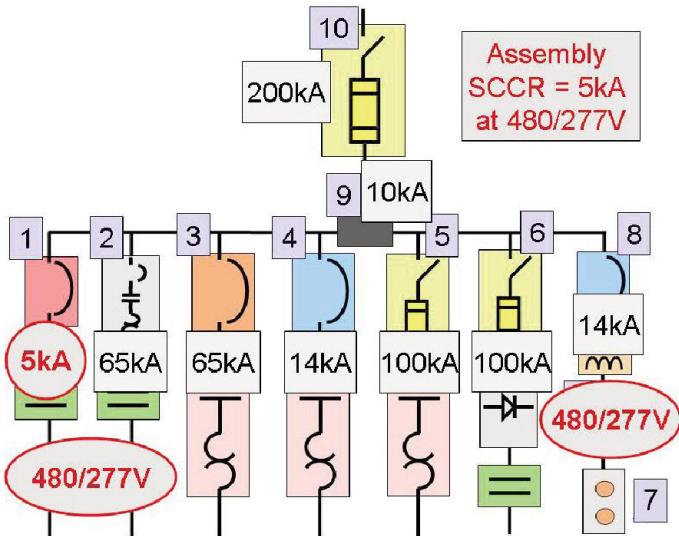
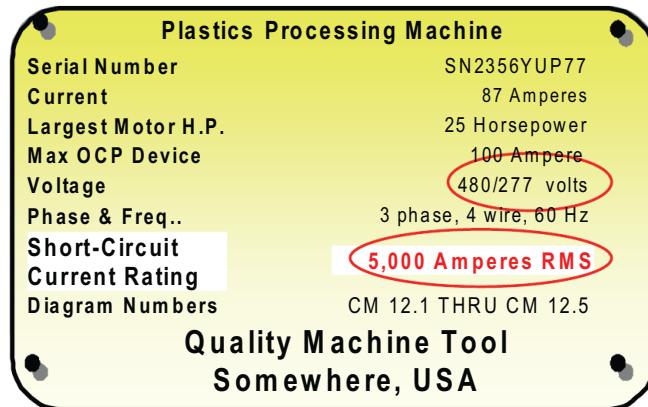


Figure 9 – Results of Sweep 2 – Step 3

Sweep 2 - Step 3 Summary

- The lowest SCCR of both Sweep 1 and Sweep 2 is 5kA @ 480/277V
- The 5kA SCCR is based on the contactor in Branch Circuit 1, analyzed in Sweep 1 - Step 1
- The 480/277 slash voltage rating is from multiple components in Sweep 1 - Steps 1 and 5, and Sweep 2, Steps 1, 2 and 3
- The Assembly SCCR is 5kA @ 480/277V



Example of assembly SCCR label marking based on the "2 Sweep" method.

Note: The assembly would have to be marked with 5kA SCCR and 480/277V. Assemblies with 480/277V devices are suitable for only 480/277V solidly grounded wye systems. These assemblies cannot be applied on 480V ungrounded, resistance grounded or corner grounded systems. See the section on Slash Voltage Ratings for more information.)

Results of Sweep 2, Step 3: Assembly SCCR = 5kA, Voltage = 480/277V

	Assessment				SCCR Revisions		Sweep 1 Results		Sweep 2 Final	
	Sweep 1-Step 1 (Branch)		Sweep 1-Step 2 (Feeder)		Sweep 1-Step 3 (Trans)	Sweep 1-Step 4 (C-L OCPDs)	Sweep 1-Step 5	Sweep 2-Steps 1, 2 & 3 (Overcurrent Device)	IR/SCCR	Voltage
	SCCR	Voltage	SCCR	Voltage	SCCR	SCCR	SCCR	Voltage	IR/SCCR	Voltage
Branch Circuit 1	5kA	600V	–	–	–	–	5kA	600V	14kA	480/277V
Branch Circuit 2	65kA	480/277V	–	–	–	200kA	200kA	480/277V	65kA	480/277V
Branch Circuit 3	65kA	480V	–	–	–	200kA	200kA	480V	65kA	480V
Branch Circuit 4	25kA	480V	–	–	–	200kA	200kA	480V	14kA	480V
Branch Circuit 5	100kA	600V	–	–	–	200kA	200kA	600V	200kA	600V
Branch Circuit 6	100kA	600V	–	–	–	200kA	200kA	600V	200kA	600V
Branch Circuit 7	2kA	–	–	–	14kA	–	14kA	–	–	–
Sub-Feeder Circuit 8	–	–	–	–	–	–	–	–	14kA	480/277V
Feeder Circuit 9	–	–	10kA	600V	–	–	10kA	600V	–	–
Supply Circuit 10	–	–	200kA	600V	–	–	200kA	600V	300kA	600V

Note: Red cells in table denote limiting components and voltages for each step.

Example: Increasing Assembly SCCR - "FIX IT"

"FIX IT"

What follows are methods to increase, or "FIX," a low assembly SCCR using the appropriate overcurrent protective devices with higher interrupting ratings and components with higher SCRRs.

To increase the assembly SCCR, identify the "weak links" and determine alternatives that can be used to increase the SCCR. Industrial control panels are required to be marked with an SCCR. NEC® 409.22 requires the industrial control panel SCCR to be not less than the available fault current, and many OEMs and Industrials are finding that SCCR ratings of 65kA, 100kA, or higher with full voltage ratings (480V in lieu of 480/277V) are often needed to assure NEC® compliance for the initial installation and flexibility for future changes to the system or moving the assembly to another location. The process to "FIX" these "weak links" is detailed below in order to meet the installation needs of OEMs and Industrials.

"Weak Link" 1

Branch Circuit 1: SCCR = 5kA and Slash Voltage

Rating

The first "weak link" from the previous "Two Sweep" example is the IEC contactor (5kA SCCR) and the slash rated circuit breaker (480/277V) from Branch Circuit 1. As shown in Figure 10, not only does the circuit breaker have a low interrupting rating (14kA) and slash voltage rating (480/277V), but the other circuit components, such as the IEC contactor (5kA), can additionally limit the SCCR since higher combination ratings are not available.

The "FIX IT" is to find a fully rated overcurrent device with a high interrupting rating and a high SCCR combination rating with the IEC contactor. A solution is to change the circuit breaker to the Bussmann Compact Circuit Protector (CCP) with Class CC fuses. The Class CC CCP is rated 600V and 200kA. Since the Class CC CCP utilizes Class CC fuses, and since the IEC contactor in this example had a combination rating of 100kA with Class CC fuses, the SCCR is now 100kA. An additional benefit of the CCP can be space savings when compared to typical lighting and industrial style circuit breakers.

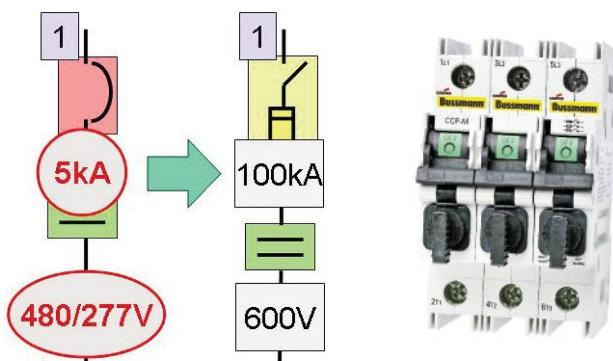


Figure 10

The Bussmann CCP with Class CC fuses can easily increase SCCR by replacing low IR and slash rated overcurrent protective devices.

"Weak Link" 2

Feeder Circuit 9: SCCR = 10kA

The next "weak link" is the unmarked power distribution block. The easy solution to this is to find a power distribution block that has a high SCCR when protected by a specific overcurrent device upstream. Since the overcurrent device upstream is a Class J fuse, the solution would be to use a Bussmann high SCCR power distribution block or terminal block. This is important to note, as most power distribution blocks and terminal blocks require a current-limiting fuse to achieve a SCCR higher than 10kA. In addition, since the power distribution block is in the feeder circuit, feeder circuit spacings are also required per UL 508A. The Bussmann PDB (open style) or PDBFS (enclosed style) Series of power distribution blocks are Listed to UL 1953 assuring compliance with feeder circuit spacing requirements in UL 508A and are UL Listed with high SCCR ratings with Class J fuses as shown in Figure 11.

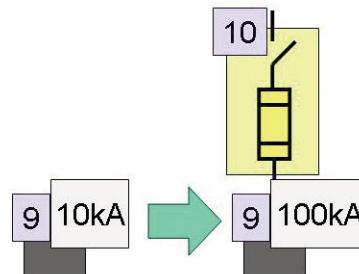


Figure 11

High SCCR PDBs

Often the power distribution block is the "weak link" holding assembly SCCR low. Using high SCCR PDBs protected with Class J fuses can deliver a higher combination SCCR. The following table shows the possible SCRRs.

This power distribution block is rated for use on a circuit capable of delivering no more than the SCCR kA shown (kA rms sym. or DC amps 600V maximum). For other SCCR options, see Bussmann Data Sheet 1049.



Figure 12

AWG Wire Range	Class J Fuse Max. Amp	Resulting SCCR
2-6	400A	200kA
2-14	200A	50kA
2-14	175A	100kA

Note: SCCR of the Bussmann PDBFS is only 10kA with a circuit breaker. Contact Eaton for power distribution blocks with high SCCR when protected by circuit breakers.

Example: Increasing Assembly SCCR - "FIX IT"

"Weak Link" 3

Branch Circuit 4: SCCR = 14kA and Sub-Feeder

Circuit 8 – SCCR = 14kA and Slash Voltage Rating

The next "weak link" is the 14kA circuit breaker in Branch Circuit 4 and the 14kA slash rated (480/277V) circuit breaker in Sub-Feeder Circuit 8. There are two possible solutions for this, either increase the interrupting rating of both circuit breakers and change to a full or straight voltage rated circuit breaker in Sub-Feeder Circuit 8 or change to the Bussmann® CCP as shown in "Weak Link 1." An economical solution is to change to the Bussmann CCP with Class CC fuses. In Branch Circuit 4, this change increases the interrupting rating to 200kA as well as increasing the rating of the IEC starter to 100kA through the use of Class CC fuses. In Branch Circuit 4, this change increases the interrupting rating to 200kA, but also improved the voltage rating from 480/277V (limits the assembly) to 600V (not limited).

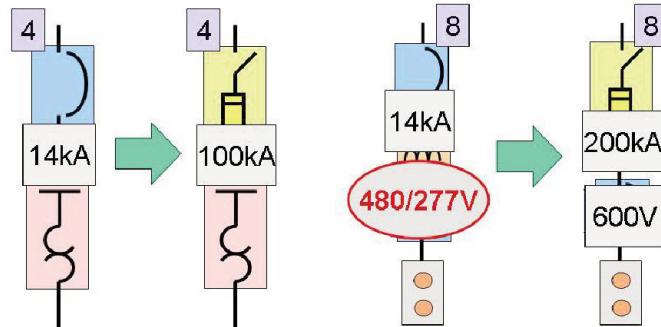


Figure 13

"Weak Link" 4

Branch Circuit 2: Slash Voltage Ratings

The next "weak link" is the slash voltage rating in Branch Circuit 2. While the self-protected starter is compact in size and has a relatively high SCCR (65kA), it typically comes with a slash voltage rating. The solution is to either add an overcurrent device with a high interrupting rating ahead of the self-protected starter or change to the CCP with Class CC fuses and a magnetic starter. The most economical solution to achieve a high SCCR and full voltage rating is to change to the CCP with Class CC fuses and a magnetic starter. With this change the circuit is rated 100kA @ 600V.

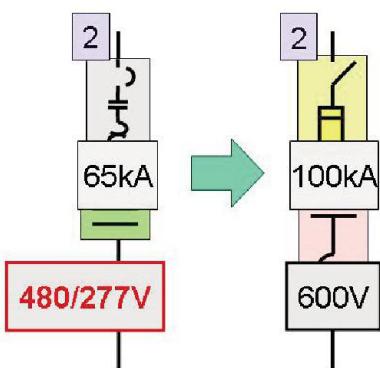


Figure 14

"Weak Link" 5

Branch Circuit 2, 3 & 4: Manufacturer Limitation

Where fusible devices are used in motor circuits, high combination SCCR with motor circuit components from multiple manufacturers are available increasing an OEMs' flexibility in sourcing components. This typically reduces costs and provides alternatives during extended product delivery situations. For instance, fuses protecting motor circuit components listed at 100kA combination SCCR generally are available from several motor circuit component manufacturers. In contrast, the self-protected starter and contactor in Branch Circuit 2 requires the same manufacturer for each component to be selected if higher combination SCRRs are desired.

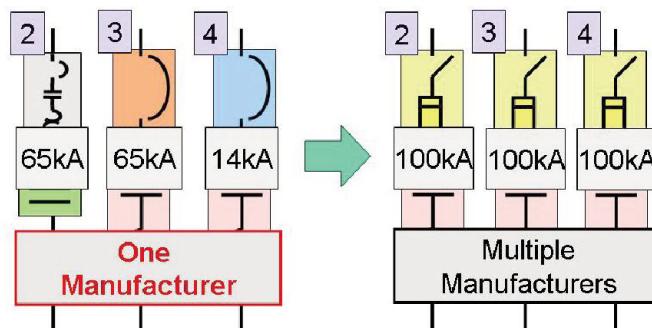


Figure 15

"FIX IT" Summary

The Figure 16 shows how all the "weak links" have been changed and now the panel has a high assembly SCCR with a full voltage rating.

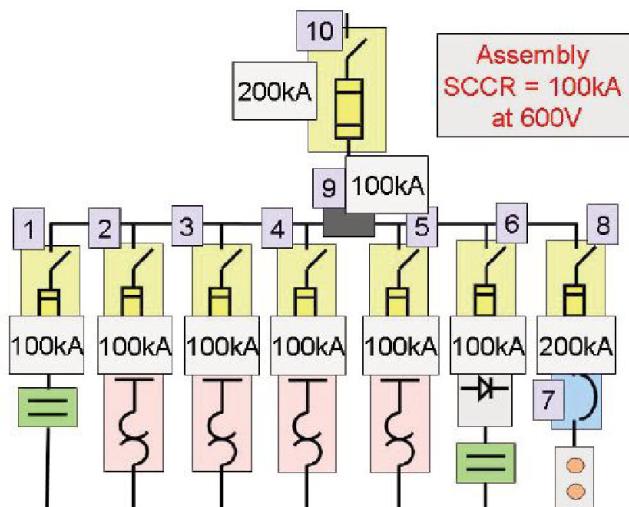
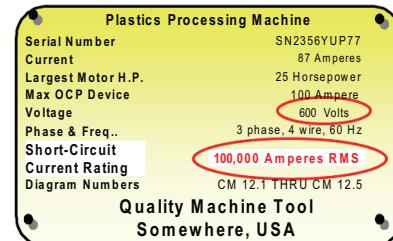


Figure 16

Increasing Assembly SCCR: “FIX IT” - Typical “Weak Links”

Typical “Weak Links” and Improving SCCR

The following table highlights the typical “weak links” in industrial control panels and provides Bussmann solutions, along with the added benefits that these solutions can provide for industrial control panels.

This is an example of how Bussmann can help “FIND” the “weakest link” and “FIX” the “weakest link.” Bussmann will provide the most versatile and reliable design for any overcurrent protection need.

“Weak Link”	“FIX IT”
 <p>UL 1077 Supplementary Protectors Assembly Limiting Factor: <ul style="list-style-type: none"> Some may have an interrupting rating of 5kA to 10kA. Default rating is 200A if unmarked. Not permitted for feeder or branch circuit protection. </p>	 <p>Increase the Interrupting Rating: <ul style="list-style-type: none"> Use Bussmann current-limiting fuses and the CCP (Class CC or CUBEFuse™) or fuse holder to achieve higher SCRRs by replacing the low interrupting rated UL 1077 supplementary protector with modern current-limiting fuses with high IRs of up to 300kA and UL 4248 fuseholders or UL 98 disconnects with SCCR of 200kA. </p>
 <p>UL 489 Instantaneous Trip Circuit Breaker Assembly Limiting Factor: <ul style="list-style-type: none"> SCCR is dependent upon combination rating when used with a listed combination motor controller. Default rating can be as low as 5kA. Varies by manufacturer. Procedure described. </p>	 <p>Increase the Interrupting Rating: <ul style="list-style-type: none"> Use Bussmann current-limiting fuses and the CCP (Class CC or CUBEFuse) or fuse holder to achieve higher short-circuit current ratings. Modern current-limiting fuses are available with high interrupting ratings of up to 300kA and UL 4248 fuseholders or UL 98 disconnects are available with SCCR of 200kA. </p>
 <p>Power Distribution Block in Feeder Circuit Assembly Limiting Factor: <ul style="list-style-type: none"> If the power distribution block is not marked with a combination SCCR the default rating of 10kA must be used. For feeder circuit applications, power distribution blocks must have feeder spacings per UL 508A. Power distribution blocks recognized to UL 1059 typically do not comply. </p>	 <p>Use PDB and PDBFS Series of Power Distribution Blocks with High SCCR: <ul style="list-style-type: none"> Bussmann has a line of power distribution blocks Listed to UL 1953 with high SCRRs up to 200kA when protected by Class J and CF fuses. By replacing a low rated power distribution block with the Bussmann PDBs or PDBFS, a panel can achieve the high ratings and proper spacings needed for feeder circuit applications. </p>
 <p>Molded Case Circuit Breakers with Low Interrupting Ratings Assembly Limiting Factor: <ul style="list-style-type: none"> Typically have interrupting ratings of 10kA to 14kA. Higher interrupting ratings are available at increased cost. </p>	 <p>Increase the Interrupting Rating: <ul style="list-style-type: none"> Use Bussmann current-limiting fuses and the CCP (Class CC or CUBEFuse) or fuse holder to achieve higher short-circuit current ratings by replacing the low interrupting rated circuit breaker with modern current-limiting fuses which are available with high interrupting ratings of up to 300kA. UL 4248 fuseholders or UL 98 disconnects are available with SCCR of 200kA. </p>
 <p>Type E Self Protected Combination Starter Assembly Limiting Factor: <ul style="list-style-type: none"> Slash voltage rating (480/277V) limits the application options for the assembly to only a solidly grounded wye system. Line-to-ground interrupting capability is limited. SCCR at 600/347V is typically limited. May require additional lineside adapter accessory to be used as a Type E self protected combination starter. </p>	 <p>Use Device With Straight Voltage Rating: <ul style="list-style-type: none"> Use Bussmann current-limiting fuses and the CCP (Class CC or CUBEFuse) or fuse holder with high SCCR combination and straight voltage rated motor starter to allow for installation on any type of system grounding. </p>

Additional Resources on SCCR

FC2 Available Fault Current Calculator for three-phase and single-phase systems. Quick, easy method to determine available fault current at one or multiple points in an electrical distribution system. Scan QR Code to download

app for Apple and Android mobile devices. Access web-based version via www.cooperbussmann.com/fc2.



Introduction

What Is Selective Coordination?

Today, more than ever, one of the most important parts of any facility is the electrical distribution system. Nothing will stop all activity, paralyze production, inconvenience and disconcert people, and possibly cause a panic, more than a major power failure. Selective coordination is critical for the reliability of the electrical distribution system and must be analyzed.

Selective coordination of overcurrent protective devices is required by the NEC® for a few building systems for a limited number of circuits that supply power to vital loads. These requirements will be discussed in a later section. For circuits supplying power to all other loads, selective coordination is a very desirable design consideration, but not mandatory. It is important to deal with selective coordination in the design phase. After switchboards, distribution panels, motor control centers, lighting panelboards, etc. are installed, there typically is little that can be done to retroactively "fix" a system that is not selectively coordinated.

While it's very important, it is not enough to select protective devices based solely on their ability to carry the system load current and interrupt the maximum fault current at their respective points of application. It is important to note that the type of overcurrent protective devices and ratings (or settings) selected determine if a system is selectively coordinated. A properly engineered and installed system will allow only the nearest upstream overcurrent protective device to open for both overloads and all types of short-circuits, leaving the remainder of the system undisturbed and preserving continuity of service. Isolation of a faulted circuit from the remainder of the installation is critical in today's modern electrical systems. Power blackouts cannot be tolerated.

Article 100 of the NEC® defines this as:

Coordination (Selective).

Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the selection and installation of overcurrent protective devices and their ratings or settings for the full range of available overcurrents, from overload to the maximum available fault current, and for the full range of overcurrent protective device opening times associated with those overcurrents.

The 2014 NEC® clarified the definition by inserting specific language that selective coordination is for the full range of overcurrents available for a system. In the Selective Coordination Objections & Misunderstandings section, Objection 1, the difference between selective coordination and coordination is discussed.

The two one-line diagrams in Figure 1 illustrate the concept of selective coordination. The system represented by the one-line diagram to the left is a system without selective coordination. A fault on the loadside of one overcurrent protective device unnecessarily opens other upstream overcurrent

Selective Coordination: Avoids Blackouts

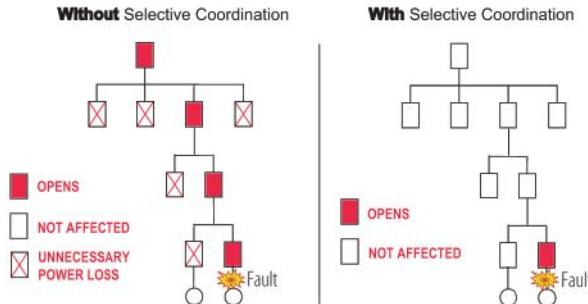


Figure 1

protective device(s). The result is unnecessary power loss to loads that should not be affected by the fault. This is commonly known as a "cascading effect" or lack of coordination. The system represented by the one-line diagram to the right is a system with selective coordination. For the full range of overload or fault currents possible for this system, only the nearest upstream overcurrent protective device opens. All the other upstream overcurrent protective devices do not open. Therefore, only the circuit with the fault is removed and the remainder of the power system is unaffected. The power for other loads in the system continues uninterrupted. The overcurrent could occur on a feeder circuit, too, and a selectively coordinated circuit would only have the immediate upstream feeder overcurrent protective device open.

Selective coordination is an easy concept to understand. However, quite often in the design or equipment selection phase, it is ignored or overlooked. And when it is evaluated, many people misinterpret the information thinking that selective coordination has been achieved, when in fact, it has not. The following sections explain how to evaluate whether overcurrent protective devices provide selective coordination for the full range of overcurrents.

Methods of Performing a Selective Coordination Study

Currently three methods are most often used to perform a coordination study:

1. For fuse systems, 600V or less, use the published selectivity ratios which are presented in the next section for Bussmann fuses. The ratios apply for all overcurrent conditions including overloads and short-circuit currents. Using the fuse selectivity ratio method is easy and quick.
2. Computer programs allow the designer to select time-current curves published by manufacturers and place curves of all OCPDs of a circuit on one graph. However, simply plotting the curves does not prove selective coordination. The curves must be analyzed and interpreted properly in relation to the available fault currents at various points in the system.
3. Overlays of time-current curves, with the manufacturers' published data hand traced on log-log paper. Proper analysis and interpretation is important in this case, also. Typically more information is needed such as in 1 above.
4. Circuit breaker manufacturers provide tested coordination tables that may be used in place of or in addition to the methods above.

Coordination Analysis

The next several pages cover selective coordination from various perspectives. The major areas include:

- Fuses
- Circuit breakers
- Systems with fuse and circuit breaker mixture
- Mandatory selective coordination requirements
- Why selective coordination is mandatory
- Selective coordination system considerations
- Ensuring compliance
- Requirements inspection check list (available in the Inspection Checklist section of this publication)
- Fuse and circuit breaker choice considerations table
- Objections and misunderstandings
- Ground fault protection relays

Fuse Curves

Figure 2 illustrates the time-current characteristic curves for two amp ratings of time-delay, dual-element fuses in series, as depicted in the one-line diagram. The horizontal axis of the graph represents the RMS symmetrical current in amps. The vertical axis represents the time, in seconds. Each fuse is represented by a band: the minimum melt characteristic (solid line) and the total clear characteristics (hash line). The band between the two lines represents the tolerance of that fuse under specific test conditions. For a given overcurrent, a specific fuse, under the same circumstances, will open at a time within the fuse's time-current band.

Fuses have an inverse time-current characteristic, which means the greater the overcurrent, the faster they interrupt. Look at the 100A fuse curve: for an overcurrent of 200A, the fuse will interrupt in approximately 200 seconds and for an overcurrent of 2000A, the fuse will open in approximately 0.15 second. In some cases, to assess coordination between two or more fuses, the fuse time-current curves are compared. This method is limited to only the overcurrent range for which the fuse curves are visible on the graph.

For example: Assume an overcurrent level of 1000A RMS symmetrical on the loadside of the 100A fuse. To determine the time it would take this overcurrent to open the two fuses, first find 1000A on the horizontal axis (Point A), follow the dotted line vertically to the intersection of the total clear curve of the 100A fuse (Point B) and the minimum melt curve of the 400A fuse (Point C). Then, horizontally from both intersection points, follow the dotted lines to Points D and E. At 1.75 seconds, Point D represents the maximum time the 100A fuse will take to open the 1000A overcurrent. At 90 seconds, Point E represents the minimum time at which the 400A fuse could open this overcurrent. These two fuses are coordinated for a 1000A overcurrent.

For overcurrents up to approximately 11,000A (Point H), since no overlap of curves exists, it can be determined that the two fuses are selectively coordinated. The 100 amp fuse will open before the 400 amp fuse can melt. However, notice above approximately 11,000A, selective coordination cannot be determined by the time-current curves. The operating characteristics for both fuses are less than 0.01 second. For operating times less than 0.01 second, a fuse is operating in or near its current-limiting range and another method must be used to assess whether two fuses selectively coordinate. Bussmann publishes selectivity ratios for their fuses that make it simple to assess whether fuses selectively coordinate. If you use the selectivity ratios, plotting fuse curves is unnecessary.

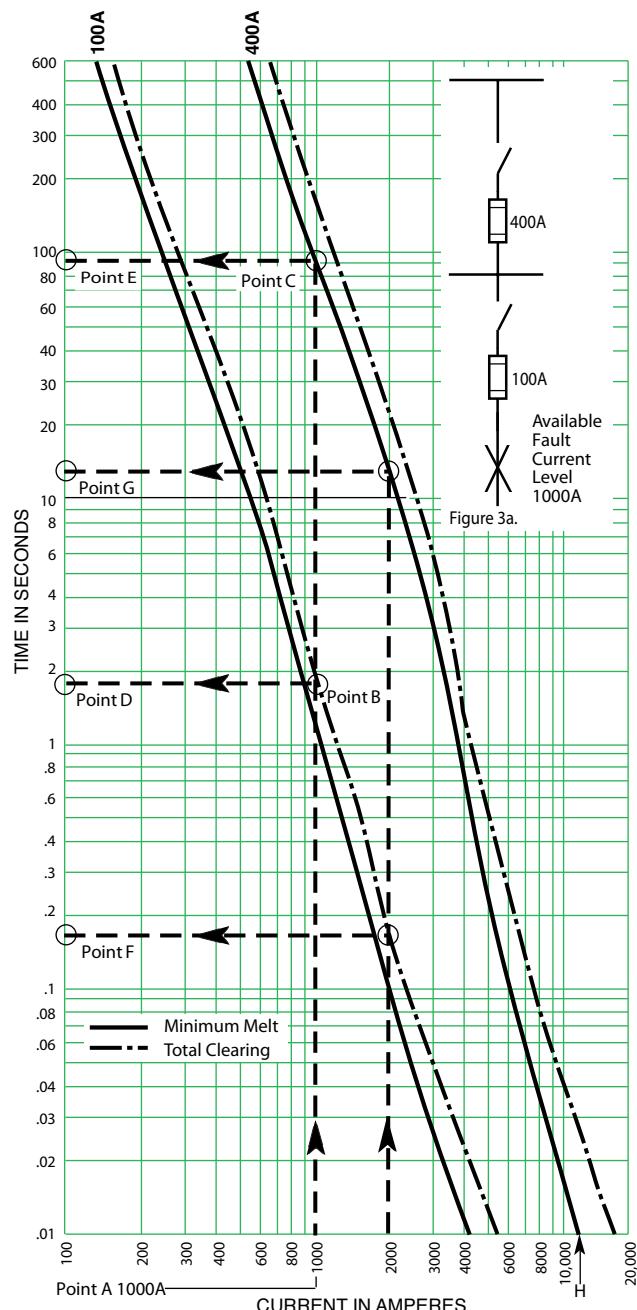


Figure 2

Fuse Selectivity Ratio Guide

Selective Coordination with Fuses

To determine fuse selectivity is simple physics. Selectivity between two fuses operating under short-circuit conditions exists when the total clearing energy of the loadside fuse is less than the melting energy of the lineside fuse. The following explains this process.

Figure 3 illustrates the principle of selective coordination when fuses are properly applied. Where high values of fault current are available, the sub-cycle region (less than 0.01 second) becomes the most critical region for selective operation of current-limiting fuses. The available short-circuit current that could flow is depicted by the dotted line. If no protective device were present the full available short-circuit current energy could be delivered to the system. When a fuse is in its current-limiting range, the fuse will clear the fault in approximately one-half cycle or less, and can greatly reduce the effective let-through current.

Note that T_m is the melting time of the fuse and T_c is the total clearing time of the fuse. The area under the current curves over a time period is indicative of the energy let-through. The amount of thermal energy delivered is directly proportional to the square of the current multiplied by clearing time (I^2t). The amount of energy being released in the circuit while the fuse element is melting (or vaporizing) is called the melting energy and energy released during the entire interruption process (melting plus arcing) is called total clearing. To achieve a selectively coordinated system the T_c and clearing I^2t of the downstream fuse must be less than the T_m and melting I^2t of the upstream fuse.

Selective Coordination - Fuses

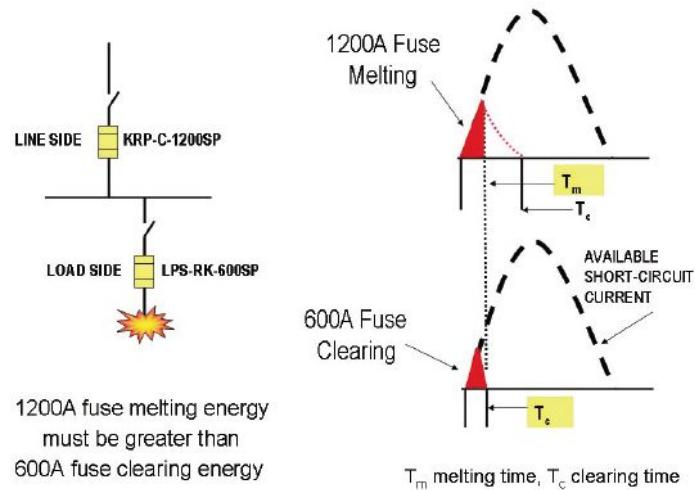


Figure 3

Fuse Selectivity Ratio Guide

Simply adhering to fuse selectivity ratios makes it easy to design and install fusible systems that are selectively coordinated. See the Bussmann Selectivity Ratio Guide. The top horizontal axis shows loadside fuses and the left vertical axis shows lineside fuses. These selectivity ratios are for all levels of overcurrents up to the fuse interrupting ratings or 200,000A, whichever is lower. The ratios are valid for all overcurrents and opening times, even for fuse opening times less than 0.01 second. The installer just needs to install the proper fuse type and amp rating. It is not necessary to plot time-current curves or do a short-circuit current analysis (if the available short-circuit current is less than 200,000A or the interrupting rating of the

fuses, whichever is less). All that is necessary is to make sure the fuse types and amp rating ratios for the mains, feeders and branch circuits meet or exceed the applicable selectivity ratios. If the ratios are not satisfied, then the designer should investigate another fuse type or design change.

Notice the Low-Peak fuses (LPJ_SP, LPN-RK_SP, LPS-RK_SP, and KRP-C_SP) as well as the CUBEFuse (TCF) only require a 2:1 amp rating ratio to achieve selective coordination. This simplifies the design process and flexibility.

Selectivity Ratio Guide (Lineside to Loadside)¹

Circuit			Loadside Fuse									
Current Rating			601-6000A	601-4000A	0-600A		601-6000A	0-600A	0-1200A	0-600A	0-60A	0-30A
Type			Time-Delay	Time-Delay	Dual-Element Time-Delay		Fast-Acting	Fast-Acting	Fast-Acting	Fast-Acting	Time-Delay	
Trade Name Class			Low-Peak (L)	Limitron (L)	Low-Peak (RK1)	Low-Peak (J)	Fusetron (RK5)	Limitron (L)	Limitron (RK1)	T-Tron (I)	Limitron (J)	SC (G) (CC)
Bussmann Symbol			KRP-C_SP	KLU	LPN-RK_SP LPS-RK_SP	LPJ-SP TCF	FRN-R FRS-R	KTU	KTN-R KTS-R	JJN JJS	JKS	SC
Lineside Fuse	601 to 6000A	Time-Delay	Low-Peak (L)	KRP-C_SP	2:1	2.5:1	2:1	2:1	2:1	2:1	2:1	2:1
	601 to 4000A	Time-Delay	Limitron (L)	KLU		2:1						
	0 to 600A	Dual-Element	Low-Peak (RK1)	LPN-RK_SP LPS-RK_SP LPJ-SP TCF	-	-	2:1	2:1	8:1	-	3:1	3:1
	0 to 600A	ment	Fusetron (RK5)	FRN-R FRS-R		-	-	1.5:1	1.5:1	2:1	1.5:1	1.5:1
	601 to 6000A	Fast-Acting	Limitron (L)	KTU	2:1	2.5:1	2:1	2:1	6:1	2:1	2:1	2:1
	0 to 600A	Fast-Acting	Limitron (RK1)	KTN-R KTS-R	-	-	3:1	3:1	8:1	-	3:1	3:1
	0 to 1200A	T-Tron (I)	JJN JJS	-	-	3:1	3:1	8:1	-	3:1	3:1	4:1
	0 to 600A	Time-Delay	Limitron (J)	JKS	-	-	2:1	2:1	8:1	-	3:1	3:1
	0 to 60A	Time-Delay	SC (G)	SC	-	-	3:1	3:1	4:1	-	2:1	2:1

1. Where applicable, ratios are valid for indicating and non-indicating versions of the same fuse. At some values of fault current, specified ratios may be lowered to permit closer fuse sizing.

Consult with Bussmann. Ratios given in this Table apply only to Bussmann fuses. When fuses are within the same case size, consult Bussmann.

NOTE: All the fuses in this table have interrupting ratings of 200kA or greater, except the SC fuses have 100kA IR.

Fuse Selectivity Ratio Guide

Example of Fuse Selective Coordination

The following example illustrates the simple process to achieve selective coordination with a fusible system. Review the oneline diagram of the fusible system in Figure 4. All the fuses are Low-Peak fuses. The Selectivity Ratio Guide provides the minimum ampacity ratio that must be observed between a lineside fuse and a loadside fuse in order to achieve selective coordination between the two fuses. If the entire electrical system maintains at least these minimum fuse ampacity ratios for each circuit path, the entire electrical system will be selectively coordinated for all levels of overcurrent. Note, time-current curves do not need to be plotted.

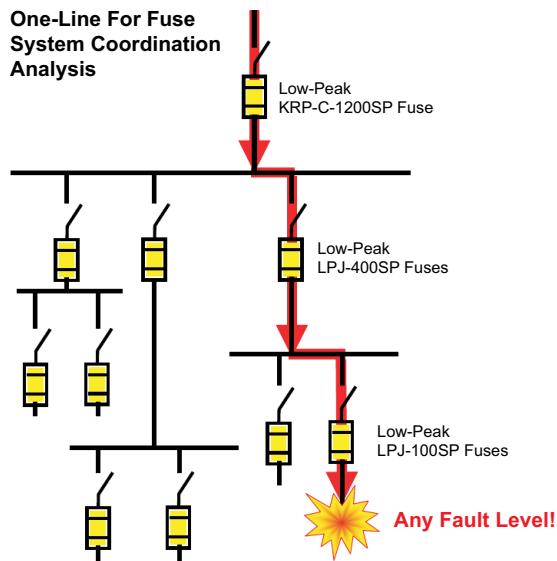


Figure 4

Check the LPJ-100SP fuse coordination with the LPJ-400SP fuse.
The ampacity ratio of these fuses in this circuit path is 400:100 which equals a 4:1 ratio. Checking the Selectivity Ratio Guide, lineside LPJ (left column) to load-side LPJ (top horizontal row), yields a minimum ratio of 2:1. This indicates selective coordination for these two sets of fuses for any overcurrent condition up to 200,000A. This means for any overcurrent on the loadside of the LPJ-100SP fuse, only the LPJ-100SP fuse opens. The LPJ-400SP fuse remains in operation as well as the remainder of the system.

Check the LPJ-400SP fuse coordination with the KRP-C-1200SP fuse.

Use the same steps as in the previous paragraph. The ampacity ratio of the two fuses in this circuit path is 1200:400, which yields an ampacity ratio of 3:1. The Selectivity Ratio Guide shows that the ampacity ratio must be maintained at 2:1 or more to achieve selective coordination for these specific fuses. Since the fuses used have a 3:1 ratio, and all that is needed is to maintain a 2:1 ratio, these two fuses are selectively coordinated for any overcurrent condition up to 200,000A. The result is this entire circuit path then is selectively coordinated for all overcurrents up to 200,000A. See Figure 5.

Selective Coordination Only Faulted Circuit Cleared

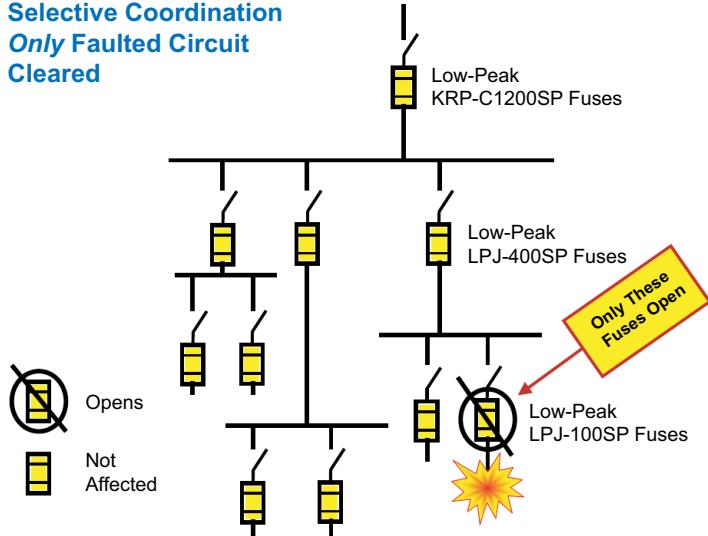


Figure 5

Fusible Lighting Panels

Fusible Panelboards

The Bussmann Quik-Spec™ Coordination Panelboard provides fusible solution for branch panelboard applications, making it simple and cost effective to selectively coordinate the lighting and other branch circuits with upstream Bussmann fuses.

This panelboard is available in MLO (Main Lug Only), as well as fused or non-fused main disconnect configurations with a choice of 18, 30 and 42 branch positions in NEMA 1 or 3R enclosures to easily meet the needs for branch or service panel installations. This branch circuit panelboard uses the Bussmann finger-safe CUBEFuse™ (1 to 100A, UL Listed, current-limiting, time-delay or fast-acting, Class CF) for the branch circuit protective devices as an integral part of the innovative, patented Compact Circuit Protector Base (CCPB) fusible UL 98 disconnect available in 1-, 2- and 3-pole versions.

The fused main disconnect options are either 100A thru 400A indicating Class J Bussmann Low-Peak™ LPJ_SPI fuses or 60A or 100A CUBEFuse. The panel is rated 600Vac/125Vdc and capable of providing high Short-Circuit Current Ratings (SCCR) up to 200kA. The footprint is the same size as traditional circuit breaker panelboards: 20" W x 5 ¾" D x 50" or 59" H (the height depends on configuration and number of branch circuit positions). Two key features of this new panelboard are fuse/CCPB disconnect switch interlock which prevents removing a fuse while energized and a CUBEFuse/CCPB disconnect ampacity rejection feature which coincides with standard branch circuit amp ratings to help ensure proper fuse replacement.

The CUBEFuse and Low-Peak LPJ_SPI fuses are easy to selectively coordinate with each other and other Low-Peak fuses that are used in upstream power distribution panelboards and switchboards. Merely maintain at least a 2:1 fuse amp rating ratio between upstream and downstream Low-Peak fuses and selective coordination is ensured up to 200kA.

For further information on this panel visit www.bussmann.com/quik-spec for Data Sheet 1160, specification, Application Notes and more.



Quik-Spec™ Coordination Panelboard



CUBEFuse™ CCPB Fused Branch Disconnect



TCF CUBEFuse Class CF

Fuses

Another Fuse Selective Coordination Example

Figure 6 is an example where the fuses considered initially do not meet the minimums in the Selectivity Ratio Guide. One option is to investigate other fuse alternatives. In doing so, it is necessary to understand the various fuse alternatives and considerations which are not covered in this section. But this example provides the reader the concept of investigating other alternatives. In this example, the FRS-R-200 fuses selectively coordinate with the FRS-R-400 fuses since they have a 2:1 ratio and the Selectivity Ratio Guide minimum is 2:1 for FRS-R to FRS-R fuses. However, the KRP-C-800SP fuse to FRS-R-400 fuse is a 2:1 ratio and the Selectivity Ratio Guide requires at least a 4:1 ratio. Figure 7 is a progression of analysis that is possible to obtain selective coordination by specifying another type of fuse. In this case, it is important to know that the FRS-R fuses and LPS-RK_SP fuses have the same mounting dimensions (they can be installed in the same holders and blocks) and the LPS-RK_SP fuses have the same overload characteristics as the FRS-R fuses. This means the LPS-RK_SP fuses should be able to be sized for the loads in the same manner as the FRS-R fuses. The LPS-RK_SP fuses have better current-limiting characteristics, which results in better component protection and in most cases, better arc flash protection. In Figure 7, Scenario A is the initial fuse selection that does not meet the selectivity ratios. In Scenario B, the FRS-R-400 fuses are changed to LPS-RK-400SP fuses and will selectively coordinate with the KRP-C-800SP fuses. However, now the FRS-R-200 fuse and LPS-RK-400SP fuse do not meet the minimum selectivity ratio, which is 8:1 for these fuses. In Scenario C, the FRS-R-200 fuses are changed to LPS-RK-200SP fuses and these are selectively coordinated, since the minimum selectivity ratio is 2:1.

Fuse Selectivity Ratio Example: Alternative Fuse Types

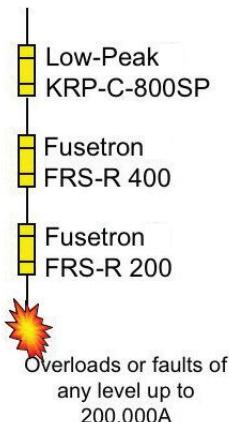


Figure 6

Fuse Selectivity Ratio Example: Alternative Fuse Types

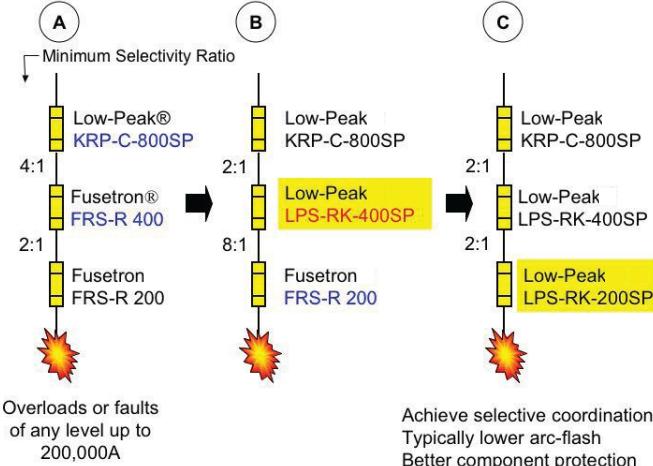


Figure 7

Building System Recommendation

As demonstrated in the previous section, doing an analysis for selective coordination of a fuse system is relatively simple. However, there are many fuse types and associated ratios. For building electrical systems, the following Low-Peak fuses are recommended for $\frac{1}{2}$ to 6000A, 600V or less (all but the LPN-RK_SP are rated 600V or less which means they can be used on any system up to 600V). Low-Peak fuses all have 2:1 selectivity ratios with any other Low-Peak fuses.

Quik-Spec™ Coordination Panelboard (branch circuit panelboard)

- TCF_RN* Class CF 1 to 100A

Main switchboards, power distribution panelboard, MCCs, etc 600A or less

- LPJ_SP Class J 1 to 600A Smaller than LPS-RK fuses

or

- LPS-RK_SP (600V) or LPN-RK_SP (250V) Class RK1 1 to 600A

Large ampacity circuits where fuse is greater than 600A

- KRP-C_SP Class L 601 to 6000A

Summary — Fuse Selective Coordination

With modern current-limiting fuses, selective coordination can be achieved by adhering to selectivity ratios. It is neither necessary to plot the time current curves nor to calculate the available short-circuit currents (for systems up to 200,000A). Just maintain at least the minimum amp rating ratios provided in the Selectivity Ratio Guide and the system will be selectively coordinated. This simple method is easy and quick. If the available fault current increases due to a transformer change, the selectivity is retained. The user should keep adequate spare fuses and the electrician should always replace opened fuses with the same type and amp rating. The selectivity ratios are not valid with a mixture of Bussmann fuses and fuses of another manufacturer. If a design does not provide selective coordination, first investigate other Bussmann fuse types that may have different selectivity ratios. Note: if another fuse type is investigated, the application sizing guidelines for that fuse should also be considered. If selective coordination still cannot be achieved, then a design change may be necessary.

*TCF_RN is non-indicating version of the CUBEFuse. CUBEFuse is UL Listed, Class CF with Class J performance with special finger-safe IP20 construction. TCF is the indicating version.

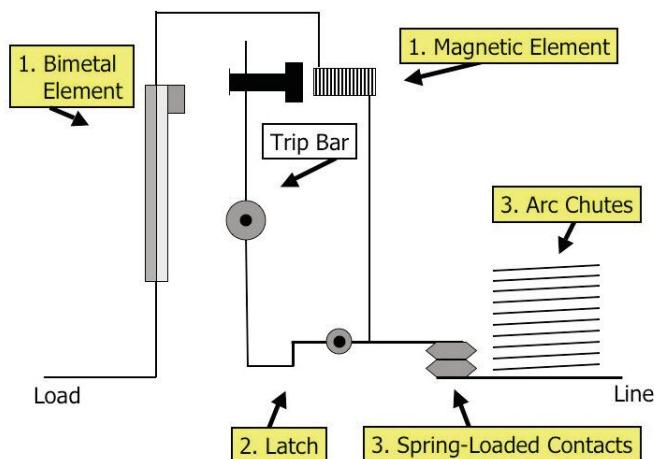
Circuit Breakers

Circuit Breaker Operation Basics

Circuit breakers are mechanical overcurrent protective devices. All circuit breakers share three common operating functions:

1. Current sensing means:
 - A. Thermal
 - B. Magnetic
 - C. Electronic
2. Unlatching mechanism: mechanical
3. Current/voltage interruption means (both)
 - A. Contact parting: mechanical
 - B. Arc chute

The circuit breaker's physics of operation is significantly different from that of a fuse. First, the circuit breaker senses the overcurrent. If the overcurrent persists for too long, the sensing means causes or signals the unlatching of the contact mechanism. The unlatching function permits a mechanism to start the contacts to part. As the contacts start to part, the current is stretched through the air and arcing between the contacts commences. The further the contacts separate the longer the arc, which aids in interrupting the overcurrent. However, in most cases, especially for fault current, the contacts alone are not sufficient to interrupt. The arcing is thrown to the arc chute which aids in stretching and cooling the arc so that interruption can be made. Figure 8 shows a simplified model with the three operating functions shown for a thermal magnetic circuit breaker, which is the most commonly used circuit breaker. Also, it should be noted that there are various contact mechanism designs that can significantly affect the interruption process.

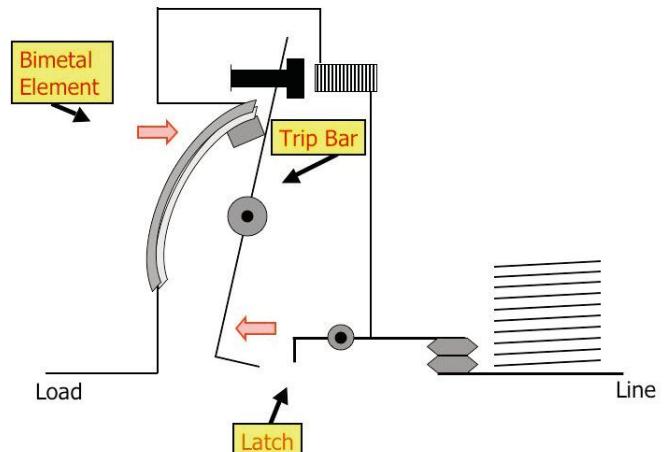


Simple Model of Thermal Magnetic Circuit Breaker

Figure 8

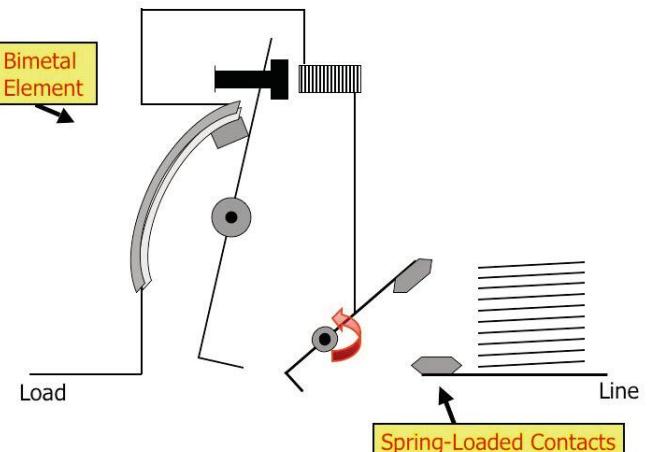
Circuit Breaker Overload Operation

Figures 9 and 10 illustrate circuit breaker operation by a thermal bimetal element sensing a persistent overload. The bimetal element senses overload conditions. In some circuit breakers, the overload sensing function is performed by electronic means. In either case, the unlatching and interruption process is the same. Figure 9 illustrates that as the overload persists, the bimetal element bends. If the overload persists for too long, the force exerted by the bimetal sensor on the trip bar becomes sufficient to unlatch the circuit breaker. Figure 10 shows that once a circuit breaker is unlatched, it is on its way to opening. The spring-loaded contacts separate and the overload is cleared. There can be some arcing as the contacts open, but the arcing is not as prominent as when a short-circuit current is interrupted.



Overload causes bi-metal to unlatch mechanism

Figure 9



Once unlatched, circuit breaker opens

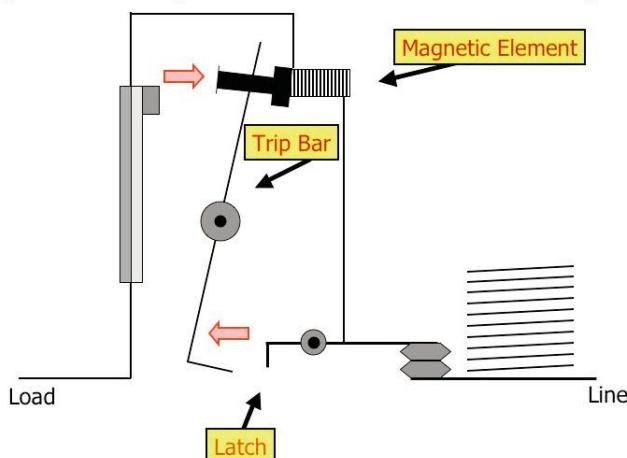
Figure 10

Circuit Breakers

Circuit Breaker Instantaneous Trip Operation

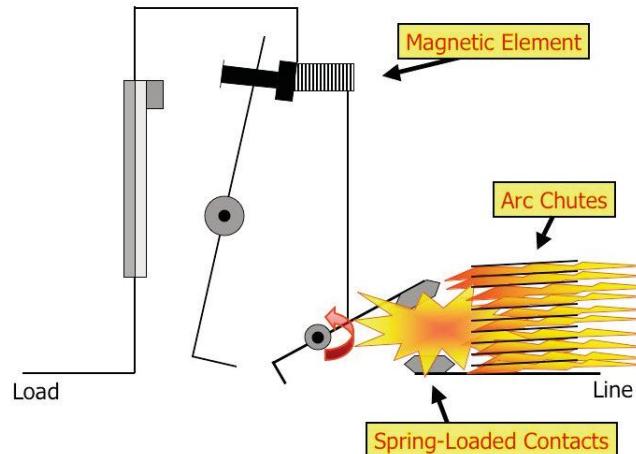
Figures 11, 12 and 13 illustrate circuit breaker instantaneous trip operation due to a short-circuit current. The magnetic element senses higher level overcurrent conditions. This element is often referred to as the instantaneous trip, which means the circuit breaker is opening without intentional delay. In some circuit breakers, the instantaneous trip sensing is performed by electronic means. In either case, the unlatching and interruption process is the same as illustrated in Figures 12 and 13. Figure 11 illustrates the high rate of change of current due to a short-circuit causing the trip bar to be pulled toward the magnetic element. If the fault current is high enough, the strong force causes the trip bar to exert enough force to unlatch the circuit breaker. This is a rapid event and is referred to as instantaneous trip.

Figure 12 shows that once unlatched, the contacts are permitted to start to part. It is important to understand that once a circuit breaker is unlatched it will open. However, the current interruption does not commence until the contacts start to part. As the contacts start to part, the current continues to flow through the air (arcing current) between the stationary contact and the movable contact. At some point, the arc is thrown to the arc chute, which stretches and cools the arc. The speed of opening the contacts depends on the circuit breaker design. The total time of the current interruption for circuit breaker instantaneous tripping is dependent on the specific design and condition of the mechanisms. Smaller amp rated circuit breakers may clear in as little as $\frac{1}{2}$ cycle or less. Larger amp rated circuit breakers may clear in a range typically from 1 to 3 cycles, depending on the design. Circuit breakers that are *listed and marked* as current-limiting can interrupt in $\frac{1}{2}$ cycle or less when the fault current is in the circuit breaker's current-limiting range. With the assistance of the arc chute, as well as the alternating current running its normal course of crossing zero, and the contacts traveling a sufficient distance, the fault current is interrupted (see Figure 13). Energy is released in the contact interruption path and via the arc chutes during the current interruption process. As a consequence, circuit breakers are designed to have specific interrupting ratings at specific voltage ratings. For instance, a circuit breaker may have a 14,000A IR at 480Vac and 25,000A IR at 240Vac.



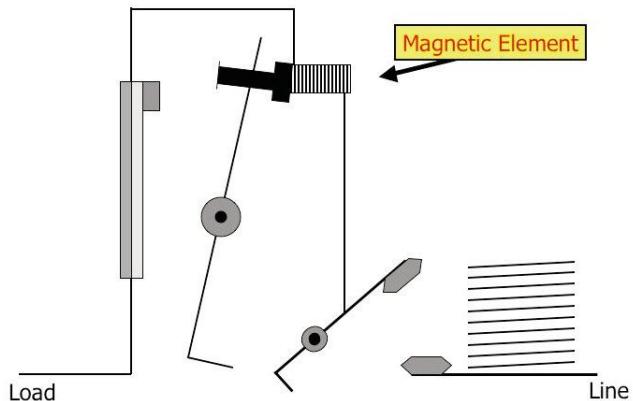
Magnetic sensor responds to short-circuit current unlatching CB

Figure 11



Once unlatched, circuit breaker starts to open creating arcing

Figure 12



As contacts part and arcing extinguished, circuit interrupted

Figure 13

Circuit Breakers

Circuit Breaker Curves

When using molded case circuit breakers of this type, there are three basic curve considerations that must be understood (see Figure 14). These are:

1. Overload region
2. Instantaneous region with unlatching
3. Interrupting rating

1. Overload Region: overloads typically can be tolerated by the circuit components for relatively longer times than faults and therefore, the opening times are in the range of seconds and minutes. As can be seen, the overload region has a tolerance band, which means the breaker should open within that area for a particular overload current.

2. Instantaneous Region: the circuit breaker will open as quickly as possible. The instantaneous trip (IT) setting indicates the multiple of the full load rating at which the circuit breaker starts to operate in its instantaneous region. Circuit breakers with instantaneous trips either have (1) fixed instantaneous trip settings or (2) adjustable instantaneous trip settings. The instantaneous region is represented in Figure 14, and for this example, is shown to be adjustable from 5x to 10x the breaker amp rating. When the breaker senses an overcurrent in the instantaneous region, it releases the latch which holds the contacts closed (unlatches). Unlatching permits the contact parting process to start.

The unlatching time is represented by the curve labeled "average unlatching times for instantaneous tripping" (this is the continuation of the instantaneous trip curve below 0.01 second). This is important when evaluating coordination of line side breakers to load side breakers. The manufacturer of the circuit breaker in Figure 14 also published a table of unlatching times for various currents (upper right). Unlatching frees or releases the spring loaded contacts to start the process of parting. After unlatching, the overcurrent is not cleared until the breaker contacts are mechanically separated and the arc is extinguished (represented in Figure 14 as the maximum interrupting time). Consequently, there is a range of time from unlatching to interruption as is indicated by the band between the unlatching time curve and the maximum interrupting time curve. This range of time affects the ability of circuit breakers with instantaneous trips to selectively coordinate when the overcurrent magnitude is in the instantaneous trip range. Two instantaneous trip settings for a 400A breaker are shown in Figure 14. The instantaneous trip region, drawn with the solid line, represents an IT = 5x, or five times 400A = 2000A. At this setting, the circuit breaker will trip instantaneously on currents of approximately 2000A or more. The $\pm 25\%$ band represents the area in which it is uncertain whether the overload trip or the instantaneous trip will operate to clear the overcurrent. The dashed portion represents the same 400A breaker with an IT = 10x, or 10 times 400A = 4000A. At this setting the overload trip will operate up to approximately 4000 amps ($\pm 10\%$). Overcurrents greater than 4000A ($\pm 10\%$) would be sensed by the instantaneous setting. The $\pm 25\%$ and $\pm 10\%$ band mentioned in this paragraph represents a tolerance. This tolerance can vary by circuit breaker manufacturer and type.

Many of the lower amp rated circuit breakers (100A and 150A frame CBs) have non-adjustable or fixed instantaneous trip settings. For larger molded case, insulated case and power breakers the instantaneous trip setting can usually be adjusted by an external dial.

The IT of a circuit breaker is typically set at its lowest setting when shipped from the factory. Note that most published circuit breaker time-current curves show the vertical time axis from 0.01 second up to about 100 or 1000 seconds. The published curves do not normally provide the instantaneous unlatching characteristic. However, if a circuit breaker has an instantaneous trip, it has unlatching times usually less than 0.01 second.

Some circuit breakers have short time-delay trip settings (STD). These will be discussed later in this section. The short time-delay trip option can be used in conjunction with (1) an instantaneous trip settings or (2) without instantaneous trip settings. Typically, molded case circuit breakers and insulated case circuit breakers that have short time-delay settings have an instantaneous trip override. This means at some fault current level, the instantaneous trip operates to protect the circuit breaker. Low voltage power circuit breakers can be specified with a short time-delay setting which does not inherently incorporate an instantaneous trip override.

Typical Circuit Breaker Time-Current Characteristic Curve

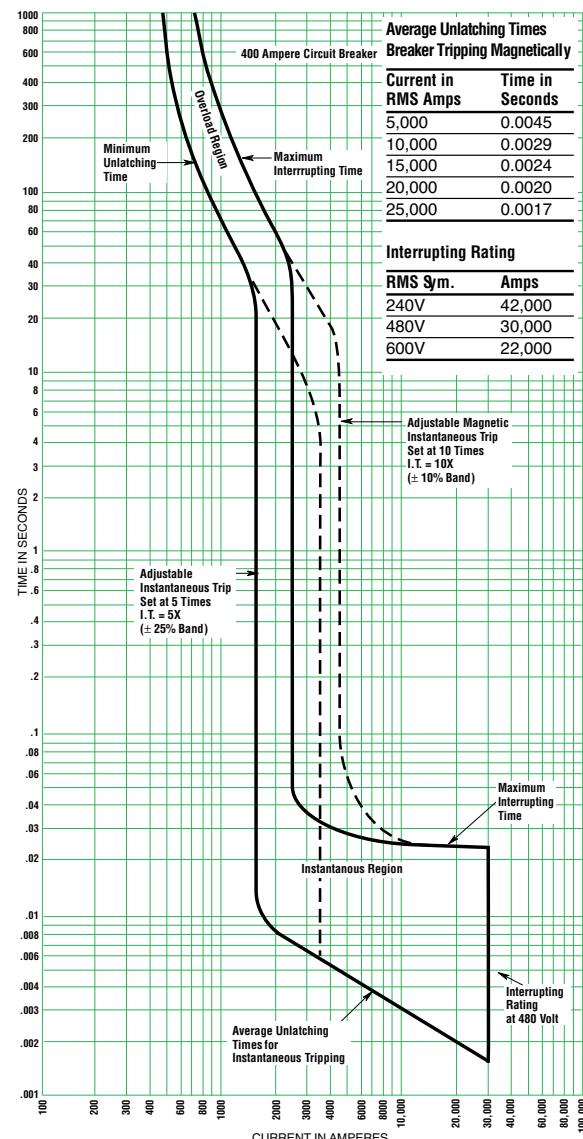


Figure 14

Circuit Breakers

Interrupting Rating: The interrupting rating is represented on the drawing by a vertical line at the right end of the curve. The interrupting rating for circuit breakers varies based on the voltage level; see the interrupting rating table in Figure 14 which lists the interrupting ratings for this specific circuit breaker. For coordination purposes, the vertical line is often drawn at the fault current level in lieu of the interrupting rating (if the interrupting rating is greater than the available short-circuit current). However, if the fault current is above the interrupting rating, a misapplication and violation of NEC® 110.9 is evident. In Figure 14, the circuit breaker interrupting rating at 480 volts is 30,000 amps.

Achieving Selective Coordination with Low Voltage Circuit Breakers

To achieve selective coordination with low voltage circuit breakers, the general rule is that no overlap of time-current curves (including the unlatching time) is permitted up to the available short-circuit current. The ability of circuit breakers to achieve coordination depends upon the type of circuit breakers selected; amp ratings, settings and options of the circuit breakers, and the available short-circuit currents. The type of circuit breaker selected could be one of three types: circuit breakers with instantaneous trips; circuit breakers with short time-delay but incorporating instantaneous overrides; or circuit breakers with short time-delays (no instantaneous override). In this section, various alternative circuit breaker schemes will be discussed in relation to assessing for selective coordination.

Two Instantaneous Trip Circuit Breakers

Figure 15 illustrates a 90 amp circuit breaker and an upstream 400 amp circuit breaker having an instantaneous trip setting of 5x (5 times 400A = 2000A). The minimum instantaneous trip current for the 400A circuit breaker could be as low as 2000A times 0.75 = 1500A ($\pm 25\%$ band). If a fault above 1500 amps occurs on the loadside of the 90 amp breaker, both breakers could open. The 90 amp breaker may unlatch before the 400 amp breaker. However, before the 90 amp breaker can part its contacts and clear the fault current, the 400 amp breaker could have unlatched and started the irreversible contact parting process.

Assume a 4000A short-circuit exists on the loadside of the 90A circuit breaker. The sequence of events would be as follows:

1. The 90A breaker will unlatch (Point A) and free the breaker mechanism to start the contact parting process.
2. The 400A breaker will unlatch (Point B) and it, too, would begin the contact parting process. Once a breaker unlatches, it will open. At the unlatching point, the process is irreversible. It is similar to pulling a trigger on a gun.
3. At Point C, the 90A breaker will have completely interrupted the fault current.
4. At Point D, the 400A breaker also will have opened, which unnecessarily disrupts power to all other loads.

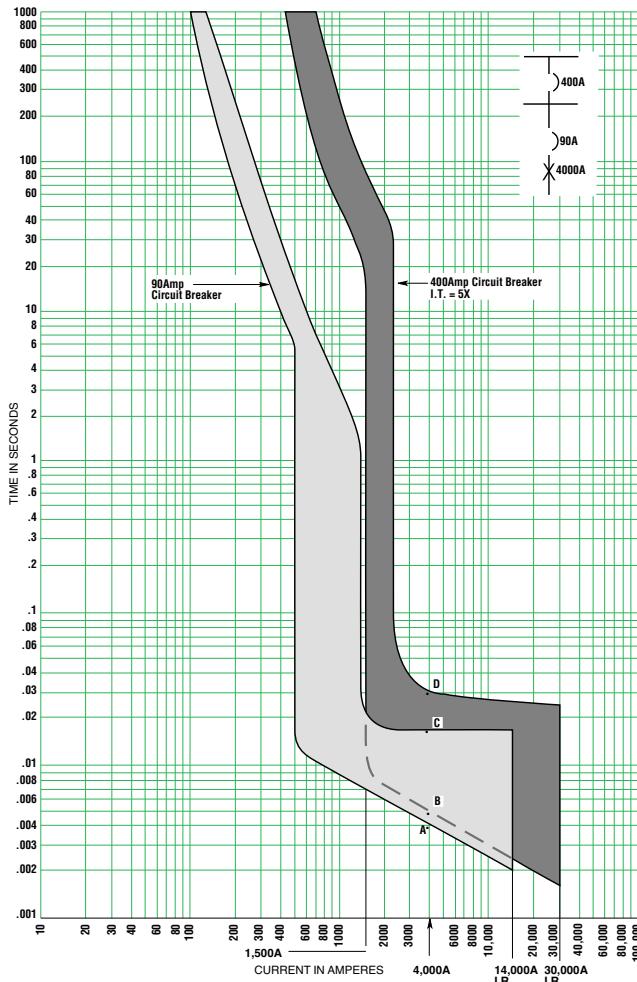


Figure 15

These two specific circuit breakers with the settings as stated are coordinated for any overcurrent up to approximately 1500A. However, this is a non-selective system where fault currents are above 1,500 amps,* causing a blackout to all the loads fed by the 400 amp breaker. As mentioned previously, this is typical for molded case circuit breakers due to the instantaneous trip and band of operation on medium to high fault conditions. In addition, this can affect other larger upstream circuit breakers depending upon the size and the instantaneous setting of the circuit breakers upstream and the magnitude of the fault current.

*Circuit breaker manufacturers provide Coordination Tables which show circuit breakers of specific types and amperage ratings coordinating to fault values greater than the crossing point where two circuit breaker time-current curves intersect.

Circuit Breakers

The norm in the industry is to display circuit breaker curves for times from 0.01 second to about 100 or 1000 seconds. So typically the circuit breaker curves are not shown with the unlatching curves as in Figure 15. The following Figure 16 illustrates a 400A (IT = 7x) circuit breaker feeding a 100A circuit breaker. However, this curve, which is the industry norm, does not show the circuit breaker characteristics below 0.01 second. For coordination analysis, the interpretation of this curve is that these two circuit breakers are coordinated for overcurrents less than approximately 2100A (arrow on Figure 16). For overcurrents greater than 2100A, these two circuit breakers, with these settings, would not be considered coordinated.

The following is an excerpt from IEEE 1015-2006 "Blue Book" *Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems*, page 145 5.5.3 Series MCCBs:

"Selective coordination is limited to currents below the instantaneous pickup of the lineside circuit breaker. For any fault downstream of the loadside MCCB having a current greater than the instantaneous pickup of the lineside MCCB, both circuit breakers trip, and power is interrupted to unfaulted circuits fed by the lineside circuit breaker."

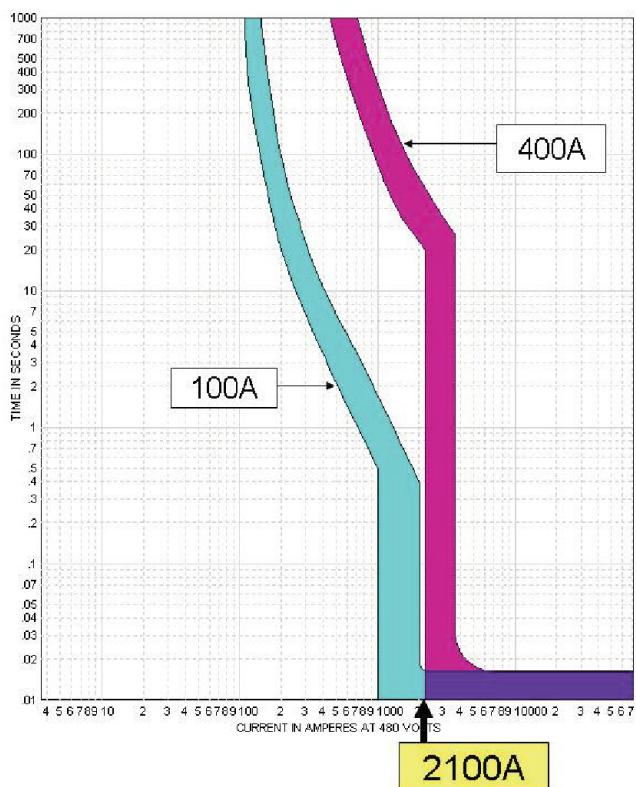


Figure 16

Interpreting Circuit Breaker Curves for Selective Coordination

Figure 17 is the one-line diagram that will be used for the next couple of examples. It has three molded case circuit breakers in series: 1200A main, 400A feeder with the 100A branch circuit. The other circuit breakers on the one-line diagram supply other circuits and loads. The fault current path from the power source is depicted by the red arrows/lines on the one-line diagram. For the coordination analysis, faults on both the branch circuit and feeder must be analyzed.

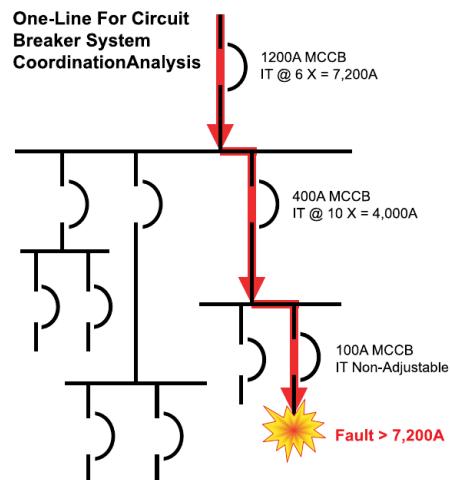


Figure 17

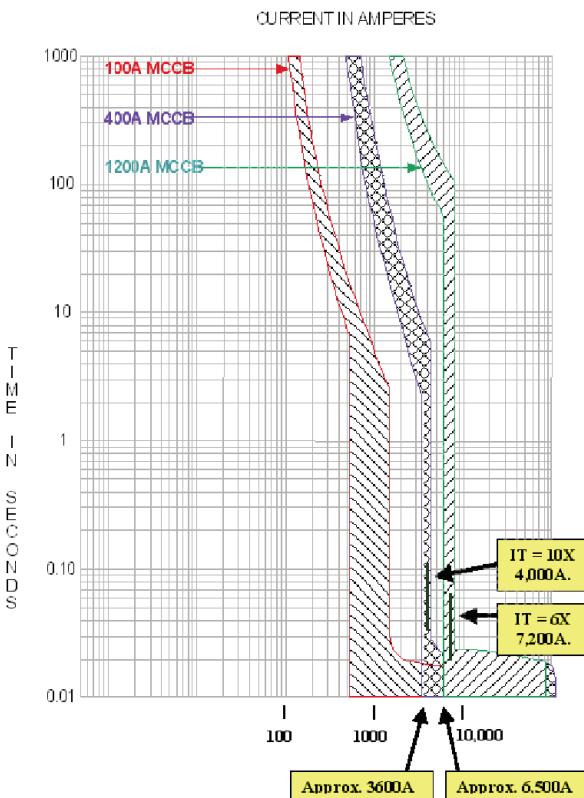


Figure 18

When the curves of two circuit breakers cross over in their instantaneous trip region, then the drawing indicates that the two circuit breakers do not coordinate for fault currents greater than this cross over point.

For instance, interpreting the curves for the 100A circuit breaker and the 400A circuit breaker. Their curves intersect in the instantaneous region starting at approximately 3600A. The 1200A circuit breaker curve intersects the 100A and 400A circuit breaker curves at approximately 6500A.

Circuit Breakers

Analysis for branch circuit fault:

For a branch circuit fault current less than 3600A on the loadside of the 100A circuit breaker, the 400A and 1200A circuit breakers will be coordinated with the 100A circuit breaker. If the fault current is greater than 3600A, then the 400A feeder circuit breaker may unnecessarily open and there is a lack of coordination.

If the branch circuit fault is greater than 6500A, then the 1200A main circuit breaker may unnecessarily open, which is a lack of coordination between the 100A, 400A and 1200A circuit breakers. The reason is, for a fault of greater than 6500A, all three of these circuit breakers are in their instantaneous trip region. Both the 400A and 1200A circuit breakers can unlatch before the 100A circuit breaker clears the fault current.

Analysis for feeder circuit fault:

For any feeder fault less than 6500 amps on the loadside of the 400A circuit breaker, the 400A and 1200A circuit breakers will be coordinated. For feeder faults greater than 6500A, the 1200A circuit breaker is not coordinated with the 400A feeder circuit breaker.

Conclusion for Figures 17 and 18 coordination analysis:

If the maximum available short-circuit current at the 100A branch circuit is less than 3600A and the maximum available short-circuit current at the 400A feeder circuit is less than 6500A, then the circuit path (100A, 400A, and 1200A) is selectively coordinated. If the maximum available short-circuit current exceeds either of these values, the circuit path is not selectively coordinated.

How does this affect the electrical system? Look at the one-line diagram in Figure 19. For any fault current greater than approximately 6500A on the loadside of the 100A circuit breaker, the 1200A and 400A circuit breakers open as well as the 100A circuit breaker. The yellow shading indicates that all three circuit breakers open - branch circuit, feeder and main. In addition, all the loads fed by the other circuit breakers, denoted by the hash shading, are blacked out unnecessarily. This is due to the lack of coordination between the 100A, 400A and 1200A circuit breakers.

How does this affect the electrical system? Look at the one-line diagram in Figure 19. For any fault current greater than approximately 6500A on the loadside of the 100A circuit breaker, the 1200A and 400A circuit breakers open as well as the 100A circuit breaker. The yellow shading indicates that all three circuit breakers open - branch circuit, feeder and main. In addition, all the loads fed by the other circuit breakers, denoted by the hash shading, are blacked out unnecessarily. This is due to the lack of coordination between the 100A, 400A and 1200A circuit breakers.

**Lack of Coordination
Takes Out Other Loads**

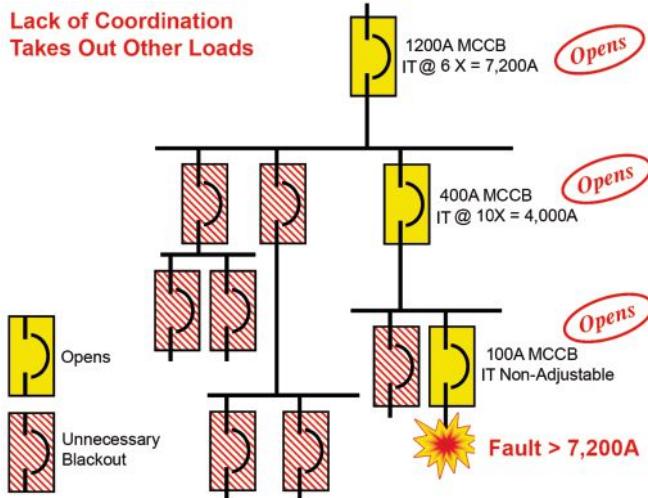


Figure 19

Circuit Breakers

CB Coordination:

Simplified Method Without Time-Current Curves

It is not necessary to draw the curves to assess circuit breaker coordination when the circuit breakers are of the instantaneous trip type. There is a simple method to determine the highest short-circuit current or short-circuit amps (I_{SCA}) at which circuit breakers will coordinate. Simply multiply the instantaneous trip setting by the circuit breaker amp rating. The product of a circuit breaker's instantaneous trip setting and its amp rating is the approximate point at which a circuit breaker enters its instantaneous trip region. This method is applicable to the instantaneous trip only, not the overload region. However, in most cases, the circuit breaker overload regions will coordinate, if they coordinate in the short-circuit current region. This simple method can be used as a first test in assessing if a system is selectively coordinated. There may be other means to determine higher values of I_{SCA} where circuit breakers coordinate (such as manufacturer's tables), but this is a practical, easy method.

As explained previously, there is a tolerance where the instantaneous trip initially picks up. A vertical band depicts the instantaneous trip pickup tolerance. The following will illustrate this simple method ignoring the tolerances. Then the simple method with the tolerances will be illustrated.

Ignoring the Tolerances

For this first example of the easy method, we will ignore the instantaneous trip pickup tolerance band. However, the fault values where the circuit breakers are selectively coordinated will differ from the same example when using the curves in the previous section.

Using the simple method for the example in Figure 17, the 400A circuit breaker has its instantaneous trip (IT) set at 10 times its amp rating (10x). Therefore for fault currents above $10 \times 400A = 4000$ amps, the 400A circuit breaker will unlatch in its instantaneous trip region, thereby opening. The same could be determined for the 1200A circuit breaker, which has its instantaneous trip set at 6x its amp rating. Therefore, for fault currents above 7200 amps ($6 \times 1200 = 7200$ A), the 1200A circuit breaker unlatches in its instantaneous trip region, thereby opening.

The coordination analysis of the circuit breakers merely requires knowing what the numbers mean.

Analysis for branch circuit faults:

In Figure 17, for a branch circuit fault less than 4000A on the loadside of the 100A circuit breaker, the 400A and 1200A circuit breakers will be coordinated with the 100A circuit breaker. If the fault current is greater than 4000A, then the 400A feeder circuit breaker unnecessarily opens and there is a lack of coordination.

If the branch circuit fault is greater than 7200A, then the 1200A main circuit breaker may unnecessarily open, which is a lack of coordination between the 100A, 400A and 1200A circuit breakers. The reason is: for a fault of greater than 7200A, all three of these circuit breakers are in their instantaneous trip region. Both the 400A and 1200A circuit breakers can unlatch before the 100A circuit breaker clears the fault current.

For faults on the loadside of the 400A circuit breaker:

For any feeder fault less than 7200 amps on the loadside of the 400A circuit breaker, the 400A and 1200A circuit breakers will be coordinated. For feeder faults greater than 7200A, the 1200A circuit breaker is not coordinated with the 400A feeder circuit breaker.

General note: Many 100A and 150A frame circuit breakers have fixed instantaneous trips which are not adjustable. For these circuit breakers the fixed instantaneous trip will typically "pickup" between 800 to 1300 amps. For adjustable circuit breakers, the instantaneous trip adjustment range can vary depending upon frame size, manufacturer and type.

Typically adjustable settings of 4 to 10 times the amp rating are available (check manufacturers' data for specific circuit breakers). Circuit breakers are generally shipped from the factory at the lowest adjustable instantaneous trip setting. This setting should not be changed without a detailed analysis of how it will affect the overall electrical system protection, coordination and personnel safety.

With the Tolerances

This second example of the easy method will include the instantaneous trip pickup tolerance band. This is a more accurate determination. The tolerance is \pm . However, for this simple method, it is only necessary to consider the negative tolerance.

Information needed for each feeder and main circuit breaker (CB):

1. CB's amp rating or amp setting
2. CB's instantaneous trip setting (IT)
 - Most feeder and main CBs have adjustable IT settings with varying ranges from 3 to 12X
 - Some CBs have fixed IT settings
 - Some newer feeder CBs have fixed IT set at 20X
3. CB's IT pickup percentage (%) tolerance
4. If CB IT pickup % tolerance is not known, here are some worst case* practical rules of thumb:
 - Thermal magnetic (high trip setting): $\pm 20\%$
 - Thermal magnetic (low trip setting): $\pm 25\%$
 - Electronic trip: $\pm 10\%$

* Based on numerous samples taken from leading CB manufacturers' data.

Equation:

$$I_{SCA} \text{ Coordination} < (\text{CB amp rating} \times \text{IT setting}) \times \left(1 - \frac{\% \text{ tolerance}^{**}}{100}\right)$$

I_{SCA} Coordination is the maximum short-circuit overcurrent at which the circuit breaker will coordinate with downstream circuit breakers.

** Use actual CB % tolerance, otherwise use assumed worst case % tolerances

Circuit Breakers

Example 1: See the one-line in Figure 20

Feeder: 200A Thermal magnetic CB with IT set at 10x and $\pm 20\%$ IT pickup tolerance

Main: 800A Electronic trip CB with IT set at 10X and $\pm 10\%$ IT pickup tolerance

Calculations:

Feeder: 200A CB with IT set at 10x and $\pm 20\%$ IT pickup tolerance

$$I_{SCA} \text{ Coordination} < (200 \times 10) \times (1 - \frac{20\%}{100})$$

$$I_{SCA} \text{ Coordination} < (2000) \times (1 - 0.20) = 2000A \times 0.8$$

$$I_{SCA} \text{ Coordination} < 1600A \text{ see Figure 22}$$

Result: For overcurrents less than 1600A, the 200A CB will coordinate with the downstream CBs in the instantaneous region. For overcurrents 1600A or greater, the 200A CB will not coordinate with downstream circuit breakers.

Main: 800A CB with IT set at 10x and $\pm 10\%$ IT pickup tolerance

$$I_{SCA} \text{ Coordination} < (800 \times 10) \times (1 - \frac{10\%}{100})$$

$$I_{SCA} \text{ Coordination} < (8000) \times (1 - 0.10) = 8000A \times 0.9$$

$$I_{SCA} \text{ Coordination} < 7200A \text{ see Figure 20}$$

Result: For overcurrents less than 7200A, the 800A CB will coordinate with the downstream CBs in the instantaneous region. For overcurrents 7200A or greater, the 800A CB will not coordinate with downstream circuit breakers.

Figure 20 shows the time-current curves of this example. This example illustrates that when assessing selective coordination for circuit breakers with instantaneous trips, it is not necessary to plot the time-current curves.

Example 2:

The following is another example for the one-line diagram in Figure 23. Using this simple method the values are easy to calculate and are shown in the following table. Once you know the equation, you can do the simple math and complete the table. It is not necessary to draw the curves, However, the curves are shown in Figure 21.

CB Amp Rating	IT Setting	Tolerance	Coordinates Up to I_{SCA}
1000	6x	$\pm 10\%$	5,400A
400	10x	$\pm 20\%$	3,200A
100	-		NA

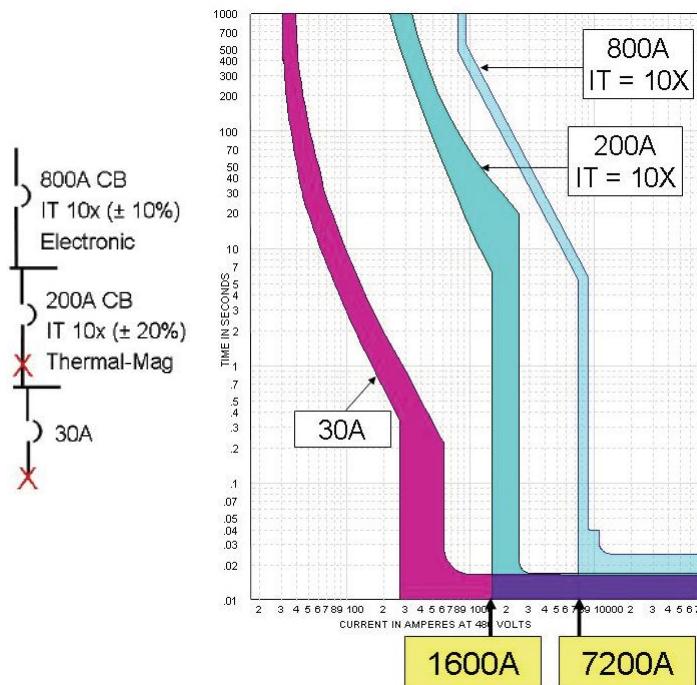


Figure 20

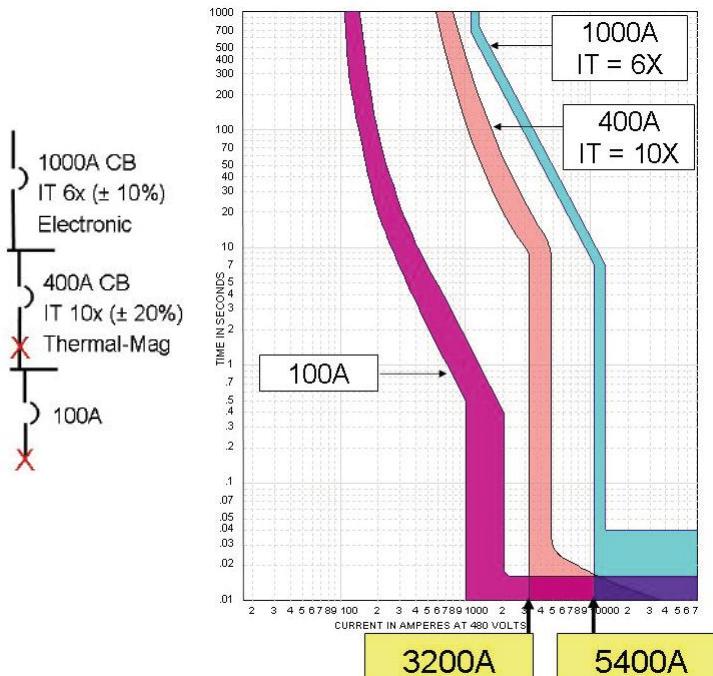


Figure 21

Circuit Breakers

Circuit Breaker Coordination Tables

With selective coordination requirements more prevalent in the NEC®, in recent years many circuit breaker manufacturers are publishing circuit breaker-to-circuit breaker coordination tables based on testing. These tables are for circuit breakers with instantaneous trips. The tables typically have a format of a lineside circuit breaker feeding a loadside circuit breaker and the values are maximum available short-circuit currents for which the circuit breakers coordinate. If these tables are used, be sure to understand the parameters of the testing and the specifics on the circuit breaker settings. Figure 22 shows the benefit of the table values versus interpreting the curves for the 200A circuit breaker coordinating with a 30A circuit breaker. Interpreting the curves shows the 200A circuit breaker coordinates with the 30A circuit breaker up to 1500A. The coordination table published by the manufacturer of these specific circuit breakers shows that they coordinate up to 2700A.

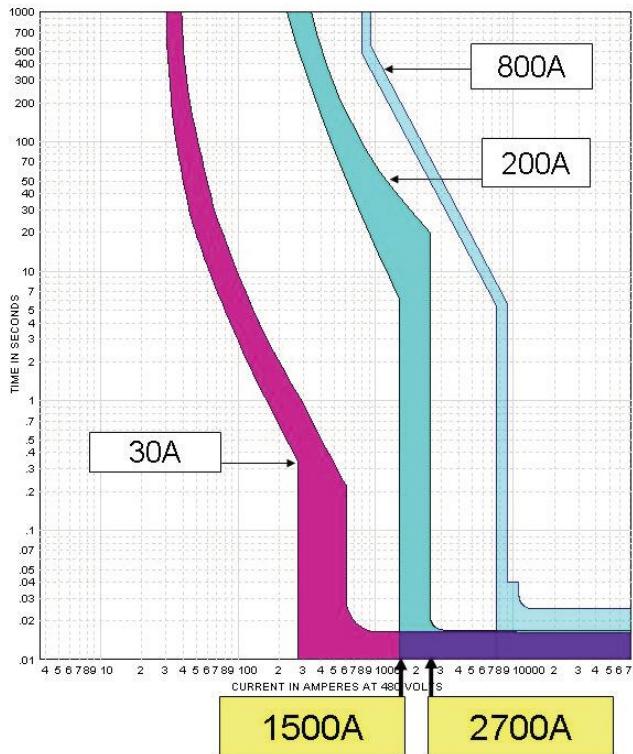


Figure 22

Fixed High Magnetic Circuit Breakers

In recent years fixed high magnetic circuit breakers have been introduced with the intent to provide more flexibility in achieving coordination. Figure 23 illustrates a 200A fixed high magnetic trip circuit breaker. By interpreting the curves, a normal 200A circuit breaker would coordinate with the 30 amp branch circuit breaker up to 1500A. This feeder 200A fixed high magnetic trip circuit breaker coordinates with the 30A branch circuit breaker up to 3200A. This allows molded case circuit breakers to coordinate on circuits with higher available short-circuit currents.

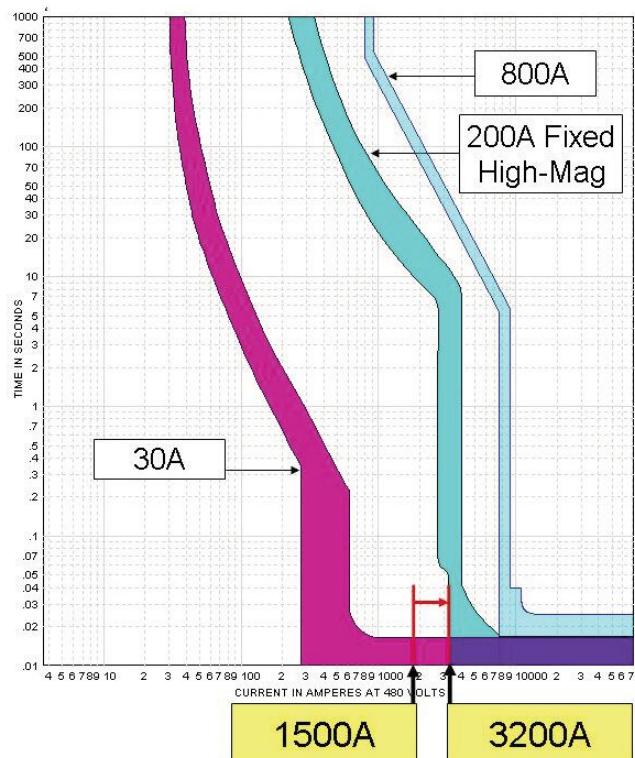


Figure 23

Circuit Breakers with Short Time-Delay and Instantaneous Override

Some electronic trip molded case circuit breakers (MCCB) and most insulated case circuit breakers (ICCB) offer short time-delay (STD) features. This allows a circuit breaker the ability to delay tripping on fault currents for a period of time, typically 6 to 30 cycles. However, with electronic trip molded case circuit breakers and insulated case circuit breakers with short time-delay setting (STD), an instantaneous trip override mechanism is typically built in to protect the circuit breaker. This instantaneous override function will override the STD for medium- to high-level faults. The instantaneous override for these devices is typically 8 to 12 times the rating of the circuit breaker and will "kick in" for faults equal to or greater than the override setting (factory set and not adjustable). Thus, while short time-delay in molded case and insulated case circuit breakers can improve coordination in the low-level fault regions, it may not be able to assure coordination for medium- and high-level fault conditions. This can be seen in Figure 24; the 800A MCCB has a STD with an IT override (activates at 8 times for this manufacturer's circuit breaker) and coordinates with the 100A downstream circuit breaker up to 6400A. As the overlap suggests, for any fault condition greater than 6400A these two circuit breakers are not coordinated: both devices may open. Because of this instantaneous override, nonselective tripping can exist above 6400A.

Circuit Breakers

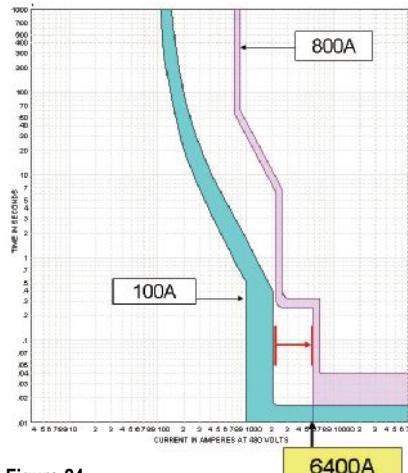


Figure 24

Low Voltage Power Circuit Breakers (LVPCB) with Short Time-Delay

Short time-delay, with settings from 6 to 30 cycles, is also available on low voltage power circuit breakers. However, with low voltage power circuit breakers an instantaneous override is not required. Thus, low voltage power circuit breakers with short time-delay may "hold on" to faults for up to 30 cycles. Figure 25 illustrates a 30A molded case circuit breaker fed by a 200A LVPCB and 800A LVPCB. The 200A and 800A circuit breakers have short time settings that provide selective coordination. The 200A circuit breaker has a STD set at 6 cycles and the 800A circuit breaker has a STD set at 20 cycles. The curves can be plotted to ensure the circuit breakers do not intersect at any point. If there is intersection, investigate different short time-delay settings. The interrupting ratings for the circuit breakers with short time-delay may be less than the same circuit breaker with an instantaneous trip.

The short time-delay that is often added to feeder and main circuit breakers, to achieve selective coordination, can have negative affects on the arc flash energy to which a worker could be exposed in an unfortunate incident. As an example, a review of the time-current curves in Figure 42 reveals that the 400 amp feeder circuit breaker will delay or hold without tripping for 12 cycles or 0.2 seconds for any type of short-circuit, whether it be an arcing fault or a bolted fault. Since arc flash energy is proportional to the opening time of the protective device, a delay for 12 cycles would allow approximately 12 times the arc flash energy that would be experienced if the circuit breaker opened in 1 cycle. NEC 240.87 mentions various methods to reduce the arc flash energy. One common method, utilization of zone selective interlocking, is detailed in response D4 to "Objection 2" under Selective Coordination Objections & Misunderstandings. Figures 43 and 44 help explain how zone selective interlocking allows for a circuit breaker to open as quickly as possible for any type of faults, arcing or bolted, within their zone of protection. A less common method, differential relaying, is very similar to zone selective interlocking, in that it allows the circuit breaker feeding the fault to open as quickly as possible. Another common method, utilization of an arc flash reducing maintenance switch, is described in detail in response D1 to "Objection 2" under Selective Coordination Objections & Misunderstandings. It allows the worker to set the circuit breaker to open as quickly as possible if an arc flash should occur while he or she is working on the equipment.

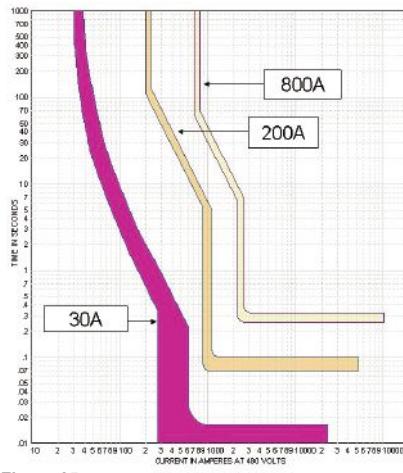


Figure 25

Summary for Circuit Breaker Selective Coordination

It is possible to design electrical systems with circuit breakers and achieve selective coordination. It requires analysis and proper choice of circuit breaker types and options. In most cases it is necessary to calculate the available short-circuit currents at the point of application of each circuit breaker, a coordination analysis (plotting of curves or review of coordination tables) and proper interpretation of the results for each circuit path. Following is a list that provides methods for using circuit breakers to achieve selective coordination, with the least expensive options appearing at the top:

1. MCCBs and ICCBs with instantaneous trip settings
2. Circuit breakers coordinated to manufacturer's tested coordination tables. These tables can enable circuit breakers to coordinate for fault currents higher than shown on the time-current curves.
3. MCCBs with fixed high magnetic trip or larger frame size may allow higher instantaneous trip
4. CBs with short time-delay having instantaneous trip override:
 - MCCBs and ICCBs with short time-delay settings have an instantaneous trip override that opens the CB instantaneously for higher fault currents (8x to 12x amp rating or a fixed setting).
 - ICCBs may have higher instantaneous override settings than MCCBs
5. LVPCBs with short time-delay (with no instantaneous override)

Notes:

- The instantaneous trip or instantaneous override of upstream circuit breakers must be greater than the available short-circuit current for alternatives 1, 3, and 4
- Some options may require larger frame size or different type CBs. In alternatives 1 through 4, if selective coordination can be achieved, it is job or application specific; i.e., the designer must do the analysis for each application or job. If the available short-circuit current increases due to system changes, the selective coordination may no longer be valid. During installation, the contractor must set the circuit breakers correctly.

Fuse & Circuit Breaker Mixture

System with Mixture of Fuses and Circuit Breakers

For downstream fuses and upstream circuit breakers, it is not a simple matter to determine if a fuse and circuit breaker will be selectively coordinated. Even if the plot of the time current curves for a downstream fuse and an upstream circuit breaker show that the curves do not cross, selective coordination may not be possible beyond a certain fault current. The one sure way to determine whether these two devices will coordinate is to test the devices together. The Bussmann Paul P. Cubany Center for High-power Technology is available to perform this testing. Look under Bussmann Services at www.cooperbussmann.com.

Figure 26 shows an example: the curve is a 400A circuit breaker with a downstream 100A fuse. Coordination is shown in the time-current curve up to about 3000A (current axis is 10x). Coordination cannot be ensured above this value without laboratory testing or further technical analysis. This is because the fuse may not clear the fault prior to unlatching of the upstream circuit breaker.

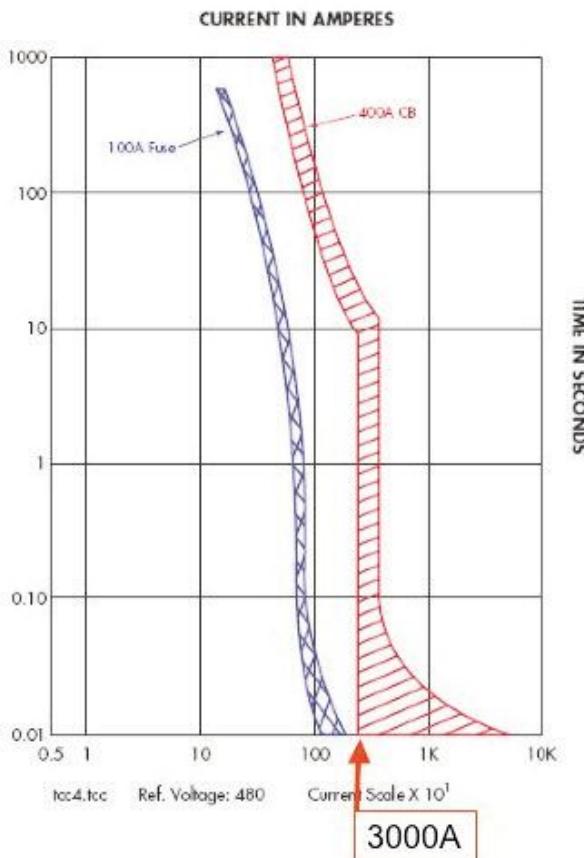


Figure 26

If a fuse is upstream and a circuit breaker is downstream, at some point the fuse time-current characteristic crosses the circuit breaker time-current characteristic. The general rule is that for short-circuit currents at that cross-over point and higher, the upstream fuse is not coordinated with the downstream circuit breaker. Figure 27 shows a 400A fuse with downstream 100A circuit breaker. Coordination is not possible above approximately 5,000 amps as shown in the overlap of the time-current curves (the current axis is 10x).

