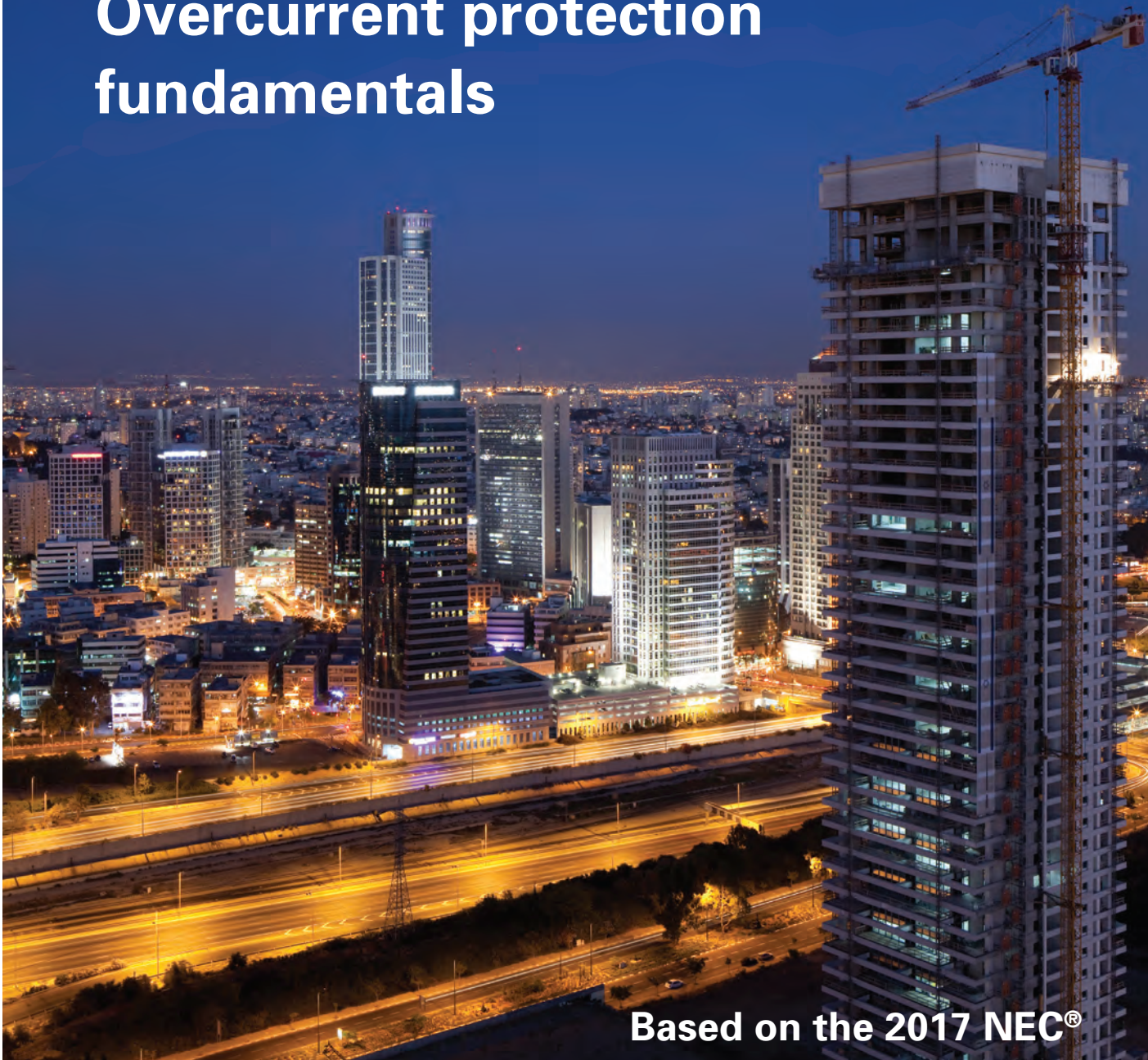


Overcurrent protection fundamentals



Based on the 2017 NEC®



Powering Business Worldwide

Benefits of the modern current-limiting fuse

Provides a flexible and worry-free solution

- With interrupting ratings up to 300 kA, fuses can be installed in almost any system without fear of misapplication
- With straight voltage ratings, fuses can be installed in any system independent of its grounding as opposed to slash voltage rated devices that can only be installed on a solidly grounded Wye system
- The fuse's interrupting rating is typically at least equal to, or in many cases greater than, the available fault current at the line terminals
- The fuse's high interrupting rating provides flexibility should system changes, such as utility transformers or equipment relocation, increase fault current levels

Increases electrical safety

- Finger-safe protection is provided in the latest fuse technology for fuse holders and blocks, switches, and power distribution fuse blocks, including the patented Bussmann™ series Low-Peak™ CUBEFuse™ and revolutionary Compact Circuit Protector (CCP) disconnect switch
- With interrupting ratings up to 300 kA, available fault currents exceeding these high values due to system changes is virtually eliminated
- UL Class branch circuit fuses have physical rejection features that help ensure the same voltage and equal to or greater interrupting ratings are retained throughout the system's life
- Arc flash hazards can be greatly reduced when fuses operate in their current-limiting range

Reduces risk and improved reliability

- Fuse rejection features reduce the potential to install an overcurrent protective device (OCPD) with different performance characteristics and lower interrupting ratings that can compromise the protection level
- Fuses do not vent during a fault, safely containing and extinguishing the arcing inside the fuse body. On some OCPDs venting is inherent, possibly causing damage to other system components
- Factory-calibrated replacement fuses ensure the same protection level throughout the system's life and eliminate the possible need to test and recalibrate an OCPD after a fault
- The fuse's enclosed, sand-filled design operates on proven thermal principles that eliminate the risk something may not be properly adjusted or operate correctly under short-circuit conditions as is the case with some mechanical OCPDs
- The enclosed, fixed design eliminates the need to adjust and change device settings in the field, thus reducing confusion and risk of misapplication

Saves time and money

- Fuses eliminate the need for expensive, time-consuming fault current studies when using 300 kA interrupting rated Low-Peak fuses
- Current-limiting fuses make achieving selective coordination easy and simple by maintaining a minimum amp ratio between upstream and downstream fuses. Using published ratio tables eliminates the need for selective coordination studies and ensures the affected circuits are isolated and prevents unnecessary power loss to upstream portions of the electrical system.
- Because fuses are an enclosed, non-venting design, they eliminate the need for additional system guards or barriers to protect from venting
- Fuses reduce the need for OCPD maintenance as they require no additional maintenance or servicing beyond periodically checking conductors and terminations

Helps achieve high equipment short-circuit current ratings (SCCR)

- Fuses have high interrupting ratings (up to 300 kA) and will not be the limiting factor in a panel SCCR
- Current limitation drastically reduces the peak let-through current to protect downstream components and help raise branch SCCRs

Reduces downtime and improved protection

- Specifying Type 2 "No Damage" (versus Type 1) protection with properly sized current-limiting fuses helps eliminate the need to replace components after a fault
- Current limitation helps reduce the extreme, destructive thermal and mechanical forces associated with short-circuit events

Facilitates code compliance

- Compliance with NEC 110.9 is easily achieved with high interrupting ratings up to 300 kA
- Compliance with NEC 110.10 for protecting equipment and components from extensive damage from short-circuits is easy with current-limiting fuses
- Compliance with OSHA 1910.334(b)2 is met by eliminating the invitation for an operator to reset the OCPD after a fault without first determining its cause. Resetting circuit breakers or replacing fuses without investigating and fixing the cause is prohibited by federal law.



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First published in the 1920s, the Fuseology handbook on fuses has promoted electrical safety by advancing the understanding of overcurrent protection.

Overcurrent protective device basics

Fuseology is the study of the fuse's fundamental operating principles. These include the ratings and operating characteristics that make the fuse an efficient overcurrent protective device (OCPD) as well as its construction that creates its unique leadership role in circuit protection.

In the simplest terms, a fuse is an overcurrent protective device with a circuit-opening fusible part that is heated and severed by the passage of overcurrent through it.

A fuse is comprised of all the parts that form a unit that can perform these functions. It may or may not be the complete device necessary to connect it into an electrical circuit.

Electrical distribution systems can be simple or complicated. Regardless, they cannot be absolutely fail-safe and are subject to destructive overcurrent events such as overloads, ground faults or short-circuits. Harsh environments, general deterioration, damage (whether accidental or from natural causes), excessive electrical system expansion or overloading are common factors leading to overcurrent events. Reliable OCPDs like the fuse shown in Figure 1 prevent or minimize costly damage to transformers, conductors, motors and many other components and loads that make up a complete power distribution system. Reliable circuit protection is also essential to electrical safety for personnel as well as avoiding severe monetary losses from power blackouts or prolonged facility downtime.



Figure 1: A regular and x-ray view of the Bussmann™ series Low-Peak™ LPN-RK dual-element fuse showing the overload and short-circuit links.

The fuse is a reliable and simple OCPD made in a variety of configurations that are fundamentally comprised of a “fusible” link or links encapsulated in a tube or housing that are connected to terminals. The link’s electrical resistance is so low that it acts as a conductor until it encounters current levels above its amp rating. Then it melts and opens the circuit to protect conductors, components and loads.

Fuses for electrical distribution systems typically have three unique performance characteristics that address Friemel’s Laws of Overcurrent Protection (see sidebar “Friemel’s Laws of Overcurrent Protection” for details):

- High interrupting rating to safely open very high fault currents without rupturing.
- Current limitation to “limit” fault currents to low values for optimum component and equipment protection, and help equipment achieve high short-circuit current ratings (SCCRs).
- Electrical system selective coordination for the full range of overcurrent events to help prevent needless “blackouts” caused by upstream OCPDs cascading open when applied with the correct amp rating ratios.