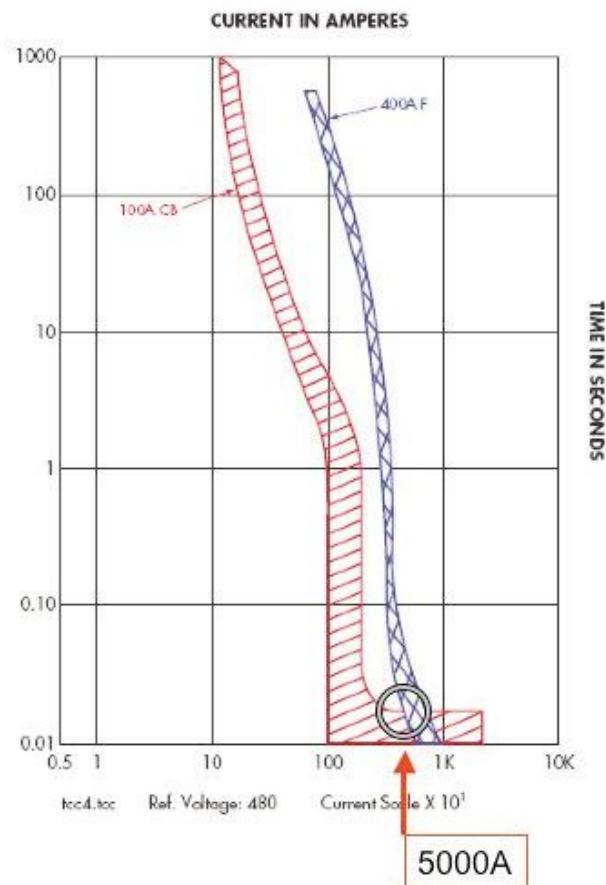


Figure 27

Mandatory Selective Coordination Requirements

Introduction

For building electrical systems, the topic of selective coordination of overcurrent protective devices can be segmented into two areas:

- (1) where it is a desirable design consideration and
- (2) where it is a mandatory NEC® requirement.

In most cases, selective coordination is a desirable design consideration and not a NEC® requirement. However, it is in the best interest of the building owner or tenants to have selectively coordinated overcurrent protection to avoid unnecessary blackouts. Selective coordination should be evaluated in the context of the reliability desired for the power system to deliver power to the loads. In today's modern commercial, institutional and manufacturing building systems, what owner would not want a selectively coordinated system?

Selective coordination is mandatory per the NEC® for a few applications. In some building systems, there are vital loads that are important for life safety, national security or business reasons. Continuity of power to these loads and the reliability of the power supply to these loads is a high priority. The sections of the NEC® defining selective coordination and those requiring the overcurrent protection devices in the circuit paths supplying these vital loads to be selectively coordinated are as follows:

Article 100 Definitions

Coordination (Selective).

Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the selection and installation of overcurrent protective devices and their ratings or settings for the full range of available overcurrents, from overload to the maximum available fault current, and for the full range of overcurrent protective device opening times associated with those overcurrents.

Article 620 Elevators

620.62 Selective Coordination

Where more than one driving machine disconnecting means is supplied by a single feeder, the overcurrent protective devices in each disconnecting means shall be selectively coordinated with any other supply side overcurrent protective devices.

Selective coordination shall be selected by a licensed professional engineer or other qualified person engaged primarily in the design, installation, or maintenance of electrical systems. The selection shall be documented and made available to those authorized to design, install, inspect, maintain, and operate the system.

Article 645 Information Technology Equipment

645.27 Selective Coordination

Critical operations data system(s) overcurrent protective devices shall be selectively coordinated with all supply-side overcurrent protective devices.

Article 695 Fire Pumps

695.3 Power Source(s) for Electric Motor - Driven Fire Pumps.

(C) Multibuilding Campus-Style Complexes. If the sources in 695.3(A) are not practicable and the installation is part of a multibuilding campus-style complex, feeder sources shall be permitted if approved by the authority having jurisdiction and installed in accordance with (C)(1) and (C)(3) or (C)(2) and (C)(3). (C)(3) Selective Coordination. The overcurrent protective device(s) in each disconnecting means shall be selectively coordinated with any other suppl-side overcurrent protective device(s).

Article 700 Emergency Systems

700.10(B)(5)(b), Exception.

Overcurrent protection shall be permitted at the source or for the equipment, provided the overcurrent protection complies with the requirements of 700.28.

700.28 Selective Coordination.

Emergency system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.

Selective coordination shall be selected by a licensed professional engineer or other qualified persons engaged primarily in the design, installation, or maintenance of electrical systems. The selection shall be documented and made available to those authorized to design, install, inspect, maintain, and operate the system.

Exception: Selective coordination shall not be required between two overcurrent protective devices located in series if no loads are connected in parallel with the downstream device.

Article 701 Legally Required Standby Systems

701.27. Selective Coordination.

Legally required standby system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.

Selective coordination shall be selected by a licensed professional engineer or other qualified persons engaged primarily in the design, installation, or maintenance of electrical systems. The selection shall be documented and made available to those authorized to design, install, inspect, maintain, and operate the system.

Exception: Selective coordination shall not be required between two overcurrent protective devices located in series if no loads are connected in parallel with the downstream device.

Article 708 Critical Operations Power Systems

708.54 Selective Coordination

Critical operations power system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.

Selective coordination shall be selected by a licensed professional engineer or other qualified persons engaged primarily in the design, installation, or maintenance of electrical systems. The selection shall be documented and made available to those authorized to design, install, inspect, maintain, and operate the system.

Exception: Selective coordination shall not be required between two overcurrent devices located in series if no loads are connected in parallel with the downstream device.

Selective coordination for elevator applications is covered in a separate section of this publication. The following addresses the selective coordination requirements for emergency, legally required, and critical operations power systems.

Why Selective Coordination is Mandatory

Why Selective Coordination is Mandatory: It Fills the Reliability “Hole”

The NEC® has mandatory selective coordination requirements for the following systems:

- Emergency Systems- Article 700: 700.28
- Legally Required Standby Systems- Article 701: 701.27
- Critical Operations Power Systems- Article 708: 708.54

(In addition, selective coordination is required in elevator circuits (620.62) in certain fire pump applications (695.3(C)(3), critical operations data systems (645.27) and for certain emergency system wiring schemes (700.10(B)(5)(b), which are not discussed in depth in this section.)

Notice these requirements are not in NEC® Chapters 1 through 4, such as Articles 210 Branch Circuits, 215 Feeders, or 240 Overcurrent Protection. Chapters 1 through 4 requirements pertain generally to all premise electrical installations. Instead, these requirements are in Chapters 5 and 7 which are under special occupancies and special conditions, respectively. Special attention is given to these systems in the NEC® and they have some unique requirements. Articles 700, 701, and 708 are for circuits and systems that are intended to deliver reliable power for loads that are vital to life safety, public safety or national security. Reliability for these systems in the above articles has to be greater than the reliability for the normal systems covered by Chapters 1 through 4.

Reviewing portions of the scopes of these Articles provides further insight.

Article 700: Emergency Systems

“700.1 Scope. The provisions of this article apply to the electrical safety of the installation, operation, and maintenance...” The inclusion of operation and maintenance indicates that reliability of these systems is very important. For these systems, installation requirements alone are not sufficient. These systems must operate when needed so this Article includes operational and maintenance requirements. Why? The following statement from the scope is clear: *“Essential for safety of human life.”* For instance, in times of emergency, these loads are critical to evacuate a mass of people from a building.

Article 708: Critical Operations Power Systems (COPS)

“708.1 Scope. IN No. 1: Critical operations power systems are generally installed in vital infrastructure facilities that, if destroyed or incapacitated, would disrupt national security, the economy, public health or safety; and where enhanced electrical infrastructure for continuity of operation has been deemed necessary by governmental authority.” Due to recent events such as 9/11 and Hurricane Katrina, Homeland Security requested that NFPA develop electrical requirements for systems that are vital to the public. Article 708 (COPS) includes requirements, such as selective coordination, that are minimum requirements for electrical systems that are important for national security and public safety.



Articles 700, 701, 708, and 517 are unique. They have more restrictive minimum requirements (versus the general requirements for normal systems) in order for these systems to provide more reliable power to vital loads. Selective coordination is one of the requirements that support higher reliability. To make the point, here are just a few of the more restrictive minimum requirements in Article 700:

- Periodic testing, maintenance and record retention
- Alternate power sources
- Wiring from emergency source to emergency loads shall be separate from all other wiring
- Special fire protection for wiring
- Locating wiring to avoid outage due to physical damage during fires, floods, vandalism, etc.
- Automatic transfer switches (ATS) with sophisticated sensors, monitors and controls
- Separate ATSs and load segmenting (emergency, legally required standby and optional standby) with sophisticated load shedding, if required

Article 708 (COPS) also has a similar list of restrictive requirements with the intent of providing a reliable power system.



Why have these special, more restrictive requirements? The reason these articles for special systems exist is that the electrical industry, the standard making bodies, the technical code panel members and Homeland Security feel special rules are needed to ensure minimum requirements for delivering reliable power for designated vital loads. To better understand why we have more restrictive requirements, focus on the loads that are being served by these special systems. There are a few vital loads that pertain to life safety, public safety and national security. For instance, 700.2 Definitions IN states: *“Emergency systems are generally installed in places of assembly where artificial illumination is required for safe exiting and for panic control in buildings subject to occupancy by large numbers of persons, such as hotels, theaters, sports arenas, healthcare facilities and similar institutions.”*

“Emergency systems may also provide power for such functions as ventilation where essential to maintain life, fire detection and alarm systems, elevators, fire pumps, public safety communications systems, industrial processes where current interruption would produce serious life safety or health hazards, and similar functions.”

The requirements for these systems are intended to increase the system reliability to deliver power and thereby increase the availability of these vital loads during emergencies, disasters and the like.

Why Selective Coordination is Mandatory

Code Making Panels (CMPs) decide whether an item is a requirement or a design consideration. Requirements are in the body of the NEC® under a Chapter, Article and Section. A design consideration or an unenforceable point of interest is a “Information Note” (IN). Prior to the 2011 NEC® IN, were designated as FPN, or Fine Print Notes. Code Making Panels make the decision as to whether an important criterion is worthy either as an informative note, IN or as a NEC® requirement. Until 2005, selective coordination was a note, IN, in Articles 700 and 701. During the 2005 NEC® cycle, Code Making Panel 13 made the decision to convert selective coordination from a Fine Print Note (desirable design consideration) to a Section requirement written in mandatory performance language in order to ensure the outcome the technical panel deemed necessary. The Code Making Panel decided that selective coordination as a FPN was not sufficient. Our society was changing, our culture was changing and our building systems have evolved to a greater dependency on electricity. It was time to make selective coordination a requirement. Their panel statement included: *“The panel agrees that selective coordination of emergency system overcurrent devices with the supply side overcurrent devices will provide for a more reliable emergency system.”*



Let's take a closer look at what may have prompted CMP 13 to change selective coordination from a FPN to a requirement (700.27 now 700.28 and 701.18, now 701.27) during the 2005 NEC® cycle and then for CMP 20 to include selective coordination as a requirement (708.54) for Critical Operations Power Systems in the new Article 708 for 2008 NEC®. The very first requirement in the NEC® is a good place to start. This requirement is the root of every requirement in the NEC®:

“90.1 Purpose. (A) Practical Safeguarding. The purpose of this Code is the practical safeguarding of persons and property from hazards arising from the use of electricity.”

A hazard would exist if power were not supplied to the loads that are vital to assist a mass of people while evacuating a building in an emergency. The NEC® has detailed requirements to address this issue. Selective coordination is one of the requirements that ensure reliability for these special systems. This is one of those examples where the NEC® requirement is putting an emphasis on protecting people, similar to GFCIs.

Let's dig a little deeper into the rationale to make selective coordination a requirement. Until the 2005 NEC®, there was a “hole” in the requirements of Article 700 and 701; a performance issue that reduced the reliability of these systems was not addressed. As already discussed, these Articles have many special requirements that are intended to keep the power flowing to a few vital loads. An emergency system could have redundant power sources, automatic transfer switches with load shedding,

location of wiring to minimize outages from floods, special fire protection provisions, no ground fault protection on the alternate source, testing, maintenance, etc. Yet the whole or part of the system could unnecessarily be left without power because the overcurrent protection was not selectively coordinated. These requirements for high reliability systems had a piece that could negate the intended reliability for these special systems. This had to be fixed. The 2005 NEC® remedied that “hole” by inclusion of the selective coordination requirements for Articles 700 and 701. The substantiation for the original 2005 NEC® proposal for 700.27 provides the reasons. For better understanding, this substantiation is separated into three segments below.

The *Need* is illustrated by the fact that there were already many existing special requirements with the intent of ensuring more reliable emergency power systems:

“This article specifically mandates that the emergency circuits be separated from the normal circuits as shown in [Section] 700.10(B) and that the wiring be specifically located to minimize system hazards as shown in [Section] 700.10(C), all of which reduce the probability of faults, or failures to the system so it will be operational when called upon. With the interaction of this Article for emergency lighting for egress, it is imperative that the lighting system remain operational in an emergency. Failure of one component must not result in a condition where a means of egress will be in total darkness as shown in [Section] 700.16...”

This part of the substantiation identifies the existing “hole” that should be rectified to ensure a more reliable system:

“Selectively coordinated overcurrent protective devices will provide a system that will support all these requirements and principles. With properly selected overcurrent protective devices, a fault in the emergency system will be localized to the overcurrent protective device nearest the fault, allowing the remainder of the system to be functional...”

This part proposes that the solution is to convert from a Fine Print Note design consideration to a requirement:

“Due to the critical nature of the emergency system uptime, selective coordination must be mandated for emergency systems. This can be accomplished by both fuses and circuit breakers based on the system design and the selection of the appropriate overcurrent protective devices.”

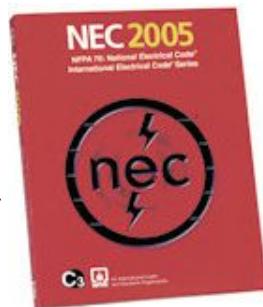
It was not a fuse or circuit breaker issue; since either technology can provide selective coordination. What was needed was the mandate to design the electrical distribution system so that the fuses and circuit breakers would provide selective coordination. Without this as a requirement, electrical distribution systems are designed and installed without regard to how the overcurrent protective devices interact and this can negatively impact the system reliability for delivering power to these vital loads.

The Code Making Panel action was to accept this proposal in principle and in part. The panel deleted the Fine Print Note and rewrote and accepted the following requirement text with a vote of 13 to 1.

700.27 Coordination. *“Emergency system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.”*

It is important to note the panel expressly used the word “all.”

The Code Making Panel 13 statement provides the panel's reasoning: *“The panel agrees that selective coordination of emergency system overcurrent devices with the supply side overcurrent devices will provide for a more reliable emergency system...”* The take away from the panel's action is that selective coordination equals reliability. Acceptance of this requirement plugged the “hole” that had previously existed.



Why Selective Coordination is Mandatory

In the comment stage, this new requirement was challenged but was not overturned. Some people incorrectly characterized this as a circuit breaker versus fuse issue. At the NFPA Annual Meeting, a motion was brought forth to delete this requirement for the 2005 NEC®. The same comments, both pro and con, that were brought up in the proposal and comment stages were discussed. After the discussion, the motion to delete this new requirement failed. So in the 2005 NEC®, selective coordination was required in emergency and legally required standby systems.

The selective coordination requirements expanded in the 2008 NEC®. A new Article 708 Critical Operations Power Systems (COPS) was developed by the newly created Code Making Panel 20 and the message carried through. The COPS scope encompasses electrical systems designated for national security and public safety. Is there a need for these systems to deliver reliable power? Absolutely, there is a need. If there is a need for reliable power, then there is a need for selective coordination. CMP 20 included a requirement for selective coordination in Article 708:

708.54 Selective Coordination *"Critical operations power system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices."*

Also, in the 2008 NEC® cycle, the selective coordination requirements in 700.27 (emergency systems), now 700.28, 701.18 (legally required standby systems), now 701.27, and 620.62 (elevator circuits) were challenged. In the proposal and comment stages, there were plenty of pro and con submittals. All rationale was presented, debated and discussed in this Code cycle. All selective coordination requirements were retained, with 700.27 and 701.18 adding two clarifying exceptions. Neither exception reduced life safety because no additional parts of the electrical system would be shut down unnecessarily.

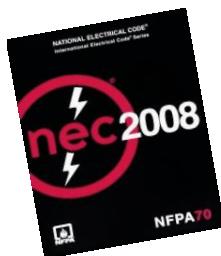


To understand the support for these requirements by the national industry experts on the technical committee, the following is official voting from the 2008 NEC® comment stage:

- Code Making Panel 12 voted unanimously (**11-0**) to retain the requirement for selective coordination in elevator circuits (620.62)
- Code Making Panel 13 voted **11-2** to add exceptions to 700.27 and 701.18 for two devices of the same amp rating in series, and single devices on the primary and secondary of a transformer
- Code Making Panel 20 voted **16-0** (three times) and **15-1** (one time) to reject all attempts to reduce or eliminate this key life safety requirement (708.54)

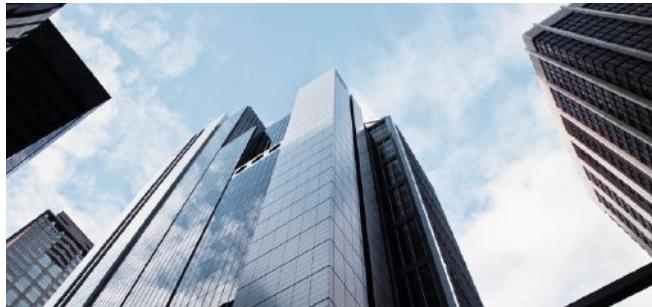
During the 2008 NEC® proposal stage, CMP 13 reaffirmed the selective coordination and communicated several key positions in their statement. In this case, the panel statement clearly communicates the panel action and position. Proposal 13-135 proposed the elimination of the selective coordination requirement for 700.27 and moving the language back to a Fine Print Note. This proposal was rejected 9 to 4.

Panel Statement: *"This proposal removes the selective coordination requirement from the mandatory text and places it in a non-mandatory FPN. The requirement for selective coordination for emergency system overcurrent devices should remain in the mandatory text. Selective coordination increases the reliability of the emergency system. The current wording of the NEC® is adequate. The instantaneous portion of the time-current curve is no less important than the long time portion. Selective coordination is achievable with the equipment available now."*



Special note: some people advocated lessening or diluting the requirement with wording similar to "for times greater than 0.1 second". This would only provide coordination for overloads, would not cover most ground faults or arcing faults, and would definitely not cover high level short-circuit currents. It certainly would reduce the reliability of these power systems. In the 2008 cycle, CMP 13 considered all these type proposals and by their above statement, clearly stated that the selective coordination requirement is for all levels of overcurrent, irrespective of the operating time of an overcurrent device. Similar proposals (13-195) and comments (13-136) were submitted for the 2011 cycle. They were soundly defeated 11-3 and 16-2 respectively.

In the 2014 NEC®, the selective coordination definition was clarified. As revised, it is clear that where the term selective coordination is used within NEC requirements, it is intended to mean full selectivity across the full range of overcurrents possible in the system. That is for overcurrents on a system from light overloads to the available short-circuit currents (bolted fault conditions) and without any restrictions or provisions for overcurrent protective devices opening times.



During the 2008 NEC® comment stage, Code Making Panel 20 reaffirmed the selective coordination requirement based on system reliability. Comment 20-13 proposed the deletion of the 708.54 selective coordination requirement. This comment was rejected 16 to 0.

Panel Statement: *"The overriding theme of Article 585 (renumbered to 708) is to keep the power on for vital loads. Selective coordination is obviously essential for the continuity of service required in critical operations power systems. Selective coordination increases the reliability of the COPS system."*

Inevitably, costs are discussed even though the first requirement in the NEC®, 90.1, tells us the NEC® is concerned about safety, even if not efficient or convenient. For designing and installing selectively coordinated overcurrent protective devices, the cost may not necessarily be greater. That depends on the design. It is important to keep in mind that the requirements in the whole of Articles 700, 701, and 708 result in extra work and cost. An alternate power source with additional electrical distribution gear, automatic transfer switches, sophisticated sensors, monitoring, control and other provisions costs more and takes additional engineering effort. These systems also require extra time and money to test, maintain, and retain records. The extra cost is expected in order to provide more reliability for these special systems compared to normal systems. For mission critical business operations, such as data servers, financial applications and communication industry centers, electrical distribution system design and equipment selection for selective coordination is the norm. No less should be expected for the few important loads that are critical for life safety. If we do it to protect our vital business assets, why can't we do it to protect our people?

New language was added to 620.62, 700.28, 701.27, and 708.54 in the 2014 NEC®.

"Selective coordination shall be selected by a licensed professional engineer or other qualified persons engaged primarily in the design, installation, or maintenance of electrical systems. The selection shall be documented and

Selective Coordination System Considerations

made available to those authorized to design, install, inspect, maintain, and operate the system." This change will help enforcement without burdening the AHJs by (1) requiring competent persons to do the selections necessary to achieve selective coordination as defined by the NEC® and (2) requiring the documentation be submitted that substantiates achieving selective coordination.

Summarizing

Selective coordination for elevator circuits has been a requirement since the 1993 NEC® and the industry has adjusted to compliance. For four NEC® cycles, opposition to the 700.28 and 701.27 requirements has vigorously worked on removing or diluting these selective coordination requirements. However, during this time, the requirements have been reaffirmed and expanded with Article 708 (COPS), 708.54, in the 2008 NEC® with 695.3(C)(3) for certain systems for fire pumps in the 2011 NEC®, and with 645.27 for critical operation data systems in the 2014 NEC®. Now three Code Making Panels have inserted selective coordination requirements in six Articles of the NEC®.

These Articles provide the minimum requirements for these special systems essential for life safety, public safety and national security. We obtain insight as to why selective coordination is a requirement by studying the panel statements. The panel's statements make clear these are special systems where reliability is of utmost importance and selective coordination increases the system reliability to deliver power to these few vital loads.

In our modern buildings, there is a greater dependence on electricity and the NEC® requirements must adjust to this greater dependency and complexity. This is evidenced by Homeland Security approaching NFPA and requesting the NEC® include requirements for Critical Operations Power Systems. The reliability of electrical systems supplying vital loads must be greater than that of the systems supplying power to normal loads. Hence, the reason for having Articles 700, 701, and 708. People's health and safety as well as possibly national security and public safety rely on the power to these vital loads, even under adverse conditions such as fires, earthquakes, hurricanes and man-made catastrophes. Selective coordination of all the overcurrent protective devices for the circuits supplying these loads adds another assurance of reliability: it fills the "hole".



A quote from an October 2007 Electrical Construction & Maintenance magazine article sums it up well. James S. Nasby is engineering director for Master Control Systems, Inc. and was the NEMA representative on Code Panel 13 for the 2005 and 2008 NEC® cycles. *"In response, Nasby asks detractors (of selective coordination requirements) to list the essential emergency systems they'd want to risk going offline. He says it's difficult to calculate risk when it's your family on the top floor of a high-rise hotel. Typically, no building owners will install anymore emergency services than are required, and what is required for that building is important" Nasby says. You don't want to lose lights in the stairwell or the emergency elevators, and you don't want a fault on one of these services to take out anything else... The premise of distribution systems is that a fault on one circuit doesn't propagate upstream – and that's what this is asking for."*

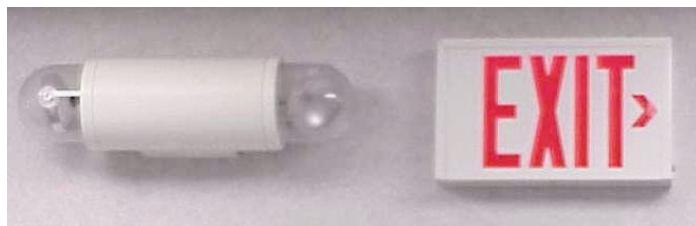
Selective Coordination System Considerations

Classifications, Codes, Standards, and the AHJ

There are various Codes and standards that are applicable for one or more of the various types of systems. Most notable is the National Electrical Code (NEC®). The applicable NEC® Articles are 700 Emergency Systems, 701 Legally Required Standby Systems and 708 Critical Operations Power Systems. The NEC® does not designate which vital loads have to be served by these systems. Typically NFPA 101 (Life Safety Code) provides guidance on the vital loads to be classified as served by emergency and legally required standby systems. Vital loads served by COPS systems are designated by a government authority or an owner may choose to comply. NEC® Article 702 covers Optional Standby Systems.

Vital Load Classifications

Emergency systems are considered in places of assembly where artificial illumination is required, for areas where panic control is needed (such as hotels, theaters, sports arenas) and similar institutions, and where interruption of power to a vital load could cause human injury or death. Emergency loads may include emergency and egress lighting, ventilation and pressurization systems, fire detection and alarm systems, elevators, fire pumps, public safety communications, or industrial process loads where interruption could cause severe safety hazards. For instance, emergency lighting is essential to prevent injury or loss of life during evacuation situations where the normal lighting is lost. NEC® Article 700 provides the electrical systems requirements. 700.28 contains the requirement for selective coordination.



Legally required standby systems are intended to supply power to selected loads in the event of failure of the normal source. Legally required standby systems typically serve loads in heating and refrigeration, communication systems, ventilation and smoke removal systems, sewage disposal, lighting systems and industrial processes where interruption could cause safety hazards. NEC® Article 701 provides the electrical system requirements. 701.27 contains the requirement for selective coordination.

Where hazardous materials are manufactured, processed, dispensed or stored, the loads that may be classified to be supplied by emergency or legally required standby systems include ventilation, treatment systems, temperature control, alarm, detection or other electrically operated systems.

Critical Operations Power Systems (COPS) are systems intended to provide continuity of power to vital operations loads. COPS are intended to be installed in facilities where continuity of operations is important for national security, the economy or public safety. These systems will be classified COPS by government jurisdiction or facility management. The type of loads may be any and all types considered vital to a facility or organization, including data centers and communications centers. NEC® Article 708 provides the requirements. 708.54 contains the requirement for selective coordination.

System Considerations

Optional Power Systems are for supplying loads with backup power, but the loads are not classified as required to be supplied by emergency systems, legally required standby systems or COPS systems. These can supply loads that are not critical for life safety. These may be data center loads, computer facility loads, critical manufacturing process loads or other loads where the building occupant wants backup power. NEC® Article 702 provides the requirements and selective coordination is not mandatory for these circuits. However, many businesses place their mission critical loads on these systems and it is best practice to provide selectively coordinated overcurrent protection for these circuit paths.



Alternate Power Systems

Since availability of power for these loads is so important, these loads are supplied by a normal electrical power source and an alternate electrical power source. These systems typically have transfer switches for the purpose of transferring the source of power feeding the loads from the normal source to the alternate source or vice versa. For the emergency system, legally required standby system and critical operation power system loads, the transfer switch is required to be automatic. For optional power system loads, the transfer switch is permitted to be manually operated. The transfer switches are typically configured so that one or more transfer switches supply only emergency loads and another one or more transfer switches supply only legally required standby loads, and one or more transfer switches supply the optional loads (see Figure 28). The systems are automated such that if normal power on the lineside terminals of a transfer switch is lost for any reason, the alternate source is called into action and a transfer is made to the alternate source supply. If for some reason the alternate power source supply can not meet the connected load demand, the loads are shed in reverse order of their priorities. First the optional standby loads are shed, and then if more shedding is necessary, the legally required standby loads are shed. For instance, in Figure 28, suppose the generator had sufficient capacity to meet the entire load demand of the three load classifications, but when called into action the generator malfunctioned and could only supply a fraction of its rating. If the normal power was lost and the generator output was limited, the system would shed the optional standby loads and if necessary, the legally required standby loads.

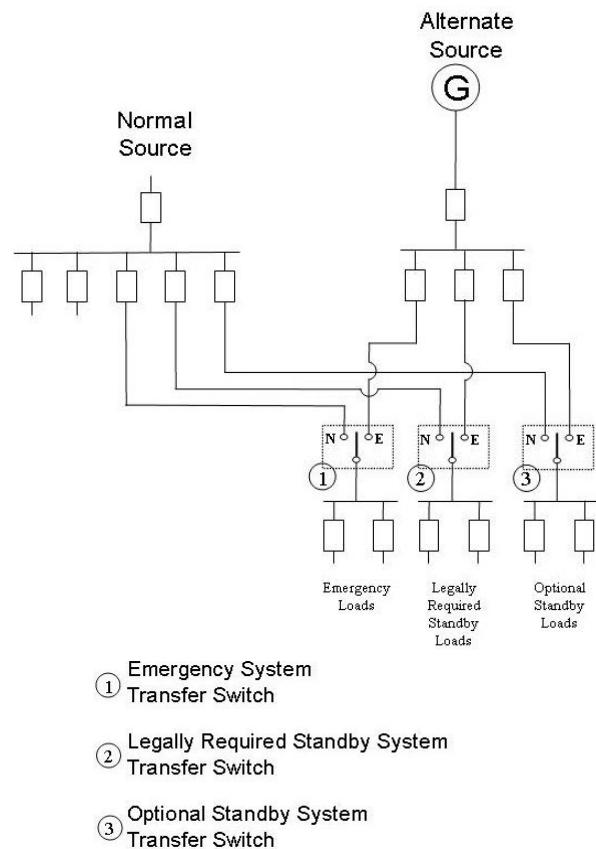


Figure 28

There are numerous types of electrical power sources that can be utilized as the alternative source, such as generators (many fuel types available) and stored energy battery systems. Uninterruptible Power Systems (UPS) are also often used. The selection of the alternate power source type(s) and possibly stored energy/conversion equipment, such as UPS systems, are based on many factors. Two of the most important criteria are:

1. After the normal power is lost, the time required for the alternative power system to commence delivering power to the vital loads.
2. The time duration that the alternative system must continue to deliver power to the vital loads.

In some systems, multiple types of alternative power source equipment are utilized: one type to quickly pick up the load and another type that takes longer to start but can supply electrical power for long time periods. For instance, a natural gas generator may be used in combination with a UPS system (with batteries). If the normal power is lost, a UPS can deliver power very rapidly for a quick transition. A generator takes longer to come on line and is capable of delivering power, (depending on the fuel capacity) for long time periods.

The following table provides the NEC® requirements on the maximum time the systems are permitted to initiate delivering current to the loads. Other Codes and standards may have requirements, also.

System Classification	Maximum Time to Initiate Delivering Current to Loads	NEC® Section
Emergency	Within time required for application, but not to exceed 10 seconds	700.12
Legally Required Standby	Within time required for application but not to exceed 60 seconds	701.12

System Considerations

Normal Path and Alternate Path

Since availability of power for these vital loads is so important, these loads are supplied by a normal electrical power source and an alternate electrical power source. Selective coordination is about the continuance of power to vital loads. These vital loads (supplied by the emergency systems, legally required standby systems, and critical operations power systems) can be powered through the normal source or through the alternate source. Selective coordination is required for both the alternate power circuit path (Figure 29) and normal power circuit path (Figure 30). The requirements state selective coordination is required, "with **all** supply side overcurrent protective devices."

Selective Coordination Includes the Entire Circuit Path, Through Both Sources

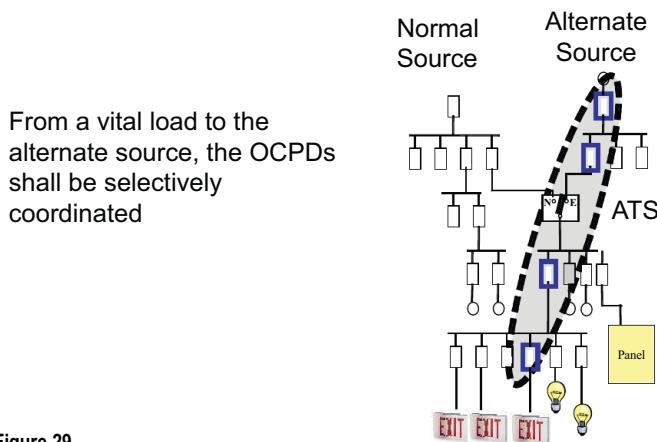


Figure 29

For a vital load to the normal source main, the OCPDs shall be selectively coordinated

"Emergency system(s) overcurrent devices shall be selectively coordinated with **all supply side overcurrent protective devices"**

This wording is inclusive of the normal source path OCPDs

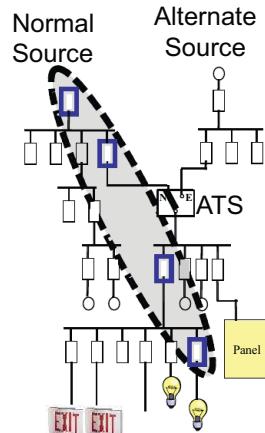


Figure 30

Which OCPDs Have to Be Selectively Coordinated

The Code text for the selective coordination requirements in 700.28 is carefully worded, stating that all emergency OCPDs shall selectively coordinate with all supply side overcurrent devices. This helps ensure that these vital loads are not disrupted, whether fed from the normal source or the alternate source. Wording for 701.27 legally required standby systems and 708.54 critical operations power systems is similar except for the system type nomenclature.

Figure 30 illustrates that all emergency overcurrent protective devices must be selectively coordinated through to the alternate power source. In addition, the emergency overcurrent protective devices on the loadside of the transfer switch must selectively coordinate with the overcurrent protective devices in the normal circuit path. However, based on the requirement wording, there is a difference on the minimum requirement for the overcurrent protective devices in the normal source path that are on the lineside of the transfer switch. This same requirement is in 701.27 for Legally Required Standby Systems and 708.54 for Critical Operations Power Systems. Read the following 700.28 requirement and the practical application of the requirement example. Best engineering practice would be to have them be selectively coordinated.

NEC® 700.28 "Emergency system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices."

This wording is inclusive of the alternate path and normal source path overcurrent devices for each emergency load.

Practical Application of Requirement Example:

- OCPD 1 Must selectively coordinate with OCPD's 2, 3, 4, 5, 6
- OCPD 2 Must selectively coordinate with OCPD's 3, 4, 5, 6
- OCPD 3 Must selectively coordinate with OCPD 4
- OCPD 5 Does not have to selectively coordinate with OCPD 6 because OCPD 5 is not an emergency system overcurrent device.

With this specific wording, the analysis effort evaluating the normal source OCPDs can be much easier. Although it is permitted to have OCPD 5 not selectively coordinate with OCPD 6, the best engineering practice would be to have them be selectively coordinated.

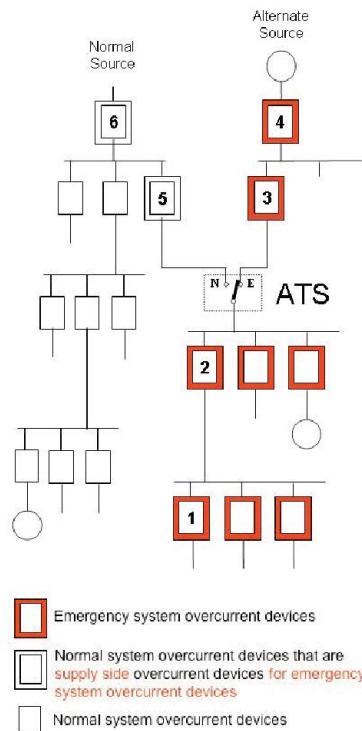


Figure 31

This Practical Application of Requirement Example and figure are reprinted with permission from *nedigest®* article *Keep The Power On For Vital Loads December 2007 Copyright® 2007, National Fire Protection Association, Quincy, MA*. This material is not the official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

System Considerations

Exceptions

700.28, 701.27, and 708.54 have an exception for selective coordination that is shown in Figure 32. The exception does not reduce life safety because no additional parts of the electrical system would be shut down unnecessarily. The striped OCPDs in both circuits shown in Figure 32 do not have to be selectively coordinated with each other.

700.27 & 701.27 Exception

Hashed OCPDs do not have to be selectively coordinated for two overcurrent protective devices in series if no other overcurrent protective devices are connected in parallel with the loadside device.

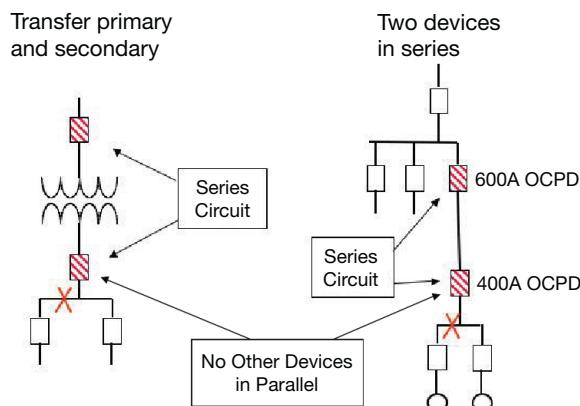


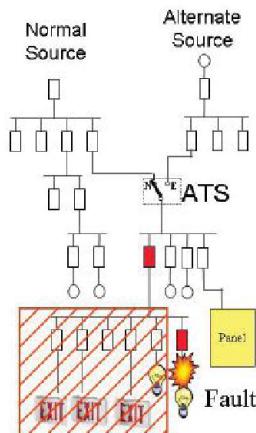
Figure 32

Lack of Selective Coordination

Example 1:

Figure 33 illustrates Example 1 where the power is from the normal source (ATS is switched to normal source). In this example, a fault opens the feeder overcurrent protective device (OCPD) as well as the branch circuit OCPD. The cause is the branch circuit OCPD is not selectively coordinated with the feeder OCPD for the full range of overcurrents at the point of application of the branch circuit OCPD. Because voltage is still present at the normal connection of the ATS, the generator will not automatically start and the ATS will not automatically transfer. The load on the faulted branch circuit is rightfully de-energized. However, the other emergency loads supplied by this feeder will incur an unnecessary loss of power. This would not comply with 700.28, 701.27, or 708.54 if this were an emergency system, legally required standby system or critical operations power system.

Example 1 Non-Coordinated



Consequences

- Non-coordinated OCPDs
 - No transfer activated
 - Unnecessary outage
- OCPD Opens
□ OCPD not affected

Figure 33

Example 2:

If the emergency overcurrent protective devices are not selectively coordinated with the normal path overcurrent protective devices, a fault in the emergency system can cause the OCPDs to cascade open thereby unnecessarily opening the normal path feeder OCPD or possibly main OCPD. Figure 34 illustrates this scenario. If this occurs, all the vital loads are unnecessarily without power at least temporarily. Since the power is lost to the ATS normal lineside termination, the generator is signaled to start. When the generator starts and the loads transfer to the alternate source, some vital loads will continue to be unnecessarily blacked out due to the emergency feeder OCPD's lack of selective coordination (it is still open). In addition, this action reduces the reliability of the system since there is some probability that the generator may not start or the transfer switch may not transfer.

Example 2 Non-Coordinated System

Consequences

- Non-coordinated OCPDs
- Blackout all emergency loads temporarily (shaded)
- Transfer activated
- Unnecessary blackout persists (hashed)
- Reliability concerns whether generator or transfer equipment operate properly— why increase possibility of unwanted outcome?

■ OCPD Opens

□ OCPD not affected

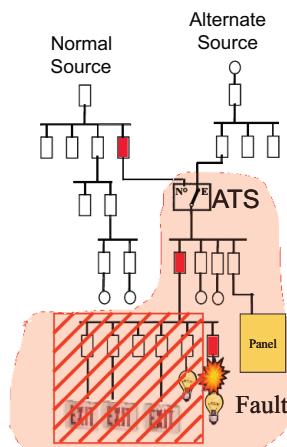


Figure 34

System Considerations

Evaluate for the Worst Case Fault Current

In assessing whether the overcurrent protective devices are selectively coordinated in the circuit path for these vital loads, it is important that the available short-circuit current from the normal source be considered (see Figure 37). This is required per 700.4(A) Capacity and Rating. ...“*The emergency system equipment shall be suitable for the maximum available fault current at its terminals.*” Generally, the normal source can deliver much more short-circuit current than the emergency generators. If the alternate source can deliver the most short-circuit current, then it must be used for determining compliance with 110.9, 110.10 and selective coordination.

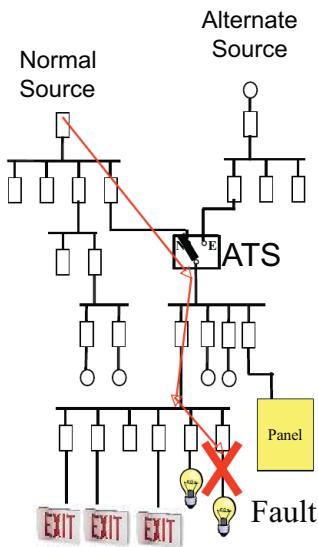


Figure 35

Full Range of Overcurrents

To comply, the overcurrent protective devices must selectively coordinate for the full range of overcurrents possible for the application: overloads and short-circuits which include ground faults, arcing faults and bolted faults. It is not selective coordination if the fuses or circuit breakers are coordinated only for overloads and low level fault currents. The fuses or circuit breakers must also be selectively coordinated for the maximum short-circuit current available at each point of application. “*The instantaneous portion of the time-current curve is no less important than the long time portion*” is extracted from a Code Making Panel 13 statement where the panel rejected a comment to eliminate the selective coordination requirement. High- and medium-level faults may not occur as frequently as overloads and very low- level faults, but they can and do occur. High- and medium-level faults will be more likely during fires, attacks on buildings, building failures or as systems age, or if proper maintenance is not regularly performed. Selective coordination has a very clear and unambiguous definition. Either overcurrent protective devices in a circuit path are selectively coordinated for the full range of overcurrents for the application or they are not. The words “optimized selective coordination,” “selectively coordinated for times greater than 0.1 second,” or other similar wording are merely attempts to not meet the selective coordination requirements. And phrases like “selective coordination where practicable” are unenforceable. For more information on this, see this publication’s section on Selective Coordination Objections and Misunderstandings.

Ground Fault Protection Relays

If a circuit path includes a Ground Fault Protection Relay (GFPR), then the selective coordination analysis should include the GFPRs. One approach is to first do the fuse or circuit breaker selective coordination analysis as described in the previous sections. (This includes all type of overcurrents). Then do a separate analysis for how the fuses or circuit breakers and GFPRs coordinate for ground faults. For more information see the section on Ground Fault Protection: Coordination Considerations.

Faster Restoration & Increased Safety

Beside minimizing an outage to only the part of the circuit path that needs to be removed due to an overcurrent condition, selective coordination also ensures faster restoration of power when only the closest upstream overcurrent protective device opens on an overcurrent. When the electrician arrives to investigate the cause, correct the problem and restore power, the electrician does not have to spend time locating upstream overcurrent protective devices that unnecessarily opened. This also increases safety by avoiding reclosing or replacing upstream OCPDs that have unnecessarily cascaded open; electrical equipment closer to the source typically has greater arc flash hazards.

Ensuring Compliance

620.62, 700.28, 701.27, and 708.54 require that persons competent for the task select OCPDs which will selectively coordinate and the selection must be documented. The documentation provides the detail on the selection of each OCPD and substantiates that all the OCPD are selectively coordinated. This includes detailing each OCPD type, ampere rating, and settings. The documentation must be made available to the inspector, contractor, and system owner. This new language, which was proposed by the IAEI International, will help improve the process for the enforcement authorities. In addition, the documentation provides the installers and future maintainers with the details so that the system can be installed and maintained as a selectively coordinated system.

Achieving overcurrent protective device selective coordination requires proper engineering, specification and installation of the required overcurrent protective devices. It is possible for both fusible systems and circuit breaker systems to be selectively coordinated with proper analysis and selection.

Selective coordination is best resolved in the design phase. Depending on the load needs and types of overcurrent protective devices, there is flexibility in the design phase to investigate various alternatives. After equipment is installed it can be costly to “fix” a system that lacks selective coordination. It is the professional engineer’s fiduciary responsibility to selectively coordinate the emergency, legally required standby and critical operations power systems. Once the distribution system is designed, without thought given to selective coordination, it is often too late to delegate the responsibility to the electrical contractor or equipment supplier. It is most efficient therefore, if the system is designed with selective coordination in mind, and not delegated to the electrical contractor, nor to the equipment supplier.

The contractor must install the proper overcurrent protective devices per the engineer’s specifications and approved submittals. If the system uses circuit breakers, the installer needs to ensure the circuit breaker settings (long time-delay, short time-delay and instantaneous trip) are set per the engineer’s coordination analysis. Circuit breakers are typically shipped from the manufacturer with the short time-delay and instantaneous trip settings on low or the minimum; these settings usually require adjustment to comply with the engineer’s selective coordination analysis.

Current Limiting Fuse and Circuit Breaker Choices for Selective Coordination

	Fuses (Current-Limiting)	MCCBs/ICCBs			LVPCBs Short Time-Delay Settings (STD) (No Instantaneous Trip)
		Instantaneous Trip	Fix High Magnetic Instantaneous Trip	Short Time-Delay With Instantaneous Override	
Short-Circuit Current (I_{SCA}) Calculations Needed	No Selectivity Ratios Applicable to 200kA*	Yes	Yes	Yes	No (I_{SCA} Needed for CB Interrupting Ratings)
Ease of Coordination Analysis	Simplest: Use Fuse Selectivity Ratios	<ul style="list-style-type: none"> • CB Manufacturers' Coordination Tables • Simple Analysis Rules • Curves (Commercial Software Packages): Interpret Properly 			Simple: Set Short Time-Delay Bands Properly
Job Specific: Is selective coordination limited to I_{SCA} Calculated for Specific Job?	Not Limited All Systems (Up to 200,000A*)	Limited Lower I_{SCA} Systems (Larger Frame CBs May Help)	Limited Expands Range of I_{SCA} Systems	Limited Expands Range of I_{SCA} Systems (Larger Frame CBs May Help)	Not Limited (up to CB Interrupting Ratings)
Cost	Low to Medium	Low to Medium	Low to Medium	Medium	High
Applicable Even if Transformer Changes (I_{SCA} Increases)	Yes (Up to 200,000A*)	No (Must Reverify)	No (Must Reverify)	No (Must Reverify)	Yes (Verify I_{SCA} Within CB Interrupting Rating and Short Time Rating)

*Or fuse interrupting rating, whichever is lower.

This simple table for **Current-Limiting Fuse and Circuit Breaker: Choices for Selective Coordination** provides a summary of what has been covered in this section on selective coordination and includes practical considerations in the design effort and identifies limitations.

Overcurrent Protective Device Choices are across the chart's top row and include:

1. Fuses: modern current-limiting fuses
2. MCCBs/ICCBs: molded case circuit breakers or insulated case circuit breakers:
 - a. With instantaneous trips
 - b. With fixed high magnetic instantaneous trips
 - c. With short time-delay (STD) and instantaneous override
3. LVPCB: low voltage power circuit breakers with short time-delay (no instantaneous trip)

The left column has five considerations for selective coordination.

Short-Circuit Current (I_{SCA}) Calculations Needed:

- With current-limiting fuses, there is no need to calculate the short-circuit current in most cases. As long as the main transformer secondary along with motor contribution is not more than 200,000A*, just use the selectivity ratios. This saves a great deal of time and lowers engineering cost.
- With LVPCBs utilizing STDs and no instantaneous trip, it is not necessary to calculate the short-circuit current in many cases. It is necessary to check for an adequate interrupting rating or short-time rating for any circuit breaker. A quick check of the available short-circuit current at the main transformer secondary will determine if a detailed short-circuit current study is required.
- With MCCBs and ICCBs it is necessary to calculate the available short-circuit currents at each point a circuit breaker is applied.

Ease of Coordination Analysis:

- With current-limiting fuses, just use the selectivity ratio guide which is applicable for the full range of overcurrents up to the fuses' interrupting ratings or 200,000A, whichever is lower. This saves a great deal of time and lowers the engineering cost.
- With LVPCBs, utilizing STDs and no instantaneous trip, it is a matter of selecting short time-delay bands that do not intersect. However, it is easy to achieve selective coordination.
- With MCCBs and ICCBs it is necessary to do a detailed analysis. The method entails knowing the available short-circuit current at each CB point of application and determining if the circuit breakers are selectively coordinated or not. Three methods are:
 1. Circuit breaker coordination tables (published by each CB manufacturer).
 2. Analysis method (without plotting curves) presented in a previous section.
 3. Using a commercial software package that plots the curves (necessary to interpret the curves properly).

Job Specific: Is Selective Coordination limited to Isca Calculated for Specific Job?

- With current-limiting fuses, the selective coordination scheme determined is not limited just to that specific job since it is a matter of utilizing the selectivity ratios. The same specification of fuse types and sizes could be utilized for another project as long as the short-circuit current is not greater than 200,000A*.
- With LVPCBs, utilizing STDs and no instantaneous trip, the selective coordination scheme determined is not limited just to that specific job since it is a matter of specifying STD bands that do not intersect. Once determined, the same specification of circuit breaker types and settings could be used on another project, as long as the short-circuit current does not exceed any circuit breaker interrupting or short time rating.
- With MCCBs and ICCBs the selective coordination scheme that is selectively coordinated for one project is not necessarily transferable to another project. The reason is that even if the same circuit breakers are used, each project will have its own specific available short-circuit currents. Therefore, using these type circuit breakers requires each project to have a short-circuit current and coordination analysis.

*Or fuse interrupting rating, whichever is lower.

Cost:

- This row is a rough estimate of the cost range of the electrical equipment.

Applicable Even if Transformer Changes (Isca increases):

- With fuses, even if there is a system change that increases the short-circuit current, such as when the main transformer gets changed, selective coordination is retained (up to 200,000A*).
- With LVPCBs, utilizing STDs and no instantaneous trip, the selective coordination is also retained. In this case, it is necessary to verify the higher short-circuit current does not now exceed the interrupting or short time rating for any circuit breaker.
- With MCCBs and ICCBs selective coordination may be negated if the short-circuit current increases due to a system change. It is necessary to perform a new short-circuit current study and revisit the selective coordination analysis to verify selective coordination is still valid.

Note: If the system includes ground fault protection relays, selective coordination must be analyzed with all these protective devices. See the section on Selective Coordination: Ground Fault Protection Relays.

*Or fuse interrupting rating, whichever is lower.

Selective Coordination Objections & Misunderstandings

Selective Coordination Objections and Misunderstandings

Mandatory selective coordination required in the NEC® for the circuit paths of some vital loads requires some changes in the industry. Although selective coordination is an easy concept to understand, the devil can be in the details. This section presents the most common objections voiced in opposition to the selective coordination requirements with accompanying clarifying facts. As with any complex subject, it is easy to provide general statements that support or oppose a position. As one digs deeper into the objections, the reality becomes:

1. For many of the objections, there are remedies or technologies that are suitable solutions
2. Some of the objections are not accurate
3. For other objections, since selective coordination is now mandatory, selective coordination is a higher priority

All these arguments as to why mandatory selective coordination requirements should be deleted or diluted have been thoroughly presented, discussed and debated in the technical Code panels as well as in other industry forums for more than four Code cycles. For elevator circuits, selective coordination has been a mandatory requirement since the 1993 NEC®. Three Code panels have made selective coordination a mandatory requirement because it increases the system reliability for powering vital life safety loads and it is achievable with existing technology. In addition, as is typical with significant industry changes, manufacturers are responding with new products that make it easier and less costly to comply.

To answer the broad question why selective coordination is needed as a NEC® requirement, see the section on: *Why Selective Coordination is Mandatory: It fills the reliability "Hole."*

Objection 1

Changing the requirement for selective coordination to times of 0.1 second and greater is a better method.

Clarifying Facts to Objection 1

There is a clear difference in system reliability if the compliance is to a “selective coordination” requirement versus compliance to a “coordination” requirement. A “coordination” requirement is less restrictive and may permit unnecessary and undesirable cascading of overcurrent protective devices for some levels of fault current.

The 2014 NEC® clarified the definition of selective coordination for the full range of overcurrents available on a system and for any associated opening times of the overcurrent protective devices. A less restrictive requirement such as “for the period of time that a fault’s duration extends beyond 0.1 second” does not meet the definition of selective coordination. This less restrictive 0.1 second requirement permits “coordination” of overcurrent protection devices for only a partial range of overcurrents and/or associated OCPDs’ opening times. Coordination only for times greater than 0.1 permits ignoring the possible lack of coordination for conditions ranging from low level fault currents to the maximum available short-circuit currents on systems when the opening times of OCPDs are less than 0.1 seconds. It ignores the instantaneous trip settings of circuit breakers and the fuse characteristics less than 0.1 seconds. Achieving only coordination and not achieving selective coordination for an electrical system permits reducing the reliability to deliver power to the loads.

Let's examine achieving a “coordination” only requirement, which is less restrictive than a “selective coordination” requirement. Then compare the level of reliability to deliver power to the loads.

Figure 36 represents an analysis for “coordination” only for times greater than 0.1 second. A system that is only “coordinated” is permitted to allow a lack of selective coordination for some range of overcurrents.

Figure 36 includes a one-line diagram and time-current curves showing only times greater than 0.1 second. If considering only times greater than 0.1 second, this system would be “acceptable” for any available short-circuit current up to the interrupting ratings of the circuit breakers. However, this system may not be selectively coordinated: see the next paragraph.

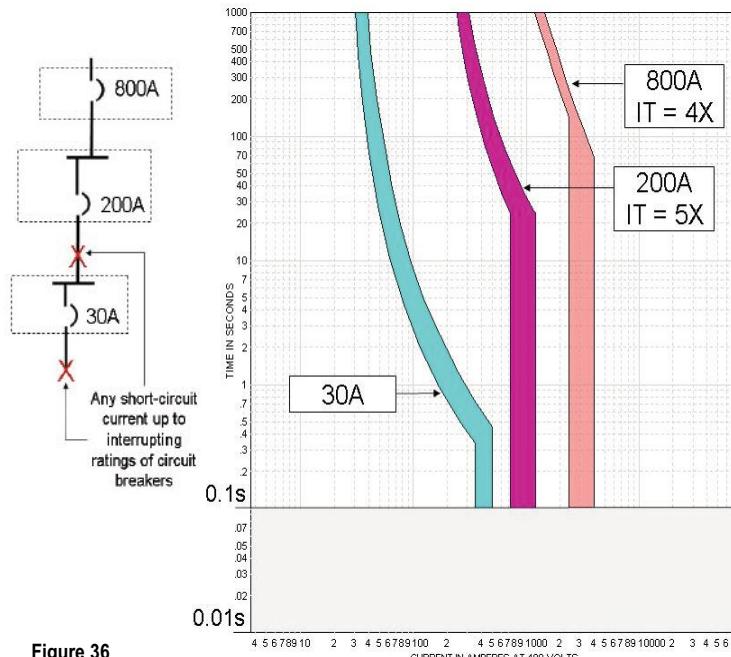


Figure 36

This system complies with a “coordination” requirement for the period of time that a fault’s duration extends beyond 0.1 second. In this case, it is only necessary to consider the circuit breaker curves for times greater than 0.1 seconds. It does not consider the ramifications of whether the circuit breakers are coordinated for times less than 0.1 seconds. Figure 37 provides a more complete analysis and the possible consequences.

Figure 37 illustrates why coordination for the period of time that a fault’s duration extends beyond 0.1 second may represent only coordination for a limited range of overcurrents and does not achieve selective coordination for the full range of overcurrents and for the full range of OCPD opening times associated with those overcurrents. It shows the time-current curves for times less than 0.1 seconds and the lack of coordination possible with the circuit breaker instantaneous trip settings. In reality interpreting the curves (without circuit breaker coordination tables), this system is only coordinated for overcurrents on the branch circuits up to 750A and for overcurrents on the feeder up to 2400A.

Why can this be? Circuit breakers are typically shipped from the factory with the instantaneous trip set at the lowest setting. These 200A and 800A circuit breakers are set at the low instantaneous trip setting. Without some engineering effort to select appropriate overcurrent protective device types, and their settings, as well as the installer using the proper devices and settings, this system could unnecessarily blackout vital loads in a critical situation. The proper selection of devices depends on the fault current level and type of OCPDs. Thus, if the requirement is permitted to be only coordination rather than selective coordination, OCPDs are permitted to be selected and installed that can adversely affect the capability of the system to be selectively coordinated, reducing system reliability, for low, medium and high-level faults.

Selective Coordination Objections & Misunderstandings

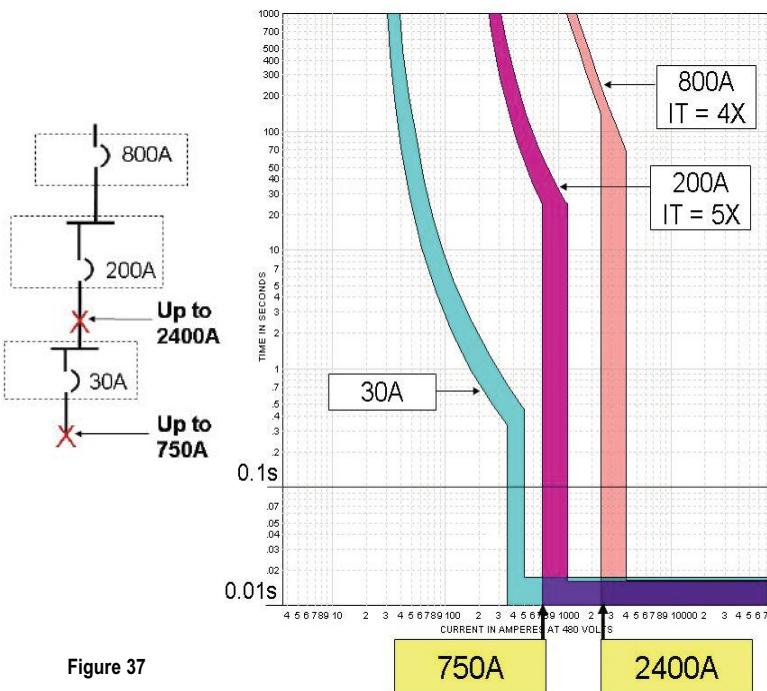


Figure 37

This figure shows the real limitations for this system to deliver reliable power for faults greater than:

- 750A, the 30A CB is not coordinated with the 200A CB.
- 2400A, the 30A CB is not coordinated with the 800A CB.
- 2400A, the 200A CB is not coordinated with the 800A CB.

While this explanation shows the difficulties encountered with these standard molded case thermal-magnetic circuit breakers, there are solutions for the full range of overcurrents of a specific system. It may be as simple as doing a coordination study and adjusting the circuit breakers to higher instantaneous trip settings to achieve selective coordination. Other, more sophisticated circuit breakers are available that selectively coordinate below 0.1 second (for the full range of overcurrents). See the section Achieving Selective Coordination with Low Voltage Circuit Breakers to assist in selecting the least costly circuit breaker alternatives for the system available fault currents.

The same situation can occur with fusible systems. Figure 38 shows fuse time-current characteristics where the curves are coordinated for faults with time durations greater than 0.1 seconds. These two fuses meet the 0.1 second coordination criteria. However, Figure 39 shows the same fuse curve, but below 0.1 seconds; obviously there is a lack of coordination for fault currents greater than where the fuses cross. Meeting a coordination requirement does not assure that the system will not unnecessarily open upstream OCPDs for some overcurrent conditions. "Coordination" is not equivalent to "selective coordination".

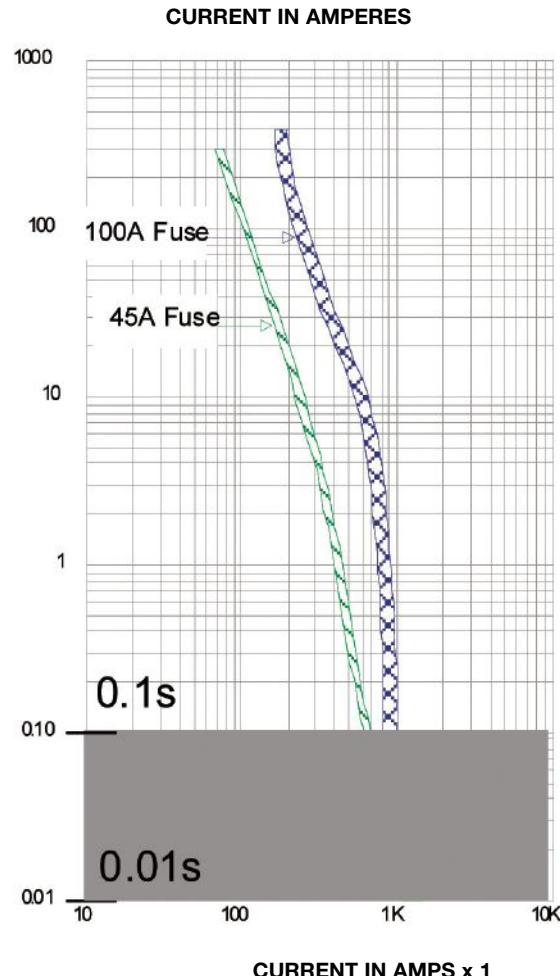


Figure 38 These two fuses comply if the requirement is coordination for OCPDs for faults greater than 0.1 seconds time duration. However, these two fuses do not comply with the requirement of selective coordination: see Figure 39.

Selective Coordination Objections & Misunderstandings

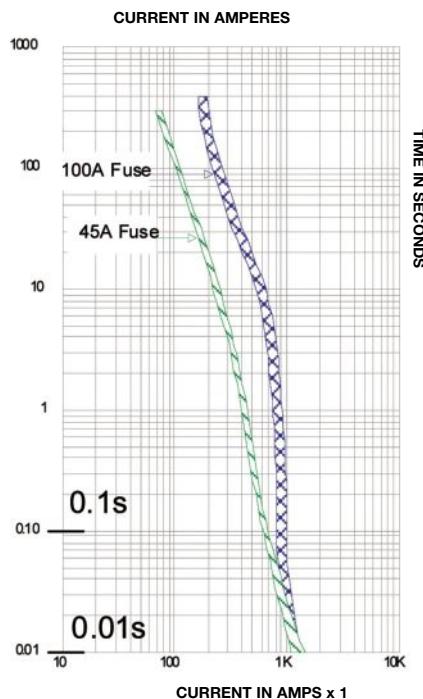


Figure 39 This is the same time-current curve as in Figure 38, except analyzing the OCPDs characteristic for times less than 0.1 seconds. This illustrates these fuses lack coordination beyond 800 amperes of fault current. If the available short-circuit current at the 45A fuse was greater than 800A these two fuses do not comply with selective coordination.

Over several NEC® cycles Code Making Panels have already considered 0.1 second coordination as an option and rejected it. The real question that has already been answered by the industry experts on three National Electrical Code panels is what level of coordination is required to provide system reliability to supply power to vital loads. Their answer is selective coordination, for the full range of overcurrents and the full range of OCPD opening times associated with those overcurrents. The less restrictive coordination specified by a time parameter did not meet the reliability requirements for 620.62, 645.27, 700.28, 701.27, and 708.54. Their answer is selective coordination for the full range of overcurrents and for any associated opening time of the overcurrent protective devices. Selective coordination cannot be specified by time parameters as some are promoting. Selective coordination is a matter of the available fault current and how characteristics of the various OCPDs in series in the electrical system circuit path perform relative to one another. Selective coordination is for the full range of overcurrents that the specific system is capable of delivering, irrespective of the OCPD opening times. In reality it comes down to this:

- Fuses: if the fuses comply with the fuse manufacturer's selectivity ratios, the fuses selectively coordinate for fault currents up to 200,000A or the fuses interrupting rating, whichever is lower. There is no need to limit reliability to times of only 0.1 second and longer.
- Circuit breakers: the fault current level in the specific system/location determines the type of circuit breakers that would be the most cost effective and still selectively coordinate. If there are low available fault currents, then molded case circuit breakers may comply. If the fault current is in a higher range, then molded case circuit breakers with fixed high magnetic instantaneous trips may comply. If not, then short time-delay circuit breakers may be necessary. See the section on Achieving Selective Coordination with Low Voltage Circuit Breakers for more details on the various options for different levels of fault current. As with fusible systems, circuit breaker solutions are available to provide selective coordination for all available fault currents.

Per 517.30(G) in 2014 NEC® the essential electrical systems in healthcare facilities must at least be "coordinated" for a fault time duration extending beyond 0.1 second. This was the result of the NFPA 99 Healthcare Facilities Code Technical Committee which has prevue over the performance of healthcare facilities.

517.30 Essential Electrical Systems for Hospitals

(G) Coordination. Overcurrent protective devices serving the essential electrical system shall be coordinated for the period of time that a fault's duration extends beyond 0.1 second.

Exception No. 1: Between transformer primary and secondary overcurrent protective devices, where only one overcurrent protective device or set of overcurrent protective devices exists on the transformer secondary.

Exception No. 2: Between overcurrent protective devices of the same size (ampere rating) in series.

Informational Note: The terms coordination and coordinated as used in this section do not cover the full range of overcurrent conditions.

The minimum level of performance required in 517.30(G) is the less restrictive "coordination" of OCPDs which does not meet the definition of selective coordination which is for the full range of overcurrents and for any associated opening time of the overcurrent protective devices. The 517.30(G) informational note correlates with the NEC definition of selective coordination to distinguish the levels of performance. Many engineering designs will continue incorporating the reliability of selective coordination in essential electrical systems to ensure the higher level of reliability for vital loads. Also, there are some healthcare facilities or parts of facilities, such as administrative buildings, which are required to comply with the NEC and the requirements of 620.62 (elevators), 645.27 (critical operations data systems), 700.28 (emergency systems), 701.27 (legally required standby systems), and 708.54 (critical operations power systems).

Objection 2

Selective coordination results in reduced electrical safety with an increased arc flash hazard.

Clarifying Facts to Objection 2

- A. In fact, the opposite can be true from a system standpoint; selective coordination improves electrical safety for the worker. Selective coordination isolates overcurrents to the lowest level possible, resulting in fewer exposures to hazards for electricians. Also, since the worker does not unnecessarily have to interface with upstream equipment closer to the source, the arc flash levels are often lower. The lack of selective coordination can actually increase the arc flash hazard for workers because the worker will have to interface with larger amp rated overcurrent protective devices upstream. The electrical equipment, closer to the source, is generally protected by larger amp rated overcurrent protective devices and has higher available short-circuit currents, which typically results in higher arc flash hazards. See Figures 40 and 41. In Figure 41, assume a fault in the branch circuit opens the branch circuit OCPD, plus it unnecessarily opens the feeder OCPD in the distribution panel, and the feeder OCPD in the service panel due to a lack of selective coordination. The electrician starts trouble shooting at the highest level in the system that is without power. At this point, the electrician does not know that a lack of selective coordination unnecessarily opened the feeder OCPDs in the distribution panel and service panel. The electrician does not even know which overcurrent

Selective Coordination Objections & Misunderstandings

protective devices opened, where the fault occurred and what damage may have occurred on the circuit paths. After interrupting a fault current, it is Federal law that a circuit breaker shall not be reset or fuses replaced [OSHA 1910.334(b)(2)] “until it has been determined that the equipment and circuit can be safely energized.” Even though the fault may have occurred on the branch circuit, the fault current may have damaged the circuit components on the feeders.

Let's assume it is a system as shown in Figure 41. At each location in the electrical system that he works, he must place the equipment in an electrically safe work condition. This requires a shock hazard analysis and flash hazard analysis for each location. In addition, at each location the electrician must wear the proper PPE (Personal Protective Equipment) until he has verified the equipment to be worked on is in an electrically safe work condition. From the top, the electrician must work through the system:

Service Panel - Check the condition of each conductor on the feeder circuit from the service panel to the distribution panel by individually testing each conductor. Check the condition of the OCPD in the feeder circuit of the service panel. This requires visual inspection and testing. Since this OCPD opened due to a lack of selective coordination, let's assume these feeder conductors are in good condition and no damage was sustained due the fault current. The electrician still does not know the cause of the opening of the service panel feeder OCPD, but he knows, after testing, this circuit is safe to energize. So he moves his attention to the distribution panel.

Distribution Panel - He finds the sub-feeder OCPD that opened. He must follow the same procedures: test the condition of each conductor on the feeder circuit from the distribution panel to the branch panel and check the condition of the OCPD in the feeder circuit of the distribution panel. This requires visual inspection and testing. Since this OCPD opened due to lack of selective coordination, let's assume these sub-feeder conductors are in good condition and no damage to the circuit was sustained due to the fault current. The electrician still does not know the cause of the opening of the distribution panel feeder OCPD, but, after testing, he knows this circuit is safe to energize. So he moves his attention to the branch panel.

Branch Panel - He finds the branch OCPD that opened. He must follow the same procedure: check the condition of each conductor on the branch circuit from the branch panel to the load and check the condition of the OCPD in the branch circuit of the branch panel. This requires visual inspection and testing. Now he finds the root cause being a fault on this circuit. He then must repair the circuit, test it thoroughly to ensure it is safe prior to re-energizing.

It is evident that selectively coordinated overcurrent protective devices can not only save restoration time, it also can reduce exposures to arc flash hazards for electricians. Even if the electrician was informed of the location of the fault when he started his troubleshooting of the circuits in Figure 41, the conductors and OCPD on the feeder and sub-feeder circuits must be verified by testing as to their suitability to be put back into service or replaced after incurring a fault.

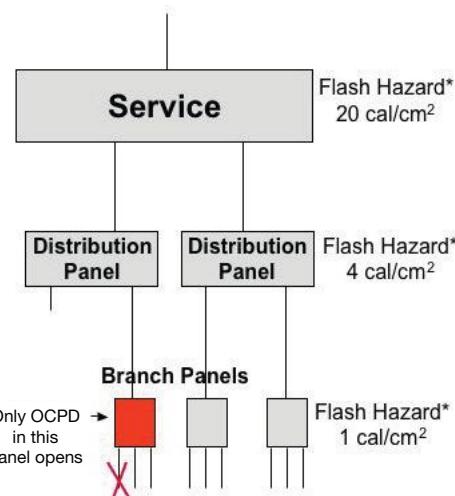


Figure 40

Selective coordination isolates overcurrents to the lowest level possible, resulting in fewer exposures to arc flash hazards and typically at lower energy levels for electricians. In this case, the electrician may not have to interface with OCPDs in upstream panels.

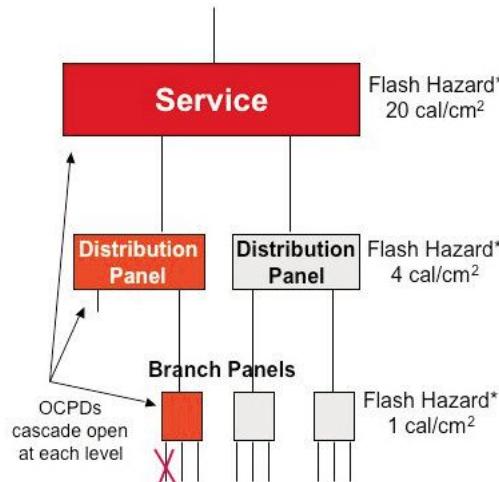


Figure 41

Lack of selective coordination can increase the arc flash hazard. When overcurrent protective devices cascade open, the electric worker must unnecessarily work at higher levels in the system, where arc flash hazards are typically higher. This also increases the trouble-shooting (power restoration) time.

* Illustrative example of how arc flash hazard levels can increase for larger equipment that is closer to the source. Actual values can vary.

Selective Coordination Objections & Misunderstandings

- B. Fuses inherently are easy to selectively coordinate and there is not a trade-off between providing selective coordination and arc flash hazard reduction. With current-limiting fuses, adding time-delay is not required for selective coordination. Therefore, arcing faults are taken off-line as quickly as possible, which does not result in increased arc flash hazards when designing for selective coordination. Some fuse types provide lower arc flash hazard levels than others. For building distribution systems, as a general rule, Low-Peak fuses are recommended because their selectivity ratios are 2:1 and their built-in current limitation may help limit arc flash hazard levels.
- C. Equipment can utilize arc flash options which deploy optic sensors that detect arc faults and react by shunt tripping a circuit breaker or switch which can result in lowering high arc flash hazards.
- D. To achieve selective coordination using circuit breakers, in some cases, upstream circuit breakers have to be intentionally delayed such as using a short time-delay. It is important to separate the electrical system normal operation from tasks such as performing maintenance or troubleshooting. Arc flash considerations are not an issue during normal operation; arc flash is a consideration when tasks such as performing maintenance or troubleshooting are needed. When an electrician has to perform maintenance or troubleshooting, there are practices and circuit breaker options that can mitigate higher arc flash hazard levels.

Where an instantaneous trip is not utilized, one of several arc energy reducing mechanisms can be deployed, including zone-selective interlocking, differential relaying, and energy reducing maintenance switching. So it is possible to have selective coordination and mitigate the arc flash hazard.

- With CBs having a short-time-delay and no instantaneous trip, a control switch option referred to as an arc flash reducing maintenance (ARM) switch is often used and may be one option required by NEC® 240.87. If a worker activates this ARM switch, the circuit breaker time current characteristics change: for fault currents within the range of the short-time-delay function, the short-time-delay function is bypassed and the circuit breaker opens without intentional delay. The ARM allows the circuit breaker under normal operation to have a short time-delay for coordination purposes, but when a worker is working on energized equipment protected by that circuit breaker, the circuit breaker ARM is switched to maintenance mode. With the switch enabled to maintenance mode, the arc flash hazard is lower than would occur with a short time-delay setting.
- Work practices may be an option. Prior to working on the equipment, the electrician may temporarily adjust the setting to lower levels for a circuit breaker supplying the equipment to be worked on. The circuit breaker setting adjustments are typically accessible without opening the enclosure. In so doing, the arc flash hazard level is reduced for the time period necessary for maintenance.
- There are other practices and equipment to mitigate higher level arc flash hazards, such as remote racking, extended length racking tools, motorized switching options, etc.
- With CBs, zone selective interlocking is a system option that reduces the arc flash hazard associated with using short time-delay. This technology makes it simple to selectively coordinate circuit breakers and still provide lower arc flash levels and better equipment protection whether during normal operation or performing maintenance on energized equipment. See Figures 42, 43, and 44.

- E. In the 2011NEC® cycle, comment 13-136 requested acceptance of the original proposal 13-195 which proposed selective coordination requirements only "for faults with a duration of 0.1 seconds and larger". This comment was rejected by a vote of 16-2. The panel statement included the following:
- "arc flash hazards are not necessarily greater for selectively coordinated systems. For circuit breakers, there are circuit breaker options whereby selective coordination can be achieved without increased arc flash hazards such as arc reduction maintenance switches and zone selective interlocking. In addition, there are other design options that can be used to achieve selective coordination and acceptable levels of incident energy".

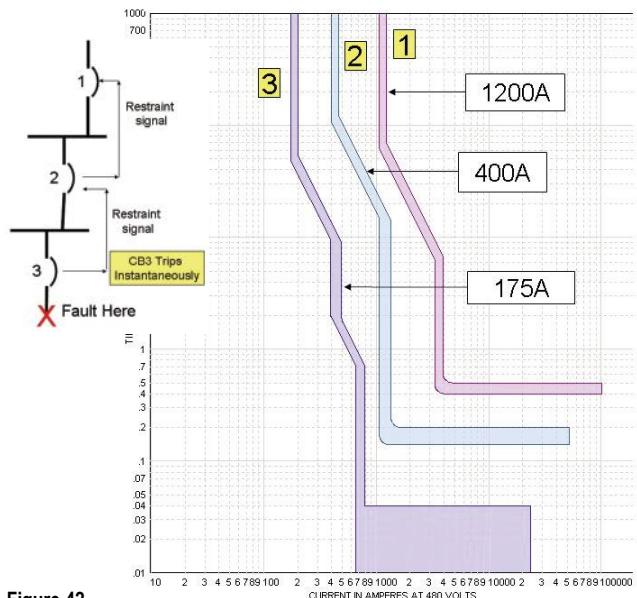


Figure 42

When there is a fault on the loadside of CB3, CB3 opens instantaneously and sends a signal to CB2 and CB1 to hold off (short time-delay).

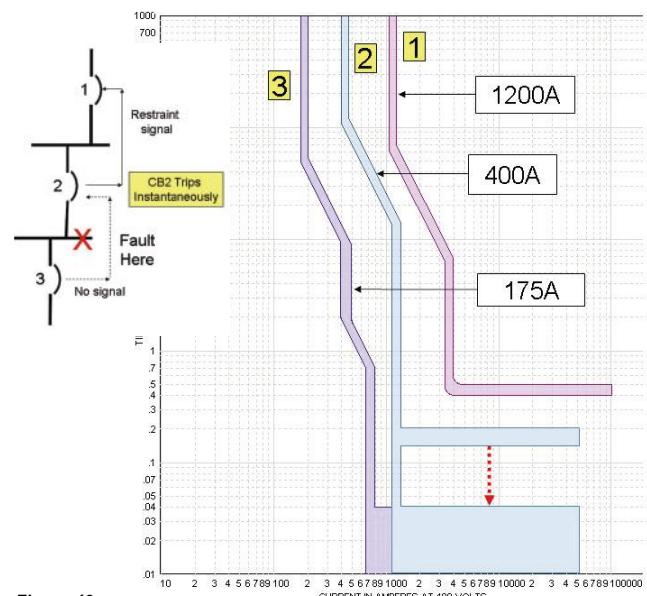


Figure 43

When there is a fault on the loadside of CB2, but on the lineside of CB3; CB2 opens without an intentional delay since there is no signal from CB3 to hold off. CB2 sends a signal to CB1 to hold off (short time-delay).

Selective Coordination Objections & Misunderstandings

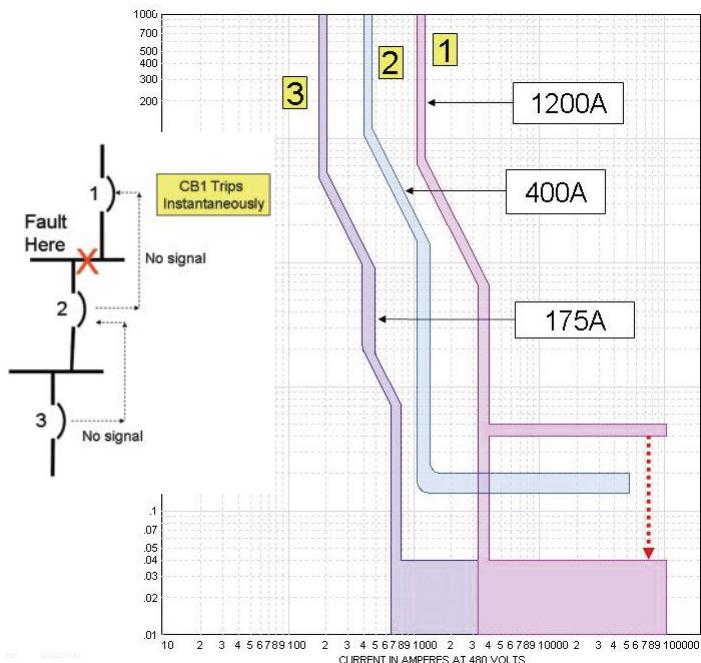


Figure 44

When there is a fault on the loadside of CB1, but on the lineside of CB2, CB1 opens without an intentional delay since there is no signal from CB3 or CB2 to hold off.

Objection 3

Bolted short-circuits or high level fault currents don't occur very frequently, so selective coordination should only be required for overload conditions.

Clarifying Facts to Objection 3

- The definition for selective coordination in the 2014 NEC® is for the full range of overcurrents available on the system.
- Bolted fault current conditions can and do occur. However, bolted faults are not the only condition that will cause multiple levels of overcurrent protective devices to open. Unless a qualified person does an analysis and selects appropriate devices and settings, it is possible that low and moderate levels of fault current may result in cascading multiple levels of overcurrent protective devices.
- It is typical that even the arcing current calculated in performing an arc flash hazard analysis will result in cascading multiple levels of overcurrent protective devices, if the devices are not selectively coordinated. Higher-level faults are more likely in fires, natural catastrophes, human caused catastrophes and other emergency situations. When continuity of power to life-safety loads is most critical, the system is most vulnerable unless the overcurrent protective devices are selectively coordinated. Line-to-ground arcing faults in enclosures tend to quickly escalate to three-phase arcing faults of significant levels. Arcing faults range from 70% to 43% of the bolted available short-circuit current in testing performed per IEEE Paper PCIC-99-36. The lower the bolted available short-circuit current, the higher the arcing fault current as a % of the bolted fault current.
- In the 2011 NEC® cycle, Panel 13 (entirely new panel membership from 2008 cycle) further clarified that the requirement is for the full range of overcurrents in their panel statement to Proposal 13-198: "The existing text of 700.27 (700.28 in 2014 NEC®) already requires selective coordination for the full range of overcurrents, from overloads through the available short-circuit current, with all upstream devices."

Objection 4

Selective coordination results in greater equipment short-circuit damage when short time-delay is used.

Clarifying Facts to Objection 4

- With current-limiting fuses, additional time-delay is not required for selective coordination. Therefore, short-circuits are taken off-line as quickly as possible; equipment damage is not increased.
- Equipment, such as transfer switches and busways, is now available with longer short-time withstand ratings (short-circuit current rating).
- With CBs, zone selective interlocking allows the upstream CB to open with no intentional delay, bypassing the short time-delay for all faults between the two CBs, thus improving equipment protection.

Objection 5

There are no documented incidents where a lack of coordination caused a problem.

Clarifying Facts to Objection 5

- Incidents are suppressed (sealed) due to litigation or fears of negative publicity.
- Eaton/Cutler-Hammer discusses details of a serious incident in a healthcare facility in their service newsletter Power Systems Outage in Critical Care Publication SA.81A.01.S.E, April 1999. Key points:
 - Fault on a fan (branch circuit) causes loss of power to entire emergency system in healthcare facility.
 - Switched to emergency – fault still present, tripped emergency generator device.
 - All power to critical care loads including life support and ventilation systems lost – patients required immediate medical attention.
 - Lack of coordination and maintenance was determined as cause of loss of power.
- Findings by informal polling: a large percentage of electricians have experienced occurrences where a lack of OCPD selective coordination unnecessarily blacked out portions of a system.
- Lack of coordination is accepted by experienced electricians as something that normally happens. Once a system is installed with overcurrent protective devices that are not selectively coordinated, the situation typically can only be corrected by changing out the electrical gear: so people live with it.
- Code Making Panel (CMP) 13 (Articles 700 and 701) panel statement included: *"The panel agrees that selective coordination of emergency system overcurrent devices with the supply side overcurrent devices will provide for a more reliable emergency system."* (Panel Statement to Proposal 13-135 during the 2005 NEC® cycle.)
- CMP 20 panel statement in 2008 NEC® cycle: *"The overriding theme of Articles 585 (renumbered to 708) is to keep the power on for vital loads. Selective coordination is obviously essential for the continuity of service required in critical operations power systems. Selective coordination increases the reliability of the COPS system."* (Panel Statement to Comment 20-13 during the 2008 NEC® cycle.)

Selective Coordination Objections & Misunderstandings

Objection 6

NEC® 700.28 selective coordination requirement conflicts with NFPA 110 Standard for Emergency and Standby Power Systems.

Clarifying Facts to Objection 6

- A. There is no conflict. NFPA 70 encompasses the entire electrical system and NFPA 110 has a limited scope, not even the entire emergency system. The scope of NFPA 110 only covers the electrical system from the generator to the load terminals of the transfer switch and includes optional standby alternate power systems where selective coordination is not required. The NEC® (NFPA 70) includes Article 700 the entire emergency system, Article 701 the entire legally required standby system, Article 702 the entire optional standby systems and Article 708 the entire critical operations power systems. See Figure 45.
- B. NFPA 110 calls for optimized selective coordination. Total selective coordination is the very best “optimization” possible.
- C. NFPA 20 Standard for the Installation of Stationary Pumps for Fire Protection (20: 9.2.2(e) and 20: 9.6.5) and NFPA 111 Standard on Stored Electrical Energy Emergency and Standby Power Systems (111: 6.5.1) have selective coordination requirements adhering to the NEC definition which governs the meaning of selective coordination as used in Articles 620, 645, 695, 700, 701, and 708.

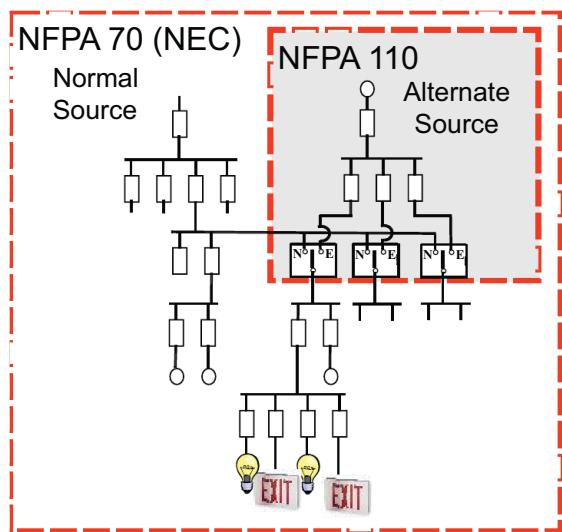


Figure 45

Objection 7

Selective coordination is not possible with multiple emergency generators in parallel (to increase reliability).

Clarifying Fact to Objection 7

For these more complex configurations, relays and transfer switch schemes can be utilized to achieve selective coordination. See Figure 46.

Parallel Generators Solution:

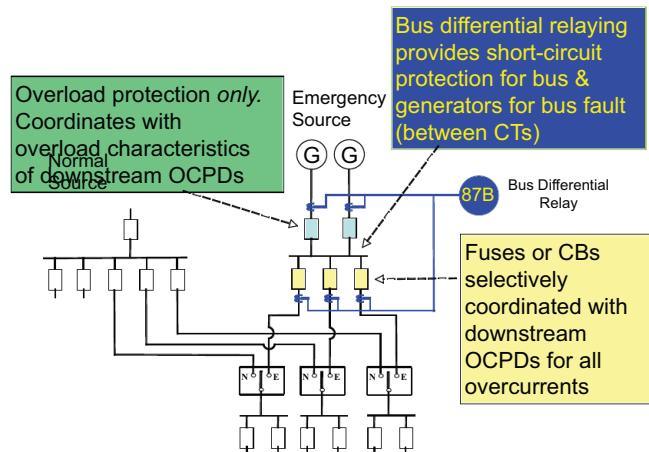


Figure 46

Objection 8

The NEC® is not a performance or a design standard, so requirements for selective coordination have no business in the NEC®.

Clarifying Facts of Objection 8

- A. NEC® provides the very minimum requirements, the starting point, or basis for all electrical designs. NEC® doesn't tell the engineer how to selectively coordinate the system. The requirement is not prescriptive.
- B. The stated purpose of the NEC® is the practical safeguarding of persons and property from hazards arising from the use of electricity. Three Code Making Panels (12, 13, and 20) of the NEC® have confirmed or reconfirmed their desire for selective coordination requirements in six articles. These requirements are for systems that supply a few important loads where system reliability is deemed very critical for life safety and national security. See the section *Why Selective Coordination is Mandatory: It fills the Reliability “Hole.”*

Objection 9

Compliance with selective coordination costs more, so it has no business in the NEC®.

Clarifying Facts to Objection 9

- A. This depends on design and system requirements. Costs are not necessarily higher.
- B. There is a cost associated with continuity of service for emergency and critical operations power systems. There can be a greater cost (lives lost) where continuity of service is not provided.
- C. If this is true, there is no need for any of Articles 700, 701, and 708 because there are additional costs with the requirements in all these Articles. The whole of these Articles increases the costs. The costs of an alternate power source, separate wiring, automatic transfer switches, sophisticated sensors and control schemes, periodic testing, and other items add cost to provide a reliable system that ensures high availability of power to these vital loads. Selective coordination is another requirement that increases the reliability of the system to deliver power during critical times/emergencies.
- D. See the section *Why Selective Coordination is Mandatory: It fills the Reliability “Hole.”*

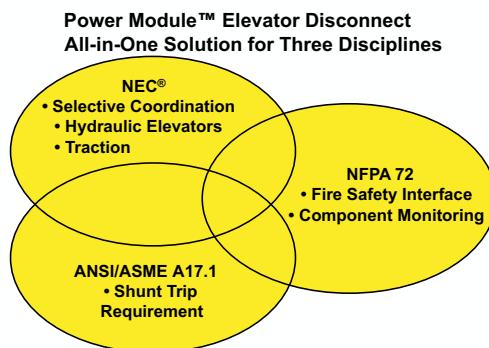
Elevator Circuit

Elevator Circuits and Required

Shunt Trip Disconnect – A Simple Solution.

When sprinklers are installed in elevator hoistways, machine rooms, or machinery spaces, ANSI/ASME A17.1 requires that the power be removed to the affected elevator upon or prior to the activation of these sprinklers. This is an elevator code requirement that affects the electrical installation. The electrical installation allows this requirement to be implemented at the disconnecting means for the elevator in NEC® 620.51(B). This requirement is most commonly accomplished through the use of a shunt trip disconnect and its own control power. To make this situation even more complicated, interface with the fire alarm system along with the monitoring of components required by NFPA 72 must be accomplished in order to activate the shunt trip action when appropriate and as well as making sure that the system is functional during normal operation. This requires the use of interposing relays that must be supplied in an additional enclosure. Other requirements that have to be met include selective coordination for multiple elevators (620.62) and hydraulic elevators with battery lowering [620.91(C)].

There is a simple solution available for engineering consultants, contractors, and inspectors to help comply with all of these requirements in one enclosure called the Bussmann Power Module™.



The Power Module contains a shunt trip fusible switch together with the components necessary to comply with the fire alarm system requirements and shunt trip control power all in one package. For engineering consultants this means a simplified specification. For contractors this means a simplified installation because all that has to be done is connecting the appropriate wires. For inspectors this becomes simplified because everything is in one place with the same wiring every time. The fusible portion of the switch utilizes Low-Peak LPJ-(amp)SP fuses that protect the elevator branch circuit from the damaging effects of short-circuit currents as well as helping to provide an easy method of selective coordination when supplied with upstream Low-Peak™ fuses with at least a 2:1 amp rating ratio. More information about the Bussmann Power Module can be found at www.cooperbussmann.com.



The Quik-Spec Power Module Switch (PS) for single elevator applications

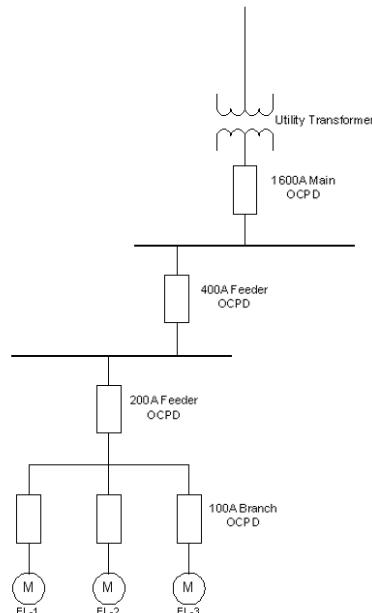
Elevator Selective Coordination Requirement

In the NEC®, 620.62 states:

Where more than one driving machine disconnecting means is supplied by a single feeder, the overcurrent protective devices in each disconnecting means shall be selectively coordinated with any other supply side overcurrent protective devices.

A design engineer must specify and the contractor must install main, feeder, sub-feeder and branch circuit protective devices that are selectively coordinated for all values of overloads and short-circuits.

To better understand how to assess if the overcurrent protective devices in an electrical system are selectively coordinated refer to the Selective Coordination Section of this publication. Below is a brief coordination assessment of an elevator system using fuses in the Power Module Elevator Disconnects with upstream fuses in the feeders and main.



Using the one-line diagram above, a coordination study must be done to see that the system complies with the 620.62 selective coordination requirement if EL-1, EL-2, and EL-3 are elevator motors. See following example: Fusible System.

Go to the Selective Coordination section for a more indepth discussion on how to analyze systems to determine if selective coordination can be achieved.



Quik-Spec Power Module Panel (PMP) for multiple elevator applications

Elevator Circuit

Example: Fusible System

In this example, LPJ-(amp)SP fuses will be used for the branch protection, LPS-RK-(amp)SP fuses will be used for the feeder protection, and KRP-C-(amp)SP fuses will be used for the main protection.

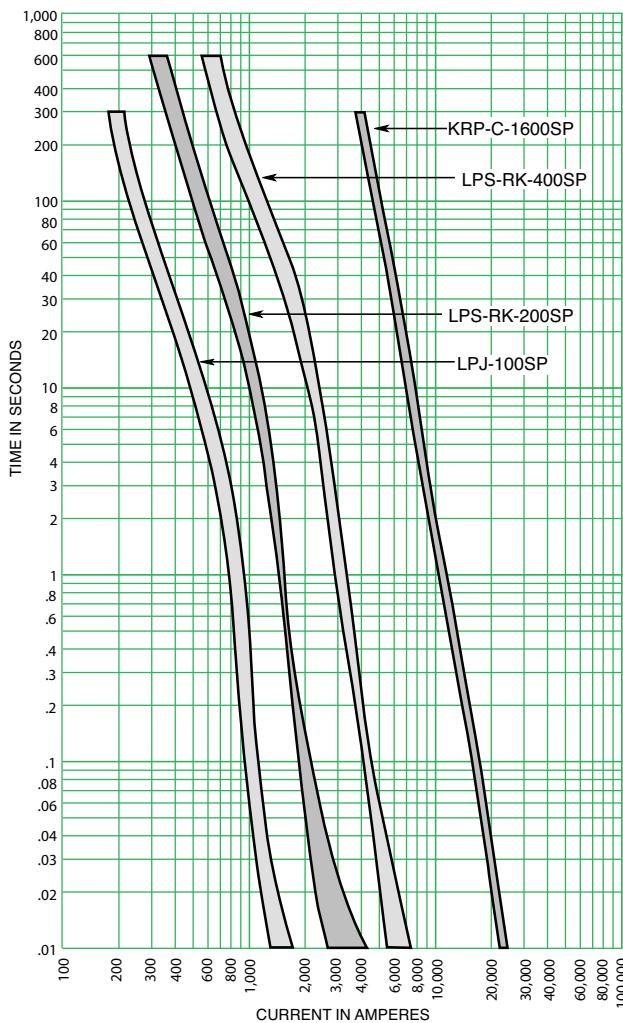


Figure 1
Elevator circuit selective coordination

To verify selective coordination, go no further than the Fuse Selectivity Ratio Guide in the Fuse Selective Coordination section in this publication. The Low-Peak fuses just require a 2:1 amp rating ratio to assure selective coordination. In this example, there is a 4:1 ratio between the main fuse (1600A) and the first level feeder fuse (400A) and a 2:1 ratio between the first level feeder fuse and the second level feeder fuse (200A). As well, there is a 2:1 ratio between the second level feeder fuse and the branch circuit fuse (100A). Since a minimum of a 2:1 ratio is satisfied at all levels for this system, selective coordination is achieved and 620.62 is met.

As just demonstrated in the prior paragraph, the fuse time-current curves do not have to be drawn to assess selective coordination. For illustrative purposes, the time-current curves for this example are shown above.

Introduction to Ground Fault Protection

Introduction

This section covers equipment protection from ground faults using ground fault protection relays per the NEC®, options to design systems without ground fault relays per the NEC® and selective coordination considerations for circuits with ground fault protection relays.

Requirements

The pertinent NEC® requirements for Ground Fault Protection Relays (GFPRs) are located in 230.95, 215.10, 240.13, 517.17, 695.6(G), 700.27, 701.26, and 708.52. These sections provide requirements where GFPRs must be used as well as requirements either not allowing GFPRs to be used or the option to not use GFPRs (where GFPRs otherwise would be required). For instance:

- GFPRs are required on 1000A or greater service disconnects for 480/277V, solidly grounded wye systems
- If a GFPR is on the service or feeder of a healthcare or COPS facility, then GFPRs must be on the next level of feeders, per 517.17(B) and 708.52(B) respectively
- GFPRs are not required for the alternate source of emergency systems (700.27) and legally required standby systems per 701.26.
- GFPRs can not be on the circuit paths for fire pumps per 695.6(G)
- For healthcare essential electrical systems, additional levels of GFPRs can not be on the loadside of certain transfer switches, per 517.17(B)

GFPRs are only required in a certain few applications. If the use of GFPRs is not desired, in some cases, there maybe design options in which GFPRs are not required, such as impedance grounded systems.

GFPR

Ground fault protection relays (or sensors) are used to sense ground faults. When the ground fault current magnitude and time reach the GFPR's pick-up setting (amp setting and time-delay setting), the control scheme signals the circuit disconnect to open. GFPRs only monitor and respond to ground fault currents.

Fuses and circuit breakers respond to any type overcurrent condition: overloads and short-circuit currents, including ground faults. Per the NEC®, for most premise circuits, the service, feeder, and branch circuit overcurrent protection (fuses or circuit breakers) are permitted to provide protection for all types of overcurrent conditions, including ground faults. However, for some very large ampacity circuits, the NEC® requires GFPRs, which are intended to provide equipment protection from lower magnitude ground fault currents.

Ground fault relays typically only provide equipment protection from the effects of low magnitude ground faults. GFPRs and disconnecting means typically are too slow for higher magnitude ground faults. Equipment protection against the effects of higher magnitude ground faults is dependent on the speed of response of the conventional overcurrent protective devices (fuses or circuit breakers).

GFPRs Do Not Provide:

- People protection: GFPRs do not prevent shock. Ground fault circuit interrupters (GFCIs) are required for certain 15 and 20A, 120V branch circuits, and are intended to protect people from shock hazard.
- Ground fault prevention
- Protection against 3-phase, phase-phase, or phase-neutral faults
- Adequate protection from high level faults of any kind.

Providing ground fault protection with a GFPR requires a sensor, monitor, shunt trip and circuit disconnecting means. A fusible switch with shunt trip capability can be equipped with GFPR. Figure 1 shows a bolted pressure switch equipped with GFPR. Circuit breakers with shunt trip capability also can be equipped in a similar manner. Some electronic trip circuit breakers have GFPR options where the GFPR components are internal to the circuit breaker.