Friemel’s Laws of Overcurrent Protection and the NEC

Law 1 — Interrupting rating

- OCPDs shall be applied with an interrupting rating equal to or greater than the maximum available fault current
- Code compliance: 110.9

Law 2 — Component protection

- OCPDs shall be selected and installed to clear a fault without extensive damage to electrical equipment and components
- Code compliance: 110.10

Law 3 — Selective coordination

- A properly engineered and installed electrical system will restrict outages to ONLY the nearest upstream OCPD for the full range of overcurrents and associated opening times, leaving the remainder of the system undisturbed and preserving service continuity
- Code compliance: 620.62, 645.27, 695.3(C)(3), 700.32, 701.27, 708.54

Friemel’s Law	Code section	How it’s achieved
1. Interrupting rating	110.9	Current limiting fuses, especially Low-Peak
2. Component protection	110.10 and numerous sections involving SCCR	Current limiting fuses, especially Low-Peak and high SCCR control panel products (CCP, PDFB, etc.)
3. Selective Coordination	620.62, 645.27, 695.3, 700.32, 701.27, 708.54	Current limiting fuses, especially Low-Peak, QSCP, Power Module, CCPLP and engineering services

Table 1: Friemel’s Laws of Overcurrent Protection in table form.



How fuses work

As an overcurrent protective device, the fuse acts as “electricity’s safety valve” by providing a weak link in the circuit path that, when properly applied, will melt and open the circuit to minimize or eliminate any damage that can be caused by an excessive flow of current. There are many fuse varieties and constructions, each developed to address an application’s need for a particular kind of overcurrent protection.

Overcurrent protection

An overcurrent is either an **overload**, a **short-circuit** or **ground fault** current. The overload current is an excessive current flow relative to normal operating current, but still confined to the normal circuit paths provided by the conductors, components and loads. A short-circuit or ground fault currents flow outside of the normal circuit paths.

Overloads

Overloads are most often between 1.35 and 6 times the normal current level. They are usually caused by harmless, temporary in-rush currents that occur when motors start up or transformers are energized. Such overloads, or transients, are normal occurrences, and their brief duration is not harmful to circuit components as the associated temperature rise is minimal with no harmful affect. It’s important that OCPDs are properly sized and have the appropriate operating characteristics so they do not react to these temporary overloads or cause “nuisance openings.”

Persistent, non-temporary overloads can result from defective motors (worn bearings) or when too many loads are on a single circuit and must not be permitted to last long enough to damage electrical system components such as conductors. This damage may eventually lead to severe fault events if the overload is not interrupted.

Due to the overload’s inherent low magnitude nature, removing them within seconds or even minutes will generally prevent thermal damage.

Short-circuits

Short-circuits differ from overloads as they can be hundreds to thousands of times greater than the normal operating current. A high level short-circuit may be up to 30 kA or 200 kA, and must be interrupted as quickly as possible to minimize the damage that can include:

- High magnetic forces that warp and distort busbars and associated bracing beyond repair
- Severe insulation damage
- Melting or vaporizing conductors
- Vaporizing metal, including busswork in electrical equipment
- Ionized gases
- Arcing fires
- Explosions

Note: “fault current” is a general term that’s used in this publication and includes ground fault, arcing fault and short-circuit currents.

Friemel’s Laws of Overcurrent Protection

Paul Friemel was known in the electrical industry as the Professor of Overcurrent Protection from the mid-1960s until his passing in 2015. As a licensed professional engineer, he presented seminars on electrical overcurrent protection for more than 40 years.

Among his many accolades, he was awarded the Outstanding Educator Award by the IEEE as a Life Senior Member in 2004 and recognized as an Outstanding Professional Engineer by the St. Louis Society of Professional Engineers in 2010. He served on the St. Louis Electrical Code Review Committee for St. Louis County for over two decades, actively participated in the International Association of Electrical Inspectors, and was a guest lecturer at Washington University and the University of Missouri. He was a long standing member of the Electrical Board of Missouri and Illinois where he served several terms on the board of directors. Friemel taught the three **C**’s of overcurrent protection which are now known as Friemel’s Laws of Overcurrent Protection:

1. Interrupting rating (**C**apacity)
2. **C**omponent Protection
3. Selective **C**oordination

An understanding of these three key electrical overcurrent protection principles will lead to a safe, reliable and code compliant electrical system.



Construction

The fuse is a highly efficient OCPD with a simple design based upon basic principles of physics to interrupt and limit overcurrent events. Insight into their construction helps in understanding their application.

As shown in Figure 2, fuses have four parts common to most designs: case/housings (tube or cartridge), terminals (end blades or ferrules), fuse link (element), and arc-quenching filler. There are different fuse types that provide the operating characteristics required to address differing circuit protection needs.

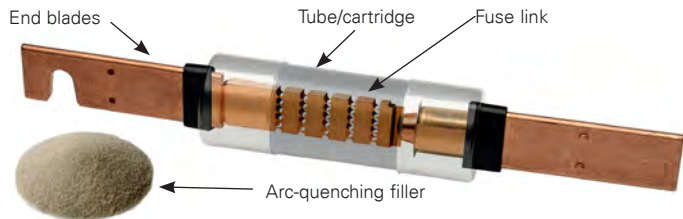


Figure 2: A dual-element, time-delay Low-Peak LPS-RK fuse showing the four common construction characteristics.

A fuse's construction typically offers the following benefits:

Physical rejection — Fuses have rejection features based on physical size or by a construction characteristic. Generally, a fuse of one class and case size cannot be installed in another fuse class and case size mounting. This ensures that the replacement fuse being installed will have the same voltage and interrupting ratings. A mild exception is that Class R fuses can be installed in Class H(K) fuse mountings for a protection upgrade, but, lower performing Class H(K) fuses cannot be installed in Class R fuse holders or blocks.

The Class J fuse is another example. Its size rejection prevents installing any other fuse type and virtually eliminates installing the wrong fuse type having different, potentially lower performance characteristics. Unless a user replaces the holder, block or switch, it's very difficult to install the wrong replacement fuse.

Enclosed, non-venting design — Fuses do not vent when they interrupt fault currents. All arcing is contained and extinguished inside the fuse body. This reduces the risk of metal vapors causing unnecessary damage to other components inside an enclosure. As part of their design, some mechanical OCPDs will vent when they interrupt fault currents. In addition, using fuses reduces cost by eliminating the need for guards or barriers to protect from the venting.

Enclosed, fixed, thermal design — Modern current-limiting fuses are constructed with an enclosed case, tube or body and have no moving parts when they open from an overcurrent. By operating on thermal energy principles of physics, the fuse improves electrical system reliability by not relying on springs, levers or latches that require periodic maintenance to ensure continued proper operation.

Factory calibrated replacements

There is no worry that a fuse may seize or not operate as intended as it's factory calibrated with no need for field adjustment. This minimizes possible misapplication by eliminating the need to adjust or change device settings in the field. Engineers and specifiers can be certain the required overcurrent protection level is met and retained.

When fuses are replaced, system integrity is maintained by ensuring the same protection for many years to come.

Using thermal or electronic OCPDs in electrical systems to protect against overloads, such as motor starters, is beneficial as they can easily be reset by an operator or user (after the overload cause has been corrected) so that production can quickly resume. On the other hand, if a fault occurs, a qualified electrician must investigate and remedy the cause prior to resetting the device or replacing the fuse. If an unqualified person is allowed to simply reset a device, a safety hazard could occur if the fault is still on the line.

Fuses help in complying with federal law and other safety standards by eliminating the invitation for an operator to "reset" a device after a fault without investigating or remedying the cause. OSHA 1910.334(b)2 does not allow this practice and similar requirements are found in NFPA 70E Section 130. Fuses help prevent this from happening as a qualified person is much more likely to be involved in replacing the fuse. In addition, many maintenance personnel in industrial facilities prefer fuses for the simple reason that the troubleshooter is more likely to investigate the cause for the fuse opening rather than simply replacing the fuse.



Non-time-delay fuse

Depending upon the fuse’s amp rating, the “single-element” non-time delay fuse may have one or more links. They are electrically connected to the terminals (end blades or ferrules) (see Figure 3) and enclosed in a case/housing (tube or cartridge) that contains an arc-quenching filler material that surrounds the link. Many Bussmann series Limitron™ fuses are “single-element” fuses.

Under normal operation, when the fuse is applied at or near its amp rating, it simply functions as a conductor. If an overload occurs and persists for more than a short time interval, as illustrated in Figure 4, the link’s temperature eventually reaches a level that causes a restricted link segment (neck) to melt. As a result, a gap is formed and an electric arc established. As the arc causes the link to “burn back,” the gap becomes progressively larger. The electric arc’s resistance eventually reaches such a high level that it cannot be sustained and is extinguished with the help of the filler material’s arc-quenching properties (see Figure 5). The fuse will have then completely cut off all current flow in the circuit.

Present day single-element fuse designs respond very quickly to overcurrents with excellent fault current component protection. However, temporary, harmless overloads (in-rush currents associated with inductive loads such as motors, transformers and solenoids) may cause nuisance openings unless these fuses are oversized. Therefore, they are best used in circuits not subject to heavy inrush currents.

Whereas overload normally falls between 1.35 and 6 times normal current, fault currents are quite high and the fuse may be subjected to fault currents of 30 kA or higher. The fuse’s current-limiting response to such high currents is extremely fast as its restricted link sections will simultaneously melt within a matter of two or three-thousandths of a second.

The multiple arcs’ high total resistance, together with the arc-quenching filler material, results in rapid arc suppression and clearing the fault (see Figures 6 and 7). Fault current is cut off in less than a quarter-cycle, long before it can reach its full value (fuse operating in its current-limiting range).



Figure 3: Cutaway view of typical single-element fuse.



Figure 4: Under sustained overload, a section of the link melts and an arc is established.



Figure 5: The “open” single-element fuse after opening a circuit overload.



Figure 6: When subjected to a fault current, several sections of the fuse link melt almost instantly.



Figure 7: The “open” single-element fuse after opening a shorted circuit.

Bussmann series UL Listed branch circuit fuses play a major role in industrial or commercial facilities by providing reliable, maximum protection to power systems. Their physical size or rejection features prevent replacing a fuse with one from another fuse class. This helps ensure the correct replacement fuse is always installed and the voltage and interrupting ratings remain the same. Shown are the case sizes for each fuse class relative to the size of a US quarter (left edge of image).