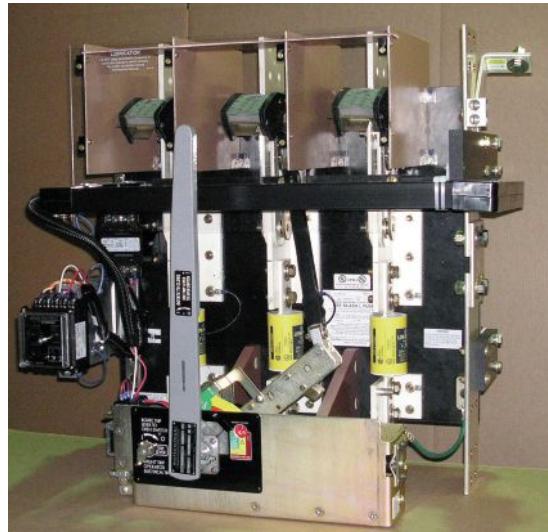


Figure 1

Fusible bolted pressure switch equipped with ground fault protection relay (Courtesy of Boltswitch, Inc.)

GFPR Characteristics and Settings

GFPRs typically have adjustable trip settings and various shaped time-current curves. The trip setting generally consists of selecting an amp set point from a range and selecting a time set point from a range. Understanding a GFPR's characteristics is important in assessing the level of protection of the equipment and in coordination. Too often a GFPR on a service is adjusted to a low amp and instantaneous trip setting. With this setting, a ground fault on a 20A branch circuit may unnecessarily cause a GFPR to open the service disconnect. If the GFPR is set properly, a fault on a 20A branch circuit would be interrupted by the 20A fuse or circuit breaker.

NEC® section 230.95 has a maximum current limit for GFPR characteristics of 1200A and an operational limit of 1 second at 3000A. GFPRs are available with various time-current shaped characteristics; some with a step function and some with an inverse time function such as shown in Figure 5. A GFPR's time-current characteristic curve shape, various amp set points, and various time-delay set points permit selecting time-current characteristics to provide the level of equipment protection needed and provide the level of coordination desired.

Selective Coordination

GFPRs should be included in a selective coordination analysis. This is covered later in GFPR Selective Coordination Considerations. If the use of a particular GFPR causes a lack of selective coordination, there may be other GFPR options available or there may be alternate design options.

The following pages on ground fault protection provide more information on the requirements and considerations for application of GFPRs.

Requirements

Section 230.95

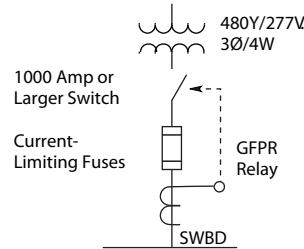
Ground Fault Protection of Equipment

This Section means that 480Y/277V, solidly grounded "wye" only connected service disconnects, 1000A and larger, must have ground fault protection in addition to conventional overcurrent protection. A ground fault protection relay, however, is not required on a service disconnect for a continuous process where its opening will increase hazards (240.13). All delta connected or impedance grounded services are not required to have GFP. The maximum setting for the ground fault protection relay (or sensor) can be set to pick up ground faults at a maximum of 1200A and actuate the main switch or circuit breaker to disconnect all phase conductors. A ground fault relay with a deliberate time-delay characteristic of up to 1 second, may be specified for currents greater than or equal to 3000A. (The use of such a relay greatly enhances system coordination and minimizes power outages - see Figure 5).

A ground fault protection relay in itself will not limit the line-to-ground or phase-to-phase short-circuit current. Therefore, it is recommended that current-limiting overcurrent protective devices be used in conjunction with GFP.

This system offers:

1. Some degree of arcing and low magnitude ground fault protection by the GFPR operating the switch.
2. Current limitation for high magnitude ground faults and short-circuits by current-limiting fuses, which provides component protection for the switchgear.

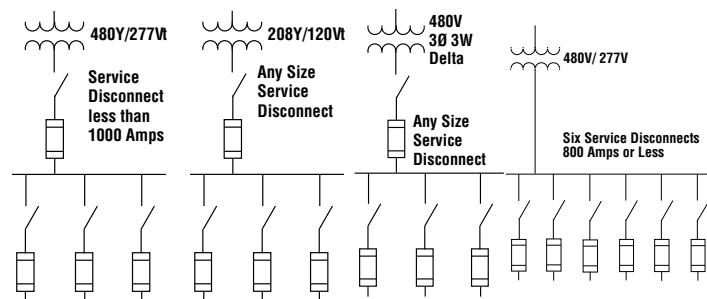


Where GFPRs are NOT Required

There are many services and feeders where 230.95, 215.10, and others do not require or permit ground fault protection including:

1. Continuous industrial process where a non-orderly shut down would increase hazards (section 230.95 exception and 240.13).
 - Alternate source of emergency systems (700.27) and legally required standby systems (701.26).
 - For healthcare essential electrical systems, additional levels of GFPRs are not permitted on the loadside of transfer switches.
2. All services or feeders where the disconnect is less than 1000 amps.
3. All 208Y/120 Volt, 3Ø, services or feeders.
4. All single-phase services or feeders including 240/120 Volt.
5. Resistance or impedance grounded systems, such as 480V, high resistance grounded wye systems.
6. High or medium voltage services or feeders; greater than 1000V. (See NEC® section 240.13 and 215.10 for feeder requirements.)
7. All services or feeders on delta systems (grounded or ungrounded) such as 480 Volt, 3Ø, 3W delta, or 240 Volt, 3Ø, 4W delta with midpoint tap.
8. Service with six disconnects or less (section 230.71) where each disconnect is less than 1000 amps. A 4000A service could be split into 5 - 800A switches.
9. Fire Pumps [(695.6(G))].
10. For feeders where ground fault protection is provided on the service (except for Healthcare Facilities and COPS. See section 517.17 and 708.52).

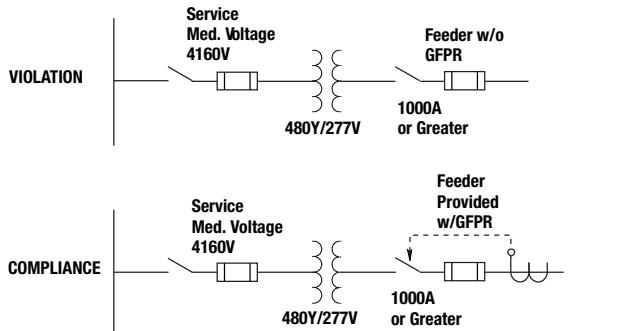
For instance, ground fault relays are not required on these systems.



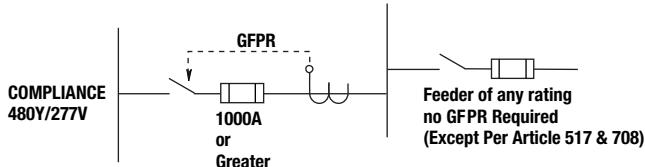
Requirements

215.10. – Ground Fault Protection of Equipment

Equipment classified as a feeder disconnect must have ground fault protection as specified in 230.95.

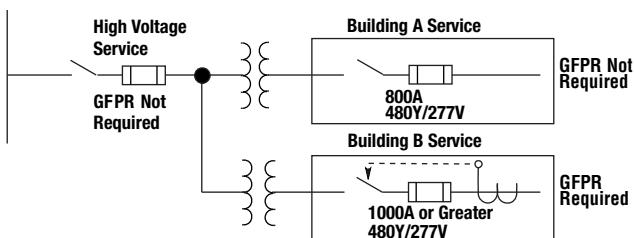


A ground fault protection relay will not be required on feeder equipment when it is provided on the supply side of the feeder (except for certain healthcare and COPS facilities Article 517 and 708).



240.13. – Ground Fault Protection of Equipment

Equipment ground fault protection of the type required in section 230.95 is required for each disconnect rated 1000A or more on 480Y/277V solidly grounded wye systems, that will serve as a main disconnect for a separate building or structure. Refer to sections 215.10 and 230.95.



Two Levels of Ground Fault Protection

If ground fault protection is placed on the main service of a healthcare facility (517.17) or critical operations power system (708.52), ground fault protection must also be placed on the next level of feeders. For COPS, the separation between ground fault relay time bands for any feeder and main ground fault protection relay must be at least six cycles in order to achieve coordination between these two ground fault protection relays. If the requirements of 230.95, 240.13, or 215.10 do not require a ground fault protection relay and no ground fault protection relay is utilized on the main service disconnect or feeder disconnect, then no ground fault protection relays are required on the next level downstream. See Figure 2.

Healthcare Facility and Critical Operations Power Systems

- When a ground fault protection relay is placed on the service or feeder then,
- Ground fault protection relays must also be placed on the next level downstream, (for selective coordination) and for COPS Systems only, the upstream ground fault protection relay time band must have a 6 cycle separation from the downstream ground fault relay.

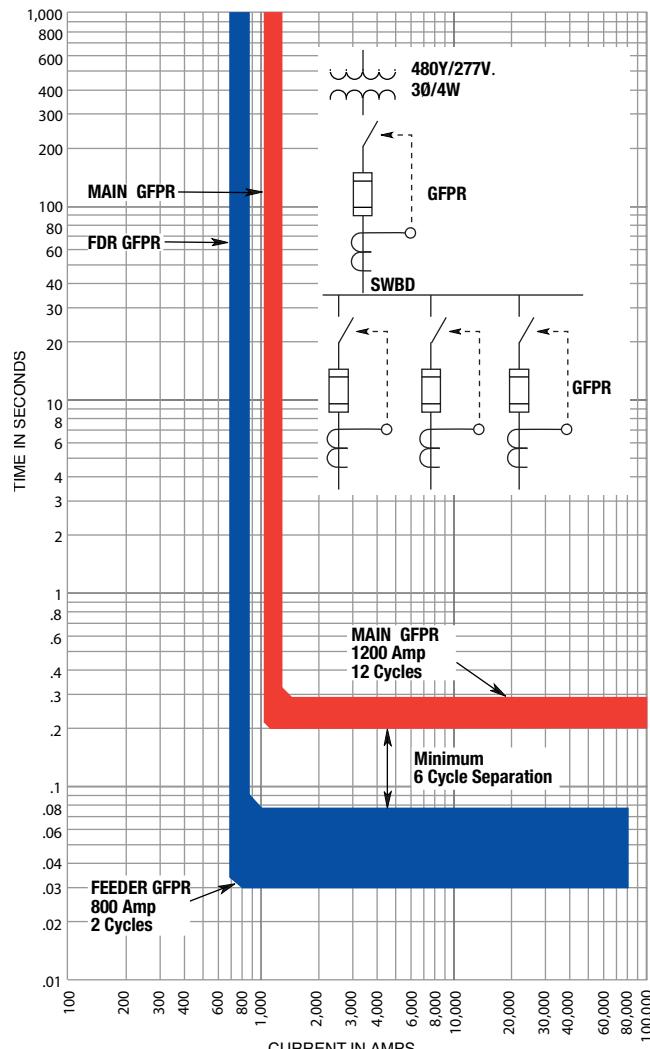


Figure 2

Note: Merely providing coordinated ground fault protection relays does not prevent a main service blackout caused by feeder or branch circuit ground faults. The phase overcurrent protective devices must also be selectively coordinated. The intent of 517.17 and 708.52 is to achieve "100 percent selectivity" for all magnitudes of ground fault current and overcurrents. 100% selectivity requires that the phase overcurrent protective devices working in conjunction with the ground fault relay(s) be selectively coordinated for all values of ground fault current, including medium and high magnitude ground fault currents. This is because the conventional phase overcurrent devices may operate at these higher levels.

Overcurrent Protective Devices

Analysis of Ground Fault Relay

Curves and Overcurrent Device Curves

To a fuse or circuit breaker, ground fault current is sensed just as any other current. If the ground fault current is high enough, the fuse or circuit breaker responds before the ground fault protection relay (this depends on the GFPR setting, overcurrent device characteristics, speed of response of the overcurrent device and ground fault current magnitude). Therefore, when analyzing ground fault protection, it is necessary to study the characteristics of the GFPR and overcurrent protective device as a combination.

The combination of the GFPR and overcurrent device have a ground fault "effective curve." This is a composite of the ground fault relay and overcurrent protective device curves. When analyzing line-to-ground faults, the "effective" curve of the ground fault protection relay and conventional overcurrent protective device must be examined.

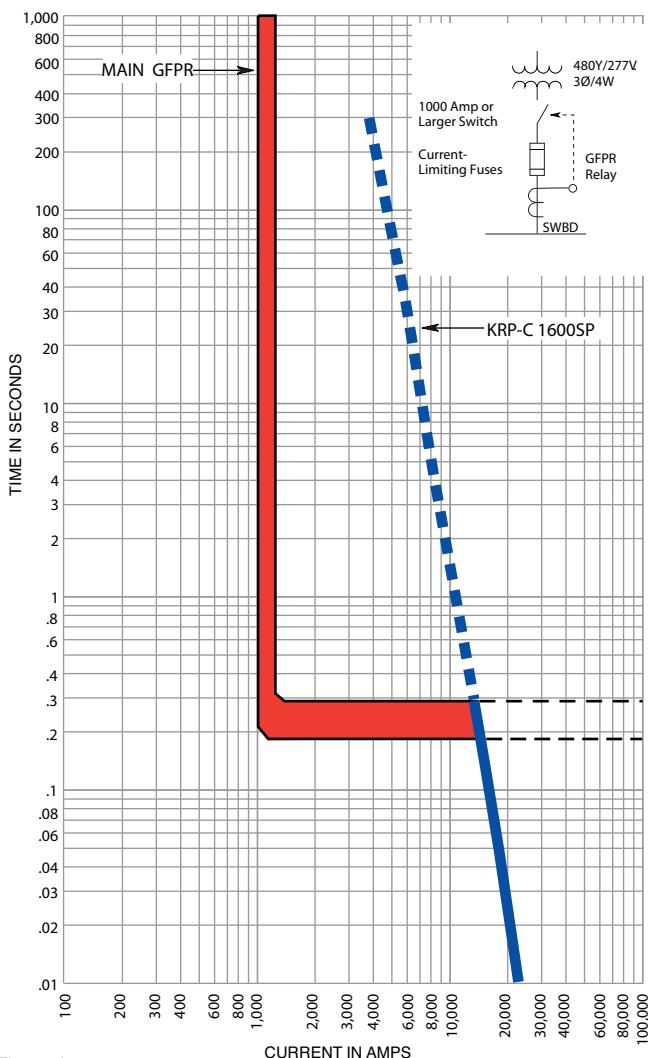


Figure 3

"Effective" time-current curve for line to ground fault with 1600A fuse and ground fault protection relay set at 1200A.

Figure 3 above is the "effective" ground fault curve for a 1600A fuse in combination with a ground fault relay scheme set at 1200A pickup and 12 cycle delay.

Figure 4 below is the "effective" ground fault curve for a 1600A circuit breaker in combination with a ground fault protection relay scheme set at 1200A and 12 cycle delay.

In Figures 3 and 4 notice that for ground fault current less than approximately 14,000A the GFPR sensor responds and signals the bolted pressure switch (Fig. 3) or circuit breaker (Fig. 4) to open. For ground fault current greater than approximately 14,000A in Figure 3 the fuses will respond faster than the GFPR and in Figure 4 the circuit breaker phase overcurrent sensors will respond faster than the GFPR. In Figure 3, the fuses become current-limiting above approximately 22,000A whether the fault is due to ground fault or other type fault.

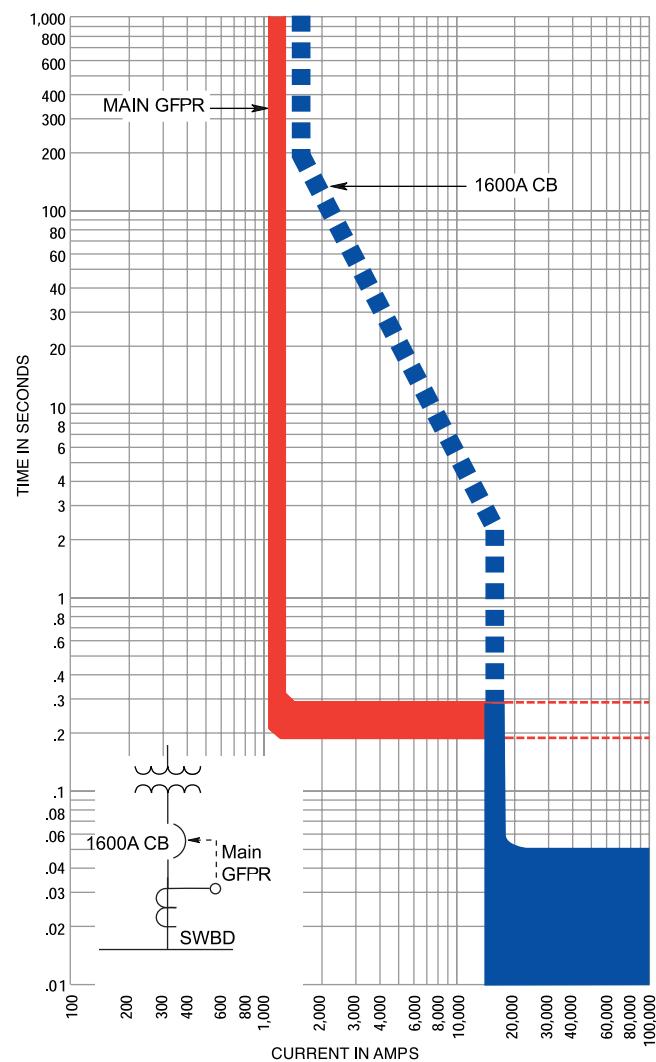


Figure 4

"Effective" time-current curve for line-to-ground fault with 1600A circuit breaker and ground fault sensor setting at 1200A.

GFPR Considerations

When ground fault protection relays are used in a system, selective coordination should include an analysis of the circuit paths for ground faults. As previously mentioned, GFPRs only monitor and respond to ground fault currents. Branch circuit fuses and circuit breakers sense and respond to all types of overcurrents. Therefore, when analyzing a circuit path for selective coordination, GFPRs should be included. For circuit paths with GFPRs, there are two components in a coordination analysis:

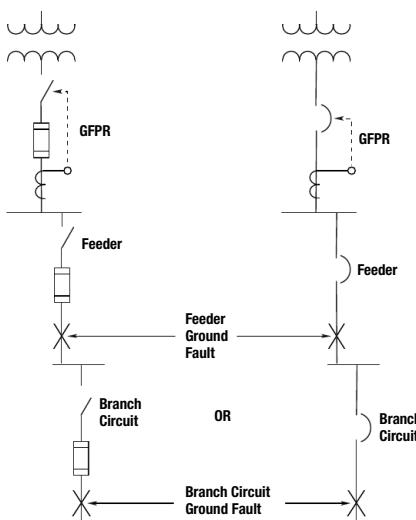
1. Analyze the circuit paths only considering the fuses or circuit breakers for all types of overcurrents. Previous sections in this publication cover this in depth.
2. Analyze the circuit paths for just ground faults. In this case, the GFPR characteristics and the fuse or circuit breaker characteristics must be considered together. Remember, fuses and circuit breakers monitor and respond to any type overcurrent, so they should be factored in also. The following pages have some important considerations for this analysis.
 - A. One step ground fault relaying (starts on this page)
 - B. Two step ground fault relaying (starting on a later page)

A. One Step Ground Fault Relaying

When a ground fault occurs on a feeder or branch circuit it is highly desirable for the feeder or branch circuit overcurrent device to clear that fault before the main device opens, thus preventing an unnecessary system blackout. However, this is not always the case when a ground fault relay is located on the main or when the overcurrent protective devices are not selectively coordinated.

To avoid unnecessary service disruptions (or BLACKOUTS):

1. The characteristics of the main overcurrent device must be analyzed with relation to the feeder and branch circuit overcurrent protective devices.
2. The characteristics of the feeder and/or branch circuit overcurrent devices must be analyzed with relation to the main ground fault protection relay characteristics and with the next lower level of ground fault relay(s) if provided.



Selective coordination should be investigated for low and high magnitude ground faults. Generally on low magnitude ground faults the feeder overcurrent device must be selective with the main ground fault relay. For high magnitude ground faults it is necessary also to consider selective coordination between the main phase overcurrent device and downstream phase overcurrent devices.

Low Magnitude Ground Faults on Feeders – One Step Ground Fault Relaying.

For low magnitude feeder ground faults, the feeder overcurrent protective device can clear the circuit without disrupting the main service if the feeder overcurrent device lies to the left of the ground fault protection relay and does not cross at any point.

In Figures 5 and 6, the ground fault protection relay located on the main has an operating time-delay of 18 cycles and 1200A pickup. Its inverse-time characteristic with the maximum 1 second opening time at 3000A improves selective coordination with downstream devices.

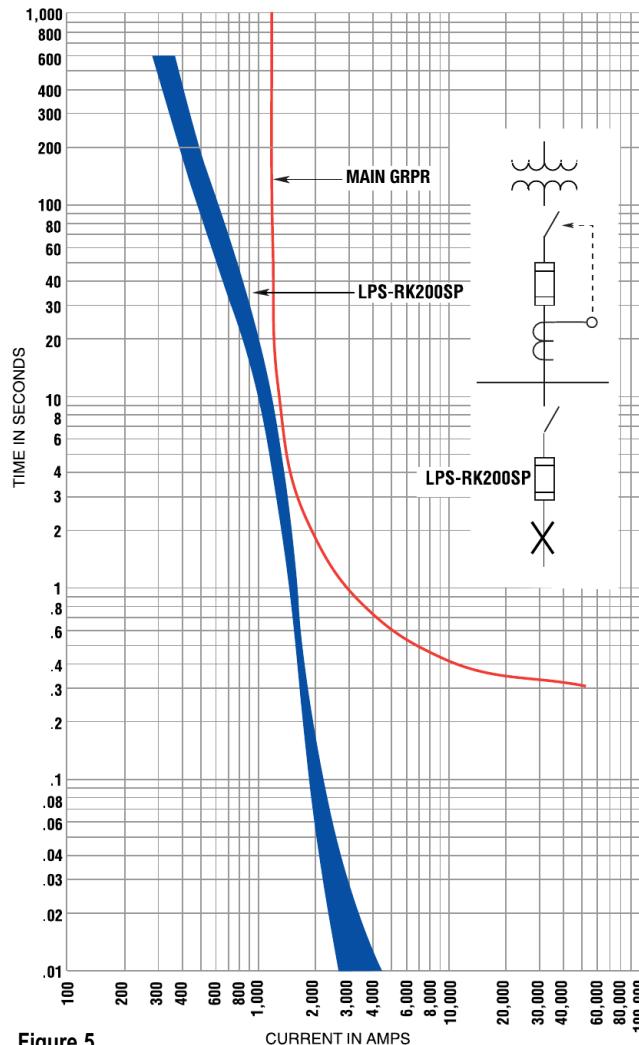


Figure 5

Fuse System

Selective coordination considerations for low magnitude feeder ground faults. Longer GFPR delay permits larger feeder fuse to coordinate with main relay.

Figure 5 illustrates that an inverse-time main ground fault relay may permit a larger size feeder fuse to selectively coordinate with the ground fault relay. In this case, the inverse time ground fault relay is set at 1200A and 18 cycle delay. An LPS-RK-200SP amp feeder fuse coordinates with this main ground fault relay. A JKS-400A feeder fuse, which is a non time-delay fuse, coordinates with this same main GFPR (figure not included).

GFPR Considerations

High Magnitude Ground Faults on Feeders – One Step Ground Fault Relaying

For higher magnitude ground faults, it is generally necessary to consider the characteristics of the main overcurrent protective device as well as the ground fault relay. Conventional phase overcurrent protective devices, fuses or circuit breakers, operate the same way for a high magnitude ground fault or a high magnitude phase-to-phase short-circuit. Therefore, when a high magnitude feeder ground fault occurs, the main overcurrent device must be considered in relation to the feeder overcurrent device. To achieve selective coordination and prevent a blackout for high magnitude ground faults, the feeder overcurrent device must be selective with the main overcurrent device.

KRP-C-1200SP 1200 amp fuses. Figure 7 fuse time-current curves show coordination for the portion of the curves shown (up to approximately 17,000A). For currents greater than 17,000A, using the Selectivity Ratio Guide presented in the Selective Coordination Section shows that the LPS-RK-200A fuses selectively coordinate with the KRP-C-1200SP fuses up to 200,000A for any type overcurrent including ground fault currents.

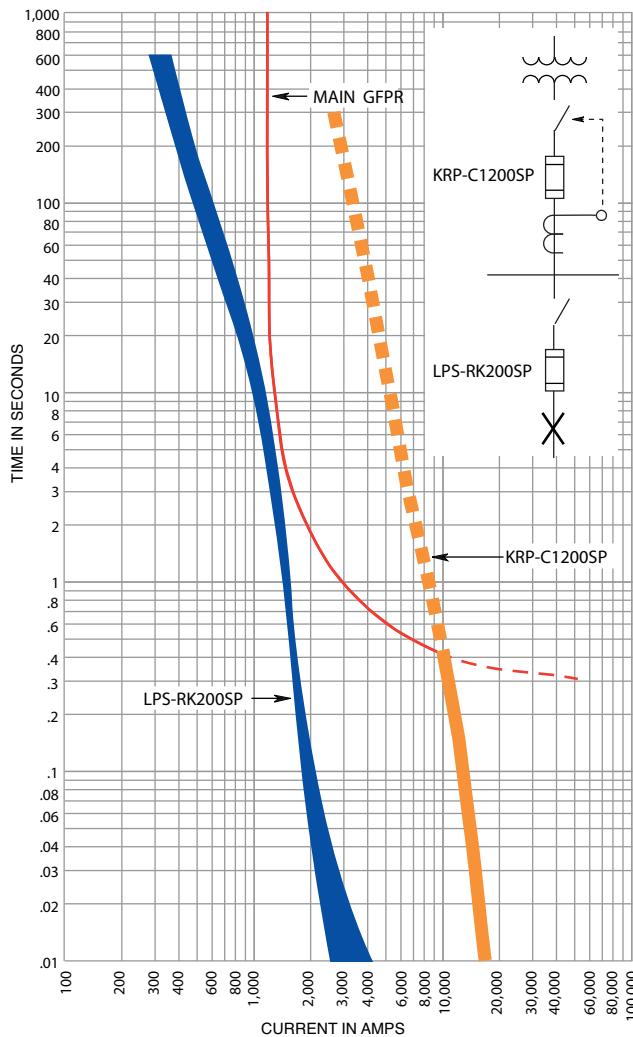


Figure 6

Selective coordination considerations for high magnitude feeder ground faults requires analysis of main and feeder overcurrent devices. In this case the fuses are selectively coordinated so that an unnecessary blackout does not occur.

Fuse System

Figure 6 illustrates that the feeder LPS-RK-200SP 200 amp fuse selectively coordinates with the inverse-time main GFPR for all levels of ground faults. Also, for any type overcurrent including low level and high level ground faults the LPS-RK-200SP fuse selectively coordinates with the main

GFPR Considerations

B. Two Step Ground Fault Relaying

Two step ground fault relaying includes ground fault relays on the main service and feeders.

In many instances, this procedure can provide a higher degree of ground fault coordination to prevent unnecessary service blackouts. Yet it is mistakenly believed by many that two step ground fault relays assure total ground fault coordination. For complete selective coordination of all ground faults, the conventional phase overcurrent protective devices must be selectively coordinated as well as the ground fault relays. The fact is that even with this two step relay provision, ground fault coordination is not assured on many systems designed where the main fuses or circuit breakers are not selectively coordinated with the feeder fuses or circuit breakers. The analysis must also include the phase overcurrent protective devices since these devices also respond to all types of fault currents, including ground faults.

In many cases two step relays do provide a higher degree of ground fault coordination. When properly selected, the main fuse can be selectively coordinated with the feeder fuses. Thus on all feeder ground faults or short circuits the feeder fuse will always open before the main fuse. When selectively coordinated main and feeder fuses are combined with selectively coordinated main and feeder ground fault protection relays, ground fault coordination between the main and feeder is predictable.

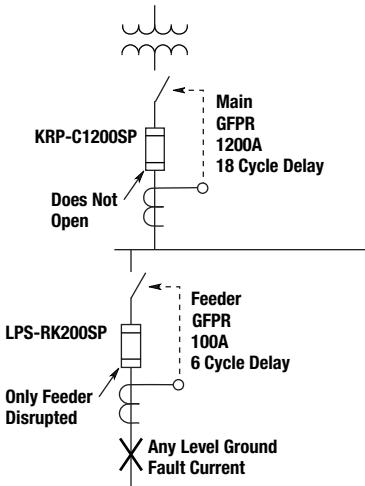


Figure 7

Figures 7 and 8 illustrate a selectively coordinated main and feeder for all levels of ground faults, overloads and short-circuits. Any fault on the feeder will not disrupt the main service.

This system offers full selective coordination for all levels of ground faults or short-circuits.

1. The feeder ground fault relay is set at a lower time band than the main ground fault relay, therefore the relays are coordinated.
2. The feeder fuses are selectively coordinated with the main fuses for all ground faults, short-circuits or overloads on the loadside of the feeder. The feeder fuses would clear the fault before the main fuses open.

If downstream circuits must be selectively coordinated with the feeder GFPR and overcurrent protective devices, the analysis needs to include the downstream overcurrent protective devices.

For healthcare facilities (517.17) and Critical Operations Power Systems (708.52), the main and feeders are required to be 100% selectively coordinated for all magnitudes of ground fault current - including low, medium and high ground fault currents. The system shown in Figures 7 & 8 comply with 517.17 and 708.52.

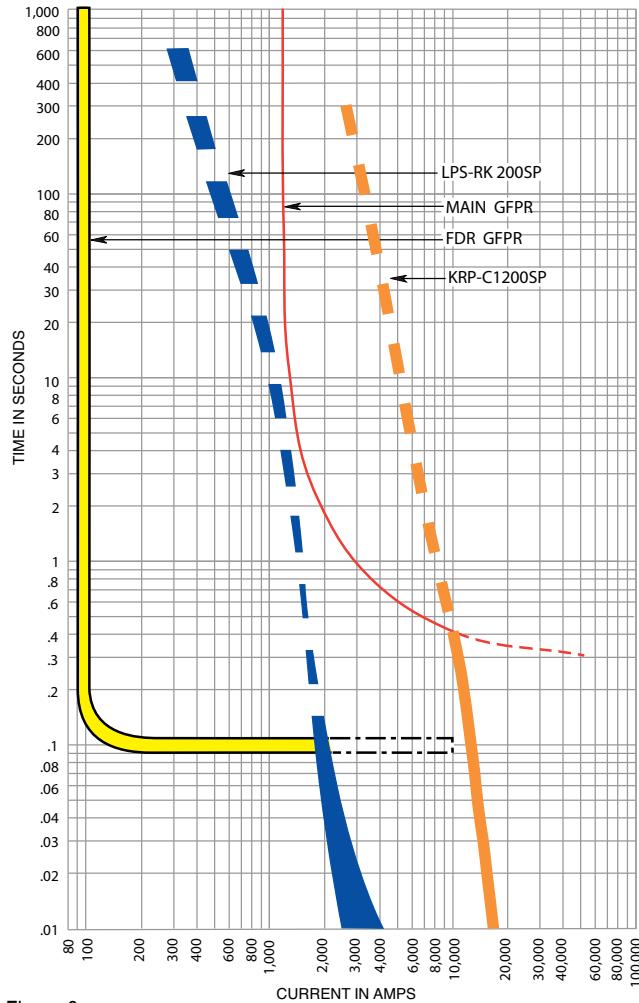


Figure 8

Design Options

GFPRs are only required in certain applications. If the use of GFPRs cause selective coordination issues, or is not desired, there are design options to resolve the issues:

- Use inverse-time ground fault relays and set the amp set point and time delay set point as high as practical
- Utilize a 480V high resistance grounded wye system. This type of system does not require GFPRs. These systems also reduce the probability of a hazardous arcing-fault starting from line-to-ground faults; this benefits worker safety. Loads requiring neutrals must be fed from downstream transformers, which can be 208/120V solidly grounded wye systems or 480/277V solidly grounded wye systems with secondary feeder disconnects of 800A or less.
- Design 480/277V solidly grounded wye services using up to six 800A or less disconnects (230.71).
- For circuits supplying loads where there are alternate sources, place the automatic transfer switches close to the loads. Use smaller transfer switches placed closer to the final panelboard or large branch circuit loads. This option requires more transfer switches and longer cable runs. However, it enhances the reliability of supplying power to vital loads.

Introduction

Introduction

There is a great deal of activity in the electrical industry concerning electrical safety. The present focus is on two of the greatest electrical hazards to workers: shock and arc flash. In recent years, significant knowledge has been gained through testing and analysis concerning arc flash hazards and how to contend with this type of hazard. Note: a third electrical hazard is arc blast and work is ongoing to learn more about how to deal with this electrical hazard. NFPA 70E "Standard for Electrical Safety in the Workplace," 2012 Edition, is the foremost consensus standard on electrical safety. References to NFPA 70E in this section are to the 2012 NFPA 70E.

Why is there an NFPA 70E?

In 1976 a new electrical standards development committee was formed to assist the Occupational Safety and Health Administration (OSHA) in preparing electrical safety standards. This committee on Electrical Safety Requirements for Employee Workplaces, NFPA 70E, was needed for a number of reasons, including:

1. The NEC® is an installation standard while OSHA addresses employee safety in the workplace,
2. Most sections in the NEC® do not relate to worker safety
3. Safety related work and maintenance practices are generally not covered, or not adequately covered, in the NEC® and
4. A national consensus standard on electrical safety for workers did not exist, but was needed – an easy to understand document that addresses worker electrical safety.

The first edition of NFPA 70E was published in 1979. In most cases, OSHA regulations can be viewed as the *Why* and NFPA 70E as the *How*. Although OSHA and NFPA 70E may use slightly different language, in essence, NFPA 70E does not require anything that is not already an OSHA regulation. In most cases, OSHA is performance language and NFPA 70E is prescriptive language.

If an arcing fault occurs, the tremendous energy released in a fraction of a second can result in serious injury or death. NFPA 70E, Article 100, defines an arc flash hazard as:

a dangerous condition associated with the possible release of energy caused by an electric arc.

The first informational note to this definition indicates that an arc flash hazard may exist when electrical conductors or circuit parts, which are not in an electrically safe work condition, are exposed or may exist if a person is interacting with the equipment even when the conductors or circuit parts within equipment are in a guarded or enclosed condition.

While awareness of arc flash hazards is increasing, there is a great challenge in communicating the message to the populace of the electrical industry so that safer system designs and safer work procedures and behaviors result. Workers continue to suffer life altering injuries or death.

Only Work On Equipment That Is In An Electrically Safe Work Condition

The rule for the industry and the law is "*don't work it hot*," OSHA 1910.333(a)(1) requires live parts to be deenergized before an employee works on or near them except for two demonstrable reasons by the employer:

1. Deenergizing introduces additional or increased hazards (such as cutting ventilation to a hazardous location) or
2. Infeasible due to equipment design or operational limitations (such as when voltage testing is required for diagnostics).

Similarly, NFPA 70E 130.2 requires energized electrical conductors and circuit parts to be put in an electrically safe work condition before an employee works

within the *Limited Approach Boundary* of those conductors or parts or the employee interacts with parts that are not exposed but an increased arc flash hazard exists, unless justified in accordance with NFPA 70E 130.2(A). *NFPA 70E, Article 100, defines an electrically safe work condition as:*

A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

NFPA 70E 130.3(A)(2) requires work on electrical conductors or circuit parts not in an electrically safe work condition to be performed by only qualified persons. In some situations, an arc flash hazard may exist beyond the Limited Approach Boundary. It is advisable to use the greater distance of either the Limited Approach Boundary or the Arc Flash Boundary in complying with NFPA 130.3(A)(2).

NFPA 70E 130.2(A)(1) permits energized work if the employer can demonstrate energized work introduces additional or increased hazards or per NFPA 130.2(A)(2) if the task to be performed is infeasible in a deenergized state due to equipment design or operational limitations. Financial considerations are not an adequate reason to perform energized work. Not complying with these regulations and practices is a violation of federal law, which is punishable by fine and/or imprisonment.

When energized work is justified per NFPA 70E 130.2(A)(1) or (A)(2), NFPA 70E 130.3(B)(1) requires an electrical hazard analysis (shock hazard analysis in accordance with NFPA 70E 130.4(A) and an arc flash hazard analysis in accordance with NFPA 70E 130.5. A written energized electrical work permit may also be required per NFPA 70E 130.2(B)(1). When an energized electrical work permit is required, it must include items as shown in NFPA 70E 130.2(B)(2). Some key items of the energized electrical work permit include determination of the shock protection boundaries in accordance with NFPA 70E 130.4(B), the Arc Flash Boundary in accordance with NFPA 70E 130.5, and the necessary protective clothing and other Personal Protective Equipment (PPE) in accordance with NFPA 70E 130.5. Similarly, OSHA 1910.132(d)(2) requires the employer to verify that the required workplace hazard assessment has been performed through a written certification that identifies the workplace evaluated; the person certifying that the evaluation has been performed; the date(s) of the hazard assessment; and, identifies the document as a certification of hazard assessment.

Note: deenergized electrical parts are considered as energized until all steps of the lockout/tagout procedure are successfully completed per OSHA 1910.333(b)(1). Similarly, all electrical conductors and circuit parts must be considered to not be in an electrically safe work condition until all the requirements of Article 120 have been met per NFPA 70E 120.2(A).

Verifying that the circuit elements and equipment parts are deenergized by a qualified person is a required step while completing the lockout/tagout procedure per OSHA 1910.333(b)(2)(iv)(B). Conductors and parts of electric equipment that have been deenergized but have not been locked out or tagged and proven to be deenergized are required to be treated as energized parts per 1910.333(b)(1). Similarly NFPA 70E 120.2(A) requires that all electrical conductors and circuit parts are not considered to be in an electrically safe work condition - until the entire process of establishing the electrically safe work condition is met.

Therefore, adequate PPE is always required during the tests to verify the absence of voltage during the lockout/tagout procedure or when putting equipment in an electrically safe work condition. Adequate PPE may also be required during load interruption and during visual inspection that verifies all disconnecting devices are open.

Shock Hazard Analysis

No matter how well a worker follows safe work practices, there will always be a risk associated with interacting with electrical equipment – even when putting equipment in an electrically safe work condition. And there are those occasions where it is necessary to work on energized equipment such as when a problem can not be uncovered by troubleshooting the equipment in a deenergized state.

What Can Be Done To Lessen the Risk?

There are numerous things that can be implemented to increase electrical safety, from design aspects and upgrading systems, to training, implementing safe work practices and utilizing PPE. Not all of these topics can be covered in this section. The focus of this section will mainly concern some overcurrent protection aspects related to electrical safety.

Shock Hazard Analysis

The Shock Hazard Analysis per NFPA 70E 130.4(A) requires the determination of the voltage exposure as well as the boundary requirements and the PPE necessary to minimize the possibility of electric shock. There are three shock approach boundaries required to be observed in NFPA 70E Table 130.4(C)(a); these shock approach boundaries are dependent upon the system voltage. The significance of these boundaries for workers and their actions while within the boundaries can be found in NFPA 70E. See Figure 2 for a graphic depiction of the three shock approach boundaries with the Arc Flash Boundary (following the section on arc flash Hazard Assessment). For electrical hazard analysis and worker protection, it is important to observe the shock approach boundaries together with the Arc Flash Boundary (which is covered in paragraphs ahead).

Although most electrical workers and others are aware of the hazard due to electrical shock, it still is a prevalent cause of injury and death. One method to help minimize the electrical shock hazard is to utilize finger-safe products and non-conductive covers or barriers. Finger-safe products and covers reduce the chance that a shock or arcing fault can occur. If all the electrical components are finger-safe or covered, a worker has a much lower chance of coming in contact with a live conductor (shock hazard), and the risk of a conductive part falling across bare, live conductive parts creating an arcing fault is greatly reduced (arc flash hazard). Shown below are the new CUBEFuses that are IP20 finger-safe, in addition, they are very current-limiting protective devices. Also shown are SAMI™ fuse covers for covering fuses, Safety J™ fuse holders for LPJ fuses, CH fuse holders, new fuseblocks with integral covers, available for a variety of Bussmann fuses and disconnect switches, with fuse and terminal shrouds. All these devices can reduce the chance that a worker, tool or other conductive item will come in contact with a live part.



Arc Flash Hazard

Arc Fault Basics

An electrician that is working in an energized panelboard or just putting equipment into an electrically safe work condition is potentially in a very unsafe place. A falling knockout, a dislodged skinned wire scrap inadvertently left previously in the panelboard or a slip of a screwdriver can cause an arcing fault. The temperature of the arc can reach approximately 35,000°F, or about four times as hot as the surface of the sun. These temperatures easily can cause serious or fatal burns and/or ignite flammable clothing.

Figure 1 is a model of an arc fault and the physical consequences that can occur. The unique aspect of an arcing fault is that the fault current flows through the air between conductors or a conductor(s) and a grounded part. The arc has an associated arc voltage because there is arc impedance. The product of the fault current and arc voltage concentrated at one point results in tremendous energy released in several forms. The high arc temperature vaporizes the conductors in an explosive change in state from solid to vapor (copper vapor expands to 67,000 times the volume of solid copper). Because of the expansive vaporization of conductive metal, a line-to-line or line-to-ground arcing fault can escalate into a three-phase arcing fault in less than a thousandth of a second. The speed of the event can be so rapid that the human system can not react quickly enough for a worker to take corrective measures. If an arcing fault occurs while a worker is in close proximity, the survivability of the worker is mostly dependent upon (1) system design aspects, such as characteristics of the overcurrent protective devices and (2) precautions the worker has taken prior to the event, such as wearing PPE, appropriate for the hazard.

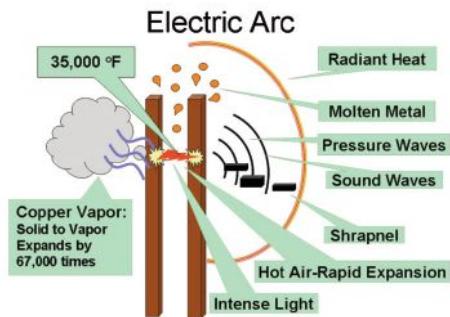


Figure 1. Electrical Arc Model

The effects of an arcing fault can be devastating on a person. The intense thermal energy released in a fraction of a second can cause severe burns. Molten metal is blown out and can burn skin or ignite flammable clothing. One of the major causes of serious burns and death to workers is ignition of flammable clothing due to an arcing fault. The tremendous pressure blast from the vaporization of conducting materials and superheating of air can fracture ribs, collapse lungs and knock workers off ladders or blow them across a room. The pressure blast can cause shrapnel (equipment parts) to be hurled at high velocity (can be in excess of 700 miles per hour). And the time in which the arcing event runs its course can be only a small fraction of a second. Testing has proven that the arcing fault current magnitude and time duration are the most critical variables in determining the energy released. Serious accidents are occurring at an alarming rate on systems of 600V or less, in part because of the high fault currents that are possible; but also, designers, management and workers mistakenly tend not to take the necessary precautions they take when designing or working on medium and high voltage systems.

The Role of Overcurrent Protective Devices In Electrical Safety

The selection and performance of overcurrent protective devices play a significant role in electrical safety. Extensive tests and analysis by industry has

shown that the energy released during an arcing fault is related to two characteristics of the overcurrent protective device protecting the affected circuit. These two characteristics are 1) the time it takes the overcurrent protective device to open and 2) the amount of fault current the overcurrent protective device lets-through. For instance, the faster the fault is cleared by the overcurrent protective device, the lower the energy released. If the overcurrent protective device can also limit the current, thereby reducing the actual fault current magnitude that flows through the arc, the lower the energy released. Overcurrent protective devices that are current-limiting can have a great affect on reducing the energy released. The lower the energy released the better for both worker safety and equipment protection.

The photos and recording sensor readings from actual arcing fault tests (next page) illustrate this point very well. An ad hoc electrical safety working group, within the IEEE Petroleum and Chemical Industry Committee, conducted these tests to investigate arc fault hazards. These tests and others are detailed in *Staged Tests Increase Awareness of Arc-Fault Hazards in Electrical Equipment*, IEEE Petroleum and Chemical Industry Conference Record, September, 1997, pp. 313-322. This paper can be found at www.bussmann.com. One finding of this IEEE paper is that current-limiting overcurrent protective devices reduce damage and arc-fault energy (provided the fault current is within the current-limiting range). To better assess the benefit of limiting the current of an arcing fault, it is important to note some key thresholds of injury for humans. Results of these tests were recorded by sensors on mannequins and can be compared to these parameters:

Just Curable Burn Threshold:	80°C / 175°F (0.1 sec)
Incurable Burn Threshold:	96°C / 205°F (0.1 sec)
Eardrum Rupture Threshold:	720 lbs/ft ²
Lung Damage Threshold:	1728 - 2160 lbs/ft ²
OSHA Required Ear Protection Threshold:	85db (for sustained time period)

(Note: an increase of 3 db is equivalent to doubling the sound level.)

Arc Flash Tests

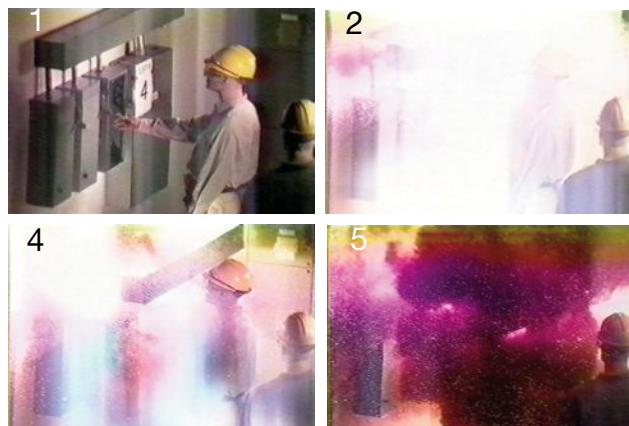
All three of these tests were conducted on the same electrical circuit set-up with an available bolted three-phase, short-circuit current of 22,600 symmetrical RMS amps at 480V. In each case, an arcing fault was initiated in a size 1 combination motor controller enclosure with the door open, as if an electrician were working on the unit "live" or before it was placed in an electrically safe work condition.

Test 4 and Test 3 were identical except for the overcurrent protective device protecting the circuit. In Test 4, a 640 OCPD protecting the circuit, interrupts the fault current in 6 cycles. In Test 3, KRP-C-601SP, 601 amp, current-limiting fuses (Class L) are protecting the circuit; they opened the fault current in less than $\frac{1}{2}$ cycle and limited the current. The arcing fault was initiated on the lineside of the motor branch circuit device in both Test 4 and Test 3. This means the fault is on the feeder circuit but within the controller enclosure.

In Test 1, the arcing fault is initiated on the loadside of the branch circuit overcurrent protective devices, which are LPS-RK-30SP, 30 amp, current-limiting fuses (Class RK1). These fuses limited this fault current to a much lower value and cleared this circuit in approximately $\frac{1}{2}$ cycle or less.

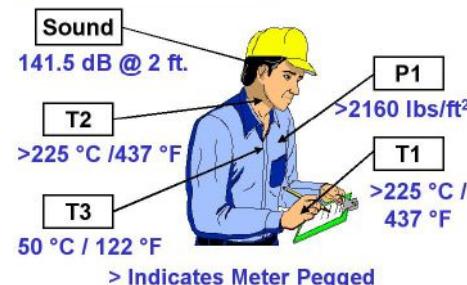
Following are the results recorded from the various sensors on the mannequin closest to the arcing fault. T1 and T2 recorded the temperature on the bare hand and neck respectively. The hand with T1 sensor was very close to the arcing fault. T3 recorded the temperature on the chest under the shirt. P1 recorded the pressure on the chest. And the sound level was measured at the ear. Some results "pegged the meter." That is, the specific measurements were unable to be recorded in some cases because the actual level exceeded the range of the sensor/recorder setting. These values are shown as ">", which indicates that the actual value exceeded the value given but it is unknown how high of a level the actual value attained.

Arc Flash Tests - Photos & Results



Test Video 4

Results: Test No.4



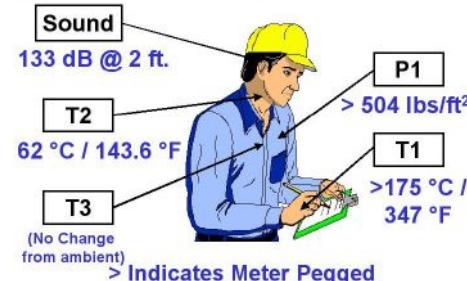
Test 4:

Staged test protected by OCPD which interrupted the fault current in six cycles (0.1 second) (not a current-limiting overcurrent protective device). Note: Unexpectedly, there was an additional fault in the wireway and the blast caused the cover to hit the mannequin in the head. Analysis results in incident energy of 5.8 cal/cm² and Arc Flash Boundary of 47 inches per 2002 IEEE 1584 (basic equations).



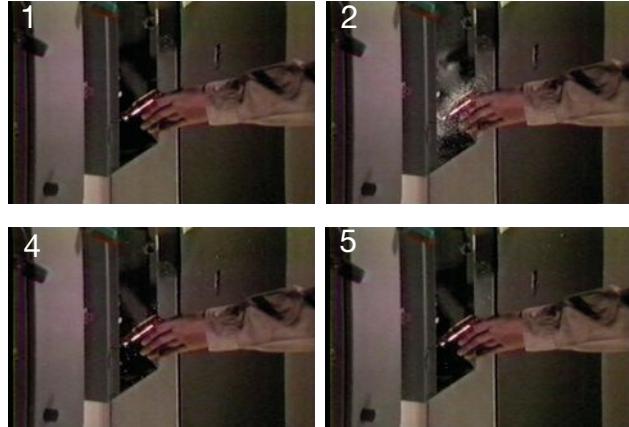
Test Video 3

Results: Test No.3



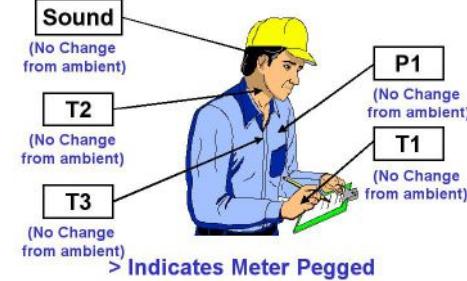
Test 3:

Staged test protected by KRP-C-601SP Low-Peak™ current-limiting fuses (Class L). These fuses were in their current-limiting range and cleared in less than a 1/2 cycle (0.008 second). Analysis results in incident energy of 1.58 cal/cm² and arc flash boundary of 21 inches per 2002 IEEE 1584 (simplified fuse equations).



Test Video 1

Results: Test No.1



Test 1:

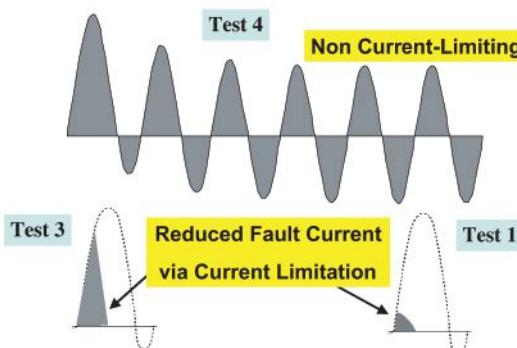
Staged test protected by LPS-RK-30SP Low-Peak current-limiting fuses (Class RK1). These fuses were in current-limiting range and cleared in approximately 1/4 cycle (0.004 second). Analysis results in incident energy of less than 0.25 cal/cm² and Arc Flash Boundary of less than 6 inches per 2002 IEEE 1584 (simplified fuse equations).

Arc Flash Hazard Analysis

A couple of conclusions can be drawn from this testing.

- (1) Arcing faults can release tremendous amounts of energy in many forms in a very short period of time. Look at all the measured values compared to key thresholds of injury for humans given in a previous paragraph. Test 4 was protected by a 640 A, non current-limiting device that opened in 6 cycles or 0.1 second.
- (2) The overcurrent protective devices' characteristic can have a significant impact on the outcome. A 601 amp, current-limiting overcurrent protective device, protects the circuit in Test 3. The current that flowed was reduced (limited) and the clearing time was $\frac{1}{2}$ cycle or less. This was a significant reduction compared to Test 4. Compare the Test 3 measured values to the key thresholds of injury for humans and the Test 4 results. The measured results of Test 1 are significantly less than those in Test 4 and even those in Test 3. The reason is that Test 1 utilized a much smaller (30 amp), current-limiting device. Test 3 and Test 1 both show that there are benefits of using current-limiting overcurrent protective devices. Test 1 just proves the point that the greater the current-limitation, the more the arcing fault energy may be reduced. Both Test 3 and Test 1 utilized very current-limiting fuses, but the lower amp rated fuses limit the current more than the larger amp rated fuses. It is important to note that the fault current must be in the current-limiting range of the overcurrent protective device in order to receive the benefit of the lower current let-through. See the diagram below that depicts the oscillographs of Test 4, Test 3 and Test 1.

Current-Limitation: Arc-Energy Reduction



- (3) The cotton shirt did not ignite and reduced the thermal energy exposure on the chest (T3 measured temperature under the cotton shirt). This illustrates the benefit of workers wearing protective garments.

Note: Per NFPA 70E 130.7(C)(6): Arc-Rated (AR) clothing is required wherever there is a possible exposure to an electric arc flash above the threshold incident energy level for a second-degree (just curable) burn (1.2 cal/cm²).

Arc Flash Hazard Analysis

As discussed, arc flash currents can release tremendous amounts of energy. NFPA 70E 130.3(B)(1) requires an arc flash hazard analysis be performed per 130.5 "before any person is exposed to the electrical hazards involved."

The incident energy (see definition in NFPA 70E) is a measure of thermal energy at a specific distance from an arc fault; the unit of measure is typically in calories per centimeter squared (cal/cm²). The distance from the fault in determining the incident energy depends on the worker's body position to the live parts. After determining the incident energy in cal/cm², the value can be used to select the appropriate PPE. There are various types of PPE with distinct values (arc ratings or AR) of thermal protection capabilities termed "Arc Thermal Performance Exposure Values" (ATPV) rated in cal/cm². Note: for 600V and less a very common working distance for which incident energy is determined is 18 inches. If it is necessary to determine incident energy at a different distance, NFPA 70E (Annex D) and 2002 IEEE 1584 have equations that can be used in many situations (for greater or less than 18 inches).

130.5 arc flash hazard analysis has several elements for compliance. The first paragraph of 130.5 requires determining the arc flash boundary (AFB), incident energy at a specified working distance, and the PPE that must be worn within the AFB. However, 130.5 permits two methods to determine the necessary information: (1) calculating the AFB and incident energy method or (2) the hazard/risk categories (HRC) "Tables" method.

The AFB, determined by NFPA 70E is the distance from the energized parts at which a worker could sustain a just curable burn (bare skin) as a result of an arcing fault. A worker entering the AFB must be qualified and must be wearing appropriate PPE (proper items and sufficient AR) in accordance with NFPA 70E 130.5(B). Figure 2 depicts the AFB and the three shock approach boundaries discussed previously that must be observed per NFPA 70E. In an actual situation, before a worker is permitted to approach equipment with exposed, energized parts or where there is an arc flash hazard and/or shock hazard, these boundaries must be determined. In addition, the worker must be wearing the required PPE and follow safe work practices.

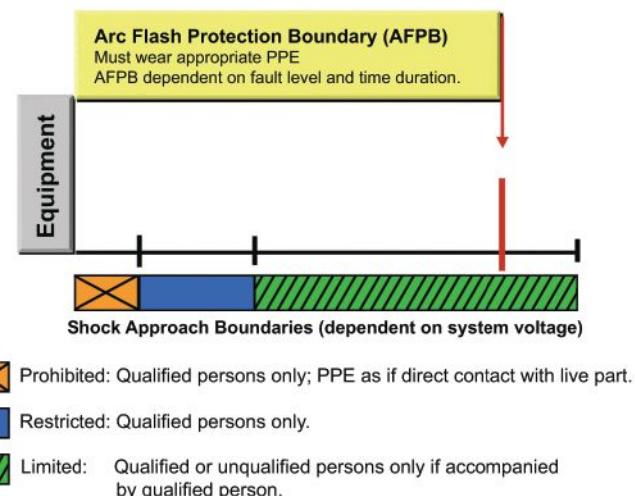


Figure 2

Prior to Doing Analysis

Important: the 3rd paragraph of 130.5 requires the arc flash hazard analysis to "take into consideration the design of the overcurrent protective device and its opening time, including the 'condition of maintenance.'" If the condition of maintenance of the OCPD used for the arc flash hazard analysis is not known to be good, it is advisable to use the characteristics of an OCPD further upstream toward the source that is known to be in good maintenance condition. See the Maintenance Considerations section.

Incident Energy Method

Calculate the AFB per 130.5(A) and the incident energy at a working distance per 130.5(B)(1). The related PPE required by 130.7(C) must have the appropriate arc rating equal to or greater than the incident energy, where applicable. For systems 50V or greater, 130.5(A) requires determining the AFB, the distance where the incident energy equals 1.2 cal/cm². NFPA 70E Annex D provides information on methods to calculate both the AFB and incident energy.

2002 IEEE 1584 is the foremost industry consensus standard for these calculations. This guide has the basic method of calculations, simplified fuse method, and simplified circuit breaker method.

Arc Flash Hazard Analysis

The available short-circuit current is necessary input information for these methods. This guide has equations for calculating arcing current for specific circuit conditions. The basic method requires the calculation of the arcing current which then requires determining the OCPD clearing time for the arcing current. Then the AFB and incident energy can be calculated.

It is important to note that current-limiting overcurrent protective devices (when in their current-limiting range) can reduce the required AFB and the required PPE AR as compared to non-current-limiting overcurrent protective devices.

There are various resources and tools available in the industry to aid in performing the 2002 IEEE 1584 calculations. Later in this section is a table method derived using the 2002 IEEE 1584 simplified methods for fuses. The incident energy calculation method with examples is covered in greater detail later in this section.

HRC Method

130.5 Exception and 130.5(B)(2) permits using the hazard/risk categories method if the requirements of 130.7(C)(15) and 130.7(C)(16) are met.

Important: the HRC method can be used for many situations but cannot be used for all situations. 130.7(C)(15) provides the conditions of use as to when Tables 130.7(C)(15)(a) and 130.7(C)(15)(b) are permitted to be used. If all the conditions of use are not satisfied, the tables cannot be used and an incident energy method must be used.

Table 130.7(C)(15)(a) Conditions of Use:

(All must be satisfied)

- Limited to equipment types and voltage ratings listed in table
- Limited to tasks listed in table
- Parameters under the specific equipment type being evaluated
 - Maximum available bolted short-circuit current at installation of equipment cannot exceed the value in the table
 - The clearing time for the type of OCPD at the given value of maximum available bolted short-circuit current in the table cannot exceed the maximum fault clearing time value in the table
 - The working distance cannot be less than the value in the table

If all conditions are met, then the AFB and the HRC number can be used in conjunction with Table 130.7(C)(16) to select PPE. The hazard/risk categories are 0, 1, 2, 3, and 4. Other PPE may be required per 130. Per 130.1 all pertinent requirements of Article 130 are applicable even when using the HRC method.

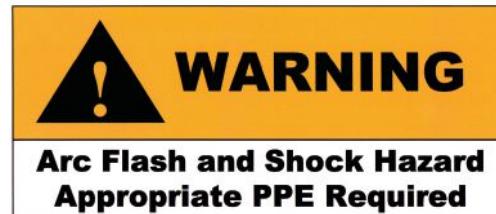
Table 130.7(C)(15)(a) has Notes at the end of the table. Notes 5 and 6 provide the basis of how the AFB was determined for each equipment type in the table. Note 4 permits reducing the HRC number by one for specific equipment type/task if the overcurrent protective device is a current-limiting fuse and that fuse is in its current-limiting range for the arcing current.

For instance, when a specific task to be performed has a hazard/risk category 2, if the equipment is protected by current-limiting fuses (with arcing current within their current-limiting range), the hazard/risk category can be reduced to a HRC 1.

In addition, NFPA 70E 130.5 requires the arc flash hazard analysis to be updated when there is an electrical system change that affects the arc flash hazard level such as when a major modification or renovation takes place. The arc flash hazard analysis must be periodically reviewed, not to exceed five years to account for changes in the electrical distribution system that could affect the results of the arc flash hazard analysis.

Arc Flash Analysis Equipment Labeling

NEC 110.16 Arc Flash Hazard Warning does not require NFPA 70E arc flash hazard analysis information to be on the label. It is merely a label to warn people that there is an arc flash hazard but does not provide specific information on the level of arc flash hazard.



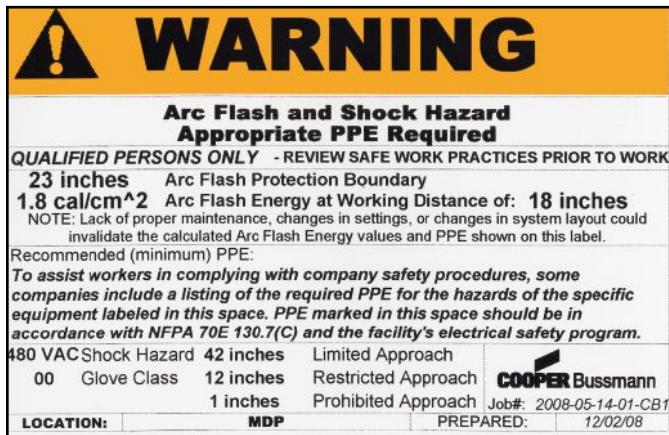
Courtesy E.I. du Pont de Nemours & Co.

Label complying to NEC 110.16

NFPA 70E 130.5(C) requires specific information on the level of arc flash hazard to be marked on the equipment when an arc flash hazard analysis has been performed. At a minimum the label must include these three items:

1. At least one of following
 - Incident energy at the working distance
 - Minimum arc rating of clothing
 - Level of PPE required
 - Required level of PPE (this may be to a specific company PPE safety program)
 - Highest HRC for the equipment type
2. System voltage
3. Arc flash boundary

Additional information is often included on the label, such as the values determined by the shock approach boundaries



Label required by NFPA 70E 130.5(C) must provide specific values determined by an arc flash hazard analysis.

The last paragraph of 130.5 requires that the calculation method and data to support this information shall be documented. For instance, in both the incident energy method and HRC method the available short-circuit current must be determined in the process of the analysis. The method of calculating the short-circuit current and the results must be documented and retained. This information may be required for a future OSHA inspection/investigation. As well, if future system changes occur, this documentation will assist in determining whether the arc flash hazard results changed.

Maintenance Considerations

The reliability of overcurrent protection devices can directly impact arc flash hazards. Poorly maintained overcurrent protective devices (OCPDs) may result in higher arc flash hazards. NFPA 70E 130.5 reads in part:

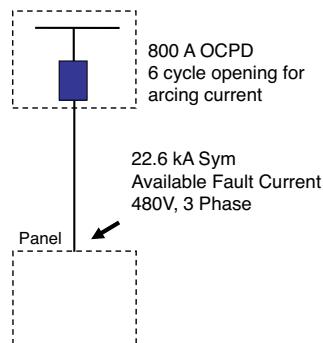
The arc flash hazard analysis shall take into consideration the design of the overcurrent protective device and its opening time, including its condition of maintenance.

130.5 has two Informational Notes (IN) concerning the importance of overcurrent protective device maintenance:

IN No.1: Improper or inadequate maintenance can result in increased opening time of the overcurrent protective device, thus increasing the incident energy.

IN No.2: For additional direction for performing maintenance on overcurrent protective devices see Chapter 2, Safety-Related Maintenance Requirements.

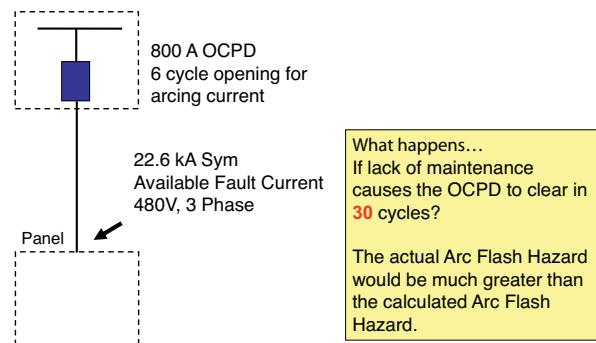
The 130.5 requirement to take into consideration the condition of maintenance of OCPDs is very relevant to arc flash hazards. The reliability of OCPDs can directly impact the incident energy. Poorly maintained OCPDs may take longer to clear, or not clear at all resulting in higher arc flash incident energies. Figure 3 illustrates the dangerous arc flash consequences due to poorly maintained OCPDs.



Arc Flash Hazard Analysis: Panel
Incident Energy: **5.8 cal/cm²** @ 18"
AFB: **47** inches

Figure 3 Arc flash hazard is affected by OCPD condition of maintenance.

3A. Arc flash hazard analysis calculation assuming the overcurrent protective device has been maintained and operates as specified by manufacturer's performance data.



Actual Arc Flash Hazard: Panel
Incident Energy: **29 cal/cm²** @ 18"
AFB: **125** inches

3B. The actual arc flash event can be significantly higher if the overcurrent protective device clearing time is greater than specified performance due to improper or lack of maintenance. Calculations are per IEEE 1584.

NFPA 70E has other OCPD maintenance requirements including:

205.4: requires OCPDs to be maintained per manufacturers' instructions or industry consensus standards. Very important: "Maintenance, tests, and inspections shall be documented."

210.5: requires OCPDs to be maintained to safely withstand or be able to interrupt the available fault current. Informational Note makes mention that improper or lack of maintenance can increase arc flash hazard incident energy.

225.1: requires fuse body and fuse mounting means to be maintained. Mountings for current-limiting fuses cannot be altered to allow for insertion of non-current-limiting fuses.

225.2: requires molded cases circuit breaker cases and handles to be maintained properly.

225.3 Circuit Breaker Testing After Electrical Fault.

Circuit breakers that interrupt faults approaching their interrupting rating shall be inspected and tested in accordance with the manufacturer's instructions.

NFPA 70E 225.3 complements an OSHA regulation which states:

OSHA 1910.334(b)(2) Use of Equipment.

Reclosing circuits after protective device operation. After a circuit is deenergized by a circuit protective device, the circuit may not be manually reenergized until it has been determined that the equipment and circuit can be safely energized. The repetitive manual reclosing of circuit breakers or reenergizing circuits through replaced fuses is prohibited.

NOTE: When it can be determined from the design of the circuit and the overcurrent devices involved that the automatic operation of a device was caused by an overload rather than a fault condition, no examination of the circuit or connected equipment is needed before the circuit is reenergized.

A key phrase in the regulation is "circuit can be safely energized." When complying with NFPA 70E 225.3 it is impractical if not impossible to determine the level of fault interrupted by a circuit breaker.

Sources for guidance in setting up maintenance programs, determining the frequency of maintenance and providing prescriptive procedures include:

1. Equipment manufacturer's maintenance manuals
2. NFPA 70B Recommended Practice for Electrical Equipment Maintenance
3. ANSI/NETA MTS-2011, Standard for Maintenance Testing Specifications for Electrical Distribution Equipment and Systems. This standard includes guidelines for the frequency of maintenance required for electrical system power equipment in Appendix B, Frequency of Maintenance Test as well as prescriptive inspections and tests in the standard.

Refer to page 37 for maintenance calibration decal system which can assist in evaluating the OCPD condition of maintenance required in NFPA 70E 130.5.

The internal parts of current-limiting fuses do not require maintenance for arc flash protective considerations. However, it is important to periodically check fuse bodies and fuse mountings.

In addition, for both fuses and fused other OCPD systems, periodically check conductor terminations for signs of overheating, poor connections and/or insufficient conductor ampacity. Infrared thermographic scans are one method that can be used to monitor these conditions. Records on maintenance tests and conditions should be retained and trended.

Arc Flash Incident Energy Calculator

Simple Method for Arc Flash Hazard Analysis

In this section there is an example of determining the arc flash hazard per 130.5(A) for the arc flash boundary and 130.5(B)(1) by the incident energy analysis method.

Various information about the system may be needed to complete this analysis but the two pieces that are absolutely necessary are:

1. The available $3\bar{I}$ bolted fault current.
2. The fuse type and amp rating.

Consider the following one-line diagram and then follow the examples that take the steps needed to conduct an arc flash hazard analysis.

The following information utilizes the simplified fuse formulas based upon IEEE 1584-2002 *Guide for arc flash Hazard Analysis* and shown in NFPA 70E Annex D.7.6.

Steps necessary to conduct an arc flash hazard analysis when using Low-Peak fuses and Table 1: arc flash Incident Energy Calculator.

1. Determine the available bolted fault current on the lineside terminals of the equipment that will be worked upon.
2. Identify the amperage of the Low-Peak fuse upstream that is protecting the panel where work is to be performed.
3. Consult the Low-Peak Fuse Incident Energy Calculator, Table 1, next pages, to determine the Incident Energy Exposure (I.E.) available.
4. Determine the AFB that will require PPE based upon the incident energy. This can also be simplified by using the column for AFB in Table 1.
5. Identify the minimum requirements for PPE when work is to be performed inside of the AFB by consulting the requirements found in NFPA 70E 130.7(C)(1) to (C)(16).

Example 1: Arc Flash Hazard Analysis using Bussmann Current-Limiting Fuses

The following is a simple method when using certain Bussmann fuses; this method is based on actual data from arcing fault tests (and resulting simplified formulas shown in NFPA 70E Annex D.7.6 and 2002 IEEE 1584) with Bussmann current-limiting fuses. Using this simple method, the first thing that must be done is to determine the incident energy exposure. Bussmann has simplified this process when using LPS-RK_SP, LPJ_SP, TCF, LP-CC_ or KRP-C_SP Low-Peak fuses or JJS_T-Tron fuses and FCF fuses. In some cases the results are conservative; see Note 6.

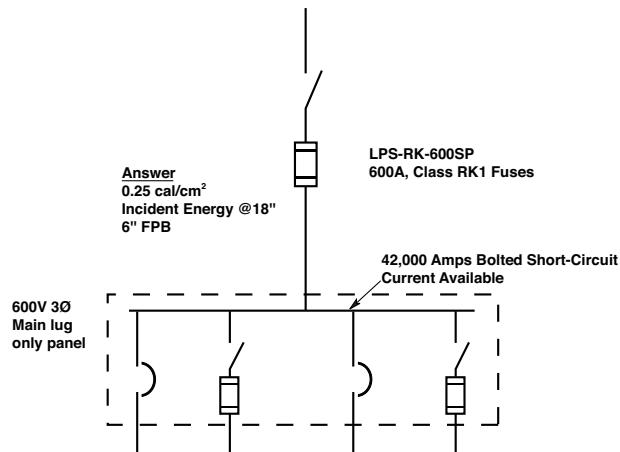


Figure 4

In this example, the line side OCPD in Figure 4 is a LPS-RK-600SP, Low-Peak current-limiting fuse. Simply take the available $3\bar{I}$ bolted short-circuit current at the panel, in this case 42,000 amps, and locate it on the vertical column in the arc flash Incident Energy Calculator Table 1 on the following page. Then proceed directly to the right to the 401-600A fuse column and identify the I.E. (incident energy) and AFB (arc flash Boundary).

With 42,000 amps of $3\bar{I}$ bolted short-circuit current available, the table shows that when relying on the LPS-RK-600SP Low-Peak fuse to interrupt an arcing fault, the incident energy is 0.25 cal/cm^2 . Notice the variables required are the available $3\bar{I}$ bolted fault current and the ampacity of the Low-Peak current-limiting fuse. See Notes 7 and 8.

The next step in this simplified arc flash hazard analysis is to determine the AFB. With an incident energy of 0.25 cal/cm^2 and using the same table, the AFB is approximately 6 inches, which is found next to the incident energy value previously located. See Note 6. This AFB distance means that anytime work is to be performed inside of this distance, including voltage testing to verify that the panel is deenergized, the worker must be equipped with the appropriate PPE.

The last step in the arc flash hazard analysis is to determine the appropriate PPE for the task. To select the proper PPE, utilize the incident energy exposure values and the requirements from NFPA 70E. NFPA 70E 130.7(C)(1) through (C)(16) that has requirements for the PPE based upon the incident energy. The 2012 NFPA 70E Annex H is a resource for guidance in selecting PPE; specifically Tables H.3(a) and (b). When selecting PPE for a given application or task, keep in mind that these requirements from NFPA 70E are minimum requirements. Having additional PPE, above what is required, can further assist in minimizing the effects of an arc flash incident. Another thing to keep in mind is that PPE available on the market today does not protect a person from the pressures, shrapnel and toxic gases that can result from an arc-blast, which are referred to as "physical trauma" in NFPA 70E. Existing PPE is only tested to minimize the potential for burns from the arc flash. See Notes 1 and 2.

Arc Flash Incident Energy Calculator**Table 1**

Bussmann Low-Peak™ LPS-RK_SP fuses 1-600A and Low-Peak KRPC_SP fuse 601-2000A.

Incident Energy (I.E.) values expressed in cal/cm², Arc Flash Boundary (AFB) expressed in inches.

Bolted Fault Current (kA)	1-100A		101-200A		201-400A		401-600A		601-800A		801-1200A		1201-1600A		1601-2000A	
	Fuse	I.E. Fuse	Fuse	I.E. Fuse	Fuse	I.E. Fuse	Fuse	I.E. Fuse	Fuse	I.E. Fuse	Fuse	I.E. Fuse	Fuse	I.E. Fuse	Fuse	I.E. Fuse
1	2.39	29	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
2	0.25	6	5.20	49	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
3	0.25	6	0.93	15	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
4	0.25	6	0.25	6	20.60	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
5	0.25	6	0.25	6	1.54	21	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
6	0.25	6	0.25	6	0.75	13	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
8	0.25	6	0.25	6	0.69	12	36.85	>120	>100	>120	>100	>120	>100	>120	>100	>120
10	0.25	6	0.25	6	0.63	12	12.82	90	75.44	>120	>100	>120	>100	>120	>100	>120
12	0.25	6	0.25	6	0.57	11	6.71	58	49.66	>120	73.59	>120	>100	>120	>100	>120
14	0.25	6	0.25	6	0.51	10	0.60	11	23.87	>120	39.87	>120	>100	>120	>100	>120
16	0.25	6	0.25	6	0.45	9	0.59	11	1.94	25	11.14	82	24.95	>120	>100	>120
18	0.25	6	0.25	6	0.39	8	0.48	10	1.82	24	10.76	80	24.57	>120	>100	>120
20	0.25	6	0.25	6	0.33	7	0.38	8	1.70	23	10.37	78	24.20	>120	>100	>120
22	0.25	6	0.25	6	0.27	7	0.28	7	1.58	22	9.98	76	23.83	>120	>100	>120
24	0.25	6	0.25	6	0.25	6	0.25	6	1.46	21	8.88	70	23.45	>120	29.18	>120
26	0.25	6	0.25	6	0.25	6	0.25	6	1.34	19	7.52	63	23.08	>120	28.92	>120
28	0.25	6	0.25	6	0.25	6	0.25	6	1.22	18	6.28	55	22.71	>120	28.67	>120
30	0.25	6	0.25	6	0.25	6	0.25	6	1.10	17	5.16	48	22.34	>120	28.41	>120
32	0.25	6	0.25	6	0.25	6	0.25	6	0.98	16	4.15	42	21.69	>120	28.15	>120
34	0.25	6	0.25	6	0.25	6	0.25	6	0.86	14	3.25	35	18.58	116	27.90	>120
36	0.25	6	0.25	6	0.25	6	0.25	6	0.74	13	2.47	29	15.49	102	27.64	>120
38	0.25	6	0.25	6	0.25	6	0.25	6	0.62	11	1.80	24	12.39	88	27.38	>120
40	0.25	6	0.25	6	0.25	6	0.25	6	0.50	10	1.25	18	9.29	72	27.13	>120
42	0.25	6	0.25	6	0.25	6	0.25	6	0.38	8	0.81	14	6.19	55	26.87	>120
44	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.49	10	3.09	34	26.61	>120
46	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	26.36	>120
48	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	26.10	>120
50	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	25.84	>120
52	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	25.59	>120
54	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	25.33	>120
56	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	25.07	>120
58	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	24.81	>120
60	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	24.56	>120
62	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	24.30	>120
64	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.93	33	24.04	>120
66	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.92	33	23.75	>120
68	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.80	32	22.71	>120
70	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.67	31	21.68	>120
72	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.54	30	20.64	>120
74	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.42	29	19.61	120
76	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.29	28	18.57	116
78	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.17	27	17.54	111
80	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	2.04	26	16.50	107
82	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.91	25	15.47	102
84	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.79	24	14.43	97
86	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.66	22	13.39	93
88	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.54	21	12.36	88
90	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.41	20	11.32	83
92	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.28	19	10.29	77
94	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.16	18	9.25	72
96	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	1.03	16	8.22	66
98	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.90	15	7.18	61
100	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.78	13	6.15	55
102	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.65	12	5.11	48
104	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.53	10	4.08	41
106	0.25	6	0.25	6	0.25	6	0.25	6	0.25	6	0.39	8	0.40	9	3.04	34

Read notes on the page following these tables. Fuse results based on actual test data and simplified fuse formulas in NFPA 70E Annex D.7.6 and 2002 IEEE 1584.

Arc Flash Hazard Analysis Tools on www.cooperbussmann.com/ArcFlashCalculatorBussmann continues to study this topic and develop more complete data and application tools. Visit www.cooperbussmann.com for interactive arc flash calculators and the most current data.

Arc Flash Incident Energy Calculator

Notes for Arc Flash Hazard Analysis Table 1

Steps necessary to conduct a Flash Hazard Analysis.

1. Determine the available bolted fault current on the line side terminals of the equipment that will be worked upon.
2. Identify the amperage of the upstream Low-Peak™ fuse that is protecting the equipment where work is to be performed.
3. Consult the table to determine the incident energy exposure and the arc flash Boundary (AFB).
4. Identify the minimum requirements for PPE when work is to be performed inside of the AFB by consulting the requirements found in *NFPA 70E*.

General Notes for fuses:

Note 1: First and foremost, this information is not to be used as a recommendation to work on energized equipment. This information is to help assist in determining the PPE to help safeguard a worker from the burns that can be sustained from an arc flash incident. This information does not take into account the effects of pressure, shrapnel, molten metal spray or the toxic vapor resulting from an arc-fault. This information does not address the maintenance conditions of the overcurrent protective device.

Note 2: This data is based upon the simplified fuse formulas in NFPA 70E Annex D.7.6 and 2002 IEEE 1584 *Guide for arc flash Hazard Analysis*.

Note 3: PPE must be utilized any time work is to be performed on equipment that is not placed in an electrically safe work condition. Voltage testing, while completing the lockout/tagout procedure (putting the equipment in an electrically safe work condition), is considered as working on energized parts per OSHA 1910.333(b).

Note 4: The data is based on 32mm (1 ¼") electrode spacing, 600V 3Ø ungrounded system, and 20" x 20" x 20" box. The incident energy is based on a working distance of 18 inches, and the AFB is based on 1.2 cal/cm² (threshold for a second-degree "just curable" burn).

Note 5: The data is based upon tests that were conducted at various fault currents for each Bussmann Low-Peak KRP-C_SP and LPS-RK_SP fuse indicated in the charts. These tests were used to develop the formulas as shown in NFPA 70E Annex D.7.6 and 2002 IEEE 1584. Actual results from incidents could be different for a number of reasons, including different (1) system voltage, (2) short-circuit power factor, (3) distance from the arc, (4) arc gap, (5) enclosure size, (6) fuse manufacturer, (7) fuse class, (8) orientation of the worker (9) grounding scheme and (10) electrode orientation. 100A LPS-RK_SP fuses were the smallest fuses tested. Data for the fuses smaller than that is based upon the 100A data. arc flash values for actual 30 and 60A fuses would be considerably less than 100A fuses. However, it does not matter since the values for the 100A fuses are already so low.

Note 6: The fuse incident energy values were chosen not to go below 0.25cal/cm² even though many actual values were below 0.25cal/cm². This was chosen to keep from encouraging work on energized equipment without PPE because of a low AFB.

Note 7: This arc flash Incident Energy Calculator Table can also be used for LPJ_SP, TCF, FCF, JJS, and LP-CC fuses to determine the incident energy available and AFB.

Note 8: These values from fuse tests take into account the translation from available 3-phase bolted fault current to the arcing fault current.

Note 9: To determine the AFB and incident energy for applications with other fuses, use the basic equations in 2002 IEEE 1584 or NFPA 70E Annex D.7.

Note 10: Where the arcing current is less than the current-limiting range of the fuse when calculated per NFPA 70E Annex D.7.6 and 2002 IEEE 1584, the value for incident energy is given as >100cal/cm². For the incident energy and arc flash boundary in these cases, use 2002 IEEE 1584 basic equation methods with the fuse time-current curve.

More on Electrical Safety

Use of PPE

Employees must wear and be trained in the use of appropriate protective equipment for the possible electrical hazards with which they may face. Examples of equipment could include (much of this has to be arc related) a hard hat, face shield, neck protection, ear protectors, Arc Rated (AR) clothing, arc flash suit, insulated rubber gloves with leather protectors, and insulated leather footwear. All protective equipment must meet the requirements as shown in Table 130.7(C)(14) of NFPA 70E. The selection of the required arc rated PPE depends on the incident energy level at the point of work.

As stated previously, the common distance used for most of the low voltage incident energy measurement research and testing is at 18 inches from the arcing fault source. So what energy does a body part experience that is closer to the arcing fault than 18 inches? The closer to the arcing fault the higher the incident energy and arc blast energy. This means that when the arc flash hazard analysis results in relatively high incident energies at 18 inches from the arcing fault source, the incident energy and arc blast energy at the point of the arcing fault can be considerably greater. Said in another way, even if the body has sufficient PPE for an 18" working distance, severe injury can result for any part of the body closer than 18" to the source of the arc.

Exposure Time

As the previous sections have illustrated, the clearing time of overcurrent protective devices is a major factor in the severity of an arc flash incident. Following is a table for some general minimum overcurrent protective device clearing times that can be used for the AFB and incident energy calculations if this data is not available from the manufacturer. "STD Setting" refers to the short time-delay setting if a circuit breaker has this feature; typical STD settings could be 6, 12, 18, 24, or 30 cycles. If an arc flash hazard analysis is being done for a circuit breaker with adjustable settings, then the maximum settings should be used for the analysis. If the lowest settings are used for the analysis, yet a maintenance person has inadvertently increased the setting to the maximum, then the analysis could yield results that are incorrect and lower than required for proper personnel protection.

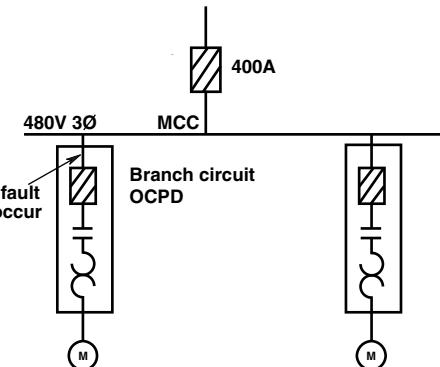


Type of Device	Clearing Time (Seconds)*
Current-limiting fuse	0.004-0.008
Circuit Breaker (5kV & 15kV)	0.08
Standard molded case circuit breakers (600V & below)	
without short time-delay (STD)	0.025
with short time-delay (STD)	STD Setting
Insulated case circuit breakers (600V & below)	
without short time-delay	0.05
with short time-delay	STD Setting
Low voltage power (air frame) circuit breakers (600V & below)	
without short time-delay	0.05
with short time-delay	STD Setting
Current-limiting molded case circuit breaker (600V & below)	0.008 or less

* These are approximate clearing times for short-circuit currents within the current-limiting range of a fuse or within the instantaneous region of circuit breakers. The clearing times for circuit breakers are based upon Table 1 in 2002 IEEE 1584 2002. The clearing time for current-limiting fuses and circuit breakers is based on published manufacturer data and tests. Lower current values may cause the overcurrent device to operate more slowly. arc flash energy may actually be highest at lower levels of available short-circuit current. This requires that arc flash energy calculations be completed for the range of sustainable arcing currents. This is also noted in NFPA 70E 130.5 IN No. 2.

Expect the Worst Case

If planning to work on a piece of equipment, it is necessary to do the arc flash hazard analysis for the worst-case situation if an incident occurred. For instance, in the diagram below, if the combination controller door were to be opened, the worst-case arc flash hazard in the enclosure would be on the lineside of the branch circuit OCPD. If an arcing fault occurred in the enclosure, on the lineside of the branch circuit circuit breaker, the 400 amp feeder OCPD is the protective device intended to interrupt. So the arc flash hazard analysis for this combination motor controller enclosure must be determined using the characteristic of the 400 amp feeder OCPD.



When performing an arc flash hazard analysis, it is important to consider the effect of improper equipment maintenance of overcurrent devices on the incident energy. Because of this, in some cases, it may be necessary to increase the protective clothing and PPE where equipment is not properly maintained. What if the ability of an overcurrent protective device to function properly is questioned? Often times, as part of the hazard/risk analysis, assuming that the OCPD will not function properly is safer. In determining the arc flash hazard, then the next overcurrent protective device upstream that is deemed reliable has to be considered as the protective device that will operate and should be used to assess the arc flash hazard. It is probable that, due to the increase in operating time, the incident energy will be substantially higher. Expert resource: if the first-level upstream circuit breakers do not operate as intended, the effects on arc flash hazard analysis has been examined for an industrial facility in "Prioritize Circuit Breaker and Protective Relay Maintenance Using an Arc Flash Assessment" (IEEE Paper No. ESW-2012-11), by Dan Doan. The results of the analysis included the following conclusion: "Based on this analysis, approximately 2/3 (91 out of 136) of the circuit breakers and relays identified in the arc flash study can be designated as 'Critical.' This means that if they fail, the PPE labeled would be inadequate, by one or more classes."

Other Arc Fault Hazards

An arcing fault may create such enormous explosive forces that there is a huge arc blast wave and shrapnel expelled toward the worker. Neither NFPA 70E nor 2002 IEEE 1584 account for the pressures and shrapnel that can result due to an arcing fault. There is little or no information on protecting a worker for these hazards.

On a somewhat positive note, because the arc pressure blows the worker away, it tends to reduce the time that the person is exposed to the extreme heat of the arc. The greater the fault current let-through, the greater the explosive forces. It is important to know that product standards do not evaluate a product for a worker's exposure to arc flash and arc blast hazards with the door(s) open. Equipment listed to a Nationally Recognized Testing Laboratory product standard is not evaluated for arc flash or arc blast protection (with the door(s) open) because the equipment is tested with the doors closed. Once a worker opens the doors, the parameters under the evaluation testing and listing do not apply.

Summary About the Risks From Arc Faults

Arc faults can be an ominous risk for workers. And an uneducated eye can not identify whether the risk is low, medium or high just by looking at the equipment. Current-limiting overcurrent protection may reduce the risk. In other words, if an incident does occur, current-limiting overcurrent protective devices may reduce the probability of a severe arc flash. In many cases, using current-limiting protective devices greatly reduces the arc flash energy that might occur for the range of arc fault currents that are likely. However, current-limiting overcurrent protective devices do not mitigate the potential hazard in all situations, such as when the overcurrent protective devices become larger than 1200 amp and the available short circuit current is low or very low. However, all things being equal, systems with protective devices that have a high degree of current-limitation generally lower the risks. Regardless it is still necessary to follow all the requirements of NFPA 70E and other safe work practices.

General Recommendations For Electrical Safety Relative to Overcurrent Protection

- (1) Finger-safe products and terminal covers: utilize finger-safe overcurrent protective devices such as the CUBEFuse or insulating covers over the overcurrent protective devices, disconnect terminals and all terminations.
- (2) Proper interrupting rating: be absolutely sure to use overcurrent protective devices that have adequate interrupting ratings at their point of application. An overcurrent protective device that attempts to interrupt a fault current beyond its interrupting rating can violently rupture. Consideration for interrupting rating should be for the life of the system. All too often, transformers are replaced or systems are upgraded and the available short-circuit currents increase. Modern fuses have interrupting ratings of 200,000 and 300,000 amps, which virtually eliminates this hazard contributor.
- (3) Current-limiting overcurrent protection: use the most current-limiting overcurrent protective devices possible. There are a variety of choices in the market for overcurrent protective devices. Many are not marked as current-limiting and therefore can not be considered current-limiting. And then for those that are marked current-limiting, there are different degrees of current-limitation to consider. For Bussmann, the brand to use for 600V and less, electrical distribution applications and general equipment circuit protection is Low-Peak fuses. The Low-Peak family of fuses is the most current-limiting type fuse family for general protection and motor circuit protection.
- (4) Upgrade existing fuse systems: if the electrical system is an existing fusible system, consider replacing the existing fuses with the Low-Peak family of fuses. If the existing fuses in the clips are not the most current-limiting type fuses, upgrading to the Low-Peak family of fuses may reduce the hazards associated with arc flash. Visit www.cooperbussmann.com/lowpeak to review the Low-Peak Fuse Upgrade Program.
- (5) Install current-limiting overcurrent protection for actual loads: if the actual maximum full load current on an existing main, feeder or branch circuit is significantly below its designed circuit ampacity, replace the existing fuses with lower amp rated Low-Peak fuses. For instance, an industrial found that many of their 800 amp feeders to their MCCs were lightly loaded; so for better arc flash protection they installed 400 and 600 amp current-limiting fuses and switches in the feeders.
- (6) Reliable overcurrent protection: use overcurrent protective devices that are reliable and do not require maintenance to assure performance per the original specifications. Modern fuses are reliable and retain their ability to react quickly under fault conditions. When a fuse is replaced, a new factory calibrated fuse is put into service – the circuit has reliable protection with performance equal to the original specifications. When an arc fault or overcurrent occurs, the overcurrent protective device must be able to operate as intended.
- (7) Reduce feeder size in design phase: Reducing the size of large feeders can greatly reduce incident energy, especially for feeders 1600A and larger.
- (8) Within sight motor disconnects: install HP rated disconnects (with permanently installed lockout provision) within sight and within 50 feet of every motor or driven machine. This measure fosters safer work practices and can be used for an emergency disconnect if there is an incident.

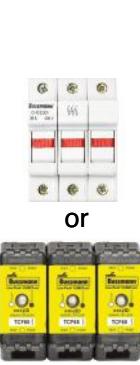
Branch Circuit Overcurrent Protective Devices and Disconnects

Fusible Solutions:

When selecting fusible overcurrent protective devices, the type of fuse holder or switch is very important to determine proper application. The most economical solution is often a standard UL 4248 Listed fuse holder, but this does not offer a disconnecting means for the fuses, required per NEC 240.40. A disconnecting means can be ahead of the fuseholder or a UL 98 or UL 508 fused disconnect switch can be selected. The UL 98 fused disconnect offer the widest range of applications whereas the UL 508 disconnect is limited to motor circuit applications only with additional restrictions as noted in Table 1.

The Compact Circuit Protector (CCP) is the smallest, most economical UL 98 Listed fusible disconnect switch available. There are two types of CCP. The CCP with Class CC fuses is available in a 30A disconnect ratings and accepts 1 to 30 amp Class CC fuses. The CCP with Class CF fuses known as the CUBEFuse are available in a DIN-Rail mount version and a bolt mount version. The CCP with CUBEFuse are in amp ratings up to 100 amps. The red italicized text indicates applications that are limited or restricted.

Table 1 – CCP Compared to Fuse Holder, Disconnect with Fuses, and Fusible Disconnect

	UL 98 Listed CCP with Class CC Fuses or CUBEFuse™ (Class CF)	UL 4248 Listed Class CC Fuse Holder with Class CC Fuses or CUBEFuse™ with Fuse Holder	UL 4248 Listed Class CC Fuse Holder with Class CC Fuses and UL 508 Listed Disconnect (Manual Motor Controller)	UL508 Listed Disconnect (Manual Motor Controller) with Integral Class CC Fuses	UL 98 Listed Disconnect with UL 4248 Listed Class CC Fuse Holder with Class CC Fuses	UL 98 Listed Fusible Disconnect with Class CC or J Fuses
Relative Size Comparison	 or  or  or  or  or 					
Branch Circuit Overcurrent Protection	Yes	Yes	Yes	Yes	Yes	Yes
Branch Circuit Disconnect	Yes	No	No	No	Yes	Yes
Motor Circuit Disconnect	Yes	No	Yes*†	Yes*	Yes	Yes
Feeder Circuit Overcurrent Protection	Yes	Yes	N/A**	N/A**	Yes	Yes
Feeder Circuit Disconnect	Yes	No	No	No	Yes	Yes
Cost	\$\$\$\$\$	\$-\$	\$\$\$	\$\$\$	\$\$\$\$	\$\$\$\$\$

*Manual motor controller must be additionally marked "Suitable as Motor Disconnect" and be installed on the loadside of the final Branch Circuit overcurrent protective device.

** Class CC fuse can provide feeder circuit overcurrent protection but UL 508 manual motor controller cannot be applied in a feeder circuit.

†The manual motor controller is the motor circuit disconnect, not the fuse holder.

Branch Circuit and Feeder Overcurrent Protective Devices and Disconnects

Fuse and Circuit Breaker Solutions:

To provide branch or feeder circuit overcurrent protection, the overcurrent protective device must be either a UL Listed 248 "Class" fuse or a UL Listed 489 circuit breaker. To provide a branch or feeder circuit disconnect, a UL 98 Listed fused disconnect switch or a UL Listed 489 circuit breaker must be selected. The CCP can replace low rated circuit breakers or misapplied supplementary protectors in branch circuit applications and provide a higher short-circuit current rating at a similar or lower cost. The CCP is a cost-

effective solution similar in size to a supplementary protector or lighting style circuit breaker, but with higher voltage ratings and higher interrupting ratings while providing better current-limiting overcurrent protection. Compared to an equivalently rated industrial circuit breaker, it is one-third the size. Table 2 shows the size and rating differences between the CCP and a supplementary protector, lighting circuit breaker (240V and 480/277V) and fully rated (600V) industrial circuit breaker. The red italicized text indicates applications that are limited or restricted.

Table 2 – CCP Compared to Supplementary Protector, Lighting Circuit Breakers, and Fully Rated Industrial Circuit Breakers

	UL 98 Listed CCP with Class CC Fuses or CUBEFuse™ (Class CF)	UL 1077 Recognized Supplementary Protector	UL 489 Listed Circuit Breaker	UL 489 Listed Circuit Breaker	UL 489 Listed Circuit Breaker
Relative Size Comparison					
Branch or Feeder Circuit Overcurrent Protection	Yes	No	Yes	Yes	Yes
Branch or Feeder Circuit Disconnect	Yes	No	Yes	Yes	Yes
Voltage Rating (AC)	600V	Typically 277V or less	Typically 240V or less	Typically 480/277V† or 600/347V†	Typically 600V or less
Interrupting Rating	200kA	Typically 5-10kA	Typically 10-14kA	Typically 14kA-18kA	Varies 14kA -100kA*
Overcurrent Protection Method	Class CC fuse or CUBEFuse	Thermal magnetic trip	Thermal magnetic trip	Thermal magnetic trip	Thermal magnetic trip
Cost	\$\$\$\$	\$	\$\$	\$\$\$	\$\$\$\$

*Cost increases as interrupting rating increases

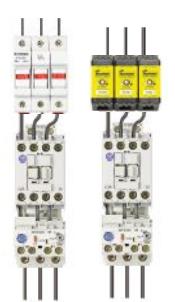
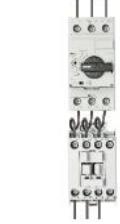
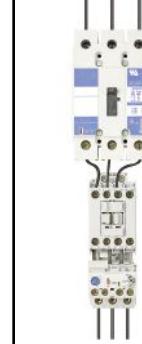
†Limits application to solidly grounded wye systems only, not permitted on ungrounded, resistance grounded or corner grounded systems

Motor Circuit Solution Comparison:

For motor circuits, there are many options available. The CCP with a magnetic starter is a cost-effective, compact solution for motor circuits. The Table below is a size and application comparison of the CCP with a magnetic starter compared to fuse and fuseholder with a magnetic starter, self-protected starter

with a magnetic contactor, fuse and fuseholder with a manual motor protector and magnetic contactor, instantaneous-trip circuit breaker (also known as motor circuit protector or MCP) with magnetic starter, and inverse-time circuit breaker with magnetic starter. The red italicized text indicates applications that are limited or restricted.

CCP-Class CC or Class CF and Magnetic Starter Compared to Other Motor Circuit Protective Devices

	UL 98 Listed CCP with Class CC Fuses or CUBEFuse™ (Class CF) and Magnetic Starter	UL 4248 Listed Class CC Fuse Holder with Class CC Fuses or CUBEFuse with Fuse Holder and Magnetic Starter	UL 508 Listed Self-Protected Starter (SPS) and Magnetic Contactor	UL 4248 Listed Class CC Fuse Holder with CUBEFuse and Manual Motor Protector (MMP) and Magnetic Contactor	UL 489 Recognized Motor Circuit Protector (MCP) and Magnetic Starter**	UL 489 Listed Circuit Breaker and Magnetic Starter
						
Branch Circuit Overcurrent Protection	Yes	Yes	Yes ^{†††}	Yes	Yes**	Yes
Motor Circuit Disconnect	Yes	No	Yes	Yes*	Yes**	Yes
Voltage Rating	600V	600V	Typically 480/277V ^t or 600/347V ^t	Typically 480V or 600V	Typically 600V	Typically 600V
SCCR	Typically 100kA	Typically 100kA	Typically 30kA or 65kA ^{††}	Typically 30kA or 65kA ^{††}	Varies 14kA to 100kA***	Varies 14kA to 100kA***
High SCCR with Multiple Manufacturers	Yes	Yes	No	No	No	No
Cost	\$\$\$\$\$	\$-\$	\$-\$	\$\$\$\$\$-\$\$\$\$\$	\$\$\$\$\$	\$\$\$\$\$

* If on loadside of the final Branch Circuit overcurrent device and MMP is marked "Suitable as Motor Disconnect"

** Must be part of a listed combination, typically from same manufacturer

*** Cost increases as interrupting rating increases

† Limits application to solidly grounded wye systems only, not permitted on ungrounded, resistance grounded or corner grounded systems

†† SCCR is lower at higher voltage rating

††† May require additional accessories such as line side terminals, to be used as a self-protected starter

Motor Branch Circuit Construction

Of all the branch circuits encountered in the electrical industry, motor branch circuits remain as one of the most unique. Listed here are a few reasons why motor branch circuits are so unique:

- The harsh demand of motor loads, such as inrush and locked rotor currents,
- The desire for various levels of functionality, such as remote push button control and automatic control.
- The multitude of potential device types used in motor circuits and associated permitted functions for different parts of the motor circuit.
- Combination of higher probability to incur faults and many motor circuit components such as starters, overload heaters, and contactors that have low short-circuit current ratings (SCCRs) or may not be completely protected from damage under short-circuit conditions (See Type 2 Protection).