FRN-R — Class RK5, 250 V, 200 kA IR up to 600 A



LPN-RK — Class RK1, 250 V, 300 kA IR up to 600 A



LPJ — Class J, 600 V, 300 kA IR up to 600 A



LP-CC, FRO-R, KTK-R — Class CC, 600 V, 200 kA IR up to 30 A



FRS-R — Class RK5, 600 V, 200 kA IR up to 600 A



LPS-RK — Class RK1, 600 V, 300 kA IR up to 600 A



JJN — Class T, 300 V, 200 kA IR up to 1200 A



JJS — Class T, 600 V, 200 kA IR up to 800 A

Dual-element, time-delay fuse

There are many advantages to using “dual-element,” time-delay fuses that feature an overload link and a short-circuit element connected in series — hence, the “dual-element” designation. Unlike single-element fuses, Bussmann series dual-element, time-delay fuses can be sized closer to the load to provide high performance for both short-circuit and overload protection.

The overload element provides the intentional “time-delay” that permits temporary overloads to harmlessly pass. This is the reason these fuses can be sized much closer to the load than non-time delay fuses that must be oversized to pass inrush currents and not produce nuisance openings.

The short-circuit element is there to handle fault currents, and when the fuse is operating in its current-limiting range, it’s not possible for the full available fault current to flow through the fuse — it’s a matter of physics. The small restricted link sections in the short-circuit element quickly vaporize with the filler material assisting in forcing the current to zero; and so it’s able to “limit” the fault current.

Anatomy of a dual-element, time-delay fuse



Figure 8: Typical Class R Low-Peak fuse.

The Low-Peak LPS-RK100SP, 100 A, 600 V, Class RK1, dual-element fuse has excellent time-delay to withstand high inrush currents along with excellent current limitation and a 300 kA interrupting rating. Figure 8 shows the fuse’s internal construction. The real fuse has a non-transparent tube and arc-quenching material that completely surrounds the element and fills the tube’s internal space.

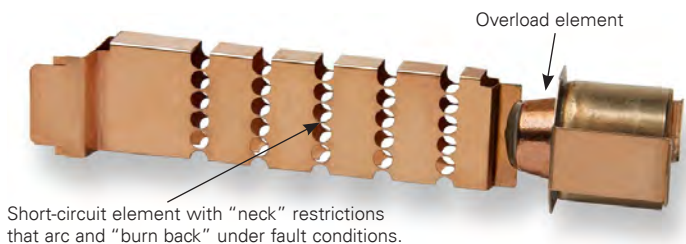
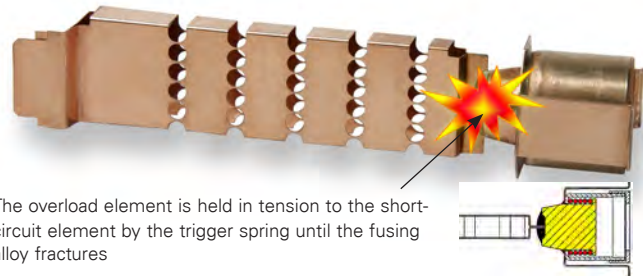
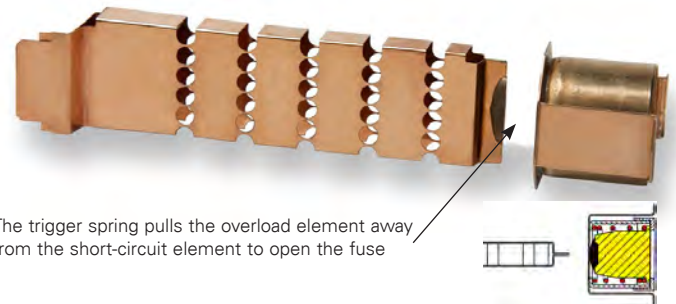


Figure 9: “Dual-element” construction.

The true dual-element fuse has separate and distinct overload and short-circuit elements connected in series as shown in Figure 9.



The overload element is held in tension to the short-circuit element by the trigger spring until the fusing alloy fractures



The trigger spring pulls the overload element away from the short-circuit element to open the fuse

Figure 10: Overload element operation.

Operation under persistent overload conditions as shown in Figure 10 causes the trigger spring to fracture the calibrated fusing alloy and releases the “connector.” The insets show the overload element before and after it opens. The coiled spring pushes the connector from the short-circuit element and the circuit is interrupted.

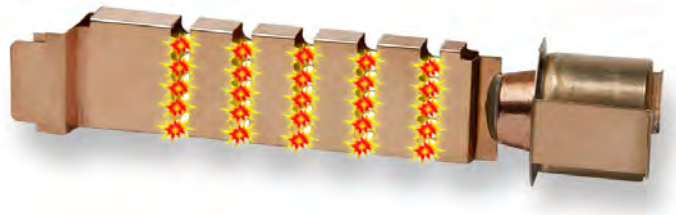


Figure 11: Short-circuit element operation under fault conditions.

For operation under fault conditions, the short-circuit element is designed with minimum metal in the restricted portions to greatly enhance the fuse’s current limitation and minimize the short-circuit current let-through. Fault current causes the short-circuit element’s restricted portions to quickly vaporize and commence arcing as shown in Figure 11. The arcs burn back the element, resulting in longer arcs that reduce the current with the arc-quenching filler helping to extinguish the arcs and force the current to zero.



Figure 12: Arc-quenching filler material helps suppress the arcing by melting and forming folgurite.

As a result of short-circuit operation, the special small granular, arc-quenching material plays an important part in the interruption process as it assists in quenching the arcs by absorbing their thermal energy and melting to form an insulating barrier material called folgurite as shown in Figure 12.

Advantages of dual-element over single element

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

1. Motor overload and short-circuit protection

When Bussmann series dual-element, time-delay fuses protect circuits with high inrush currents, such as motors, transformers and other inductive components, the Bussmann series Low-Peak and Fusetron™ dual-element, time-delay fuses can be sized close to full-load amps to maximize overcurrent protection. Sized properly, they will hold until normal, temporary overloads subside. For example, a 200 volt three-phase 10 HP motor with a 1.15 service factor has a 32.2 A full-load current rating (see Figure 13).

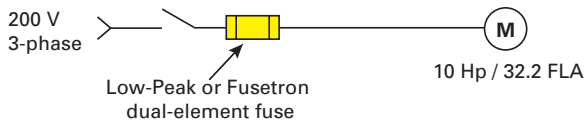


Figure 13: Motor circuit with a dual-element, time-delay fuse.

A 40 A, dual-element, time-delay fuse will protect the 32.2 A motor, compared to a much larger, 100 A, non-time delay, single-element fuse that would be necessary to withstand the temporary inrush current. If a harmful, sustained 200% overload occurred in the motor circuit, the 100 A, non-time delay, single-element fuse would never open and the motor would be damaged because it only provides ground fault and short-circuit protection. Additionally, the non-time delay fused circuit would require separate motor overload protection per the NEC. In contrast, the 40 A time-delay dual-element fuse provides the same ground fault and short-circuit protection, plus overload protection (eliminating the code requirement for separate motor overload protection) (see Figure 14).

Fuse and switch sizing for 10 Hp motor (200 V, 3Ø, 32.2 FLA)

Fuse type	Max fuse (A)	Required switch (A)
Dual-element, time-delay Fusetron FRS-R or FRN-R	40*	60
Single element non-time delay Limitron	100†	100

* Per NEC 430.32
† Per NEC 430.52

In normal installations, Bussmann series dual-element fuses sized for motor-running, overload protection, provide better fault protection plus a high degree of back up protection against motor burnout from overload or single-phasing should other overload protective devices fail (see sidebar “Single-phasing...are fuses an issue?” on page 10). If thermal overloads, relays or contacts should fail to operate, the properly sized dual-element fuse will act independently to provide “back-up” protection for the motor.

When secondary single-phasing occurs, current in the remaining phases increases from 173% to 200% of the motor’s rated full-load current. When primary single-phasing occurs, unbalanced voltages occurring in the motor circuit also cause excessive current. Dual-element fuses sized for motor overload protection can help protect against overload damage caused by single-phasing.

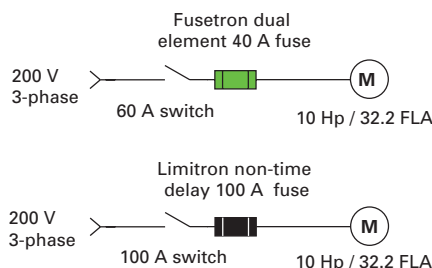


Figure 14: Closer fuse sizing to load can result in using smaller, less costly switches.

2. Permit using smaller and less costly switches

Bussmann series dual-element, time-delay fuses permit using smaller, space saving and less costly switches because a properly sized higher amp rated single-element fuse would make it necessary to use larger switches as the switch rating must be equal to or larger than the fuse’s amp rating. As a result, a larger switch may cost two or three times more than necessary rather than using a dual-element Bussmann series Low-Peak or Fusetron fuse. (Note: should a larger switch already be installed for single-element fuses, smaller, properly sized dual-element fuses can also be installed for motor overload or back-up protection using fuse reducers. These permit installing a smaller case size fuse into a larger case size mounting.)

3. Better short-circuit component protection (current limitation)

Bussmann series dual-element, time-delay fuses provide better component protection than non-time delay, fast-acting fuses that must be oversized for circuits with in-rush or temporary overloads. Oversized non-time delay fuses respond slower to faults than smaller, time-delay fuses because the current will build up to a higher level before the fuse opens, thus the oversized fuse’s current limitation is less than a fuse with an amp rating that’s closer to the circuit’s normal full-load current.

4. Simplify and improve selective coordination for blackout prevention

The larger an upstream fuse is relative to a downstream fuse (feeder to branch), the less likely an overcurrent in the downstream circuit to cause both fuses to open (lack of selective coordination). To be selectively coordinated, Bussmann series Low-Peak fuses require only a 2:1 amp rating ratio. Contrast this to a fast-acting, non-time delay fuse that would require at least a 3:1 amp rating ratio between a large upstream, lineside Low-Peak time-delay fuse and the downstream, loadside Bussmann series Limitron fuse.