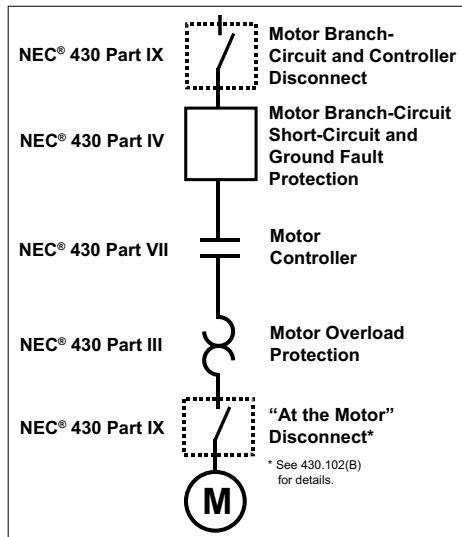


Figure 1

In order to provide a reliable motor branch circuit installation, a thorough understanding of the requirements for various functional parts of motor branch circuits, and their intended purpose, is required. Motor branch circuits can be broken down into 4 and sometimes 5 major functional blocks for motor operation as shown in Figure 1. (This figure is a subset of NEC® Figure 430.1 found at the beginning of Article 430.)

They include:

- Motor Branch-Circuit and Controller Disconnect
- Motor Branch-Circuit Short-Circuit and Ground Fault Protection
- Motor Controller
- Motor Overload Protection
- And sometimes an additional Motor Disconnect, often referred to as the “at the motor” or “in sight from motor” disconnect may be required if the motor branch-circuit and controller disconnect is not in sight of the motor and driven machinery location

Overcurrent protection for motor circuits can be broken into two parts:

- Motor overload protection (430.32)
- Motor branch circuit short-circuit and ground fault protection (430.52)

Motor overload protective devices provide protection from low level, long time overcurrent conditions which generally cause overheating of motor or motor branch circuit components over a long period of time (10 seconds or longer).

Motor branch circuit devices provide short-circuit and ground fault protection for motor branch circuits and the components of the circuit, i.e. motor starters, conductors, equipment grounding conductors, etc. The proper selection of overcurrent protection is extremely important. If not properly protected for short-circuit currents, motor circuit components can be extensively damaged under fault conditions. It is possible for the component to violently rupture and emit conductive gases that can lead to other faults.

The motor branch-circuit and controller disconnect and the “at the motor” disconnect provide the function of isolating the motor circuit or motor from the source of supply for maintenance work (electrically safe work condition) and serves as an emergency disconnect. Motor controllers serve as an On/Off function for the motor and, as the name implies, control the operation of the motor. Motor controllers can be manual or automatic.

In addition to these functional blocks, there are various requirements for motor control circuit components and other specialized components. This discussion will focus on the motor (power) branch circuit requirements and the devices corresponding thereto. Various devices are available on the market to provide these functions. Some devices perform only one of these functions and some perform multiple functions. Some devices, such as UL508 disconnects and Manual Motor Protectors have spacing requirements that are less than UL98 disconnects or UL489 molded case circuit breakers, and therefore, have limitations on their application.

Suitability for Use of Motor Branch Circuit Devices

Two of the main objectives of this section are to provide an understanding of devices that can be used in motor branch circuits and then understand that each device must be judged as suitable per the NEC® for specific motor circuit functions. Product listing or recognition of a device is one means used to judge suitability for use. However, these facts are often overlooked or ignored and devices get applied in applications beyond their intended use and listing, which is a safety hazard. It is important for designers and installers to recognize and understand the various NEC® motor circuit functions and requirements. In addition, one needs to know how to read device labeling, markings, and instructions to determine the proper applications for devices based on this information and the NEC® requirements. NEC® 110.3(A) and (B) identify the proper examination, identification, installation and use of equipment. The text of NEC 110.3(A) and (B) is partially reprinted as following:

110.3 Examination, Identification, Installation, and Use of Equipment.

(A) Examination. In judging equipment, considerations such as the following shall be evaluated:

- (1) Suitability for installation and use in conformity with the provisions of this Code

Informational Note: Suitability of equipment use may be identified by a description marked on or provided with a product to identify the suitability of the product for a specific purpose, environment, or application. Special conditions of use or other limitations and other pertinent information may be marked on the equipment, included in the product instructions, or included in the appropriate listing and labeling information. Suitability of equipment may be evidenced by listing or labeling.

(B) Installation and Use. Listed or labeled equipment shall be installed and used in accordance with any instructions included in the listing or labeling.

In addition, the specific application must comply with NEC 110.9 and NEC 110.10. This means each overcurrent protective device must have an interrupting rating equal to or greater than the available short-circuit current and the short-circuit current rating for each component must be equal to or greater than the available short-circuit current.

The table shown in Figure 2 summarizes the suitability of some common devices for the five possible NEC® motor branch circuit functions. The device suitability should be evidenced by its product listing mark and any instructions included in the listing or labeling. The NEC® requirements for each function are found in Article 430 under the respective Part as shown in Figure 1. Remember for specific applications, all overcurrent protective device interrupting ratings (NEC® 110.9) and all component short-circuit current ratings (NEC® 110.10) must be equal to or greater than the available short-circuit current at the point of installation.

Motor Circuit Protection Device Selection Chart	UL248 Fuses and Disconnect	UL489 Circuit Breaker	Instantaneous Trip Circuit Breaker	Self Protected Combination Starter (Type E Starter)	IEC Manual Motor Controller (Manual Motor Protector)	Magnetic Motor Starter	Manual Motor Controller (UL508 Switch)	UL1077 Supplemental Protector
Allowed Uses Per NFPA79 and NEC®								
Motor Branch-Circuit and Controller Disconnect	Yes ¹	Yes	Yes ^{5,6}	Yes ^{6,7}	No	No	No	No
Motor Branch-Circuit Short-Circuit and Ground Fault Protection	Yes	Yes ⁸	Yes ^{5,6}	Yes ^{6,8}	No	No	No	No
Motor Controller	Yes ²	Yes	No	Yes ⁹	Yes ⁹	Yes	Yes ⁹	No
Motor Overload Protection	Yes	Yes ³	No	Yes ¹⁰	Yes ¹⁰	Yes	No	No
"At the Motor" Disconnect*	Yes ²	Yes	No	Yes	Yes ⁴	No	Yes ⁴	No

* See 430.102(B) for details.

M

1. When used in conjunction with a UL98 Fusible Switch.
 2. Where used in conjunction with a UL98 or UL508 fusible switch. If UL508 switch, see footnote 4
 3. Often cannot be sized close enough.
 4. Must be located on the load side of motor branch short-circuit protective device, marked "Suitable as Motor Disconnect," and be provided with a lockable handle.
 5. When used in conjunction with a motor starter as part of a listed and labeled combination motor controller.
 6. Limited to single motor circuit applications.
 7. Additional Terminal Kit Often Required.
 8. If Flash Voltage Rated, Limited to Solidly Grounded Wye Systems ONLY.
 9. Additional Contactor Required for Remote Control.
 10. Class 10 Overload Protection Only.

Motor Branch Circuit Devices

Branch Circuit

Fuses

As Listed To

UL/CSA/ANCE 248 Series of Standards

These are fuses that cannot be replaced with fuses having a lower voltage rating. When installed in rejection style clips, current-limiting branch circuit fuses cannot be

replaced with fuses which are not current-limiting. Examples of branch circuit fuses are Class L, RK1, RK5, T, J, K1, K5, G, H, CC, CF, and plug fuses. Interrupting ratings range from 10,000 amps to 300,000 amps. These fuses are listed for branch, feeder, and main protection. In a motor circuit they provide branch circuit, short-circuit, and ground fault protection. In addition, enhanced overcurrent protection such as back-up overload and Type 2 "No Damage" protection can be provided with the selection of certain fuse sizes and types.



Allowed Uses:

- Motor Branch Short-circuit and Ground Fault Protection
- Motor Overload Protection (some fuse types based upon amount of time delay)
- Group Motor Protection as the short-circuit and ground fault protective device per NEC® 430.53
- Motor Branch Circuit and "at the motor" Disconnecting Means when used in conjunction with a UL98 fusible switch
- Motor Controller when used in conjunction with a UL98 fusible switch, UL508 Manual Motor Controller, or UL1429 pullout.

Identification

Fuses listed to UL/CSA/ANCE 248 will contain a marking near the agency symbol. This marking should read "Listed Fuse".



Disconnect Switches: Fused and Non-Fused As Listed To UL 98

These are disconnect switches from 30 through 6000 amps, that may be used in mains, feeders, and branch-circuits for service equipment, panelboards, switchboards, industrial control equipment, motor control centers, motor branch circuits, etc. These switches may be used as a motor branch-circuit and controller disconnect or an "at the motor" disconnect to meet NEC® 430.109. They may also be used as a motor controller (on-off function) to meet NEC® article 430, Part VII, and may be used as both a motor branch-circuit disconnect or "at the motor" disconnect and a motor controller (NEC® 430.111).



Allowed Uses:

- Motor Branch-Circuit and Controller Disconnect or "at the motor" Disconnect
- Motor Controller

Identification

Disconnect switches as listed to UL98 will contain a marking near the agency symbol. This marking should read "Listed Misc. Sw" or "Open Type Switch."



Pullout Switches As Listed To UL 1429

These are fused and non-fused switches from 30 through 400 amps at 600V or less. Pullout switches with horsepower ratings are suitable for branch-circuit and controller disconnect or "at the motor" disconnect to meet NEC® 430.109, as motor controllers to meet NEC® Article 430 Part VII (if rated 100Hp or less. Per UL 1429, pullout switches are not permitted to be used as a motor controller for motors above 100 HP), and in general use for panelboards, switchboards, etc. They may be used as both a motor branch-circuit and controller disconnect or "at the motor" disconnect and a motor controller to meet NEC® 430.111. Pullout switches with amp ratings only (no Hp ratings) are suitable for general use only, not motor circuits. If they are marked "Motor circuit pullout switch" they may be used only in a motor circuit. When used with properly sized branch-circuit fuses, pullout switches may be used for motor, motor circuit, and group motor protection.



Allowed Uses:

- Motor Branch-Circuit and Controller Disconnect or "at the motor" Disconnecting Means
- Motor Controller

Identification

Pullout switches as listed to UL1429 will contain a marking near the agency symbol. This marking should read "Listed Pullout Switch."



Motor Switches (Manual Motor Controllers) As Listed To UL 508

These switches may be used as a motor controller (On-Off function) to meet NEC® Article 430 Part VII. As motor controllers, they have creepage and clearance distances that are less than those required by UL 98. As a result, they can not be used as a motor branch-circuit and controller disconnect to meet NEC® 430.109. If the device is listed as a "manual motor controller" and is additionally marked "Suitable as Motor Disconnect" it is permitted to serve as an "at the motor" disconnect if it is located between the final motor branch-circuit short-circuit and ground-fault protective device and the motor. This marking and listing is optional, so a review of the device markings will be required if intended to be used for this purpose.



Allowed Uses:

- Motor Controller
- "At the Motor" Disconnect if marked "Suitable as motor Disconnect" and located between the final motor branch-circuit short-circuit and ground fault protective device and the motor.

Identification

Motor Switches/Manual motor controllers as listed to UL508 will contain a marking near the agency symbol. This marking should read "Listed Manual Motor Controller" or an abbreviation such as "Man. Mtr. Cntrl." Manual motor controllers listed for use as an "at the motor" disconnect means will be marked "Suitable as Motor Disconnect."



Fuse Holders As Listed to UL 4248 (previously UL 512)

When used with a motor branch-circuit and controller disconnect and properly sized branch-circuit fuses, fuse holders may provide main, feeder, branch circuit, motor, motor circuit, and group motor protection. They can not be used alone as a motor branch-circuit and controller disconnect or an "at the motor" disconnect to meet NEC® 430.109, nor can they be used alone as a motor controller (On-Off function) to meet NEC® Article 430, Part VII.



Identification

Fuse holders as listed to UL 4248 will contain a marking near the agency listing symbol. This marking should read "Listed Fuse Holder".



Thermal Magnetic (Inverse Time) Circuit Breakers As Listed to UL 489

These circuit breakers are intended to provide branch, feeder, and main protection, with interrupting ratings from 5,000 to 200,000 amps. Properly sized inverse time circuit breakers are intended to provide motor branch-circuit short-circuit and ground fault protection. They may be used for group motor protection. They are suitable for use as a motor branch-circuit and controller disconnect or "at the motor" disconnect per NEC® 430.109, as a motor controller (On-Off function) per NEC® Article 430, Part VII and as both a motor branch-circuit and controller disconnect or "at the motor" disconnect and motor controller per NEC® 430.111.



Allowed Uses:

- Motor Branch-Circuit Short-Circuit and Ground Fault Protection
- Motor Overload Protection
- Group Motor Protection as the short-circuit and ground-fault protective device per NEC® 430.53
- Motor Branch-Circuit and controller Disconnect or "at the motor" Disconnect
- Motor Controller

Identification

Circuit Breakers listed to UL489 will contain a marking near the agency symbol. This marking should read "Listed Circuit Breaker" or an abbreviation such as "Cir. Bkr."



Instantaneous Trip Circuit Breakers (MCPs)

As Recognized To UL 489

These are circuit breakers without overload (thermal) protection capability. They are intended to provide only branch circuit, short-circuit and ground fault protection for individual motor branch circuits. They may not be used to provide main, motor feeder, motor overload, general branch-circuit or group motor protection. Because they are recognized, not listed, they can not be used with loose control (or other manufacturers control equipment). NEC® 430.52 requires that they shall only be used as part of a listed combination controller (typically from the same manufacturer). MCPs are short-circuit tested only in combination with a motor controller and overload device. Because of this, they are not labeled with an interrupting rating by themselves. Per NEC® 430.109, they may be used as a motor branch-circuit and controller disconnect or "at the motor" disconnect only when part of a listed combination motor controller.



Allowed Uses:

- Motor Branch-Circuit Short-Circuit and Ground Fault Protection only when part of a listed combination motor controller
- Motor Branch-Circuit and Controller Disconnect or "at the motor" Disconnect only when part of a listed combination motor controller
- Motor Controller

Identification

Instantaneous Trip Circuit Breakers recognized to UL489 will contain a recognition or component acceptance marking. This marking indicates that the product can not be used "stand alone" and is limited to certain conditions of use.



Molded Case Switches As Listed to UL 489

Molded case switches are another switch type that can be used with fuses. These switches are very similar to molded case thermal magnetic circuit breakers except that they have no thermal overload protection. They may or may not be equipped with a "magnetic" instantaneous trip as a self-protect mechanism. They may be used in mains, feeders, and branch circuits for service equipment, panelboards, switchboards, industrial control equipment, motor control centers, motor branch circuits, etc. They are suitable for use as a motor branch-circuit and controller disconnect or "at the motor" disconnect per NEC® 430.109. They may be used as a motor controller (On-Off function) to meet NEC® Article 430 Part VII, and as both a motor branch-circuit and controller disconnect or "at the motor" disconnect and motor controller to meet NEC® 430.111.



Allowed Uses:

- Motor Branch-Circuit and Controller Disconnect or "at the motor" Disconnect
- Motor Controller

Identification

Molded Case Switches as listed to UL489 will contain a marking near the agency listing symbol. This marking should read "Listed Molded Case Switch."



Self-Protected Combination Starters (Type E) As Listed To UL 508

Self-protected combination starters are often called "coordinated protected starters", "self-protected starters", "self-protected combination controllers", "Type E combination starters" or "Type E starters". In some cases self-protected combination starters can be marked and applied as either self-protected combination starters or manual motor controllers. However, the device ratings will typically be much more restrictive if applied as a self-protected combination starter. Self-protected combination starters are intended to provide motor overload and motor branch-circuit short-circuit and ground fault protection by combining a magnetic short-circuit trip and adjustable motor overload in one package. A self-protected combination starter is a listed combination starter suitable for use without additional motor branch-circuit overcurrent protection and is limited to single motor circuits. Type E starters have additional test requirements for low level short-circuit interrupting tests followed by endurance tests that are not required for other combination motor controllers. Self-protected starters can be either manual or electro-mechanical.



A self-protected combination starter marked with a slash voltage rating is limited to use only on solidly grounded wye type systems per the device listing. When marked with such a slash rating, they can not be used on ungrounded, corner-grounded or impedance-grounded systems. Creepage

and clearance on the line terminals has to be the same as UL 489 and UL 98 devices. Because of this a self-protected combination starter that is marked for use with a terminal kit, must be installed with a terminal kit to ensure line-side terminal spacings are adequate. Additional accessory parts, such as lockable handles, may need to be added to off-the-shelf, self-protected combination starters, in order for the device to be suitable for use. Self-Protected combination starters are suitable for use as a motor branch-circuit and controller disconnect or "at the motor" disconnect per NEC® 430.109, as a motor controller (On-Off Function) per NEC® Article 430, Part VII, and as both a motor branch-circuit disconnect or "at the motor" disconnect and motor controller per NEC® 430.111. Note, self-protected starters are permitted for use only on single motor branch circuits.

Allowed Uses:

- Motor Branch-Circuit Short-circuit and Ground Fault Protection
- Motor Overload Protection
- Motor Branch-Circuit and Controller Disconnect or "at the motor" Disconnect
- Motor Controller

Identification

Self-protected combination starters as listed to UL 508 will contain a marking near the agency symbol. This marking should read "Listed Self-Protected Combination Motor Controller" for factory assembled units.

If separate components are used, the manual self-protected combination starter must be marked "Self-Protected Combination Motor Controller when used with (manufacturer and part number of load side component or "Motor Controllers Marked For Use With This Component")". If not marked with manufacturer and part number, the other components of the assembly must be marked "Suitable For Use On Load Side Of (manufacturer and part number) Manual Self-Protected Combination Motor Controller".

In addition, self-protected combination starters which are limited in application to only solidly grounded wye type systems will be marked with a slash voltage rating such as 480Y/277 or 600Y/347. When marked with such a slash rating, they can not be used on ungrounded, corner-grounded, or impedance-grounded systems.

Type F Combination Starters

As Listed to UL 508

If an IEC contactor is combined with the self-protected combination starter, they may be referred to as "Type F" starters. This however does not make it a "self-protected" starter unless tested and listed as a Type E starter. If listed as a Type F combination starter, the additional tests required for Type E starters have not been performed.



Allowed Uses:

- Motor Branch-Circuit Short-circuit and Ground Fault Protection
- Motor Overload Protection
- Motor Branch-Circuit and Controller Disconnect or "at the motor" Disconnect
- Motor Controller

Identification

Type F starters as listed to UL 508 will contain a marking near the agency symbol. This marking should read "Combination Motor Controller" for factory assembled units. If separate components are used, the



manual self-protected combination starter must be marked "Combination Motor Controller when used with (manufacturer and part number of load side component or "Motor Controllers Marked For Use With This Component")". If not marked with manufacturer and part number, the other components of the assembly must be marked "Suitable For Use On Load Side Of (manufacturer and part number) Manual Self-Protected Combination Motor Controller".

In addition, Type F combination starters which are limited in application to only solidly grounded wye type systems will be marked with a slash voltage rating such as 480Y/277 or 600Y/347. When marked with such a slash rating, they can not be used on ungrounded, corner-grounded, or impedance-grounded systems.

Manual Motor Controllers (Manual Motor Protectors) As Listed to UL 508

Manual motor starters, sometimes called MMPs, are permitted to provide motor overload protection as required per NEC® 430.32 and to provide motor control. MMPs are not listed nor permitted to provide motor branch-circuit



short-circuit and ground fault protection. Their creepage and clearance distances are typically not as great as required in UL 489, and therefore they cannot be tested and listed as a circuit breaker. They need a motor branch-circuit overcurrent device and a motor branch-circuit and controller disconnect on the line side for both single motor and group motor applications.

Some IEC manual motor protectors have been tested and listed for group motor applications [as the protected (downstream) device, not the protecting (upstream) device] so that several of them may be able to be protected by a single motor branch-circuit overcurrent protective device, such as an upstream fuse sized not to exceed the maximum size allowed per the device listing. In group motor applications, other limitations such as horsepower ratings and tap rule restrictions must also be investigated. Devices listed for use in group motor installations will be marked for such use to indicate that the device has undergone the appropriate testing to deem it suitable for such use.

Some of these devices are rated with slash voltage limitations (such as 480Y/277V). This limits their use to solidly grounded wye type systems only. Manual motor controllers may be used as a motor controller (On-Off Function) to meet NEC® Article 430 Part VII. Unless otherwise marked, MMPs do not meet requirements for a motor branch-circuit and controller disconnect or "at the motor" disconnect as required in NEC® 430.109. If it is marked "Suitable as Motor Disconnect" it is permitted to serve as an "at the motor" disconnect if it is located between the final motor branch-circuit, short-circuit and ground fault protective device and the motor. If investigated for tap conductor protection in group motor installations, they can additionally be marked "Suitable for Tap Conductor Protection in Group Installations. These additional markings and listings are optional, so a review of the device markings will be required if it is intended to be used for this purpose.

Allowed Uses:

- Motor Overload Protection
- Group motor applications as the protected (downstream) device only when the device is tested, listed and marked and the upstream fuse (protecting device) is sized within the maximum allowed per the device's listing and other limitations such as horsepower ratings and tap rules are met.
- Motor Controller
- "At the Motor" Disconnect if marked "Suitable as Motor Disconnect" and located between the final motor branch-circuit short-circuit and ground fault protective device and the motor.

- Protection of tap conductors in group installations if marked "Suitable for Tap Conductor Protection in Group Installations" and located on the load side of the final motor branch-circuit short-circuit and ground fault protective device.

Identification

Manual motor protectors as listed to UL508 will contain a marking near the agency symbol. This marking should read "Listed Manual Motor Controller" or an abbreviation such as "Man. Mtr. Cntrlr."

Manual motor controllers listed for use within group motor applications, as the downstream, protected overload/controller device, will be marked for such use along with the required maximum size for the upstream fuses. Manual motor controllers, additionally listed for use as an "at the motor" disconnect, will be marked "Suitable as Motor Disconnect." Manual motor controllers, additionally listed for use as protection of tap conductors in group installations, will be marked "Suitable for Tap Conductor Protection in Group Installations".

Integrated Starters As Listed To UL 508

Integrated starters are a modular style type of motor starter. Typically, it consists of an IEC manual motor controller (manual motor protector), as just previously discussed, and an IEC contactor. For some manufacturers, various types of controllers, control units, communication modules and accessories are available. The user can select from a variety of different components to meet the specific application needs. These starters can be factory assembled units or assembled from selected components.



Application requirements are the same as manual motor controllers including the need for motor branch-circuit overcurrent protective device and a line-side disconnect suitable for motor branch-circuits and motor controllers upstream. See the description above, for manual motor controllers, for application requirements and device identification.

In some cases, these motor starters may be additionally tested and listed as self-protected Type E or Type F starters if the appropriate components and accessories are selected. When applied as self-protected Type E or Type F starters, the device ratings are usually limited compared to the device ratings when applied as a manual motor controller or motor starter.

Magnetic Motor Starters

Magnetic motor starters are a combination of a magnetic contactor and overload relay. The overload relay of the magnetic starter is intended to provide single motor overload protection per NEC® 430.32. The horsepower rated magnetic contactor of the magnetic motor starter is intended to be used as a motor controller (On-Off Function) to meet NEC® Article 430 Part VII. The horsepower rated magnetic contactor also allows for remote operation of the motor. They are available in either NEMA or IEC versions. Magnetic motor starters must be protected by a separate motor branch-circuit overcurrent device per NEC® 430.52. They must have a line side disconnecting means suitable for a motor branch-circuit NEC® 430.109.



Allowed Uses:

- Motor Overload Protection
- Motor Controller.

Identification

Magnetic motor starters as listed to UL508 will contain a marking near the agency symbol. This marking should read "Listed Industrial Control Equipment" or an abbreviation such as "Ind. Cont. Eq"



Supplementary Overcurrent Protective Devices For Use in Motor Control Circuits

Branch Circuit vs. Supplemental Overcurrent Protective Devices

Branch circuit overcurrent protective devices (OCPDs) can be used everywhere overcurrent protection is needed, from protection of motors and motor circuits, control circuits and group motor circuits, to protection of distribution and utilization equipment. Supplemental OCPDs can only be used where proper overcurrent protection is already being provided by a branch circuit overcurrent protective device, by exception [i.e., 430.72(A)], or if additional overcurrent protection is not required but desired for increased overcurrent protection and isolation of loads. **Supplemental OCPD can often be used to protect motor control circuits but they can not be used to protect motors or motor branch circuits.** A very common misapplication is the use of a supplementary overcurrent protective device such as a UL Recognized 1077 mechanical overcurrent device for motor branch-circuit short-circuit and ground fault protection and motor branch-circuit and controller disconnect or "at the motor" disconnect. Supplementary OCPDs are incomplete in testing compared to devices, such as UL Listed 489 circuit breakers that are evaluated for branch-circuit overcurrent protection and as a branch-circuit or "at the motor" disconnect. THIS IS A SERIOUS MISAPPLICATION AND SAFETY CONCERN!! Caution should be taken to assure that the proper overcurrent protective device is being used for the application at hand. A description of popular supplementary overcurrent protective devices is given below.

Most supplemental overcurrent protective devices have very low interrupting ratings. Just as any other overcurrent protective device, supplemental OCPDs must have an interrupting rating equal to or greater than the available short-circuit current.

Supplemental Fuses As Listed or Recognized To The UL/CSA/ANCE 248-14 Standard



These are fuses that can have varying voltages and interrupting ratings within the same case size. Examples of supplemental fuses are 13/32" X 1 1/2", 5 x 20mm, and 1/4" x 1 1/4" fuses. Interrupting ratings range from 35 to 100,000 amps.

Supplementary Protectors (Mini-Breakers) As Recognized To UL 1077



With applications similar to supplemental fuses, these supplementary protectors, often referred to as mini-circuit breakers, are not permitted to be used as a branch circuit overcurrent protective devices. As such they are not permitted to provide motor circuit or group motor protection. They can only be used for

Supplemental Protectors

protecting an appliance or other electrical equipment where branch circuit overcurrent protection is already provided, or is not required. They typically have creepage and clearance distances that are less than those in UL 489, so they can not be listed as a circuit breaker or used as a motor branch-circuit and controller disconnect or "at the motor" disconnect to meet the requirements of NEC® 430.109. Interrupting ratings are typically quite low. Those devices that are short-circuit tested in series with a fuse must be applied with a branch-circuit rated fuse on their line side.

Identification

Supplemental protectors as recognized to UL 1077 will contain a recognition mark rather than a listing mark.



Warning Supplemental Protectors are NOT suitable for Motor Branch Circuit Protection

Supplemental protectors are being improperly used for motor branch-circuit overcurrent protection and as motor branch-circuit and controller disconnects or "at the motor" disconnects in numerous applications throughout the industry. This is a MISAPPLICATION and the urgency of the matter is prompting the creation of safety notices, articles, and technical bulletins to alert the users of this misapplication.

Why Are They Being Misapplied?

Here are some of the foremost reasons why:

- Supplemental protectors look very similar to Molded Case Circuit Breakers leading to the assumption that they provide the same protection
- Supplemental protectors are often labeled as circuit breakers or Miniature Circuit Breakers (MCB) in literature
- Many of these devices are rated as a circuit breaker per IEC standards. Confusion over North American and IEC ratings leads to misapplication.

So What Do I Need To Do?

In order to correct the application, suitable protection for the motor branch circuit needs to be provided. The simplest correction to this problem is the replacement of the misapplied supplemental protector with a device that is suitable for branch-circuit protection.

So What Can I Use?

NEC® 430.52 provides a list of acceptable devices for motor branch-circuit short-circuit and ground fault protection. Among the list of acceptable devices are time delay and fast acting branch-circuit fuses in conjunction with a disconnect.

Summary

Supplemental protectors are being misapplied on numerous occasions. Many reasons lead to this misapplication including mistaking supplemental protectors as North American circuit breakers. The key to properly identifying supplemental protectors is to look for the recognition mark. If the device has a recognition mark, more than likely it is a supplemental protector and replacement by a branch circuit overcurrent protective device is necessary for a proper installation. For more in-depth discussion, see section on supplemental protectors.

Voltage Unbalance & Single-Phasing

For Summary of Suggestions to Protect Three-Phase Motors Against Single-Phasing see the end of this section.

Historically, the causes of motor failure can be attributed to:

Overloads	30%
Contaminants	19%
Single-phasing	14%
Bearing failure	13%
Old age	10%
Rotor failure	5%
Miscellaneous	9%
	<hr/>
	100%

From the above data, it can be seen that 44% (30% + 14%) of motor failure problems are related to HEAT.

Allowing a motor to reach and operate at a temperature 10°C above its maximum temperature rating will reduce the motor's expected life by 50%. Operating at 10°C above this, the motor's life will be reduced again by 50%. This reduction of the expected life of the motor repeats itself for every 10°C. This is sometimes referred to as the "half life" rule.

Although there is no industry standard that defines the life of an electric motor, it is generally considered to be 20 years.

The term, temperature "rise", means that the heat produced in the motor windings (copper losses), friction of the bearings, rotor and stator losses (core losses), will continue to increase until the heat dissipation equals the heat being generated. For example, a continuous duty, 40°C rise motor will stabilize its temperature at 40°C above ambient (surrounding) temperature at full load current.

Standard motors are designed so the temperature rise produced within the motor, when delivering its rated horsepower, and added to the industry standard 40°C ambient temperature rating, will not exceed the safe winding insulation temperature limit.

The term, "Service Factor" for an electric motor, is defined as: "a multiplier which, when applied to the rated horsepower, indicates a permissible horsepower loading which may be carried under the conditions specified for the Service Factor of the motor."

"Conditions" include such things as operating the motor at rated voltage and rated frequency.

Example: A 10Hp motor with a 1.0 SF can produce 10Hp of work without exceeding its temperature rise requirements. A 10Hp motor with a 1.15 SF can produce 11.5Hp of work without exceeding its temperature rise requirements.

Overloads, with the resulting overcurrents, if allowed to continue, will cause heat build-up within the motor. The outcome will be the eventual early failure of the motor's insulation. As stated previously for all practical purposes, insulation life is cut in half for every 10°C increase over the motor's rated temperature.

Voltage Unbalance

When the voltage between all three phases is equal (balanced), current values will be the same in each phase winding.

The NEMA standard for electric motors and generators recommends that the maximum voltage unbalance be limited to 1%.

When the voltages between the three phases (AB, BC, CA) are not equal (unbalanced), the current increases dramatically in the motor windings, and if allowed to continue, the motor will be damaged.

It is possible, to a limited extent, to operate a motor when the voltage between phases is unbalanced. To do this, the load must be reduced.

Voltage Unbalance in Percent	Derate Motor to These Percentages of the Motor's Rating*
1%	98%
2%	95%
3%	88%
4%	82%
5%	75%

*This is a general "rule of thumb", for specific motors consult the motor manufacturer.

Some Causes of Unbalanced Voltage Conditions

- Unequal single-phase loads. This is why many consulting engineers specify that loading of panelboards be balanced to $\pm 10\%$ between all three phases.
- Open delta connections.
- Transformer connections open - causing a single-phase condition.
- Tap settings on transformer(s) not proper.
- Transformer impedances (Z) of single-phase transformers connected into a "bank" not the same.
- Power factor correction capacitors not the same, or off the line.

Insulation Life

The effect of voltage unbalance on the insulation life of a typical T-frame motor having Class B insulation, running in a 40°C ambient, loaded to 100%, is as follows:

Voltage Unbalance	Insulation Life	
	Service Factor 1.0	Service Factor 1.15
0%	1.00	2.27
1%	0.90	2.10
2%	0.64	1.58
3%	—	0.98
4%	—	0.51

Note that motors with a service factor of 1.0 do not have as much heat withstand capability as do motors having a service factor of 1.15.

Older, larger U-frame motors, because of their ability to dissipate heat, could withstand overload conditions for longer periods of time than the newer, smaller T-frame motors.

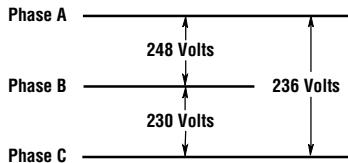
Insulation Classes

The following shows the maximum operating temperatures for different classes of insulation.

Class A Insulation	105°C
Class B Insulation	130°C
Class F Insulation	155°C
Class H Insulation	180°C

Voltage Unbalance & Single-Phasing

How to Calculate Voltage Unbalance and The Expected Rise in Heat



Step 1: Add together the three voltage readings:

$$248 + 236 + 230 = 714V$$

Step 2: Find the "average" voltage.

$$\frac{714}{3} = 238V$$

Step 3: Subtract the "average" voltage from one of the voltages that will indicate the greatest voltage difference. In this example:

$$248 - 238 = 10V$$

Step 4:

$$100 \times \frac{\text{greatest voltage difference}}{\text{average voltage}}$$

$$- 100 \times \frac{10}{238} = 4.2 \text{ percent voltage unbalance}$$

Step 5: Find the expected temperature rise in the phase winding with the highest current by taking $2 \times (\text{percent voltage unbalance})^2$

In the above example:

$$2 \times (4.2)^2 = 35.28 \text{ percent temperature rise.}$$

Therefore, for a motor rated with a 60°C rise, the unbalanced voltage condition in the above example will result in a temperature rise in the phase winding with the highest current of:

$$60^\circ\text{C} \times 35.28\% = 81.17^\circ\text{C}$$

The National Electrical Code®

The National Electrical Code®, in Table 430.37, requires three over-load protective devices, one in each phase, for the protection of all three-phase motors.

Prior to the 1971 National Electrical Code®, three-phase motors were considered to be protected from overload (overcurrent) by two overload protective devices. These devices could be in the form of properly sized time-delay, dual-element fuses, or overload heaters and relays (melting alloy type, bi-metallic type, magnetic type, and solid-state type.)

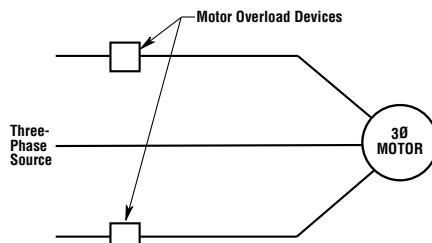


Diagram showing two overload devices protecting a three-phase motor. This was acceptable by the National Electrical Code® prior to 1971.

Two motor overload protective devices provide adequate protection against balanced voltage overload conditions where the voltage between phases is equal. When a balanced voltage over-load persists, the protective devices usually open simultaneously. In some cases, one device opens, and shortly thereafter, the second device opens. In either case, three-phase motors are protected against balanced voltage overload conditions.

Three-phase motors protected by two overload protective devices are not assured protection against the effect of single-phasing. For example, when the electrical system is WYE/DELTA or DELTA/WYE connected, all three phases on the secondary side of the transformer bank will continue to carry current when a single-phasing caused by an open phase on the primary side of the transformer bank occurs. As will be seen later, single-phasing can be considered to be the **worst case** of unbalanced voltage possible.

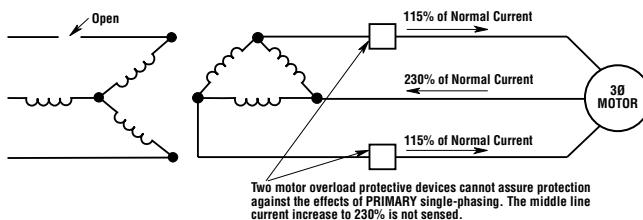
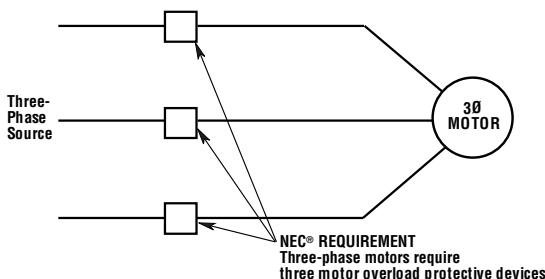


Diagram of a WYE/DELTA transformation with one primary phase open. The motor is protected by two overload devices. Note that one phase to the motor is carrying two times that of the other two phases. Without an overload device in the phase that is carrying two times the current in the other two phases, the motor will be damaged.

The National Electrical Code®, Section 430.36 requires that when fuses are used for motor overload protection, a fuse shall be inserted in each phase. Where thermal overload devices, heaters, etc. are used for motor overload protection, Table 430.37 requires one be inserted in each phase. With these requirements, the number of single-phasing motor burnouts are greatly reduced, and are no longer a serious hazard to motor installations. The following figure shows three overload protective devices protecting the three-phase motor.



Since 1971, The National Electrical Code® has required three overload protective devices for the protection of three-phase motors, one in each phase.

Motor Branch Circuit, Short Circuit and Ground Fault Protection

When sized according to NEC® 430.52, a 3-pole common trip circuit breaker or MCP can not protect against single-phasing damage.

It should be emphasized, the causes of single-phasing cannot be eliminated. However, motors can be protected from the damaging effects of single-phasing through the use of proper overcurrent protection.

Voltage Unbalance & Single-Phasing

In many applications FRN-R/FRS-R dual-element, time-delay fuses can be sized at or close to the motor's nameplate full-load amp rating without opening on normal motor start-up. This would require sizing the fuses at 100-125% of the motors full-load current rating. Since all motors are not necessarily fully loaded, it is recommended that the actual current draw of the motor be used instead of the nameplate rating. This is possible for motor's that have a fixed load, but not recommended where the motor load varies.*

Thus, when single-phasing occurs, Fusetron FRS-R and FRN-R dual-element, time-delay fuses can sense the overcurrent situation and respond accordingly to take the motor off the line.

For motor branch-circuit protection only, the following sizing guidelines † per 430.52 of the National Electrical Code® are allowed.

	<u>Normal</u>	<u>Maximum</u>
• Dual-element, time-delay fuses	175%	225%
• Non-time-delay fuses and all Class CC fuses	300%	400%
• Inverse-time circuit breaker	250%	400% for motors 100 amps or less. 300% for motors more than 100 amps.
• Instantaneous only trip** circuit breakers (sometimes referred to as MCPs. These are motor circuit protectors, not motor protectors.)	800%†† circuits	1300%†††

*See NEC® 430.52 for specifics and exceptions.

††100% for design B energy efficient motors.

†††1700% for design B motors.

*When sizing to the actual running current of the motor is not practical, an economic analysis can determine if the addition of one of the electronic "black boxes" is financially justified. These electronic "black boxes" can sense voltage and current unbalance, phase reversal, single-phasing, etc.

**Instantaneous only trip breakers are permitted to have time-delay. This could result in more damaging let-through current during short circuits.

Note: When sized according to table 430.52, none of these overcurrent devices can provide single-phasing protection.

Single-Phasing

The term single-phasing, means one of the phases is open. A secondary single-phasing condition subjects an electric motor to the worst possible case of voltage unbalance.

If a three-phase motor is running when the "single-phase" condition occurs, it will attempt to deliver its full horsepower ...enough to drive the load. The motor will continue to try to drive the load...until the motor burns out...or until the properly sized overload elements and/or properly sized dual-element, time-delay fuses take the motor off the line.

For lightly loaded three-phase motors, say 70% of normal full-load amps, the phase current will increase by the square root of three ($\sqrt{3}$) under secondary single-phase conditions. This will result in a current draw of approximately 20% more than the nameplate full load current. If the overloads are sized at 125% of the motor nameplate, circulating currents can still damage the motor. That is why it is recommended that motor overload protection be based upon the actual running current of the motor under its given loading, rather than the nameplate current rating, assuming that running current is less than nameplate current.

Single-Phasing Causes Are Numerous

One fact is sure: Nothing can prevent or eliminate all types of single-phasing.

There are numerous causes of both primary and secondary single-phasing. A device must sense and respond to the resulting increase in current when the single-phasing condition occurs...and do this in the proper length of time to save the motor from damage.

The term "single-phasing" is the term used when one phase of a three-phase system opens. This can occur on either the primary side or secondary side of a distribution transformer. Three-phase motors, when not individually protected by three time-delay, dual-element fuses (sized per 430.32), or three overload devices, are subject to damaging overcurrents caused by primary single-phasing or secondary single-phasing.

Single-Phasing on Transformer Secondary – Typical Causes

1. Damaged motor starter contact—one pole open. The number of contact kits sold each year confirms the fact that worn motor starter contacts are the most common cause of single-phasing. Wear and tear of the starter contacts can cause contacts to burn open, or develop very high contact resistance, resulting in single-phasing. This is most likely to occur on automatically started equipment such as air conditioners, compressors, fans, etc.
2. Burned open overload relay (heater) from a line-to-ground fault on a 3 or 4 wire grounded system. This is more likely to occur on smaller size motor starters that are protected by non-current-limiting overcurrent protective devices.
3. Damaged switch or circuit breaker on the main, feeder, or motor branch circuit.
4. Open fuse or open pole in circuit breaker on main, feeder, or motor branch circuit.
5. Open cable or bus on secondary of transformer terminals.
6. Open cable caused by overheated lug on secondary side connection to service.
7. Open connection in wiring such as in motor junction box (caused by vibration) or any pull box. Poor connections, particularly when aluminum conductors are not properly spliced to copper conductors, or when aluminum conductors are inserted into terminals and lugs suitable for use with copper conductors or copper-clad conductors only.
8. Open winding in motor.
9. Open winding in one phase of transformer.
10. ANY open circuit in ANY phase ANYWHERE between the secondary of the transformer and the motor.

Hazards of Secondary Single-Phasing For A Three-Phase Motor

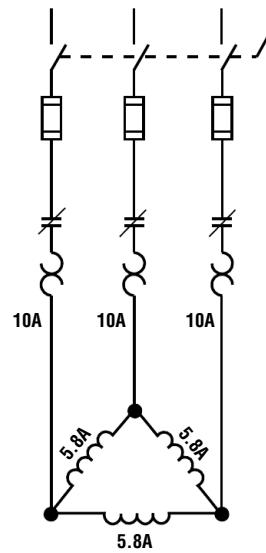
When one phase of a secondary opens, the current to a motor in the two remaining phases theoretically increases to 1.73 (173%) times the normal current draw of the motor. The increase can be as much as 2 times (200%) because of power factor changes. Where the motor has a high inertia load, the current can approach locked rotor values under single-phased conditions. Three properly sized time-delay, dual-element fuses (sized per 430.32), and/or three properly sized overload devices will sense and respond to this overcurrent.

Voltage Unbalance & Single-Phasing

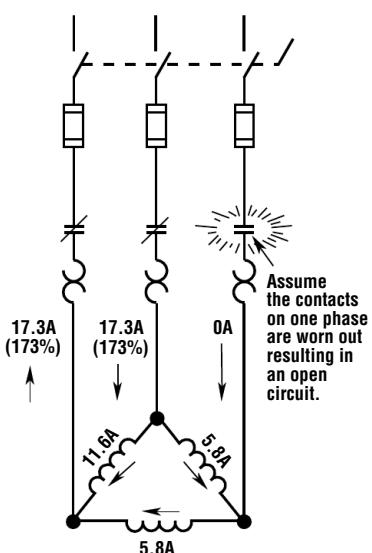
Single-Phasing On Secondary

Delta-Connected Motor, FLA = 10 Amps

Normal Condition



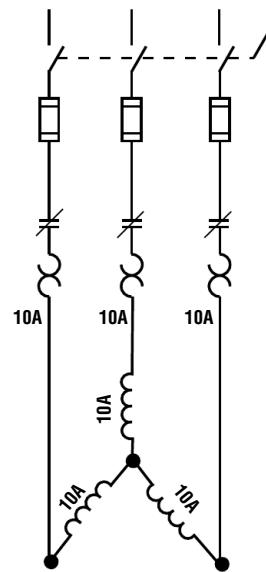
Single-Phasing Condition



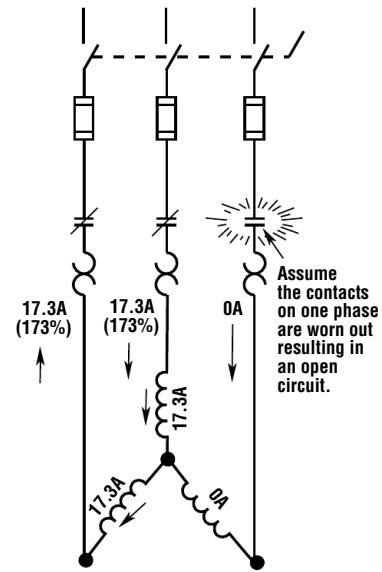
(Delta-Connected Motor) Diagram showing the increase in the two remaining phases after a single-phasing occurs on the secondary of a transformer.

Wye-Connected Motor, FLA = 10 Amps

Normal Condition



Single-Phasing Condition



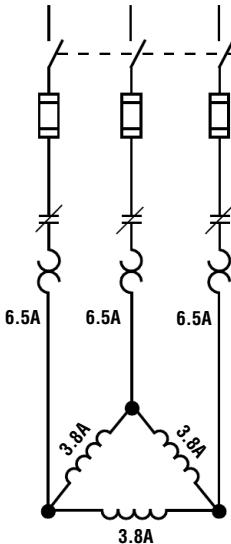
(WYE-Connected Motor) Diagram showing the increase in the two remaining phases after a single-phasing occurs on the secondary of a transformer.

Single-Phasing On Secondary

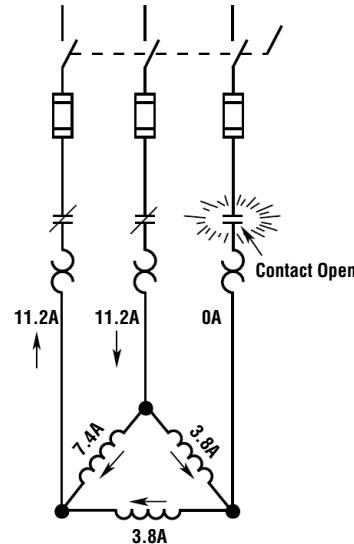
Delta-Connected Motor, FLA = 10 Amp

Connected Load = 6.5 Amp

Normal Condition



Single-Phasing Condition



Delta-connected three-phase motor loaded to only 65% of its rated horsepower. Normal FLA = 10 amps. Overload (overcurrent) protection should be based upon the motor's actual current draw for the underloaded situation for optimum protection. If load varies, overload protection is difficult to achieve. Temperature sensors, phase failure relays and current differential relays should be installed.

When a motor is single-phased, the current in the remaining two phases increases to 173% of normal current. Normally the overload relays will safely clear the motor from the power supply. However, should the overload relays or controller fail to do so, Low-Peak or Fusetron time-delay, dual-element fuses, properly sized to provide back-up overload protection, will clear the motor from its power supply.

If the overload relays were sized at 12 amps, based upon the motor nameplate FLA of 10 amps, they would not "see" the single-phasing. However, if they were sized at 8 amps ($6.5A \times 1.25 = 8.13$ amps), they would "see" the single-phasing condition.

Single-Phasing on Transformer Primary – Typical Causes

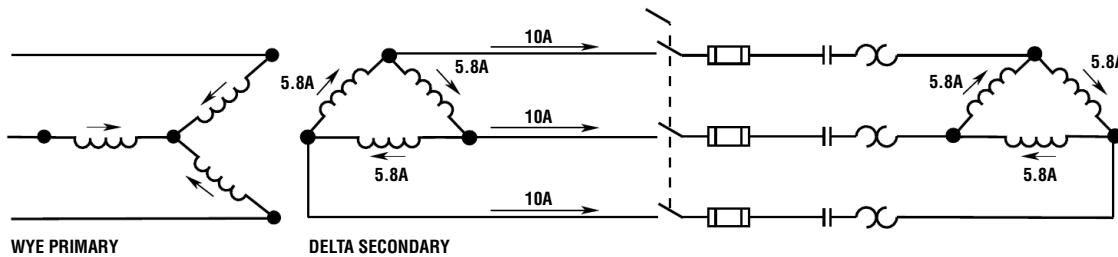
1. Primary wire broken by:
 - a. Storm – wind
 - b. Ice – sleet – hail
 - c. Lightning
 - d. Vehicle or airplane striking pole or high-line
 - e. Falling trees or tree limbs
 - f. Construction mishaps
2. Primary wire burned off from short circuit created by birds or animals.
3. Defective contacts on primary breaker or switch – failure to make up on all poles.
4. Failure of 3-shot automatic recloser to make up on all 3 poles.
5. Open pole on 3-phase automatic voltage tap changer.
6. Open winding in one phase of transformer.
7. Primary fuse open.

Voltage Unbalance & Single-Phasing

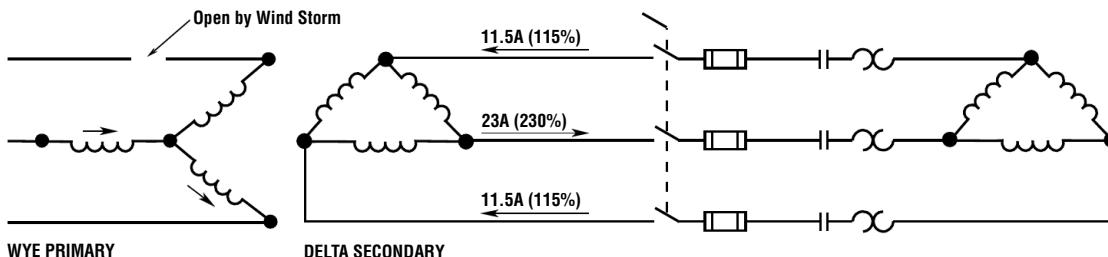
Single-Phasing On Primary

Delta-Connected Motor; FLA = 10 Amps

Normal Condition



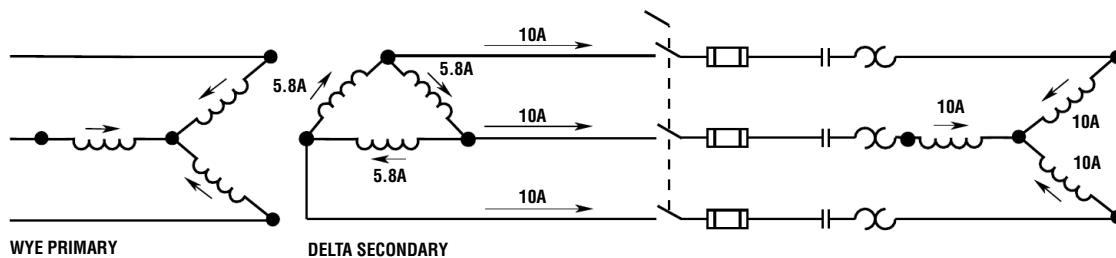
Single-Phasing Condition



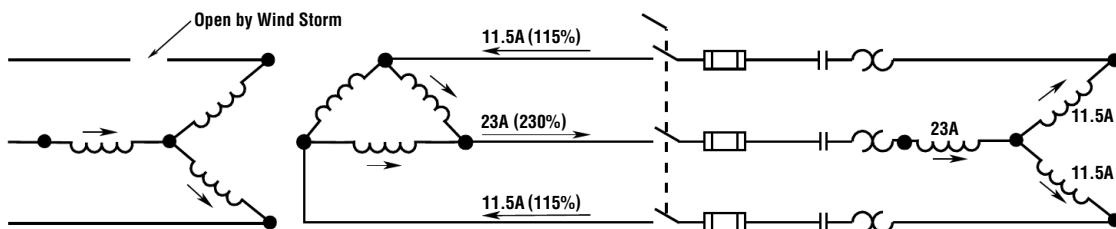
(Delta-Connected Motor) Diagram showing how the phase currents to a three-phase motor increase when a single-phasing occurs on the primary. For older installations where the motor is protected by two overload devices, the phase winding having the 230% current will burn up if it occurs in the phase that does not have the overload device. However, properly sized overload relays or Low-Peak or Fusetron dual-element, time-delay fuses will clear the motor from the power supply.

Single-Phasing On Primary

WYE-Connected Motor; FLA = 10 Amps



Normal Condition



Single-Phasing Condition

(WYE-Connected Motor) Diagram showing how the phase currents to a three-phase motor increase when a single-phasing occurs on the primary. For older installations where the motor is protected by two overload devices, the phase winding having the 230% current will burn up if it occurs in the phase that does not have the overload device.. However, properly sized over-load relays or Low-Peak or Fusetron dual-element, time-delay fuses, will clear the motor from the power supply.

Voltage Unbalance & Single-Phasing

Hazards of Primary Single-Phasing For A Three-Phase Motor

Probably the most damaging single-phase condition is when one phase of the primary side of WYE/DELTA or DELTA/WYE transformer is open. Usually these causes are not within the control of the user who purchases electrical power. When primary single-phasing occurs, unbalanced voltages appear on the motor circuit, causing excessive unbalanced currents. This was covered earlier in this bulletin.

When primary single-phasing occurs, the motor current in one secondary phase increases to 230% of normal current. Normally, the overload relays will protect the motor. However, if for some reason the overload relays or controller fail to function, the Low-Peak and Fusetron time-delay, dual-element fuses properly sized to provide backup overload protection will clear the motor from the power supply.

Effect of Single-Phasing on Three-Phase Motors

The effects of single-phasing on three-phase motors varies with service conditions and motor thermal capacities. When single-phased, the motor temperature rise may not vary directly with the motor current. When single-phased, the motor temperature may increase at a rate greater than the increase in current. In some cases, protective devices which sense only current may not provide complete single-phasing protection. However, PRACTICAL experience has demonstrated that motor running overload devices properly sized and maintained can greatly reduce the problems of single-phasing for the majority of motor installations. In some instances, additional protective means may be necessary when a higher degree of single-phasing protection is required. Generally, smaller horsepower rated motors have more thermal capacity than larger horsepower rated motors and are more likely to be protected by conventional motor running overload devices.

Case Study

During the first week of January, 2005, an extended primary single phasing situation of over two hours occurred at the Bussmann facility in St. Louis, Missouri. While the utility would not divulge the root cause of the single-phasing incident, Bussmann was running over 100 motors in their St. Louis facility. Since the motors were adequately protected with a motor overload protective device or element in each phase (such as a starter with three heater elements/ overload relay) and with three properly sized Fusetron or Low-Peak fuses for backup motor overload protection, all motors survived the single-phasing incident. Not a single motor replacement nor repair was needed and the facility was quickly returned to service after replacing fuses and resetting overload relays.

Summary of Suggestions to Protect Three-Phase Motors Against Single-Phasing

1. Per NEC® 430.37, three-phase motors must have an overload protective device in each phase. Use motor overload protection such as overload relays/heater elements in each phase of the motor. Prior to 1971, only two overload protective devices were required and motors were much more susceptible to motor burnout.
2. For fully loaded motors, size the heater elements or set the overload protection properly per the motor nameplate FLA.
3. If the motor is oversized for the application or not fully loaded, then determine the full load current via a clamp on amp meter and size the heaters or set the overload protection per the motor running current.
4. Electronic motor overload protective devices typically have provisions to signal the controller to open if the phase currents/voltages are significantly unbalanced.
5. Install phase voltage monitor devices that detect loss of phase or significant imbalances and signal the controller to open.
6. Periodically test overload protective devices using proper testing equipment and procedures to ensure the overload heaters/overload relays are properly calibrated.

With one or more of the above criteria, three-phase motors can be practically protected against overloads including single-phasing. Then the motor circuit branch circuit, short circuit, ground fault protection required per NEC® 430.52 can be achieved by many different types of current-limiting fuses including LPJ_SP, LP-CC, TCF, LPN-R, LPS-R, FRN-R, FRS-R, JJS, JJN, SC and others. Many personnel size these fuses for short circuit protection only. However, some engineers and maintenance personnel want another level of protection and utilize the fuse types and sizing in (7) below.

7. In addition to the motor overload protection in the circuit, use three Fusetron dual-element, time-delay fuses (FRS-R/FRN-R) sized for backup motor overload protection. Low-Peak dual-element, time-delay fuses (LPS-R/LPN-RK) can also be used, but in some cases, must be sized slightly greater than the FRS-R and FRN-R fuses. These fuses, sized properly, serve two purposes: (1) provide motor branch circuit, short circuit and ground fault protection (NEC 430.52) and (2) provide motor running back-up overload protection. For further details, refer to the Motor Circuit Protection section or contact Bussmann Application Engineering.

Basic Explanation

Overload Protection

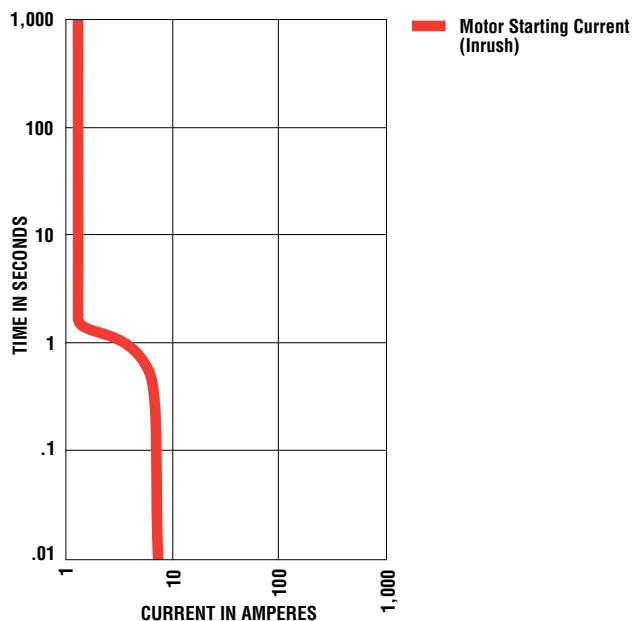
Overcurrents

An overcurrent exists when the normal load current for a circuit is exceeded. It can be in the form of an overload or short circuit. When applied to motor circuits an overload is any current, flowing within the normal circuit path, that is higher than the motor's normal Full Load Amps (FLA). A short-circuit is an overcurrent which greatly exceeds the normal full load current of the circuit. Also, as its name infers, a short-circuit leaves the normal current carrying path of the circuit and takes a "short cut" around the load and back to the power source. Motors can be damaged by both types of currents.

Single-phasing, overworking and locked rotor conditions are just a few of the situations that can be protected against with the careful choice of protective devices. If left unprotected, motors will continue to operate even under abnormal conditions. The excessive current causes the motor to overheat, which in turn causes the motor winding insulation to deteriorate and ultimately fail. Good motor overload protection can greatly extend the useful life of a motor. Because of a motor's characteristics, many common overcurrent devices actually offer limited or no protection.

Motor Starting Currents

When an AC motor is energized, a high inrush current occurs. Typically, during the initial half cycle, the inrush current is often higher than 20 times the normal full load current. After the first half-cycle the motor begins to rotate and the starting current subsides to 4 to 8 times the normal current for several seconds. As a motor reaches running speed, the current subsides to its normal running level. Typical motor starting characteristics are shown in Curve 1.

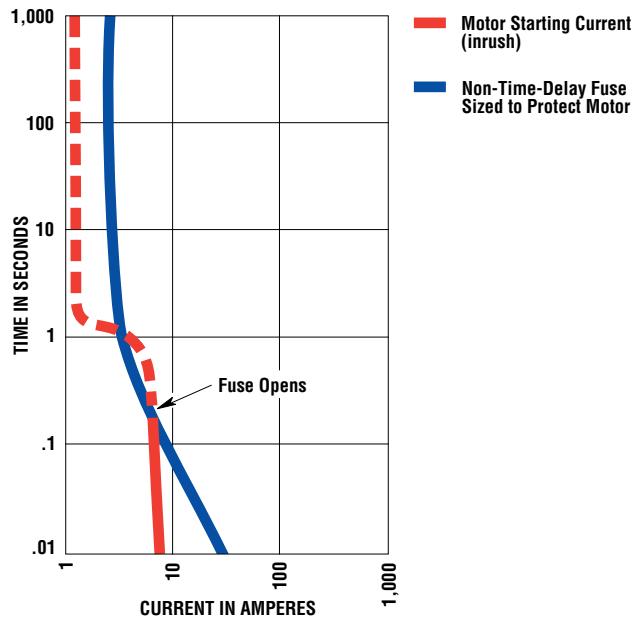


Curve 1

Because of this inrush, motors require special overload protective devices that can withstand the temporary overloads associated with starting currents and yet protect the motor from sustained overloads. There are four major types. Each offers varying degrees of protection.

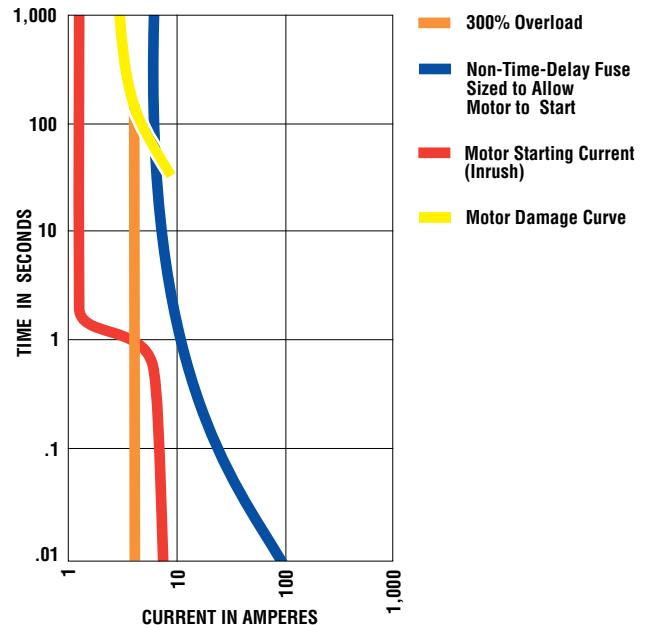
Fast Acting Fuses

To offer overload protection, a protective device, depending on its application and the motor's Service Factor (SF), should be sized at 115% or less of motor FLA for 1.0 SF or 125% or less of motor FLA for 1.15 or greater SF. However, as shown in Curve 2, when fast-acting, non-time-delay fuses are sized to the recommended level the motor's inrush will cause nuisance openings.



Curve 2

A fast-acting, non-time-delay fuse sized at 300% will allow the motor to start but sacrifices the overload protection of the motor. As shown by Curve 3 below, a sustained overload will damage the motor before the fuse can open.



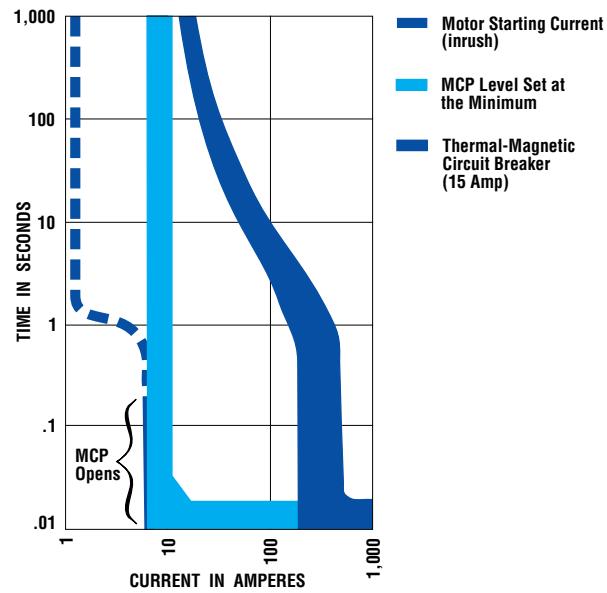
Curve 3

Basic Explanation

MCPs and Thermal Magnetic Breakers

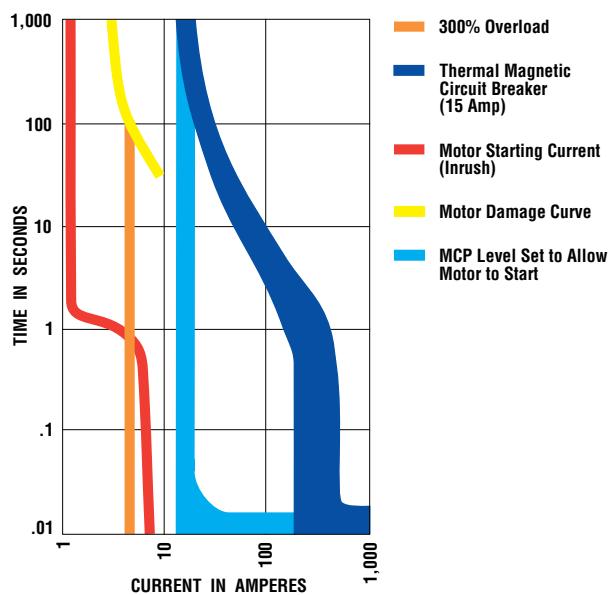
Magnetic only breakers (MCPs) and thermal magnetic breakers are also unsatisfactory for the protection of motors. Once again to properly safeguard motors from overloads, these devices should be sized at 115% or less of motor FLA for 1.0 SF or 125% or less of motor FLA for 1.15 or greater SF. When sized this close to the FLA the inrush causes these breakers to open needlessly.

Curve 4 shows an MCP opening from motor inrush and an unaffected 15 amp thermal magnetic circuit breaker (the minimum standard size).



Curve 4

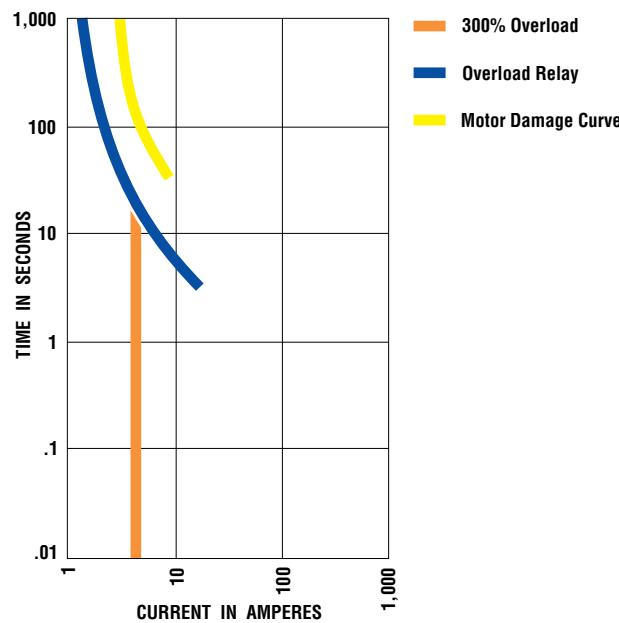
To allow the motor to start, the MCP must be sized at about 700-800% of the FLA and the thermal magnetic breaker must be sized at about 250% of FLA. Curve 5 clearly shows that breakers sized to these levels are unable to protect motors against over-loads.



Curve 5

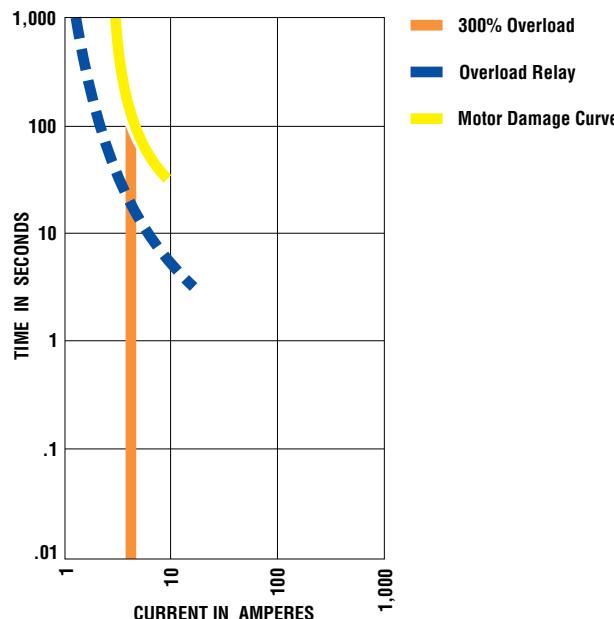
Overload Relays

Overload relays, or heaters, installed in motor starters are usually the melting alloy or bi-metallic type. When properly sized and maintained, the relay can offer good overload protection. When operating properly, overload relays allow the motor to start, but when a sustained overload occurs the overload relays cause the contacts to open (Curve 6).



Curve 6

However, if the overload relays are oversized or if the contacts fail to open for any reason (i.e., welded contacts), the motor is left unprotected. Also, overload relays cannot offer any protection for short circuits, and in fact must be protected by fuses or circuit breakers under short circuit conditions Curve 7.

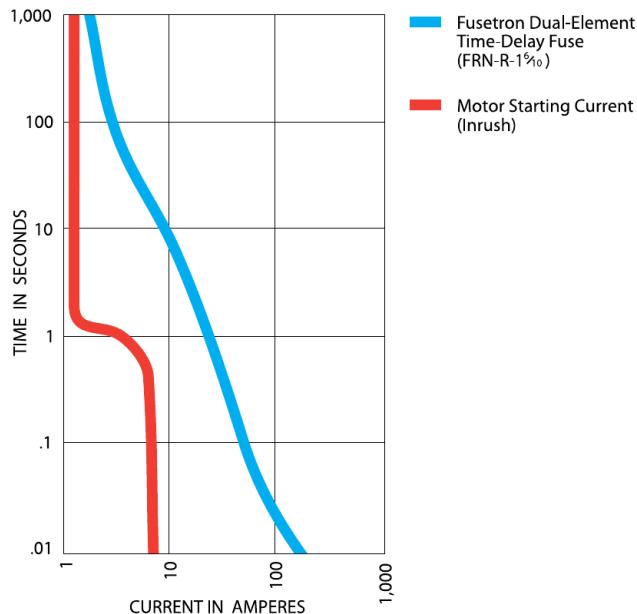


Curve 7

Basic Explanation

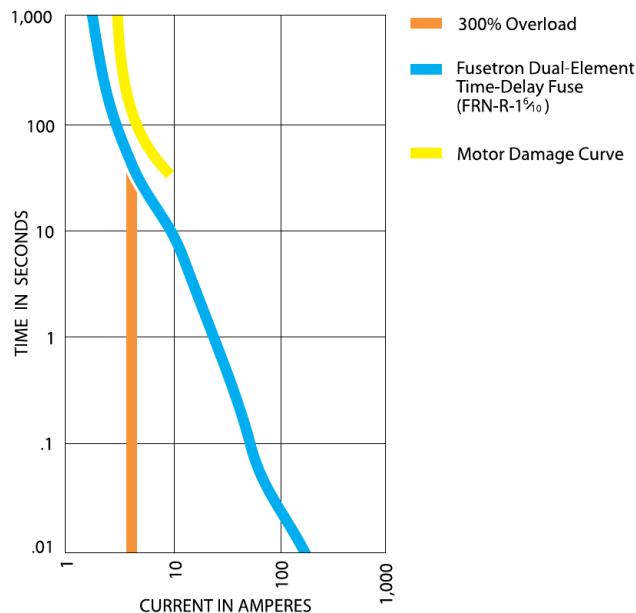
Dual-Element Fuses

The dual-element fuse is unaffected by the motor inrush current (Curve 8), but opens before a sustained overload can reach the motor damage curve (Curve 9).



Curve 8

The NEC® allows dual-element fuses to be used by themselves for both overload and short circuit protection, (see NEC® sections 430.36, 430.55, 430.57, & 430.90). Curve 9 shows that the dual-element fuse offers excellent overload protection of motors.



Curve 9

Motor Overload Protection

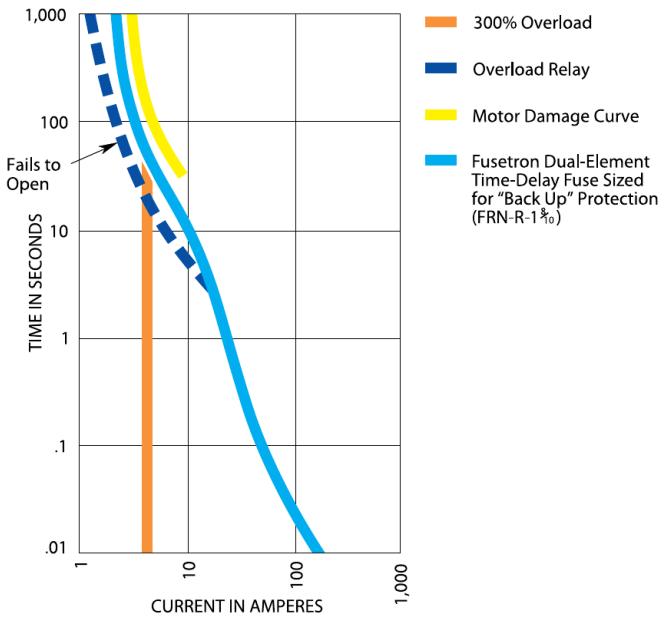
Given a motor with 1.15 service factor or greater, size the FRN-R or FRS-R fuse at 125% of the motor full load current or the next smaller available fuse size. With a motor having a service factor of less than 1.15, size these same fuses at 115% of the motor's FLA or the next smaller size.

Motor Backup Overload Protection

By using the following "backup" method of fusing, it is possible to have two levels of overload protection. Begin by sizing the overload relays according to the manufacturers directions. Then, size the fuse at 125%-130% or the next larger size. With this combination you have the convenience of being able to quickly reset the overload relay after solving a minor problem, while the fuses remain unopened. However, if the overload relays are sized too large, if the contacts fail to open for any reason or the heaters lose calibration, the fuses will open before the motor damage curve is reached.

Typically LPN-RK_SP, and LPS-RK_SP or FRN-R, and FRS-R fuses have sufficient delay and thermal capacity to be sized for motor backup overload protection.

Curve 10 below shows the backup protection available with this method.



Curve 10

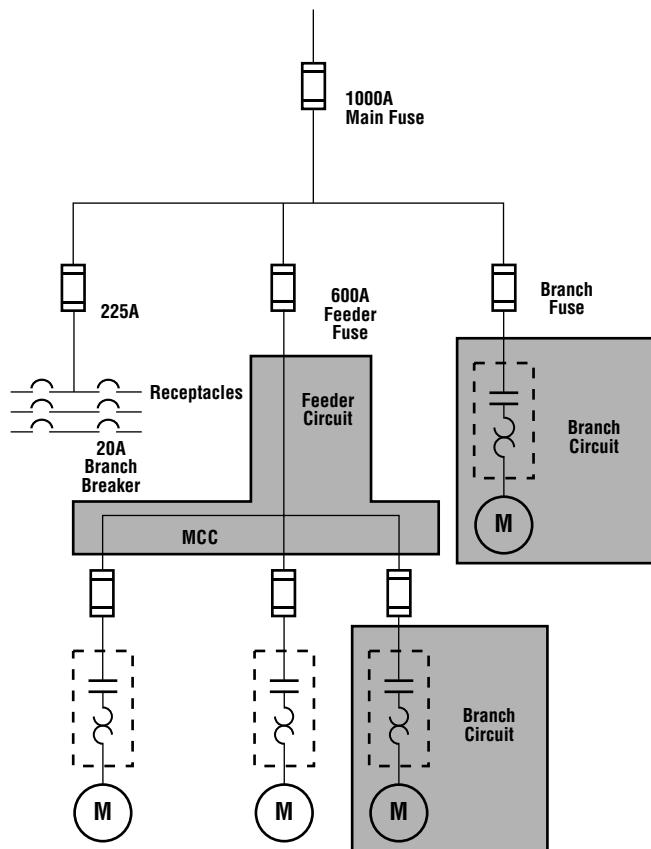
NEC® 430.52 Explanation

Motor Circuit Protection

Motor circuit protection describes the short-circuit protection of conductors supplying power to the motor, the motor controller, and motor control circuits/conductors.

430.52 provides the maximum sizes or settings for overcurrent devices protecting the motor branch circuit. A branch circuit is defined in Article 100 as "The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s)."

NEC® Motor Circuit Protection Requirements



Note that the branch circuit extends from the last branch circuit overcurrent device to the load.

Table 430.52 lists the maximum sizes for Non-Time-Delay Fuses, Dual Element (Time-Delay) Fuses, Instantaneous Trip Circuit Breakers, and Inverse Time Circuit Breakers. Sizing is based on full load amp values shown in Table 430.247 through 430.250, not motor nameplate values.

For example, the maximum time-delay fuse for a 10HP, 460 volt, 3 phase motor with a nameplate FLA of 13 amps would be based on 175% of 14 amps, not 175% of 13 amps.

Table 430.52. Maximum Rating or Setting of Motor Branch Circuit, Short-Circuit and Ground Fault Protective Devices

Type of Motor	Percent of Full-Load Current			
	Non-Time-Delay Fuse**	Dual-Element (Time-Delay) Fuse**	Instantaneous Trip Breaker	Inverse Time Breaker*
Single-phase motors	300	175	800	250
AC polyphase motors other than wound-rotor	300	175	800	250
Squirrel Cage: Other than Design B	300	175	800	250
Design B	300	175	1100	250
Synchronous†	300	175	800	250
Wound Rotor	150	150	800	150
Direct-current (constant voltage)	150	150	250	150

For certain exceptions to the values specified, see 430.52 through 430.54.

* The values given in the last column also cover the ratings of non-adjustable inverse time types of circuit breakers that may be modified as in 430.52.

** The values in the Non-Time-Delay Fuse Column apply to Time-Delay Class CC fuses.

† Synchronous motors of the low-torque, low-speed type (usually 450 rpm or lower), such as are used to drive reciprocating compressors, pumps, etc., that start unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200 percent of full-load current.

Standard sizes for fuses and fixed trip circuit breakers, per 240.6, are 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000 5000, and 6000 amps. Additional standard fuse sizes are 1, 3, 6, 10, and 601 amps.

The exceptions in 430.52 allow the user to increase the size of the overcurrent device if the motor is not able to start. All Class CC fuses can be increased to 400%, along with non-time-delay fuses not exceeding 600 amps. Time-delay (dual-element) fuses can be increased to 225%. All Class L fuses can be increased to 300%. Inverse time (thermal-magnetic) circuit breakers can be increased to 400% (100 amp and less) or 300% (larger than 100 amps). Instant trip circuit breakers may be adjusted to 1300% for other than Design B motors and 1700% for energy efficient Design B motors.

430.52(C)(2) reminds the user that the maximum device ratings which are shown in a manufacturer's overload relay table must not be exceeded even if higher values are allowed by other parts of 430.52.

430.52(C)(3) details the requirements that instant-trip CBs can only be used if part of a listed combination motor controller.

Disconnecting Means for Motor Circuits

Notes:

1. "In Sight From" means that the motor must be visible and not more than 50 feet distant. (Definitions in Article 100.)
2. "Controller" includes any switch or device normally used to start or stop a motor by making and breaking the motor circuit current (430.81).
3. A disconnecting means must be located in sight of the controller (430.102). For exceptions see 430.102.
4. A switch can serve both as a controller and disconnecting means if properly rated in accordance with 430.111 and 430.83.

Switches for Motor Circuits

The Code requirements for switches used as controllers and disconnect switches are as follows (430.81, 430.83, 430.109, 430.110, 430.111):

For 0 to 300 volt stationary motors:

- **2Hp or Less** – Use horsepower rated switch, or general use switch having amp rating at least twice the amp rating of the motor, or general use AC (only) snap switch having amp rating at least 125% of motor current rating.
- **Greater than 2Hp to 100Hp** – Switch must have horsepower rating.
- **Larger than 100Hp** – Disconnect purposes–switch must have an amp rating at least 115% of the motor full load current from Tables 430.247 through 430.250.
- Controller purposes–switch must have horsepower rating.

For 301 to 600 Volt Stationary Motors:

- **Less than 100Hp** – Switch must have horsepower rating.
- **Larger than 100Hp** – Disconnect purposes–switch must have an amp rating at least 115% of the motor full load current from Tables 430.247 through 430.250.
- Controller purposes–switch must have horsepower rating.

For Portable Motors:

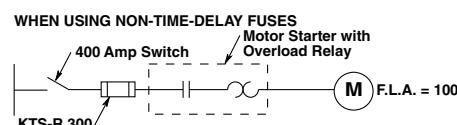
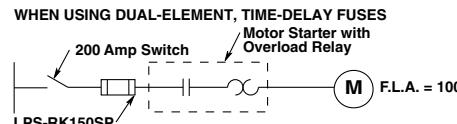
- An attachment plug and receptacle may serve as disconnect on all sizes.
- $\frac{1}{8}$ Hp or Less – An attachment plug and receptacle may serve as controller.
- Larger than $\frac{1}{8}$ Hp – Controller must meet requirements as outlined for stationary motors (shown above).

Size of Hp Rated Switches (Switch Size Savings)

Low-Peak and Fusetron dual-element fuses rather than non-time-delay fuses are recommended for motor branch circuit protection because normally dual-element fuses permit the use of a smaller switch size, give better protection, reduce cost, and require less space.

For motors, oversized switches must be used with non-time-delay fuses because this type of fuse has very little time-lag. Non-time-delay fuses are generally sized at 300% of the motor rating to hold normal motor starting current. Consequently, the switch also has to be oversized to accommodate these fuses.

The dual-element fuse can be sized close to the motor full-load amps and a smaller switch used, as shown in the following illustrations.



Branch circuit (short-circuit) protection can be provided for the given motor by either a 150 amp dual-element, time-delay fuse or a 300 amp non-time-delay fuse. The dual-element fuse selection above provides these advantages: (1) Backup overload protection, (2) smaller switch size, resulting in lower cost, (3) smaller fuse amp case size, resulting in lower cost, (4) short-circuit protection that is comparable or better than non-time-delay (fast-acting) fuse.

Most switches are listed with two Hp ratings. The Standard horsepower rating is based on the largest non-time-delay (non-dual-element) fuse rating (1) which can be used in the switch, and (2) which will normally permit the motor to start. The Maximum horsepower rating is based on the largest rated time-delay Low-Peak or Fusetron dual-element fuse (1) which can be used in the switch, and (2) which will normally permit the motor to start. Thus when Low-Peak or Fusetron dual-element fuses are used, smaller size switches can be used (430.57 Exception).

Conductors For Motor Branch and Feeder Circuits Motor Branch Circuit Conductors

The ampacity of branch circuit conductors supplying a single motor must be at least 125% of the motor full-load current rating [430.22].

Exceptions: For conductors supplying motors used for short-time, intermittent, periodic, or varying duty refer to 430.22(E).

Any motor application must be considered continuous duty unless the nature of the apparatus it drives is such that the motor will not operate continuously with load under any conditions of use.

Requirements for 18AWG and 16AWG conductors supplying small motors are found in 430.22(G).

Feeder Circuits For Motors

Feeder Conductor Ampacity

The ampacity of a conductor supplying two or more motors must be at least equal to the sum of (1) 125% of the largest motor (if there are two or more motors of the largest size, one of them is considered to be the largest), and (2) the total of the full-load amp ratings for all other motors and other loads.

Where different voltages exist, the current determined per the above shall be multiplied by the ratio of output to input voltage.

Feeder Fuse Size

On normal installations, size Fusetron dual-element fuses or Low-Peak dual-element fuses equal to the combined amp rating of (1) 150% to 175% F.L.A. of the largest AC motor (if there are two or more motors of the same size, one of them is considered to be the largest), and (2) the sum of all the F.L.A. for all other motors.

This dual-element fuse size should provide feeder protection without unnecessary fuse openings on heavy motor startings.

Where conditions are severe, as where a high percentage of motors connected must be started at one time, a larger size may be necessary. In that event, use the maximum size permitted by the Code as detailed in the maximum motor circuit feeder fuse (430.62) under motor circuit protection.

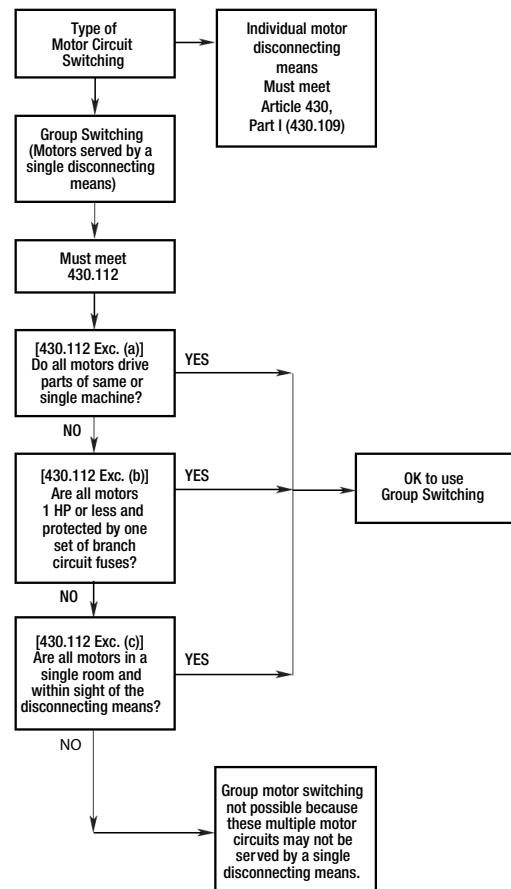
Group Switching

Motors Served by a Single Disconnecting Means (Group Switching)

430.112 covers the requirements for serving two or more motors with the same disconnecting means. Each motor must be provided with an individual disconnecting means unless:

- (a) all motors drive parts of a single machine
- or (b) all motors are 1HP or less as permitted by 430.53(A)
- or (c) all motors are in a single room and within sight (visible and not more than 50 feet) of the disconnecting means.

Group Switching



OPM-NG



CH Series



TCFH & TCF Fuse



OPM1038



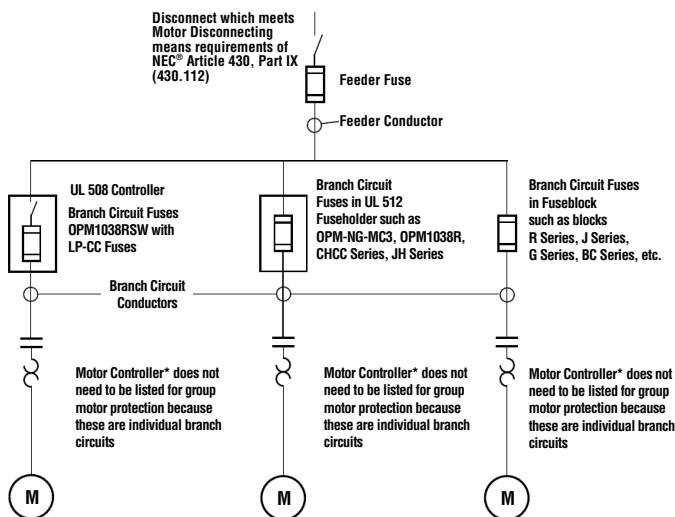
JT Series



OPM1038SW

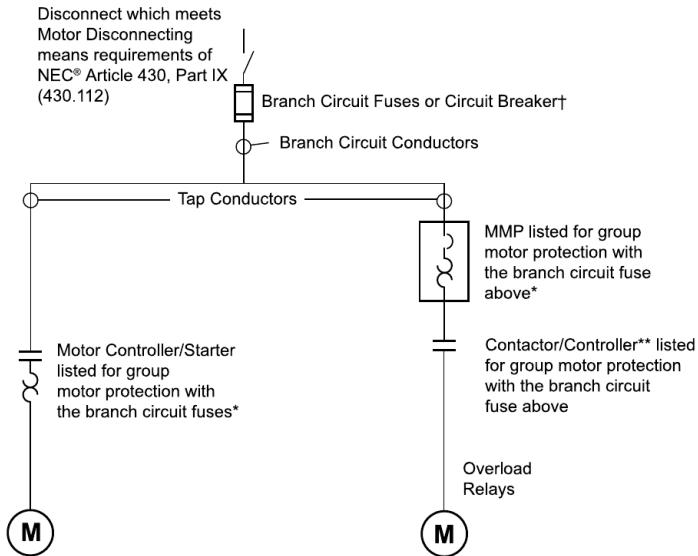
Group Switching Application

Preferred Method: Can achieve excellent protection and lower cost.



Group Switching with Group Motor Protection Application[§]

Group Switching with Group Motor Protection Application[§]



* Must be within sight of the branch circuit disconnecting means.

§ Must meet both group motor protection (430.53) and group switching requirements (430.112). Often limited in application.

**Often used in addition to MMP for automatic/remote control.

NEC® Article 430 and Tables Explanation

Columns 1 & 2

Motor horsepower ratings are listed in Column 1. Full load amps from Tables 430.247 through 430.250 are provided in Column 2.

Column 3

Various fuse types are listed in Column 3. The LPJ_SP is a 600Vac, 0 - 600 amp, time-delay, Class J, "Low-Peak" fuse, with a 300,000 amp interrupting rating. The TCF is a 600Vac, 1 - 100 amp dual-element, time-delay, Class CF IP-20 finger-safe fuse with a 300,000 amp interrupting rating. The LP-CC is a 600Vac, 0 - 30 amp, time-delay, Class CC, Low-Peak fuse with a 200,000 amp interrupting rating. The LPS-RK_SP and LPN-RK_SP are 600 and 250Vac, 0 - 600 amp, time-delay, Class RK1, Low-Peak fuses with interrupting ratings of 300,000 amps. FRS-R and FRN-R are 600 and 250Vac, 0 - 600 amp, time-delay, Class RK5, Fusetron Dual-Element fuses with interrupting ratings of 200,000 amps. The KRP-C_SP is a 600Vac, 601 - 6000 amp, time-delay, Class L, Low-Peak fuse, with a 300,000 amp AC interrupting rating. The DC listed ratings for these fuses are:

LPJ	1 to 600SP	300Vdc	LPN-RK	0 to 60SP	125Vdc
TCF	1 to 100	300Vdc	LPN-RK	70 to 600SP	250Vdc
LP-CC	½ to 2 %	300Vdc	LPS-RK	0 to 600SP	300Vdc
LP-CC	3 to 15	150Vdc	FRN-R	0 to 60	125Vdc
FRN-R	110-200	125Vdc	FRN-R	225 to 600	250Vdc
LP-CC	20 to 30	300Vdc	FRS-R	0 to 600	300Vdc

Column 4 - Optimal Branch Circuit Protection

There are two distinct levels of protection philosophy provided in this Column. LPS-RK_SP, LPN-RK_SP, FRS-R and FRN-R fuses are sized for motor running "back-up" protection and provide superb short circuit protection at the same time. LPJ_SP, TCF, and LP-CC fuses are sized a little larger but are even more current limiting, providing an even greater degree of short circuit protection for the motor circuit.

All the fuses selected from this column provide short circuit and ground-fault protection for motor branch circuits (430.52), but typically are not the maximum allowed. Fuses sized in accordance with Column 4 must be used in conjunction with properly sized motor overload protection such as overload relays or solid state motor controllers (430.32). This fuse sizing is normally large enough to allow the overload protective device to operate on overloads without opening the fuse. Yet for many cases, this fuse amp rating selection is smaller than the maximums allowed per Columns 5 or 6 (430.52). In some cases, this smaller amp rating selection may provide the benefits of a smaller size disconnect and better short circuit protection. If a motor has a long starting time, high starting current profile or is cycled frequently, it may be necessary to use Column 5 or 6.

The LPS-RK_SP, LPN-RK_SP, FRS-R and FRN-R fuses sized per this column provide short circuit and ground-fault protection for motor branch circuits (430.52) as discussed in the previous paragraph. In addition, these dual-element fuses exhibit longer time-delay characteristics and can therefore be sized to provide back-up motor overload protection. The fuse sizing in Column 4 for LPS-RK_SP, LPN-RK_SP, FRS-R and FRN-R fuses provides a degree of motor and circuit overload protection to back-up the normal motor overload protective device. Note: This level of protection requires a well-designed, true dual-element fuse. The Fusetron Fuses, FRS-R and FRN-R, and Low-Peak Fuses, LPS-RK_SP and LPN-RK_SP, are the industry leading dual-element fuses with excellent over-load time-delay characteristics and current-limiting short circuit ability. The Low-Peak Dual-Element Fuses have better current-limiting ability than Fusetron Dual-Element Fuses.

The amp ratings in Column 4 are determined by using Column 2 motor ampacity values and the following:

LPJ_SP & TCF: 150% or the next larger Bussmann amp rating if 150% does not correspond to a Bussmann fuse amp rating.

LP-CC ½ to 15A: 200% (150% for DC) or the next larger Bussmann size if 200% (150% for DC) does not correspond to a Bussmann fuse amp rating.

LP-CC 20 to 30A: 300% (150% for DC) or the next larger Bussmann size if 300% (150% for DC) does not correspond to a Bussmann fuse amp rating.

LPS-RK_SP and LPN-RK_SP: 130% or the next larger Bussmann amp rating if 130% does not correspond to a Bussmann fuse amp rating.

FRS-R and FRN-R: 125% or the next larger Bussmann amp rating if 125% does not correspond to a Bussmann fuse amp rating.

Column 5 - Branch Circuit Protection, Max. General Applications

Fuses selected from this column are intended to provide short circuit and ground-fault protection for motor branch circuits. Fuses sized in accordance with Column 5 must be used in conjunction with properly sized motor overload protection such as overload relays or solid state motor controllers (430.32). Column 5 fuse sizing provides the maximum NEC® 430.52 amp ratings for general purpose applications. It takes into account 430.52(C)(1) Exception No. 1, which allows the next standard amp rating fuse (per standard fuse amp ratings in 240.6) to be used if the maximum percentage in Table 430.52 does not correspond to a standard fuse amp rating. If this Column 5 fuse sizing does not allow the motor to start, then Column 6 may provide a larger amp rating.

The amp ratings in Column 5 are determined by using Column 2 motor ampacity values and the following:

LPJ_SP, TCF, LPS-RK_SP, LPN-RK_SP, FRS-R, FRN-R and KRP-C_SP: 175% (150% for DC motors) or the next larger **240.6 standard** fuse amp rating if 175% (150% for DC motors) does not correspond to a standard fuse amp rating.

LP-CC: 300% (150% for DC motors) or the next larger **240.6 standard** fuse amp rating if 300% (150% for DC motors) does not correspond to a standard fuse amp rating.

Sizes shown for the LP-CC can also be used for non-time delay fuses such as **JKS, KTN-R, KTS-R, JJN, JJS, and KTK-R**.

Column 6 - Branch Circuit Protection, Max. Heavy Start

When the amp rating shown in Column 5 is not sufficient to start a motor, a larger amp rating is often available by utilizing 430.52(C)(1) Exception No. 2. The amp ratings in Column 6 are the larger of the amp rating allowed by 430.52(C)(1) Exception No. 1, or 430.52(C)(1) Exception No. 2. These amp ratings will often be required when acceleration times are greater than 5 seconds, when plugging or jogging applications exist, or where there are high inrush currents (such as energy efficient Design B motors). (In a few cases, the amp rating in Column 6 may be smaller than the maximum permitted due to the limitation of the fuse type, such as LP-CC, Class CC fuses that are only available in ratings up to 30 amps. In these cases, if the amp rating shown is not sufficient to start the motor, select a different family of fuses that meet the requirements.) The amp ratings in Column 6 are determined by using Column 2 motor ampacity values and the following:

LPJ_SP, TCF, LPS-RK_SP, LPN-RK_SP, FRS-R, and FRN-R: 225% or the next smaller Bussmann amp rating if 225% does not correspond to a Bussmann fuse amp rating.

LP-CC: 400% or the next smaller Bussmann amp rating if 400% does not correspond to a Bussmann fuse amp rating.

KRP-C_SP: 300% or the next smaller Bussmann amp rating, if 300% does not correspond to a Bussmann amp rating.

Sizes shown for the LP-CC can also be used for non-time delay fuses such as **FCF, JKS, KTN-R, KTS-R, JJN, JJS, AND KTK-R**.

Column 7

Horsepower-rated switch sizes given in Column 7 are based on 115% (430.110) of Column 2. Switch sizes need to be increased when, because of starting requirements, the fuses are sized above the rating of the switch shown in this column.

Column 8

Sizes listed are for general-purpose magnetic controllers (single speed, full-voltage for limited plugging and jogging-duty) as shown in NEMA Standards Publication ICS-2-2000.

NEC® Article 430 and Tables Explanation

Column 9

Copper wire sizes are based upon 125% (430.22) of values shown in Column 2 and ampacities listed in Table 310.15(B)(16) for 75°C terminals. Although the NEC® allows 60°C terminations for equipment rated 100 amp or less, most equipment terminations have been rated for 75°C conductors. If equipment terminations are rated for 60°C conductors only, the 60°C ampacities must be utilized and therefore larger conductor sizes may be required than those shown in this column. See 110.14(C)(1)(a). Where utilized in industrial machinery, per the requirements in NFPA79 and per the requirements of 430.22(G) smaller conductors (18 AWG and 16 AWG) may be able to be used.

200Vac Three-Phase Motors & Circuits

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applic 430.52(C)(1)	NEC® Max for Heavy Start 430.52(C)(1)	Minimum Switch Size 430.110	Minimum NEMA Starter NEMA ICS 2-2000 Size	Minimum Copper Wire THWN or THHN AWG or KCML Table 310.15(B)(16) Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.250 HP	Table 430.250 AMPS	Type	Class		Exc. No. 1 AMPS ¹	Exc. No. 2 AMPS ¹	AMPS	Size		
$\frac{1}{2}$	2.5	LPJ_SP	J	4	6	6	30	00	14	$\frac{1}{2}$
		TCF	CF/ ^f	6	6	6				
		LP-CC	CC	5	10	10				
		LPN-RK_SP	RK1	3 $\frac{1}{2}$	6	6				
		FRN-R	RK5	3 $\frac{3}{4}$	6	6				
$\frac{3}{4}$	3.7	LPJ_SP	J	5 $\frac{1}{2}$	10	10	30	00	14	$\frac{1}{2}$
		TCF	CF/ ^f	6	10	10				
		LP-CC	CC	7 $\frac{1}{2}$	15	15				
		LPN-RK_SP	RK1	5	10	10				
		FRN-R	RK5	5	10	10				
$1\frac{1}{2}$	4.8	LPJ_SP	J	8	10	10	30	00	14	$\frac{1}{2}$
		TCF	CF/ ^f	10	10	10				
		LP-CC	CC	10	15	15				
		LPN-RK_SP	RK1	6 $\frac{1}{4}$	10	10				
		FRN-R	RK5	6	10	10				
$1\frac{1}{2}$	6.9	LPJ_SP	J	12	15	15	30	00	14	$\frac{1}{2}$
		TCF	CF/ ^f	15	15	15				
		LP-CC	CC	15	25	25				
		LPN-RK_SP	RK1	9	15	15				
		FRN-R	RK5	9	15	15				
$2\frac{1}{2}$	7.8	LPJ_SP	J	12	15	17 $\frac{1}{2}$	30	0	14	$\frac{1}{2}$
		TCF	CF/ ^f	15	15	17 $\frac{1}{2}$				
		LP-CC	CC	25	25	30				
		LPN-RK_SP	RK1	12	15	17 $\frac{1}{2}$				
		FRN-R	RK5	10	15	17 $\frac{1}{2}$				
$3\frac{1}{2}$	11	LPJ_SP	J	17 $\frac{1}{2}$	20	20	30	0	14	$\frac{1}{2}$
		TCF	CF/ ^f	17 $\frac{1}{2}$	20	20				
		LP-CC	CC	25	—	20				
		LPN-RK_SP	RK1	15	20	20				
		FRN-R	RK5	15	20	20				
$5\frac{1}{2}$	17.5	LPJ_SP	J	30	35	35	30*	1	12	$\frac{1}{2}$
		TCF	CF/ ^f	30	35	35				
		LPN-RK_SP	RK1	25	35	35				
		FRN-R	RK5	25	35	35				
		LPJ_SP	J	40	45	50				
$7\frac{1}{2}$	25.3	TCF	CF/ ^f	40	45	50	60	1	10**	$\frac{1}{2}**$
		LPN-RK_SP	RK1	35	45	50				
		FRN-R	RK5	35	45	50				
		LPJ_SP	J	50	60	70				
		TCF	CF/ ^f	50	60	70				
$10\frac{1}{2}$	32.2	LPN-RK_SP	RK1	45	60	70	60*	2	8**	$\frac{1}{2}**$
		FRN-R	RK5	45	60	70				
		LPJ_SP	J	80	90	100				
		TCF	CF/ ^f	80	90	100				
		LPN-RK_SP	RK1	70	90	100				
$15\frac{1}{2}$	48.3	FRN-R	RK5	70	90	100	100*	3	6**	$\frac{1}{2}**$
		LPJ_SP	J	100	110	125				
		TCF	CF/ ^f	100	—	—				
		LPN-RK_SP	RK1	90	110	125				
		FRN-R	RK5	80	110	125				

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

/ Class J performance, special finger-safe dimensions.

Column 10

These rigid metallic conduit sizes are based upon copper conductors with THWN or THHN insulation, Table C8 of Annex C, and 75°C equipment terminals.

Conduit sizes are for three conductors per circuit for three phase motors and two conductors per circuit for single phase and DC motors. Conduit sizes may need to be increased if equipment grounding conductors or neutrals are also installed in the conduit (See 310.15(B)(3)).

If equipment terminations are rated for 60°C conductors only, the 60°C ampacities must be utilized and therefore larger conductor sizes and conduit sizes may be required.

Conductors operated in a high ambient temperature (greater than 30°C) may need to be derated. (See correction factor 310.15(B)(2).)

200Vac Three-Phase Motors & Circuits continued

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applic 430.52(C)(1) Exc. No. 1 AMPS ¹	NEC® Max for Heavy Start 430.52(C)(1) Exc. No. 2 AMPS ¹	Minimum Switch Size 430.110 AMPS	Minimum NEMA Starter NEMA ICS 2-2000 Size	Minimum Copper Wire THWN or THHN AWG or KCMIL Table 310.15(B)(16) Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.250 HP	Table 430.250 AMPS	Type	Class							
25	78.2	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	125 110 100	150 150 150	175 175 175	100*	3	3**	1**
30	92	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	150 125 125	175 175 175	200 200 200	200	4	2**	1**
40	120	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	200 175 150	225 225 225	250 250 250	200*	4	1/0	1 1/4
50	150	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	225 200 200	300 300 300	300 300 300	200*	5	3/0	1 1/4
60	177	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	300 250 225	350 350 350	350 350 350	400	5	4/0	2
75	221	LPJ_SP LPN-RK_SP FRN-R KRP-C_SP	J RK1 RK5 L	350 300 300 —	400 400 400 —	450 450 450 650	400*	5	300	2
100	285	LPJ_SP LPN-RK_SP FRN-R KRP-C_SP	J RK1 RK5 L	450 400 400 —	500 500 500 —	600 600 600 800	400*	6	500	3
125	359	LPJ_SP LPN-RK_SP FRN-R KRP-C_SP	J RK1 RK5 L	600 500 450 —	— — — 700	— — — 1000	600*	6	4/0 2/PHASE	(2)2
150	414	LPN-RK_SP FRN-R KRP-C_SP	RK1 RK5 L	600 600 —	— — 800	— — 1200	600*	6	300 2/PHASE	(2)2
200	552	KRP-C_SP	L	—	1000	1600	1200	7 ²	500 2/PHASE	(2)3

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

2 These sizes are typical. They are not shown in NEMA ICS 2-2000.

208Vac Three-Phase Motors & Circuits

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applic 430.52(C)(1) Exc. No. 1 AMPS ¹	NEC® Max for Heavy Start 430.52(C)(1) Exc. No. 2 AMPS ¹	Minimum Switch Size 430.110 AMPS	Minimum NEMA Starter NEMA ICS 2-2000 Size	Minimum Copper Wire THWN or THHN AWG or KCMIL Table 310.15(B)(16) Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.250 HP	Table 430.250 AMPS	Type	Class							
½	2.4	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	4 6 5 3 ½ 3	6 6 10 6 6	6 6 10 6 6	30	00	14	½
¾	3.5	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	5 ½ 6 7 5 4 ½	10 10 15 10 10	10 10 15 10 10	30	00	14	½
1	4.6	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	7 10 10 6 6	10 10 15 10 10	10 10 15 10 10	30	00	14	½
1 ½	6.6	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	10 10 15 9 9	15 15 20 15 15	15 15 25 15 15	30	00	14	½

*Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

2 These sizes are typical. They are not shown in NEMA ICS 2-2000.

/ Class J performance, special finger-safe dimensions.

208Vac Three-Phase Motors & Circuits continued

1	2	3		4	5	6	7	8	9	10			
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applic 430.52(C)(1) Exc. No. 1 AMPS ¹	NEC® Max for Heavy Start 430.52(C)(1) Exc. No. 2 AMPS ¹	Minimum Switch Size 430.110 AMPS	Minimum NEMA Starter NEMA ICS 2-2000 Size ²	Minimum Copper Wire THWN or THHN AWG or KCMIL Table 310.15(B)(16) Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches			
Table 430.250 HP	Table 430.250 AMPS	Type	Class										
2	7.5	LPJ_SP	J	12	15	15	30	0	14	½			
		TCF	CF/		15	15							
		LPN-CC	CC		15	25							
		LPN-RK_SP	RK1		10	15							
		FRN-R	RK5		10	15							
3	10.6	LPJ_SP	J	17 ½	20	20	30	0	14	½			
		TCF	CF/		17 ½	20							
		LPN-RK_SP	RK1		15	20							
		FRN-R	RK5		15	20							
		LPJ_SP	J		30	35		1	12	½			
5	16.7	TCF	CF/	25	30	35	30*						
		LPN-RK_SP	RK1		25	30							
		FRN-R	RK5		25	35							
		LPJ_SP	J	40	45	50	1	10**	½				
		TCF	CF/		40	45							
7 ½	24.2	LPN-RK_SP	RK1		35	45	1	10**	½				
		FRN-R	RK5		35	45							
		LPJ_SP	J		50	60	60	2	8	½**			
		TCF	CF/		50	60							
		LPN-RK_SP	RK1		45	60							
		FRN-R	RK5		40	60							
10	30.8	LPJ_SP	J	70	90	100	60*	3	6**	½**			
		TCF	CF/		70	90							
		LPN-RK_SP	RK1		70	90							
		FRN-R	RK5		60	90							
		LPJ_SP	J		100	100							
15	46.2	TCF	CF/	100	100	100	60*	3	6**	½**			
		LPN-RK_SP	RK1		100	100							
		FRN-R	RK5		100	100							
		LPJ_SP	J		125	125		3	4**	1			
		TCF	CF/		125	125							
20	59.4	LPN-RK_SP	RK1	125	150	150	100*	3	3**	1**			
		FRN-R	RK5		100	150							
		LPJ_SP	J		150	175		4	2**	1**			
		LPN-RK_SP	RK1		125	175							
		FRN-R	RK5		110	175							
25	74.8	LPJ_SP	J	175	200	250	200*	4	1/0	1 ½			
		LPN-RK_SP	RK1		150	200							
		FRN-R	RK5		150	200							
		LPJ_SP	J		225	300		5	3/0	1 ½			
		LPN-RK_SP	RK1		200	300							
30	88	FRN-R	RK5	225	300	300	200*	4	4/0	2			
		LPJ_SP	J		300	350							
		LPN-RK_SP	RK1		225	300							
		FRN-R	RK5		225	300							
		KRP-C_SP	L		—	—							
40	114	LPJ_SP	J	350	400	450	400*	5	300	2			
		LPN-RK_SP	RK1		300	400							
		FRN-R	RK5		300	400							
		LPJ_SP	J		400	450							
		LPN-RK_SP	RK1		400	450							
50	143	FRN-R	RK5	400	400	450	400*	5	3/0	1 ½			
		KRP-C_SP	L		—	—							
		LPJ_SP	J		500	600							
		LPN-RK_SP	RK1		500	600		6	500	3			
		FRN-R	RK5		500	600							
60	169	LPJ_SP	J	600	700	800	600*	6	4/0 2/PHASE	(2)2			
		LPN-RK_SP	RK1		600	700							
		FRN-R	RK5		600	700							
		KRP-C_SP	L		—	—							
		LPJ_SP	J		1000	1500							
75	211	LPN-RK_SP	RK1	1000	1200*	1400*	7	400 2/PHASE	(2)2-2 ½				
		FRN-R	RK5		1000	1200*							
		KRP-C_SP	L		—	—							
		LPJ_SP	J		1200*	1400*							
		LPN-RK_SP	RK1		1200*	1400*							
100	273	FRN-R	RK5	1200*	1400*	1600	6	500	3				
		KRP-C_SP	L		—	—							
		LPJ_SP	J		1400*	1600							
		LPN-RK_SP	RK1		1400*	1600							
		FRN-R	RK5		1400*	1600							
125	343	KRP-C_SP	L	1400*	1600	1800	6	4/0 2/PHASE	(2)2				
		LPJ_SP	J		1600	1800							
		LPN-RK_SP	RK1		1600	1800							
		FRN-R	RK5		1600	1800							
		KRP-C_SP	L		—	—							
150	396	LPJ_SP	J	1800	2000	2200	6	250 2/PHASE	(2)2				
		LPN-RK_SP	RK1		1800	2000							
		FRN-R	RK5		1800	2000							
		KRP-C_SP	L		—	—							
		LPJ_SP	J		2000	2200							
200	528	KRP-C_SP	L	2000	2200	2400	7	400 2/PHASE	(2)2-2 ½				
		LPJ_SP	J		2200	2400							
		LPN-RK_SP	RK1		2200	2400							
		FRN-R	RK5		2200	2400							
		KRP-C_SP	L		—	—							

*Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor amperages must be utilized and therefore larger conductor sizes or conduit sizes may be required.

2 These sizes are typical. They are not shown in NEMA ICS 2-2000.

/ Class J performance, special finger-safe dimensions.

230Vac Three-Phase Motors & Circuits (220-240Vac Systems)

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applc	NEC® Max for Heavy Start	Minimum Switch Size	Minimum NEMA Starter NEMA ICS 2-2000 Size	Minimum Copper Wire THWN or THHN AWG or KCML Table 310.15(B)(16) Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.250 HP	Table 430.250 AMPS	Type	Class		430.52(C)(1) Exc. No. 1 AMPS ¹	430.52(C)(1) Exc. No. 2 AMPS ¹	AMPS			
½	2.2	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	3 ½ 6 4 ½ 3 2 8/10	6 6 10 6 6	6 6 10 6 6	30	00	14	½
¾	3.2	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	5 6 7 4 ½ 4	6 6 10 6 6	7 6 12 7 7	30	00	14	¾
1	4.2	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	7 10 9 5 ½ 5 ½	10 10 15 10 10	10 10 15 10 10	30	00	14	½
1 ½	6	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	9 10 12 8 7 ½	15 15 20 15 15	15 15 20 15 15	30	00	14	½
2	6.8	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	12 15 15 9 9	15 15 25 15 15	15 15 25 15 15	30	0	14	½
3	9.6	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	15 15 30 15 12	20 20 30 20 20	20 20 30 20 20	30	0	14	¾
5	15.2	LPJ_SP TCF LPN-RK_SP FRN-R	J CF/ RK1 RK5	25 25 20 20	30 30 30 30	30 30 30 30	30	1	14	½
7 ½	22	LPJ_SP TCF LPN-RK_SP FRN-R	J CF/ RK1 RK5	35 35 30 30	40 40 40 40	45 45 45 45	30*	1	10	½
10	28	LPJ_SP TCF LPN-RK_SP FRN-R	J CF/ RK1 RK5	45 45 40 35	50 50 50 50	60 60 60 60	60	2	10**	½
15	42	LPJ_SP TCF LPN-RK_SP FRN-R	J CF/ RK1 RK5	70 70 60 60	80 80 80 80	90 90 90 90	60*	2	6	¾
20	54	LPJ_SP TCF LPN-RK_SP FRN-R	J CF/ RK1 RK5	90 90 80 70	100 100 100 100	110 — 110 110	100*	3	4	1
25	68	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	110 90 90	125 125 125	150 150 150	100*	3	4**	1
30	80	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	125 110 100	150 150 150	175 175 175	100*	3	3**	1**
40	104	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	175 150 150	200 200 200	225 225 225	200*	4	1**	1 ¼**
50	130	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	200 175 175	250 250 250	250 250 250	200*	4	2/0	1 ½
60	154	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	250 225 200	300 300 300	300 300 300	200*	5	3/0	1 ½

*Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

J Class J performance, special finger-safe dimensions.

4 Limited by 600 amp being the largest amp rating for FRN-R and LPN-RK_SP.

230Vac Three-Phase Motors & Circuits (220-240Vac Systems) continued

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applic 430.52(C)(1) Exc. No. 1 AMPS ¹	NEC® Max for Heavy Start 430.52(C)(1) Exc. No. 2 AMPS ¹	Minimum Switch Size 430.110 AMPS	Minimum NEMA Starter NEMA ICS 2-2000 Size	Minimum Copper Wire THWN or THHN AWG or KCMIL Table 310.15(B)(16) Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.250 HP	Table 430.250 AMPS	Type	Class							
75	192	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	300 250 250	350 350 350	400 400 400	400	5	250	2
100	248	LPJ_SP LPN-RK_SP FRN-R KRP-C SP	J RK1 RK5 L	400 350 350 —	450 450 450 —	500 500 500 700	400*	5	350	2 ½
125	312	LPJ_SP LPN-RK_SP FRN-R KRP-C SP	J RK1 RK5 L	500 450 400 —	600 600 600 —	— — — 900	400*	6	3/0 2/PHASE	(2) 1 ½
150	360	LPJ_SP LPN-RK_SP FRN-R KRP-C SP	J RK1 RK5 L	600 500 450 —	— 6004 6004 700	— — — 1000	600*	6	4/0 2/PHASE	(2) 2
200	480	FRN-R KRP-C SP	RK5 L	600 —	— 1000	— 1400	600*	6	350 2/PHASE	(2) 2-2 ½

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

4 Limited by 600 amp being the largest amp rating for FRN-R and LPN-RK_SP.

460Vac Three-Phase Motors & Circuits (440-480Vac Systems)

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applic 430.52(C)(1) Exc. No. 1 AMPS ¹	NEC® Max for Heavy Start 430.52(C)(1) Exc. No. 2 AMPS ¹	Minimum Switch Size 430.110 AMPS	Minimum NEMA Starter NEMA ICS 2-2000 Size	Minimum Copper Wire THWN or THHN AWG or KCMIL Table 310.15(B)(16) Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.250 HP	Table 430.250 AMPS	Type	Class							
½	1.1	LPJ_SP TCF LP-CC LPS-RK_SP FRS-R	J CF/ CC RK1 RK5	1 ½ 3 2 ¼ 1 1½ 1 ½	3 3 6 3 3	3 3 6 3 3	30	00	14	½
¾	1.6	LPJ_SP TCF LP-CC LPS-RK_SP FRS-R	J CF/ CC RK1 RK5	2 ½ 3 3 ¾ 2 ¼ 2	3 3 6 3 3	3 ½ 3 6 ¼ 3 ½ 3 ½	30	00	14	½
1	2.1	LPJ_SP TCF LP-CC LPS-RK_SP FRS-R	J CF/ CC RK1 RK5	3 ½ 6 4 ½ 2 ½ 2 ½	6 6 10 6 6	6 6 10 6 6	30	00	14	½
1 ½	3	LPJ_SP TCF LP-CC LPS-RK_SP FRS-R	J CF/ CC RK1 RK5	4 ½ 6 6 4 4	6 6 10 6 6	6 6 12 6 ¼ 6 ¼	30	00	14	½
2	3.4	LPJ_SP TCF LP-CC LPS-RK_SP FRS-R	J CF/ CC RK1 RK5	5 ½ 6 7 4 ½ 4 ½	6 6 15 6 6	7 6 15 7 7 ½	30	00	14	½
3	4.8	LPJ_SP TCF LP-CC LPS-RK_SP FRS-R	J CF/ CC RK1 RK5	8 10 10 6 ¼ 6	10 10 15 10 10	10 10 15 10 10	30	0	14	½
5	7.6	LPJ_SP TCF LP-CC LPS-RK_SP FRS-R	J CF/ CC RK1 RK5	12 15 25 10 10	15 15 25 15 15	15 15 30 15 15	30	0	14	½

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

f Class J performance, special finger-safe dimensions.

460Vac Three-Phase Motors & Circuits (440-480Vac Systems) continued

1 Motor Size Table 430.250 HP	2 Motor FLA Table 430.250 AMPS	3 Fuse		4 Optimal Branch Ckt Protection AMPS ¹	5 NEC® Max for Gen. Applic 430.52(C)(1) Exc. No. 1 AMPS ¹	6 NEC® Max for Heavy Start 430.52(C)(1) Exc. No. 2 AMPS ¹	7 Minimum Switch Size 430.110 AMPS	8 Minimum NEMA Starter NEMA ICS 2-2000 Size	9 Minimum Copper Wire THWN or THHN AWG or KCML Table 310.15(B)(16) Size	10 Minimum Rigid Metallic Conduit Annex C Table C8 Inches
7 1/2	11	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	17 1/2 17 1/2 15 15	20 20 20 20	20 20 20 20	30	1	14	1/2
10	14	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	25 25 20 17 1/2	25 25 25 25	30 30 30 30	30	1	14	1/2
15	21	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	35 35 30 30	40 40 40 40	45 45 45 45	30*	2	10	1/2
20	27	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	45 40 40 35	50 50 50 50	60 60 60 60	60	2	10**	1/2
25	34	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	60 60 45 45	60 60 60 60	70 70 70 70	60*	2	8**	1/2**
30	40	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	60 60 60 50	70 70 70 70	90 90 90 90	60*	3	8**	1/2**
40	52	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	80 80 70 70	100 100 100 100	110 — 110 110	100*	3	6**	3/2**
50	65	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	100 100 90 90	125 — 125 125	125 — 125 125	100*	3	4**	1
60	77	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	125 110 100	150 150 150	150 150 150	100*	4	3**	1**
75	96	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	150 125 125	175 175 175	200 200 200	200	4	1**	1 1/2**
100	124	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	200 175 175	225 225 225	250 250 250	200*	4	2/0	1 1/2
125	156	LPJ_SP LPS-RK_SP FRS-R KRP-C_SP	J RK1 RK5 L	250 225 200 —	300 300 300 —	350 350 350 700	200*	5	3/0	1 1/2
150	180	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	300 250 225	350 350 350	400 400 400	400	5	4/0	2
200	240	LPJ_SP LPS-RK_SP FRS-R KRP-C_SP	J RK1 RK5 L	400 350 300 —	450 450 450 —	500 500 500 700	400*	5	350	2 1/2
250	302	LPJ_SP LPS-RK_SP FRS-R KRP-C_SP	J RK1 RK5 L	500 400 400 —	600 600 600 —	— — — 900	400*	6	3/0 2/PHASE	(2) 1 1/2
300	361	LPJ_SP LPS-RK_SP FRS-R KRP-C_SP	J RK1 RK5 L	600 500 500 —	— 6004 6004 700	— — — 1000	600*	6	4/0 2/PHASE	(2) 2
350	414	LPS-RK_SP FRS-R KRP-C_SP	RK1 RK5 L	600 600 —	— — 800	— — 1200	600*	6	300 2/PHASE	(2) 2
400	477	KRP-C_SP FRS-R	L RK5	— 600	1000 —	1400 —	600*	6	350 2/PHASE	(2) 2 1/2
450	515	KRP-C_SP	L	—	1000	1500	1200*	7	400 2/PHASE	(2) 2 1/2
500	590	KRP-C_SP	L	—	1200	1600	1200*	7	500 2/PHASE	(2) 3

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor amperages must be utilized and therefore larger conductor sizes or conduit sizes may be required.

4 Limited by 600 amp being the largest amp rating for FRS-R and LPS-RK_SP.

f Class J performance, special finger-safe dimensions.

575Vac Three-Phase Motors & Circuits (550-600Vac Systems)

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applic 430.52(C)(1) Exc. No. 1 AMPS ¹	NEC® Max for Heavy Start 430.52(C)(1) Exc. No. 2 AMPS ¹	Minimum Switch Size 430.110 AMPS	Minimum NEMA Starter NEMA ICS 2-2000 Size	Minimum Copper Wire THWN or THHN AWG or KCML Table 310.15(B)(16) Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.250 HP	Table 430.250 AMPS	Type	Class							
½	0.9	LPJ_SP	J	1 ½	3	3	30	0	14	½
		TCF	CF ¹	3	3	3				
		LP-CC	CC	1 ½	3	3 ½				
		LPS-RK_SP	RK1	1 ¼	3	3				
		FRS-R	RK5	1 ¼	3	3				
¾	1.3	LPJ_SP	J	2	3	3	30	0	14	½
		TCF	CF ¹	3	3	3				
		LP-CC	CC	2 ½	6	6				
		LPS-RK_SP	RK1	1 ½	3	3				
		FRS-R	RK5	1 ½	3	3				
1	1.7	LPJ_SP	J	2 ½	3	3 ½	30	0	14	½
		TCF	CF ¹	3	3	3				
		LP-CC	CC	3 ½	6	6 ¼				
		LPS-RK_SP	RK1	2 ¼	3	3 ½				
		FRS-R	RK5	2 ¼	3	3 ½				
1 ½	2.4	LPJ_SP	J	4	6	6	30	0	14	½
		TCF	CF ¹	6	6	6				
		LP-CC	CC	5	10	10				
		LPS-RK_SP	RK1	3 ¾	6	6				
		FRS-R	RK5	3	6	6				
2	2.7	LPJ_SP	J	4 ½	6	6	30	0	14	½
		TCF	CF ¹	6	6	6				
		LP-CC	CC	5 ½	10	10				
		LPS-RK_SP	RK1	4	6	6				
		FRS-R	RK5	3 ½	6	6				
3	3.9	LPJ_SP	J	6	10	10	30	0	14	½
		TCF	CF ¹	6	10	10				
		LP-CC	CC	8	15	15				
		LPS-RK_SP	RK1	5 ½	10	10				
		FRS-R	RK5	5	10	10				
5	6.1	LPJ_SP	J	10	15	15	30	0	14	½
		TCF	CF ¹	10	15	15				
		LP-CC	CC	15	20	20				
		LPS-RK_SP	RK1	8	15	15				
		FRS-R	RK5	8	15	15				
7 ½	9	LPJ_SP	J	15	20	20	30	1	14	½
		TCF	CF ¹	15	20	20				
		LP-CC	CC	30	30	30				
		LPS-RK_SP	RK1	12	20	20				
		FRS-R	RK5	12	20	20				
10	11	LPJ_SP	J	17 ½	20	20	30	1	14	½
		TCF	CF ¹	17 ½	20	20				
		LP-CC	CC	15	20	20				
		LPS-RK_SP	RK1	15	20	20				
		FRS-R	RK5	15	20	20				
15	17	LPJ_SP	J	30	30	35	30*	2	12	½
		TCF	CF ¹	30	30	35				
		LPS-RK_SP	RK1	25	30	35				
		FRS-R	RK5	25	30	35				
		FRS-R	RK5	25	30	35				
20	22	LPJ_SP	J	35	40	45	30*	2	10	½
		TCF	CF ¹	35	40	45				
		LP-CC	CC	30	40	45				
		LPS-RK_SP	RK1	30	40	45				
		FRS-R	RK5	30	40	45				
25	27	LPJ_SP	J	45	50	60	60*	2	10**	½**
		TCF	CF ¹	45	50	60				
		LPS-RK_SP	RK1	40	50	60				
		FRS-R	RK5	35	50	60				
		FRS-R	RK5	35	50	60				
30	32	LPJ_SP	J	50	60	70	60*	3	8	½
		TCF	CF ¹	50	60	70				
		LPS-RK_SP	RK1	45	60	70				
		FRS-R	RK5	40	60	70				
		FRS-R	RK5	40	60	70				
40	41	LPJ_SP	J	70	80	90	60*	3	6	¾
		TCF	CF ¹	70	80	90				
		LPS-RK_SP	RK1	60	80	90				
		FRS-R	RK5	60	80	90				
		FRS-R	RK5	60	80	90				
50	52	LPJ_SP	J	80	100	110	100*	3	6**	¾**
		TCF	CF ¹	80	100	110				
		LPS-RK_SP	RK1	70	100	110				
		FRS-R	RK5	70	100	110				
		FRS-R	RK5	70	100	110				

*Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

/ Class J performance, special finger-safe dimensions.

575Vac Three-Phase Motors & Circuits (550-600Vac Systems) continued

1 Motor Size	2 Motor FLA	3 Fuse		4 Optimal Branch Ckt Protection	5 NEC® Max for Gen. Applic 430.52(C)(1) Exc. No. 1 AMPS ¹	6 NEC® Max for Heavy Start 430.52(C)(1) Exc. No. 2 AMPS ¹	7 Minimum Switch Size 430.110 AMPS	8 Minimum NEMA Starter NEMA ICS 2- 2000 Size	9 Minimum Copper Wire THWN or THHN AWG or KCML Table 310.15(B)(16) Size	10 Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.250 HP	Table 430.250 AMPS	Type	Class	AMPS ¹	AMPS ¹	AMPS ¹	AMPS	AMPS	AMPS	AMPS
60	62	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	100 90 80	110 110 110	125 125 125	100*	4	4**	1
75	77	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	125 110 100	150 150 150	150 150 150	100*	4	3**	1**
100	99	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	150 150 125	175 175 175	200 200 200	200	4	1**	1 ½**
125	125	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	200 175 175	225 225 225	250 250 250	200*	5	2/0	1 ½
150	144	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	225 200 200	300 300 300	300 300 300	200*	5	3/0	1 ½
200	192	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	300 250 250	350 350 350	400 400 400	400	5	250	2
250	242	LPJ_SP LPS-RK_SP FRS-R KRP-C_SP	J RK1 RK5 L	400 350 350 —	450 450 450 —	500 500 500 700	400*	6	350	2 ½
300	289	LPJ_SP LPS-RK_SP FRS-R KRP-C_SP	J RK1 RK5 L	450 400 400 —	600 600 600 —	600 600 600 800	400*	6	500	3
350	336	LPJ_SP LPS-RK_SP FRS-R KRP-C_SP	J RK1 RK5 L	600 450 450 —	600 600 600 601	— — — 1000	600*	6	4/0 2/PHASE	(2) 2
400	382	LPJ_SP LPS-RK_SP FRS-R KRP-C_SP	J RK1 RK5 L	600 500 500 —	— — — 700	— — — 1100	600*	6	250 2/PHASE	(2) 2
450	412	LPS-RK_SP FRS-R KRP-C_SP	RK1 RK5 L	600 600 —	— — 800	— — 1200	600*	7	300 2/PHASE	(2) 2
500	472	FRS-R KRP-C_SP	RK5 L	600 —	— 1000	— 1400	600*	7	350 2/PHASE	(2) 2 ½

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

115Vac Single-Phase Motors & Circuits (110-120Vac Systems)

1 Motor Size Table 430.248 HP	2 Motor FLA Table 430.248 AMPS	3 Fuse		4 Optimal Branch Ckt Protection	5 NEC® Max for Gen. Applic 430.52(C)(1) Exc. No. 1 AMPS ¹	6 NEC® Max for Heavy Start 430.52(C)(1) Exc. No. 2 AMPS ¹	7 Minimum Switch Size 430.110	8 Minimum NEMA Starter NEMA ICS 2-2000 Size	9 Minimum Copper Wire THWN or THHN AWG or KC MIL Table 310.15(B)(16) Size	10 Minimum Rigid Metallic Conduit Annex C Table C8 Inches
%	4.4	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	8 10 9 6 5 6/10	10 10 15 10 10	10 10 15 10 10	30	00	14	½
%	5.8	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	9 10 12 8 7 ½	15 15 20 15 15	15 15 20 15 15	30	00	14	½
%	7.2	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	12 15 15 10 9	15 15 25 15 15	15 15 25 15 15	30	00	14	½
%	9.8	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	15 15 30 15 15	20 20 30 20 20	20 20 30 20 20	30	0	14	½
%	13.8	LPJ_SP TCF LPN-RK_SP FRN-R	J CF/ RK1 RK5	25 25 20 17 ½	25 25 25 25	30 30 30 30	30	0	14	½
1	16	LPJ_SP TCF LPN-RK_SP FRN-R	J CF/ RK1 RK5	25 25 25 20	30 30 30 30	35 35 35 35	30*	0	14	½
1 ½	20	LPJ_SP TCF LPN-RK_SP FRN-R	J CF/ RK1 RK5	30 30 30 25	35 35 35 35	45 45 45 45	30*	1	12	½
2	24	LPJ_SP TCF LPN-RK_SP FRN-R	J CF/ RK1 RK5	40 40 35 30	45 45 45 45	50 50 50 50	30*	1	10	½
3	34	LPJ_SP TCF LPN-RK_SP FRN-R	J CF/ RK1 RK5	60 50 45 45	60 60 60 60	70 70 70 70	60*	2	8**	¾**
5	56	LPJ_SP TCF LPN-RK_SP FRN-R	J CF/ RK1 RK5	90 90 80 70	100 100 100 100	125 — 125 125	100*	3	4	¾**
7 ½	80	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	125 110 100	150 150 150	175 175 175	100*	3	3**	1**
10	100	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	150 150 125	175 175 175	225 225 225	200*	4 ²	1	1 ¼

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

2 These sizes are typical. They are not shown in NEMA ICS 2-2000.

/ Class J performance, special finger-safe dimensions.

230Vac Single-Phase Motors & Circuits (220-240Vac Systems)

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applic 430.52(C)(1) Exc. No. 1 AMPS ¹	NEC® Max for Heavy Start 430.52(C)(1) Exc. No. 2 AMPS ¹	Minimum Switch Size 430.110	Minimum NEMA Starter NEMA ICS 2-2000 Size	Minimum Copper Wire THWN or THHN AWG or KCML Table 310.15(B)(16) Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.248 HP	Table 430.248 AMPS	Type	Class	AMPS ¹	AMPS ¹	AMPS ¹	AMPS	AMPS	AMPS	AMPS
$\frac{1}{6}$	2.2	LPJ_SP	J	3 $\frac{1}{2}$	6	6	30	00	14	$\frac{1}{2}$
		TCF	CF/	6	6	6				
		LP-CC	CC	4 $\frac{1}{2}$	10	10				
		LPN-RK_SP	RK1	3	6	6				
		FRN-R	RK5	2 $\frac{1}{2}$	6	6				
$\frac{1}{4}$	2.9	LPJ_SP	J	4 $\frac{1}{2}$	6	6	30	00	14	$\frac{1}{2}$
		TCF	CF/	6	6	6				
		LP-CC	CC	6	10	10				
		LPN-RK_SP	RK1	4	6	6 $\frac{1}{2}$				
		FRN-R	RK5	4	6	6 $\frac{1}{2}$				
$\frac{1}{3}$	3.6	LPJ_SP	J	5 $\frac{1}{2}$	10	10	30	00	14	$\frac{1}{2}$
		TCF	CF/	6	10	10				
		LP-CC	CC	7	15	15				
		LPN-RK_SP	RK1	5	10	10				
		FRN-R	RK5	4 $\frac{1}{2}$	10	10				
$\frac{1}{2}$	4.9	LPJ_SP	J	8	10	10	30	00	14	$\frac{1}{2}$
		TCF	CF/	10	10	10				
		LP-CC	CC	10	15	15				
		LPN-RK_SP	RK1	8	10	10				
		FRN-R	RK5	6 $\frac{1}{2}$	10	10				
$\frac{3}{4}$	6.9	LPJ_SP	J	12	15	15	30	00	14	$\frac{1}{2}$
		TCF	CF/	15	15	15				
		LP-CC	CC	15	25	25				
		LPN-RK_SP	RK1	9	15	15				
		FRN-R	RK5	9	15	15				
$\frac{1}{2}$	8	LPJ_SP	J	12	15	17 $\frac{1}{2}$	30	00	14	$\frac{1}{2}$
		TCF	CF/	15	15	17 $\frac{1}{2}$				
		LP-CC	CC	25	25	30				
		LPN-RK_SP	RK1	12	15	17 $\frac{1}{2}$				
		FRN-R	RK5	10	15	17 $\frac{1}{2}$				
$1\frac{1}{2}$	10	LPJ_SP	J	15	20	20	30	0	14	$\frac{1}{2}$
		TCF	CF/	15	20	20				
		LP-CC	CC	30	30	30				
		LPN-RK_SP	RK1	15	20	20				
		FRN-R	RK5	15	20	20				
2	12	LPJ_SP	J	20	25	25	30	0	14	$\frac{1}{2}$
		TCF	CF/	20	25	25				
		LP-CC	CC	25	—	—				
		LPN-RK_SP	RK1	17 $\frac{1}{2}$	25	25				
		FRN-R	RK5	15	25	25				
3	17	LPJ_SP	J	30	30	35	30*	1	12	$\frac{1}{2}$
		TCF	CF/	30	30	35				
		LPN-RK_SP	RK1	25	30	35				
		FRN-R	RK5	25	30	35				
		LPJ_SP	J	45	50	60				
5	28	TCF	CF/	45	50	60	60	2	10**	$\frac{1}{2}$
		LPN-RK_SP	RK1	40	50	60				
		FRN-R	RK5	35	50	60				
		LPJ_SP	J	60	70	90	60*	2	8**	$\frac{1}{2}^{**}$
		TCF	CF/	60	70	90				
$7\frac{1}{2}$	40	LPN-RK_SP	RK1	60	70	90				
		FRN-R	RK5	50	70	90				
		LPJ_SP	J	80	90	110	100*	3	6**	$\frac{1}{2}^{**}$
		TCF	CF/	80	90	—				
		LPN-RK_SP	RK1	70	90	110				
		FRN-R	RK5	70	90	110				

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

/ Class J performance, special finger-safe dimensions.

90Vdc³ Motors & Circuits

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applic 430.52(C)(1) Exc. No. 1 AMPS ¹	NEC® Max for Heavy Start 430.52(C)(1) Exc. No. 2 AMPS ¹	Minimum Switch Size 430.110 AMPS	Minimum NEMA Starter NEMA ICS 2-2000 Size ² AMPS	Minimum Copper Wire THWN or THHN AWG or KCMIL Table 310.15(B)(16) Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.247 HP	Table 430.247 AMPS	Type	Class							
1/4	4.0	LPJ_SP TCF LPC_CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	6 6 6 6 5	6 6 6 6 6	6 6 15 9 9	30	1	14	1/4
1/2	5.2	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	8 10 10 8 7	10 10 10 10 10	10 10 20 10 10	30	1	14	1/4
1/2	6.8	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	12 15 15 9 9	15 15 15 15 15	15 15 25 15 15	30	1	14	1/4
3/4	9.6	LPJ_SP TCF LP-CC LPN-RK_SP FRN-R	J CF/ CC RK1 RK5	15 15 15 15 12	15 15 15 15 15	20 20 30 20 20	30	1	14	1/4

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

2 These sizes are typical. They are not shown in NEMA ICS 2-2000.

3 All equipment manufacturers should be consulted about DC voltage ratings of their equipment.

f Class J performance, special finger-safe dimensions.

120Vdc³ Motors & Circuits

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applic	NEC® Max for Heavy Start	Minimum Switch Size	Minimum NEMA Starter NEMA ICS 2-	Minimum Copper Wire THWN or THHN AWG or KCMIL Table 310.15(B)(16) Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.247 HP	Table 430.247 AMPS	Type	Class		430.52(C)(1) Exc. No. 1 AMPS ¹	430.52(C)(1) Exc. No. 2 AMPS ¹	430.110 AMPS	2000 Size ²		
½	3.1	LPJ_SP	J	5	6	6	30	1	14	½
		TCF	CF/	6	6	6				
		LP-CC	CC	6	6	12				
		LPN-RK_SP	RK1	4 ½	6	6 ½				
		FRN-R	RK5	4	6	6 ½				
½	4.1	LPJ_SP	J	7	10	10	30	1	14	½
		TCF	CF/	10	10	10				
		LP-CC	CC	9	10	15				
		LPN-RK_SP	RK1	5 ½	10	10				
		FRN-R	RK5	5 ½	10	10				
½	5.4	LPJ_SP	J	9	10	12	30	1	14	½
		TCF	CF/	10	10	10				
		LP-CC	CC	10	10	20				
		LPN-RK_SP	RK1	7 ½	10	12				
		FRN-R	RK5	7	10	12				
¾	7.6	LPJ_SP	J	12	15	15	30	1	14	½
		TCF	CF/	15	15	15				
		LP-CC	CC	15	15	30				
		LPN-RK_SP	RK1	10	15	15				
		FRN-R	RK5	10	15	15				
1	9.5	LPJ_SP	J	15	15	20	30	1	14	½
		TCF	CF/	15	15	20				
		LP-CC	CC	15	15	30 ³				
		LPN-RK_SP	RK1	15	15	20				
		FRN-R	RK5	12	15	20				
1 ½	13.2	LPJ_SP	J	20	20	25	30	1	14	½
		TCF	CF/	20	20	25				
		LP-CC	CC	20	20	30 ⁵				
		LPN-RK_SP	RK1	17 ½	20	25				
		FRN-R	RK5	17 ½	20	25				
2	17	LPJ_SP	J	30	30	35	30*	1	12	½
		TCF	CF/	30	30	35				
		LP-CC	CC	30	30	30 ⁵				
		LPN-RK_SP	RK1	25	30	35				
		FRN-R	RK5	25	30	35				
3	25	LPJ_SP	J	40	40	50	60	1	10**	½
		TCF	CF/	40	40	50				
		LPN-RK_SP	RK1	35	40	50				
		FRN-R	RK5	35	40	35				
		LPJ_SP	J	60	60	90				
5	40	TCF	CF/	60	60	60	60*	2	8**	½**
		LPN-RK_SP	RK1	60	60	90				
		FRN-R	RK5	50	60	90				
		LPJ_SP	J	90	90	125		3	4**	¾**
		TCF	CF/	90	90	—				
7 ½	58	LPN-RK_SP	RK1	80	90	125	100*	3	3**	1
		FRS-R	RK5	80	90	125				
10	76	LPJ_SP	J	125	125	150	100*	3	3**	1
		LPN-RK_SP	RK1	100	125	150				
			FRS-R	100	125	150				

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor amperages must be utilized and therefore larger conductor sizes or conduit sizes may be required.

2 Reduced voltage magnetic controller ratings

3 All equipment manufacturers should be consulted about DC voltage ratings of their equipment.

5 Largest LP-CC Fuse 30 amp. With other type fuse, could use larger amp rating in this application.

f Class J performance, special finger-safe dimensions.

180Vdc³ Motors & Circuits

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applic 430.52(C)(1) Exc. No. 1 AMPS ¹	NEC® Max for Heavy Start 430.52(C)(1) Exc. No. 2 AMPS ¹	Minimum Switch Size 430.110 AMPS	Minimum NEMA Starter NEMA ICS 2-2000 Size ² AMPS	Minimum Copper Wire THWN or THHN AWG or KCML Table 310.15(B)(16) Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.247 HP	Table 430.247 AMPS	Type	Class							
1/4	2.0	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	3 3 2 1/2 2 1/2	3 3 3 3	4 1/2 3 4 1/2 4 1/2	30	1	14	1/2
1/4	2.6	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	4 6 3 1/2 3 1/2	6 6 6 6	6 6 6 6	30	1	14	1/2
1/2	3.4	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	5 1/2 6 4 1/2 4 1/2	6 6 6 6	6 6 6 1/2 7 1/2	30	1	14	1/2
1/4	4.8	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	8 10 6 1/2 6	10 10 10 10	10 10 10 10	30	1	14	1/2
1	6.1	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	10 10 8 8	10 10 10 10	12 10 12 12	30	1	14	1/2
1 1/2	8.3	LPJ_SP TCF LP-CC LPS-RK_SP FRS-R	J CF/ CC RK1 RK5	15 15 — 12 12	15 15 — 15 15	17 1/2 15 30 17 1/2 17 1/2	30	1	14	1/2
2	10.8	LPJ_SP TCF LP-CC LPS-RK_SP FRS-R	J CF/ CC RK1 RK5	15 15 20 15 15	20 20 20 20 20	20 20 30 20 20	30	1	14	1/2
3	16	LPJ_SP TCF LP-CC LPS-RK_SP FRS-R	J CF/ CC RK1 RK5	25 25 25 20 20	25 25 25 25 25	35 35 30 35 35	30*	1	14	1/2
5	27	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	40 40 40 35	45 45 45 45	60 60 60 60	60	2	10**	1/2

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

2 These sizes are typical. They are not shown in NEMA ICS 2-2000.

3 All equipment manufacturers should be consulted about DC voltage ratings of their equipment.

/ Class J performance, special finger-safe dimensions.

240Vdc³ Motors & Circuits

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applic 430.52(C)(1) Exc. No. 1 AMPS ¹	NEC® Max for Heavy Start 430.52(C)(1) Exc. No. 2 AMPS ¹	Minimum Switch Size 430.110 AMPS	Minimum NEMA Starter NEMA ICS 2-2000 Size ² AMPS	Minimum Copper Wire THWN or THHN AWG or KCML Table 310.16 Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.247 HP	Table 430.247 AMPS	Type	Class							
1/4	1.6	LPJ_SP TCF LPN-RK_SP FRS-R	J CF/ RK1 RK5	2 1/2 3 2 1/2 2	3 3 3 3	3 1/2 3 3 1/2 3 1/2	30	1	14	1/2
1/3	2.0	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	3 3 2 1/2 2 1/2	3 3 3 3	4 1/2 3 4 1/2 4 1/2	30	1	14	1/2

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

2 Reduced voltage magnetic DC controller ratings.

3 All equipment manufacturers should be consulted about DC voltage ratings of their equipment.

/ Class J performance, special finger-safe dimensions.

240Vdc³ Motors & Circuits continued

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC® Max for Gen. Applic 430.52(C)(1)	NEC® Max for Heavy Start 430.52(C)(1)	Minimum Switch Size 430.110	Minimum NEMA Starter NEMA ICS 2-2000 Size ²	Minimum Copper Wire THWN or THHN AWG or KCMIL Table 310.15(B)(16) Size	Minimum Rigid Metallic Conduit Annex C Table C8 Inches
Table 430.247 HP	Table 430.247 AMPS	Type	Class	AMPS ¹	Exc. No. 1 AMPS ¹	Exc. No. 2 AMPS ¹	AMPS	AMPS		
½	2.7	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	4 ½ 6 4 3 ½	6 6 6 6	6 6 6 6	30	1	14	½
¾	3.8	LPJ_SP TCF LP-CC LPS-RK_SP FRS-R	J CF/ CC RK1 RK5	6 6 — 5 5	6 6 — 6 6	8 6 15 8 8	30	1	14	½
1	4.7	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	8 10 6 ½ 6	10 10 10 10	10 10 10 10	30	1	14	½
1 ½	6.6	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	10 10 9 9	10 10 10 10	12 10 12 12	30	1	14	½
2	8.5	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	15 15 12 12	15 15 15 15	17 ½ 15 17 ½ 17 ½	30	1	14	½
3	12.2	LPJ_SP TCF LP-CC LPS-RK_SP FRS-R	J CF/ CC RK1 RK5	20 20 20 17 ½ 17 ½	20 20 20 20 20	25 25 30 25 25	30	1	14	½
5	20	LPJ_SP TCF LP-CC LPS-RK_SP FRS-R	J CF/ CC RK1 RK5	30 30 30 30 25	30 30 30 30 30	45 45 45 45 45	30*	1	12	½
7 ½	29	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	45 45 40 40	45 45 45 45	60 60 60 60	60	2	8	½
10	38	LPJ_SP TCF LPS-RK_SP FRS-R	J CF/ RK1 RK5	60 60 50 50	60 60 60 60	80 60 80 80	60*	2	8**	½**
15	55	LPJ_SP TCF LPN-RK_SP FRS-R	J CF/ RK1 RK5	90 90 80 70	90 90 90 90	110 — 110 110	100*	3	4	3/4**
20	72	LPJ_SP LPN-RK_SP FRS-R	J RK1 RK5	110 100 90	110 110 110	150 150 150	100*	3	3**	1
25	89	LPJ_SP LPN-RK_SP FRS-R	J RK1 RK5	150 125 125	150 150 150	200 200 200	200	3	2**	1**
30	106	LPJ_SP LPN-RK_SP FRS-R	J RK1 RK5	175 150 150	175 175 175	225 225 225	200*	4	1/0**	1 ¼
40	140	LPJ_SP LPN-RK_SP FRS-R	J RK1 RK5	225 200 175	225 225 225	300 300 300	200*	4	2/0**	1 ¼**
50	173	LPJ_SP LPN-RK_SP FRS-R	J RK1 RK5	300 225 225	300 300 300	350 350 350	400	5	4/0**	1 ½**
60	206	LPJ_SP LPN-RK_SP FRS-R	J RK1 RK5	350 300 300	350 350 350	450 450 450	400*	5	300**	2**
75	255	LPJ_SP LPN-RK_SP FRS-R	J RK1 RK5	400 350 350	400 400 400	500 500 500	400*	5	400**	2**
100	341	LPJ_SP LPN-RK_SP FRS-R	J RK1 RK5	600 450 450	600 600 600	— — —	600	6	4/0 2/PHASE	(2) 1 ½**

* Switch size must be increased if the amp rating of the fuse exceeds the amp rating of the switch.

1 Per 430.52(C)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

** If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

2 Reduced voltage magnetic DC controller ratings for 230V circuits.

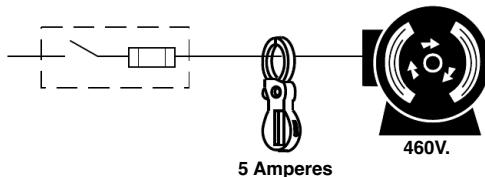
3 All equipment manufacturers should be consulted about DC voltage ratings of their equipment.

/ Class J performance, special finger-safe dimensions.

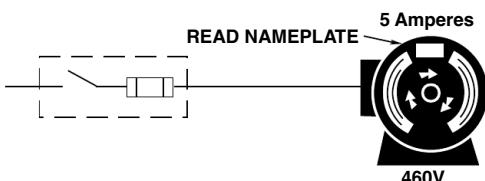
Tips For Electricians & Maintenance Crews

Recommendations for Electrician and Maintenance Crews

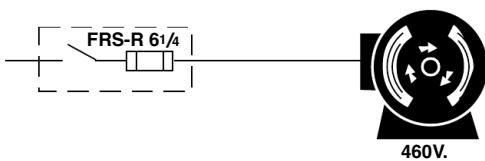
Often, for various reasons, motors are oversized for applications. For instance, a 5HP motor is installed when the load demand is only 3HP. In these cases a much higher degree of protection can be obtained by sizing the overload relay elements and/or Fusetron (FRN-R/FRS-R) and Low-Peak (LPN-RK_SP/LPS-RK_SP) dual-element, time-delay fuses based on the actual full-load current draw.



- Preferable – With a clamp-on meter, determine running RMS current when the motor is at normal full-load. (Be sure this current does not exceed nameplate current rating.) The advantage of this method is realized when a lightly loaded motor (especially those over 50 HP) experiences a single-phase condition. Even though the relays and fuses may be sized correctly based on motor nameplate, circulating currents within the motor may cause damage.



Alternate – if unable to meter the motor current, then take the current rating off the nameplate.



- Then size the overload relay elements and Fusetron FRS-R and FRN-R or Low-Peak LPS-RK_SP and LPN-RK_SP dual-element fuses based on this current. For optimum motor circuit protection offering a high degree of "back-up overload" protection, use the table that follows to assist in sizing dual-element fuses. The other fuses in the table LPJ_SP, TCF and LP-CC can provide excellent short circuit protection when sized for Optimum Motor Circuit Protection. However, they typically can not be sized close enough to provide motor back-up overload protection.
- Use a labeling system to mark the type and amp rating of the fuse that should be in the fuse clips, such as FRS-R 6 1/4. This simple step makes it easy to run spot checks for proper fuse replacement. When installing the proper fuses in the switch to give the desired level of protection, it often is advisable to leave spare fuses on top of the disconnect, the starter enclosure or in a cabinet adjacent to the motor control center. In this way, should the fuses open, the problem can be corrected and proper size fuses easily reinstalled.

* Abnormal installations may require Fusetron or Low-Peak dual-element fuses of a larger size than shown providing only short circuit protection. These applications include:

- Fusetron or Low-Peak dual-element fuses in high ambient temperature environments.
- A motor started frequently or rapidly reversed.
- A motor is directly connected to a machine that cannot be brought up to full speed quickly (large fans, centrifugal machines such as extractors and pulverizers, machines having large fly wheels such as large punch presses).
- Motor has a high Code Letter (or possibly no Code Letter) with full voltage start.
- WYE delta open transition start.
- Motor has a large inrush current, such as a Design B.

Selection of Fusetron or Low-Peak Dual-Element Fuses based upon Motor FLA for Optimum Motor Circuit Protection*

Fusetron or Low-Peak Dual-Element Fuse Size	Motor Current			
	FRN-R FRS-R Class RK5	LPN-RK_SP LPS-RK_SP Class RK1	LPJ_SP Class J	LP-CC Class CC
1/10	0-0.08	0.0000-0.0769	—	—
1/8	0.09-0.10	0.0770-0.0961	—	—
1/6 ¹⁰⁰	0.11-0.12	0.0962-0.1153	—	—
1/5	0.13-0.16	0.1154-0.1538	—	—
1/4	0.17-0.20	0.1539-0.1923	—	—
1/3	0.21-0.24	0.1924-0.2307	—	—
1/2	0.25-0.32	0.2308-0.3076	—	—
5/16	0.33-0.40	0.3077-0.3846	—	0.0000-0.2500
1/16	0.41-0.48	0.3847-0.4615	—	0.2501-0.3000
1/12	0.49-0.64	0.4616-0.6153	—	0.3001-0.4000
1/10	0.65-0.80	0.6154-0.7692	0.0-0.6666	0.4001-0.5000
1/8	0.81-0.90	0.7693-0.8653	0.6667-0.7500	0.5001-0.5625
1/6	0.91-1.00	0.8654-0.9615	0.7501-0.8333	0.5626-0.6250
1/5	1.01-1.12	0.9616-1.076	0.8334-0.9333	0.6251-0.7000
1/4	1.13-1.20	1.077-1.153	0.9334-1.000	0.7001-0.7500
1/3	1.21-1.28	1.154-1.230	1.001-1.066	0.7501-0.8000
1/2	1.29-1.44	1.231-1.384	1.067-1.200	0.8001-0.9000
2	1.45-1.60	1.385-1.538	1.201-1.333	0.9001-1.000
2 1/2	1.61-1.80	1.539-1.730	1.334-1.500	1.001-1.125
2 1/2	1.81-2.00	1.731-1.923	1.501-1.666	1.126-1.250
2 1/2	2.01-2.24	1.924-2.153	1.667-1.866	1.251-1.400
3	2.25-2.40	2.154-2.307	1.867-2.000	1.401-1.500
3 1/2	2.41-2.56	2.308-2.461	2.001-2.133	1.501-1.600
3 1/2	2.57-2.80	2.462-2.692	2.134-2.333	1.601-1.750
4	3.81-3.20	2.693-3.076	2.334-2.666	1.751-2.000
4 1/2	3.21-3.60	3.077-3.461	2.667-3.000	2.001-2.250
5	3.61-4.00	3.462-3.846	3.001-3.333	2.251-2.500
5 1/2	4.01-4.48	3.847-4.307	3.334-3.733	2.501-2.800
6	4.49-4.80	4.308-4.615	3.734-4.000	2.801-3.000
6 1/2	4.81-5.00	4.616-4.807	—	3.001-3.125
7	5.01-5.60	4.808-5.384	4.001-4.666	3.126-3.500
7 1/2	5.61-6.00	—	—	3.501-3.750
8	6.01-6.40	5.385-6.153	4.667-5.333	3.751-4.000
9	6.41-7.20	6.154-6.923	5.334-6.000	4.001-4.500
10	7.21-8.00	6.924-7.692	6.001-6.666	4.501-5.000
12	8.01-9.60	7.693-9.230	6.667-8.000	5.001-6.000
15	9.61-12.00	9.231-11.53	8.001-10.00	6.001-7.500
17 1/2	12.01-14.00	11.54-13.46	10.01-11.66	7.501-8.750
20	14.01-16.00	13.47-15.38	11.67-13.33	8.751-10.00
25	16.01-20.00	15.39-19.23	13.34-16.66	10.01-12.50
30	20.01-24.00	19.24-23.07	16.67-20.00	12.51-15.00
35	24.01-28.00	23.08-26.92	20.01-23.33	—
40	28.01-32.00	26.93-30.76	23.34-26.66	—
45	32.01-36.00	30.77-34.61	26.67-30.00	—
50	36.01-40.00	34.62-38.46	30.01-33.33	—
60	40.01-48.00	38.47-46.15	33.34-40.00	—
70	48.01-56.00	46.16-53.84	40.01-46.66	—
75	56.01-60.00	—	—	—
80	60.01-64.00	53.85-61.53	46.67-53.33	—
90	64.01-72.00	61.54-69.23	53.34-60.00	—
100	72.01-80.00	69.24-76.92	60.01-66.66	—
110	80.01-88.00	76.93-84.61	66.67-73.33	—
125	88.01-100.00	84.62-96.15	73.34-83.33	—
150	100.01-120.00	96.16-115.3	83.34-100.0	—
175	120.01-140.00	115.4-134.6	100.1-116.6	—
200	140.01-160.00	134.7-153.8	116.7-133.3	—
225	160.01-180.00	153.9-173.0	133.4-150.0	—
250	180.01-200.00	173.1-192.3	150.1-166.6	—
300	200.01-240.00	192.4-230.7	166.7-200.0	—
350	240.01-280.00	230.8-269.2	200.1-233.3	—
400	280.01-320.00	269.3-307.6	233.4-266.6	—
450	320.01-360.00	307.7-346.1	266.7-300.0	—
500	360.01-400.00	346.2-384.6	300.1-333.3	—
600	400.01-480.00	384.7-461.5	333.4-400.0	—

Graphic Explanation

Motor Starter Protection

Motor controllers are highly susceptible to damage due to short circuits. Even for moderate or low-level faults, extensive damage may occur if the short circuit protective device is not carefully selected. The most vulnerable parts are the starter contacts and heater elements. Fault currents can weld the contacts and cause the heater elements to vaporize or be critically damaged. The metalized vapors from such damage then can initiate further starter destruction in the enclosure.

Often, after a fault, no apparent damage is visible (i.e., the contacts are not welded and the heater elements are not burnt up). However, the heat energy from the fault may have caused too high of a heat excursion for the heater elements or overload relay sensing element to withstand, with the result being a permanently altered and degraded level of overload protection.

The question is, what can be done to obtain the highest degree of short circuit protection for motor controllers? The solution is to use short circuit protective devices that are current-limiting and size them as close as practical. A current-limiting fuse can cut off the short-circuit current before it reaches damaging levels. Even for potentially high short-circuit currents, the quick clearing of the fuse can limit the current passed through the starter to safe levels. Dual-element Class RK5 and RK1 fuses are recommended since they can be sized at 125% or 130% respectively of the motor full-load current, rather than 300% sizing for non-time-delay fuses.

The branch circuit protective device size cannot exceed the maximum rating shown on equipment labels or controller manufacturer's tables. 430.53 requires observance of the requirements of 430.52 plus, for circuits under 430.53(C) the motor running overload device and controller must be listed for group installation with a specified maximum rating protective device. Under 430.54 for multi-motor and combination-load equipment, the rating of the branch circuit protective device cannot exceed the rating marked on the equipment. Therefore, be sure to check labels, controller overload relay tables, equipment nameplates, etc. In no case can the manufacturer's specified rating be exceeded. This would constitute a violation of NEC® 110.3(B). When the label, table, etc. is marked with a "Maximum Fuse Amp Rating" rather than marked with a "Maximum Overcurrent Device" this then means only fuses can be used for the branch circuit protective device.

Achieving Short Circuit Protection

In order to properly select an overcurrent device for a motor starter, four areas require particular attention:

1. Withstand rating of the contactor.
2. Wire Damage,
3. Cross-over point of the fuse and relay curve,
4. Motor Damage.

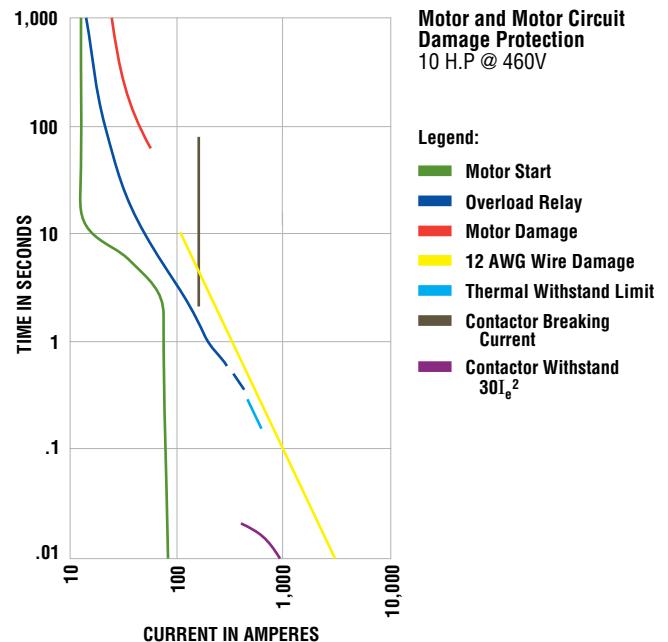
Please refer to the following graph.

Contactor Withstand Rating

The first area of concern is the withstand rating of the contactor. In order to prevent damage to the contactor, the maximum peak let-through current (I_p) and maximum clearing energy (I^2t) (amps² seconds) of the fuse must be less than the equivalent ratings for the contactor. The clearing time and let-through characteristics of the fuse must be considered when verifying adequate protection of the contactor.

Wire Damage

Secondly, motor circuit conductors have a withstand rating that must not be exceeded. If the overcurrent protective device is not capable of limiting the short-circuit current to a value below the wire withstand, the wire may be damaged, or destroyed.



Cross-Over Point

Thirdly, the cross-over point (I_c) is the point where the fuse curve intersects the overload relay curve. For current levels less than the cross-over point the overload relay opens the circuit. For current values greater than the cross-over point the fuses open the circuit and prevent thermal damage to the overload relay, contacts, and the motor circuit. This point of intersection should be approximately 7-10 times I_e , where I_e is rated current. Ideally the fuse should allow the overload relay to function under overload conditions, and operate before the overcurrent reaches the contactor's breaking capacity.

Motor Damage

Finally, all motors have an associated motor damage curve. Single phasing, overworking, and locked rotor conditions are just a few of the situations that cause excessive currents in motor circuits. Excessive currents cause motors to overheat, which in turn causes the motor winding insulation to deteriorate and ultimately fail. Overload relays and dual-element, time-delay fuses, are designed to open the motor circuit before current levels reach the motor damage curve.

IEC and UL Standards for Allowable Damage

IEC 947-4-1 and UL508E differentiate between two different types of coordination, or damage levels.

- Type "1" Considerable damage, requiring replacement. No external damage to the enclosure. short circuit protective devices interrupt intermediate to high short-circuit currents which exceed the withstand rating of the motor starter. A non-current-limiting device will interrupt these high currents, but this type of damage will typically result.
- Type "2" "No Damage" is allowed to either the contactor or overload relay. Light contact welding is allowed, but must be easily separable. (Note: If access is not possible and the contacts cannot be separated, Type "2" protection cannot be achieved.) This level of protection typically can only be provided by a current-limiting device, that is, one which limits the available short-circuit current to a significantly lower value.

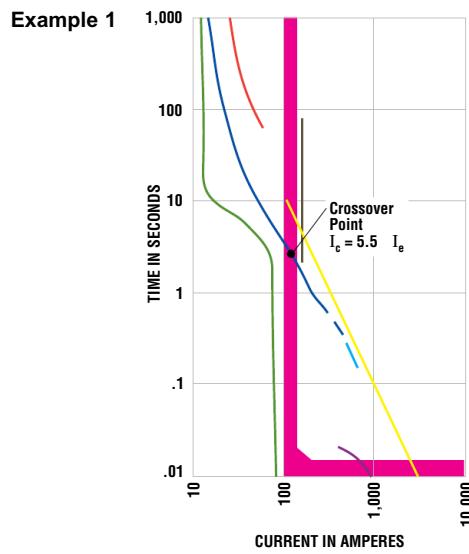
Graphic Explanation

Five Choices — 1 Solution

IEC Motor Starter Protection

Five methods of providing motor starter overcurrent protection are delineated in the five examples that follow. In noting the levels of protection provided by each method, it becomes apparent that the use of dual-element, time-delay fuses (Example 5) is the only one that gives protection at all levels whether it be "Type 2," "Back-up Overload," "Back-up Single-Phase," etc.

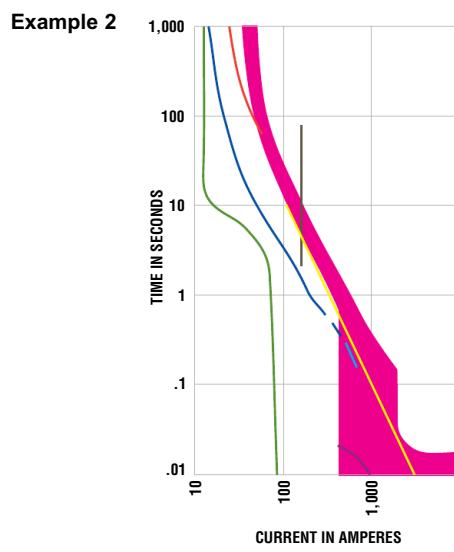
These examples are based on a typical motor circuit consisting of an IEC Starter, and a 10 HP, 460V motor (Service factor = 1.15). These "Level of Protection" examples reflect the branch circuit protective device operating in combination with the IEC starter overload relays sized at approximately 115% of motor FLA and contactor I_e = 18 amps.



Motor Circuit Protector (700% FLA)

Legend:
 — Motor Start
 — Overload Relay
 — Motor Damage
 — 12 AWG Wire Damage
 — Thermal Withstand Limit
 — Contactor Breaking Current
 — Contactor Withstand $30I_e^2$
 — MCP (700%)

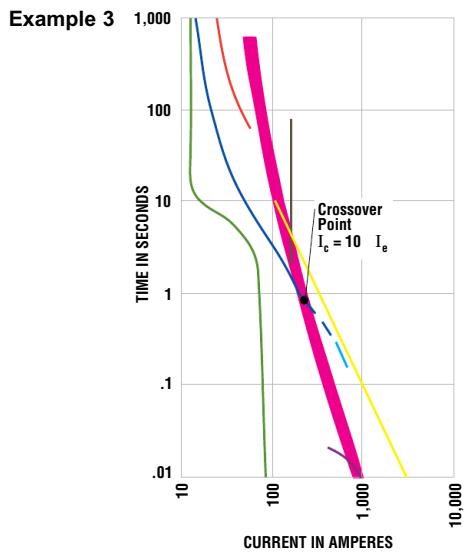
Level of Protection:
 Type "2"
 Single-Phase Yes
 Back-up Single-Phase No
 Overload Yes
 Back-up Overload No
 Meets 110.10 No
 Meets 430.52 Yes



Molded Case Circuit Breaker (250% FLA)

Legend:
 — Motor Start
 — Overload Relay
 — Motor Damage
 — 12 AWG Wire Damage
 — Thermal Withstand Limit
 — Contactor Breaking Current
 — Contactor Withstand $30I_e^2$
 — MCCB 40A

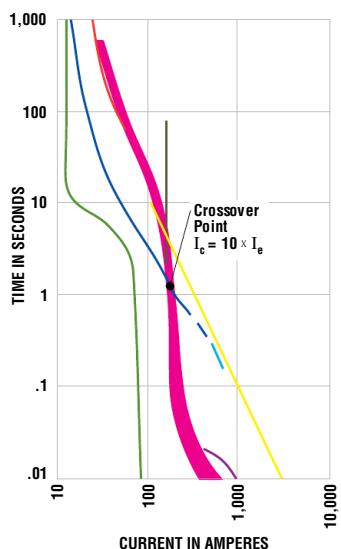
Level of Protection:
 Type "2"
 Single-Phase Yes
 Back-up Single-Phase No
 Overload Yes
 Back-up Overload No
 Meets 110.10 No
 Meets 430.52 Yes



Fast-Acting Fuse (300% FLA)

Legend:
 — Motor Start
 — Overload Relay
 — Motor Damage
 — 12 AWG Wire Damage
 — Thermal Withstand Limit
 — Contactor Breaking Current
 — Contactor Withstand $30I_e^2$
 — Fast-Acting Fuse 45A

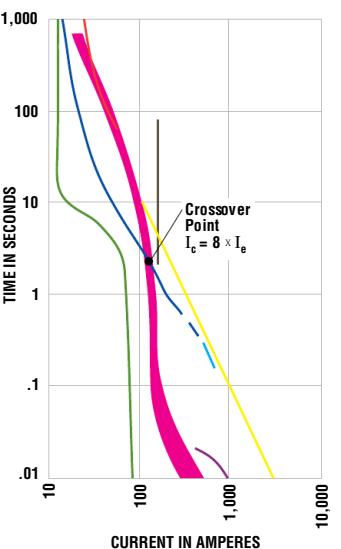
Level of Protection:
 Type "2"
 Single-Phase Yes
 Back-up Single-Phase No
 Overload Yes
 Back-up Overload No
 Meets 110.10 Yes
 Meets 430.52 Yes



Dual-Element, Time-Delay Fuse (175% FLA)

Legend:
 — Motor Start
 — Overload Relay
 — Motor Damage
 — 12 AWG Wire Damage
 — Thermal Withstand Limit
 — Contactor Breaking Current
 — Contactor Withstand $30I_e^2$
 — Low-Peak, Dual-Element, Time-Delay 25A

Level of Protection:
 Type "2"
 Single-Phase Yes
 Back-up Single-Phase No
 Overload Yes
 Back-up Overload No
 Meets 110.10 Yes
 Meets 430.52 Yes



Dual-Element, Time-Delay Fuse (125%) - Class RK1 or J

Legend:
 — Motor Start
 — Overload Relay
 — Motor Damage
 — 12 AWG Wire Damage
 — Thermal Withstand Limit
 — Contactor Breaking Current
 — Contactor Withstand $30I_e^2$
 — Low-Peak, Dual-Element, Time-Delay 17½A

Level of Protection:
 Type "2"
 Single-Phase Yes
 Back-up Single-Phase Yes
 Overload Yes
 Back-up Overload Yes
 Meets 110.10 Yes
 Meets 430.52 Yes

Low Voltage Motor Controllers

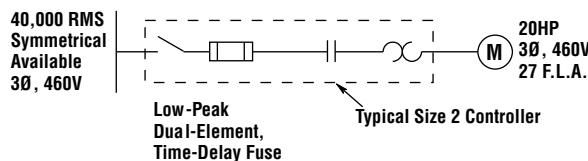
Motor Controller Marking

NEC® 430.8 requires that most motor controllers be marked with their short-circuit current rating (SCCR). Controller manufacturers have the discretion to test, list, and mark their controllers at the standard fault levels of UL 508 (shown in the table below) or the manufacturer can choose to test, list and mark for higher levels of short-circuit currents. A controller with a marked SCCR makes it easier to establish the short-circuit current rating for an industrial control panel as is now required in NEC® 409.110.

Motor Controller Protection

The diagram below shows a Size 2, combination motor controller supplying a 460 volt, 3Ø, 20Hp motor. The short-circuit withstand of this and other motor controllers are established so that they may be properly protected from short-circuit damage.

Short Circuit Protection of Motor Controller



There are several independent organizations engaged in regular testing of motor controllers under short circuit conditions. One of these, Underwriter's Laboratories, tests controllers rated one horsepower or less and 300V or less with 1000 amps short-circuit current available to the controller test circuit. Controllers rated 50Hp or less are tested with 5000 amps available and controllers rated above 50Hp to 200Hp are tested with 10,000 amps available. See the table below for these values.*

Motor Controller HP Rating	Test Short Circuit Current Available*
1Hp or less and 300V or less	1000A
50Hp or less	5000A
Greater than 50Hp to 200Hp	10,000A
201Hp to 400Hp	18,000A
401Hp to 600Hp	30,000A
601Hp to 900Hp	42,000A
901Hp to 1600Hp	85,000A

* From Industrial Control Equipment, UL508.

It should be noted that these are basic short circuit requirements. Higher combination ratings are attainable if tested to an applicable standard. However, damage is usually allowed.

430.52 of the National Electrical Code® allows dual-element, time-delay fuses and other overcurrent protective devices to be sized for branch circuit protection (short circuit protection only). Controller manufacturers often affix labels to the inside of the motor starter cover which recommend the maximum size fuse for each overload relay size.

NEC® 430.52 states:

430.52(C)(2) Overload Relay Table.

Where maximum branch circuit short circuit and ground fault protective device ratings are shown in the manufacturer's overload relay table for use with a motor controller or are otherwise marked on the equipment, they shall not be exceeded even if higher values are allowed as shown above. **

** "Above" refers to other portions of 430.52 not shown here.

This paragraph means that the branch circuit overcurrent protection for overload relays in motor controllers must be no greater than the maximum size as shown in the manufacturer's overload relay table. These maximum branch circuit sizes must be observed even though other portions of 430.52 allow larger sizing of branch circuit overcurrent protection.

The reason for this maximum overcurrent device size is to provide short-circuit protection for the overload relays and motor controller.

Why Type 2 Protection is Better Than Type 1 Protection

UL has developed a short circuit test procedure designed to verify that motor controllers will not be a safety hazard and will not cause a fire.

Compliance to the standard allows deformation of the enclosure, but the door must not be blown open and it must be possible to open the door after the test. In the standard short circuit tests, the contacts must not disintegrate, but welding of the contacts is considered acceptable. Tests allow the overload relay to be damaged with burnout of the current element completely acceptable. For short circuit ratings in excess of the standard levels listed in UL 508, the damage allowed is even more severe. Welding or complete disintegration of contacts is acceptable and complete burnout of the overload relay is allowed. Therefore, a user cannot be certain that the motor starter will not be damaged just because it has been UL Listed for use with a specific branch circuit protective device. UL tests are for safety, with the doors closed but do allow a significant amount of damage as long as it is contained within the enclosure.

In order to properly select a branch circuit protective device that not only provides motor branch circuit protection, but also protects the circuit components from damage, the designer must look beyond mere safety standards. Coordination (protection) of the branch circuit protective device and the motor starter is necessary to insure that there will be no damage or danger to either the starter or the surrounding equipment. There is an "Outline of Investigation," (UL 508E) and an IEC (International Electrotechnical Commission) Standard IEC Publication 60947, "Low Voltage Switchgear and Control, Part 4-1: Contactors and Motor Starters," that offer guidance in evaluating the level of damage likely to occur during a short circuit with various branch circuit protective devices. These standards address the coordination (protection) between the branch circuit protective device and the motor starter. They provide a method to measure the performance of these devices should a short circuit occur. They define two levels of protection (coordination) for the motor starter:

- Type 1.** Considerable damage to the contactor and overload relay is acceptable. Replacement of components or a completely new starter may be needed. There must be no discharge of parts beyond the enclosure.
- Type 2.** No damage is allowed to either the contactor or over-load relay. Light contact welding is allowed, but must be easily separable.

Where Type 2 protection is desired, the controller manufacturer must verify that Type 2 protection can be achieved by using a specified protective device. US manufacturers have both their NEMA and IEC motor controllers verified to meet the Type 2 requirements outlined in UL508E and IEC 60947-4. As of this writing only current-limiting devices have been able to provide the current limitation necessary to provide verified Type 2 protection. In many cases, Class J, Class CF, Class RK1, or Class CC fuses are required, because Class RK5 fuses and other OCPD(s) aren't fast enough under short-circuit conditions to provide Type 2 protection.

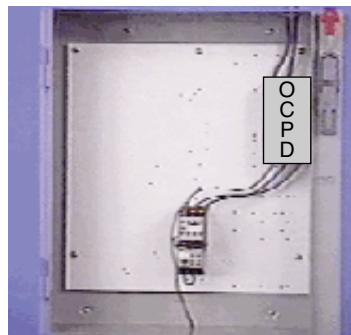


Photo 1 Before Test: Overcurrent protective device that only provides Type 1 protection as motor branch circuit protection for 10HP, IEC Starter with 22,000 amps available at 480V.

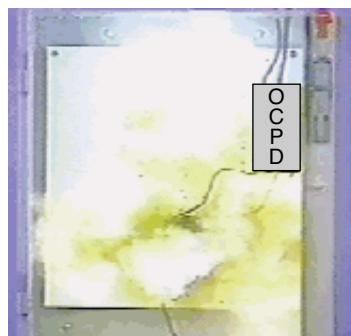


Photo 2: Same as Photo 1, but during the test the heater elements vaporized and the contacts were severely welded. Extensive starter repair or total starter replacement would be required. This level of damage is permissible by UL 508 or UL 508E/IEC60947-4-1 Type 1 protection.

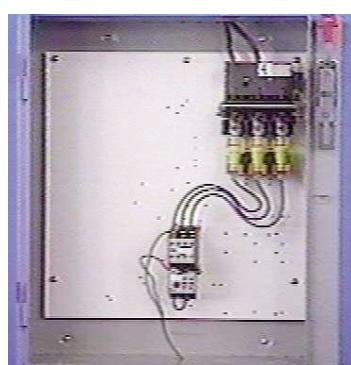


Photo 3 During Test: same test circuit and same type starter during short circuit interruption. The difference is current-limiting fuses provide the motor branch circuit protection. This illustrates the level of protection required by UL 508E and IEC 60947-4-1 for Type 2 "no damage" protection. The heaters and overload relays maintained calibration, which is extremely important to retain circuit overload protection. This starter could be put back into service without any repair.

Tables: Type 2 Motor Starter/Bussmann Fuses

On the following pages are motor starters of several manufacturers that have been verified by testing for Type 2 protection using the fuses denoted. These are maximum fuse sizes; for specific applications, it may be desirable to size closer. In some cases, the fuse type/amp rating shown is greater than that permitted for branch circuit protection for a single motor per 430.52 (footnoted); however, the size may be applicable for group motor protection applications. In a few cases, the fuse type/amp rating may be too small for typical motor starting applications (footnoted). It is recommended to use these fuse types/amp ratings in conjunction with the fuse type/sizing philosophy (backup motor overload, optimal or maximum branch circuit protection - see Motor Protection Table explanation in Motor Circuit Protection Section of this book.) This data was obtained from the manufacturers or their web sites.

Eaton Freedom Series — IEC
(UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	STARTER NUMBER	HEATER ELEMENT	MAX FUSE	
			LPJ_SP CLASS J	LP-CC CLASS CC
0.5 (2.5)	AE16ANSO_C	H2106B-3	6	6
0.75 (3.7)	AE16ANSO_C	H2107B-3	6	6†
1 (4.8)	AE16ANSO_C	H2108B-3	10	15
1.5 (6.9)	AE16ANSO_C	H2109B-3	15	20
2 (7.8)	AE16BNSO_C	H2110B-3	17.5	25
3 (11.0)	AE16CNSO_C	H2111B-3	20	
5 (17.5)	AE16DNSO_C	H2112B-3	35	
7.5 (25.3)	AE16ENSO_B	H2114B-3	50	
10 (32.2)	AE16HNSO_B	H2115B-3	70	
15 (48.3)	AE16JNSO_B	H2116B-3	100	
20 (62.1)	AE16KNSO_B	H2117B-3	110	
25 (78.2)	AE16LNSO_	H2022-3	150	
30 (92.0)	AE16MNSO_	H2023-3	200	
40 (119.6)	AE16NNSO_	H2024-3	200	

230 Volt, Three-Phase Motors

HP (FLC)	STARTER NUMBER	HEATER ELEMENT	MAX FUSE	
			LPJ_SP CLASS J	LP-CC CLASS CC
0.5 (2.2)	AE16ANSO_C	H2106B-3	6	6
0.75 (3.2)	AE16ANSO_C	H2107B-3	6	6†
1 (4.2)	AE16ANSO_C	H2108B-3	10	15
1.5 (6.0)	AE16ANSO_C	H2109B-3	15	20
2 (6.8)	AE16BNSO_C	H2109B-3	15	20
3 (9.6)	AE16BNSO_C	H2110B-3	20	
5 (15.2)	AE16DNSO_C	H2112B-3	30	
7.5 (22.0)	AE16ENSO_C	H2113B-3	45	
10 (28.0)	AE16FNSO_B	H2114B-3	50	
15 (42.0)	AE16HNSO_B	H2116B-3	90	
20 (54.0)	AE16JNSO_B	H2117B-3	110	
25 (68.2)	AE16KNSO_B	H2117B-3	110	
30 (80.0)	AE16LNSO_	H2022-3	150	
40 (104.0)	AE16MNSO_	H2023-3	200	
50 (130.0)	AE16NNSO_	H2024-3	200	

460 Volt, Three-Phase Motors

HP (FLC)	STARTER NUMBER	HEATER ELEMENT	MAX FUSE	
			LPJ_SP CLASS J	LP-CC CLASS CC
0.5 (1.1)	AE16ANSO_C	H2104B-3	3	3
0.75 (1.6)	AE16ANSO_C	H2105B-3	3	3†
1 (2.1)	AE16ANSO_C	H2106B-3	6	6
1.5 (3.0)	AE16ANSO_C	H2106B-3	6	6
2 (3.4)	AE16ANSO_C	H2107B-3	6	6†
3 (4.8)	AE16ANSO_C	H2108B-3	10	15
5 (7.6)	AE16BNSO_C	H2110B-3	15	25
7.5 (11.0)	AE16CNSO_C	H2111B-3	20	
10 (14.0)	AE16DNSO_C	H2111B-3	30	
15 (21.0)	AE16ENSO_C	H2113B-3	45	
20 (27.0)	AE16FNSO_B	H2114B-3	50	
25 (34.0)	AE16GNSO_B	H2115B-3	70	
30 (40.0)	AE16HNSO_B	H2116B-3	90	
40 (52.0)	AE16JNSO_B	H2116B-3	100	
50 (65.0)	AE16KNSO_B	H2117B_3	110	
60 (77.0)	AE16LNSO_	H2022-3	150	
75 (96.0)	AE16MNSO_	H2023-3	200	
100 (124.0)	AE16NNSO_	H2024-3	200	

575 Volt, Three-Phase Motors

HP (FLC)	STARTER NUMBER	HEATER ELEMENT	MAX FUSE	
			LPJ_SP CLASS J	LP-CC CLASS CC
0.75 (1.3)	AE16ANSO_C	H2104B-3	3	3
1 (1.7)	AE16ANSO_C	H2105B-3	3	3†
1.5 (2.4)	AE16ANSO_C	H2106B-3	6	6
2 (2.7)	AE16ANSO_C	H2107B-3	6	6
3 (3.9)	AE16ANSO_C	H2108B-3	10	15
5 (6.1)	AE16DNSO_C	H2109B-3	15	20
7.5 (9.0)	AE16BNSO_C	H2110B-3	20	
10 (11.0)	AE16CNSO_C	H2111B-3	20	
15 (17.0)	AE16DNSO_C	H2112B-3	35	
20 (22.0)	AE16ENSO_C	H2113B-3	45	
25 (27.0)	AE16FNSO_B	H2114B-3	50	
30 (32.0)	AE16GNSO_B	H2115B-3	70	
40 (41.0)	AE16HNSO_B	H2116B-3	90	
50 (52.0)	AE16JNSO_B	H2116B-3	100	
60 (62.0)	AE16KNSO_B	H2021-3	110	
75 (77.0)	AE16LNSO_	H2022-3	150	
100 (99.0)	AE16MNSO_	H2023-3	200	
125 (125.0)	AE16NNSO_	H2024-3	200	

“_” Empty space designates where coil suffix must be added.

† May be too small to allow some motors to start.

Eaton Freedom Series — IEC

(UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	STARTER NUMBER (Fixed Heaters)	MAX FUSE	
		LPJ_SP CLASS J	LP-CC CLASS CC
0.5 (2.5)	AE17ANSO_FJ	6	6
0.75 (3.7)	AE17ANSO_FK	6	6
1 (4.8)	AE17ANSO_FL	10	15
1.5 (6.9)	AE17ANSO_FM	15	15
2 (7.8)	AE17BNSO_FP	17.5	25
3 (11.0)	AE17CNSO_FQ	20	20†
5 (17.5)	AE17DNSO_FR	35	
7.5 (25.3)	AE17FNSO_FT	50	
10 (32.2)	AE17HNSO_KC	70	
15 (48.3)	AE17JNSO_KE	100	
20 (62.1)	AE17KNSO_KF	110	

230 Volt, Three-Phase Motors

HP (FLC)	STARTER NUMBER (Fixed Heaters)	MAX FUSE	
		LPJ_SP CLASS J	LP-CC CLASS CC
0.5 (2.2)	AE17ANSO_FH	3†	3†
0.75 (3.2)	AE17ANSO_FK	6	6†
1 (4.2)	AE17ANSO_FL	6†	6†
1.5 (6.0)	AE17ANSO_FM	15	15
2 (6.8)	AE17BNSO_FN	15	15
3 (9.6)	AE17CNSO_FP	20	20†
5 (15.2)	AE17DNSO_FR	30	30†
7.5 (22.0)	AE17ENSO_FS	45	
10 (28.0)	AE17FNSO_FT	60	
15 (42.0)	AE17HNSO_KD	90	
20 (54.0)	AE17JNSO_KE	110	
25 (68.2)	AE17KNSO_KF	110	

460 Volt, Three-Phase Motors

HP (FLC)	STARTER NUMBER (Fixed Heaters)	MAX FUSE	
		LPJ_SP CLASS J	LP-CC CLASS CC
0.5 (1.0)	AE17ANSO_FF	2	2
0.75 (1.6)	AE17ANSO_FG	3	3
1 (2.1)	AE17ANSO_FH	3	3†
1.5 (3.0)	AE17ANSO_FJ	6	6
2 (3.4)	AE17ANSO_FK	6	6†
3 (4.8)	AE17ANSO_FM	10	15
5 (7.6)	AE17BNSO_FN	15	15
7.5 (11.0)	AE17CNSO_FQ	20	20†
10 (14.0)	AE17DNSO_FR	30	30†
15 (21.0)	AE17ENSO_FS	45	
20 (27.0)	AE17FNSO_FT	60	
25 (34.0)	AE17GNSO_KC	70	
30 (40.0)	AE17HNSO_KD	90	
40 (52.0)	AE17JNSO_KE	110	
50 (65.0)	AE17KNSO_KF	110	

575 Volt, Three-Phase Motors

HP (FLC)	STARTER NUMBER (Fixed Heaters)	MAX FUSE	
		LPJ_SP CLASS J	LP-CC CLASS CC
0.75 (1.3)	AE17ANSO_FF	2	2†
1 (1.7)	AE17ANSO_FG	3	3†
1.5 (2.4)	AE17ANSO_FH	3†	3†
2 (2.7)	AE17ANSO_FJ	6	6
3 (3.9)	AE17ANSO_FL	10	15
5 (6.1)	AE17ANSO_FM	15	15
7.5 (9.0)	AE17BNSO_FP	20	20†
10 (11.0)	AE17CNSO_FQ	20	20†
15 (17.0)	AE17DNSO_FR	35	
20 (22.0)	AE17ENSO_FS	45	
25 (27.0)	AE17FNSO_FT	60	
30 (32.0)	AE17GNSO_KC	70	
40 (41.0)	AE17HNSO_KD	90	
50 (52.0)	AE17KNSO_KE	110	

“.” Empty space designates where coil suffix must be added.

† May be too small to allow some motors to start.

Eaton Hammer Freedom Series — NEMA
(UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	SIZE	STARTER CAT. #	HEATER ELEMENT	MAX FUSE LPN-RK SP CLASS RK1
0.5 (2.5)	00	AN16ANO_C	H2006B-3	4.5
0.75 (3.7)	00	AN16ANO_C	H2008B-3	8
1 (4.8)	00	AN16ANO_C	H2009B-3	10
1.5 (6.9)	0	AN16ENDO_C	H2010B-3	15
2 (7.8)	0	AN16BNO_C	H2010B-3	17.5
3 (11.0)	0	AN16BNO_C	H2011B-3	20
7.5 (25.3)	1	AN16ENDO_B	H2013B-3	45
10 (32.2)	2	AN16GNO_B	H2015B-3	70
15 (48.3)	3	AN16KNO_	H2021-3	100
20 (62.1)	3	AN16KNO_	H2021-3	110
25 (78.2)	3	AN16KNO_	H2022-3	175
40 (119.6)	4	AN16NNO_	H2024-3	200
50 (149.5)	5	AN16SNO_B	H2007B-3	300
60 (166.8)	5	AN16SNO_B	H2007B-3	350
75 (220.8)	5	AN16SNO_B	H2008B-3	400

230 Volt, Three-Phase Motors

HP (FLC)	SIZE	STARTER CAT. #	HEATER ELEMENT	MAX FUSE LPN-RK SP CLASS RK1
0.5 (2.2)	00	AN16ANO_C	H2006B-3	4.5
0.75 (3.2)	00	AN16ANO_C	H2007B-3	5.6
1 (4.2)	00	AN16ANO_C	H2008B-3	8
1.5 (6.0)	00	AN16ANO_C	H2009B-3	12
2 (6.8)	0	AN16BNO_C	H2009B-3	12
3 (9.6)	0	AN16BNO_C	H2011B-3	20
5 (15.2)	1	AN16ENDO_B	H2012B-3	30
7.5 (22.0)	1	AN16ENDO_B	H2013B-3	45
7.5 (22.0)	2	AN16GNO_B	H2013B-3	45
10 (28.0)	2	AN16GNO_B	H2014B-3	60
15 (42.0)	2	AN16GNO_B	H2015B-3	70
20 (54.0)	3	AN16KNO_	H2021-3	110
25 (68.2)	3	AN16KNO_	H2022-3	150
30 (80.0)	3	AN16KNO_	H2022-3	175
30 (92.0)	4	AN16NNO_	H2023-3	200
40 (104.0)	4	AN16NNO_	H2023-3	200
50 (130.0)	4	AN16NNO_	H2024-3	200
60 (145.0)	5	AN16SNO_B	H2007B-3	300
75 (192.0)	5	AN16SNO_B	H2007B-3	400
100 (248.0)	5	AN16SNO_B	H2008B-3	400

460 Volt, Three-Phase Motors

HP (FLC)	SIZE	STARTER CAT. #	HEATER ELEMENT	MAX FUSE LPS-RK SP CLASS RK1
0.5 (1.1)	00	AN16ANO_C	H2004B-3	2
0.75 (1.6)	00	AN16ANO_C	H2005B-3	2.8
1 (2.1)	00	AN16ANO_C	H2006B-3	4.5
1.5 (3.0)	00	AN16ANO_C	H2007B-3	5.6
2 (3.4)	00	AN16ANO_C	H2008B-3	7
3 (4.8)	0	AN16BNO_C	H2009B-3	10
5 (7.6)	0	AN16BNO_C	H2010B-3	15
7.5 (11.0)	1	AN16ENDO_B	H2011B-3	20
10 (14.0)	1	AN16ENDO_B	H2012B-3	30
15 (21.0)	2	AN16GNO_B	H2013B-3	45
20 (27.0)	2	AN16GNO_B	H2014B-3	60
25 (34.0)	2	AN16GNO_B	H2015B-3	70
30 (40.0)	3	AN16KNO_	H2020-3	80
40 (52.0)	3	AN16KNO_	H2021-3	110
50 (65.0)	3	AN16KNO_	H2022-3	125
60 (77.0)	4	AN16NNO_	H2023-3	150
75 (96.0)	4	AN16NNO_	H2023-3	200
100 (124.0)	4	AN16NNO_	H2024-3	200
125 (156.0)	5	AN16SNO_B	H2007B-3	350
150 (180.0)	5	AN16SNO_B	H2007B-3	400
200 (240.0)	5	AN16SNO_B	H2008B-3	400

575 Volt, Three-Phase Motors

HP (FLC)	SIZE	STARTER CAT. #	HEATER ELEMENT	MAX FUSE LPS-RK SP CLASS RK1
0.75 (1.3)	00	AN16ANO_C	H2005B-3	2.8
1 (1.7)	00	AN16ANO_C	H2005B-3	2.8
1.5 (2.4)	00	AN16ANO_C	H2006B-3	4.5
2 (2.7)	00	AN16ANO_C	H2007B-3	5.6
3 (3.9)	0	AN16BNO_C	H2008B-3	8
5 (6.1)	0	AN16BNO_C	H2009B-3	12
7.5 (9.0)	1	AN16ENDO_B	H2010B-3	17.5
10 (11.0)	1	AN16ENDO_B	H2011B-3	20
15 (17.0)	2	AN16GNO_B	H2012B-3	35
20 (22.0)	2	AN16GNO_B	H2013B-3	45
25 (27.0)	2	AN16GNO_B	H2014B-3	60
30 (32.0)	3	AN16KNO_	H2019-3	60
40 (41.0)	3	AN16KNO_	H2020-3	80
50 (52.0)	3	AN16KNO_	H2021-3	110
60 (62.0)	4	AN16NNO_	H2021-3	110
75 (77.0)	4	AN16NNO_	H2022-3	150
100 (99.0)	4	AN16NNO_	H2023-3	200
125 (125.0)	5	AN16SNO_B	H2006B-3	250
150 (144.0)	5	AN16SNO_B	H2007B-3	300
200 (192.0)	5	AN16SNO_B	H2007B-3	400

^{“ ”} Empty space designates where coil suffix must be added.

General Electric Company — IEC
(UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	MAX FUSE LPJ SP CLASS J
0.5 (2.5)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1J	4
0.5 (2.5)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8†
0.75 (3.7)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8
1 (4.8)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1L	10
1.5 (6.9)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1M	12
2 (7.8)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1N	20†
3 (11.0)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1P	20
5 (17.5)	CL02, CL03, CL04, CL25, CL45	RT*1S	35
5 (17.5)	CL06, CL07, CL08, CL09, CL10	RT*2B	35
5 (17.5)	CL03, CL04, CL45	RT*1T	45†
7.5 (25.3)	CL04, CL05	RT*1U	45
7.5 (25.3)	CL06, CL07, CL08, CL09, CL10	RT*2D	60†
7.5 (25.3)	CL04, CL45	RT*1V	60†
10 (32.2)	CL45	RT*1W	70
10 (32.2)	CL06, CL07, CL08, CL09, CL10	RT*2E	70
15 (48.3)	CL07, CL08, CL09, CL10	RT*2G	100
20 (62.1)	CL08, CL09, CL10	RT*2H	125
20 (62.1)	CK08, CK09, CK95	RT*3B	125
25 (78.2)	CK08, CK09	RT*3C	150

230 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	MAX FUSE LPJ SP CLASS J
0.5 (2.2)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1J	4
0.75 (3.2)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8†
1 (4.2)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1L	10
1.5 (6.0)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1L	10
2 (6.8)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1M	12
3 (9.6)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1N	20
5 (15.2)	CL02, CL03, CL04, CL25, CL45	RT*1S	35†
5 (15.2)	CL06, CL07, CL08, CL09, CL10	RT*2B	35†
7.5 (22.0)	CL03, CL04, CL45	RT*1T	45
7.5 (22.0)	CL06, CL07, CL08, CL09, CL10	RT*2C	45
7.5 (22.0)	CL03, CL04, CL45	RT*1U	45
10 (28.0)	CL04	RT*1V	60
10 (28.0)	CL45	RT*1V	60
10 (28.0)	CL06, CL07, CL08, CL09, CL10	RT*2D	60
15 (42.0)	CL06, CL07, CL08, CL09, CL10	RT*2F	90
20 (54.0)	CL07, CL08, CL09, CL10	RT*2G	100
20 (54.0)	CL07, CL08, CL09, CL10	RT*2H	125†
25 (68.0)	CK08, CK09, CK95	RT*3B	125
25 (68.0)	CL08, CL09, CL10	RT*2J	125
30 (80.0)	CK08, CK09, CK95	RT*3B	125
25 (68.0)	CK08, CK09	RT*3C	150

460 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	MAX FUSE LPJ SP CLASS J
0.5 (1.1)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1F	1.5††
0.5 (1.1)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1G	2
0.75 (1.6)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1H	4†
1 (2.1)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1J	4
1.5 (3.0)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8†
2 (3.4)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8†
3 (4.8)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1L	10
5 (7.6)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1N	20†
7.5 (11.0)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1P	20
10 (14.0)	CL02, CL03, CL04, CL25, CL45	RT*1R	25
10 (14.0)	CL06, CL07, CL08, CL09, CL10	RT*2A	30
15 (21.0)	CL03, CL04, CL45	RT*1T	45
15 (21.0)	CL06, CL07, CL08, CL09, CL10	RT*2C	45
20 (27.0)	CL04, CL45	RT*1V	60
20 (27.0)	CL06, CL07, CL08, CL09, CL10	RT*2D	60
25 (34.0)	CL45	RT*1W	70
25 (34.0)	CL06, CL07, CL08, CL09, CL10	RT*2E	70
30 (40.0)	CL06, CL07, CL08, CL09, CL10	RT*2E	70
30 (40.0)	CL06, CL07, CL08, CL09, CL10	RT*2F	90
40 (52.0)	CL07, CL08, CL09, CL10	RT*2G	100
50 (65.0)	CL08, CL09, CL10	RT*2H	125
50 (65.0)	CL08, CL09, CL10	RT*3B	125
50 (65.0)	CL08, CL09, CL10	RT*2J	125
60 (77.0)	CL09, CL10	RT*3B	125

575 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	MAX FUSE LPJ SP CLASS J
0.5 (0.9)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1F	1.5
0.75 (1.3)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1G	2
0.75 (1.3)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1H	4†
1 (1.7)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1H	4†
1.5 (2.4)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1J	4
2 (2.7)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1J	4
2 (2.7)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8†
3 (3.9)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1K	8
5 (6.1)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1L	10
5 (6.1)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1M	12
7.5 (9.0)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1N	20
10 (11.0)	CL00, CL01, CL02, CL03, CL04, CL25, CL45	RT*1P	20
15 (17.0)	CL02, CL03, CL04, CL25, CL45	RT*1S	35
15 (17.0)	CL06, CL07, CL08, CL09, CL10	RT*2B	35
20 (22.0)	CL03, CL04, CL45	RT*1T	45
20 (22.0)	CL06, CL07, CL08, CL09, CL10	RT*2C	45
20 (22.0)	CL03, CL04, CL45	RT*1U	45
25 (27.0)	CL04, CL45	RT*1V	60
25 (27.0)	CL06, CL07, CL08, CL09, CL10	RT*2D	60
30 (32.0)	CL04, CL45	RT*1V	60
30 (32.0)	CL06, CL07, CL08, CL09, CL10	RT*2D	60
30 (32.0)	CL45	RT*1W	70
30 (32.0)	CL06, CL07, CL08, CL09, CL10	RT*2E	70
40 (41.0)	CL06, CL07, CL08, CL09, CL10	RT*2E	70
40 (41.0)	CL06, CL07, CL08, CL09, CL10	RT*2F	90
50 (52.0)	CL07, CL08, CL09, CL10	RT*2G	100
60 (62.0)	CL07, CL08, CL09, CL10	RT*2H	125
60 (62.0)	CK08, CK09, CK95	RT*3B	125
75 (77.0)	CK08, CK09, CK95	RT*3B	125

General Electric Company — NEMA
(UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	OLR	MAX FUSE LPJ_SP CLASS J
0.5 (2.5)	CR324CXE	6
0.5 (2.5)	CR123C326A	6
0.75 (3.7)	CR123C356A	8
0.75 (3.7)	CR324CXF	10
1 (4.8)	CR324CXF	10
1 (4.8)	CR123C526A	10
1.5 (6.9)	CR324CXG	15
1.5 (6.9)	CR123C778A	15
1.5 (6.9)	CR123C695A	15
2 (7.8)	CR324CXG	17.5
2 (7.8)	CR123C867A	17.5
3 (11.0)	CR324CXG	20
3 (11.0)	CR123C125B	20
5 (17.5)	CR234CXH	35
5 (17.5)	CR234FXK	35
5 (17.5)	CR123C180B	35
5 (17.5)	CR123C198B	35
5 (17.5)	CR123F233B	35

230 Volt, Three-Phase Motors

HP (FLC)	OLR	MAX FUSE LPJ_SP CLASS J
0.5 (2.2)	CR123C268A	5
0.5 (2.2)	CR324CXE	6
0.75 (3.2)	CR324CXF	7
0.75 (3.2)	CR123C356A	7
1 (4.2)	CR324CXF	10
1 (4.2)	CR123C466A	10
1.5 (6.0)	CR324CXF	15
1.5 (6.0)	CR123C695A	15
2 (6.8)	CR324CXG	15
2 (6.8)	CR324DXG	15
2 (6.8)	CR123C778A	15
3 (9.6)	CR324CXG	20
3 (9.6)	CR324DXG	20
3 (9.6)	CR123C104B	20
5 (15.2)	CR234CXH	30
5 (15.2)	CR234DXH	30
5 (15.2)	CR123C163B	30
7.5 (22.0)	CR324DXH	45
7.5 (22.0)	CR324FXK	45
7.5 (22.0)	CR123C228B	45
7.5 (22.0)	CR123C250B	45
7.5 (22.0)	CR123C270B	45

460 Volt, Three-Phase Motors

HP (FLC)	OLR	MAX FUSE LPJ_SP CLASS J
0.5 (1.1)	CR123C131A	2.5
0.5 (1.1)	CR324CXD	3
0.75 (1.6)	CR324CXD	3.5
0.75 (1.6)	CR123C196A	3.5
1 (2.1)	CR123C268A	5
1 (2.1)	CR324CXE	6
1.5 (3.0)	CR324CXE	6
1.5 (3.0)	CR123C356A	6
2 (3.4)	CR324CXF	7
2 (3.4)	CR123C379A	7
3 (4.8)	CR324CXF	10
3 (4.8)	CR123C526A	10
5 (7.6)	CR324CXG	15
5 (7.6)	CR324DXG	15
5 (7.6)	CR123C867A	15
7.5 (11.0)	CR324CXG	20
7.5 (11.0)	CR324DXG	20
7.5 (11.0)	CR123C125B	20
10 (14.0)	CR234CXH	30
10 (14.0)	CR234DXH	30
10 (14.0)	CR123C163B	30
15 (21.0)	CR324CXH	45
15 (21.0)	CR324DXH	45
15 (21.0)	CR324FXK	45
15 (21.0)	CR123C228B	45
15 (21.0)	CR123F243B	45

575 Volt, Three-Phase Motors

HP (FLC)	OLR	MAX FUSE LPJ_SP CLASS J
0.5 (0.9)	CR123C109A	2
0.5 (0.9)	CR324CXD	3
0.75 (1.3)	CR324CXD	3
0.75 (1.3)	CR123C163A	3
1 (1.7)	CR324CXD	3.5
1 (1.7)	CR123C196A	3.5
1 (1.7)	CR324CXE	3.5
1.5 (2.4)	CR324CXE	6
1.5 (2.4)	CR123C301A	6
2 (2.7)	CR324CXE	6
2 (2.7)	CR123C326A	6
3 (3.9)	CR324CXF	10
3 (3.9)	CR123C419A	10
5 (6.1)	CR324CXF	15
5 (6.1)	CR123C695A	15
7.5 (9.0)	CR324CXG	20
7.5 (9.0)	CR324DXG	20
7.5 (9.0)	CR123C104B	20
7.5 (9.0)	CR123C955A	20
10 (11.0)	CR123C125B	20
10 (11.0)	CR324CXG	20
10 (11.0)	CR324DXG	20
15 (17.0)	CR324DXH	35
15 (17.0)	CR234FXK	35
15 (17.0)	CR123C180B	35
20 (22.0)	CR324DXH	45
20 (22.0)	CR324FXK	45
20 (22.0)	CR123C228B	45
20 (22.0)	CR123C250B	45
20 (22.0)	CR123C270B	45

* Replace * with "A" or "M"

† Sized larger than code max for single motor.