As shown in Figure 15, closely sized Bussmann series Low-Peak dual-element fuses in the branch circuit for motor overload protection provides a large difference in the amp ratings (3.75:1 ratio) between the feeder and branch fuses, compared to the single-element, non-time delay Limitron fuse (1.67:1 ratio) with the 90 A Limitron fuse not conforming to the 3:1 published ratio needed for selective coordination.

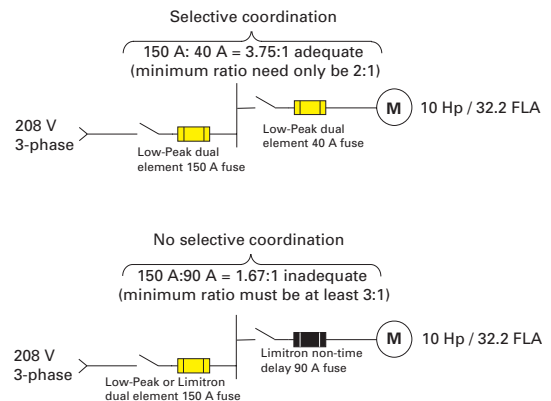


Figure 15: Using Low-Peak fuses permits closer fuse sizing to load for better protection and using smaller, less costly switches while retaining selective coordination to help prevent blackouts.

Single-phasing...are fuses an issue?

Single-phasing conditions on three-phase motor circuits can create unbalanced voltage and/or overcurrent conditions that, if allowed to persist, will damage motors. In modern motor circuits, properly applied fuses and overload protective devices provide a high degree of single-phasing protection. Major considerations of single-phasing include the following.

- Single-phasing cannot be eliminated, there are numerous causes including:
 - The utility loses one phase
 - Overheated conductor termination
 - Disconnect does not “make” one pole
 - Controller contact burns open
- Prior to 1971, single-phasing plagued three-phase motors installed per the NEC because overload protection was only required on two phases. The 1971 NEC remedied this problem by adding the requirement for three-phase-motor circuits to have motor overload protection on all three phases. This provided protection for the worst condition seen when a utility loses a phase on the transformer primary.
- Three properly sized (to the actual motor running current) motor overload protective devices, now required in NEC 430.37, provide sufficient protection
- Most electronic overloads, soft-start controllers, and drives have options to sense voltage imbalance to provide single-phasing protection
- Although circuit breakers do not cause single-phasing, unless one pole’s contact does not “make,” they do not provide single-phasing protection
- Fuses provide excellent short-circuit, current limitation to protect motor circuit starters and conductors, including Type 2 “No-Damage” protection when properly sized
- Fusible motor control centers benefit from the fast clearing time of a current-limiting fuse that also helps to reduce incident energy levels, mitigate arc flash hazards and protect workers

5. Better motor protection in elevated ambient temperatures

Before selecting a fuse or any OCPD, the application’s ambient temperature should be known so the proper amp rating can be determined through what’s called “derating.” Like all fuses, the dual-element fuse should be derated based on increased ambient temperatures. The fuse derating curves closely parallel motor derating curves in elevated ambient temperatures. Figure 16 illustrates the affect ambient temperature has on Bussmann series Fusetron and Low-Peak dual-element fuse operating characteristics. This unique feature allows for optimum motor protection, even in high temperatures. For derating affects of single-element or non-time delay fuses, see Figure 17.

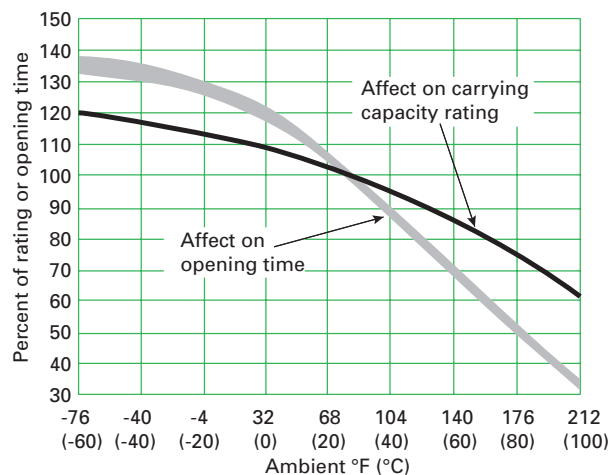


Figure 16: Ambient temperature dual-element fuse derating curve.

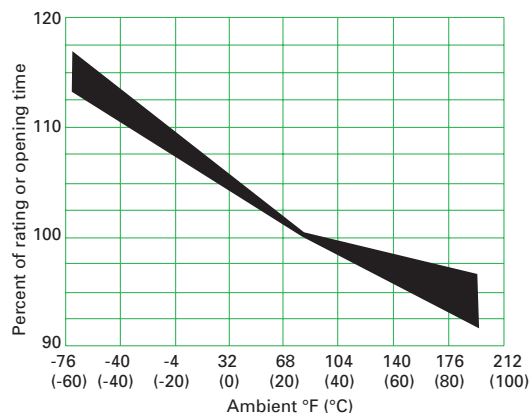
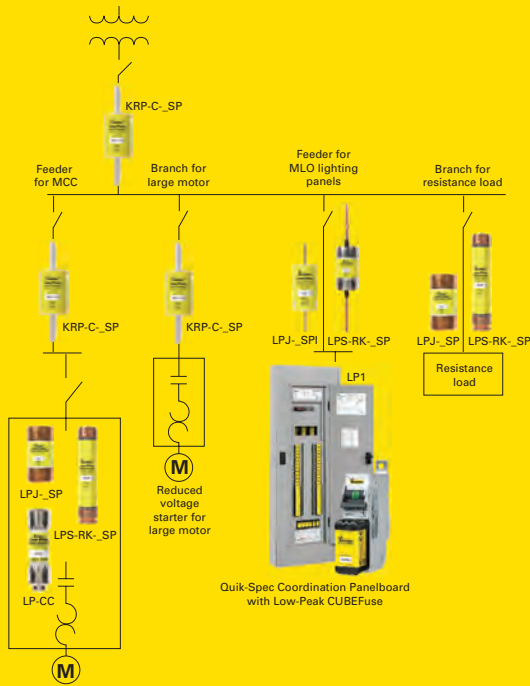


Figure 17: Ambient temperature single-element derating curve.

6. Provide Type 2 “No Damage” motor starter protection when properly sized

Fuses help reduce downtime when Type 2 “No Damage” (versus Type 1) protection is specified with properly sized fuses. Type 2 protection ensures that no damage, within specified limits, occurs to the contactor or overload relay. With Type 2 protection, light contact welding is allowed, but must be easily separable allowing equipment to be placed back into service without having to replace or recalibrate any components. A current-limiting device is necessary to achieve Type 2, often requiring Class CC, CF, J, or RK1 fuses. In this scenario, when the branch-circuit fuse protects the motor circuit, the starter does not need replacing and downtime is reduced or eliminated.

The Bussmann series Low-Peak fuse system



Specifying the Low-Peak fuse family throughout a building results in:

- Built-in fuse size and class rejection for greater safety
- Selective coordination with a minimum 2:1 amp ratio
- Maximum current-limiting protection for distribution equipment
- Type 2 “No Damage” motor starter protection when properly sized
- Reduced inventory
- Up to 300 kA interrupting ratings
- Arc flash hazard mitigation

Ratings

All fuses have three basic ratings:

- Voltage (AC, DC or both)
- Amp
- Interrupting

Understanding these three ratings, their significance and how they apply to circuit protection is crucial to specifying the correct, and in many cases, optimal circuit protection.

Voltage rating

One aspect of proper OCPD application requires the OCPD’s voltage rating be equal to or greater than the system voltage. When an OCPD is applied beyond its voltage rating, there may not be any initial indications that anything is wrong, but when it attempts to interrupt an overcurrent, adverse consequences can result and it may self-destruct in an unsafe manner. There are two OCPD voltage rating types: straight voltage rated and slash voltage rated.

Straight rated devices

A straight voltage rated OCPD can be installed in any electrical system regardless of the grounding system.

All fuses are straight voltage rated and their proper application is straightforward (i.e., 600 V, 480 V, 240 V). These OCPDs have been evaluated for proper performance with full phase-to-phase voltage used during testing, listing and marking.

The fuse’s voltage rating is its ability to open under an overcurrent condition while suppressing the internal arcing that occurs after the link melts and an arc is produced. If a fuse is applied with a voltage rating lower than the circuit voltage, arc suppression will be impaired, and, under some conditions, it may not safely clear the overcurrent.

The fuse’s voltage rating must be at least equal to or greater than the circuit voltage. For example, a 600 V rated fuse can be used in a 208 V circuit, but a 250 V rated fuse cannot be used in a 480 V circuit.

Most low voltage power distribution fuses have 250 V or 600 V ratings (other ratings include 125 V, 300 V, and 480 V). Bussmann series Low-Peak LPJ (Class J) fuses are rated at 600 V and can be used on any 600 V or less system, whether it’s solidly grounded, ungrounded, impedance grounded or corner grounded Delta.

A straight rated OCPD (whether a fuse or circuit breaker) that protects a single pole can be used to protect single-phase, line-to-neutral loads when supplied from a three-phase, solidly grounded circuit. For example, a 300 V rated fuse can be used to protect single-phase, line-to-neutral loads when supplied from a three-phase, solidly grounded, 480/277 V circuit, where the single-phase, line-to-neutral voltage is 277 V. This is allowed in this application because a 300 V fuse will not have to interrupt a voltage greater than its 300 V rating.

Slash rated devices

Slash voltage rated OCPDs have limitations imposed upon them that straight rated voltage OCPDs do not. Multiple-pole, mechanical OCPDs with a slash voltage rating, such as circuit breakers, self-protected starters and manual motor controllers, are limited in their application and require extra evaluation for use.

The slash rating can be broken down into its higher and lower numbers and are understood as follows:

- The lower rating number pertains to overcurrents at **line-to-ground** voltages, intended to be cleared by one pole of the device.
- The higher rating number pertains to overcurrents at **line-to-line** voltages, intended to be cleared by two or three poles of the device.

The proper slash rated circuit breaker application is such that:

- The **line-to-ground** voltage does not exceed the device's lower voltage rating
- The **line-to-line** voltage (between any two conductors) does not exceed the device's higher voltage rating. (Reference NEC Section 240.85.)