General Electric Company — NEMA
(UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	OLR	MAX FUSE	
		LPJ_SP CLASS J	KRP-C_SP CLASS L
7.5 (25.3)	CR324DXH	50	
7.5 (25.3)	CR324FXK	50	
7.5 (25.3)	CR123C273B	50	
7.5 (25.3)	CR123C303B	50	
7.5 (25.3)	CR123F300B	50	
10 (32.2)	CR324DXJ	70	
10 (32.2)	CR324FXK	70	
10 (32.2)	CR123C330B	70	
10 (32.2)	CR123F395B	70	
15 (48.3)	CR324DXJ	100	
15 (48.3)	CR324FXL	100	
15 (48.3)	CR123F614B	100	
20 (62.1)	CR324FXL	125	
20 (62.1)	CR123F772B	125	
25 (78.2)	CR234FXM	175	
25 (78.2)	CR324GXP	175	
25 (78.2)	CR123F104C	175	
30 (92.0)	CR234FXM	200	
30 (92.0)	CR324GXP	200	
30 (92.0)	CR123F118C	200	
40 (120.0)	CR234FXM	250	
40 (120.0)	CR324GXP	250	
40 (120.0)	CR123F161C	250	
50 (150.0)	CR324GXQ	300	
50 (150.0)	CR324HXS	300	
60 (177.0)	CR324GXQ	350	
60 (177.0)	CR324HXS	350	
75 (221.0)	CR324GXQ	450	
75 (221.0)	CR324HXS	450	
100 (285.0)	CR324HXT	600	
125 (359.0)	CR324HXT		1000
150 (414.0)	CR324HXT		1000

230 Volt, Three-Phase Motors

HP (FLC)	OLR	MAX FUSE	
		LPJ_SP CLASS J	KRP-C_SP CLASS L
10 (28.0)	CR324DXJ	60	
10 (28.0)	CR324FXK	60	
10 (28.0)	CR123C303B	60	
10 (28.0)	CR123F327B	60	
15 (42.0)	CR324DXJ	90	
15 (42.0)	CR324FXL	90	
15 (42.0)	CR123F567B	90	
15 (42.0)	CR123F487B	90	
15 (42.0)	CR123F440B	90	
20 (54.0)	CR324FXL	110	
20 (54.0)	CR123F719B	110	
25 (68.2)	CR324FXL	150	
25 (68.2)	CR324FXM	150	
25 (68.2)	CR324GXP	150	
25 (68.2)	CR123F848B	150	
25 (68.2)	CR123F914B	150	
30 (80.0)	CR234FXM	175	
30 (80.0)	CR324GXP	175	
30 (80.0)	CR123F104C	175	
40 (104.0)	CR234FXM	225	
40 (104.0)	CR324GXP	225	
40 (104.0)	CR123F133C	225	
50 (130.0)	CR234FXM	250	
50 (130.0)	CR324GXP	250	
50 (130.0)	CR123F161C	250	
60 (145.0)	CR324GXQ	300	
60 (145.0)	CR324HXS	300	
75 (192.0)	CR324GXQ	400	
75 (192.0)	CR324HXS	400	
100 (248.0)	CR324GXQ	500	
100 (248.0)	CR324HXS	500	
125 (312.0)	CR324HXT		900
150 (360.0)	CR324HXT		1000
200 (480.0)	CR324HXT		1000

General Electric Company — NEMA
(UL & CSA Verified, Type 2 Combination SCCR = 100kA)

460 Volt, Three-Phase Motors

HP (FLC)	OLR	MAX FUSE	
		LPJ SP CLASS J	KRP-C SP CLASS L
20 (27.0)	CR324DXH	60	
20 (27.0)	CR324DXJ	60	
20 (27.0)	CR324FXK	60	
20 (27.0)	CR123C303B	60	
20 (27.0)	CR123F327B	60	
20 (27.0)	CR123C330B	60	
25 (34.0)	CR324DXJ	70	
25 (34.0)	CR324FXK	70	
25 (34.0)	CR123C366B	70	
25 (34.0)	CR123F430B	70	
30 (40.0)	CR324DXJ	90	
30 (40.0)	CR324FXL	90	
30 (40.0)	CR123C400B	90	
30 (40.0)	CR123F487B (SIZE 3)	90	
30 (40.0)	CR123F487B (SIZE 4)	90	
40 (52.0)	CR324FXL	110	
40 (52.0)	CR123F658B (SIZE 3)	110	
40 (52.0)	CR123F658B (SIZE 4)	110	
50 (65.0)	CR324FXL	125	
50 (65.0)	CR123F772B	125	
50 (65.0)	CR324FXM	125	
50 (65.0)	CR324GXP	125	
50 (65.0)	CR123F848B	125	
60 (77.0)	CR324FXM	150	
60 (77.0)	CR324GXP	150	
60 (77.0)	R123F104C (SIZE 3)	150	
60 (77.0)	R123F104C (SIZE 4)	150	
75 (96.0)	CR234FXM	200	
75 (96.0)	CR324GXP	200	
75 (96.0)	CR123F118C	200	
100 (124.0)	CR234FXM	250	
100 (124.0)	CR324GXP	250	
100 (124.0)	CR123F161C	250	
125 (156.0)	CR324GXQ	350	
125 (156.0)	CR324HXS	350	
150 (180.0)	CR324GXQ	400	
150 (180.0)	CR324HXS	400	
200 (240.0)	CR324GXQ	500	
200 (240.0)	CR324HXS	500	
250 (302.0)	CR324HXT		900
300 (361.0)	CR324HXT		1000
350 (414.0)	CR324HXT		1000
400 (477.0)	CR324HXT		1000
450 (515.0)	CR324HXT		1000

575 Volt, Three-Phase Motors

HP (FLC)	OLR	MAX FUSE	
		LPJ SP CLASS J	KRP-C SP CLASS L
25 (27.0)	CR324DXH	60	
25 (27.0)	CR324DXJ	60	
25 (27.0)	CR324FXK	60	
25 (27.0)	CR123C303B	60	
25 (27.0)	CR123F327B	60	
25 (27.0)	CR123C330B	60	
30 (32.0)	CR324DXJ	70	
30 (32.0)	CR324FXK	70	
30 (32.0)	CR123C330B	70	
30 (32.0)	CR123F395B	70	
40 (41.0)	CR324DXJ	90	
40 (41.0)	CR324FXL	90	
40 (41.0)	CR123C400B	90	
40 (41.0)	CR123F567B	90	
40 (41.0)	CR123F487B	90	
50 (52.0)	CR324FXL	110	
50 (52.0)	CR123F658B (SIZE 3)	110	
50 (52.0)	CR123F658B (SIZE 4)	110	
60 (62.0)	CR324FXL	125	
60 (62.0)	CR123F772B	125	
75 (77.0)	CR324FXM	150	
75 (77.0)	CR324GXP	150	
75 (77.0)	R123F104C (SIZE 3)	150	
75 (77.0)	R123F104C (SIZE 4)	150	
100 (99.0)	CR234FXM	200	
100 (99.0)	CR324GXP	200	
100 (99.0)	CR123F118C	200	
125 (125.0)	CR234FXM	250	
125 (125.0)	CR324GXP	250	
125 (125.0)	CR123F161C	250	
150 (144.0)	CR324GXQ	300	
150 (144.0)	CR324HXS	300	
200 (192.0)	CR324GXQ	400	
200 (192.0)	CR324HXS	400	
250 (242.0)	CR324GXQ	500	
250 (242.0)	CR324HXS	500	
300 (289.0)	CR324HXT		800
350 (336.0)	CR324HXT		1000
400 (382.0)	CR324HXT		1000
450 (412.0)	CR324HXT		1000
500 (472.0)	CR324HXT		1000

Rockwell Automation, Allen-Bradley — IEC (UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR BASIC CAT. # (a)	OVERLOAD RELAY BASIC CAT. # (b)	MAX FUSE	
			LPJ SP CLASS J	LP-CC CLASS CC
0.5 (2.5)	100-C09	193-E**EB	6	6
0.75 (3.7)	100-C09	193-E**EB	10	10
1 (4.8)	100-C09	193-E**FB	15†	15
1.5 (6.9)	100-C09	193-E**FB	15	15
2 (7.8)	100-C09	193-E**FB	15	15††
3 (11)	100-C12	193-E**FB	20	20††
5 (17.5)	100-C23	193-E**GB	30	30††
7.5 (25.3)	100-C30	193-E**HC	40	
10 (32.2)	100-C37	193-E**HC	50	
15 (48.3)	100-C60	193-E**KE	80	
20 (62.1)	100-C72	193-E**KE	100	

230 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR BASIC CAT. # (a)	OVERLOAD RELAY BASIC CAT. # (b)	MAX FUSE	
			LPJ SP CLASS J	LP-CC CLASS CC
0.5 (2.2)	100-C09	193-E**DB	6	6
0.75 (3.2)	100-C09	193-E**EB	10†	10
1 (4.2)	100-C09	193-E**FB	15†	15
1.5 (6)	100-C09	193-E**FB	15	15
2 (6.8)	100-C09	193-E**FB	15	15
3 (9.6)	100-C12	193-E**FB	20	20
5 (15.2)	100-C16	193-E**GB	20††	20††
7.5 (22)	100-C23	193-E**GB	30††	30††
10 (28)	100-C30	193-E**HC	40††	
15 (42)	100-C43	193-E**JD	50††	
20 (54)	100-C60	193-E**KE	80††	
25 (68)	100-C72	193-E**KE	100	

460 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR BASIC CAT. # (a)	OVERLOAD RELAY BASIC CAT. # (b)	MAX FUSE	
			LPJ SP CLASS J	LP-CC CLASS CC
0.5 (1.1)	100-C09	193-E**DB	3	3
0.75 (1.6)	100-C09	193-E**DB	6†	6
1 (2.1)	100-C09	193-E**DB	6	6
1.5 (3)	100-C09	193-E**EB	10†	10
2 (3.4)	100-C09	193-E**EB	10†	10
3 (4.8)	100-C09	193-E**FB	15†	15
5 (7.6)	100-C09	193-E**FB	15	15††
7.5 (11)	100-C12	193-E**FB	20	20††
10 (14)	100-C16	193-E**GB	20††	20††
15 (21)	100-C23	193-E**GB	30††	30††
20 (27)	100-C30	193-E**HC	40	
25 (34)	100-C37	193-E**HC	50	
30 (40)	100-C43	193-E**JD	50††	
40 (52)	100-C60	193-E**KE	80	
50 (65)	100-C72	193-E**KE	100	

575 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR BASIC CAT. # (a)	OVERLOAD RELAY BASIC CAT. # (b)	MAX FUSE	
			LPJ SP CLASS J	LP-CC CLASS CC
0.5 (0.9)	100-C09	193-E**DB	3	3
0.75 (1.3)	100-C09	193-E**DB	3	3
1 (1.7)	100-C09	193-E**DB	6†	6
1.5 (2.4)	100-C09	193-E**DB	6	6
2 (2.7)	100-C09	193-E**EB	10†	10
3 (3.9)	100-C09	193-E**FB	10	10
5 (6.1)	100-C09	193-E**FB	15	15
5 (7.6)	100-C09	193-E**FB	15	15††
7.5 (9)	100-C09	193-E**FB	15	15††
10 (11)	100-C12	193-E**FB	20	20††
15 (17)	100-C23	193-E**GB	30	30††
20 (22)	100-C30	193-E**HC	40	
25 (27)	100-C37	193-E**HC	50	
30 (32)	100-C37	193-E**HC	50	
40 (41)	100-C60	193-E**KE	80	
50 (52)	100-C72	193-E**KE	100	
60 (62)	100-C85	193-E**KE	100	

(a) Catalog number is not complete, add coil voltage code and auxiliary contact description.

(b) Catalog number is not complete, replace ** with trip class and reset mode.

†† May be too small to allow some motors to start.

† Sized larger than code max for single motor.

Rockwell Automation, Allen-Bradley — NEMA
(UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	STARTER† SIZE	CAT. #	HEATER # ELEMENT	MAX FUSE LPN-RK SP/LPJ_SP CLASS RK1/J
1.5 (6.9)	0	509-A	W48	15
2 (7.8)	0	509-A	W50	15
3 (11.0)	0	509-A	W53	20
5 (17.5)	1	509-B	W59	30
7.5 (25.3)	2	509-C	W63	50
10 (32.2)	3	509-D	W65	60
15 (48.3)	3	509-D	W68	100
20 (62.1)	3	509-D	W71	100
25 (78.2)	3	509-D	W75	150
30 (92.0)	4	509-E	W77	175
40 (120.0)	4	509-E	W81	200
50 (150.0)	5	509-F	W37	200††
60 (177.1)	5	509-F	W39	250††
75 (221.0)	5	509-F	W41	350

230 Volt, Three-Phase Motors

HP (FLC)	STARTER† SIZE	CAT. #	HEATER ELEMENT	MAX FUSE LPN-RK SP/LPJ_SP CLASS RK1/J
2 (6.8)	0	509-A	W48	15
3 (9.6)	0	509-A	W52	20
5 (15.2)	1	509-B	W57	30
7.5 (22.0)	2	509-C	W61	45
10 (28.0)	3	509-C	W64	60
15 (42.0)	3	509-D	W66	90
20 (54.0)	3	509-D	W69	100
25 (68.2)	3	509-D	W73	100††
30 (80.0)	3	509-D	W75	150
40 (104.0)	4	509-E	W79	175
50 (130.0)	4	509-E	W83	200
60 (154.0)	5	509-F	W37	200††
75 (192.0)	5	509-F	W40	300
100 (248.0)	5	509-F	W43	400

460 Volt, Three-Phase Motors

HP (FLC)	STARTER† SIZE	CAT. #	HEATER ELEMENT	MAX FUSE LPS-RK SP/LPJ_SP CLASS RK1/J
5 (7.6)	0	509-A	W49	15
7.5 (11.0)	1	509-B	W53	20
10 (14.0)	1	509-B	W56	30
15 (21.0)	2	509-C	W61	45
20 (27.0)	2	509-C	W63	60
25 (34.0)	3	509-D	W66	60
30 (40.0)	3	509-D	W66	90
40 (52.0)	3	509-D	W69	100
50 (65.0)	3	509-D	W72	100
60 (77.0)	4	509-E	W74	125
75 (96.0)	4	509-E	W77	175
100 (124.0)	4	509-E	W82	200
125 (156.0)	5	509-F	W37	200††
150 (180.0)	5	509-F	W39	250††
200 (240.0)	5	509-F	W42	400

575 Volt, Three-Phase Motors

HP (FLC)	STARTER† SIZE	CAT. #	HEATER ELEMENT	MAX FUSE LPS-RK SP/LPJ_SP CLASS RK1/J
5 (6.1)	0	509-A	W47	12
7.5 (9.0)	1	509-B	W51	20
10 (11.0)	1	509-B	W53	20
15 (17.0)	2	509-C	W58	35
25 (27.0)	2	509-C	W63	60
30 (32.0)	3	509-D	W64	70
40 (41.0)	3	509-D	W66	90
50 (52.0)	3	509-D	W69	100
60 (62.0)	4	509-E	W71	100
75 (77.0)	4	509-E	W74	125
100 (99.0)	4	509-E	W78	175
125 (125.0)	5	509-F	W35	200
150 (144.0)	5	509-F	W36	200††
200 (192.0)	5	509-F	W40	300

† Catalog number is not complete. Refer to Bulletin 509 Section of A-B Industrial Control Catalog to specify complete catalog starter number.

†† May be too small to allow some motors to start.

Square D Company — IEC (UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	LPJ_SP CLASS J	MAX FUSE LPN-RK_SP CLASS RK1	KRP-C_SP CLASS L
0.5 (2.5)	LC1D09	LR2D1307	4		
0.75 (3.7)	LC1D09	LR2D1308	6		
1 (4.8)	LC1D09	LR2D1310	10		
1.5 (6.9)	LC1D09	LR2D1312	15		
2 (7.8)	LC1D09	LR2D1312	15		
2 (7.8)	LC1D09	LR2D1314	15		
3 (11.0)	LC1D012	LR2D1316	20		
5 (17.5)	LC1D018	LR2D1321	25††		
5 (17.5)	LC1D025	LR2D1322	35		
7.5 (25.3)	LC1D032	LR2D2353	40		
10 (32.2)	LC1D040	LR2D3355	60		
15 (48.3)	LC1D050	LR2D3357	70††		
15 (48.3)	LC1D050	LR2D3359	80		
15 (48.3)	LC1D065	LR2D3359	100		
20 (62.1)	LC1D050	LR2D3359	80††		
20 (62.1)	LC1D065	LR2D3359	100		
30 (92.0)	LC1F115	LR2F5367	200	200	
40 (120.0)	LC1F150	LR2F5569	250	250	
50 (150.0)	LC1F185	LR2F5569	300	250	
50 (150.0)	LC1F185	LR2F5571	300	300	
60 (177.0)	LC1F265	LR2F6573		350	
60 (177.0)	LC1F265	LR2F5571	350	350	
75 (221.0)	LC1F400	LR2F6575		450	
100 (285.0)	LC1F400	LR2F6575	500	500	
100 (285.0)	LC1F400	LR2F6577	600		601
125 (359.0)	LC1F500	LR2F6577	600		800

230 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	LPJ_SP CLASS J	MAX FUSE LPN-RK_SP CLASS RK1	KRP-C_SP CLASS L
0.5 (2.2)	LC1D09	LR2D1307	4		
0.75 (3.2)	LC1D09	LR2D1308	6		
1 (4.2)	LC1D09	LR2D1310	10		
1.5 (6.0)	LC1D09	LR2D1310	10		
1.5 (6.0)	LC1D09	LR2D1312	15		
2 (6.8)	LC1D09	LR2D1312	15		
3 (9.6)	LC1D09	LR2D1314	15		
3 (9.6)	LC1D012	LR2D1316	20		
5 (15.2)	LC1D018	LR2D1321	25		
7.5 (22.0)	LC1D032	LR2D1322	35		
10 (28.0)	LC1D032	LR2D2353	40††		
15 (42.0)	LC1D050	LR2D3357	70		
20 (54.0)	LC1D050	LR2D3359	80††		
20 (54.0)	LC1D065	LR2D3359	100		
40 (104.0)	LC1F115	LR2F5367	225	200	
40 (104.0)	LC1F115	LR2F5369	225	225	
50 (130.0)	LC1F150	LR2F5569	250	250	
60 (154.0)	LC1F185	LR2F5569	300	250	
60 (154.0)	LC1F185	LR2F5571	300	300	
75 (192.0)	LC1F265	LR2F6571	400	350	
75 (192.0)	LC1F265	LR2F6573	400	400	
100 (248.0)	LC1F400	LR2F6575	500	500	
125 (312.0)	LC1F400	LR2F6575	500	500	
125 (312.0)	LC1F400	LR2F6577	600		700
150 (360.0)	LC1F500	LR2F6577	600		800
200 (480.0)	LC1F500	LR2F7579			1000
250 (600.0)	LC1F630	LR2F7581			1350
300 (720.0)	LC1F630	LR2F8583			1600

460 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	LPJ_SP CLASS J	MAX FUSE LPS-RK_SP CLASS RK1	KRP-C_SP CLASS L
0.5 (1.1)	LC1D09	LR2D1306	3		
0.75 (1.6)	LC1D09	LR2D1306	3		
1 (2.1)	LC1D09	LR2D1307	4		
1.5 (3.0)	LC1D09	LR2D1308	6		
2 (3.4)	LC1D09	LR2D1308	6		
3 (4.8)	LC1D09	LR2D1310	10		
5 (7.6)	LC1D09	LR2D1312	15		
5 (7.6)	LC1D09	LR2D1314	15		
7.5 (11.0)	LC1D012	LR2D1316	20		
10 (14.0)	LC1D018	LR2D1321	25		
15 (21.0)	LC1D032	LR2D1322	35		
20 (27.0)	LC1D032	LR2D2353	40		
25 (34.0)	LC1D040	LR2D3355	60		
30 (40.0)	LC1D040	LR2D3355	60		
30 (40.0)	LC1D050	LR2D3357	70		
40 (52.0)	LC1D050	LR2D3359	80		
40 (52.0)	LC1D065	LR2D3359	100		
50 (65.0)	LC1D050	LR2D3359	80††		
50 (65.0)	LC1D065	LR2D3359	100		
75 (96.0)	LC1F115	LR2F5367	200	200	
100 (124.0)	LC1F150	LR2F5569	250	250	
125 (156.0)	LC1F185	LR2F5569	300	250	
125 (156.0)	LC1F185	LR2F5571	350	350	
150 (180.0)	LC1F265	LR2F6571	400	350	
150 (180.0)	LC1F265	LR2F6573	400	400	
200 (240.0)	LC1F400	LR2F6573	450	500	
200 (240.0)	LC1F400	LR2F6575	500	500	
250 (302.0)	LC1F400	LR2F6575	500	500	
250 (302.0)	LC1F400	LR2F6577	600		650
300 (361.0)	LC1F500	LR2F6577	600		800
350 (414.0)	LC1F500	LR2F7579			800
400 (477.0)	LC1F500	LR2F7579			1000
500 (590.0)	LC1F630	LR2F7581			1350
600 (720.0)	LC1F630	LR2F8583			1600

575 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	LPJ_SP CLASS J	MAX FUSE LPS-RK_SP CLASS RK1	KRP-C_SP CLASS L
0.75 (1.3)	LC1D09	LR2D1306	3		
1 (1.7)	LC1D09	LR2D1306	3		
1.5 (2.4)	LC1D09	LR2D1307	4		
2 (2.7)	LC1D09	LR2D1308	6		
3 (3.9)	LC1D09	LR2D1308	6		
5 (6.1)	LC1D09	LR2D1312	10		
7.5 (9.0)	LC1D012	LR2D1314	15		
7.5 (9.0)	LC1D018	LR2D1316	20		
10 (11.0)	LC1D018	LR2D1316	20		
15 (17.0)	LC1D025	LR2D1321	25		
15 (17.0)	LC1D032	LR2D1322	35		
20 (22.0)	LC1D032	LR2D1322	35		
30 (32.0)	LC1D040	LR2D3355	45††		
40 (41.0)	LC1D050	LR2D3357	70		
50 (52.0)	LC1D065	LR2D3359	80		
50 (52.0)	LC1D080	LR2D3359	90		
60 (62.0)	LC1D065	LR2D3359	80††		
60 (62.0)	LC1D080	LR2D3359	90††		
75 (77.0)	LC1F115	LR2D3363	150	125	
100 (99.0)	LC1F115	LR2F5367	200	200	
125 (125.0)	LC1F150	LR2F5569	250	250	
150 (144.0)	LC1F185	LR2F5569	300	250	
150 (144.0)	LC1F185	LR2F5571	300	300	
200 (192.0)	LC1F265	LR2F5571	400	350	
200 (192.0)	LC1F265	LR2F6573	400	400	
250 (242.0)	LC1F400	LR2F6575	500	500	
300 (289.0)	LC1F400	LR2F6575	500	500	
300 (289.0)	LC1F400	LR2F6577	600		601
350 (336.0)	LC1F500	LR2F6577	600		700
400 (382.0)	LC1F500	LR2F6577	600		800
500 (472.0)	LC1F500	LR2F7579			1000
600 (576.0)	LC1F630	LR2F7581			1200
800 (770.0)	LC1F630	LR2F8583			1600

†† May be too small to allow some motors to start.

Square D Company — IEC
(UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	MAX FUSE		
			LP-CC CLASS CC	LPJ_SP CLASS J	TCF CUBEFuse
0.5 (2.5)	LC1D09	LRD1508	8	6	6
0.75 (3.7)	LC1D09	LRD1508	8	6	6
1 (4.8)	LC1D09	LRD1510	25	20	20
1.5 (6.4)	LC1D09	LRD1512	25	20	20
2 (7.8)	LC1D09	LRD1512	25	20	20
3 (11.0)	LC1D12	LRD1516	25	20	20
5 (17.5)	LC1D18	LRD1522		25*	25*
7.5 (25.3)	LC1D40	LRD1530		50	50
10 (32.2)	LC1D40	LRD3555		60	60
15 (48.3)	LC1D50	LRD3557		70*	70*
20 (62.1)	LC1D65	LRD3559		100	100
25 (78.2)	LC1D80	LRD3563		125	
30 (92.0)	LC1D115	LRD5569		175	
40 (120)	LC1D150	LRD5569		200	

230 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	MAX FUSE		
			LP-CC CLASS CC	LPJ_SP CLASS J	TCF CUBEFuse
0.75 (3.4)	LC1D09	LRD1508	8	6	6
1 (4.2)	LC1D09	LRD1510	25	20	20
1.5 (6.0)	LC1D09	LRD1512	25	20	20
2 (6.8)	LC1D09	LRD1512	25	20	20
3 (9.5)	LC1D12	LRD1516	25	20	20
5 (15.2)	LC1D18	LRD1521		25	25
7.5 (22.0)	LC1D25	LRD1522		35	35
10 (28.0)	LC1D40	LRD1530		50	50
15 (42.0)	LC1D50	LRD3557		70	70
20 (54.0)	LC1D65	LRD3559		100	100
25 (68.0)	LC1D80	LRD3563		125	
30 (80.0)	LC1D80	LRD3560		125	
40 (104)	LC1D115	LRD5569		175	

460 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	MAX FUSE		
			LP-CC CLASS CC	LPJ_SP CLASS J	TCF CUBEFuse
1.5 (3.0)	LC1D09	LRD1508	8	6	6
2 (3.4)	LC1D09	LRD1508	8	6	6
3 (4.8)	LC1D09	LRD1510	25	20	20
5 (7.6)	LC1D09	LRD1512	25	20	20
7.5 (11.0)	LC1D12	LRD1516	25	20	20
10 (14.0)	LC1D18	LRD1521		25	25
15 (21.0)	LC1D25	LRD1522		35	35
20 (27.0)	LC1D40	LRD1530		50	50
25 (34.0)	LC1D40	LRD3555		60	60
30 (40.0)	LC1D40	LRD3555		60	60
30 (40.0)	LC1D50	LRD3557		70	70
40 (52.0)	LC1D50	LRD3559		80	80
50 (65.0)	LC1D65	LRD3559		80*	80*
50 (65.0)	LC1D65	LRD3559		100	100
60 (77.0)	LC1D80	LRD3563		125	
75 (96.0)	LC1D115	LRD5569		175	
100 (124)	LC1D125	LRD5569		200	

575 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	MAX FUSE		
			LP-CC CLASS CC	LPJ_SP CLASS J	TCF CUBEFuse
2 (2.7)	LC1D09	LRD1508	8	6	6
3 (3.9)	LC1D09	LRD1508	8	6	6
5 (6.1)	LC1D09	LRD1512	25	20	20
7.5 (9.0)	LC1D09	LRD1514	25	20	20
10 (11.0)	LC1D12	LRD1516	25	20	20
10 (11.0)	LC1D18	LRD1516	30	20	20
15 (17.0)	LC1D18	LRD1522		25	25
20 (22.0)	LC1D25	LRD1522		35	35
25 (27.0)	LC1D40	LRD1530		50	50
30 (32.0)	LC1D40	LRD3555		60	60
40 (41.0)	LC1D50	LRD3557		70	70
50 (52.0)	LC1D65	LRD3559		100	100
60 (62.0)	LC1D80	LRD3561		125	
75 (77.0)	LC1D115	LR9D5567		150	
100 (99.0)	LC1D115	LR9D5569		175	
125 (125)	LC1D150	LR9D5569		200	

* May be too small to allow some motors to start.

Square D Company — IEC
 (UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	MAX FUSE		
			LP-CC CLASS CC	LPJ SP CLASS J	TCF CUBEFuse
0.5 (2.5)	LC1D09	LRD07	8	6	6
0.75 (3.7)	LC1D09	LRD08	8	6	6
1 (4.8)	LC1D09	LRD10	25	17.5	17.5
1.5 (6.9)	LC1D09	LRD12	25	17.5	17.5
2 (7.8)	LC1D09	LRD12	25	17.5	17.5
3 (11.0)	LC1D12	LRD16	25	17.5	17.5
5 (17.5)	LC1D18	LRD21		25*	25*
7.5 (25.3)	LC1D40	LRD40		50	50
10 (32.2)	LC1D40	LRD3555		60	60
15 (48.3)	LC1D50	LRD3557		70	70
20 (62.1)	LC1D65	LRD3559		100	100
25 (78.2)	LC1D80	LRD3563		125	
30 (92.0)	LC1D115	LRD5569		175	
40 (120)	LC1D150	LRD5569		225	

230 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	MAX FUSE		
			LP-CC CLASS CC	LPJ SP CLASS J	TCF CUBEFuse
0.5 (2.2)	LC1D09	LRD07	8	6	6
0.75 (3.2)	LC1D09	LRD08	8	6	6
1 (4.2)	LC1D09	LRD10	25	17.5	17.5
1.5 (6.0)	LC1D09	LRD12	25	17.5	17.5
2 (6.8)	LC1D09	LRD12	25	17.5	17.5
3 (9.6)	LC1D12	LRD16	25	17.5	17.5
5 (15.5)	LC1D18	LRD21		25	25
7.5 (22.0)	LC1D25	LRD22		35	35
10 (28.0)	LC1D40	LRD32		50	50
15 (42.0)	LC1D50	LRD3357		70	70
20 (54.0)	LC1D65	LRD3359		100	100
25 (68.0)	LC1D80	LRD3363		125	
30 (80.0)	LC1D80	LRD3363		125	
40 (104)	LC1D115	LRD5369		175	

460 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	MAX FUSE		
			LP-CC CLASS CC	LPJ SP CLASS J	TCF CUBEFuse
0.75 (1.6)	LC1D09	LRD06	8	3	3
1 (2.1)	LC1D09	LRD07	8	6	6
1.5 (3.0)	LC1D09	LRD08	8	6	6
2 (3.4)	LC1D09	LRD08	8	6	6
3 (4.8)	LC1D09	LRD10	25	17.5	17.5
5 (7.6)	LC1D09	LRD12	25	17.5	17.5
7.5 (11.0)	LC1D12	LRD16	25	17.5	17.5
10 (14.0)	LC1D18	LRD21		25	25
15 (21.0)	LC1D25	LRD22		35	35
20 (27.0)	LC1D40	LRD32		50	50
25 (34.0)	LC1D40	LRD3355		60	60
30 (40.0)	LC1D40	LRD3355		60	60
30 (40.0)	LC1D50	LRD3357		70	70
40 (52.0)	LC1D50	LRD3359		80	80
50 (65.0)	LC1D65	LRD3359		100	100
60 (77.0)	LC1D80	LRD3363		125	
75 (96.0)	LC1D115	LRD5369		175	
100 (124)	LC1D125	LRD5369		225	

575 Volt, Three-Phase Motors

HP (FLC)	CONTACTOR	OLR	MAX FUSE		
			LP-CC CLASS CC	LPJ SP CLASS J	TCF CUBEFuse
0.75 (1.3)	LC1D09	LRD06	8	3	3
1 (1.7)	LC1D09	LRD07	8	6	6
1.5 (2.4)	LC1D09	LRD07	8	6	6
2 (2.7)	LC1D09	LRD08	8	6	6
3 (3.9)	LC1D09	LRD08	25	6	6
5 (6.1)	LC1D09	LRD12	25	17.5	17.5
7.5 (9.0)	LC1D09	LRD14	25	17.5	17.5
10 (11.0)	LC1D12	LRD16	25	17.5	17.5
10 (11.0)	LC1D18	LRD16	30	17.5	17.5
15 (17.0)	LC1D18	LRD21		25*	25*
20 (22.0)	LC1D25	LRD22		35	35
25 (27.0)	LC1D40	LRD32		50	50
30 (32.0)	LC1D40	LRD3355		60	60
40 (41.0)	LC1D50	LRD3357		70	70
50 (52.0)	LC1D65	LRD3359		100	100
60 (62.0)	LC1D80	LRD3361		125	
75 (77.0)	LC1D115	LR9D5367		150	
100 (99.0)	LC1D115	LR9D5369		175	
125 (125)	LC1D150	LR9D5369		225	

* May be too small to allow some motors to start.

Square D Company — NEMA
(UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	STARTER	CAT. #	HEATER SIZE	MAX FUSE	
				LPN-RK SP CLASS RK1	LPJ SP CLASS J
1.5 (6.9)	0	SB02V02S	B11.5*	12	15
2 (7.8)	0	SB02V02S	B12.8	15	15
3 (11.0)	0	SB02V02S	B19.5	17.5	20
5 (17.5)	1	SC03V02S	B32	25	30
7.5 (25.3)	1	SC03V02S	B50	40	45
10 (32.2)	2	SD01V02S	B62	50	60
15 (48.3)	3	SE01V02S	CC81.5	70	80
20 (62.1)	3	SE01V02S	CC112	100	100
25 (78.2)	3	SE01V02S	CC180	125	125
30 (92.0)	4	SF01V02S	CC156	150	150
40 (120.0)	4	SF01V02S	CC208	175	200
50 (150.0)	5	SG01V02S**	B3.70	225	250
60 (177.0)	5	SG01V02S**	B4.15	300	300
75 (221.0)	5	SG01V02S**	B5.50	350	400

230 Volt, Three-Phase Motors

HP (FLC)	STARTER	CAT. #	HEATER SIZE	MAX FUSE	
				LPN-RK SP CLASS RK1	LPJ SP CLASS J
1.5 (6.0)	0	SB02V02S	B10.2	10	12
2 (6.8)	0	SB02V02S	B11.5*	12	15
3 (9.6)	0	SB02V02S	B15.5	17.5	17.5
5 (15.2)	1	SC03V02S	B28.0	25	30
7.5 (22.0)	1	SC03V02S	B45	35	50†
10 (28.0)	2	SD01V02S	B50	45	50
15 (42.0)	3	SE01V02S	CC68.5	70	70
20 (54.0)	3	SE01V02S	CC94.0	80	90
25 (68.0)	3	SE01V02S	CC132	110	125
30 (80.0)	3	SE01V02S	CC196	125	150
40 (104.0)	4	SF01V02S	CC180	175	175
50 (130.0)	5	SG01V02S**	B3.30	200	200
60 (154.0)	5	SG01V02S**	B3.70	225	250
75 (192.0)	5	SG01V02S**	B4.15	300	300
100 (248.0)	5	SG01V02S**	B6.25	400	400

460 Volt, Three-Phase Motors

HP (FLC)	STARTER	CAT. #	HEATER SIZE	MAX FUSE	
				LPS-RK SP CLASS RK1	LPJ SP CLASS J
3 (4.8)	0	SB02V02S	B7.70*	8	9
5 (7.6)	0	SB02V02S	B12.8	15	15
7.5 (11.0)	1	SC03V02S	B19.5	17.5	20
10 (14.0)	1	SC03V02S	B25	20	25
15 (21.0)	2	SD01V02S	B36	30	35
20 (27.0)	2	SD01V02S	B45	40	45
25 (34.0)	2	SD01V02S	B70	50	60
30 (40.0)	3	SE01V02S	CC64.3	60	70
40 (52.0)	3	SE01V02S	CC87.7	80	90
50 (65.0)	3	SE01V02S	CC121	100	110
60 (77.0)	4	SF01V02S	CC121	125	125
75 (96.0)	4	SF01V02S	CC167	150	175
100 (124.0)	5	SG01V02S**	B3.00	200	200
125 (156.0)	5	SG01V02S**	B3.70	225	250
150 (180.0)	5	SG01V02S**	B4.15	300	300
200 (240.0)	5	SG01V02S**	B6.25	400	400

575 Volt, Three-Phase Motors

HP (FLC)	STARTER	CAT. #	HEATER SIZE	MAX FUSE	
				LPS-RK SP CLASS RK1	LPJ SP CLASS J
3 (3.9)	0	SB02V02S	B6.25	6	8
5 (6.1)	0	SB02V02S	B10.2	10	12
7.5 (9.0)	1	SC03V02S	B15.5	15	17.5
10 (11.0)	1	SC03V02S	B19.5	17.5	20
15 (17.0)	2	SD01V02S	B28.0	25	30
20 (22.0)	2	SD01V02S	B40	35	40
25 (27.0)	2	SD01V02S	B45	40	45
30 (32.0)	3	SE01V02S	CC50.1	50	50
40 (41.0)	3	SE01V02S	CC68.5	60	70
50 (52.0)	3	SE01V02S	CC87.7	80	90
60 (62.0)	4	SF01V02S	CC103	100	100
75 (77.0)	4	SF01V02S	CC121	125	125
100 (99.0)	4	SF01V02S	CC167	150	175
125 (125.0)	5	SG01V02S**	B3.00	200	200
150 (144.0)	5	SG01V02S**	B3.70	225	250
200 (192.0)	5	SG01V02S**	B4.15	300	300

* These overloads were not tested. Maximum fuse sizes are for the lower value of over-load which was tested.

** Y500

† Sized larger than code max for single motor.

Siemens — IEC
(UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	STARTER	OLR	MAX FUSE		
			LPN-RK SP CLASS RK1	LPJ SP CLASS J	LP-CC CLASS CC
0.5 (2.5)	3TF30/40	3UA5000-1D	6	6	6
0.75 (3.7)	3TF30/40	3UA5000-1E	6	6	6††
1 (4.8)	3TF30/40	3UA5000-1F	8	8	10
1 (4.8)	3TF30/40	3UA5000-1G	10	10	10
1.5 (6.9)	3TF30/40	3UA5000-1H	15	15	20
2 (7.8)	3TF30/40	3UA5000-1J	15	15	20
3 (11.0)	3TF31/41	3UA5000-1K	20	20	30
3 (11.0)	3TF31/41	3UA5000-2S	25†	25†	30
5 (17.5)	3TF32/42	3UA5200-2B	30	30	30††
7.5 (25.3)	3TF34/44	3UA5500-2D	50	50	
10 (32.2)	3TF46	3UA5800-2E	60	60	
15 (48.3)	3TF46	3UA5800-2T	90	90	
20 (62.1)	3TF47	3UA5800-2V	125	125	
25 (78.2)	3TF48	3UA5800-8W	175	175	
30 (92.0)	3TF50	3UA6000-2X	200	200	
40 (120.0)	3TF50	3UA6000-3J	250	250	
50 (150.0)	31T52	3UA6200-3L	300	300	
75 (221.0)	3TF54	3UA6600-3C	400	400	
75 (221.0)	3TF54	3UA6600-3D	450	450	
100 (285.2)	3TF56	3UA6600-3D	500	500	
125 (359.0)	3TF56	3UA6600-3E	500	500††	

230 Volt, Three-Phase Motors

HP (FLC)	STARTER	OLR	MAX FUSE		
			LPN-RK SP CLASS RK1	LPJ SP CLASS J	LP-CC CLASS CC
0.5 (2.2)	3TF30/40	3UA5000-1C	2.8	3††	3††
0.75 (3.2)	3TF30/40	3UA5000-1E	6	6	6††
1 (4.2)	3TF30/40	3UA5000-1F	8	8	10
1.5 (6.0)	3TF30/40	3UA5000-1G	10	10	10††
2 (6.8)	3TF30/40	3UA5000-1H	15	15	20
3 (9.6)	3TF30/40	3UA5000-1J	15	15	20
3 (9.6)	3TF31/41	3UA5000-1J	15	15	20
5 (15.2)	3TF32/42	3UA5200-2A	25	25	30
7.5 (22.0)	3TF33/43	3UA5200-2C	40	40	30††
10 (28.0)	3TF34/44	3UA5500-2D	50	50	
15 (42.0)	3TF46	3UA5800-2F	70	70	
20 (54.0)	3TF46	3UA5800-2T	90	90	
25 (68.0)	3TF47	3UA5800-2V	125	125	
30 (80.0)	3TF48	3UA5800-8W	175	175	
40 (104.0)	3TF50	3UA6000-2X	200	200	
50 (130.0)	3TF50	3UA6000-3J	250	250	
60 (154.0)	31T52	3UA6200-3L	300	300	
75 (192.0)	3TF54	3UA6600-3C	400	400	
100 (248.0)	3TF54	3UA6600-3D	450	450	
125 (312.0)	3TF56	3UA6600-3D	500	500	
150 (360.0)	3TF56	3UA6600-3E	500	500††	

460 Volt, Three-Phase Motors

HP (FLC)	STARTER	OLR	MAX FUSE		
			LPS-RK SP CLASS RK1	LPJ SP CLASS J	LP-CC CLASS CC
0.5 (1.1)	3TF30/40	3UA5000-1A	1.6	2	2.25
0.75 (1.6)	3TF30/40	3UA5000-1A	1.6††	2††	2.25††
1 (2.1)	3TF30/40	3UA5000-1C	2.8	3††	3††
1.5 (3.0)	3TF30/40	3UA5000-1D	6	6	6
2 (3.4)	3TF30/40	3UA5000-1E	6	6	6††
3 (4.8)	3TF30/40	3UA5000-1F	8	8	10
3 (4.8)	3TF30/40	3UA5000-1G	10	10	10
5 (7.6)	3TF30/40	3UA5000-1H	15	15	20
5 (7.6)	3TF30/40	3UA5000-1J	15	15	20
7.5 (11.0)	3TF31/41	3UA5000-1K	20	20	30
7.5 (11.0)	3TF31/41	3UA5000-2S	25†	25†	30
10 (14.0)	3TF32/42	3UA5200-2A	25	25	30
15 (21.0)	3TF33/43	3UA5200-2C	40	40	30††
20 (27.0)	3TF34/44	3UA5500-2D	50	50	
25 (34.0)	3TF46	3UA5800-2E	60	60	
30 (40.0)	3TF46	3UA5800-2F	70	70	
40 (52.0)	3TF46	3UA5800-2T	90	90	
50 (65.0)	3TF47	3UA5800-2V	125	125	
60 (77.0)	3TF48	3UA5800-8W	175†	175†	
75 (96.0)	3TF50	3UA6000-2X	200	200	
100 (124.0)	3TF50	3UA6000-3J	250	250	
125 (156.0)	31T52	3UA6200-3L	300	300	
150 (180.0)	3TF54	3UA6600-3B	300	300	
200 (240.0)	3TF54	3UA6600-3C	400	400	
250 (302.0)	3TF56	3UA6600-3D	500	500	
300 (361.0)	3TF56	3UA6600-3E	500	500††	

†† May be too small to allow some motors to start.

† Sized larger than code max for single motor.

Siemens — NEMA
(UL & CSA Verified, Type 2 Combination SCCR = 100kA)

200 Volt, Three-Phase Motors

HP (FLC)	STARTER	OLR	MAX FUSE		
			LPN-RK SP CLASS RK1	LPJ SP CLASS J	LP-CC CLASS CC
0.5 (2.5)	SXLA	3UA5000-1D	6	6	6
0.75 (3.7)	SXLA	3UA5000-1E	6	6	6††
1 (4.8)	SXLA	3UA5000-1F	8	8	10
1.5 (6.9)	SXLA	3UA5000-1H	15	15	20
2 (7.8)	SXLB	3UA5400-1J	15	15	20
3 (11.0)	SXLB	3UA5400-1K	20	20	30
5 (17.5)	SXLC	3UA5400-2B	30	30	30††
7.5 (25.3)	SXLC	3UA5400-2D	50	50	
10 (32.2)	SXLD	3UA5800-2E	60	60	
15 (48.3)	SXLE	3UA5800-2T	90	90	
20 (62.1)	SXLE	3UA5800-2V	125	125	
25 (78.2)	SXLE	3UA5800-8W	175	175	
30 (92.0)	SXLF	3UA6200-2X	200	200	
40 (120.0)	SXLF	3UA6200-3J	250	250	
50 (150.0)	SXLG	3UA6600-3B	300	300	
60 (177.0)	SXLG	3UA6600-3C	400†	400†	
75 (221.0)	SXLG	3UA6600-3D	500†	450	

230 Volt, Three-Phase Motors

HP (FLC)	STARTER	OLR	MAX FUSE		
			LPN-RK SP CLASS RK1	LPJ SP CLASS J	LP-CC CLASS CC
0.5 (2.2)	SXLA	3UA5000-1C	2.8	3††	3††
0.75 (3.2)	SXLA	3UA5000-1E	6	6	6††
1 (4.2)	SXLA	3UA5000-1F	8	8	10
1.5 (6.0)	SXLA	3UA5000-1G	10	10	10††
2 (6.8)	SXLB	3UA5400-1H	15	15	20
3 (9.6)	SXLB	3UA5400-1K	20	20	30
5 (15.2)	SXLC	3UA5400-2B	30	30	30
7.5 (22.0)	SXLC	3UA5400-2C	40	40	30††
10 (28.0)	SXLD	3UA5800-2D	50	50	
15 (42.0)	SXLD	3UA5800-2F	70	70	
20 (54.0)	SXLE	3UA5800-2T	90	90	
25 (68.0)	SXLE	3UA5800-2U	150	150	
30 (80.0)	SXLE	3UA5800-8W	175	175	
40 (104.0)	SXLF	3UA6200-3H	225	225	
50 (130.0)	SXLF	3UA6200-3J	250	250	
60 (154.0)	SXLG	3UA6600-3B	300	300	
75 (192.0)	SXLG	3UA6600-3C	400	400	
100 (248.0)	SXLG	3UA6600-3D	500	450	

460 Volt, Three-Phase Motors

HP (FLC)	STARTER	OLR	MAX FUSE		
			LPS-RK SP CLASS RK1	LPJ SP CLASS J	LP-CC CLASS CC
0.5 (1.1)	SXLA	3UA5000-1A	1.6	2	2.25
0.75 (1.6)	SXLA	3UA5000-1A	1.6	2††	2.25††
1 (2.1)	SXLA	3UA5000-1C	2.8	3††	3††
1.5 (3.0)	SXLA	3UA5000-1D	6	6	6
2 (3.4)	SXLA	3UA5000-1E	6	6	6††
3 (4.8)	SXLB	3UA5400-1G	10	10	10
5 (7.6)	SXLB	3UA5400-1H	15	15	20
7.5 (11.0)	SXLC	3UA5400-1K	20	20	30
10 (14.0)	SXLC	3UA5400-2A	25	25	30
15 (21.0)	SXLD	3UA5800-2C	40	40	30††
20 (27.0)	SXLD	3UA5800-2D	50	50	
25 (34.0)	SXLD	3UA5800-2E	60	60	
30 (40.0)	SXLE	3UA5800-2F	70	70	
40 (52.0)	SXLE	3UA5800-2T	90	90	
50 (65.0)	SXLE	3UA5800-2V	125	125	
60 (77.0)	SXLF	3UA6200-2W	175†	175†	
75 (96.0)	SXLF	3UA6200-2X	200	200	
100 (124.0)	SXLF	3UA6200-3J	250	250	
125 (156.0)	SXLG	3UA6600-3B	300	300	
150 (180.0)	SXLG	3UA6600-3C	400	400	
200 (240.0)	SXLG	3UA6600-3D	500	450	

†† May be too small to allow some motors to start.

† Sized larger than code max for single motor.

Power Electronic Device Circuit Protection

Variable frequency drives, soft starters, and other power electronic devices are becoming increasingly more common in motor circuits. These power electronic devices are much more sensitive to the damaging effects of short-circuit currents and therefore require a level of protection that may not be provided by circuit breakers or conventional fuses. In the past, manufacturers of these devices provided internal protection in the form of high speed fuses, which are much more current-limiting than conventional branch circuit fuses. However, as drives and soft-starters have grown smaller and smaller, the internal fuses have been omitted by starter manufacturers in favor of short-circuit testing to UL standards with external protection.

Now, in many cases, drives are shipped without fuses, and it is the responsibility of the installer or owner to provide this protection. During the design and installation stages, it is important to check the data sheets, label, or manual of the power electronic device to understand the short-circuit protection options. With the proper fuse selection, a safer installation may result, with better power electronic device protection. This can result in more productive operation and higher short-circuit current ratings.

Short-Circuit Testing

UL 508C, the standard to which drives and soft starters are listed, provides at least two levels of short-circuit protection. The Standard Fault Current test is mandatory to be listed, and there is an optional High Fault Current test which can be performed during the listing of the device.

UL also provides an "Outline of Investigation", UL 508E, which can be used to verify Type 2 (no damage) protection when protected by a specific current-limiting overcurrent protective device.

1. The Standard Fault Current tests evaluate the drives at rather low levels of fault current, and significant damage to the drive is permitted – i.e. the drive does not have to be operational after the testing. Examples of the level of fault currents are 5000 amps for 1.5 to 50Hp drives and 10,000 amps for 51 to 200Hp drives.

The drive must be marked with the maximum short-circuit current rating (at which it was tested). It does not have to be marked with the type overcurrent protective device if it has followed certain procedures. However, the manufacturer can list the drive with fuse protection only and then the label will be marked to identify that branch-circuit protection shall be provided by fuses only (either high speed or branch circuit types).

2. The High Fault Current tests can be at any level of short-circuit current above the standard fault current tests. Significant damage to the drive is permitted – i.e. the drive does not have to be operational after the testing.

The drive must be marked with the short-circuit current rating at which it was tested. In addition it must be marked with the type overcurrent protective device(s) that were used for the test. If current-limiting branch circuit fuses (such as Class J, T, CC, etc.) are used, then the tests are conducted with special umbrella fuses. Umbrella fuses have energy let-through levels greater than the UL limits for various classes and amp rated fuses. These umbrella fuses have energy let-through levels that are greater than commercially available fuses.

A drive can be listed and marked for either fuses or circuit breakers or both. Typically the drives are marked for protection only by fuses since current-limitation is necessary to meet the requirements set forth in the product standard. If the unit is marked for fuse protection only, then only fuses can be used for protection of that drive unit and the proper type and size must be used. Some drives will be marked for protection by a specific amp and class fuse (for branch circuit fuses).

3. Type 2 Protection (no damage) is the best level of protection. With this protection, the drive cannot be damaged, and the unit is tested and marked with a high short-circuit current rating. It must be able to be put into service after the fault has been repaired and the fuses replaced.

A clear understanding of semiconductor device types is needed when considering Type 2 protection (coordination) with variable speed drives. Only silicon controlled rectifier (SCR), gate turn-off thyristor (GTO) and diode based devices can achieve Type 2 protection, and it is only possible with properly selected high speed fuses. Thyristor type devices can effectively share energy equally across the PN junction. They have short-circuit energy withstand levels that are lower than conventional branch circuit fuse let-throughs, however, Type 2 protection can be achieved with properly selected high-speed fuses.

Equipment that uses insulated gate bipolar transistors (IGBTs), high frequency devices, cannot presently achieve Type 2 protection levels. IGBTs do not have enough surface area contact with the actual junction to help share energy evenly. IGBTs share energy very well during long duration pulses, but during short duration, high amplitude faults most of the energy is being carried by an individual bonding wire or contact. Current fuse technology cannot effectively protect the bonding wires of IGBT based equipment from overcurrent conditions, and therefore Type 2 no damage protection is not possible. However, current high speed fuse technology can protect IGBTs from case rupture under short-circuit conditions.

Protecting Drives and Soft Starters

There are two important considerations when selecting protective devices for drives and soft starters:

1. The device must be able to withstand the starting current and duty cycle of the motor circuit without opening.
2. The device must be able to clear a fault quickly enough to minimize damage to the drive or soft starter.

The melting time current characteristic curve can be used to verify a fuse's ability to withstand starting currents and duty cycle, while clearing I^2t at the available fault current can be used to verify the various levels of protection described earlier. For more information on proper sizing of high speed fuses, please see the High Speed Application Guide, available on www.bussmann.com.

There are two types of faults that can occur with drives and soft starters – internal faults and external faults. Internal faults are caused by failures of components within the drive or soft starter, such as failure of the switching components (capacitors, SCRs, thyristors, IGBTs, etc.) External faults occur elsewhere in the circuit, such as a motor winding faulting to the grounded case.

Most soft starters utilize either silicon-controlled rectifiers (SCRs) or gate turn-off thyristors (GTOs) for power conversion. These devices depend on high speed fuses for protection from both internal and external faults. If high speed fuses are properly selected, Type 2 protection may be achieved.

Modern adjustable speed drives often utilize insulated gate bipolar transistors (IGBTs) as the main switching components. IGBTs have drastically lower energy withstands than SCRs and GTOs, which makes protection of these components very difficult. For external faults, drives using IGBTs incorporate electronic protection that shut off the switching components when fault currents are detected. However, over time, transient voltage surges can lead to the electronics' inability to shut off the IGBT switching. This can lead to internal faults as the IGBTs fail and rupture. The violent rupture of IGBTs can cause additional faults to adjacent components as a result of the expelling of gases and shrapnel. High speed fuses may not be able to prevent the IGBT from failing, but properly selected high speed fuses can prevent the violent rupture of IGBT devices and the resultant additional faults and safety hazard.

Large adjustable speed drives often include internal high speed fusing in order to protect against rupturing of components. However, small drives (below 200Hp) often do not include internal fusing, so the user must supply protection. With properly sized and applied high speed fuses, repair, replacement and lost productivity costs will be minimized.

Power Electronic Device Circuit Protection

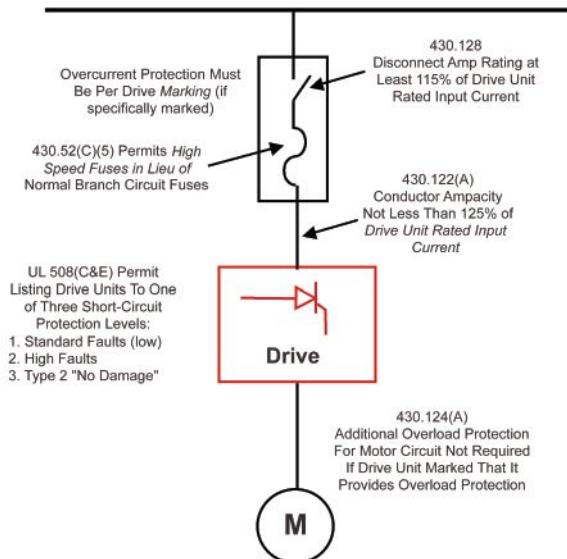
Fuses for Specific Drives

Selection tables for various manufacturers' drives with Bussmann fuse recommendations by specific drive model / part # are available on www.bussmann.com.

Complying with the NEC®

Traditional high speed fuses come in many different shapes and sizes. They can be recognized to UL and CSA standard 248-13. This standard does not contain requirements for overload performance or dimensions, therefore, these fuses are not considered branch circuit protection per the NEC®. However, NEC® article 430, which covers motor circuits, does allow high speed fuses to be used in lieu of branch circuit protection when certain conditions are met.

The use of high speed fuses (also referred to as semiconductor fuses) for protection of power electronic devices in lieu of normal branch circuit overcurrent protective devices is allowed per NEC® 430.52(C)(5), which states that "Semiconductor fuses intended for the protection of electronic devices shall be permitted in lieu of devices listed in Table 430.52 for power electronic



devices, associated electromechanical devices (such as bypass contactors and isolation contactors), and conductors in a solid state motor controller system, provided that the marking for replacement fuses is provided adjacent to the fuses." Please note that this only allows the use of high speed fuses in lieu of branch circuit protection.

Per NEC® 430.124(A), if the adjustable speed drive unit is marked that it includes overload protection, additional overload protection is not required.

NEC® 430.128 states that the disconnecting means for an adjustable speed drive system shall have a rating not less than 115% of the rated input current on the drive unit. This means that the disconnect required in front of each drive unit must be sized in accordance with the drive unit rated input current, not the motor current. When connecting conductors between the disconnecting means and the drive, NEC® 430.122(A) states that "Circuit conductors supplying power conversion equipment included as part of an adjustable speed drive system shall have an ampacity not less than 125% of the rated input to the power conversion equipment." This means that the conductors shall be sized to the rated current on the conversion unit nameplate and not the motor rating.

Bussmann Series DFJ (Class J) Drive Fuse

The Bussmann Drive Fuse (Series DFJ) provides the performance of a high speed fuse for protection of semiconductor devices and is a Class J fuse. Unlike traditional high speed fuses, the Bussmann DFJ Drive Fuse is suitable for branch circuit protection (per the NEC®), and fits in standard Class J fuse clips, holders and disconnects.

Figure 1 - The above comparison of time-current characteristics shows the superior performance of the Bussmann DFJ Drive Fuse at three critical performance points.

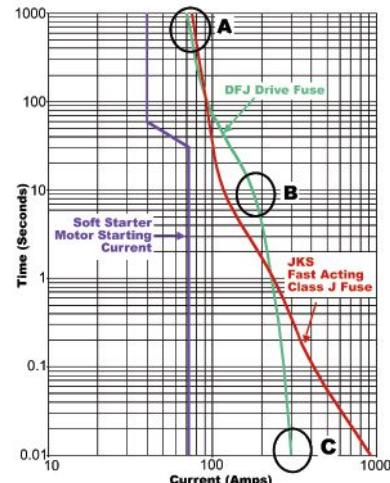


Figure 1 represents the typical starting parameters of an AC drive, as well as the melting characteristics of a traditional, non-time delay, Class J fuse and the DFJ Drive Fuse from Bussmann. There are three critical performance points that are shown:

- A: Continuous Region (Amp Rating)** – The continuous current-carrying capacity of the DFJ Drive Fuse is identical to the tradition Class J fuse. This is key to meeting UL branch circuit opening time requirements.
- B: Overload Region** – Traditional, non-time delay Class J fuses have far less overload withstand than the DFJ Drive Fuse from Bussmann. This extended withstand allows for more reliable protection without nuisance openings.
- C: Short-Circuit Region** – The DFJ Drive Fuse has far lower required melting current and clearing I^t than the traditional Class J fuse, allowing for greater current limitation and lower energy let-through.

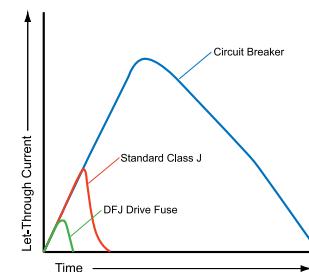


Figure 2 – The graph shown above is representation of the energy let-through by a circuit breaker, a standard, non-time delay Class J fuse, and the Bussmann DFJ Drive Fuse during the same magnitude fault.

Under fault conditions, the DFJ Drive Fuse clear the fault much faster, and are much more current-limiting, than circuit breakers and standard Class J fuses. The DFJ Drive Fuse has high speed fuse performance under fault conditions, which means high speed fuse protection for power electronic devices, and is a Class J fuse which permits using standard switches, fuse blocks and holders that are suitable for Class J fuses.

Group Motor Protection

Group Fusing

430.53 covers the requirements for group motor installations. Two or more motors, or one or more motors and other loads may be protected by the same branch circuit fuse or inverse time circuit breaker if:

- (A) All motors are 1HP or less, protected at not over 20A at 120V or at 15A at 600V or less, the full load amp rating of each motor does not exceed 6 amps, the device rating marked on the controller is not exceeded, and individual overload protection conforms to 430.32.
- or (B) The circuit for the smallest motor is protected per 430.52; i.e. the branch circuit overcurrent protective device protecting the group meets 430.52 for the circuit with the smallest motor.
- or (C) The complete assembly of properly sized branch circuit overcurrent protective device, controller, and overload devices is tested, listed, and marked for a group installation. (The overload device or motor controller does not need to be listed for group installation if the branch circuit, short-circuit and ground fault protective device provides protection for the overload device/motor controller per 430.52).

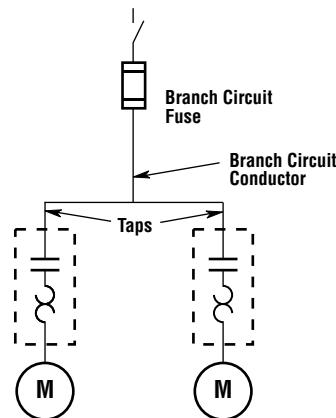
and one of the following:

- (D)(1) the ampacity of conductors to motors are no less than the ampacity of the branch circuit conductors
- or (D)(2) the conductors to motors have at least $\frac{1}{2}$ the ampacity of the branch circuit conductors, are protected from physical damage and are not more than 25 feet long before being connected to the motor overload device.
- or (D)(3) The tap conductors from the branch circuit overcurrent protective device (OCPD) to each manual motor controller* marked "Suitable for Tap Conductor Protection in Group Installations" shall have an ampacity of at least $\frac{1}{10}^{**}$ the amp rating of the branch circuit OCPD. These tap conductors shall be 10 feet or less, enclosed and protected from physical damage; if not, then these conductors shall have an ampacity of at least the same as the branch circuit conductors. The conductor ampacity from the controller to the motor shall be per 430.22.

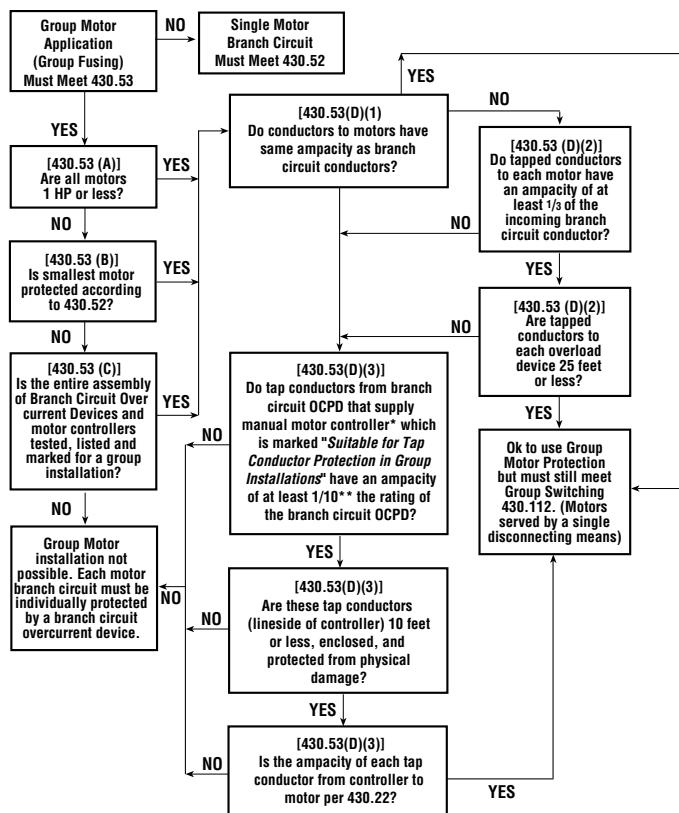
Another Approach

Typically, group motor installations protected by one branch circuit OCPD and group switching are considered for cost savings. However, caution should be taken where a conductor is expected to be protected by an overcurrent protective device significantly larger than the conductor ampacity. The NEC® implies this caution in 430.53(C) IN, referring back to 110.10 and 240.4IN which references ICEA P-32-382-2007 for conductor insulation damage under short-circuit conditions. Under short circuit conditions, smaller conductors are difficult to protect, especially by non current-limiting protective devices. Also, group protection sacrifices selective coordination; a fault on one circuit shuts down all the loads on the group circuit. As a better alternative, consider group switching with fuses/fuse holders for each motor or other type load. See information on group switching. Use holders such a OPM-NG, OPM1038SW, OPM1038, CH Series, JT Series or TCFH & TCF.

Group Motor Installation (Group Fusing) NEC® 430.53



Group Motor Protection



* If a manual motor controller is utilized for this application, it must:

1. Be marked "Suitable for Tap Conductor Protection in Group Installations".
2. Be applied within its voltage limitations (slash voltage rating), if applicable.
3. Be protected by a branch circuit protective device that meets all limitations of the manual motor controller listing criteria. For instance, it may be required to be protected by a fuse no greater than a specified amp rating.

** Even though permitted by this section, the branch circuit overcurrent protective device may not be able to provide adequate short-circuit protection for a conductor having an ampacity $1/10$ the rating of the branch circuit overcurrent protective device. This is especially the case with non current-limiting branch circuit protective devices. It is suggested an engineering conductor protection analysis be conducted for this application (110.10) and (240.4IN).

The Maximum Motor Circuit Feeder Fuse (430.62)

- For the one motor in the group with the highest starting current — Find the largest fuse permitted for branch circuit protection using Table 430.52 or 440.22(A). The fuse capacity permitted for the motor with the heaviest starting current may be considered for only one motor. If two or more motors can each have a fuse of the same maximum size, only one of them can be considered. Then add:
- The Amp Rating of All other Motors on that feeder.

Feeder Motor Schedule – Example

No. of Units	HP	Amps*	Multipplier†
1	3	4.8	1½
1	5	7.6	1½
1	15	21	1½
1	40	52	1½
1	75	96	1½

*Per Table 430.250.

†Per Table 430.52.

Calculations — Maximum:

- Largest motor ($96A \times 175\% = 168A$) (Round up to 175A)
- F.L.A. all other motors (85.4A)
- Total ($175A + 85.4A = 260.4A$) (Round down to 250A)

Choose 250 amp dual-element fuse.

Feeder Circuit-Combination

Motor, Power and Lighting Loads

Where a feeder supplies motor load and power and/or lighting load, the permitted feeder fuse size calculation is the sum of that calculated for the motor load in accordance with 430.62, plus that calculated for the other loads in accordance with Articles 210 and 220 (430.63). The conductor ampacity supplying motors and other loads must be at least the sum of that calculated for the motor load in accordance with 430.22 and 430.24, plus that calculated for the other loads in accordance with Article 220 (430.25). (For exceptions see 430.25.)

Example of Sizing of Dual-Element Fuses for Combination Load Feeder

Motor Load (Use "Motor Schedule" in preceding example)

Continuous Heating and Lighting Load 135A

Non-Continuous Loads 110A

Calculations:

- Motor Load: (Use calculation in preceding example) 260.4A
 - Continuous Non-Motor Load $135A \times 125\% = 168.8A$
 - Non-Continuous, Non-Motor Load 110.0A
- Total 539.2A
(Round down to 500A)
Choose 500 amp dual-element fuse.

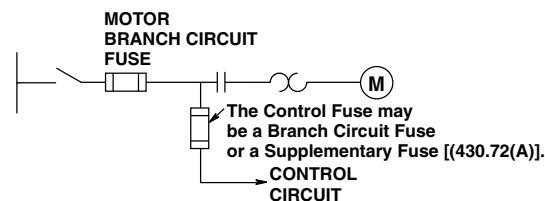
Motor Control Circuit Protection

General

A motor control circuit is a circuit of a control apparatus or system that carries the electric signal directing the performance of the controller (430.2). It does not carry the main power current.

A control circuit tapped on the load-side of the motor branch circuit fuse which controls the motor on that branch circuit shall be protected against overcurrent as in 430.72. Such a circuit is not considered a branch circuit and may be protected by a supplementary fuse or a branch circuit fuse. In either case, the fuse must have an adequate interrupting rating for point of application.

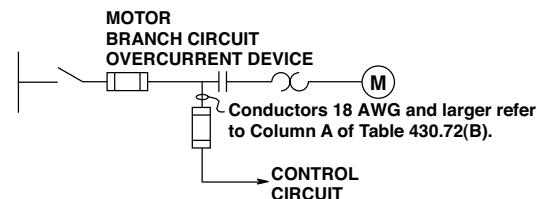
A standards requirement pertinent to motor controllers listed for available fault currents greater than 10,000 amps, states that the control circuit fuse must be a branch circuit fuse with a sufficient interrupting rating. (The use of Bussmann KTK-R, FNQ-R, LP-CC,JJS, JJN, TCF, or LPJ_SP fuses are recommended—these fuses have branch circuit listing status, high interrupting rating, and small size.)



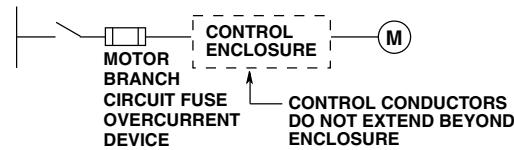
Motor Control Circuit Conductors

Control Circuits Tapped on Load-Side of Branch Circuit Fuse [430.72(B)]

- Control circuit conductors 18 AWG and larger shall be protected against overcurrent in accordance with Table 430.72(B), Column A, as applicable. **430.72(B)(2)**



Control conductors not extending beyond the enclosure shall be considered protected by the branch circuit fuse if in accordance with Table 430.72(B), Column B.



For control conductors extending beyond the enclosure, the motor branch circuit overcurrent device shall be considered to protect the conductors if in accordance with Table 430.72(B), Column C.

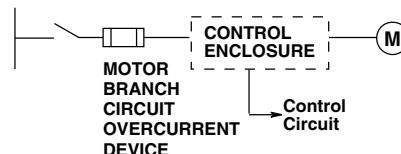


Table 430.72(B). Maximum Rating of Overcurrent Protective Device-Ampères

Control Circuit Conductor Size, AWG	Column A Basic Rule		Column B Exception No. 1		Column C Exception No. 2	
	Copper	Alum. or Copper-Clad	Copper	Alum.	Copper	Alum.
18	7	—	25	—	7	—
16	10	—	40	—	10	—
14	Note 1	—	100	—	45	—
12	Note 1	Note 1	120	100	60	45
10	Note 1	Note 1	160	140	90	75
larger than 10	Note 1	Note 1	Note 2	Note 2	Note 3	Note 3

Note 1: Value specified in Section 310.15, as applicable.

Note 2: 400 percent of value specified in Table 310.17 for 60°C conductors.

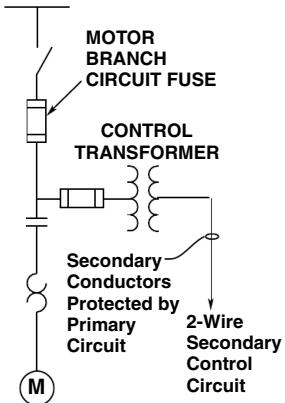
Note 3: 300 percent of value specified in Table 310.16 for 60°C conductors.

430.72(C)

Secondary conductors of a single-phase transformer having only a 2-wire secondary are protected by the primary fuse (600V or less) if the primary fuse rating is:

- Not larger than that determined in Table 430.72(B), multiplied by secondary-to-primary voltage ratio and,
- not more than the following percent of transformer rated primary current:

Control conductors are permitted to be protected by the motor branch circuit overcurrent device where the opening of the control circuit would create a hazard.



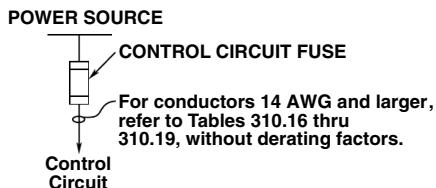
Transformer Primary Current	Primary Fuse Ampacity Must Not Exceed†
Less than 2 amps	500%
2 to 9 amps	167%
9 amps or more	125%*

* If 125% of rated primary current does not correspond to a standard fuse rating, then the next higher standard fuse rating is permitted (1, 3, 6, 10, 15,...).

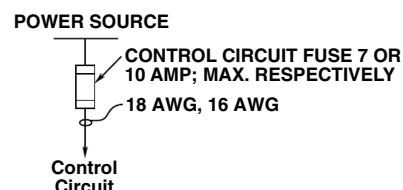
† Refer to Section 8.12 of NFPA79 for the allowable sizing for control transformers in Industrial Machinery.

Class 1 POWER LIMITED, Class 2 and Class 3 Remote Motor Control Circuits

- Control circuit conductors shall be protected from overcurrent in accordance with 725.43 or the notes to Table (11A) and (B) in NEC® chapter 9.



- Control circuit conductors 18 AWG and 16 AWG, shall be protected by a control circuit fuse not to exceed 7 and 10 amps respectively.



Exception No. 2 Relative to Transformer Protection

Refer to Exception 2, [430.72(B)], covered in preceding paragraphs.

Motor Control Circuit Transformers [430.72(C)]

430.72(C)(3): Control circuit transformers rated less than 50VA can be protected by a primary fuse, impedance limiting means, or other inherent means. The transformer must be an integral part of the motor controller, and be located within the controller.

430.72(C)(4): Allows transformers with primary currents less than 2 amps to be protected with primary fuses at 500% or less of primary full-load amps.

430.72(C)(1): Allows the control transformer to be protected by the motor branch circuit overcurrent device when the transformer supplies a Class 1 power-limited, circuit [see 725.41] Class 2, or Class 3 remote control circuit conforming with the requirements of Article 725.

430.72(C)(5): Allows the control transformer to be protected by the motor branch circuit overcurrent device where protection is provided by other approved means.

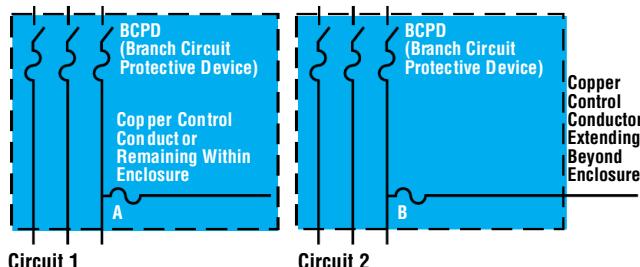
430.72(C) Exception: States that overcurrent protection shall be omitted where the opening of the control circuit would create a hazard, as for example, the control circuit of a fire pump motor.

Catalog Number Designations for Fuse Blocks.

Fuse	Amp Rating	Single Pole	Double Pole	Single Pole Dove Tail for Ganging
Supplementary	1½" x 1 ½"	BM6031SQ	BM6032SQ	
	FRN-R	R25030-1SR	R25030-2SR	
	LPN-RK_SP	R25030-1SR	R25030-2SR	
	FRS-R	R60030-1SR	R60030-2SR	
Branch Circuit	LPS-RK_SP	R60030-1SR	R60030-2SR	
	SC	BG3011SQ	BG3012SQ	
	KTK-R	BG3021SQ	BG3022SQ	
	FNQ-R	BC6031S	BC6032S	
	LP-CC	TCF	TCFH 30	
		1-30A		TCFH 60
		1-60A		

The following Selection Guide Tables simplify and permit easy application of fuses for the protection of the motor control circuits in accordance within the National Electrical Code®. Apply fuses per Table 1 for control circuit without a control transformer (see Circuit Diagrams 1 and 2). Apply fuses per Table 2 for a control circuit with a control transformer (see Circuit Diagrams 3 and 4).

Control Circuit Without Control Transformer (See Table 1)



Control Circuit With Control Transformer (See Table 2)

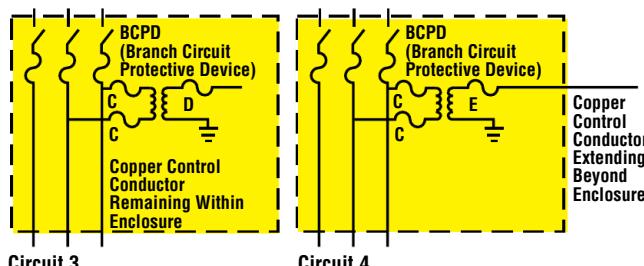


Table 1. Fuse Selection Guide—Control Circuit Without Control Transformer (See Circuit Diagrams 1 & 2)

Ampere Rating of Branch Circuit Protective Device (BCPD)	Circuit 1 (Control Conductor (AWG) Not Extending Beyond Enclosure)				Circuit 2 (Control Conductor (AWG) Extending Beyond Enclosure)			
	18 AWG Wire	16 AWG Wire	14 AWG Wire	12 AWG Wire	18 AWG Wire	16 AWG Wire	14 AWG Wire	12 AWG Wire
Fuse Size	7A	10A	15A	20A	7A	10A	15A	20A

Requirements For Control Circuit Protection (See footnote data)

$\nu_{10} - 7$	■	■	■	■	■	■	■
$7\frac{1}{2} - 10$	■	■	■	■	▲	■	■
$12 - 25$	■	■	■	■	▲	▲	■
$30 - 40$	▲	■	■	■	▲	▲	■
45	▲	▲	■	■	▲	▲	■
$50 - 60$	▲	▲	■	■	▲	▲	▲
$65 - 100$	▲	▲	■	■	▲	▲	▲
110	▲	▲	▲	■	▲	▲	▲
125 - up	▲	▲	▲	▲	▲	▲	▲

▲ Control circuit fuse protection required.

- Protection recommended but not mandatory when BCPD is a Class CC, G, J, R, or T fuse. Protection is mandatory when BCPD is a thermal magnetic or a magnetic-only circuit breaker (MCP), and available short-circuit current exceeds the values in the table below.

Control Circuit Conductor (AWG Copper)	Available Short-Circuit Current At Branch Circuit Protective Device (BCPD)	
	1 Cycle Clearing Time†	$\frac{1}{2}$ Cycle Clearing Time†
18	660A	940A
16	1050A	1500A
14	1700A	2400A
12	2700A	3800A

*Thermoplastic Insulation. †Based on ICEA Conductor Withstand Data.

Table 3. Eucs Selection Guide, Central Circuit With Central Transformer (See Circuit Diagrams 3 and 4)

Control Xfrm Rating	Vpri/Vsec (Volts)	Ipri (Amps)	I _{sec} (Amps)	'Fuse C		Fuse D or E					
				² Req'd. If BCPD Exceeds These Amps Values		^{4,5} Maximum Amps		Required if BCPD and Fuse C (When Provided) Exceed These Amp Values			
						18 AWG Wire	16 AWG Wire	14 AWG Wire	12 AWG Wire	Time Delay ¹	Non-Time Delay ²
25VA	480/120	0.05	0.21	See 430.72(C)(3)	0.25	0.25	0.25	0.25	0.25	0.25	0.60
	480/24	0.05	1.00		0.25	0.25	0.25	0.25	0.25	1.25	3.0
	240/120	0.10	0.21		0.50	0.50	0.50	0.50	0.50	0.25	0.60
	240/24	0.10	1.00	Except. 1	0.50	0.50	0.50	0.50	0.50	1.25	3.0
50VA	480/120	0.10	0.42	0.5	0.50	0.50	0.50	0.50	0.50	0.50	1.0
	480/24	0.10	2.10	0.5	0.50	0.50	0.50	0.50	0.50	2.5	6.0
	240/120	0.21	0.42	1.0	1.0	1.0	1.0	1.0	1.0	0.50	1.0
	240/24	0.21	2.10	1.0	1.0	1.0	1.0	1.0	1.0	2.5	6.0
100VA	480/120	0.21	0.83	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0
	480/24	0.21	4.20	1.0	1.0	1.0/.35 ⁹	1.0/.50 ⁹	1.0	1.0	5.0	12.0 ⁷
	240/120	0.42	0.83	2.0	2.0	2.0	2.0	2.0	2.0	1.0	2.0
	240/24	0.42	4.20	2.0	2.0	2.0/.70 ⁹	2.0/1.0 ⁹	2.0	2.0	5.0	12.0 ⁷
150VA	480/120	0.31	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.50	3.50
	480/24	0.31	6.25	1.5	1.5	—	1.5/0.5 ⁹	1.5	1.5	7.50	15.0 ⁷
	240/120	0.62	1.25	3.0	3.0	3.0	3.0	3.0	3.0	1.50	3.50
	240/24	0.62	6.25	3.0	3.0	—	3.0/1.0 ⁹	3.0	3.0	7.50	15.0 ⁷
200VA	480/120	0.42	1.67	2.0	2.0	2.0/1.75 ⁹	2.0	2.0	2.0	2.0	5.0
	480/24	0.42	8.33	2.0	2.0	—	—	2.0	2.0	10.0	20.0 ⁸
	240/120	0.84	1.67	4.0	4.0	4.0/3.5 ⁹	2.0	4.0	4.0	2.0	5.0
	240/24	0.84	8.33	4.0	4.0	—	—	4.0	4.0	10.0	20.0 ⁸

¹ Time-Delay Fuses: FNQ, FNW, FNM, FNA—Supplementary Type; FNQ-R, FRN-R, FRS-R, LPN-RK SP, LPS-RK SP, LPJ SP, LP-CC, SC6 & above—Branch Circuit Fuses (Rejection Type).

² For exceptions, see 430.72(C).

³ Non-Time-Delay Fuses: KTK, BAN, BAF, MIN, MIC—Supplementary Fuses; KTK-R, JJN, JJS, SC 1/2-5—Branch Circuit Fuses (Rejection Types).

⁴ These are maximum values as allowed by 430.72(C). Closer sizing at 125%-300% may be possible for better overload protection using time-delay branch circuit fuses.

5 Fuse shall be a rejection type branch circuit fuse when withstand rating of controller is greater than 10,000 amps RMS symmetrical

⁶ These transformers less than 50VA still need protection—either primary overcurrent protection, inherent protection, or the equivalent. Note that the primary conductors may be protected as shown in Circuit 1 Table 1. ⁷ Minimum copper secondary control conductor for this application is 14 AWG. ⁸ Minimum copper secondary control conductor for this application is 12 AWG.

⁹ Smaller value applied to Fuse "E".

Bussmann FNQ-R Maximum Primary Fuse Selection Guide for Motor Control Circuit Transformer Protection***

XFMER VA	600V	550V	480V	460V	415V	380V	277V	240V	230V	208V
50	½A	½A	½A	½A	½A	½A	½A	1A	1A	1 ¼A
75	¾A	¾A	¾A	¾A	¾A	¾A	1 ¼A	1 ½A	1 ¾A	1 ¾A
100	¾A	¾A	1A	1A	1 ¼A	1 ¼A	1 ¼A	2A	2A	2 ¼A
150	1 ¼A	1 ¾A	1 ¼A	1 ¾A	1 ¾A	1 ¾A	2 ¼A	3A	3 ¾A	3 ¾A
200	1 ¾A	1 ¾A	2A	2A	2 ¼A	2 ¼A	3 ¼A	4A	4A	4 ¼A
250	2A	2 ¼A	2 ¼A	2 ¼A	3A	3 ¾A	4 ¼A	5A	5A	6A
300	2 ½A	2 ¾A	3A	3 ¾A	3 ¾A	3 ¾A	5A	6 ½A	6 ½A	7A
350	2 ¾A	3A	3 ½A	3 ½A	4A	4 ¼A	6 ¼A	7A	7 ½A	8A
500	4A	4 ¼A	5A	5A	6A	6 ¼A	9A	3 ¾A**	3 ¾A**	4A**
750	6 ¼A	6 ¼A	7 ¼A	8A	9A	9A	4 ¼A*	5A**	5A**	6A**
1000	8A	9A	3 ¾A*	3 ¾A*	4A*	4A*	6A*	6 ½A**	7A**	8A**
1500	4A*	4 ¼A*	5A*	5A*	6A*	6 ¼A*	9A*	10A**	10A**	12A**
2000	5A*	6A*	6 ¼A*	7A*	8A*	8A*	12A*	12A**	12A**	15A**

*For increased time-delay, use FRS-R, LPS-RK_SP, LPJ_SP, or TCF

**For increased time-delay, use FRN-R, LPN-RK_SP

***Based upon the NEC®

Supplementary Fuses ($1\frac{3}{8}$ " x $1\frac{1}{2}$) (All Voltage and Interrupting Ratings are AC)

Fast-Acting				Time-Delay																	
BAF	BBS	KLM	MIC	FNA	FNM	FNQ	KTK	Ratings	Color	Ratings	Color	Ratings	Color	Ratings	Color	Ratings	Color				
								½-30A 250V†	●	½-6A 600V	●	1A 250V	●	½-9A 250V†	●	½-1A 250V†	●	½-30A 500V†	●	½-30A 600V	●
								7-10A 250V	●	2-3A 250V	●	1-6A 250V*	●	1 ⅔-3 ⅓A 250V*	●	4-10A 250V	●	10K AIR (FNQ ½ - 3 ¾ Dual-Element)	●		
								12-30A 48V	●	5-10A 250V	●	6 ¼-15A 125V	●	12-30A 32V	●	12-30A 250V	●				
								20-30A 32V	●	15A 250V	●	20-30A 32V	●								

Branch Circuit Fuses (All Voltage and Interrupting Ratings are AC)

Class R Dual-Element, Time-Delay				Class G	Class CC Class Fast-Acting, Time-Delay			CF Time-Delay
								
½-30A 250V 300K AIR	½-30A 250V 200K AIR	½-30A 600V 200K AIR	½-30A 600V 300K AIR	½-20A 600V\$ 25-30A 480V\$ 100K AIR	½-30A 600V 200K AIR	½-30A 600V 200K AIR	½-30A 600V 200K AIR	½-30A 600V 200K AIR
LC	LC	LC	LC	LC	LC	LC	LC	LC
LPN-RK_SP	FRN-R	FRS-R	LPS-RK_SP	SC	KTK-R	FNQ-R	LP-CC	TCF
½-30A 250V 300K AIR	½-30A 250V 200K AIR	½-30A 600V 200K AIR	½-30A 600V 300K AIR	½-20A 600V\$ 25-30A 480V\$ 100K AIR	½-30A 600V 200K AIR	½-30A 600V 200K AIR	½-30A 600V 200K AIR	½-30A 600V 300K AIR

† 0 to 1 amp-35 AIR; 1.1 to 3.5 amp-100 AIR; 3.6 to 10 amp-200 AIR; 10.1 to 15 amp-750 AIR; 15.1 to 30 amps-1500AIR *10K AIR. **1K AIR.

§ ½ thru 6 amp fuses are Non-Time-Delay Type; 7 thru 60 amp fuses are Time-Delay Type.

|| 0 to 3.5 amp-35 AIR; 3.6 to 10 amp-100 AIR; 10.1 to 15 amp-200 AIR; 15.1-30 amp-750 AIR

R-Rated Medium Voltage Fuses

R-rated medium voltage fuses are back-up current-limiting fuses used in conjunction with medium voltage motors and motor controllers. These fuses are designed for short-circuit protection only and do not protect themselves or other components during extended overloads. Thus, this type of fuse does not have an amp rating, but rather an R-rating. Current-limiting fuses may be designated as R-rated if they meet the following requirements:

1. The fuse will safely interrupt any currents between its minimum and maximum interrupting ratings,
2. The fuse will melt in a range of 15 to 35 seconds at a value of 100 times the "R" number (ANSI C37.46).

Bussmann R-rated current-limiting fuses are designed for use with medium voltage starters to provide short-circuit protection for the motor circuit and motor-controller. These fuses offer a high level of fault current interruption in a self-contained, non-venting package which can be mounted indoors or in an enclosure. All of the R-rated product comes with open fuse indication. Some of the product is available with a hookeye option. A hookstick can be used for non-loadbreak isolation.

Application

Medium voltage motors are efficiently protected by overload relays applied in conjunction with back-up current-limiting fuses which are intended to open the circuit for high fault conditions. The overload relay is chosen to interrupt currents below the minimum interrupting rating of the fuse. Since multiple devices are used to provide protection it is very important that they be properly coordinated. The motor starter manufacturer typically chooses the proper fuse R-rating, overload relay, and contactor. The following guideline can be used to insure proper coordination.

Guideline for Applying R-Rated Fuses

The current-limiting fuse should be selected so that the overload relay curve crosses the minimum melting curve of the fuse at a current greater than 110% of the locked rotor current of the motor being utilized.

A preliminary choice is obtained through the following formula:

$$\frac{6.6 \times \text{Full Load Current}}{100} = \text{R rating of fuse}$$

This value is rounded up to the next R-rating fuse.

Example:

A 2300V motor has a 100 amp full load current rating and a locked rotor current of 600 amps.

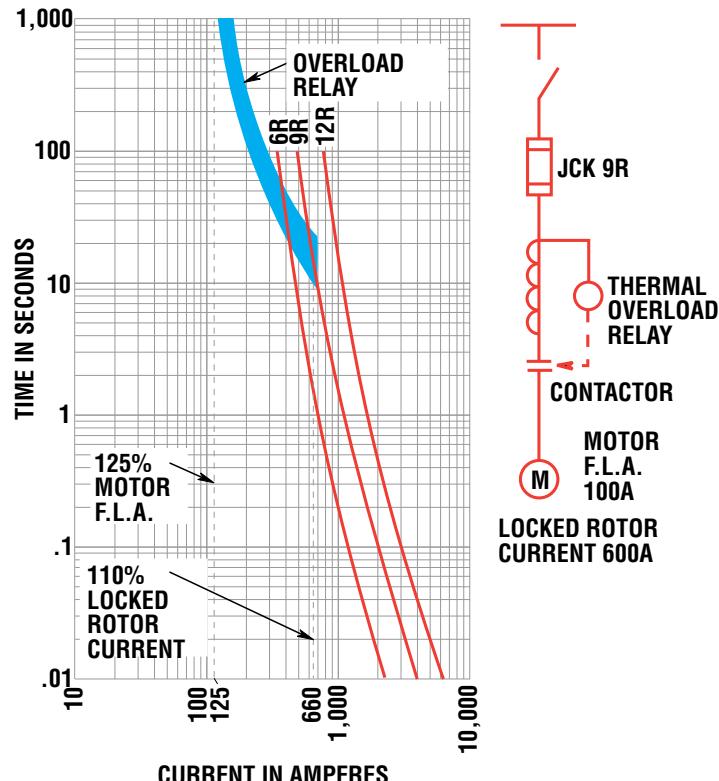
The preliminary choice is

$$\frac{6.6 \times 100}{100} = 6.6$$

Thus one rounds up to the next standard R-rating, 9R. But this must be checked with the appropriate time-current characteristics curves.

The overload relay being used has the time-current characteristic as shown in the adjacent Figure. To choose the proper fuse one must plot 110% of the locked rotor current and the family of fuses on the same graph as the overload relay.

The fuse that should be selected is the smallest fuse whose minimum melting characteristic crosses the overload relay at a current greater than 110% of the locked rotor current. In this example, it would be a 2400V 9R fuse. This agrees with the quick selection choice. Depending on the type of installation and starter being used, a JCK-9R, JCK-A-9R, or JCH-9R would be the correct choice.



Hazardous Locations

Fuses for Use in Classified (Hazardous) Locations (based upon the NEC®)

The characteristics of various atmospheric mixtures of hazardous gases, vapors and dusts depend on the specific hazardous material involved. Therefore, it is necessary that equipment be identified not only for the class of location but also for the specific gas, vapor or dust that will be present (500.5).

Class I Division 1

Fuses located in Class I Division 1 locations are required to be provided with enclosures that are identified as a complete assembly for use in Class I locations [501.115(A)].

Class I Division 2

Fuses located in Class I Division 2 locations should be selected based upon the application and enclosure type. Only certain fuse types are permitted to be used in general purpose enclosures. 501.105(B)(5), 501.115(B)(3) & 501.115(B)(4) address the use of fuses in Class I Division 2 locations. (See Figure 1)

- Any plug or cartridge type fuse, as allowed by Chapters 1 through 4 of the NEC®, is suitable for the protection of motors, appliances, and lamps, provided the fuse is installed in an enclosure identified for the location.
- Fuses for the protection of motors, appliances, and lamps installed in general purpose enclosures must also meet one of the following:
 - a) They are non-indicating, filled and current-limiting type. Bussmann offers many fuses that meet the criteria for non-indicating, filled, current-limiting type (See Note 1 and Note 2)
 - b) They are the type in which the element is immersed in oil or other approved liquid. Bussmann does not offer this type of product.
 - c) The element is hermetically sealed against gases and vapors. Bussmann does not offer hermetically sealed fuses for this type of application.
- Fuses protecting meters, instruments and relays can be any plug or cartridge type if they meet the following criteria:
 - a) Fuse is installed in a circuit not subject to overloading
 - b) Fuse is installed on the load side of a switch complying with 501.105(B)(1)
- Fuses installed in a luminaire and used as supplementary protection can be any listed cartridge type.

Since there are so many potential variables governing the proper selection of a fuse for use in general purpose enclosures, the quickest and most appropriate selection is a current-limiting, non-indicating, filled fuse. This fuse type is suitable for all applications mentioned above so the chance for misapplication is minimized. In addition, a rejection style fuse will help ensure only the proper fuse type is installed in the future. For 30A and less power or control applications the Bussmann Class CC fuses meet the necessary criteria. (See Note 1)

Class II and Class III

Class II, Division 1 — Fuses must be provided with enclosures identified for the location [502.115(A)].

Class II, Division 2 — Fuses must be provided with enclosures that are dust-tight or otherwise identified for the location [502.115(B) and 502.135(B)(3)].

Class III — Fuses must be provided with dust-tight enclosures [503.115].

Note 1: Bussmann non-indicating, filled, current-limiting fuses.



Class CC: LP-CC 1/2 - 30A, KTK-R 1/2 - 30 A, FNQ-R 8/10 - 30A*

Class CF: Class CF: TCF1RN to TCF100RN, FCF1RN to FCF100RN

Class T: JJN 1 - 1200A, JJS 1 - 800A

Class J: JKS 1 - 600A, LPJ_SP 1 - 600A

Class G: SC 1/2 - 60A

Class RK1: KTN-R 1 - 600A, KTS-R 1 - 600A, LPN-RK_SP* 31/2 - 61/4 and 70 - 600A, LPS-RK_SP* 65 - 600A

Class RK5: FRN-R 31/2 - 71/2 and 225 - 600A, FRS-R** 65 - 600A

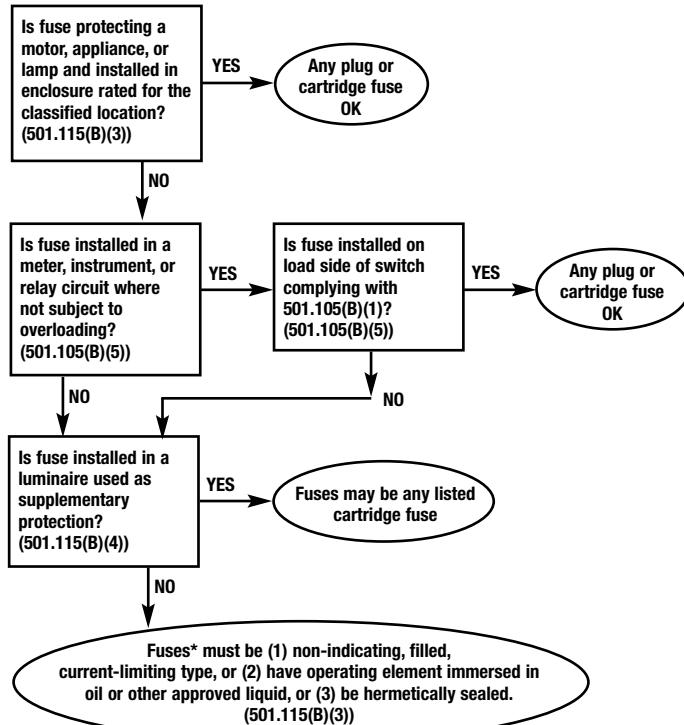
Class L: KRP-C_SP 601 - 6000A, KTU 601 - 6000A, KLU 601 - 4000A

*Fuses from July 1996 or date code C28 to present only.

**Fuses from October 1997 or date code D40 to present only

Note 2: How to verify a fuse as current-limiting. 600V or less current-limiting fuses are listed, and marked "current-limiting".

Figure 1 – NEC Article 501 – Fuses for use in Class I Division 2 Locations



*For the protection of motors, appliances, and lamps installed in general purpose enclosures.

Photovoltaic Systems Protection

Overview

Photovoltaic (PV) systems convert the energy from the sun to useable electrical power. In most cases, system components are as follows:

- Solar PV Modules: Convert the sun's energy to a DC voltage.
- PV Inverters: Convert DC voltage generated from the PV modules to useable AC voltage.
- Balance of System: Combiner boxes, conductors, overcurrent protection devices, disconnect switches, mounting brackets, and various accessories that connect from the DC source to AC system or DC source to DC utilization system.
- Larger PV systems may also contain transformers to change the AC voltage levels to the desired levels.

There are three basic types of solar photovoltaic systems:

- A. Stand alone systems,
- B. Interactive (grid-connected) systems, and
- C. Hybrid systems.

Stand alone systems supply power independent of any other electrical power source. Interactive systems operate in parallel with another electrical power source such as being connected to an electrical utility system. An interactive system may also supply electric power to the production or distribution network. Hybrid systems include other power sources, such as wind and hydroelectric generation.

Solar photovoltaic system requirements are in NEC® Article 690.

There are various overcurrent protection needs and requirements for different parts of the PV system. This section is an introductory discussion of the various PV systems with many of the overcurrent protection requirement considerations.

See Figure 1. The basic power-generating component of a solar photovoltaic system is the solar cell. In order to generate useful levels of power, groups of cells are combined to form modules. Modules are then grouped into panels, and several panels form a solar array. A photovoltaic power source can consist of one or more arrays.

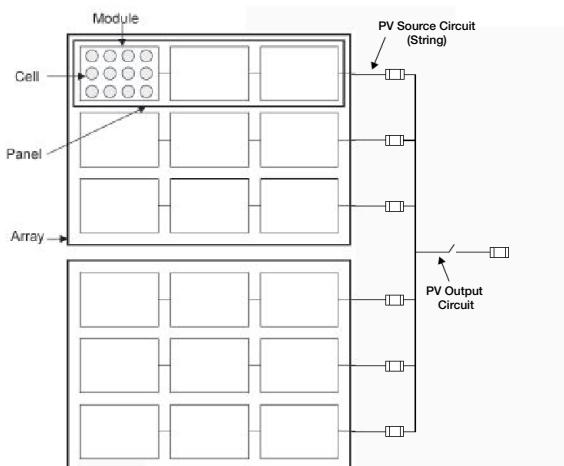


Figure 1

What is Different with PV?

AC Interruption vs. DC Interruption: For disconnects and overcurrent protective devices, arcs that are generated from opening DC currents are generally more difficult to extinguish than the arcs generated from disconnecting AC currents.

Fault Conditions: The maximum fault current generated by a PV source (I_{sc} , short circuit current), is generally 110% to 115% of its max power current ratings. Refer to individual PV module specifications for the exact value of I_{sc} . This is quite different from the conventional AC system supplied by utility or on-site generators. However, parts of photovoltaic systems may have to withstand higher short-circuit currents. Many systems have battery banks, which can deliver substantial short-circuit current. Also, if the system is connected to a conventional electrical distribution system fed by a utility, short-circuit current can be substantial.

Environmental Conditions: There can be harsh temperatures, extreme temperature cycling, wind, and humidity considerations with PV systems. Operating temperature variations are typically specified from - 40 to 85°C. As ambient temperature decreases (assuming the same sunlight intensity), the maximum power delivery of the PV modules increases. This is evidenced by the negative temperature coefficient of the maximum power of the modules typically at -0.5%/°C.

UL Standards for DC PV:

- (1) UL 1741 Inverters, Converters, Controllers, and Interconnection System for Use with Distributed Energy Resources
- (2) UL 2579 Low-Voltage Fuses – Fuses for Photovoltaic Systems: DC rated fuses which have performance criteria suitable for the high temperature extremes under cyclic load conditions experienced in the DC PV source circuits (such as combiner boxes) and in the DC PV output circuits (such as recombiner boxes or at the inverter).
- (3) UL 248 Class fuses: Fuses with general industry DC ratings for use in other portions of dc PV system not subject to the harsh environment that the source and output circuits must endure.
- (4) UL 98B Enclosed and Dead-Front Switches for use in Photovoltaic Systems, for fusible and non-fusible switches for DC PV applications.

Typical System Voltages: The typical PV system DC voltage ratings are 600V or less, 1000V and 1500V. The overcurrent protective device PV DC voltage ratings for these systems are 600Vdc, 1000Vdc, and 1500Vdc.

Generalized PV System Layout

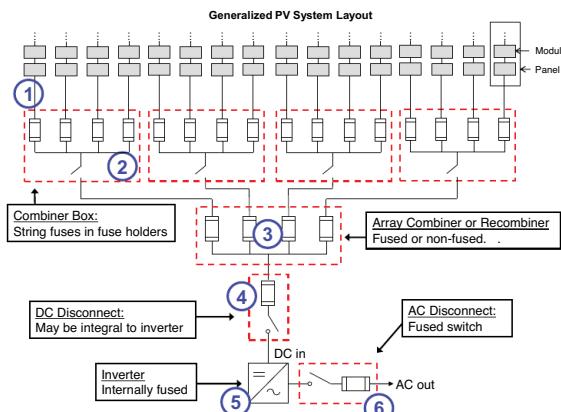


Figure 2 The numbers align with Products for PV Systems at end of this PV application material

Types of PV System Grounding: PV systems can be negative ground, positive ground, center ground, or ungrounded. From a circuit protection stand-point, there are no differences between negative or positive grounding. In a grounded system, the ungrounded conductor legs are fused. Ungrounded systems utilize an isolated array where neither of the array poles are grounded. In an ungrounded system, both positive and negative legs are fused. See NEC® 690.35 for more information.

Photovoltaic Systems Protection

All PV DC Overcurrent Protective Devices

Per NEC® 690.9(A), the PV source circuit, PV output circuit, inverter output circuit, storage battery circuit conductors and equipment shall be protected per Article 240. 690.9(D) requires any fuse or circuit breaker in the DC portion of the PV system to be listed and have suitable DC voltage, current, and interrupting ratings.

Fuses in the DC PV source circuits and DC PV output circuits must be listed to UL 2579 Low-Voltage Fuses – Fuses for Photovoltaic Systems [690.9(D)]. UL 2579 does not have standardized dimensional requirements or standard specific DC voltage ratings. These fuses at a minimum have performance criteria suitable for the high temperature extremes under cyclic load conditions experienced in the PV source circuits and output circuits. The components in PV source circuits and output circuits experience very unique, harsh application conditions many of which are addressed by UL 2579 testing and evaluation criteria, such as:

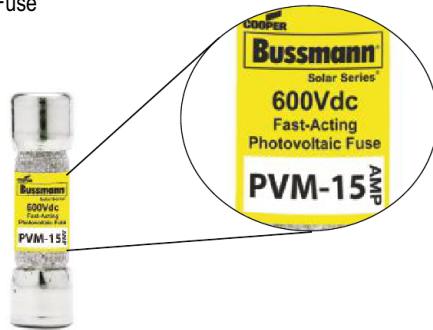
- Thermal drift test: fuses are subject to temperature cycling tests that range from -40°C to 90°C. After the temperature cycling, the fuses are subjected to the overload and short circuit electrical testing and evaluation criteria to confirm proper performance.
- Temperature extremes test: fuses are conditioned to a temperature of 50°C and specific electrical tests are conducted at this elevated temperature to ensure the fuses operate properly at higher ambient temperatures.

For other than DC PV source and output circuit applications, UL Class fuses which are DC listed to UL 248 may be suitable. For instance, the output of storage batteries in a battery room would be suitably protected by UL Class fuses with proper DC ratings.

It is important to note that the suitability of use is different for UL 2579 fuses compared to UL 248 Class fuses listed for DC (general industry DC applications). UL 2579 fuses are suitable for the DC PV source and output circuits. UL 248 Class DC fuses are not suitable for DC PV source and output circuits. A PV DC fuse listed to UL 2579 has not been tested and evaluated for general industry DC voltage operation and may not be suitable in general industry DC voltage applications, such as in DC crane applications.

UL 2579 Fuses:

1. Listed to UL 2579 which will be evidenced by a listing mark on the fuse.
2. Will be marked with one of the following:
 - a. Letters "PV"
 - b. Letters "gPV"
 - c. Text "Photovoltaic Fuse"



Side View of Label

Disconnects (Isolation) for Fuses

If a fuse is energized from both directions, a means to disconnect (isolate) the fuse from all sources of supply is required (690.16 (A)). While the phrase "disconnecting means" is used, the second paragraph of 690.16(B) makes it clear that it is actually isolation that is required. Isolation can be accomplished by either a load-break disconnecting means, or by a non-loadbreak fuseholder such as the CHPV1 PV modular DIN-Rail fuseholder. Non-load-break disconnecting (isolating) means must be marked "Do not open under load." Fuses in source circuits must be able to be isolated independently of fuses in other source circuits.

Fuses on PV output circuits must also have disconnecting means (isolation) so that they can be isolated from all energized sources (690.16(B)). A disconnecting (isolation) means must be within sight of the fuses, readily accessible, externally operable, not allow the operator to be exposed to live parts, clearly show whether it is in the open or closed position, and have an interrupting rating sufficient for the application. If the disconnecting or isolating means is more than 6 feet from the fuses, a directory is to be posted at the fuses showing the location of the disconnecting (isolating) means.

PV Switch Ampacity

The ampacity of DC fusible PV switches must be equal to or greater than the fuse ampacity. The ampacity of DC non-fused PV switches must be equal to or greater than 1.25 times the maximum circuit current. In all cases, switches must have an interrupting rating suitable for the nominal DC circuit voltage and fault current available at the switch line terminals.

Battery Circuit Current-Limiting Fuse

Protection

Battery systems can deliver dangerously high short-circuit currents. If the available short-circuit current exceeds the withstand rating of the equipment, then a listed, current-limiting fuse must be used in each ungrounded conductor from the battery in order to limit the current that a battery bank can deliver to below the withstand of the components to be protected per 690.71(C). Overcurrent protective devices that are listed as current-limiting are marked "Current-Limiting" on the label.

Overvoltage Protection

The unique nature of PV installations makes these electrical systems vulnerable to overvoltages and surges from lightning strikes and static discharges. These surges need to be intercepted before they take down the entire PV system by damaging the PV components such as the arrays, charge controller, inverter, or combiner boxes.

These voltage protective devices are called Surge Protective Devices (SPDs) and are normally placed in every PV electrical enclosure such as combiner boxes, re-combiner boxes, inverters, and chargers. Bussmann surge protector product series are specifically tested and recognized to UL1449 third edition for PV applications. Refer to Bussmann photovoltaic SPDs on www.cooperbussmann.com.

Photovoltaic Systems Protection

PV Source and Output Circuits

690.2 defines PV source circuits as "circuits between the modules and from the modules to a common connection point(s) of the dc system." PV output circuits are defined as "circuit conductors between the PV source circuit(s) and the inverter or DC utilization equipment." Figure 3 illustrates simple PV source circuits and a PV output circuit. Fuses in PV source circuits and PV output circuits are required to be listed to UL 2579 per 690.9(D).

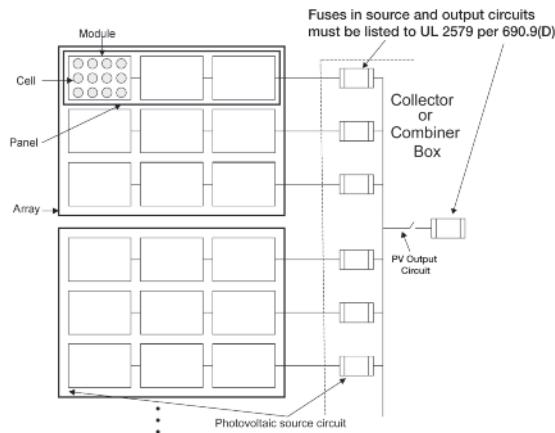


Figure 3

Figure 4 illustrates how PV source fuses are applied. The fuses in Figure 4, normally located in a "combiner box", protect the PV source circuit. They are typically the PVM fuses in CHPV holders for 600Vdc or PV-10F fuses in CHPV1 holders for 1000Vdc. The fuseholders are capable of isolating the fuses for servicing purposes.

A source circuit fuse is intended to open if the PV source circuit faults. When one PV source circuit faults all the other PV source circuits will supply short-circuit current into the faulted PV source circuit. The fuse on the faulted source circuit opens before the other fuses melt. Therefore, the other PV source circuits can continue in normal operation.

The short-circuit current which would flow through fuse 1, if there is a fault on source circuit 1, is the number of parallel source circuits which can feed into the fault (n) minus 1 times the module short-circuit current rating. If there are 10 source circuits and a fault occurs on source circuit 1, the available fault current that can flow through fuse 1 to the fault can be determined by:

$$(n-1) \times I_{SC} = (10 - 1) \times 5.9A = 9 \times 5.9A = 53.1A$$

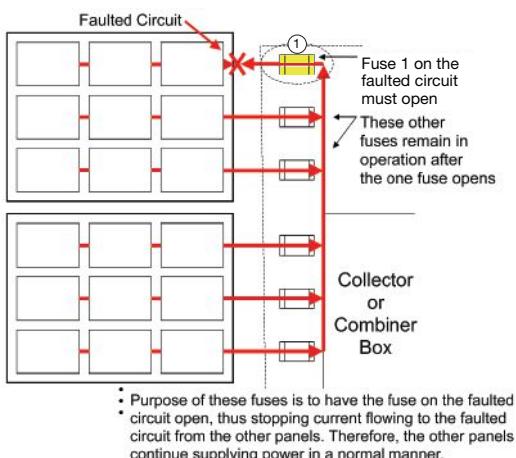


Figure 4

Determining the Maximum Circuit Currents

Per 690.8(A)(1) to (5) the maximum current for PV source circuits, PV output circuits, inverter output circuits, stand-alone inverter input circuits and DC-to-DC converter output circuits are determined, respectively in 1 to 5 below:

1. The PV source circuit maximum current is 1.25 times the sum of the parallel module rated short-circuit currents.
2. The PV output circuit maximum current is the sum of the parallel source circuit maximum currents.
3. Inverter output circuit maximum current is the continuous output current rating of the inverter.
4. Stand-alone inverter input circuit maximum current is the stand-alone continuous inverter input current rating when the inverter is producing rated power at the lowest input voltage.
5. DC-to-DC converter maximum current is the converter continuous output current rating.

Calculating Conductor Ampacity

PV systems currents are considered continuous. The minimum conductor ampacity for each of the five items in 690.8(A)(1) to (5) is the greater of two calculations in 690.8(B) which are summarized as follows:

1. 1.25 times the maximum current determined in the immediately above (Determining the Maximum Circuit Currents) for the respective part of the PV system 1 to 5.

For PV source circuits, this results in the conductor ampacity calculation being 1.56 times the module rated short-circuit current (I_{SC}), which is provided by the module manufacturer. For the PV output circuits, this results in the conductor ampacity calculation being the number of parallel PV source circuits times 1.56 times the module rated short-circuit current (I_{SC}).

2. The maximum currents determined in the above (Determining the Maximum Circuit Currents) for the respective circuit of the PV system 1 to 5 after the application of adjustment and correction factors.

Conductors installed in PV systems typically are in conditions where adjustment and correction factors are significant. Some of factors include ambient temperature correction, ambient temperature adjustment for raceways and cable exposed to sunlight or above rooftops, adjustment factor for more than three current carrying conductors in a raceway or cable. See Article 310.

(There is an exception to 690.8(B)(1) for an assembly with OCPDs that are listed for 100% rating.)

Overcurrent Protection

The fuse amp rating is not to be less than 1.25 times the maximum current as calculated for the respective location in the PV system in Maximum Circuit Current of 1 to 5 above.

Photovoltaic Systems Protection

This results in the following:

PV source circuit (string): the fuse amp rating is not less than 1.56 times the array module rated short circuit current (I_{SC}). This is because the source circuit maximum current is 1.25 times the module rated short circuit current [690.8(A)(1)] and then the fuse amp rating must be at least 1.25 times the source circuit maximum current [690.9(B)]. $1.25 \times 1.25 = 1.56$.

PV Output circuit (recombiner circuit): the recombiner fuse amp rating is not less than 1.56 times the array module rated short-circuit current times the number of parallel PV source circuits (strings) that feed into the recombiner circuit [690.9(B)].

Simple Calculations

PV Source Circuit (String)

$$\text{Conductor ampacity}^* = 1.56 \times \text{module } I_{SC}$$

$$\text{Fuse amp rating}† = 1.56 \times \text{module } I_{SC}$$

Note: The module manufacturer may state the maximum string fuse amp rating on the module label or instructions; fuse amp rating must not exceed this value.

PV Output Circuit (Recombiner)

$$\text{Conductor ampacity}^* = \# \text{ parallel PV source circuits} \times (1.56 \times \text{module } I_{SC})$$

$$\text{Fuse amp rating}† = \# \text{ parallel PV source circuits} \times (1.56 \times \text{module } I_{SC})$$

* For the conductor ampacity calculation, 690.8(B) requires using the greater of either 1.56 times the module rated short-circuit current or the conductors rated to carry ampacity of the maximum current ($1.25 \times I_{SC}$) after adjustment and correction factors.

** For the conductor ampacity calculation, 690.(B) requires using the greater of either the number of parallel source circuits x 1.56 x the module rated short-circuit current or the conductor rated to carry ampacity of the # parallel source circuits x 1.25 x module rated short-circuit current after adjustments and correction factors.

† If this value does not correspond to a standard fuse amp rating, it is permitted to select the next higher fuse amp rating [240.4(B)].

Determine Fuse DC Voltage Rating

1. Obtain module open-circuit voltage (V_{OC}) from the module instructions or label
2. $V_{OC} \times \# \text{ of modules in series on source circuit} = \text{source circuit open-circuit voltage}$
3. Adjust source circuit open-circuit voltage for lowest expected ambient temperature per NEC Table 690.7. If temperature coefficient is provided in instructions of listed module, use that value. See 690.7(A). This is for crystalline or polycrystalline modules.

Practical PV Source Circuit Conductor Sizing

In some applications, the source circuit conductor sizing may be more dependent on voltage drop considerations. Source conductor ampacity selected at the minimum permitted by 690.8(B) for long length source circuits may result in unacceptable voltage drops. For long length source circuits, the source conductor may be sized to minimize voltage loss and as a result the chosen conductor ampacity is greater than the minimum conductor ampacity per 690.8(B).

Example PV Source and Output Circuit Calculations

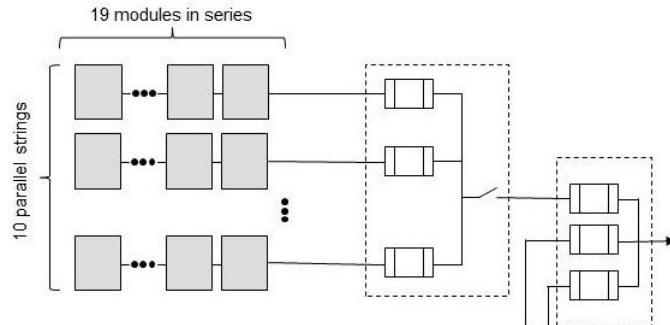
Module Description	
Cell Type	Polycrystalline Silicon
Cell Size	125mm (5")
No. of Cells and Connection	72 in Series
Maximum System Voltage	1000Vdc
Electrical Data	
Maximum Power Voltage (V_{PM})	34.6V
Open Circuit Voltage (V_{OC})	43.1V
Maximum Power Current (I_{PM})	5.31A
Short-circuit Current (I_{SC})	5.90A

System configuration/location information

19 modules per string (in series)

10 parallel strings

-4°F is installation location lowest expected ambient temperature



Source Circuit

Conductor ampacity and fuse amp rating use the same equation:

$$1.56 \times \text{module } I_{SC} = 1.56 \times 5.9A = 9.2A$$

Conductor ampacity at least 9.2A*
Next larger fuse amp rating is 10A†

Output Circuit

Conductor ampacity and fuse amp rating use the same equation:

$$\begin{aligned} \# \text{ parallel source circuits} \times (1.56 \times \text{module } I_{SC}) &= \\ &= 10 \times (1.56 \times 5.9A) \\ &= 92A \end{aligned}$$

Conductor ampacity at least 92A*
Next larger fuse amp rating is 100A†

* For the conductor ampacity calculation, 690.8(B) requires using the greater of either this calculated result or the result using the maximum current calculated in 690.8(A) after applying adjustment and correction factors.

† If this value does not correspond to a standard fuse amp rating, it is permitted to select the next higher fuse amp rating [240.4(B)].

Fuse Voltage Rating

$$V_{OC} \times \# \text{ modules in series} = 43.1V \times 19 = 818.9V$$

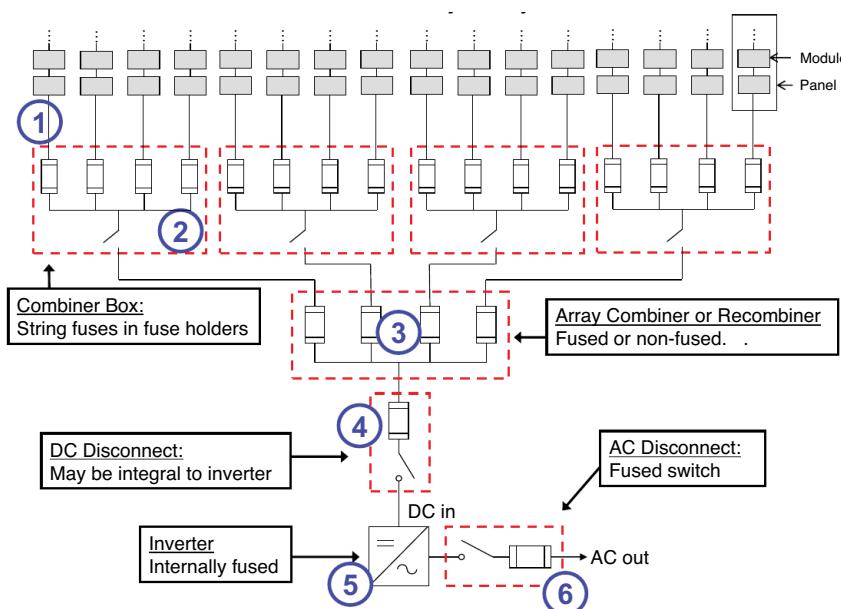
Table 690.7 voltage correction factor for lowest temperature: 1.18

$$\text{Maximum PV system voltage} = 818.9V \times 1.18 = 966.3V$$

Use UL 2579 fuses with minimum of 1000V DC rating

Photovoltaic Systems: Bussmann Products

Generalized PV System Layout



The numbers on the Generalized PV System Layout align with the Bussmann products below.

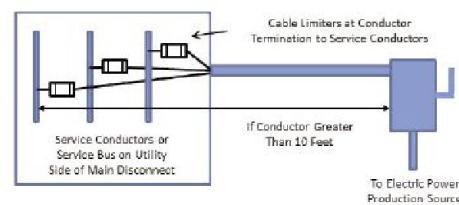
①	①	① ②	②	③	③ ④
② ③ ④	③ ④	③ ④	⑤	⑥	⑥

For more information on products for PV systems visit www.cooperbussmann.com/Markets/Solar

Conductor Protection for Interconnected Electric Power Production Sources Connected Ahead of Service Disconnect: 705.31

When an interconnected power production source, such as a PV system or a wind system, is connected to the supply side of the service disconnect, the conductors connecting this system must have overcurrent protection within 10 feet of their connection to the service conductors/bus. Normally, an AC disconnect with overcurrent protection can be installed within the 10 foot limit. If however this disconnect with overcurrent protection is not installed within 10 feet of the connection point, then it is permitted to use cable limiters (or a current limiting circuit breaker) to connect the Interconnected Electric Power Production source (normally a PV system or wind system) ahead of the

service disconnect/overcurrent protection. The cable limiters provide short-circuit protection for these conductors. Installing cable limiters on the supply side of the service disconnect is permitted in 230.82.



Service Conductors or Service Bus on Utility Side of Main Disconnect

Data Center

Mission Critical/Data Center Electrical Distribution Systems

Data center electrical distribution designs are rapidly evolving, driven by needs such as increasing power densities, energy efficiency, more flexibility for making changes after the initial install, increased uptime, adhering to safe electrical work practices, and minimizing maintenance while retaining reliability. Many of these design advances result in higher distribution voltages, high available fault currents, and greater potential arc flash hazard. Current-limiting fuses provide excellent overcurrent protection for the challenging needs of modern data centers. The following section will discuss some of these trends and challenges facing designers and users along with the solutions that current-limiting fuses can provide. This section will discuss:

1. Products for data center overcurrent protection
2. Fusible solutions for two broad architectures: PDU architecture and busway architecture
3. Highlight the benefits of fusible data center distribution systems
4. Trend to higher distribution voltages

1. Data Center Distribution Architectures

PDU Architecture:

See Figure 1 for power distribution unit (PDU) architecture. The line side of the UPS system can consist of a normal source and alternate source utilizing standard fusible power distribution panels or fusible switchboards. PDU manufacturers are now incorporating the new Bussmann Quik-Spec™ Coordination Panelboard (QSCP) in their PDU and RPP (remote power panel) offerings. The new QSCP panelboard utilizes the innovative 600Vac rated Compact Circuit Protector (15A to 100A) integrated with the 1 to 100A UL Class CF CUBEFuse. The width of the standard enclosed QSCP panelboard for general construction branch panels is the same as standard 20" circuit breaker panelboards. The single pole Compact Circuit Protector (CCP) with CUBEFuse is 1" wide and is available in one, two, or three pole versions. At the cabinet, a fusible rack PDU provides another level of current-limiting fuse protection. Fusible solutions offer many benefits which will be discussed later in this section.

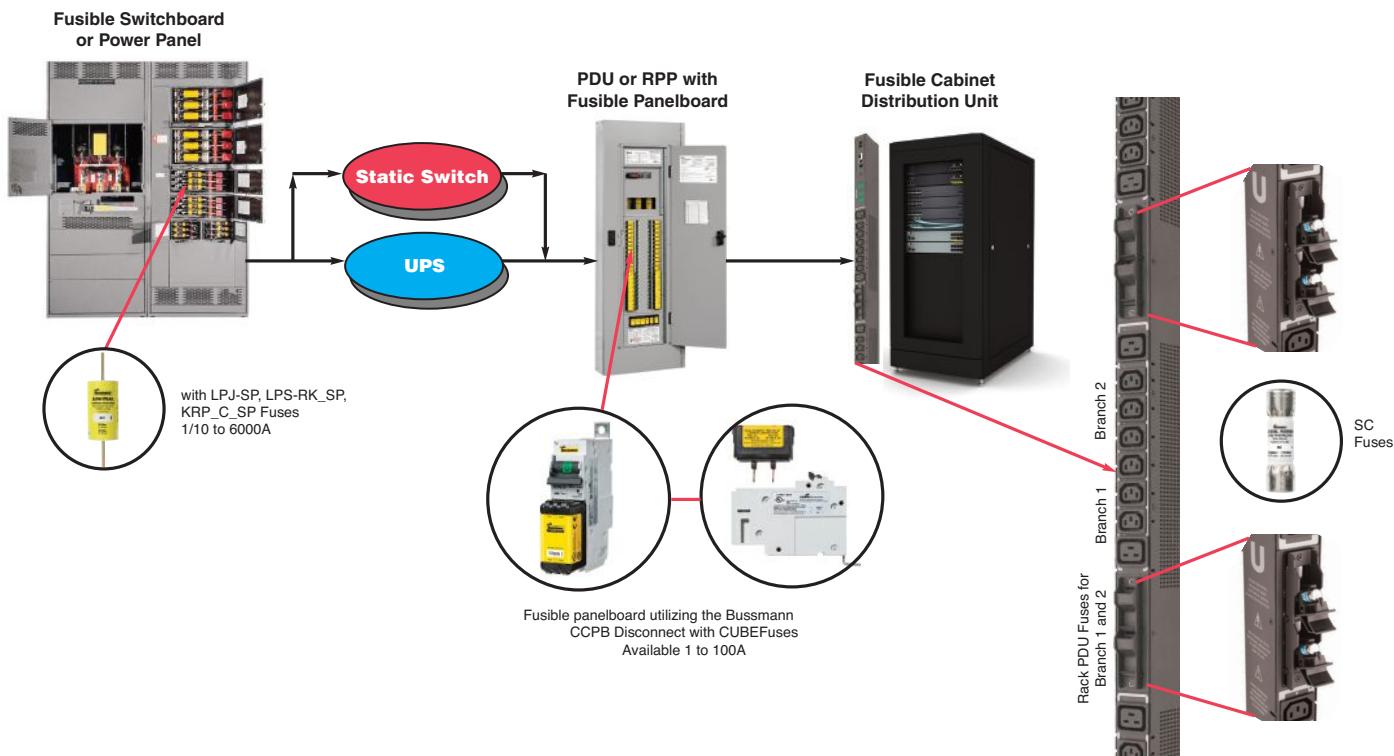


Figure 1. The fusible solution PDU architecture utilizes standard available fusible distribution panels/switchboards, PDUs/RPPs with the new QSCP panelboards incorporating the CCP disconnects and CUBEFuse, and rack PDU systems with fuse protection.

Data Center

Busway Architecture:

See Figure 2 for busway architecture which utilizes a plug-in busway to distribute power on the loadside of the UPS to the cabinets. The plug-in busway is suspended above server cabinets. The bus plug-in unit can utilize the 30A, 60A, or 100A Compact Circuit Protector integrated with 1 to 100A CUBEFuse. The fusible bus plug-in unit is attached to the rack PDU via cable. At the cabinet, a fusible rack PDU provides another level of current-limiting fuse protection. The fusible solution offers many benefits which will be discussed later in this section.

With bus plug-in units utilizing the CCP disconnect and CUBEFuse, the plug-in unit does not have to be changed out for ampacity changes to rack, if proper foresight and work practices are followed. Instead the disconnect can be switched to off. Then the CUBEFuse can be changed to the amp rating that is necessary for the cabinet or server change. See the discussion under Data Center Products.

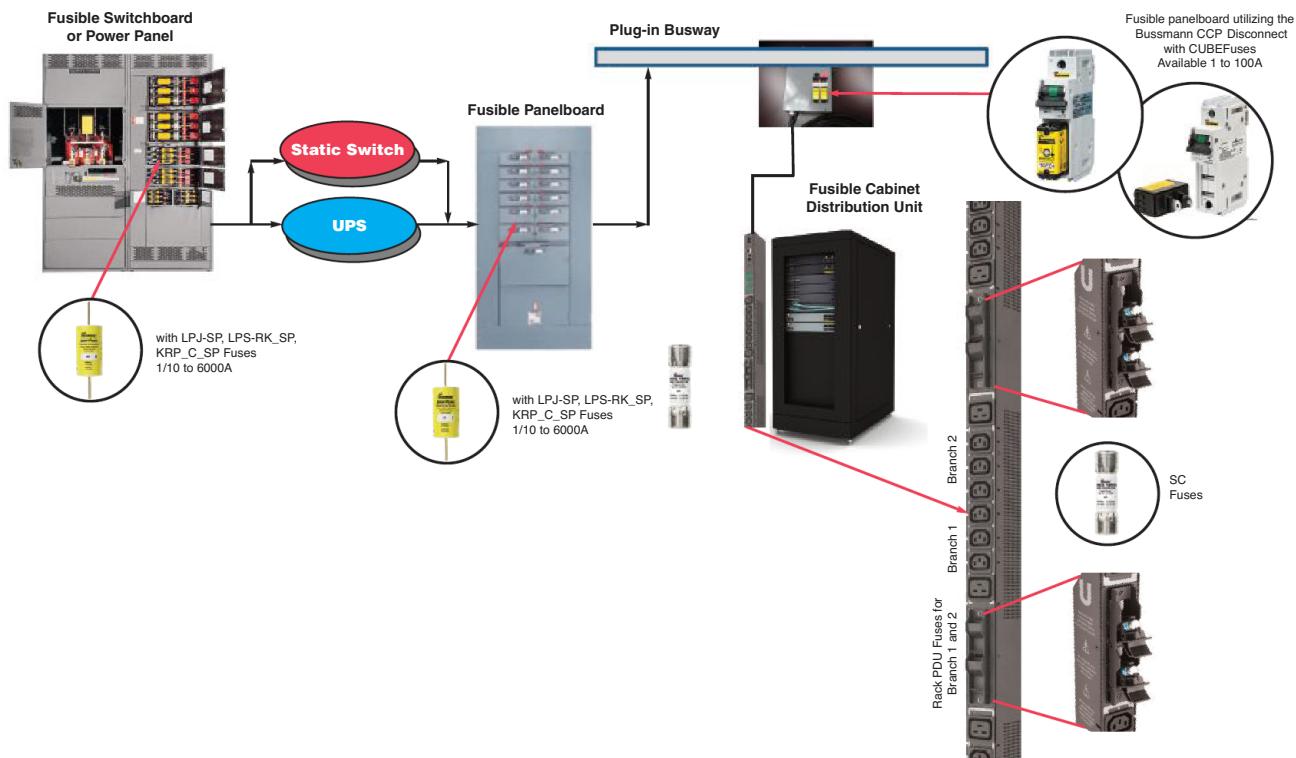


Figure 2. The fusible solution plug-in busway architecture utilizes standard available fusible distribution panels/switchboards, fusible bus plug-in units incorporating the CCP/CUBEFuse fusible disconnects, and fusible rack PDU systems.

2. Trend to Higher Distribution Voltage

The majority of the installed data center distribution systems are 208/120Vac. However, there is a major trend to utilizing higher electrical distribution voltages with the most prominent being 415/240Vac and with some 480/277Vac and 600/347Vac.

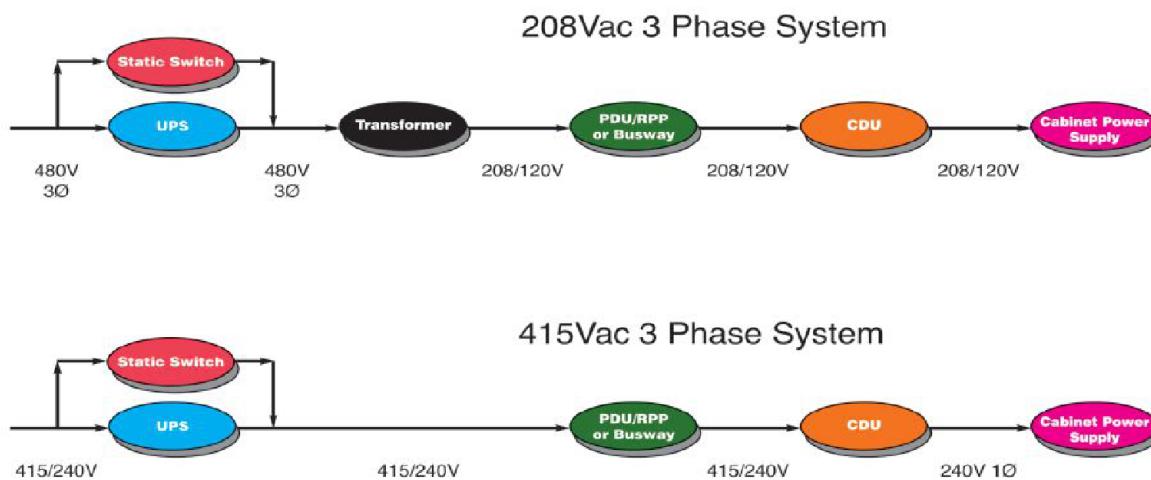


Figure 3. 208/120Vac and 415/240Vac data center distribution centers. In the 208V system the PDU includes the transformer. In the 415V system configuration, the 415V is transformed from a higher voltage prior to the data center and as a result there are no transformers in the data center. For either system the circuits to the cabinets could be from a panelboard or busway with plug-in fusible disconnect.

Data Center

See the 208/120Vac 3 phase system example in Figure 3. The three phase UPS output supplies a transformer from which the downstream distribution can be via a PDU architecture or busway architecture. With the PDU architecture, the transformer PDU may distribute 208V to a number of other panels (referred to as remote power panels or RPP) located throughout the data center which then distributes power to rack PDUs at the server cabinets. The cabinet power supplies are connected to the rack PDU.

See the 415/240Vac 3 phase system example in Figure 3. Industry experts have found that data center distribution at higher voltage can increase energy efficiency and reliability within a data center. There are many ways to configure 415Vac data center electrical systems. This 415Vac example illustrates a "transformerless" data center, where the transformation to 415Vac from a higher voltage is outside the data center. Moving to 415/240Vac data centers accommodates the typically available cabinet power supplies. The typical cabinet power supplies operate within a voltage range of 200Vac to 240Vac with some of the lower wattage power supplies operating within a voltage range of 100 VAC to 240 Vac. Commonly, 415/240Vac three phase is brought to the rack PDU and the rack PDU distributes single phase 240Vac to the cabinet power supplies. This is a significant advantage since higher efficiency is achieved while using existing power supplies.

The drivers moving to 415Vac data centers include increased mean time between failure (MTBF), double the power to the rack in the same footprint, double the power for a given conductor size, and reduction in components with a result of less space utilization and lower cost. However, there is the resulting increase in voltage and available short-circuit currents. It is important to consider the OCPD type, ratings, and characteristic best suited to meet the desired design criteria and the operational practices while complying with the NEC and OSHA.

3. Benefits of Fusible Designs

Current-limiting fuses offer many benefits to the data center designer and owners. These advantages are more pronounced with the challenges posed by the trend to higher voltage, higher energy efficiency and greater power density data centers. As a consequence, the overcurrent protective devices in the PDUs, RPPs, busway plug-in units, and cabinet rack PDU must have higher interrupting ratings at higher voltage ratings. In addition, this electrical equipment must also have higher short-circuit current ratings.

With higher fault currents, ensuring selective coordination becomes even more essential to avoid cascading overcurrent protective devices causing unnecessary outages.

Similarly, higher fault currents typically result in higher arc flash incident energy unless mitigated by current-limiting overcurrent protective devices.

Interrupting Rating:

Interrupting rating is the maximum short-circuit current that an overcurrent protective device can safely interrupt under standard test conditions. IR is an abbreviation for the term interrupting rating. Interrupting capacity with an abbreviation of IC is an older synonymous term carried over from years past. The National Electrical Code, UL Standards, and markings on fuses and circuit breakers now use the term interrupting rating and markings such as "IR 200KA" or "200kA IR." The term AIC or KAIC, such as in "200k AIC," is no longer used for product markings nor in the NEC or UL Standards.

All overcurrent protective devices must have interrupting ratings equal to or greater than the available fault current at their lineside terminals per NEC 110.9 and OSHA 1910.303(b)(4). In addition to fault currents trending up in new data centers, existing data centers can be expanded, increasing fault current beyond the interrupting ratings of existing OCPDs. Current-limiting fuses typically have interrupting ratings of 100,000A, 200,000A or 300,000A for 600Vac or less. With higher voltage distribution to the cabinet (i.e., 415Vac or greater), it is not uncommon to have 50kA or greater short circuit current available at a RPP or server cabinet busway plug-in unit. Even the cabinet power distribution unit can have high fault currents. Therefore, the 5kA IR or 10kA IR overcurrent protective devices often used in rack PDUs may be inadequate for many installations.

Circuit breaker solutions for higher available short-circuit currents either (a) use fully rated circuit breakers (each circuit breaker has an individual interrupting rating equal to or greater than the available fault current at its lineside terminals) or (b) use series combination rated circuit breakers (a circuit breaker is permitted to have an interrupting rating less than the available fault current at its lineside terminals if installed in a panelboard that is tested, listed, and marked with a specific line side circuit breaker or

fuse). Fully rated circuit breakers with higher interrupting ratings cost more and may have a larger footprint. In either case with fully rated or series rated circuit breaker systems, achieving selective coordination is usually more difficult to achieve when using standard molded case circuit breakers; this is more pronounced as the fault currents increase.

Fuses inherently provide fully rated high interrupting ratings for systems with fault currents up to 200kA without any price premium or footprint increase. The high interrupting rated fuses are all current-limiting making it simple to achieve selective coordination and easy to provide excellent protection of circuit components.

Component Protection and Short-Circuit Current

Rating of Equipment:

One of the principal advantages to fusing data center circuits is the current-limiting ability of fuses which can greatly reduce the let-through energy during faults. Per the fuse product standard UL 248, current-limiting fuses are not permitted to exceed maximum allowable energy let-through values under fault conditions. This provides excellent protection for components. The most current-limiting fuses (UL fuse Classes CF, J, RK1, T, CC, G, and L) provide superior short-circuit current protection. All equipment and components in the data center electrical system are required per NEC 110.10 and OSHA 1910.303(b)(5) to have a short-circuit current rating equal to or greater than the available short-circuit current. This includes the transfer switches, UPSs, PDUs, RPPs, busway, bus plug-in units, rack PDUs, and power supplies. The trend is that systems are capable of delivering more fault current as a result of the higher voltage and higher power density designs being used in data centers.

A current limiting device is needed to quickly drive the short-circuit current down to zero and keep the let-through energy below the damage levels of the equipment.

For instance, most fusible panelboards and enclosed disconnects can be tested, listed, and marked with a 200,000A short-circuit current rating. If busway is tested, listed, and labeled with current-limiting fuses as the short-circuit protection, 200,000A short-circuit current rating is typically achievable.

Selective Coordination:

The ability of a system to prevent an unnecessary blackout, has been a design consideration in data centers and mission critical systems long before it was a code requirement in the NEC® for systems supplying life safety loads. Mission critical system designers understand the added reliability that selective coordination of overcurrent protective devices brings to systems. The 2014 NEC® 645.27 requires the overcurrent protective devices in critical operations data systems to be selectively coordinated.

The use of properly selected fuses in data centers alleviates the design hassle of trying to achieve selectively coordinated overcurrent protective devices at the cabinet and busway (or PDU) levels as well as further upstream. Fuses simply need to maintain a 2:1* amp rating ratio for Bussmann Low-Peak fuses from the lineside fuse to the load-side fuse in order to achieve selective coordination. This eliminates the possibility of cascading multiple levels of overcurrent protective devices under fault conditions.

When overcurrent protective devices are not selectively coordinated multiple levels of overcurrent protective devices can cascade open on a fault condition. An example of a non selectively coordinated system: a fault in a power supply or rack PDU results not only in one of the rack PDU overcurrent protective devices opening as it should, but the RPP or busway plug-in overcurrent protective device opens unnecessarily resulting in the unnecessary power outage to the entire rack PDU. Even worse is if the feeder overcurrent protective device would open for a fault in the rack PDU resulting in an unnecessary power outage to an entire PDU/RPP or busway run.

See the clarifying Note under the section Fusible Cabinet Power Distribution Unit for selective coordination on 415/240V systems between SC 20A fuse to CUBEFuse 40A or larger.

*Where fuses are in same case size the 2:1 ratio may not apply, consult Bussmann.

Reliability:

Fuse operation is based on a simple thermal principle; the internal fuse element will rapidly melt, at a very specific level of energy. Users can be assured that a fuse's precise thermal element will always operate when called upon to remove a fault and protect valuable equipment. It's a matter of physics. The internal parts of modern current-limiting fuses do not require maintenance. Periodic checking fuse bodies, fuse mountings, adjacent conductor terminations for signs of overheating, poor connections, or insufficient conductor ampacities is important. As a result, the ongoing maintenance costs of fusible systems are typically less.

Data Center

Renewability:

OSHA 1910.334(b)(2) is the law when an overcurrent protective device opens due to an overcurrent. If an overload caused the opening, then fuses can be replaced or circuit breakers reset. However, if a faulted circuit caused the opening, then fuses cannot be replaced or circuit breakers reset "until it has been determined that the equipment and circuit can be safely energized." To avoid possible catastrophic damage to equipment or danger for workers, it is important to identify the source of the fault and repair the faulted circuit. In addition, the conductors and electrical components on the faulted circuit path should be tested and verified suitable to be placed back in service. When a fuse opens an overcurrent, it is replaced with a new factory calibrated fuse and the same level of protection is assured.

Safe Work Practices

See Figure 4. CUBEfuses can be serviced without removing the deadfront to a PDU/RPP or accessing the interior of a plug-in busway enclosure. CCPB/CUBEfuses are IP 20, finger-safe when installed in a panelboard/RPP with deadfront construction as shown in Figure 8 and CCP/CUBEfuses are IP 20, finger-safe when installed in plug-in busway enclosures as shown in Figure 12. In the event of a fuse opening, simply open the door of the panelboard to view the CCPB/CUBEfuses or merely look at the plug-in busway exterior to view the CCP/CUBEfuses. The open fuse(s) will be identified by either the open fuse indicating light on the CCPB or CCP (circuit must be closed for indication light to illuminate) or the optional indicator on the CUBEfuse. The CCPB disconnect is interlocked with the CUBEfuse. When extracting or inserting a CUBEfuse, place the CCPB disconnect handle in the "OFF" position.

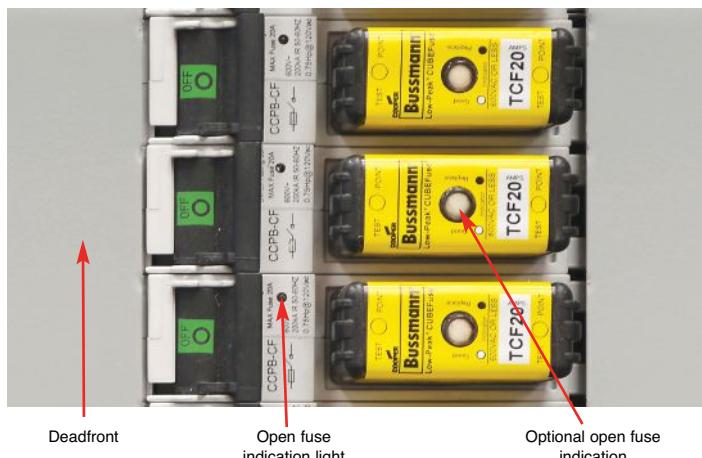


Figure 4. Servicing fuses is easy with equipment using Compact Circuit Protectors with CUBEfuses.

Arc Flash Mitigation:

Arc Flash is a frequent concern in today's data centers. With minimizing downtime as a priority, it is important to have current-limiting overcurrent protective devices mitigating the arc flash hazard where possible. By limiting the energy let-through and quickly bringing the current down to zero, fuses can reduce the arc flash hazard experienced during most arc flash events.

In addition, arc flash hazard mitigation is dependent on the "design and condition of maintenance" of the overcurrent protective device per 2012 NFPA 70E 130.5. If overcurrent protective devices that require maintenance are not maintained, an actual arc flash event can be more severe than that determined by the arc flash hazard analysis. 2012 NFPA 70E 205.4 requires overcurrent protective devices to be maintained and the "maintenance, tests, and inspections to be documented." Fuses are inherently reliable for fault conditions. There is no need to maintain the internal parts of fuses. All that is necessary is to maintain the external connections and proper environmental conditions.

Flexibility

There are data center operation flexibility and inventory advantages for some applications with the CCP/CUBEfuse. These are described in the next section Compact Circuit Protector and CUBEfuse.

4. Data Center Products

Compact Circuit Protector and CUBEfuse™ (CCP/TCF):

The innovative CUBEfuse™ with 300kA interrupting rating is available in amp ratings from 1A to 100A. These fuses have been on the market for more than a decade and offer many advantages including smallest footprint and finger-safe. The CUBEfuse is available in a time-delay version (TCF) which has a 600Vac/300Vdc rating and fast-acting version (non-time-delay) (FCF) which has a 600Vac/600Vdc rating. See Figure 5. Both CUBEfuse versions are very current-limiting, resulting in excellent equipment short-circuit current protection and arc flash incident energy mitigation. The TCF is available in an on-board indicating version and a non-indicating version. The FCF is available in a non-indicating version.



100A, 60A, & 30A TCF - with and without optional indication

View showing blades



100A, 60A, & 30A FCF - non-indicating

View showing blades

Figure 5. CUBEfuse™ TCF and FCF versions

For datacenter applications, the CUBEfuse in conjunction with the Compact Circuit Protector, which is a small UL 98 fused disconnect, offer great advantages. The amp ratings of the Compact Circuit Protector range up through 100A. This combination of Compact Circuit Protector disconnect and CUBEfuse provides excellent overcurrent protection solutions. The Quik-Spec Coordination Panelboard (QSCP) incorporates the Compact Circuit Protector/CUBEfuse and provides the means for fusible PDUs/RPPs. For the busway data center architecture the Compact Circuit Protector with CUBEfuse is incorporated into busway plug-in units.

These products offer excellent switch/fuse combinations for data center applications.

There are two versions of the Compact Circuit Protector using the CUBEfuse™. See Figure 6.

1. CCP: DIN-Rail mount version, which allows small fusible switch applications such as the plug-in busway unit up to 100A.
2. CCPB: bolt mount version used in the QSCP panelboard, which allows fusible panelboards having up to 100 amp rated branch circuits with panel width and depth the same as traditional circuit breaker panelboards.



Bolt mounted 30A versions

60A DIN-Rail version

Figure 6. Bolt mounted Compact Circuit Protector Base (CCPB) with non-indicating CUBEfuse, and DIN-Rail mount Compact Circuit Protector with indicating CUBEfuse.

Data Center

A CCP or CCPB has a disconnect amp rating and horsepower rating. A CCP or CCPB of a specific amp rating can accept any CUBEFuse amp rating equal or less than the CCP or CCPB amp rating.

There is a notable difference in the bolt mounted version versus the DIN-Rail mount version. The DIN-Rail mount version CCP disconnect is available in 30A, 60A, and 100A ratings. So the 30A CCP will accept 1A to 30A CUBEFuse. The CCP 60A will accept the 1A to 60A CUBEFuse and the CCP 100A will accept the 1A to 100A CUBEFuse. The bolt-on CCPB is available in the NEC® standard branch circuit amp ratings of 15, 20, 30, 40, 50, 60, 70, 90, and 100 amperes. Each bolt mounted CCPB will accept any CUBEFuse amp rating equal or less than the CCPB amp rating.

This feature of a given Compact Circuit Protector accepting CUBEFuse amp ratings equal or less than its amp rating provides some important flexibility options for data center management. For instance, if a plug-in busway unit uses a CCP 60A and the cable whip is rated 60A, then any CUBEFuse from 1A to 60A can be installed.

For example, assume on the initial installation, a 15A CUBEFuse is needed so a 15A CUBEFuse is inserted in the plug-in busway unit CCP. Then modifications are required to the cabinet changing the load so that a 35A CUBEFuse is needed. All that is necessary is to switch the 60A CCP disconnect to "off," remove the 15A CUBEFuses and insert the 35A CUBEFuses. Then switch the CCP to "on." This can save time and reduce inventory of busway plug-in units since the entire plug-in busway unit does not have to be removed and replaced with a larger amp rating unit.



Figure 7. Both CCP and CCPB are available in 1-, 2-, or 3-pole versions. Shown are CCPs.

Quik-Spec Coordination Panelboard and PDU/RPP:

The Quik-Spec Coordination Panelboard (QSCP) is rated 600Vac and can be utilized for either 208Vac or 415Vac data centers applications (or up to 600Vac). The left image of Figure 8 shows the QSCP as a complete panelboard and the right image of Figure 8 shows a QSCP chassis or interior only version which other manufacturers integrate into their PDU/RPP equipment. Examples of QSCP chassis versions in other manufacturers' RPPs are shown in Figures 9, 10 and 11.

The complete panelboard version QSCP with high SCCR, 300kA IR CUBEFuses, ease in achieving selective coordination, and excellent arc flash hazard mitigation is also an excellent panelboard for electrical distribution system supplying non-IT equipment loads in a data center such as the computer room air conditioners/air handlers (CRAC/CRAH).

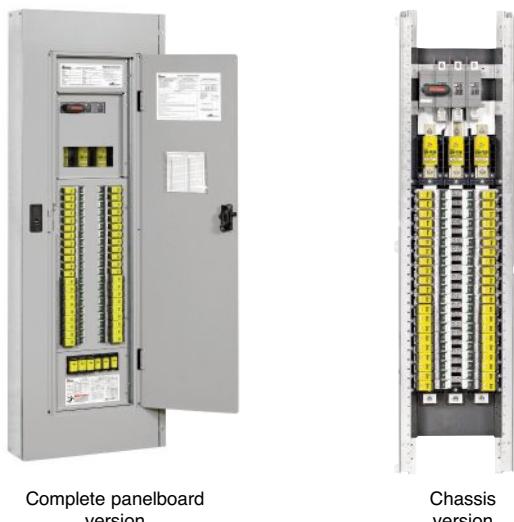


Figure 8. Quik-Spec Coordination Panelboard (QSCP).



Figure 9. Remote power panel incorporating chassis QSCP with CCPB/CUBEFuse.
Courtesy Eaton.

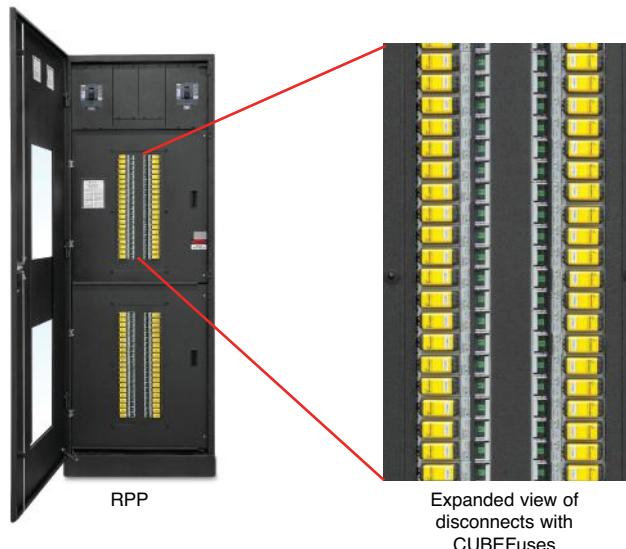


Figure 10. Remote power panel incorporating chassis QSCP with CCPB/CUBEFuse.
Courtesy Cyberex, Thomas & Betts Power Solutions.



Figure 11. Remote power panel incorporating chassis QSCP with CCPB/CUBEFuse as well as spare CUBEFuses in holders. Courtesy Liebert® FDC™ power distribution cabinet from Emerson Network Power™.

Data Center

There are two alternatives in specifying CCPBs for PDUs/RPPs.

1. The CCPBs can be specified for the specific branch circuit amp ratings of 15A, 20A, 30A, 40A, 50A, 60A, 70A, 90A, or 100A. Each CCPB will accept CUBEFuse amp ratings equal to or less than its respective ampere rating.
2. The CCPB can be specified all 30A, or 60A, or 100A or a mixture of these ampere ratings. This approach allows for more flexibility and less inventory of CCPB disconnects needed when circuit changes or PDU/RPP changes are made. For instance, if all the CCPBs disconnects in an RPP are 60A, then CUBEFuses that may be inserted in the 60A CCPB can range from 1 to 60A. With this alternative, if the branch circuit conductors are changed to a different ampacity, the CCPB disconnect does not have to be replaced, only the CUBEFuses with the appropriate amp rating needs to be inserted in the CCPB. Similarly, if the RPP is moved, only the fuses have to be changed to reconfigure for the circuits at the new location.

Plug-In Busway Fusible Disconnect:

A plug-in busway utilizing the DIN-Rail mount version CCP/CUBEFuse is suitable for any voltage up to 600Vac. The cable whip connects the busway unit to the cabinet distribution unit. See Figure 12.



Figure 12. StarLine® Track Busway fusible disconnects using the DIN-Rail mount CCP with CUBEFuse.

Courtesy of Universal Electric Corporation (UEC).

Fusible Rack Power Distribution Unit:

By using fuses in the rack PDU, the rack PDU IT and circuits can be properly protected in systems even with high available fault levels. In addition, this scheme can isolate a faulted subsection of the rack PDU, thereby keeping the power supplies fed by the remainder of the energized rack PDU (when rack PDU fuses are selectively coordinated with upstream RPP fuses or busway plug-in fuses see Note on Selective Coordination for rack PDU below). See Figure 13. If a fault or overload were to occur on branch 1, the branch 1 fuse would open and remove the overcurrent from the circuit. The rest of the rack PDU would remain in normal operation. Rack PDU manufacturers provide options for local and remote notification if a fuse opens. Remote notification includes both SNMP traps (simple network management protocol traps) and email alerts.

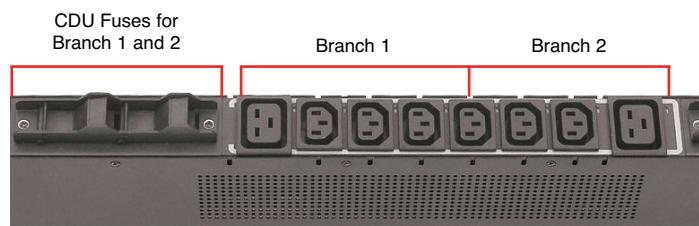


Figure 13. Partial views of fused rack PDU or cabinet power distribution unit (CDU). SC fuses are used in this rack PDU to protect the receptacles and circuit to the power supplies.

Courtesy of Server Technology, Inc.

Note on selective coordination for rack PDU fuses with upstream fuses: the easiest way to achieve selective coordination with fuses is to adhere to the published Fuse Selectivity Ratio Guide (see this section in SPD publication). 20 amp SC fuses are commonly used in the rack PDU as shown in Figure 13. CUBEFuses, either TCF or FCF, are often used in the supply circuit to the rack PDU via the RPP or busway plug-in disconnect. The published selectivity ratio for a TCF fuse supplying a SC fuse is 4:1(for a 600 volt system), which means for a rack PDU using a SC20 fuse the minimum upstream TCF fuse would need to be 80 amps to ensure selective coordination. However, tests have demonstrated that either TCF40 or FCF40 fuses (or larger) will selectively coordinate with downstream SC 20 fuses for 415/240V systems up to 100,000 available short-circuit amperes (the SC fuse interrupting rating). The deviation from the published ratio for these specific type fuses and amp ratings is due to the characteristics of these specific fuses being used at the lower application voltage of 415/240V.

Introduction

Several sections of the National Electrical Code® relate to proper overcurrent protection. Safe and reliable application of overcurrent protective devices based on these sections mandate that a short circuit study and a selective coordination study be conducted.

These sections include, among others:

- 110.9 Interrupting Rating
- 110.10 Component Protection
- 110.24 Available Fault Current
- 240.4 Conductor Protection
- 250.122 Equipment Grounding Conductor Protection
- Marked Short-Circuit Current Rating:
 - 230.82 (3) Meter Disconnect
 - 409.110 Industrial Control Panels
 - 430.8 Motor Controllers
 - 440.4(B) Air Conditioning & Refrigeration Equipment
 - 670.3(A) Industrial Machinery
- Selective Coordination
 - 620.62 Selective Coordination for Elevator Circuits
 - 645.27 Critical Operations Data Systems
 - 700.28 Emergency Systems
 - 701.27 Legally Required Standby Systems
 - 708.54 Critical Operations Power Systems

Compliance with these code sections can best be accomplished by conducting a short circuit study as a start to the analysis. Once the short circuit levels are determined, the engineer can specify proper interrupting rating requirements, selectively coordinate the system and provide component protection. See the various sections of this book for further information on each topic.

Low voltage fuses have their interrupting rating expressed in terms of the symmetrical component of short-circuit current. They are given an RMS symmetrical interrupting rating at a specific power factor. This means that the fuse can interrupt the asymmetrical current associated with this rating. Thus only the symmetrical component of short-circuit current need be considered to determine the necessary interrupting rating of a low voltage fuse.

NEC® 110.24 requires field marking service equipment (other than dwelling units and certain industrial facilities) with the maximum available short-circuit current.

To determine arc flash boundary and the proper arc rated personal protective equipment per NFPA 70E whether by using the incident energy method or HRC (Table) method (70E 130.5), the available short-circuit current is required.

General Comments on Short Circuit Calculations

Sources of short-circuit current that are normally taken under consideration include:

- Utility Generation
- Local Generation
- Synchronous Motors
- Induction Motors
- Alternate Power Sources

Short circuit calculations should be done at all critical points in the system. These would include:

- Service Entrance
- Transfer Switches
- Panel Boards
- Load Centers
- Motor Control Centers
- Disconnects
- Motor Starters

Normally, short circuit studies involve calculating a bolted 3-phase fault condition. This can be characterized as all 3-phases "bolted" together to create a zero impedance connection. This establishes a "worst case" (highest current) condition that results in maximum three phase thermal and mechanical stress in the system. From this calculation, other types of fault conditions can be approximated. This "worst case" condition should be used for interrupting rating, component protection, "Table" method of determining PPE, and selective coordination. However, in doing an arc flash hazard analysis calculation it is recommended to do the arc flash hazard analysis at the highest bolted 3 phase short circuit condition and at the "minimum" bolted three-phase short circuit condition. There are several variables in a distribution system that affect

calculated bolted 3-phase short-circuit currents. It is important to select the variable values applicable for the specific application analysis. In the Point-to-Point method presented in this section there are several adjustment factors given in Notes and footnotes that can be applied that will affect the outcomes. The variables are utility source short circuit capabilities, motor contribution, transformer percent impedance tolerance, and voltage variance.

In most situations, the utility source(s) or on-site energy sources, such as on-site generation, are the major short-circuit current contributors. In the Point-to-Point method presented in the next few pages, the steps and example assume an infinite available short-circuit current from the utility source. Generally this is a good assumption for highest worst case conditions and since the property owner has no control over the utility system and future utility changes. And in many cases a large increase in the utility available does not increase the short-circuit currents a great deal for a building system on the secondary of the service transformer. However, there are cases where the actual utility medium voltage available provides a more accurate short circuit assessment (minimum bolted short-circuit current conditions) that may be desired to assess the arc flash hazard.

When there are motors in the system, motor short circuit contribution is also a very important factor that must be included in any short-circuit current analysis. When a short circuit occurs, motor contribution adds to the magnitude of the short-circuit current; running motors contribute 4 to 6 times their normal full load current. Series rated combinations can not be used in specific situations due to motor short circuit contributions (see the section on Series Ratings in this book).

For capacitor discharge currents, which are of short time duration, certain IEEE (Institute of Electrical and Electronic Engineers) publications detail how to calculate these currents if they are substantial.

Procedures and Methods

To determine the fault current at any point in the system, first draw a one-line diagram showing all of the sources of short-circuit current feeding into the fault, as well as the impedances of the circuit components.

To begin the study, the system components, including those of the utility system, are represented as impedances in the diagram.

The impedance tables include three-phase and single-phase transformers, cable, and busway. These tables can be used if information from the manufacturers is not readily available.

It must be understood that short circuit calculations are performed without current-limiting devices in the system. Calculations are done as though these devices are replaced with copper bars, to determine the maximum "available" short-circuit current. This is necessary to project how the system and the current-limiting devices will perform.

Also, multiple current-limiting devices do not operate in series to produce a "compounding" current-limiting effect. The downstream, or load side, fuse will operate alone under a short circuit condition if properly coordinated.

The application of the point-to-point method permits the determination of available short-circuit currents with a reasonable degree of accuracy at various points for either $3\bar{0}$ or $1\bar{0}$ electrical distribution systems. This method can assume unlimited primary short-circuit current (infinite bus) or it can be used with limited primary available current.

FC2 Available Fault Current Calculator

A Point-to-Point method electronic application is available either as a downloadable app for Apple and Droid mobile devices (scan the QR) or can be run from the Bussmann website at www.cooperbussmann.com/FC2.



Basic Point-to-Point Calculation Procedure

Step 1. Determine the transformer full load amps (F.L.A.) from

$$3\text{Ø Transformer} \quad I_{F.L.A.} = \frac{kVA \times 1000}{E_{L-L} \times 1.732}$$

$$1\text{Ø Transformer} \quad I_{F.L.A.} = \frac{kVA \times 1000}{E_{L-L}}$$

either the nameplate, the following formulas or Table 1:

$$\text{Multiplier} = \frac{100}{*\%Z_{\text{transformer}}}$$

Step 2. Find the transformer multiplier. See Notes 1 and 2

* Note 1. Get %Z from nameplate or Table 1. Transformer impedance (Z) helps to determine what the short circuit current will be at the transformer secondary.

Transformer impedance is determined as follows: The transformer secondary is short circuited. Voltage is increased on the primary until full load current flows in the secondary. This applied voltage divided by the rated primary voltage (times 100) is the impedance of the transformer.

Example: For a 480 Volt rated primary, if 9.6 volts causes secondary full load current to flow through the shorted secondary, the transformer impedance is $9.6/480 = .02 = 2\%Z$.

* Note 2. In addition, UL 1561 listed transformers 25kVA and larger have a $\pm 10\%$ impedance tolerance. Short circuit amps can be affected by this tolerance. Therefore, for high end worst case, multiply %Z by .9. For low end of worst case, multiply %Z by 1.1. Transformers constructed to ANSI standards have a $\pm 7.5\%$ impedance tolerance (two-winding construction).

Step 3. Determine by formula or Table 1 the transformer let-through short-circuit current. See Notes 3 and 4.

$$I_{S.C.} = \text{Transformer}_{F.L.A.} \times \text{Multiplier}$$

Note 3. Utility voltages may vary $\pm 10\%$ for power and $\pm 5.8\%$ for 120 Volt lighting services. Therefore, for highest short circuit conditions, multiply values as calculated in step 3 by 1.1 or 1.058 respectively. To find the lower end worst case, multiply results in step 3 by .9 or .942 respectively.

Note 4. Motor short circuit contribution, if significant, may be added at all fault locations throughout the system. A practical estimate of motor short circuit contribution is to multiply the total motor current in amps by 4. Values of 4 to 6 are commonly accepted.

Step 4. Calculate the "f" factor.

3Ø Faults

$$f = \frac{1.732 \times L \times I_{3Ø}}{C \times n \times E_{L-L}}$$

1Ø Line-to-Line (L-L) Faults

See Note 5 & Table 3

$$f = \frac{2 \times L \times I_{L-L}}{C \times n \times E_{L-L}}$$

1Ø Line-to-Neutral (L-N) Faults

See Note 5 & Table 3

$$f = \frac{2 \times L \times I_{L-N^+}}{C \times n \times E_{L-N}}$$

Where:

L = length (feet) of conductor to the fault.

C = constant from Table 4 of "C" values for conductors and Table 5 of "C" values for busway.

n = Number of conductors per phase (adjusts C value for parallel runs)

I = Available short-circuit current in amperes at beginning of circuit.

E = Voltage of circuit.

† Note 5. The L-N fault current is higher than the L-L fault current at the secondary terminals of a single-phase center-tapped transformer. The short-circuit current available (I) for this case in Step 4 should be adjusted at the transformer terminals as follows: At L-N center tapped transformer terminals, $I_{L-N} = 1.5 \times I_{L-L}$ at Transformer Terminals.

At some distance from the terminals, depending upon wire size, the L-N fault current is lower than the L-L fault current. The 1.5 multiplier is an approximation and will theoretically vary from 1.33 to 1.67. These figures are based on change in turns ratio between primary and secondary, infinite source available, zero feet from terminals of transformer, and $1.2 \times \%Z$ and $1.5 \times \%R$ for L-N vs. L-L resistance and reactance values. Begin L-N calculations at transformer secondary terminals, then proceed point-to-point.

Step 5. Calculate "M" (multiplier) or take from Table 2.

$$M = \frac{1}{1+f}$$

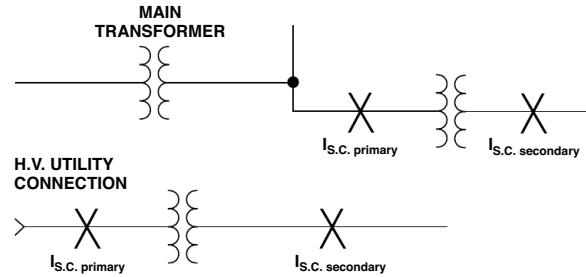
Step 6. Calculate the available short circuit symmetrical RMS current at the point of fault. Add motor contribution, if applicable.

$$I_{S.C.\text{sym.RMS}} = I_{S.C.} \times M$$

Step 6A. Motor short circuit contribution, if significant, may be added at all fault locations throughout the system. A practical estimate of motor short circuit contribution is to multiply the total motor current in amps by 4. Values of 4 to 6 are commonly accepted.

Calculation of Short-Circuit Currents When Primary Available Short-Circuit Current is Known

Use the following procedure to calculate the level of fault current at the secondary of a second, downstream transformer in a system when the level of fault current at the transformer primary is known.



Step A. Calculate the "f" factor (I_{S.C.} primary known)

3Ø Transformer
(I_{S.C.} primary and
I_{S.C.} secondary are
3Ø fault values)

$$f = \frac{I_{S.C.\text{primary}} \times V_{\text{primary}} \times 1.73 (\%Z)}{100,000 \times \text{kVA}_{\text{transformer}}}$$

1Ø Transformer
(I_{S.C.} primary and
I_{S.C.} secondary are
1Ø fault values:
I_{S.C.} secondary is L-L)

$$f = \frac{I_{S.C.\text{primary}} \times V_{\text{primary}} \times (\%Z)}{100,000 \times \text{kVA}_{\text{transformer}}}$$

Step B. Calculate "M" (multiplier).

$$M = \frac{1}{1+f}$$

Step C. Calculate the short-circuit current at the secondary of the transformer. (See Note under Step 3 of "Basic Point-to-Point Calculation Procedure".)

$$I_{S.C.\text{secondary}} = \frac{V_{\text{primary}}}{V_{\text{secondary}}} \times M \times I_{S.C.\text{primary}}$$

Three-Phase Short Circuits

System A

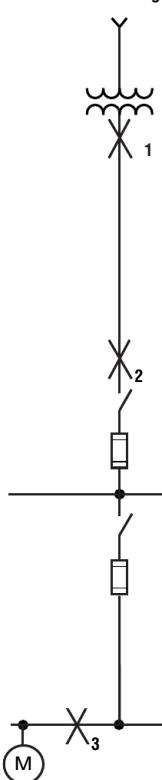
Available Utility
Infinite Assumption

1500 KVA Transformer
480V, 3Ø, 3.5%Z,
3.45% X, 0.56%R

$$I_{LL} = 1804A$$

25' - 500kcmil Cu
3 Single Conductors
6 Per Phase
Magnetic Conduit

One-Line Diagram



Fault X₁

$$\text{Step 1. } I_{f.L.} = \frac{1500 \times 1000}{480 \times 1.732} = 1804.3A$$

$$\text{Step 2. Multiplier } \frac{100}{3.5 \times 0.9^t} = 31.746$$

$$\text{Step 3. } I_{s.c.} = 1804.3 \times 31.746 = 57,279A$$

$$I_{s.c. \text{ motor contrib.}^{**}} = 4 \times 1804.3 = 7217A$$

$$I_{\text{total s.c. sym RMS}} = 57,279 + 7217 = 64,496A$$

Fault X₃

$$\text{Step 4. } f = \frac{1.732 \times 50 \times 55,137}{22,185 \times 1 \times 480} = 0.4484$$

$$\text{Step 5. } M = \frac{1}{1 + 0.4483} = 0.6904$$

$$\text{Step 6. } I_{s.c. \text{ sym RMS}} = 55,137 \times 0.6904 = 38,067A$$

$$I_{s.c. \text{ motor contrib.}^{**}} = 4 \times 1804.3 = 7217A$$

$$I_{\text{total s.c. sym RMS (X}_3\text{)}} = 38,067 + 7217 = 45,284A$$

Fault X₂

$$\text{Step 4. } f = \frac{1.732 \times 25 \times 57,279}{22,185 \times 6 \times 480} = 0.0388$$

$$\text{Step 5. } M = \frac{1}{1 + 0.0388} = 0.9626$$

$$\text{Step 6. } I_{s.c. \text{ sym RMS}} = 57,279 \times 0.9626 = 55,137A$$

$$I_{s.c. \text{ motor contrib.}^{**}} = 4 \times 1804.3 = 7217A$$

$$I_{\text{total s.c. sym RMS}} = 55,137 + 7217 = 62,354A$$

2000A Switch
KRP-C 2000SP Fuse

400A Switch
LPS-RK-400SP Fuse

50' - 500 kcmil Cu
3 Single Conductors
Magnetic Conduit

Motor Contribution*

*See note 4 on page 240.

**Assumes 100% motor load. If 50% of this load was from motors. $I_{s.c. \text{ motor contrib.}} = 4 \times 1804 \times 0.5 = 3,608A$

† See note 2 on page 240

System B

Available Utility
Infinite Assumption

1000 KVA Transformer
480V, 3Ø, 3.5%Z,

$$I_{LL} = 1203A$$

30' - 500kcmil Cu
3 Single Conductors
4 Per Phase
PVC Conduit

1600A Switch

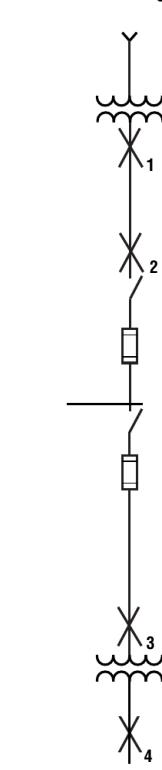
KRP-C 1500SP Fuse

400A Switch
LPS-RK-350SP Fuse

20' - 2/0 Cu
3 Single Conductors
2 Per Phase
PVC Conduit

225 KVA Transformer
208V, 3Ø
1.2%Z

One-Line Diagram



Fault X₁

$$\text{Step 1. } I_{s.c.} = \frac{1000 \times 1000}{480 \times 1.732} = 1202.8A$$

$$\text{Step 2. Multiplier } \frac{100}{3.5 \times 0.9^t} = 31.746$$

$$\text{Step 3. } I_{s.c.} = 1202.8 \times 31.746 = 38,184A$$

Fault X₃

$$\text{Step 4. } f = \frac{1.732 \times 20 \times 36,761}{2 \times 11,424 \times 480} = 0.1161$$

$$\text{Step 5. } M = \frac{1}{1 + 0.1161} = 0.8960$$

$$\text{Step 6. } I_{s.c. \text{ sym RMS}} = 36,761 \times 0.8960 = 32,937A$$

Fault X₂

$$\text{Step 4. } f = \frac{1.732 \times 30 \times 38,184}{26,706 \times 4 \times 480} = 0.0387$$

$$\text{Step 5. } M = \frac{1}{1 + 0.0387} = 0.9627$$

$$\text{Step 6. } I_{s.c. \text{ sym RMS}} = 38,184 \times 0.9627 = 36,761A$$

Fault X₄

$$\text{Step A. } f = \frac{32,937 \times 480 \times 1.732 \times (1.2 \times 0.9)}{100,000 \times 225} = 1.3144$$

$$\text{Step B. } M = \frac{1}{1 + 1.3144} = 0.4321$$

$$\text{Step C. } I_{s.c. \text{ sym RMS}} = \frac{480 \times 0.4321 \times 32,937}{208} = 32,842A$$

This example assumes no motor contribution.

Single-Phase Short Circuits

Short circuit calculations on a single-phase center tapped transformer system require a slightly different procedure than $3\varnothing$ faults on $3\varnothing$ systems.

1. It is necessary that the proper impedance be used to represent the primary system. For $3\varnothing$ fault calculations, a single primary conductor impedance is used from the source to the transformer connection. This is compensated for in the $3\varnothing$ short circuit formula by multiplying the single conductor or single-phase impedance by 1.73. However, for single-phase faults, a primary conductor impedance is considered from the source to the transformer and back to the source. This is compensated in the calculations by multiplying the $3\varnothing$ primary source impedance by two.
2. The impedance of the center-tapped transformer must be adjusted for the half-winding (generally line-to-neutral) fault condition.

The diagram at the right illustrates that during line-to-neutral faults, the full primary winding is involved but, only the half-winding on the secondary is involved.

Therefore, the actual transformer reactance and resistance of the half-winding condition is different than the actual transformer reactance and resistance of the full winding condition. Thus, adjustment to the %X and %R must be made when considering line-to-neutral faults. The adjustment multipliers generally used for this condition are as follows:

- 1.5 times full winding %R on full winding basis.
- 1.2 times full winding %X on full winding basis.

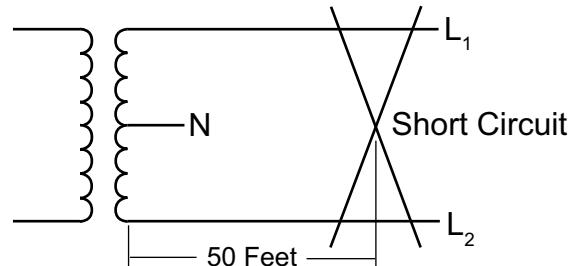
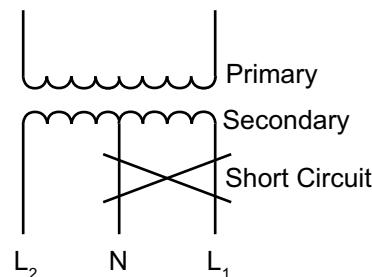
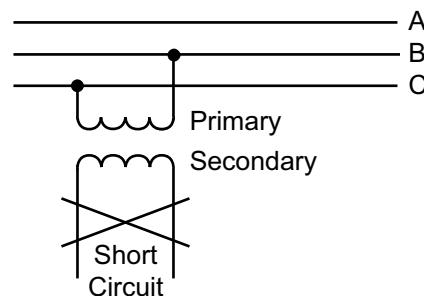
Note: %R and %X multipliers given in "Impedance Data for Single Phase Transformers" Table may be used, however, calculations must be adjusted to indicate transformer kVA/2.

3. The impedance of the cable and two-pole switches on the system must be considered "both-ways" since the current flows to the fault and then returns to the source. For instance, if a line-to-line fault occurs 50 feet from a transformer, then 100 feet of cable impedance must be included in the calculation.

The calculations on the following pages illustrate $1\varnothing$ fault calculations on a single-phase transformer system. Both line-to-line and line-to-neutral faults are considered.

Note in these examples:

- a. The multiplier of 2 for some electrical components to account for the single-phase fault current flow,
- b. The half-winding transformer %X and %R multipliers for the line-to-neutral fault situation, and



Single-Phase Short Circuits

System A

Available Utility
Infinite Assumption

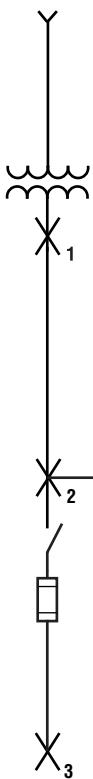
75KVA, 1Ø Transformer.
1.22%X, 0.68%R
1.40%Z
120/240V

25' - 500kcmil Cu
Magnetic Conduit
3 Single Conductors

400A Switch
LPN-RK-400SP Fuse

50' - 3 AWG Cu
Magnetic Conduit
3 Single Conductors

One-Line Diagram



Line-to-Line (L-L) Fault

Fault X₁

$$\text{Step 1. } I_{f.L.} = \frac{75 \times 1000}{240} = 312.5\text{A}$$

$$\text{Step 2. Multiplier} = \frac{100}{1.4 \times 0.9^\dagger} = 79.37$$

$$\text{Step 3. } I_{s.c. (L-L)} = 312.5 \times 79.37 = 24,802\text{A}$$

Fault X₂

$$\text{Step 4. } f = \frac{2 \times 25 \times 24,802}{22,185 \times 1 \times 240} = 0.2329$$

$$\text{Step 5. } M = \frac{1}{1 + 0.2329} = 0.8111$$

$$\text{Step 6. } I_{s.c. (L-L)} (X_2) = 24,802 \times 0.8111 = 20,116$$

Fault X₃

$$\text{Step 4. } f = \frac{2 \times 50 \times 20,116}{4774 \times 1 \times 240} = 1.7557$$

$$\text{Step 5. } M = \frac{1}{1 + 1.7557} = 0.3629$$

$$\text{Step 6. } I_{s.c. (L-L)} (X_3) = 20,116 \times 0.3629 = 7,300\text{A}$$

[†] In addition, UL 1561 listed transformers 25kVA and larger have a ± 10% impedance tolerance. Short circuit amps can be affected by this tolerance. Therefore, for high end worst case, multiply %Z by 0.9. For low end of worst case, multiply %Z by 1.1. Transformers constructed to ANSI standards have a ±7.5% impedance tolerance (two-winding construction).

Line-to-Neutral (L-N) Fault

Fault X₁

$$\text{Step 1. } I_{f.L.} = \frac{75 \times 1000}{240} = 312.5\text{A}$$

$$\text{Step 2. Multiplier} = \frac{100}{1.4 \times 0.9^\dagger} = 79.37$$

$$\text{Step 3*. } I_{s.c. (L-N)} = 24,802 \times 1.5 = 37,202\text{A}$$

Fault X₂

$$\text{Step 4. } f = \frac{2 \times 25 \times 37,202}{22,185 \times 1 \times 120} = 0.6987$$

$$\text{Step 5. } M = \frac{1}{1 + 0.6987} = 0.5887$$

$$\text{Step 6*. } I_{s.c. (L-N)} (X_2) = 37,202 \times 0.5887 = 21,900\text{A}$$

Fault X₃

$$\text{Step 4. } f = \frac{2 \times 50 \times 21,900^{**}}{4774 \times 1 \times 120} = 3.8323$$

$$\text{Step 5. } M = \frac{1}{1 + 3.823} = 0.2073$$

$$\text{Step 6*. } I_{s.c. (L-N)} (X_3) = 21,900 \times 0.2073 = 4,540\text{A}$$

* Note 5. The L-N fault current is higher than the L-L fault current at the secondary terminals of a single-phase center-tapped transformer. The short-circuit current available (I) for this case in Step 4 should be adjusted at the transformer terminals as follows: At L-N center tapped transformer terminals, $I_{L-N} = 1.5 \times I_{L-L}$ at Transformer Terminals.

**Assumes the neutral conductor and the line conductor are the same size.

Impedance & Reactance Data

Transformers

Table 1. Short-Circuit Currents Available from Various Size Transformers

(Based upon actual field nameplate data or from utility transformer worst case impedance)

Voltage and Phase	KVA	Full Load Amps	% Impedance ^{††} (Nameplate)	Short Circuit Amps [‡]
120/240 1 ph.*	25	104	1.5	12175
	37.5	156	1.5	18018
	50	208	1.5	23706
	75	313	1.5	34639
	100	417	1.6	42472
	167	696	1.6	66644
120/208 3 ph.**	45	125	1.0	13879
	75	208	1.0	23132
	112.5	312	1.11	31259
	150	416	1.07	43237
	225	625	1.12	61960
	300	833	1.11	83357
	500	1388	1.24	124364
	750	2082	3.50	66091
	1000	2776	3.50	88121
	1500	4164	3.50	132181
	2000	5552	4.00	154211
	2500	6940	4.00	192764
	75	90	1.00	10035
	112.5	135	1.00	15053
277/480 3 ph.**	150	181	1.20	16726
	225	271	1.20	25088
	300	361	1.20	33451
	500	602	1.30	51463
	750	903	3.50	28672
	1000	1204	3.50	38230
	1500	1806	3.50	57345
	2000	2408	4.00	66902
	2500	3011	4.00	83628

*Single-phase values are L-N values at transformer terminals. These figures are based on change in turns ratio between primary and secondary, 100,000 kVA primary, zero feet from terminals of transformer, 1.2 (%X) and 1.5 (%R) multipliers for L-N vs. L-L reactance and resistance values and transformer X/Rratio = 3.

**Three-phase short-circuit currents based on "infinite" primary.

†† UL listed transformers 25 kVA or greater have a ±10% impedance tolerance. Short-circuit amps shown in Table 1 reflect -10% condition. Transformers constructed to ANSI standards have a ±7.5% impedance tolerance (two-winding construction).

‡Fluctuations in system voltage will affect the available short-circuit current. For example, a 10% increase in system voltage will result in a 10% greater available short-circuit currents than as shown in Table 1.

Table 2. "M" (Multiplier)

$$M = \frac{1}{1+f}$$

f	M	f	M	f	M
0.01	0.99	0.50	0.67	7.00	0.13
0.02	0.98	0.60	0.63	8.00	0.11
0.03	0.97	0.70	0.59	9.00	0.10
0.04	0.96	0.80	0.55	10.00	0.09
0.05	0.95	0.90	0.53	15.00	0.06
0.06	0.94	1.00	0.50	20.00	0.05
0.07	0.93	1.20	0.45	30.00	0.03
0.08	0.93	1.50	0.40	40.00	0.02
0.09	0.92	1.75	0.36	50.00	0.02
0.10	0.91	2.00	0.33	60.00	0.02
0.15	0.87	2.50	0.29	70.00	0.01
0.20	0.83	3.00	0.25	80.00	0.01
0.25	0.80	3.50	0.22	90.00	0.01
0.30	0.77	4.00	0.20	100.00	0.01
0.35	0.74	5.00	0.17		
0.40	0.71	6.00	0.14		

Impedance Data for Single-Phase Transformers

KVA 10	Suggested X/R Ratio for Calculation	Normal Range of Percent Impedance (%Z)*	Impedance Multipliers** For Line-to-Neutral Faults for %X	Impedance Multipliers** for %R
25.0	1.1	1.2-6.0	0.6	0.75
37.5	1.4	1.2-6.5	0.6	0.75
50.0	1.6	1.2-6.4	0.6	0.75
75.0	1.8	1.2-6.6	0.6	0.75
100.0	2.0	1.3-5.7	0.6	0.75
167.0	2.5	1.4-6.1	1.0	0.75
250.0	3.6	1.9-6.8	1.0	0.75
333.0	4.7	2.4-6.0	1.0	0.75
500.0	5.5	2.2-5.4	1.0	0.75

*National standards do not specify %Z for single-phase transformers. Consult manufacturer for values to use in calculation.

**Based on rated current of the winding (one-half nameplate kVA divided by secondary line-to-neutral voltage).

Note: UL Listed transformers 25 kVA and greater have a ± 10% tolerance on their impedance nameplate.

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Impedance Data for Single-Phase and Three-Phase Transformers-Supplement[†]

KVA 10	30	%Z	Suggested X/R Ratio for Calculation
10	—	1.2	1.1
15	—	1.3	1.1
75	—	1.11	1.5
150	—	1.07	1.5
225	—	1.12	1.5
300	—	1.11	1.5
333	—	1.9	4.7
500	—	1.24	1.5
500	—	2.1	5.5

†These represent actual transformer nameplate ratings taken from field installations.

Note: UL Listed transformers 25kVA and greater have a ±10% tolerance on their impedance nameplate.

Table 3. Various Types of Short -Circuit Currents as a Percent of Three Phase Bolted Faults (Typical).

Three Phase Bolted Fault	100%
Line-to-Line Bolted Fault	87%
Line-to-Ground Bolted Fault	25-125%* (Use 100% near transformer, 50% otherwise)
Line-to-Neutral Bolted Fault	25-125% (Use 100% near transformer, 50% otherwise)
Three Phase Arcing Fault	89% (maximum)
Line-to-Line Arcing Fault	74% (maximum)
Line-to-Ground Arcing Fault (minimum)	38% (minimum)

*Typically much lower but can actually exceed the Three Phase Bolted Fault if it is near the transformer terminals. Will normally be between 25% to 125% of three phase bolted fault value.

Conductors & Busways "C" Values

Table 4. "C" Values for Conductors

Copper		Three Single Conductors						Three-Conductor Cable						
AWG or kcmil	Steel	Nonmagnetic			Conduit			Steel	Nonmagnetic			Steel	Nonmagnetic	
		600V	5kV	15kV	600V	5kV	15kV		600V	5kV	15kV			
14	389	-	-	-	389	-	-	389	-	-	-	389	-	
12	617	-	-	-	617	-	-	617	-	-	-	617	-	
10	981	-	-	-	982	-	-	982	-	-	-	982	-	
8	1557	1551	-	1559	1555	-	1559	1557	-	1560	1558	-	-	
6	2425	2406	2389	2430	2418	2407	2431	2425	2415	2433	2428	2421	-	
4	3806	3751	3696	3826	3789	3753	3830	3812	3779	3838	3823	3798	-	
3	4774	4674	4577	4811	4745	4679	4820	4785	4726	4833	4803	4762	-	
2	5907	5736	5574	6044	5926	5809	5989	5930	5828	6087	6023	5958	-	
1	7293	7029	6759	7493	7307	7109	7454	7365	7189	7579	7507	7364	-	
1/0	8925	8544	7973	9317	9034	8590	9210	9086	8708	9473	9373	9053	-	
2/0	10755	10062	9390	11424	10878	10319	11245	11045	10500	11703	11529	11053	-	
3/0	12844	11804	11022	13923	13048	12360	13656	13333	12613	14410	14119	13462	-	
4/0	15082	13606	12543	16673	15351	14347	16392	15890	14813	17483	17020	16013	-	
250	16483	14925	13644	18594	17121	15866	18311	17851	16466	19779	19352	18001	-	
300	18177	16293	14769	20868	18975	17409	20617	20052	18319	22525	21938	20163	-	
350	19704	17385	15678	22737	20526	18672	22646	21914	19821	24904	24126	21982	-	
400	20566	18235	16366	24297	21786	19731	24253	23372	21042	26916	26044	23518	-	
500	22185	19172	17492	26706	23277	21330	26980	25449	23126	30096	28712	25916	-	
600	22965	20567	17962	28033	25204	22097	28752	27975	24897	32154	31258	27766	-	
750	24137	21387	18889	29735	26453	23408	31051	30024	26933	34605	33315	29735	-	
1,000	25278	22539	19923	31491	28083	24887	33864	32689	29320	37197	35749	31959	-	
Aluminum														
14	237	-	-	237	-	-	237	-	-	237	-	-	-	-
12	376	-	-	376	-	-	376	-	-	376	-	-	-	-
10	599	-	-	599	-	-	599	-	-	599	-	-	-	-
8	951	950	-	952	951	-	952	951	-	952	952	-	-	-
6	1481	1476	1472	1482	1479	1476	1482	1480	1478	1482	1481	1479	-	-
4	2346	2333	2319	2350	2342	2333	2351	2347	2339	2353	2350	2344	-	-
3	2952	2928	2904	2961	2945	2929	2963	2955	2941	2966	2959	2949	-	-
2	3713	3670	3626	3730	3702	3673	3734	3719	3693	3740	3725	3709	-	-
1	4645	4575	4498	4678	4632	4580	4686	4664	4618	4699	4682	4646	-	-
1/0	5777	5670	5493	5838	5766	5646	5852	5820	5717	5876	5852	5771	-	-
2/0	7187	6968	6733	7301	7153	6986	7327	7271	7109	7373	7329	7202	-	-
3/0	8826	8467	8163	9110	8851	8627	9077	8981	8751	9243	9164	8977	-	-
4/0	10741	10167	9700	11174	10749	10387	11185	11022	10642	11409	11277	10969	-	-
250	12122	11460	10849	12862	12343	11847	12797	12636	12115	13236	13106	12661	-	-
300	13910	13009	12193	14923	14183	13492	14917	14698	13973	15495	15300	14659	-	-
350	15484	14280	13288	16813	15858	14955	16795	16490	15541	17635	17352	16501	-	-
400	16671	15355	14188	18506	17321	16234	18462	18064	16921	19588	19244	18154	-	-
500	18756	16828	15657	21391	19503	18315	21395	20607	19314	23018	22381	20978	-	-
600	20093	18428	16484	23451	21718	19635	23633	23196	21349	25708	25244	23295	-	-
750	21766	19685	17686	25976	23702	21437	26432	25790	23750	29036	28262	25976	-	-
1,000	23478	21235	19006	28779	26109	23482	29865	29049	26608	32938	31920	29135	-	-

Note: These values are equal to one over the impedance per foot and based upon resistance and reactance values found in IEEE Std 241-1990 (Gray Book), IEEE Recommended Practice for Electric Power Systems in Commercial Buildings & IEEE Std 242-1986 (Buff Book), IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems. Where resistance and reactance values differ or are not available, the Buff Book values have been used. The values for reactance in determining the C Value at 5 KV & 15 KV are from the Gray Book only (Values for 14-10 AWG at 5 KV and 14-8 AWG at 15 KV are not available and values for 3 AWG have been approximated).

Table 5. "C" Values for Busway

Ampacity	Busway				
	Plug-In		Feeder		
	Copper	Aluminum	Copper	Aluminum	Copper
225	28700	23000	18700	12000	—
400	38900	34700	23900	21300	—
600	41000	38300	36500	31300	—
800	46100	57500	49300	44100	—
1000	69400	89300	62900	56200	15600
1200	94300	97100	76900	69900	16100
1350	119000	104200	90100	84000	17500
1600	129900	120500	101000	90900	19200
2000	142900	135100	134200	125000	20400
2500	143800	156300	180500	166700	21700
3000	144900	175400	204100	188700	23800
4000	—	—	277800	256400	—

Note: These values are equal to one over the impedance per foot for impedance in a survey of industry.

Ratings of Conductors and Tables to Determine Volt Loss

With larger loads on new installations, it is extremely important to consider volt loss, otherwise some very unsatisfactory problems are likely to be encountered.

The actual conductor used must also meet the other sizing requirements such a full-load current, ambient temperature, number in a raceway, etc.

How to Figure Volt Loss

Multiply *distance* (length in feet of one wire) by the *current* (expressed in amps) by the *figure* shown in table for the kind of current and the size of wire to be used, by one over the number of conductors per phase.

Then, put a decimal point in front of the last 6 digits—you have the *volt loss* to be

Example – 6 AWG copper wire, one per phase, in 180 feet of steel conduit—3 phase, 40 amp load at 80% power factor.

Multiply feet by amperes: $180 \times 40 = 7200$

Multiply this number by number from table for 6 AWG wire three-phase at 80% power factor: $7200 \times \underline{745}^{\dagger} = 5364000$

Multiply by $\frac{1}{\#/\text{phase}} \times 5364000 = \frac{1}{1} \times 5364000 = 5364000$

Place decimal point 6 places to left:

This gives volt loss to be expected: 5.364V

(For a 240V circuit the % voltage drop is $\frac{5.364}{240} \times 100$ or 2.23%).

Table A and B take into consideration *reactance on AC circuits* as well as resistance of the wire.

Remember on short runs to check to see that the size and type of wire indicated has sufficient ampacity.

expected on that circuit.

How to Select Size of Wire

Multiply *distance* (length in feet of one wire) by the *current* (expressed in amps), by one over the number of conductors per phase.

Divide that figure into the permissible *volt loss* multiplied by 1,000,000.

Example – Copper in 180 feet of steel conduit—3 phase, 40 amp load at 80% power factor—maximum volt loss permitted from local code equals 5.5 volts.

Multiply feet by amperes by $\frac{1}{\#/\text{phase}}$ $180 \times 40 \times \frac{1}{1} = 7200$.

Divide permissible volt loss multiplied by 1,000,000 by this number: $\frac{5.5 \times 1,000,000}{7200} = 764$.

Look under the column in Table A and B applying to the type of current and power factor for the value nearest, but not above your result – you have the size of wire needed.

Select number from Table A, three-phase at 80% power factor, that is nearest but not greater than 764. This number is 745 which indicates the size of wire needed: 6 AWG.

Line-to-Neutral

For line to neutral voltage drop on a 3 phase system, divide the three phase value by 1.73. For line to neutral voltage drop on a single phase system, divide single phase value by 2.

Open Wiring

The volt loss for open wiring installations depends on the separation between conductors. The volt loss is approximately equal to that for conductors in non-magnetic conduit.

Installation in Conduit, Cable or Raceway

NEC® Tables 310.15(B)(16) through 310.15(B)(19) give allowable ampacities (current-carrying capacities) for not more than three current carrying conductors in a conduit, cable, or raceway. Where the number of current carrying conductors exceeds three the allowable ampacity of each conductor must be reduced as shown in the following tables:

Installation in Conduit, Cable or Raceway per 310.15(B)(2)(a)

The Number of Conductors In One Conduit, Raceway Or Cable	Percentage of Values In Tables 310.16 And 310.18
4 to 6	80%
7 to 9	70%
10 to 20	50%
21 to 30	45%
31 to 40	40%
41 and over	35%

Conditions Causing Higher Volt Loss

The voltage loss is increased when a conductor is operated at a higher temperature because the resistance increases.

Room Temperature Affects Ratings

The ampacities (carrying capacities) of conductors are based on a room temperature of either 30°C or 40°C. For derating based upon 30°C ambient, if room temperature is higher, the ampacities are reduced by using the following multipliers; (for 0-2000 volt, insulated conductors not more than 3 conductors in raceway or direct buried, Table 310.15(B)(2)(a)). For room temperatures based upon a 40°C ambient, see Table 310.15(B)(2)(b).

Room Temperature Affects Ratings

Room Temperature °C	TW °F	Ampacity Multiplier		
		THW, THWN (60°C Wire)	THHN, XHHW* (75°C Wire)	(90°C Wire)
31-35	87-95	.91	.94	.96
36-40	96-104	.82	.88	.91
41-45	105-113	.71	.82	.87
46-50	114-122	.58	.75	.82
51-55	123-131	.41	.67	.76
56-60	132-140	—	.58	.71
61-70	141-158	—	.33	.58
71-80	159-176	—	—	.41

[†] Value from Table A

Table A – Copper Conductors – Ratings & Volt Loss[†]

Conduit	Wire Size	Ampacity			Direct Current	Volt Loss (See explanation prior page.)						Single-Phase						
		Three-Phase (60 Cycle, Lagging Power Factor.)				Single-Phase (60 Cycle, Lagging Power Factor.)												
		Type	Type	Type		100%	90%	80%	70%	60%	100%	90%	80%	70%	60%			
Steel Conduit	14	20*	20*	25*	6140	5369	4887	4371	3848	3322	6200	5643	5047	4444	3836			
	12	25*	25*	30*	3860	3464	3169	2841	2508	2172	4000	3659	3281	2897	2508			
	10	30	35*	40*	2420	2078	1918	1728	1532	1334	2400	2214	1995	1769	1540			
	8	40	50	55	1528	1350	1264	1148	1026	900	1560	1460	1326	1184	1040			
	6	55	65	75	982	848	812	745	673	597	980	937	860	777	690			
	4	70	85	95	616	536	528	491	450	405	620	610	568	519	468			
	3	85	100	110	490	433	434	407	376	341	500	501	470	434	394			
	2	95	115	130	388	346	354	336	312	286	400	409	388	361	331			
	1	110	130	150	308	277	292	280	264	245	320	337	324	305	283			
	0	125	150	170	244	207	228	223	213	200	240	263	258	246	232			
	00	145	175	195	193	173	196	194	188	178	200	227	224	217	206			
	000	165	200	225	153	136	162	163	160	154	158	187	188	184	178			
	0000	195	230	260	122	109	136	140	139	136	126	157	162	161	157			
	250	215	255	290	103	93	123	128	129	128	108	142	148	149	148			
	300	240	285	320	86	77	108	115	117	117	90	125	133	135	135			
	350	260	310	350	73	67	98	106	109	109	78	113	122	126	126			
	400	280	335	380	64	60	91	99	103	104	70	105	114	118	120			
	500	320	380	430	52	50	81	90	94	96	58	94	104	109	111			
	600	335	420	475	43	43	75	84	89	92	50	86	97	103	106			
	750	400	475	535	34	36	68	78	84	88	42	79	91	97	102			
	1000	455	545	615	26	31	62	72	78	82	36	72	84	90	95			
Non-Magnetic Conduit	14	20*	20*	25*	6140	5369	4876	4355	3830	3301	6200	5630	5029	4422	3812			
	12	25*	25*	30*	3464	3464	3158	2827	2491	2153	4000	3647	3264	2877	2486			
	10	30	35*	40*	2420	2078	1908	1714	1516	1316	2400	2203	1980	1751	1520			
(Lead Covered Cables or Installation in Fibre or Other Non-Magnetic Conduit, Etc.)	8	40	50	55	1528	1350	1255	1134	1010	882	1560	1449	1310	1166	1019			
	6	55	65	75	982	848	802	731	657	579	980	926	845	758	669			
	4	70	85	95	616	536	519	479	435	388	620	599	553	502	448			
	3	85	100	110	470	433	425	395	361	324	500	490	456	417	375			
	2	95	115	130	388	329	330	310	286	259	380	381	358	330	300			
	1	110	130	150	308	259	268	255	238	219	300	310	295	275	253			
	0	125	150	170	244	207	220	212	199	185	240	254	244	230	214			
	00	145	175	195	193	173	188	183	174	163	200	217	211	201	188			
	000	165	200	225	153	133	151	150	145	138	154	175	173	167	159			
	0000	195	230	260	122	107	127	128	125	121	124	147	148	145	140			
	250	215	255	290	103	90	112	114	113	110	104	129	132	131	128			
	300	240	285	320	86	76	99	103	104	102	88	114	119	120	118			
	350	260	310	350	73	65	89	94	95	94	76	103	108	110	109			
	400	280	335	380	64	57	81	87	89	89	66	94	100	103	103			
	500	320	380	430	52	46	71	77	80	82	54	82	90	93	94			
	600	335	420	475	43	39	65	72	76	77	46	75	83	87	90			
	750	400	475	535	34	32	58	65	70	72	38	67	76	80	83			
	1000	455	545	615	26	25	51	59	63	66	30	59	68	73	77			

* The overcurrent protection for conductor types marked with an (*) shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper; or 15 amperes for 12 AWG and 25 amperes for 10 AWG aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

† Figures are L-L for both single-phase and three-phase. Three-phase figures are average for the three-phase.