Understanding the higher and lower ratings is important as slash rated device misapplication can result in it being applied outside its voltage rating with dire consequences should the device be called upon to interrupt overcurrents.

Slash voltage rated circuit breakers are not intended to open line-to-line (phase-to-phase) voltages across only one pole. Where it is possible for line-to-line voltage to appear across only one pole, a straight rated OCPD must be used. For example, a 480 V circuit breaker may have to open an overcurrent at 480 V with only one pole, such as might occur when Phase A goes to ground on a 480 V, B-phase, corner grounded Delta system.

Slash voltage rated circuit breakers can only be used on solidly grounded power distribution systems. The proper application of molded case circuit breakers on 3-phase systems, other than solidly grounded Wye, particularly on corner grounded Delta systems, must consider the circuit breakers' individual pole-interrupting capability. (Ref. NEC Section 240.85).

Slash rated devices, such as motor controllers, cannot be used on the following systems (Ref. NEC Section 430.83(E)):

- Impedance-grounded
- Ungrounded Wye systems
- Ungrounded Delta systems
- Corner-grounded Delta systems

Other slash rated devices, such as motor controllers, have these same limitations. They include, but are not limited to:

- Manual motor controllers — UL 508
- Self-protected Type E combination starters — UL 508
- Supplementary protectors — UL 1077. These look like small circuit breakers and are sometimes referred to as a mini-breaker. However, these devices are not rated for branch circuit protection and cannot be used where branch circuit protection is required.

Product standards require slash voltage rated devices to be marked with their rating such as 480 Y/277 V. If a machine or equipment panel utilizes a slash voltage rated device, it's recommended that the equipment nameplate or label designate the slash voltage rating as the equipment voltage rating. UL 508A industrial control panels require the electrical panel voltage marking to be slash-rated if one or more devices in the panel are slash voltage rated.



Amp rating

In general, the OCPD amp rating indicates the amount of current that can flow through the device without causing it to open. Standard amp ratings for fuses and inverse time circuit breakers are shown in the Table 2 below (Reference NEC Section 240.6).

Understanding this NEC table is important. NEC Section 240.6 is referenced whenever the requirements specify "... the next standard overcurrent device size shall be used..." The next standard OCPD size is not based on a manufacturer's literature, but always obtained from NEC 240.6.

Fuse only ratings				
1	3	6	10	601
Fuse and circuit breaker ratings				
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	6000	—	—	—

Table 2: NEC Table 240.6, standard amp ratings. Also see sidebar on "The NEC and Fuses only ratings."

In selecting the fuse's amp rating, consideration must be given to the load type and code requirements. The fuse amp rating normally should not exceed the circuit's conductor current carrying capacity that's determined by ampacity adjustment factors covering how and where it's routed or other NEC related adjustment areas. For the most part, if a conductor's current carrying capacity is 20 A, a 20 A fuse is the largest that should be used to protect it.

There are specific circumstances in which the OCPD amp rating is permitted to be greater than the circuit's current carrying capacity, with motor circuits a common exception. Dual element time-delay fuses are generally permitted to be sized up to 175% and non-time delay fuses up to 300% of the motor's full-load amps. As a rule, the fuse amp rating and switch combination should be selected at 125% of the continuous motor 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.



Figure 18: Fires can result if the correct OCPD amp rating is not applied.

The photograph in Figure 18 vividly illustrates the affects overcurrents have on electrical components when the OCPD's amp rating is not sized to the component's rating.

The NEC and “Fuse only ratings”

As part of 1978 NEC, the “fuse only ratings” shown in Table 2 were added because public inputs focused on protecting motors and the desire to provide the smallest fuse amp rating possible for effective short-circuit protection. There were two inputs accepted.

One public input addressed fuses rated less than 15 amps with the submitter noting in the substantiation that these fuses are often required on motor branch circuits to provide short-circuit and ground-fault protection. The substantiation for these fuse ratings came from test results showing fuses rated 1, 3, 6 and 10 amps provided the intended protection in motor branch circuits for motors with full load currents less than 3.75 amps ($3.75 \times 400\% = 15$). These ratings are also commonly shown on control manufacturers’ overload relay tables. Overload relay elements for very small motors, with small full load motor currents, have such a high resistance that a bolted fault at the controller load terminals produces a less than 15 amp fault current, regardless of the available current at the line terminals. An overcurrent protective device rated or set for 15 amps is unable to provide the short-circuit or ground fault protection required by Section 110.10 in such circuits.

The other public input added the 601 A Class L fuse for motor protection as the 601 A fuse size was not listed in this table, and the next standard size up that would be permitted would be a 700 A fuse. When the NEC called for the next standard OCPD size to be permitted, and when the calculated amp rating is greater than 500 A, only a 700 A Class L fuse would have been permitted for the installation.

Before the 1978 NEC, the 1975 NEC cycle placed the 601 A fuse as an exception to Section 430-52 (the requirements for rating or setting for individual motor circuits). This exception is still a part of the NEC as Exception “d” to this requirement and states, “The rating of a fuse of 601—6000 ampere classification shall be permitted to be increased but shall in no case exceed 300 percent of the full-load current.”

The public input pointed out in the substantiation that “since the intent of Table 430-52 and Section 430-52 is to encourage closer short-circuit protection, it seems prudent to encourage availability and use of 601 amp fuses in combination with motor controllers that can accept a Class L fuse.

The submitter recognized that inverse time circuit breakers are not subjected to the same limitation that fuses are when related to the fuse mounting means. For this reason, a distinction between 600 and 601 amps in circuit breakers has no purpose, and thus simply adding 601 A to the list for all OCPDs was not supported by the code panel.

Interrupting rating

An OCPD must be able to safely interrupt destructive fault current energy. If a fault current exceeds a level beyond the OCPD’s capability, it may rupture, causing damage and posing a safety hazard. The rating that defines OCPD’s capacity to maintain its integrity when reacting to fault currents is its interrupting rating. It’s important when applying a fuse or circuit breaker, to use one that can safely interrupt the largest potential fault currents. Most modern, current-limiting fuses have a 200 kA or 300 kA interrupting rating and can be used in just about any system without fear of misapplication. NEC 110.9 requires equipment intended to break current at fault levels to have an interrupting rating sufficient for the available fault current at point of application.

The fuse interrupting rating is not dependent on a particular voltage when applied within its rating. For example, a 600 Vac rated LPJ fuse has a UL Listed 300 kA interrupting rating for any voltage up to 600 Vac. Whether for the initial installation or system updates, a fusible system can maintain a sufficient interrupting rating throughout its life. There is little need for additional fault current calculation or worry that a fuse will be misapplied due to an improper interrupting rating. Nor is a short-circuit study needed when applying Bussmann series Low-Peak fuses for selective coordination, so meeting NEC 110.9 requirements is easy. Additionally, high interrupting ratings help equipment achieve a high short-circuit current rating that may be limited by the installed OCPD’s low interrupting rating. Finally, fuses provide peace of mind as the interrupting rating is always at least equal to or, in many cases, greater than the available fault current at the line terminals.

When applying a fuse or circuit breaker, as shown in Figure 19, the chosen OCPD must be able to safely interrupt the largest available fault currents at its line terminals (Ref. NEC Section 110.9).

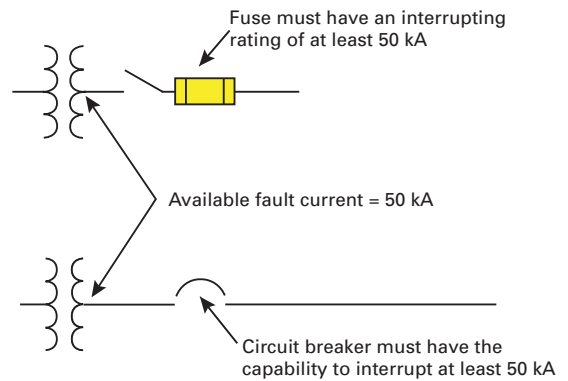


Figure 19: The interrupting rating of the fuse or circuit breaker must be greater than the calculated maximum available fault current at its line terminals.

As with other ratings, applying an OCPD in an AC or DC system matters because interrupting ratings for alternating current (AC) will generally be different from direct current (DC), with AC interrupting ratings being higher in general. The primary difference between AC and DC interrupting ratings is alternating current has a zero voltage potential that happens 60 times a second (60 Hz) when its sine wave passes through zero. It’s when the voltage potential is at zero that arc suppression is easiest to achieve. On the other hand, there aren’t any “zero voltages” in DC, so the arc that’s generated never experiences “zero volts” and, as such, is more difficult to suppress.

Products must be rated for the application within which they are placed. The fuse’s simplicity limits areas of misapplication with this regard, as most modern current-limiting fuses have an AC interrupting rating of 200 kA or 300 kA. For example, Bussmann series Low-Peak* fuses are UL Listed at 300 kA IR at 600 Vac, allowing them to be safely applied on any 600 V or less system and still provide a 300 kA interrupting rating.

* Does not include LP-CC Class CC fuses which are 200 kA.

Table 3 on the following page illustrates the highest AC and DC interrupting ratings available for Bussmann series low voltage branch circuit fuses by fuse class.

Busmann series fuse voltage and interrupting ratings

Busmann series product	UL Class	Catalog symbol	Amps	Vac	IR AC (kA)	Vdc	IR DC (kA)
Low-Peak	CC	LP-CC	Up to 30	600	200	300 (1/2 to 2-1/2 and 20-30 150 (2-8/10 to 15 A))	20
	CF*	TCF	Up to 100	600	300	300	100
	J	LPJ	Up to 600	600	300	300	100
	L	KRP-C	601 to 6000	600	300	300 (601-200, 300 A)	100
	RK1	LPN-RK	Up to 600	250	300	125 (up to 60 A) 250 (70-600 A)	100
		LPS-RK	Up to 600	600	300	300	100
Fast-acting CUBEFuse	CF*	FCF	Up to 100	600	300	600	50
Fusetron	RK5	FRN-R	Up to 600	250	200	125 (1/10 — 60, 110-200 A) 250 (225-600 A)	20
		FRS-R	Up to 600	600	200	300 (1/10 — 30, 65-600 A) 250 (35-60 A)	20
Limitron	CC	FNQ-R	Up to 30	600	200	300 (15-20 A)	20
		KTK-R	Up to 30	600	200	—	—
	J	JKS	Up to 600	600	200	—	—
	L	KLU	601 to 4000	600	200	—	—
		KTU	601 to 6000	600	200	—	—
	RK1	KTN-R	Up to 600	250	200	250 (70-350 A)	100
		KTS-R	Up to 600	600	200	—	—
T	JJN	Up to 1200	300	200	160 (15-600 A) 170 (601-1200 A)	20	
	JJS	Up to 800	600	200	—	—	
General purpose	G	SC	Up to 60	600 (1/2-20 A) 480 (25-60 A)	100	170 (1/2-20 A) 170 (1/2 — 20 A) 300 (25-60 A)	10
		H(K)	NOS	600	Up to 600	50 (up to 60 A) 10 (70-600 A)	—

* UL Class CF fuses have UL Class J electrical performance.