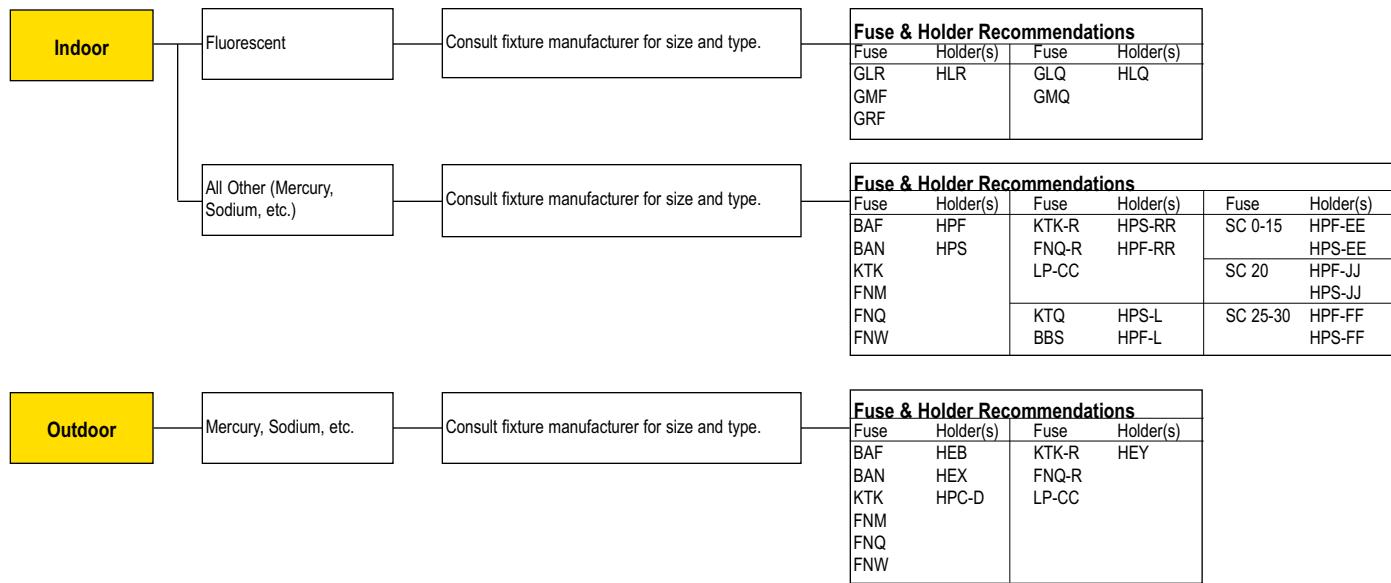
Table B – Aluminum Conductors – Ratings & Volt Loss[†]

Conduit	Wire Size	Ampacity			Direct Current	Volt Loss (See explanation two pages prior.)						Single-Phase						
		Three-Phase				(60 Cycle, Lagging Power Factor.)						(60 Cycle, Lagging Power Factor.)						
		Type	Type	Type		100%	90%	80%	70%	60%	100%	90%	80%	70%	60%			
Steel Conduit	12	20*	20*	25*	6360	5542	5039	4504	3963	3419	6400	5819	5201	4577	3948			
	10	25	30*	35*	4000	3464	3165	2836	2502	2165	4000	3654	3275	2889	2500			
	8	30	40	45	2520	2251	2075	1868	1656	1441	2600	2396	2158	1912	1663			
	6	40	50	60	1616	1402	1310	1188	1061	930	1620	1513	1372	1225	1074			
	4	55	65	75	1016	883	840	769	692	613	1020	970	888	799	708			
	3	65	75	85	796	692	668	615	557	497	800	771	710	644	574			
	2	75	90	100	638	554	541	502	458	411	640	625	580	529	475			
	1	85	100	115	506	433	432	405	373	338	500	499	468	431	391			
	0	100	120	135	402	346	353	334	310	284	400	407	386	358	328			
	00	115	135	150	318	277	290	277	260	241	320	335	320	301	278			
	000	130	155	175	259	225	241	234	221	207	260	279	270	256	239			
	0000	150	180	205	200	173	194	191	184	174	200	224	221	212	201			
	250	170	205	230	169	148	173	173	168	161	172	200	200	194	186			
	300	190	230	255	141	124	150	152	150	145	144	174	176	173	168			
	350	210	250	280	121	109	135	139	138	134	126	156	160	159	155			
	400	225	270	305	106	95	122	127	127	125	110	141	146	146	144			
	500	260	310	350	85	77	106	112	113	113	90	122	129	131	130			
	600	285	340	385	71	65	95	102	105	106	76	110	118	121	122			
	750	320	385	435	56	53	84	92	96	98	62	97	107	111	114			
	1000	375	445	500	42	43	73	82	87	89	50	85	95	100	103			
Non-Magnetic Conduit (Lead Covered Cables or Installation in Fibre or Other Non-Magnetic Conduit, Etc.)	12	20*	20*	25*	6360	5542	5029	4490	3946	3400	6400	5807	5184	4557	3926			
	10	25	30*	35*	4000	3464	3155	2823	2486	2147	4000	3643	3260	2871	2480			
	8	30	40	45	2520	2251	2065	1855	1640	1423	2600	2385	2142	1894	1643			
	6	40	50	60	1616	1402	1301	1175	1045	912	1620	1502	1357	1206	1053			
	4	55	65	75	1016	883	831	756	677	596	1020	959	873	782	668			
	3	65	75	85	796	692	659	603	543	480	800	760	696	627	555			
	2	75	90	100	638	554	532	490	443	394	640	615	566	512	456			
	1	85	100	115	506	433	424	394	360	323	500	490	455	415	373			
	0	100	120	135	402	346	344	322	296	268	400	398	372	342	310			
	00	115	135	150	318	277	281	266	247	225	320	325	307	285	260			
	000	130	155	175	252	225	234	223	209	193	260	270	258	241	223			
	0000	150	180	205	200	173	186	181	171	160	200	215	209	198	185			
	250	170	205	230	169	147	163	160	153	145	170	188	185	177	167			
	300	190	230	255	141	122	141	140	136	130	142	163	162	157	150			
	350	210	250	280	121	105	125	125	123	118	122	144	145	142	137			
	400	225	270	305	106	93	114	116	114	111	108	132	134	132	128			
	500	260	310	350	85	74	96	100	100	98	86	111	115	115	114			
	600	285	340	385	71	62	85	90	91	91	72	98	104	106	105			
	750	320	385	435	56	50	73	79	82	82	58	85	92	94	95			
	1000	375	445	500	42	39	63	70	73	75	46	73	81	85	86			

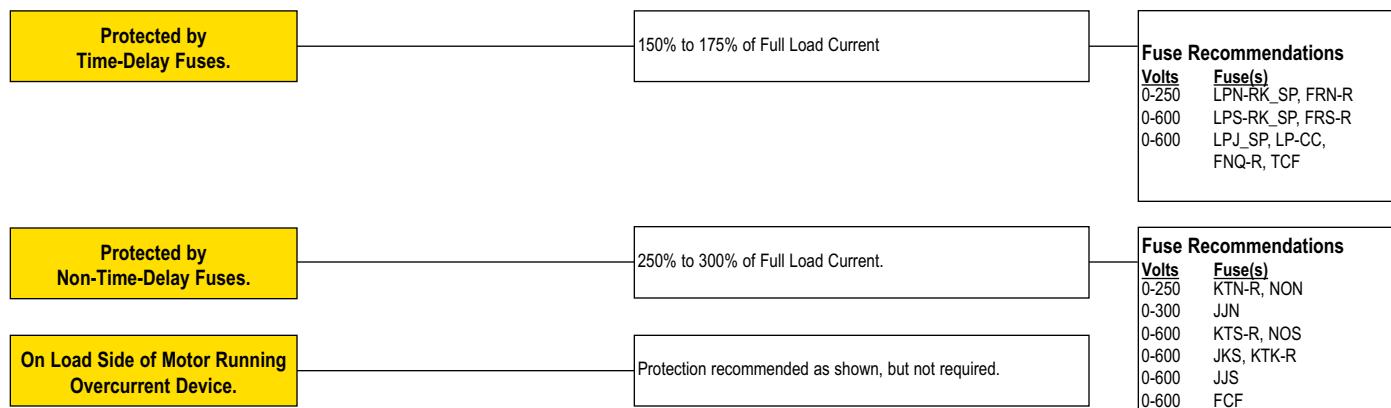
* The overcurrent protection for conductor types marked with an (*) shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper; or 15 amperes for 12 AWG and 25 amperes for 10 AWG aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

† Figures are L-L for both single-phase and three-phase. Three-phase figures are average for the three-phase.

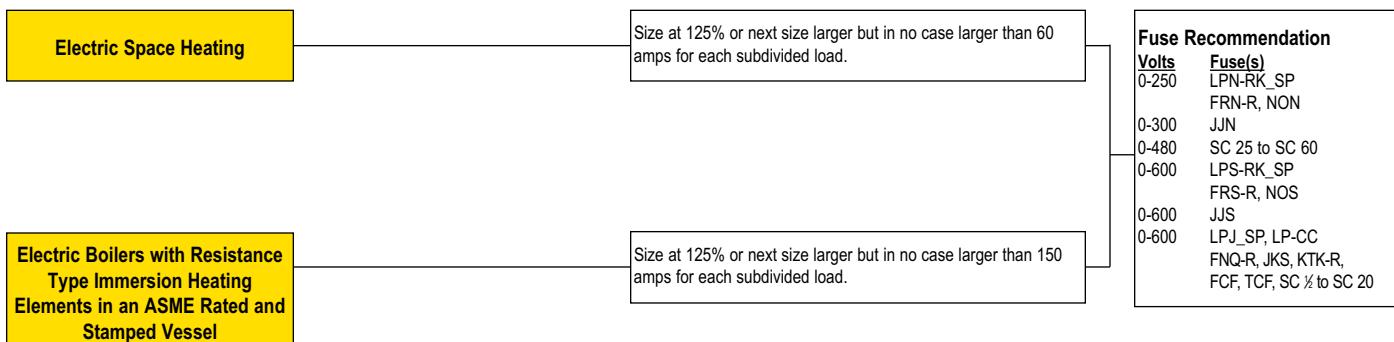
Ballasts



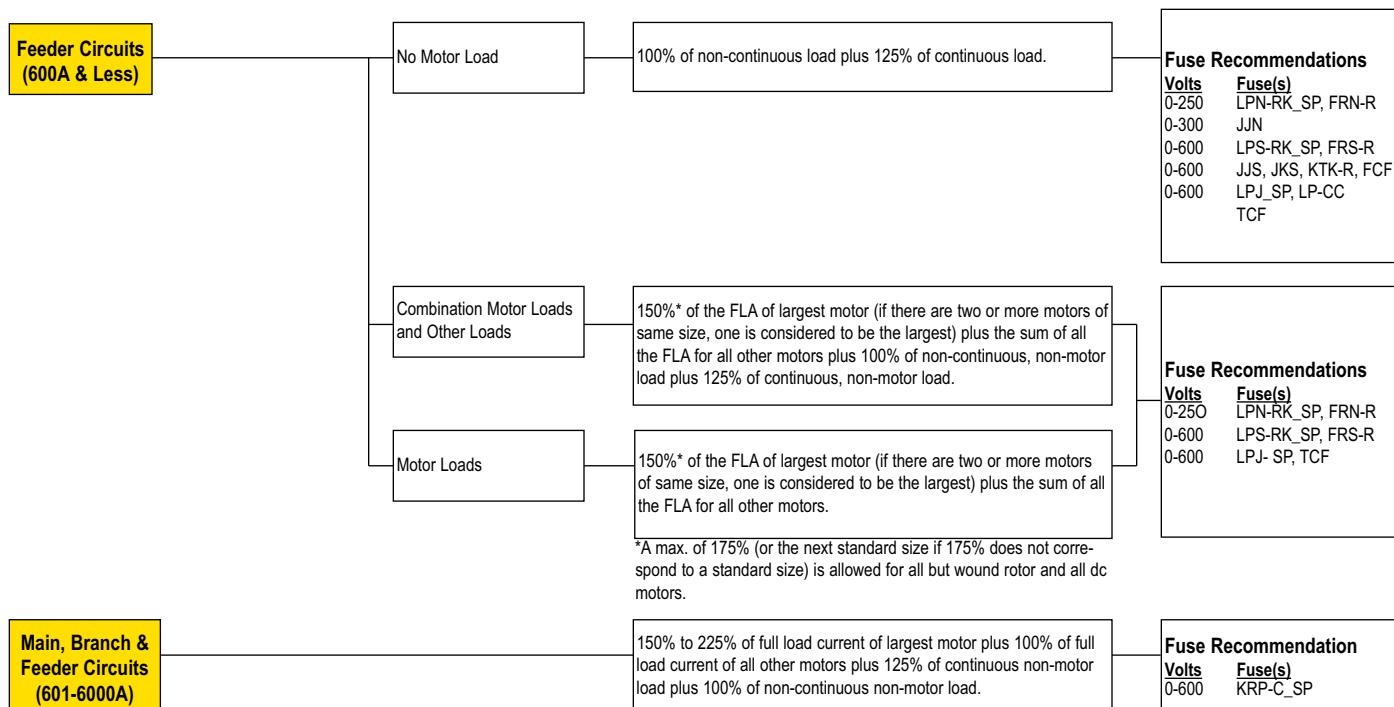
Capacitors (NEC® 460)



Electric Heat (NEC® 424)

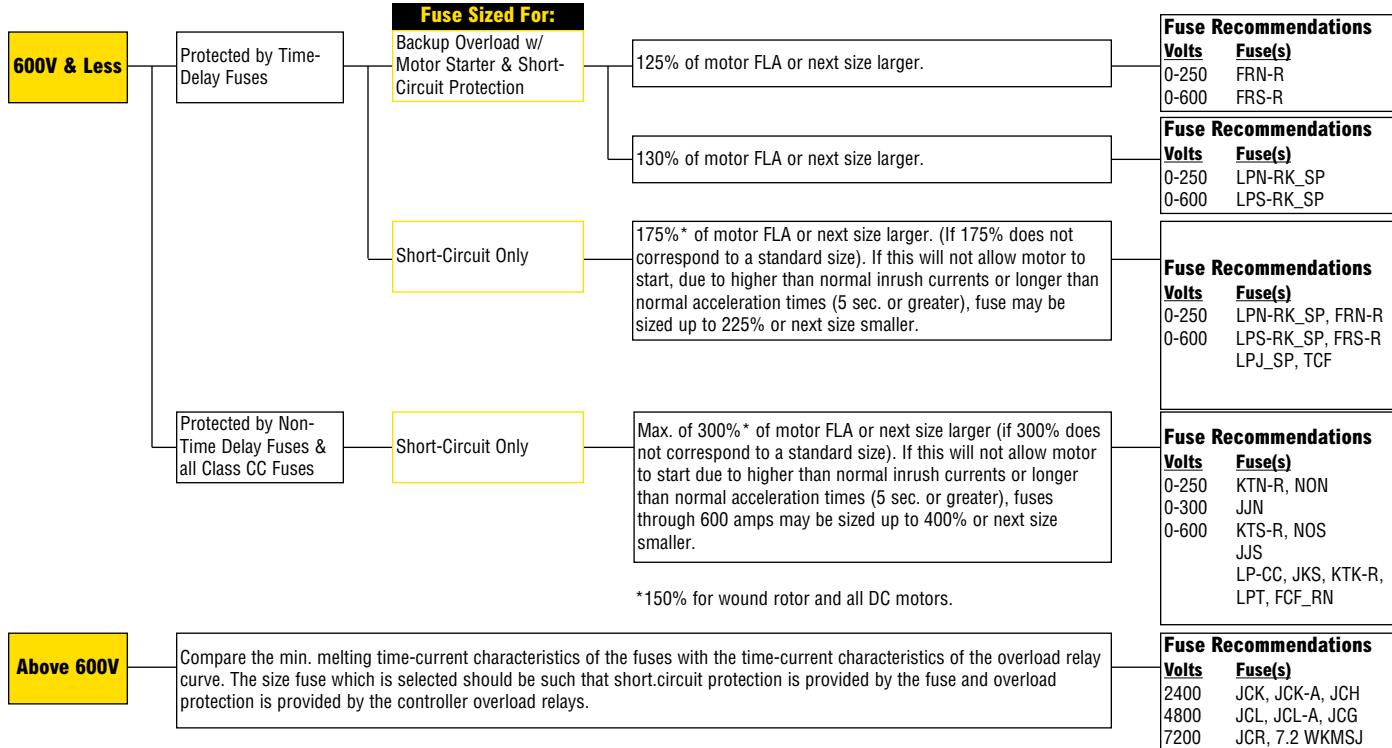


Mains, Feeders, Branches

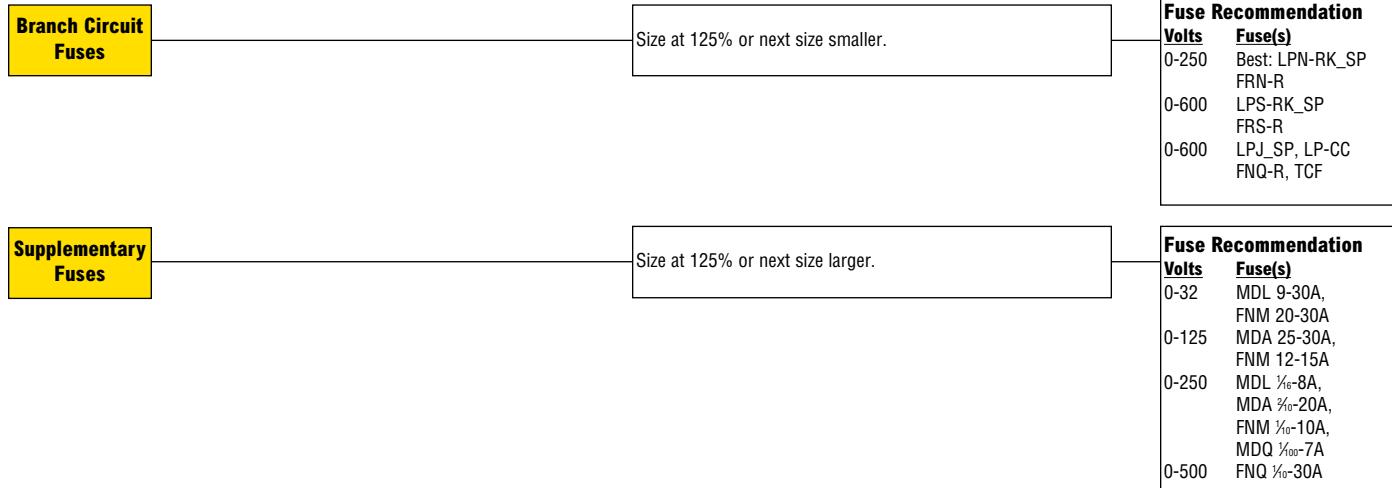


Motor Loads (NEC® 430)

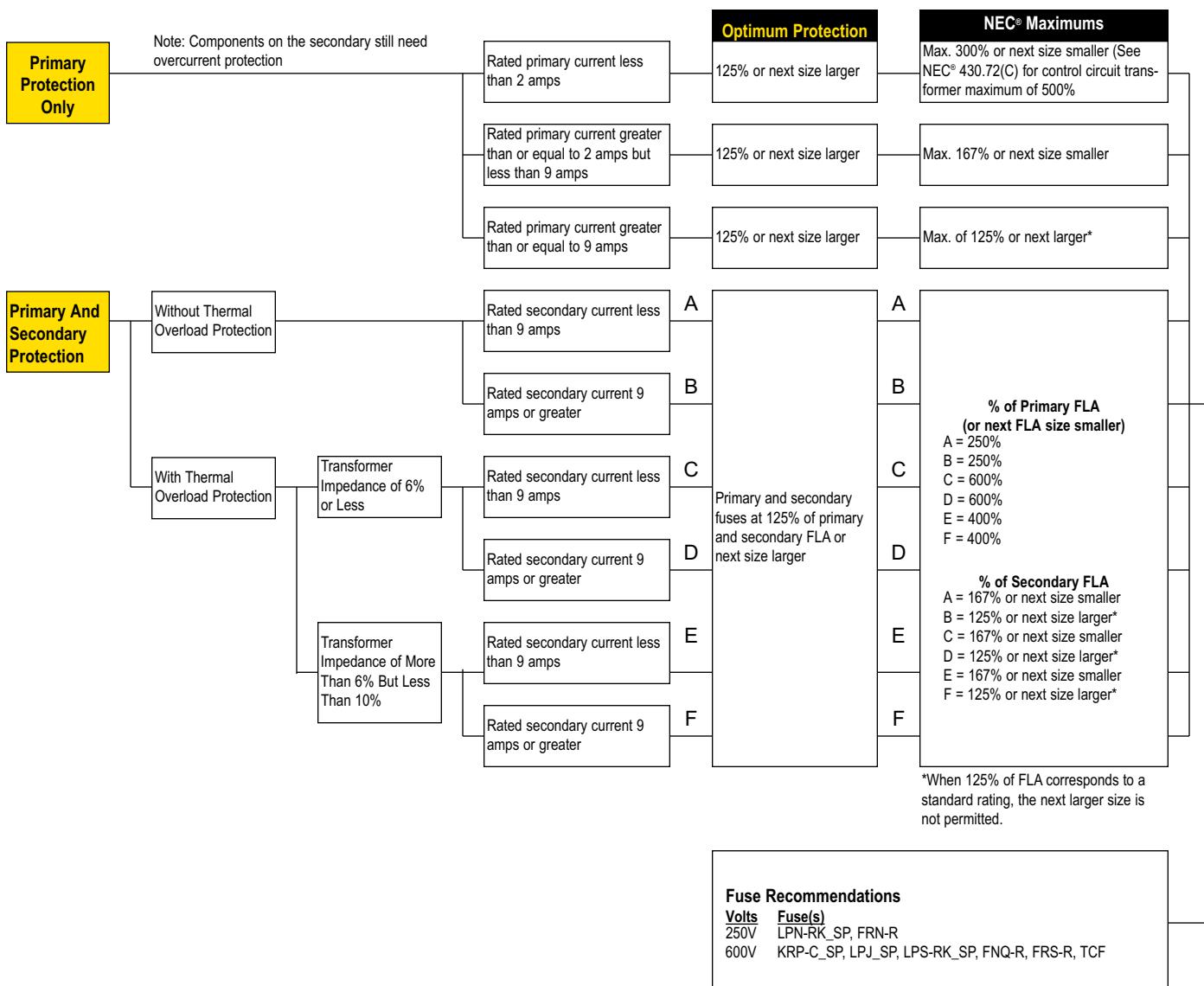
Motor Loads (NEC® 430)



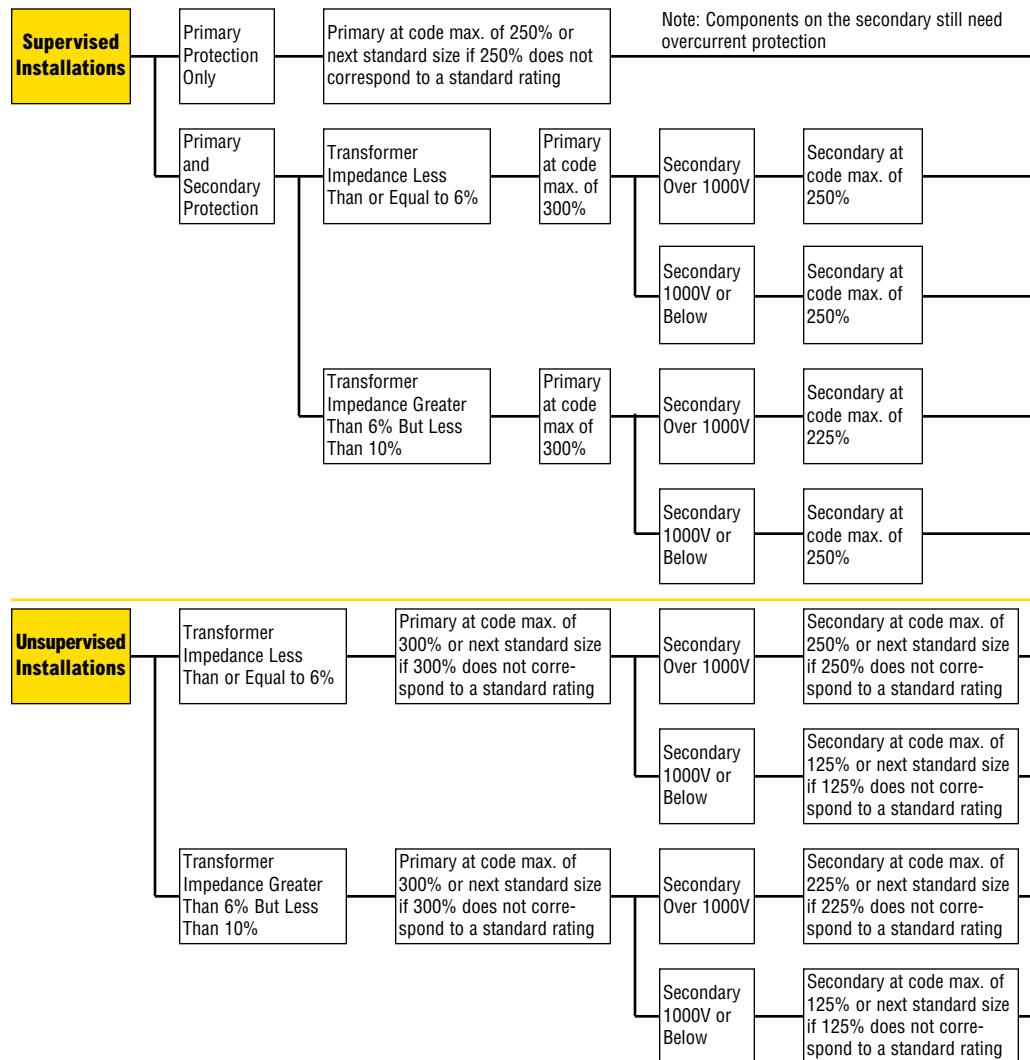
Solenoids (Coils)



Transformers 1000V Nominal or Less (NEC® 450.3)



Transformers Over 1000V Nominal (NEC® 450.3)



Fuse Recommendations

Volts	Fuse(s)
250V	LPN-RK_SP, FRN-R
600V	LPS-RK_SP, LPJ_SP, KRP-C_SP, FRS-R, FNQ-R, TCF
2475V	JCD
2750V	JCX
2750/5500V	JCW
5500V	MV05, 5.5 ABWNA, 5.5 AMWNA, 5.5 FFN
7200V	7.2 AMWNA, 7.2 TDLSJ, 7.2 TFLSJ
8300V	JCZ, JDZ, 8.25 FFN
15500V	MV155, 15.5 CAVH
17500V	17.5 CAV, 17.5 TDM
24000V	24 TDM, 24 TFM, 24 FFM
36000V	36 CAV, 36 TDQ, 36 TFQ
38000V	38 CAV

Solid State Devices (Diodes, SCRs, Triacs, Transistors)

Short-Circuit Protection Only

"F," "S," "K," & 170M Series fuses sized up to several sizes larger than full load RMS or DC rating of device.
DFG is 600V high speed fuse and UL Class J.

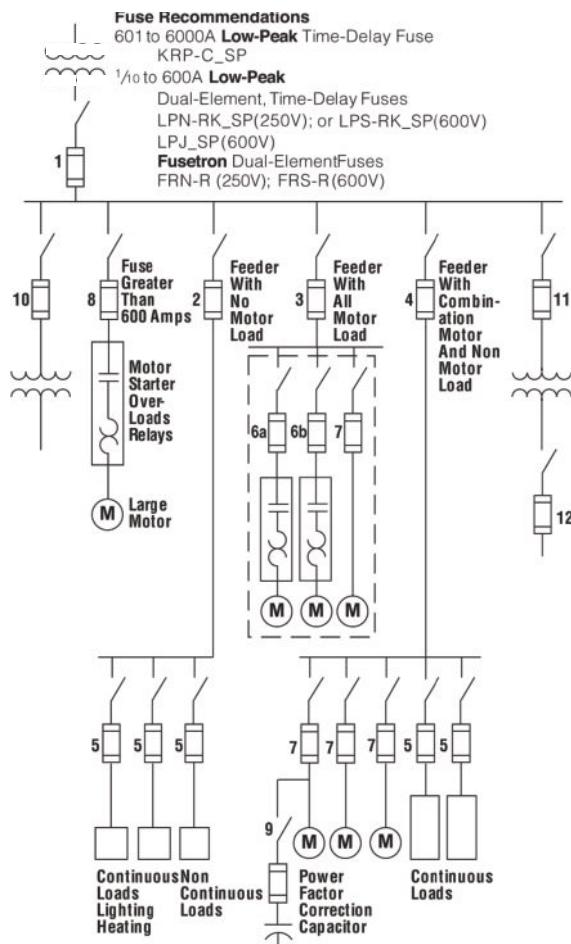
Fuse Recommendations

Volts	Fuse(s)
0-130	FWA
0-250	FWX
0-500	FWH
0-600	FWC, KAC, KBC, DFJ
0-700	FWP, 170M Series, SPP
0-1000	FWJ, 170M Series, SPJ

Building Electrical System, 600V or less

Fuse Ampacity Selection Guide

General guidelines are given for selecting fuse amp ratings for most circuits. Some specific applications may warrant other fuse sizing; in these cases the load characteristics and appropriate NEC® sections should be considered. The selections shown here are not, in all cases, the maximum or minimum amp ratings permitted by the NEC®. Demand factors as permitted per the NEC® are not included in these guidelines. Study the pertinent NEC® Sections referenced by () and reference pertinent footnotes.



Dual-Element, Time-Delay Classes J, CF, RK1, and RK5 Fuses (1A to 600A)

(For fuses above 600A, use Class L time-delay fuses, which have ampere ratings 601 to 6000A; these fuses are not dual-element construction.)

- Main Service.** Size fuse according to method in 4 below.
- Feeder Circuit With No Motor Loads. (215.3)** The fuse size must be at least 125% of the continuous load† plus 100% of the non-continuous load. Do not size larger than ampacity of conductor.*
- Feeder Circuit With All Motor Loads. (430.62)** Size the fuse at 150% to 175% of the full load current** of the largest motor plus the full-load current** of all other motors^a.
- Feeder Circuit With Mixed Loads^a. (430.63)** Size fuse at sum of:
 - 150% to 175%† of the full-load current** of the largest motor plus
 - 100% of the full-load current** of all other motors plus
 - 125% of the continuous, non-motor load† plus
 - 100% of the non-continuous, non-motor load.

- Branch Circuit With No Motor Load. (210.20)** The fuse size must be at least 125% of the continuous load† plus 100% of the non-continuous load. Do not size larger than ampacity of conductor.*

- Motor Branch Circuit With Overload Relays.** Where overload relays are sized per 430.32 for motor running overload protection, there are various alternatives:

- Motor branch circuit short-circuit and ground fault protection. (430.52)** (Most common) Size the fuse between 150 to 175%†† of the full load current.** Provides branch circuit short-circuit and ground fault protection only.

- Motor branch circuit short-circuit and ground fault protection (430.52) as well as backup overload protection.** Size FRN-R and FRS-R Class RK5, dual-element, time-delay fuses at 125% and LPN-RK_SP and LPS-RK_SP Class RK1, dual-element, time-delay fuses at 130% of motor full-load current or next higher size. This results in closer fuse sizing and provides a degree of backup running overload protection. In addition, it provides motor branch circuit short-circuit and ground fault protection.

Sizing in this manner may result in better motor protection if the overload relays are not sized properly or are not calibrated properly.

- Motor Branch Circuit With Fuse Protection Only.** Where the fuse is the only motor protection, the following FRS-R and FRN-R, Class RK5, fuses provide motor running overload protection (430.32) and short-circuit protection (430.52):

- Motor 1.15 service factor or 40°C rise:** size the fuse at 110% to 125% of the motor full-load current on the name plate [430.6(a)(2)].
- Motor less than 1.15 service factor or over 40°C rise:** size fuse at 100% to 115% of motor full-load current on the name plate [430.6(a)(2)].

- Large Motor Branch Circuit. Fuse larger than 600 amps. [436.52(c) and 430.52(c)(1) exceptions 2(d)]** For large motors, size KRP-C_SP Low-Peak time-delay fuse at 175% to 300% of the motor full-load current**, depending on the starting method; i.e. part-winding starting, reduced voltage starting, etc.

- Power Factor Correction Capacitors. [460.8(b)]** Size dual-element fuses as low as practical, typically 150% to 175% of capacitor rated current.

- Transformer Primary Fuse (without secondary fuse protection). [450.3(b)]**

When transformer primary current is equal to or greater than 9 amps, the dual-element, time-delay fuse should be sized at 125% of transformer primary current or the next size larger if 125% does not correspond to a standard fuse size. Note: Secondary conductors must be protected from overcurrent damage per Article 240.

- Transformer Primary Fuse (with secondary fuse protection). [450.3(b)]** May be sized at 250% of transformer primary current if,

- The secondary fuse is sized** at no more than 125% of secondary full-load current. [450.3(b)] Note: Secondary conductors must be protected at their ampacities per Article 240.

Non-Time-Delay and all Class CC Fuses (JKS, FCF, KTS-R, KTN-R, JJS, JJN, LP-CC, KTK-R, and FNQ-R)

- Main service.** Size fuse according to method in 4.
- Feeder Circuit With No Motor Loads. (215.3)** The fuse size must be at least 125% of the continuous load† plus 100% of the non-continuous load. Do not size larger than the ampacity of the conductor.*
- Feeder Circuit With All Motor Loads. (430.62)** Size the fuse at 300% of the full-load current** of the largest motor plus the full-load current** of all other motors.
- Feeder Circuit With Mixed Loads. (430.62)** Size fuse at sum of:
 - 300% of the full-load current** of the largest motor plus
 - 100% of the full-load current** of all other motors plus
 - 125% of the continuous, non-motor load† plus
 - 100% of the non-continuous, non-motor load.
- Branch Circuit With No Motor Loads. (210.20)** The fuse size must be at least 125% of the continuous load† plus 100% of the non-continuous load. Do not size larger than the ampacity of conductor.*

Building Electrical System, 600V or less

6a. Motor Branch Circuit with Overload Relays. (430.52) Size the fuse at 300% of the full load current**. Provides branch circuit short-circuit and ground fault protection only. Other means must be utilized to provide motor overload protection (see 430.32).

(If 300% is not a standard fuse ampere rating, 430.52(C)(1) Exception 1 permits the next standard fuse ampere rating. If the motor cannot start with this size fuse, 430.52(C)(1) Exception 2 permits increasing the fuse size up to 400% provided the fuse rating does not exceed 600 amperes.)

6b. Motor branch circuit short-circuit and ground fault protection (430.52) as well as backup overload protection. Not applicable for non-time-delay fuses; use FRN-R and FRS-R, Class RK5, dual-element time-delay fuses or LPN-RK_SP and LPS-RK_SP Class RK1, dual-element, time-delay fuses (see 6b under dual-element time-delay fuse selection). Non-time-delay fuses cannot be sized close enough to provide motor running backup overload protection. If sized for motor overload backup protection, non-time-delay fuses would open due to motor starting current.

7. Motor Branch Circuit With Fuse Protection Only. Not applicable for non-time-delay fuses; use FRN-R and FRS-R, Class RK5, dual-element time-delay fuses (see 7 under dual-element time-delay fuse selection). Non-time-delay fuses cannot be sized close enough to provide motor running overload protection. If sized for motor overload protection, non-time-delay fuses would open due to motor starting current.

8. Power Factor Correction Capacitors. [460.8(B)] Size non-time-delay fuses as low as practical, typically 250% to 300% of capacitor rated current.

† 100% of the continuous load can be used rather than 125% when the switch and fuse are listed for 100% continuous operation as an assembly (for instance, 215.3 Exc 1). Some bolted pressure switches and high pressure contact switches 400A to 6000A with Class J and L fuses in specified assemblies are listed for 100% continuous operation.

* Where conductor ampacity does not correspond to a standard fuse amp rating, the next higher amp rating fuse is permitted when 800 amps or less ([240.4(B)]. Above 800A the conductor ampacity must be equal or greater than the fuse amp rating ([240.4(C)]). However, per 240.91(B), when above 800A for supervised industrial installations, the conductor ampacity is permitted to be 95% of the fuse amp rating as long as the equipment is listed for that size conductor and the conductor is protected within its time vs. current limits [240.4 Informational Note].

Δ In many motor feeder applications dual-element fuses can be sized at ampacity of feeder conductors.

• Available short-circuit current and the clearing time of the overcurrent device must be considered so that the conductor's ICEA (P32.382) withstand rating is not exceeded.

** On general motor applications, motor full load amperes for calculating conductor ampacity and for calculating fuse ampere ratings for motor branch circuit short-circuit and ground fault protection (430.52) are selected from NESC Tables 430.247 through 430.250 per 430.6(A)(1). However, the motor nameplate current rating is used for sizing motor overload protection (430.32) per 430.6(A)(2).

†† 430.52(C)(1) allows a maximum of 175% for time-delay fuses, for all but wound rotor and DC motors. A range of 150% to 175% was used for these guidelines, even though 430.52(C)(1) allows a maximum of 175% for time-delay fuses as stated above. The reason for showing this range is to highlight the possibility for application selection. In some situations, there may be a difference in the switch ampere rating or fuse block ampere rating in selecting 150% versus 175%. Using 175% is permitted and is suggested for heavy starting current or longer starting time applications.

Further note: the NEC permits larger sizing via two exceptions. 430.52(C)(1) Exception 1 permits the next standard size if 175% does not correspond with a standard fuse amp rating. If the motor cannot start with this size fuse, 430.52(C)(1) Exception 2 permits increasing a time-delay fuse size up to 225%.

(Note that while a time-delay fuse may not exceed 225% when using Exception 2, the use of a time-delay fuse could exceed 225% when using Exception 1. For example, assume a motor with a FLA of 1.0 ampere. 430.52(C)(1) would allow a 1.75 ampere fuse. Exception 1 would allow a 3 ampere time-delay fuse per 240.6(A). Exception 2 limits the time delay fuse to 2.25 amperes as a maximum, but Exception 2 is not utilized or needed if Exception 1 is adequate.)

***The conductor ampacity may have to be greater due to application of adjustment or correction factors per 210.19(A)(1) and 215.2(A)(1).

Conductor Ampacity Selection

- 1. Feeder Circuit And Main Circuit With Mixed Loads. (430.24)** Conductor ampacity at least sum of:
 - a. 100%^{††} of the full-load current** of the largest motor plus
 - a. 100% of the full-load current** of all other motors plus
 - c. 125% of the continuous, non-motor load† plus
 - d. 100% of the non-continuous, non-motor load.
- 2. Feeder Circuit With No Motor Load. [215.2(A)(1)]***** Conductor ampacity at least 125% of the continuous load plus 100% of the non-continuous load.
- 3. Feeder Circuit With All Motor Loads. (430.24)** Conductor ampacity at least 125% of the largest motor full-load amps plus 100% of all other motors' full-load amps.
- 4. Feeder Circuit With Mixed Loads. (430.24)** Size according to method 1 above.
- 5. Branch Circuit With No Motor Load. [210.19(A)(1)]** Conductor ampacity at least 125% of the continuous load plus 100% of the non-continuous load.
- 6, 7, & 8. Motor Branch Circuits. (430.22)** Conductor ampacity at least 125% of the motor full-load current.
- 9. Capacitor connected to motor branch circuit. (460.8)** Conductor ampacity at least 135% of capacitor rated current, and at least $\frac{1}{2}$ the ampacity of the motor circuit conductors.
- 10, 11. Conductor ampacity minimum 125% of transformer full-load current.**
- 12. Conductor ampacity per 1 above.**

Suggestions

General

Final tests and inspections shall be made prior to energizing the equipment. This shall include a thorough cleaning, tightening, and review of all electrical connections and inspection of all grounding conductors. All fuses shall be furnished and installed. All fuses shall be of the same manufacturer. Fuses shall be as follows:

A. Main, Feeder, and Branch Circuit Fuses

1. Circuits 601 through 6000 amps

Circuits 601 through 6000 amps shall be protected by current-limiting Bussmann Low-Peak Time-Delay Fuses KRP-C(amp)SP. Fuses shall be time-delay and shall hold 500% of rated current for a minimum of 4 seconds, clear 20 times rated current in .01 seconds or less, with an interrupting rating of 300,000 amps RMS symmetrical, and be listed by a nationally recognized testing laboratory. Peak let-through currents and I_t let-through energies shall not exceed the values established for Class L fuses. Larger Hp motors shall be protected by these fuses, with ratings as shown on the drawings.

2. Circuits 0 through 600 amps

Circuits 0 through 600 amps shall be protected by current-limiting Bussmann Low-Peak Dual-Element, Time-Delay Fuses LPN-RK(amp) SP/LPS-RK(amp)SP, TCF(amp) or LPJ(amp)SP. All fuses shall have separate overload and short-circuit elements. Fuses shall incorporate a spring activated thermal overload element that has a 284 degrees Fahrenheit melting point alloy. The fuses shall hold 500% of rated current for a minimum of 10 seconds (30A, 250V Class RK1 case size may be a minimum of 8 seconds at 500% of rated current) with an interrupting rating of 300,000 amps RMS symmetrical, and be listed by a nationally recognized testing laboratory. Peak let-through currents and I_t let-through energies shall not exceed the values established for Class RK1, CF or J fuses.

Motor Circuits - All individual motor circuits with full-load amp ratings (F.L.A.) of 461 (or 400) amps or less shall be protected by Bussmann Low-Peak Dual-Element, Time-Delay Fuses LPN-RK(amp)SP/LPS-RK(amp)SP, or TCF(amp), LPJ(amp)SP. The following guidelines apply for motors protected by properly sized overload relays: LPN-RK(amp)SP/LPS-RK(amp)SP fuses shall be installed in ratings of 130% (or 150% for TCF(amp), LPJ(amp)SP fuses) of motor full-load current (or next size larger if this does not correspond to a fuse size), except where high ambient temperatures prevail, or where the motor drives a heavy revolving part which cannot be brought up to full speed quickly, such as large fans. Under such conditions the fuse may be 175%* of the motor full-load current, or the next standard size larger if 175%* does not correspond to a standard fuse size. If this will not allow the motor to start due to higher than normal inrush currents or longer than normal acceleration times, fuses may be sized up to 225% (or next size smaller).

Motor Controllers - NEMA and IEC Style motor controllers shall be protected from short-circuits by Bussmann Low-Peak Dual-Element, Time-Delay Fuses in order to provide testing agency-witnessed Type 2 coordination for the controller. This provides "no damage" protection for the controller, under low and high level fault conditions, as required by IEC Publication 947-4-1 and UL 508E (Outline of Investigation).

*150% for wound rotor and all DC motors.

3. Switchboards, Panelboards, Load Centers, and Elevator Disconnects

The manufacturer shall supply equipment utilizing fully rated and listed components. This equipment shall be tested, listed and labeled for the available short-circuit current.

Fusible panelboards 400 amperes or less shall be Bussmann Quik-Spec™ panelboards type QSCP.

(Where series-rated fuse/circuit breaker systems are acceptable, the systems shall utilize tested, recognized components. The manufacturer shall supply switchboards, panelboards and load centers which have been tested, listed, and labeled for the available short-circuit current, and those combinations specified on the drawings.)

Elevator disconnect(s) with associated relays, control transformers, and other options shall be Bussmann Power Module™ Switch - PS or Bussmann Power Module™ Panel - PMP.

B. Supplementary - Light Fixture Protective Fuses

1. Fluorescent fixtures shall be protected by Bussmann GLR or GMF Fuses in HLR Holders. These fixtures shall have individual protection on the line side of the ballast. A fuse and holder shall be mounted within, or as part of, the fixture. Size and type of fuse to be recommended by the fixture manufacturer.
2. All other ballast-controlled light fixtures shall be protected by Bussmann KTK or FNQ Fuses in HEB HEX, HEY, HPF, or HPS Holders. These fixtures shall have individual protection on the line side of the ballast. Fuse and holder shall be mounted in a location convenient for changing fuses. Holder shall be mounted in protected location or be an in-line waterproof holder (HEB, HEX, or HEY). Size and type of fuse to be recommended by the fixture manufacturer or as indicated on plans.

C. Spares

Upon completion of the building, the electrical contractor shall provide the owner with spare fuses as shown below:

1. 10% (minimum of 3) of each type and rating of installed fuses shall be supplied as spares.
2. Bussmann spare fuse cabinets - Catalog No. SFC - shall be provided to store the above spares. A supply of "Low-Peak NOTICE Labels shall be provided along with the spare fuses in the spare fuse cabinet.

D. Substitution Approvals

The electrical contractor's proposal shall be based upon the fuses specified, using the manufacturer's catalog numbers as called for in the specification or on the drawings. Coordination and current limitation requirements for protection of each part of the electrical system have been engineered on the basis of the type, class and manufacturer specified.

In the event that the electrical contractor wishes to furnish materials other than those specified, a written request, along with a complete short-circuit, component protection and selective coordination study, shall be submitted to the engineer for evaluation at least two weeks prior to bid date. If the engineer's evaluation indicates acceptance, a written addendum will be issued listing the other acceptable manufacturer.

Suggested Fuse and Fusible Equipment Specifications

Bussmann provides fuse and fusible equipment specifications available online at www.cooperbussmann.com/afpn/fusible/.

The information contained within these documents constitutes what Bussmann considers to be a complete, comprehensive, performance based construction specification. These documents can be viewed or downloaded in Microsoft Word or PDF format.

The specifications are arranged per the recommended CSI MasterFormat™ Sections. In some cases, the number for these specifications has been left open for the specifier to choose the appropriate number and the title can be adjusted to best suit their project manual. The specifications include:

16011 Electrical System Studies

- Short Circuit, Component Protection, Flash Hazard, and Selective Coordination Study

16411 Enclosed Switches

- Enclosed Disconnect Switches (Fused and Non-Fused)
- Elevator Shunt-Trip Fused Disconnect Switches

164XX Open Disconnect Switches

- Open Disconnect Switches (Fused and Non-Fused)

16421 Enclosed Controllers

- Enclosed Fused Combination Motor Controllers

16441 Switchboards

- Fused Main and Distribution Switchboards

16442 Panelboards

- Fused Distribution Panelboards
- Elevator Shunt-Trip Fused Distribution Panel
- Fused Lighting and Appliance Panelboards

16443 Motor Control Centers

- Fused Motor Control Centers

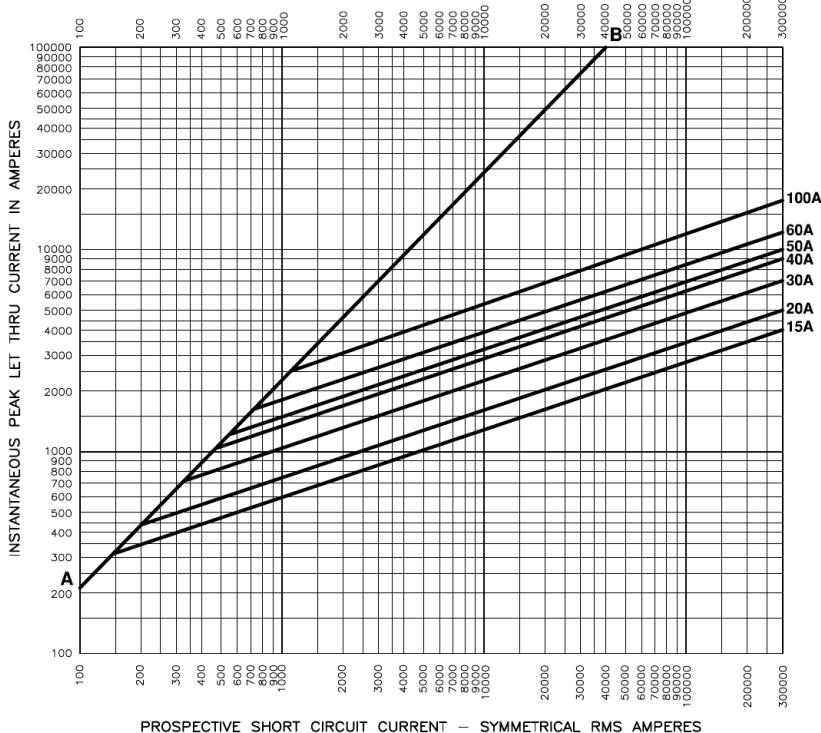
16451 Busway

- Busway and Fused Busplugs

16491 Fuses

- Fuses

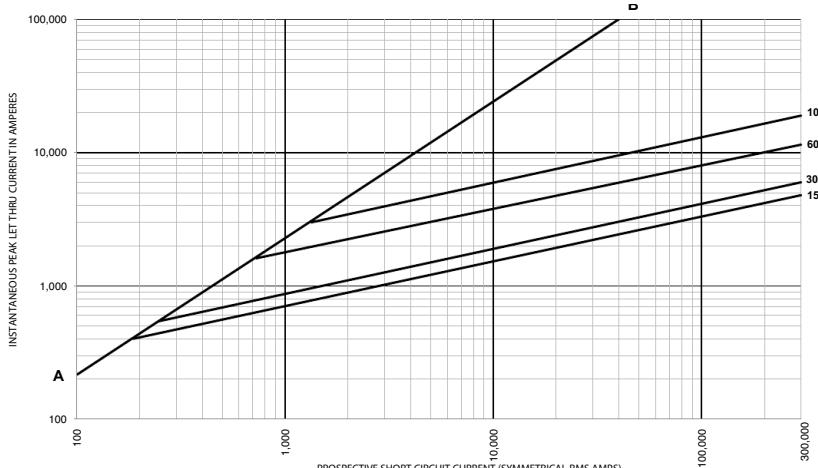
Low-Peak CUBEFuse™ Class CF, Dual-Element, Time-Delay Fuses – TCF_ and TCF_RN



TCF_ and TCF_RN – RMS Let-Through Currents (kA)

Prospt. Short C.C.	Fuse Size			
	15	30	60	100
	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}
1,000	1	1	1	1
3,000	1	1	2	2
5,000	1	1	2	2
10,000	1	1	2	3
15,000	1	2	2	3
20,000	1	2	3	3
25,000	1	2	3	4
30,000	1	2	3	4
35,000	1	2	3	4
40,000	1	2	3	4
50,000	1	2	3	5
60,000	1	2	4	5
80,000	2	2	4	5
100,000	2	3	4	5
150,000	2	3	5	6
200,000	2	3	5	7
250,000	2	3	5	7
300,000	2	3	5	8

CUBEFuse™ Class CF, Fast-Acting Fuses – FCF_RN

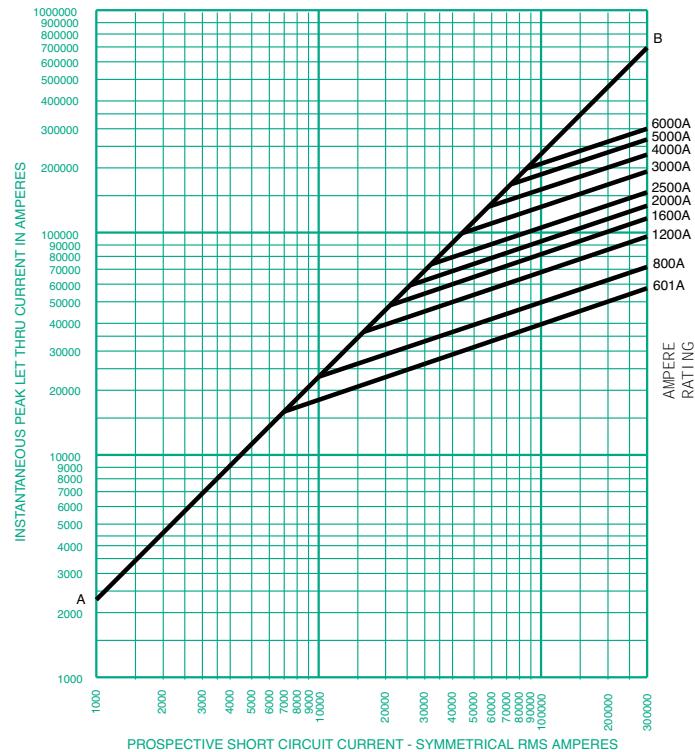


FCF_RN – RMS Let-Through Currents (kA)

Prospt. Short C.C.	Fuse Size			
	15	30	60	100
	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}
1,000	1	1	1	1
3,000	1	1	1	2
5,000	1	1	2	2
10,000	1	1	2	3
15,000	1	1	2	3
20,000	1	1	3	4
25,000	1	2	3	4
30,000	1	2	3	4
35,000	1	2	3	4
40,000	1	2	3	4
50,000	1	2	3	4
60,000	2	2	3	5
80,000	2	2	4	5
100,000	2	2	4	6
150,000	2	3	4	6
200,000	2	3	5	7
250,000	2	3	5	8
300,000	2	3	5	8

Low-Peak Class L Time-Delay Fuses

KRP-C_SP



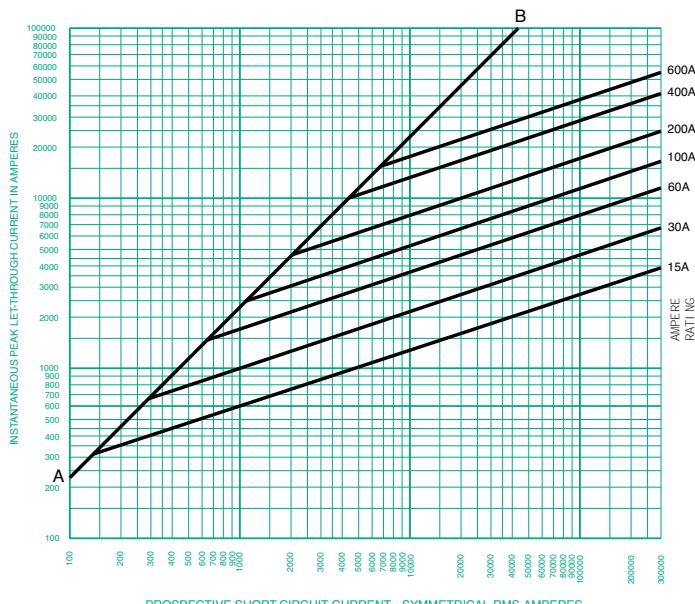
KRP-C_SP Fuse – RMS Let-Through Currents (kA)

Prosper. Short C.C.	Fuse Size									
	601	800	1200	1600	2000	2500	3000	4000	5000	6000
I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}
5,000	5	5	5	5	5	5	5	5	5	5
10,000	8	10	10	10	10	10	10	10	10	10
15,000	9	12	15	15	15	15	15	15	15	15
20,000	10	13	17	20	20	20	20	20	20	20
25,000	11	14	19	22	25	25	25	25	25	25
30,000	11	14	20	24	27	30	30	30	30	30
35,000	12	15	21	25	29	35	35	35	35	35
40,000	13	16	22	26	30	35	40	40	40	40
50,000	14	17	23	28	32	37	50	50	50	50
60,000	15	18	25	30	34	40	49	60	60	60
70,000	15	19	26	32	36	42	52	62	70	70
80,000	16	20	27	33	38	44	54	65	76	80
90,000	17	21	29	34	39	45	56	67	79	90
100,000	17	22	30	36	41	47	58	70	81	100
150,000	20	25	34	41	47	54	67	80	93	104
200,000	22	27	37	45	51	59	73	87	102	114
250,000	24	29	40	49	55	64	79	94	110	123
300,000	25	31	43	52	59	68	84	100	117	30

Note: For I_{RMS} value at 300,000 amperes, consult Factory.

Low-Peak Class J, Dual-Element Time-Delay Fuses

LPJ_SP

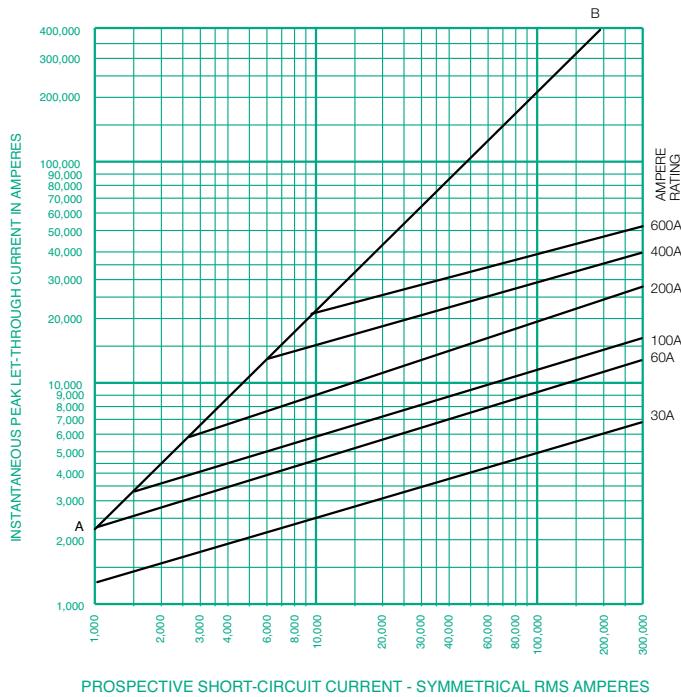


LPJ_SP Fuse – RMS Let-Through Currents (kA)

Prosper. Short C.C.	Fuse Size						
	15	30	60	100	200	400	600
I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}
1,000	1	1	1	1	1	1	1
3,000	1	1	1	2	2	3	3
5,000	1	1	1	2	3	5	5
10,000	1	1	2	2	4	6	8
15,000	1	1	2	3	4	7	9
20,000	1	1	2	3	4	7	10
25,000	1	1	2	3	5	8	10
30,000	1	1	2	3	5	8	11
35,000	1	1	2	4	5	9	12
40,000	1	2	3	4	6	9	12
50,000	1	2	3	4	6	10	13
60,000	1	2	3	4	6	11	14
80,000	1	2	3	5	7	12	15
100,000	1	2	4	5	8	12	17
150,000	1	2	4	6	9	14	19
200,000	2	3	4	6	9	16	21
250,000	2	3	5	7	10	17	23
300,000	2	3	5	7	11	18	24

Note: For I_{RMS} value at 300,000 amperes, consult Factory.

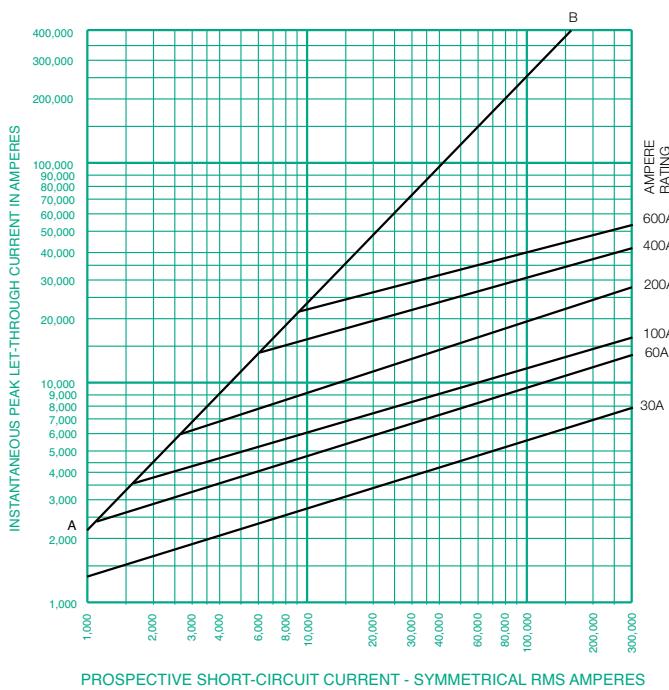
Low-Peak Class RK1 Dual-Element Time-Delay Fuses LPN-RK_SP



LPN-RK_SP – RMS Let-Through Currents (kA)

Prospr. Short C.C.	Fuse Size					
	30	60	100	200	400	600
	I _{RMS}					
1,000	1	1	1	1	1	1
2,000	1	1	2	2	2	2
3,000	1	1	2	3	3	3
5,000	1	2	2	3	5	5
10,000	1	2	3	4	7	9
15,000	1	2	3	5	8	11
20,000	1	3	3	5	8	11
25,000	1	3	3	5	9	12
30,000	2	3	4	6	9	12
35,000	2	3	4	6	10	13
40,000	2	3	4	6	10	13
50,000	2	3	4	7	11	14
60,000	2	3	4	7	11	16
70,000	2	3	4	7	12	16
80,000	2	4	5	8	12	16
90,000	2	4	5	7	13	17
100,000	2	4	5	8	13	17
150,000	2	4	6	9	15	19
200,000	3	5	6	11	16	20
250,000	3	5	7	11	17	21
300,000	3	6	7	12	18	22

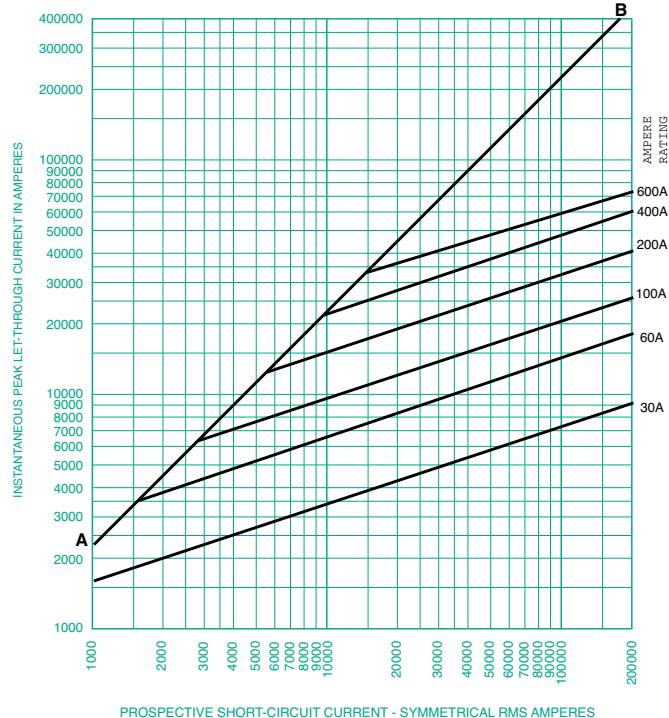
Low-Peak Class RK1 Dual-Element Time-Delay Fuses LPS-RK_SP



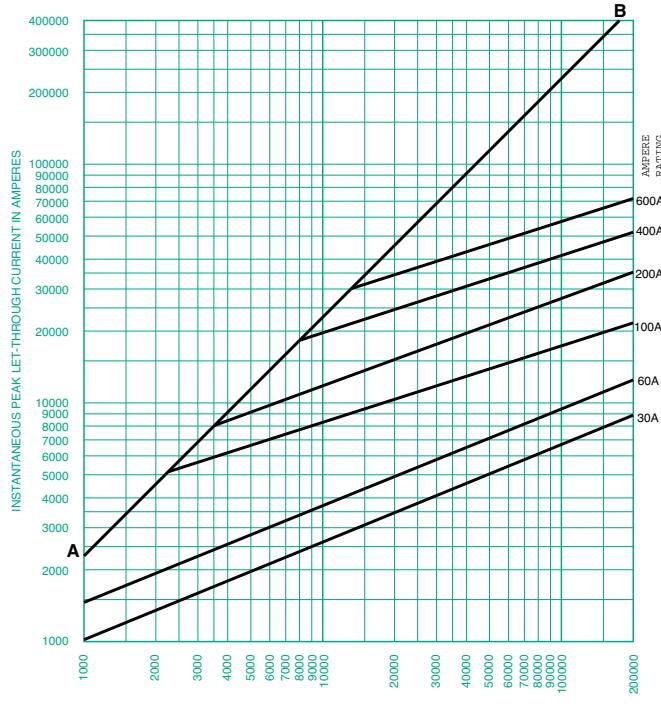
LPS-RK_SP – RMS Let-Through Currents (kA)

Prospr. Short C.C.	Fuse Size					
	30	60	100	200	400	600
	I _{RMS}					
1,000	1	1	1	1	1	1
2,000	1	1	2	2	2	2
3,000	1	1	2	3	3	3
5,000	1	2	2	3	5	5
10,000	1	2	3	4	7	10
15,000	1	2	3	5	8	11
20,000	2	3	3	5	9	12
25,000	2	3	4	6	9	12
30,000	2	3	4	6	10	13
35,000	2	3	4	6	10	13
40,000	2	3	4	6	10	14
50,000	2	3	5	7	11	15
60,000	2	4	5	7	12	15
70,000	2	4	5	8	13	16
80,000	2	4	5	8	13	16
90,000	2	4	5	8	13	17
100,000	2	4	6	9	14	17
150,000	3	5	6	10	15	19
200,000	3	5	7	11	16	21
250,000	3	6	7	12	17	22
300,000	3	6	7	12	18	23

Fusetron Class RK5 Dual-Element Time-Delay Fuses FRN-R



Fusetron Class RK5 Dual-Element Time-Delay Fuses FRS-R



FRN-R – RMS Let-Through Currents (kA)

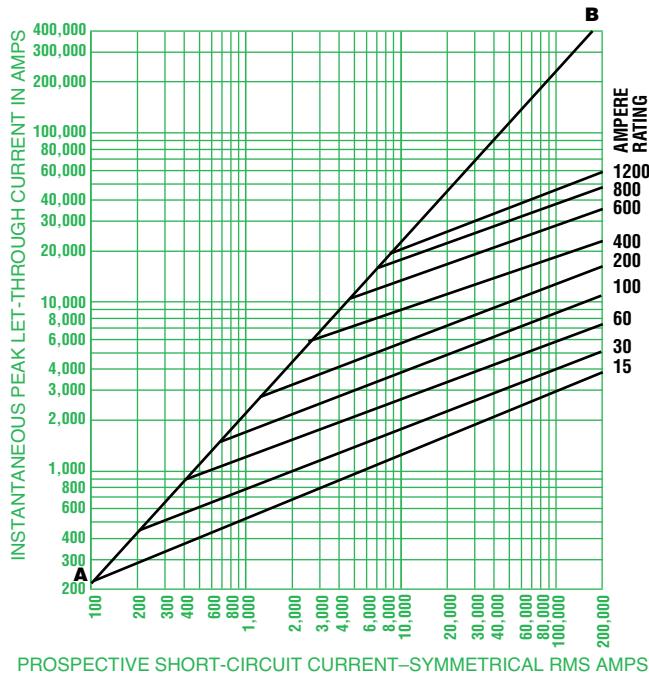
Prosper. Short C.C.	Fuse Size					
	30	60	100	200	400	600
	I _{RMS}					
5,000	1	2	3	5	5	5
10,000	2	3	4	7	10	10
15,000	2	3	5	8	11	15
20,000	2	4	5	8	12	16
25,000	2	4	6	9	13	17
30,000	2	4	6	10	14	18
35,000	2	4	6	10	15	19
40,000	2	5	7	11	15	20
50,000	3	5	7	11	17	21
60,000	3	5	8	12	18	22
70,000	3	6	8	13	19	23
80,000	3	6	8	13	19	24
90,000	3	6	9	14	20	25
100,000	3	6	9	14	21	26
150,000	4	7	10	16	24	29
200,000	4	8	11	18	26	32

FRS-R – RMS Let-Through Currents (kA)

Prosper. Short C.C.	Fuse Size					
	30	60	100	200	400	600
	I _{RMS}					
5,000	1	1	3	4	5	5
10,000	1	2	4	5	9	10
15,000	1	2	4	6	10	14
20,000	2	2	5	7	11	15
25,000	2	2	5	7	12	17
30,000	2	3	5	8	13	18
35,000	2	3	5	8	13	18
40,000	2	3	6	9	14	19
50,000	2	3	6	9	14	20
60,000	2	3	6	10	15	22
70,000	3	4	7	11	17	23
80,000	3	4	7	12	17	23
90,000	3	4	7	12	17	24
100,000	3	4	8	13	18	25
150,000	3	5	9	14	21	27
200,000	4	6	9	16	23	32

Tron Class T Fast-Acting Fuses

JJN

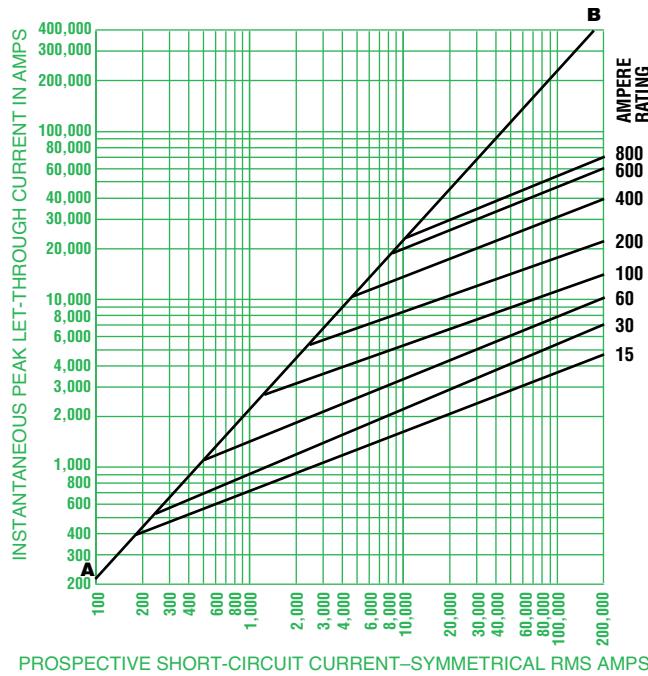


JJN – RMS Let-Through Current (kA)

Prospt. Short C.C.	Fuse Size									15		30		60		100		200	
	I_{RMS}		I_{RMS}		I_{RMS}		I_{RMS}		I_{RMS}		I_{RMS}		I_{RMS}		I_{RMS}		I_{RMS}		
	I_{RMS}																		
500	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1,000	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
5,000	1	1	1	1	1	2	3	5	5	5	5	5	5	5	5	5	5	5	
10,000	1	1	1	2	2	2	4	6	7	9	9	9	9	9	9	9	9	9	
15,000	1	1	1	2	3	3	4	6	9	10	10	10	10	10	10	10	10	10	
20,000	1	1	1	2	3	3	5	7	10	11	11	11	11	11	11	11	11	11	
25,000	1	1	2	2	3	3	5	7	10	12	12	12	12	12	12	12	12	12	
30,000	1	1	2	2	3	3	5	8	11	13	13	13	13	13	13	13	13	13	
35,000	1	1	2	3	4	4	6	8	11	13	13	13	13	13	13	13	13	13	
40,000	1	1	2	3	4	4	6	9	11	13	13	13	13	13	13	13	13	13	
50,000	1	1	2	3	4	4	7	9	12	15	15	15	15	15	15	15	15	15	
60,000	1	1	2	3	4	4	7	10	13	16	16	16	16	16	16	16	16	16	
70,000	1	1	2	3	5	5	7	10	14	17	17	17	17	17	17	17	17	17	
80,000	1	2	2	3	5	5	8	11	15	17	17	17	17	17	17	17	17	17	
90,000	1	2	2	3	6	8	11	15	18	20	20	20	20	20	20	20	20	20	
100,000	1	2	2	4	6	8	12	16	19	22	22	22	22	22	22	22	22	22	
150,000	1	2	3	4	6	9	13	17	22	22	22	22	22	22	22	22	22	22	
200,000	2	2	3	4	7	9	15	19	23	23	23	23	23	23	23	23	23	23	

Tron Class T Fast-Acting Fuses

JJS

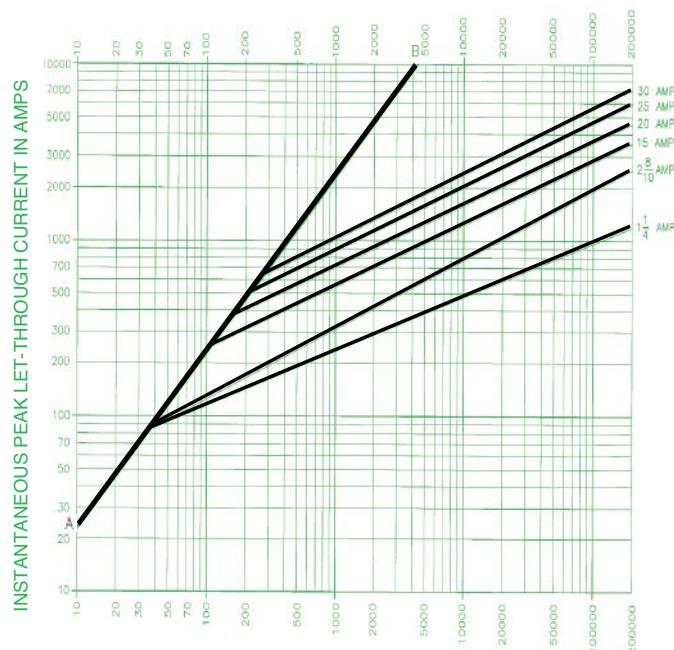


JJS – RMS Let-Through Current (kA)

Prospt. Short C.C.	Fuse Size									15		30		60		100		200	
	I_{RMS}		I_{RMS}		I_{RMS}		I_{RMS}		I_{RMS}		I_{RMS}		I_{RMS}		I_{RMS}		I_{RMS}		
	I_{RMS}																		
500	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1,000	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
5,000	1	1	1	1	2	3	4	5	5	5	5	5	5	5	5	5	5	5	
10,000	1	1	1	2	3	3	6	8	9	9	9	9	9	9	9	9	9	9	
15,000	1	1	2	3	3	4	7	10	11	11	11	11	11	11	11	11	11	11	
20,000	1	1	2	3	3	4	7	10	12	12	12	12	12	12	12	12	12	12	
25,000	1	1	2	3	3	5	7	11	13	13	13	13	13	13	13	13	13	13	
30,000	1	1	2	3	3	5	8	12	14	14	14	14	14	14	14	14	14	14	
35,000	1	1	2	3	3	5	9	13	15	15	15	15	15	15	15	15	15	15	
40,000	1	2	2	3	4	5	9	13	15	15	15	15	15	15	15	15	15	15	
50,000	1	2	2	3	4	4	6	10	14	17	17	17	17	17	17	17	17	17	
60,000	1	2	3	4	4	6	10	16	18	20	20	20	20	20	20	20	20	20	
70,000	1	2	3	4	4	7	11	17	19	20	20	20	20	20	20	20	20	20	
80,000	1	2	3	4	4	7	11	17	20	20	20	20	20	20	20	20	20	20	
90,000	1	2	3	4	4	7	12	18	21	21	21	21	21	21	21	21	21	21	
100,000	2	2	3	5	7	12	19	22	22	22	22	22	22	22	22	22	22	22	
150,000	2	3	4	6	8	14	22	25	25	25	25	25	25	25	25	25	25	25	
200,000	2	3	4	6	9	16	24	28	28	28	28	28	28	28	28	28	28	28	

Low-Peak Class CC Time-Delay Fuses

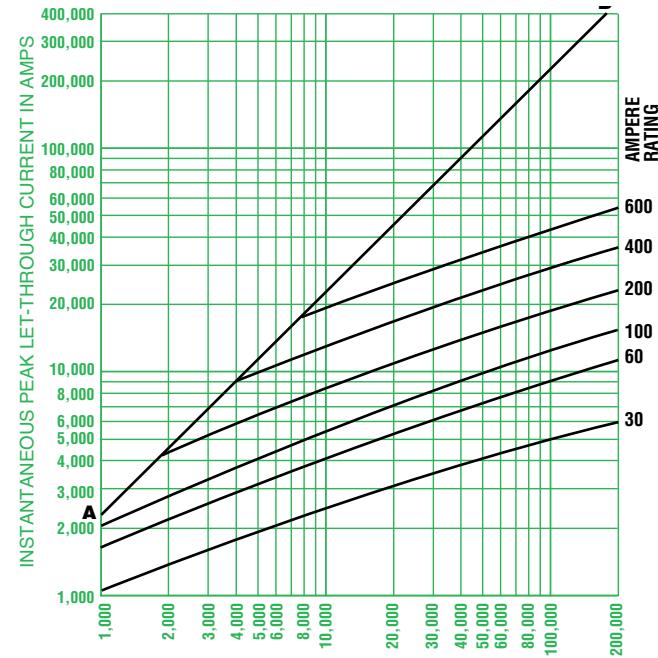
LP-CC



PROSPECTIVE SHORT-CIRCUIT CURRENT—SYMMETRICAL RMS AMPS

Limitron Class J Fast-Acting Fuses

JKS



PROSPECTIVE SHORT-CIRCUIT CURRENT—SYMMETRICAL RMS AMPS

LP-CC – RMS Let-Through Currents (A)

Pros. Short C.C.	Fuse Size					
	1 1/4	2 1/10	15	20	25	30
I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}
1,000	100	135	240	305	380	435
3,000	140	210	350	440	575	580
5,000	165	255	420	570	690	710
10,000	210	340	540	700	870	1000
20,000	260	435	680	870	1090	1305
30,000	290	525	800	1030	1300	1520
40,000	315	610	870	1150	1390	1700
50,000	340	650	915	1215	1520	1820
60,000	350	735	1050	1300	1650	1980
80,000	390	785	1130	1500	1780	2180
100,000	420	830	1210	1600	2000	2400
200,000	525	1100	1600	2000	2520	3050

JKS – RMS Let-Through Currents (kA)

Pros. Short C.C.	Fuse Size					
	30	60	100	200	400	600
I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}	I _{RMS}
5,000	1	1	2	3	4	5
10,000	1	2	3	4	6	9
15,000	1	2	3	4	7	10
20,000	1	2	3	5	8	11
25,000	2	3	3	6	9	12
30,000	2	3	3	6	9	13
35,000	2	3	4	6	9	13
40,000	2	3	4	7	10	14
50,000	2	3	4	7	10	15
60,000	2	3	5	7	11	16
70,000	2	3	5	8	11	17
80,000	2	3	5	8	12	17
90,000	2	4	6	9	13	18
100,000	2	4	6	9	13	18
150,000	2	5	6	9	14	22
200,000	3	5	7	10	16	24

Bussmann Surge Protection Products - (See Surge Application Guide #3193)

SurgePOD™ HEAVY DUTY

Robust Type 1 SPDs provide ultimate surge protection for critical commercial and industrial applications.

Features

- Type 1 UL 1449 3rd Edition Listed SPDs are easily selected and installed on the loadside or lineside of the service entrance overcurrent protective device
- Patented Bussmann SurgePOD™ module technology eliminates the need for additional fusing
- Voltage specific models precisely match and protect electrical systems and equipment up to 600Vac
- Compact UV resistant NEMA 4X for indoor or outdoor applications
- easyID™ LED status indicator provides surge protection status at a glance

[Data Sheet No. 2163](#)

PV Surge Protection Device

UL 1449 3rd edition recognized SPD for the protection of damaging surges and overvoltages.

Features

- Modular DIN-rail design with color-coding & rejection feature makes it easy to identify, install & maintain
- Built-in overcurrent protection eliminates the need for any additional fuse installation and wiring
- easyID™ visual indication and optional remote contact signaling make status monitoring simple
- Patented, fast-acting hybrid Short-Circuit Interrupting (SCI) technology isolates system for safe module replacement without DC arc formation

[Data Sheet No. 2055](#)

Wind Surge Protection Device

Advanced, easy-to-use surge and lightning protection product for Wind power systems.

Features

- Modular DIN-rail design with color-coding & rejection feature makes it easy to identify, install & maintain
- High surge discharge capacity due to heavy-duty zinc oxide varistor and spark-gap technology
- easyID™ visual indication and optional remote contact signaling make status monitoring simple
- Vibration and shock resistant according to EN 60068-2 standards
- Wide range of IEC Class I and Class II SPD covering all the major markets around the world

[Data Sheets No. 2091 to 2095](#)

Low Voltage Surge Protection Device

Efficient and reliable network protection for telecom and low voltage applications.

Features

- Modular DIN-Rail design with color-coding & rejection feature makes it easy to identify, install & maintain
- High surge discharge capacity provided by combination of spark-gap and heavy-duty zinc oxide varistors
- easyID™ visual indication and optional remote contact signaling make status monitoring simple
- Vibration and shock resistant according to EN 60068-2 standards
- Energy coordination with other Bussmann DIN-Rail surge protection devices

[Data Sheet No. 2056 to 2057](#)



SurgePOD™ PRO

Type 1 SPDs provide optimal surge protection for light commercial and residential applications.

Features

- Type 1 UL 1449 3rd Edition Listed SPDs are easily selected and installed on the loadside or lineside of the service entrance overcurrent protective device
- Voltage specific models precisely match and protect electrical systems and equipment better than "one-size-fits-all" SPD
- Thermal disconnect technology eliminates the need for additional fusing
- Compact UV resistant NEMA 4X for indoor or outdoor applications
- easyID™ LED status indicator provides surge protection status at a glance

[Data Sheet No. 10033](#)

UL Surge Protection Device

Comprehensive UL 1449 3rd edition approved surge protection solution for North American AC/DC applications.

Features

- Modular DIN-rail design with color-coding & rejection feature makes it easy to identify, install & maintain
- High surge discharge capacity due to heavy-duty zinc oxide varistor and spark-gap technology
- easyID™ visual indication and optional remote contact signaling make status monitoring simple
- Vibration and shock resistant according to EN 60068-2 standards
- Wide range of UL 1449 3rd Edition approved SPD devices covering all North American markets

[Data Sheet No. 2149 to 2152](#)



IEC Surge Protection Device

High Performance Lightning and surge protection device.

Features

- Vibration and shock resistant according to EN 60068-2 standards
- easyID™ visual indication and optional remote contact signaling make status monitoring simple
- High surge discharge capacity due to heavy-duty zinc oxide varistor and spark-gap technology
- Wide range of IEC Class I and Class II SPD covering all the major markets around the world
- Modular DIN-rail design with color-coding & rejection feature makes it easy to identify, install & maintain



[Data Sheets No. 1163 to 1169](#)

Data Signal SPDs

Complete data signal surge protection for Telecom and instrumentation applications.

Features

- UL 497B Listed to protect equipment and wiring against the effects of excessive currents caused by lightning
- BNC Coax Cable, RJ45 / Ethernet Data Cable and Universal 4-Pole versions available for popular data signal applications
- DIN-Rail mount makes installation easy
- Universal 4-Pole SPD is easy to apply in most instrumentation applications up to 180V
- Data signal SPDs complement SurgePOD™ Type 1 and DIN-Rail UL/Low Voltage surge product lines for comprehensive system overvoltage protection



[Data Sheet No. 2158 to 2161](#)

Common Electrical Terminology

Ampere (Amp)

The measurement of intensity of rate of flow of electrons in an electric circuit. An amp is the amount of current that will flow through a resistance of one ohm under a pressure of one volt.

Amp Rating

The current-carrying capacity of a fuse. When a fuse is subjected to a current above its amp rating, it will open the circuit after a predetermined period of time.

Amp Squared Seconds, I^2t

The measure of heat energy developed within a circuit during the fuse's clearing. It can be expressed as "Melting I^2t ", "Arcing I^2t " or the sum of them as "Clearing I^2t ". " I " stands for effective let-through current (RMS), which is squared, and " t " stands for time of opening, in seconds.

Arcing Time

The amount of time from the instant the fuse link has melted until the overcurrent is interrupted, or cleared.

Breaking Capacity

(See Interrupting Rating)

Cartridge Fuse

A fuse consisting of a current responsive element inside a fuse tube with terminals on both ends.

Class CC Fuses

600V, 200,000 amp interrupting rating, branch circuit fuses with overall dimensions of $\frac{1}{2}'' \times 1\frac{1}{2}''$. Their design incorporates a rejection feature that allows them to be inserted into rejection fuse holders and fuse blocks that reject all lower voltage, lower interrupting rating $\frac{1}{2}'' \times 1\frac{1}{2}''$ fuses. They are available from $\frac{1}{10}$ amp through 30 amps.

Class G Fuses

$\frac{1}{2}$ - 20A @ 600Vac, 25-60A@480Vac, 100,000 amp interrupting rating branch circuit fuses that are size rejecting to eliminate overfusing. The fuse diameter is $\frac{1}{2}''$ while the length varies from $1\frac{1}{16}''$ to $2\frac{1}{4}''$. These are available in ratings from $\frac{1}{2}$ amp through 60 amps.

Class H Fuses

250V and 600V, 10,000 amp interrupting rating branch circuit fuses that may be renewable or non-renewable. These are available in amp ratings of 1 amp through 600 amps.

Class J Fuses

These rejection style fuses are rated to interrupt a minimum of 200,000 amps AC. They are labeled as "Current-Limiting", are rated for 600Vac, and are not interchangeable with other classes. They are available from 1 through 600 amps.

Class K Fuses

These are fuses listed as K-1, K-5, or K-9 fuses. Each subclass has designated I^2t and I_p maximums. These are dimensionally the same as Class H fuses, and they can have interrupting ratings of 50,000, 100,000, or 200,000 amps. These fuses are current-limiting. However, they are not marked "current-limiting" on their label since they do not have a rejection feature.

Class L Fuses

These fuses are rated for 601 through 6000 amps, and are rated to interrupt a minimum of 200,000 amps AC. They are labeled "current-limiting" and are rated for 600Vac. They are intended to be bolted into their mountings and are not normally used in clips. Some Class L fuses have designed in time-delay features for all purpose use.

Class R Fuses

These are high performance fuses rated $\frac{1}{10}$ - 600 amps in 250 volt and 600V ratings. All are marked "current-limiting" on their label and all have a minimum of 200,000 amp interrupting rating. They have identical outline dimensions with the Class H fuses but have a rejection feature which prevents the user from mounting a fuse of lesser capabilities (lower interrupting capacity) when used with special Class R Clips. Class R fuses will fit into either rejection or non-rejection clips.

Class T Fuses

An industry class of fuses in 300V and 600V ratings from 1 amp through 1200 amps. They are physically very small and can be applied where space is at a premium. They are fast-acting fuses, with an interrupting rating of 200,000 amps RMS.

Classes of Fuses

The industry has developed basic physical specifications and electrical performance requirements for fuses with voltage ratings of 600V or less. These are known as standards. If a type of fuse meets the requirements of a standard, it can fall into that class. Typical classes are K, RK1, RK5, G, L, H, T, CC, CF, and J.

Clearing Time

The total time between the beginning of the overcurrent and the final opening of the circuit at rated voltage by an overcurrent protective device. Clearing time is the total of the melting time and the arcing time.

Current-Limitation

A fuse operation relating to short-circuits only. When a fuse operates in its current-limiting range, it will clear a short-circuit in less than $\frac{1}{2}$ cycle. Also, it will limit the instantaneous peak let-through current to a value substantially less than that obtainable in the same circuit if that fuse were replaced with a solid conductor of equal impedance.

Dual-Element Fuse

Fuse with a special design that utilizes two individual elements in series inside the fuse tube. One element, the spring actuated trigger assembly, operates on overloads up to 5 - 6 times the fuse current rating. The other element, the short-circuit section, operates on short-circuits up to its interrupting rating.

Electrical Load

That part of the electrical system which actually uses the energy or does the work required.

Fast Acting Fuse

A fuse which opens on overload and short circuits very quickly. This type of fuse is not designed to withstand temporary overload currents associated with some electrical loads, when sized near the full load current of the circuit.

Fuse

An overcurrent protective device with a fusible link that operates and opens the circuit on an overcurrent condition.

High Speed Fuses

Fuses with no intentional time-delay in the overload range and designed to open as quickly as possible in the short-circuit range. These fuses are often used to protect solid-state devices.

Inductive Load

An electrical load which pulls a large amount of current – an inrush current – when first energized. After a few cycles or seconds the current "settles down" to the full-load running current.

Interrupting Capacity

Actual test current an overcurrent device sees during the short circuit test.

Interrupting Rating

The rating which defines a fuse's ability to safely interrupt and clear short-circuits. This rating is much greater than the amp rating of a fuse. The NEC® defines Interrupting Rating as "The highest current at rated voltage that an overcurrent protective device is intended to interrupt under standard test conditions."

Melting Time

The amount of time required to melt the fuse link during a specified overcurrent. (See Arcing Time and Clearing Time.)

"NEC" Dimensions

These are dimensions once referenced in the National Electrical Code®. They are common to Class H and K fuses and provide interchangeability between manufacturers for fuses and fusible equipment of given amp and voltage ratings.

Common Electrical Terminology

Ohm

The unit of measure for electric resistance. An ohm is the amount of resistance that will allow one amp to flow under a pressure of one volt.

Ohm's Law

The relationship between voltage, current, and resistance, expressed by the equation $E = IR$, where E is the voltage in volts, I is the current in amps, and R is the resistance in ohms.

One Time Fuses

Generic term used to describe a Class H nonrenewable cartridge fuse, with a single element.

Overcurrent

A condition which exists on an electrical circuit when the normal load current is exceeded. Overcurrents take on two separate characteristics – overloads and short-circuits.

Overload

Can be classified as an overcurrent which exceeds the normal full load current of a circuit. Also characteristic of this type of overcurrent is that it does not leave the normal current carrying path of the circuit – that is, it flows from the source, through the conductors, through the load, back through the conductors, to the source again.

Peak Let-Through Current, I_p

The instantaneous value of peak current let-through by a current-limiting fuse, when it operates in its current-limiting range.

Renewable Fuse (600V & below)

A fuse in which the element, typically a zinc link, may be replaced after the fuse has opened, and then reused. Renewable fuses are made to Class H standards.

Resistive Load

An electrical load which is characteristic of not having any significant inrush current. When a resistive load is energized, the current rises instantly to its steady-state value, without first rising to a higher value.

RMS Current

The RMS (root-mean-square) value of any periodic current is equal to the value of the direct current which, flowing through a resistance, produces the same heating effect in the resistance as the periodic current does.

Semiconductor Fuses

Fuses used to protect solid-state devices. See "High Speed Fuses."

Short-Circuit

Can be classified as an overcurrent which exceeds the normal full load current of a circuit by a factor many times (tens, hundreds or thousands greater). Also characteristic of this type of overcurrent is that it leaves the normal current carrying path of the circuit – it takes a "short cut" around the load and back to the source.

Short-Circuit Current Rating

The maximum short-circuit current an electrical component can sustain without the occurrence of excessive damage when protected with an overcurrent protective device.

Single-Phasing

That condition which occurs when one phase of a three-phase system opens, either in a low voltage (secondary) or high voltage (primary) distribution system. Primary or secondary single-phasing can be caused by any number of events. This condition results in unbalanced currents in polyphase motors and unless protective measures are taken, causes overheating and failure.

Threshold Current

The symmetrical RMS available current at the threshold of the current-limiting range, where the fuse becomes current-limiting when tested to the industry standard. This value can be read off of a peak let-through chart where the fuse curve intersects the A - B line. A threshold ratio is the relationship of the threshold current to the fuse's continuous current rating.

Time-Delay Fuse

A fuse with a built-in delay that allows temporary and harmless inrush currents to pass without opening, but is so designed to open on sustained overloads and short-circuits.

Voltage Rating

The maximum open circuit voltage in which a fuse can be used, yet safely interrupt an overcurrent. Exceeding the voltage rating of a fuse impairs its ability to clear an overload or short-circuit safely.

Withstand Rating

The maximum current that an unprotected electrical component can sustain for a specified period of time without the occurrence of extensive damage.

Electrical Formulas

To Find	Single-Phase	Two-Phase	Three-Phase	Direct Current
Amperes when kVA is known	$\frac{kVA}{1000}$ E	$\frac{kVA}{1000}$ $E \sqrt{2}$	$\frac{kVA}{1000}$ $E \sqrt{3}$	Not Applicable
Amperes when horsepower is known	$\frac{HP}{746}$ $E \% \text{ eff. } pf$	$\frac{HP}{746}$ $E \sqrt{2} \% \text{ eff. } pf$	$\frac{HP}{746}$ $E \sqrt{3} \% \text{ eff. } pf$	$\frac{HP}{746}$ $E \% \text{ eff. }$
Amperes when kilowatts are known	$\frac{kW}{1000}$ $E pf$	$\frac{kW}{1000}$ $E \sqrt{2} pf$	$\frac{kW}{1000}$ $E \sqrt{3} pf$	$\frac{kW}{1000}$ E
Kilowatts	$I \frac{E}{1000} pf$	$I \frac{E}{1000} \sqrt{2} pf$	$I \frac{E}{1000} \sqrt{3} pf$	$I \frac{E}{1000}$
Kilovolt-Amperes	$I \frac{E}{1000}$	$I \frac{E}{1000} \sqrt{2}$	$I \frac{E}{1000} \sqrt{3}$	Not Applicable
Horsepower	$I \frac{E}{746} \% \text{ eff. } pf$	$I \frac{E}{746} \sqrt{2} \% \text{ eff. } pf$	$I \frac{E}{746} \sqrt{3} \% \text{ eff. } pf$	$I \frac{E}{746} \% \text{ eff. }$
Watts	$E I pf$	$E I \sqrt{2} pf$	$E I \sqrt{3} pf$	$E I$
Energy Efficiency = $\frac{\text{Load Horsepower}}{\text{Load Input kVA}} \times 746 / 1000$				
Power Factor = $pf = \frac{\text{Power Consumed}}{\text{Apparent Power}} = \frac{W}{VA} \text{ or } \frac{kW}{kVA} = \cos\theta$				

I = Amperes

E = Volts

kW = Kilowatts

kVA = Kilovolt-Amperes

HP = Horsepower

% eff. = Percent Efficiency

pf = Power Factor

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Bussmann Fuse Cross Reference & Low-Peak™ Upgrade

The left column represents Bussmann and competitors' part numbers. The right column represents the Bussmann upgrades.

The Bussmann fuse upgrade offers superior performance while reducing the number of SKUs that need to be in stock. Low-Peak™ fuses feature a high degree of current limitation, which will provide the best component protection and may reduce the arc flash hazard. Listings are alpha-numerical by fuse class and fuse catalog symbol.

This list is only a consolidated cross reference to some of our most common products. For a much more extensive database please consult the *Product Profiler* competitor cross-reference. Just visit www.cooperbussmann.com and click on the magnifying glass icon in the upper right corner.

Class CC and Midget	
Existing Fuse	Low-Peak™ Upgrade
A6Y (type 2B)	LP-CC
ABU	
AGU	
ATDR	
ATM	
ATMR	
ATQ	
BAF	
BAN	
BLF	
BLN	
CCMR	
CM	
CMF	
CNM	
CNQ	
CTK	
CTK-R	
FLM	
FLQ	
FNM	
FNQ	
GGU	
HCLR	
KLK	
KLK-R	
KTK	
KTK-R	
MCL	
MEN	
MEQ	
MOF	
MOL	
OTM	
TRM	
6JX	LP-CC
*FNQ-R suggested on primary of control transformers.	
ATQR	FNQ-R
FNQ-R	
KLDR	

Class J	
Existing Fuse	Low-Peak™ Upgrade
A4J	LPJ_SP
AJT	
CJ	
CJS	
GF8B	
HRCXXJ	
J	
JA	
JCL	
JDL	
JFL	
JHC	
JKS	
JLS	
JTD	

Class L	
Existing Fuse	Low-Peak™ Upgrade
A4BQ	KRP-C_SP
A4BT	
A4BY	
A4BY (type 55)	
CLASS L	
CLF	
CLL	
CLU	
HRC-L	
KLLU	
KLPC	
KLU	
KTU	
L	
LCL	
LCU	

250 Volt Class R	
Existing Fuse	Low-Peak™ Upgrade
A2D	LPN-RK_SP
A2D-R	
A2K	
A2K-R	
A2Y (type 1)	
AT-DE	
CHG	
CRN-R (type 3)	
CTN-R	
DEN	
DLN	
DLN-R	
ECN	
ECN-R	
ERN	
FLN	
FLN-R	
FRN	
FRN-R	
FTN-R	
GDN	
HAC-R	
HB	
KLN-R	
KON	
KTN-R	
LENRK	
LKN	
LLN-RK	
LON-RK	
NCLR	
NLN	
NON	
NRN	
OTN	
REN	
RFN	
RHN	
RLN	
TR	
655	
660	
10KOTN	
50KOTN	

600 Volt Class R	
Existing Fuse	Low-Peak™ Upgrade
A6D	LPS-RK_SP
A6K-R	
A6X (type 1)	
ATS-DE	
CHR	
CTS-R	
DES	
DES-R	
DLS	
ECS-R	
ERS	
FLS	
FLS-R	
FRS	
FRS-R	
FTS-R	
GDS	
HA	
KLS-R	
KOS	
KTS-R	
LES	
LES-R	
LES-RK	
LKS	
LLS-RK	
LOS-RK	
NLS	
NOS	
NRS	
OTS	
RES	
RFS	
RHS	
RLS	
SCLR	
TRS	
TRS-R	
656	
10KOTS	
50KOTS	

The comparative catalog numbers shown were derived from the latest available published information from various manufacturers. Because competitors' products may differ from Bussmann products, it is recommended that each application be checked for required electrical and mechanical characteristics before substitutions are made. Bussmann is not responsible for misapplications of our products. Overcurrent protection is application dependent. Consult the latest catalogs and application literature, or contact our Application Engineering Department toll free at 855-287-7626 (855-BUSSMANN).

Customer Assistance

Customer Satisfaction Team

Available to answer questions regarding Bussmann products & services Monday-Friday, 7:00 a.m. – 6:00 p.m. Central Time. Contact:

- Toll-free phone: 855-287-7626 (855-BUSSMANN)
- Toll-free fax: 800-544-2570
- E-mail: busscstsat@eaton.com

Emergency and After-Hours Orders

Next flight out or will call shipment for time-critical needs. Customers pay only standard product price, rush freight charges, & modest emergency service fee. Place these orders through the Customer Satisfaction Team during regular business hours. For after-hours, contact:

- After hours 314-995-1342

C3 – the Enhanced, Online Cooper Customer Center

Provides real time product availability, net pricing, order status & shipment tracking for: B-Line, Bussmann, Crouse-Hinds, Lighting, Power Systems & Wiring Devices. Call 877-995-5955 for log-in assistance. Available at:

- www.cooperc3.com

Application Engineering

Technical assistance is available to all customers. Application support is available Monday-Friday, 7:00 a.m. – 5:00 p.m. Central Time. Contact:

- Toll-free phone: 855-287-7626 (855-BUSSMANN)
- E-mail: fusetech@eaton.com

Online Resources

Visit www.cooperbussmann.com for the following resources:

- Product search & cross-reference
- Product & technical materials
- Solutions centers for information on topical issues including arc flash, selective coordination & short-circuit current rating
- Technical tools, like our arc flash calculator
- Where to purchase Bussmann product

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