Table 3: Interrupting ratings of Busmann series UL branch circuit fuses.

Interrupting rating examples

Figure 20 shows four different scenarios involving an OCPD with an interrupting rating of 10 kA and varying levels of fault currents that they will be called upon to interrupt. This illustrates the importance of knowing the available fault current and the advantage of applying a fuse with 100 kA, 200 kA or higher interrupting rating.

In the first three scenarios, the circuit current conditions are within the OCPD's safe operating capabilities. However, the fourth instance involves an OCPD misapplication. A fault on the device's loadside resulted in a 50 kA fault current that's well above the OCPD's interrupting rating. This resulted in a violent rupture and possible damage to equipment or injury to personnel. Using high interrupting rated fuses (typically rated at 200 kA or 300 kA) would prevent this potentially dangerous situation.

The following examples on the next page are from fault current tests. They demonstrate the destructive power associated with fault currents.

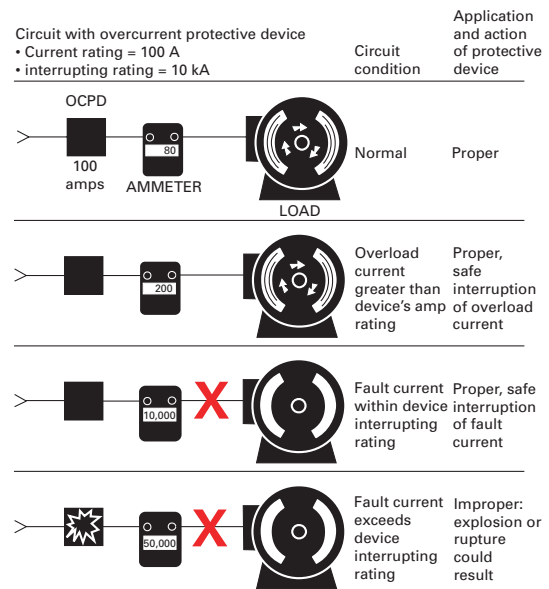


Figure 20: Interrupting ratings are important for protection against short-circuits.

Misapplied circuit breaker

Figure 21 is a series of images depicting a test conducted on a 480 V circuit breaker with a 14 kA interrupting rating and a test circuit capable of delivering fault current of 50 kA at 480 V. The dramatic results are shown below. This video is available through the QR code below.

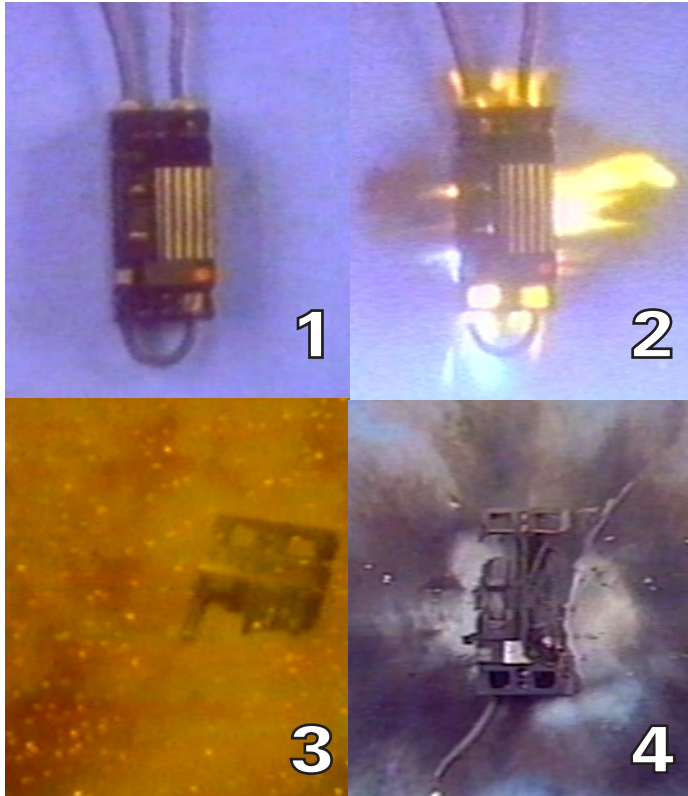


Figure 21: A severe misapplication of a circuit breaker beyond its interrupting rating.

Misapplied general purpose fuses

Figure 22 is a series of images depicting the same test circuit as the previous test with a pair of 600 V, general purpose fuses having a 10 kA interrupting rating. Notice in this test (as well as the circuit breaker test), the large destructive force that was released. Misapplying OCPDs in this manner is a serious safety hazard as shrapnel and molten metal could strike electricians or maintenance personnel, or anyone who happens to be nearby. This video is available through the QR code below.

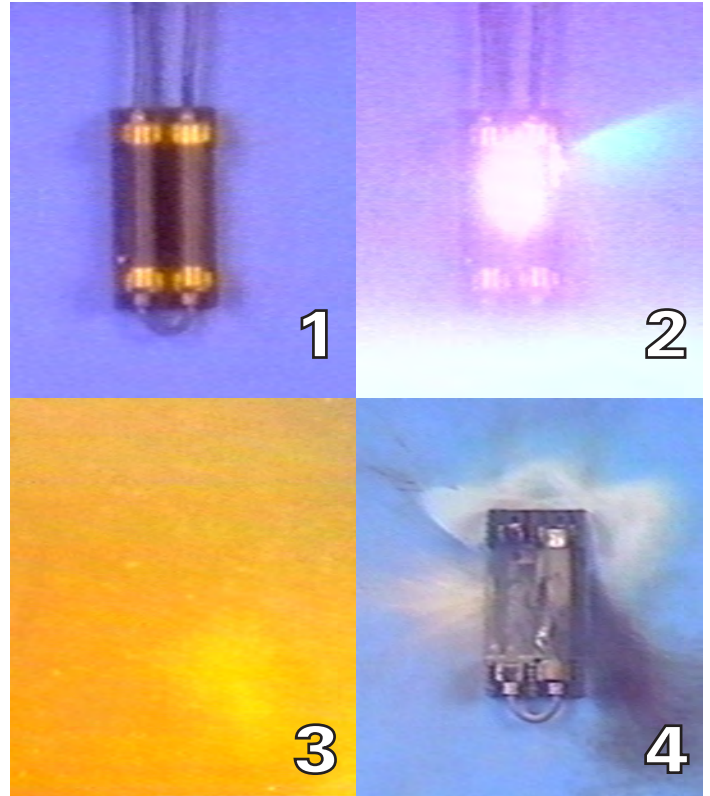


Figure 22: A severe misapplication of a fuse beyond its interrupting rating.



Properly applied Low-Peak fuses

Figure 23 is a series of images depicting the same test circuit as the previous two tests (50 kA available at 480 V) only this time the test was performed with modern, Bussmann series Low-Peak current-limiting fuses with a 300 kA interrupting rating. Notice that the fault was contained and cleared without violence. This video is available through the QR code below.

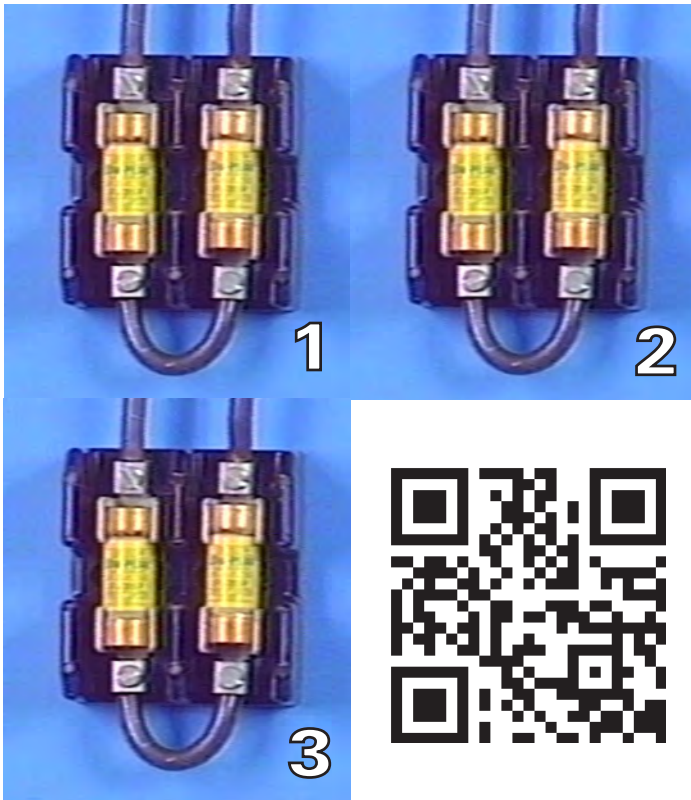


Figure 23: A fuse applied within its interrupting rating.

As depicted in Figure 24, it becomes necessary to determine the available fault currents at each OCPD location. The fault currents in an electrical system can be easily calculated if sufficient information is known. The advantage of high 200 kA or 300 kA fuse interrupting ratings are that they can be used to eliminate the need for fault current calculations — 200 kA and 300 kA will exceed available fault currents for virtually all power distribution system.



Test conditions for a 300 kA interrupting rated fuse

The NEC defines interrupting rating as the highest current at rated voltage that an overcurrent protective device can safely interrupt under standard test conditions. The phrase “under standard test conditions” considers the importance of understanding how the overcurrent protective device is tested in order to ensure it is properly applied.

The UL 248 Standard defines the branch circuit fuse test configuration to establish the necessary performance requirements for interrupting ratings. The process to achieve a UL Listed 300 kA interrupting rating is:

- To confirm that the interrupting capacity is not less than the interrupting rating, the test circuit is established without any additional conductor lengths in the test circuit configuration. The fuse is efficient at interrupting very high fault currents and does not require any help from additional impedances in the configuration.
- The test circuit is calibrated to have at least 300 kA fault current at the rated fuse voltage. During the test circuit calibration, a busbar is used in place of the fuse to verify the 300 kA fault current level.
- The busbar is then replaced with a fuse and the test conducted. If the fuse passes the test, the fuse can be marked with a 300 kA interrupting rating.

This test procedure ensures the fuse has 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. Per UL/CSA/ANCE 248 Fuse Standards, fuses are tested and evaluated as single-pole devices. Although most electrical systems are designed with OCPDs having adequate three-phase interrupting ratings, the single/individual pole interrupting capabilities are easily overlooked. Because the fuse interrupting rating is all encompassing, there is no need for concern about single-pole interrupting capabilities.

300 kA Low-Peak fuses

Bussmann series Low-Peak fuses (excluding Class CC) are the only fuses tested and Listed by UL to 300 kA IR. This high interrupting rating is capable of safely interrupting virtually any available fault current level to be encountered in a 600 V or less system. The 300 kA IR provides assurance that when a properly sized Low-Peak fuse is installed, the system is covered for any worst case overcurrent event.

Electrical system short-circuit current levels and appropriate protection

Knowing the available fault current levels throughout an electrical system helps determine the necessary OCPD interrupting ratings. Figure 24 is a one-line diagram showing available fault current levels at different points in an electrical system.

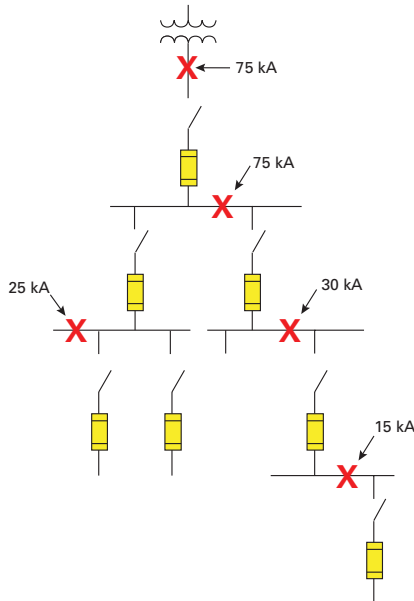


Figure 24: Determining the fault current at each OCPD is necessary to ensure proper device application.

Fuses can be applied on single-phase or three-phase circuits without any concern for single-pole interrupting capabilities. There is no need to perform special calculations due to the grounding system utilized. All Bussmann series Low-Peak LPJ, KRP-C, LPS-RK and LPN-RK fuses have UL Listed 300 kA single-pole interrupting ratings.

This is a simple solution to ensure adequate interrupting ratings for present and future systems regardless of the grounding scheme.

Figure 25 illustrates the fusible, high impedance grounded system allowing the fuse performance during fault conditions to be reviewed.

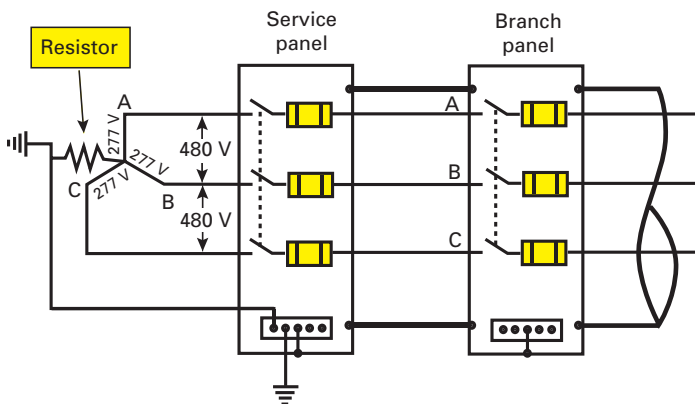


Figure 25: Fusible high impedance grounded system.

Figure 26 illustrates what occurs during the first system fault which is limited by the grounding resistor's impedance that keeps the ground fault current in the low range of 5 amps. Here the fuse does not open as expected and designed.

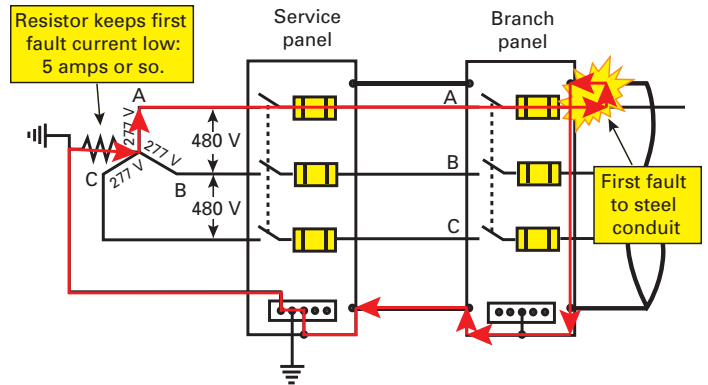


Figure 26: The grounding resistor's impedance keeps the ground fault current low.

Figure 27 illustrates the system should a second fault occur before the first fault can be addressed. The fault is essentially line-to-line with the conductors and ground path impedance, and the fuse must interrupt this second fault. Since a fuse's interrupting rating is the same as its single-pole interrupting capacity, fuses with 200 kA or 300 kA interrupting rating can be applied without further analysis for single-pole interrupting capabilities.

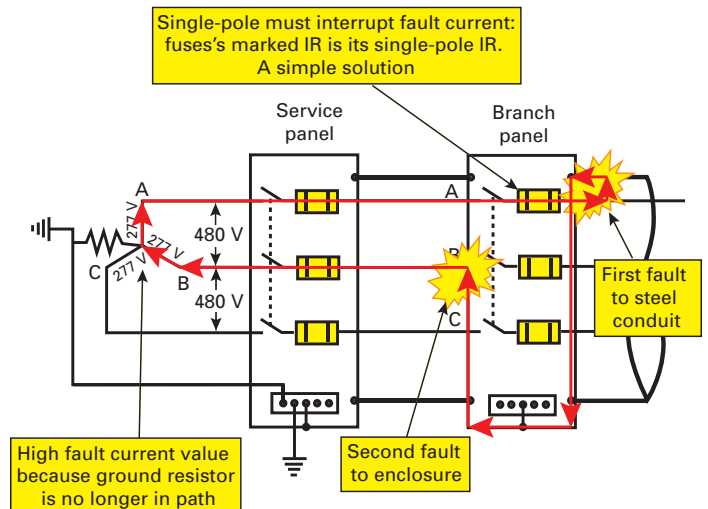
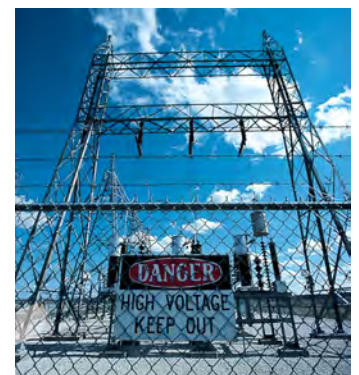


Figure 27: The fault is essentially line-to-line with the conductors and ground path impedance.

As fault current levels increase with the continued growth in electrical power generation, so too has the need for OCPDs with higher interrupting ratings.

Utilities desire to obtain greater efficiencies, lower energy costs and improved voltage regulation by installing lower impedance transformers with larger kVA ratings that produce higher available fault currents. To meet this challenge, OCPDs that only interrupt moderate fault current levels are being replaced with fuses able to interrupt fault currents up to 300 kA.



Utilities are increasing available fault current through installing lower impedance and larger kVA transformers.

Performance characteristics

Current limitation

Current limitation is a function of how quickly the fuse can react to a fault and clear it before the fault current can build up to destructive magnitudes.

NEC 240.2 defines a current-limiting device as:

“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.”

Fuses that limit the let-through current to downstream components provide protection from thermal and magnetic forces while providing numerous benefits.

- Current-limiting fuses enhance workplace safety by reducing the incident energy personnel are exposed to under fault conditions. Arc flash hazards may be greatly reduced when compared to using a non-current-limiting OCPD, especially at 600 amps and below.
- Fuses can protect components and equipment from extreme thermal and magnetic forces by clearing the fault current within the first half or quarter cycle. Conductors, busway, motor starters, switches and other devices can be well protected with current-limiting fuses. In addition, fuses, when properly sized, help comply with NEC 110.10 by protecting equipment and components from extensive damage.
- Fuse current limitation helps equipment achieve a high SCCR. Branch circuit components inside industrial control panels and machines, HVAC control panels, and other UL 508A Listed equipment can be protected by current-limiting fuses in the feeder circuit. The low peak let-through current can help raise the overall equipment short-circuit current rating — even with lower rated devices in the branch circuit — so long as the peak let-through current is less than the branch components’ SCCR and the branch circuit overcurrent protective device’s interrupting rating is sufficient.
- Current limitation is a key part of selective coordination and current-limiting fuses save the engineer or designer time and money by reducing the need for a selective coordination study. As long as a minimum amp ratio is maintained between upstream and downstream fuses (2:1 for Bussmann series Low-Peak fuses), selective coordination is achieved and unnecessary power loss to upstream circuits is prevented for any fault current up to the interrupting rating of the fuse (see “Bussmann series fuse selectivity ratios” table on page 26).

Figure 28 shows the minimum Low-Peak fuse amp rating ratios required for “selective coordination” (discrimination) between upstream and downstream fuses.

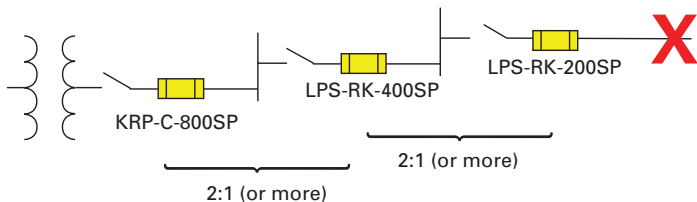


Figure 28: Low-Peak fuses only need a 2:1 amp ratio for selective coordination.

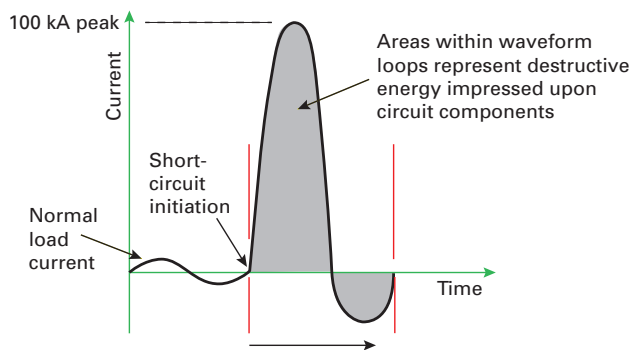
It’s a simple matter to selectively coordinate modern design fuses. By maintaining a minimum fuse amp rating ratio between an upstream and downstream fuse, selective coordination is achieved. Minimum selectivity ratios for Bussmann series fuses can be found on page 26.

Most electrical distribution systems today can deliver very high fault currents, some in excess of 200 kA. Many circuit components have relatively low (a few thousand amps) short-circuit current withstand capabilities.

If the components can’t withstand these high fault currents, they can be easily damaged or destroyed. The fuse’s current-limiting ability allows components with low SCCR to be specified despite high available fault currents.

Protecting electrical system components from fault currents is critical when selecting OCPDs. The engineer or specifier should consider the electrical circuit components’ SCCR, such as wire, bus or motor starters, and whether proper circuit protection will improve reliability and reduce the possibility of injury. Electrical systems can be destroyed if OCPDs do not limit the fault current to within the system’s component SCCR. Merely matching the component amp rating with the protective device amp rating does not ensure component protection under fault conditions.

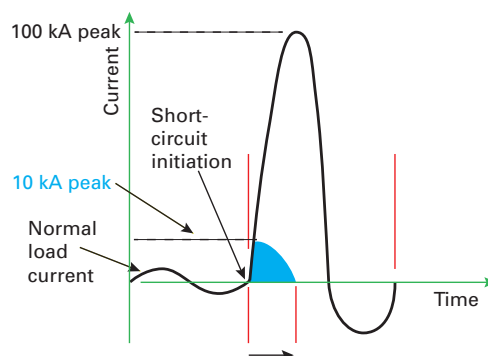
Current limitation is illustrated in Figures 29 and 30. When not protected by a current-limiting OCPD, the prospective available short-circuit current is shown in Figure 29. A non-current-limiting OCPD permits fault current to build up to its full value and lets through an immense amount of destructive current, heat and magnetic energy before opening. Some OCPDs will permit short-circuit currents to flow for more than 1 cycle.



Non-current limiting OCPD opens short-circuit in about 1 cycle

Figure 29: Fault current can become great in the first full cycle.

The waveform in Figure 30 demonstrates this same short-circuit when the fuse operates within its current-limiting range. A current-limiting fuse has such a fast response speed that it cuts off the current long before it can build up to its full peak value.



Current limiting fuse opens and clears short-circuit in less than 1/2 cycle

Figure 30: Cutting off the fault current in the first 1/4 cycle greatly reduces its magnitude.

The shaded area under the curve represents energy being dissipated in the circuit with both magnetic forces and thermal energy being directly proportional to the square of the current, making it 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.

In the first major fault current cycle loop depicted by the waveform in Figure 29, a non-current-limiting OCPD would let through approximately 100 times as much destructive energy as the current-limiting fuse would ($100 \text{ kA} / 10 \text{ kA})^2 = 100$).

The current-limiting fuse in Figure 30 opens and clears the fault within the first 1/2 cycle and limits the let-through energy to a fraction of the system's available short-circuit current.

This performance is an important consideration when selecting OCPDs. Most fuses are current-limiting and greatly reduce a fault current's destructive peak and duration to protect downstream equipment, and can reduce the bracing needs for bus structures and minimize the need for components to have high SCCRs (withstand ratings).

Current-limiting fuses reduce the magnetic forces on downstream equipment during fault events that, if not limited, can reach levels of 30 kA or higher (even above 200 kA) in the first half cycle (0.008 seconds, at 60 Hz). The immense heat that can be produced in circuit components can cause conductor insulation damage or violent component explosions. At the same time, huge magnetic forces developed between conductors can crack insulators and distort or destroy bracing structures with the maximum mechanical force exerted being proportional to the square of the instantaneous peak current (I_p^2). Thus, it is important that an OCPD limit fault currents before they reach their full potential.

Cable whip test

The "cable whip test" is a current limitation demonstration that visually illustrates the difference between current-limiting and non-current limiting OCPDs. The following tests (A and B) were conducted with the same parameters/configuration:

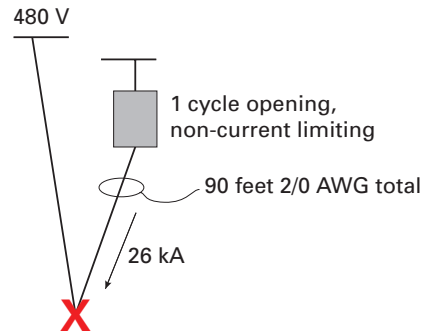
- Test voltage: 480 volts
- Conductor: 90 ft. of 2/0 AWG cable placed on the test lab floor
- The short-circuit current during a calibration test: asymmetrical with an approximately 26 kA symmetrical RMS component

Test A was conducted without current limitation and Test B utilized a 200 A current-limiting fuse.

Tests videos are available through the QR codes. Figure 31 is a photograph of the test configuration that was performed without an upstream current-limiting OCPD. Figure 32 illustrates how Test A was conducted with the resulting peak current that flowed in one cycle.



Figure 31: Test A: One cycle interrupting time — non-current limiting OCPD.

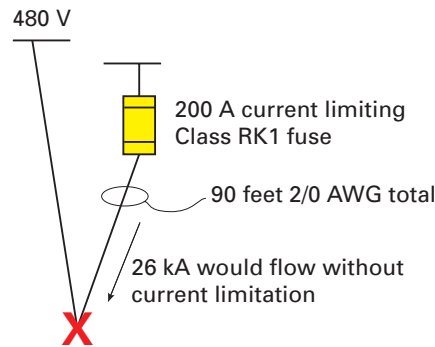


Test results:

- I_p let-through = 48,100 A
- Clearing time = 0.0167 sec.

Figure 32: Test A with a non-current limiting OCPD.

Test B results and video are available in Figure 33. This test was conducted with an upstream current-limiting device with dramatically different results from Test A.



Test results:

- I_p let-through = 10,200 A
- Clearing time = 0.004 sec.

Figure 33: Test B with a 200 A current-limiting OCPD.

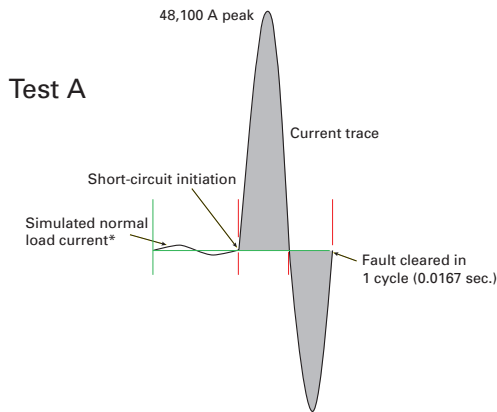
Reviewing the Test A and Test B cable whip results demonstrate a significant reduction in let-through current by the 200 A current-limiting fuse versus the one-cycle non-current limiting OCPD. Since the mechanical forces exerted on electrical equipment is directly proportional to the instantaneous peak current squared (I_p^2) let-through, the current-limiting fuse reduced the maximum mechanical force let-through by over 95% as shown in this equation:

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



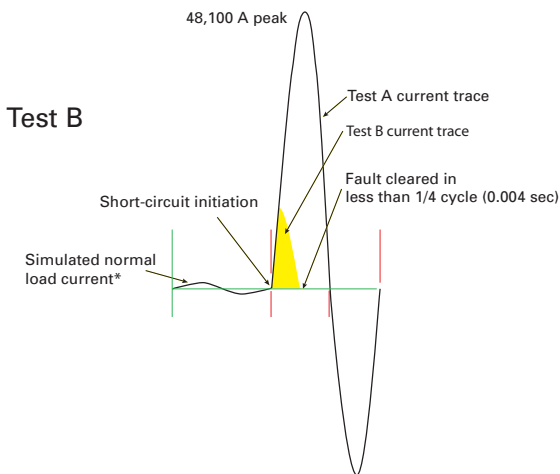
Test A and B short-circuit current waveforms

The equivalent Test A and Test B waveforms are illustrated in Figures 34 and 35.



* Normal load current did not flow prior to short-circuit initiation.
Figure 34: Test A fault current waveform.

Figure 34 illustrates the current trace of Test A depicting normal current flow until the fault occurs, and then the fault current that flows for one cycle, achieving a peak let-through of 48,100 A.



* Normal load current did not flow prior to short-circuit initiation.
Figure 35: Test B fault current waveform.

Figure 35 illustrates the current trace of Test B showing normal current until the fault occurs, and then the short-circuit current being cleared in less than 1/4 cycle by the Bussmann series current-limiting Low-Peak LPS-RK-200SP fuse that limited the instantaneous peak current to only 10.2 kA.

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 current was 1/123 the thermal energy compared to Test A.

How to use current limitation charts

Analysis of current-limiting fuse let-through graphs

The degree of current limitation of a given size and type of fuse depends, in general, upon the available fault current that can be delivered by the electrical system. Current-limitation of fuses is best described in the form of a let-through curve (see Figure 36) that, when applied from a practical point of view, is useful to determine the let-through currents when a fuse opens.

Fuse let-through curves 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 fault 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 fault 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 fuse analysis

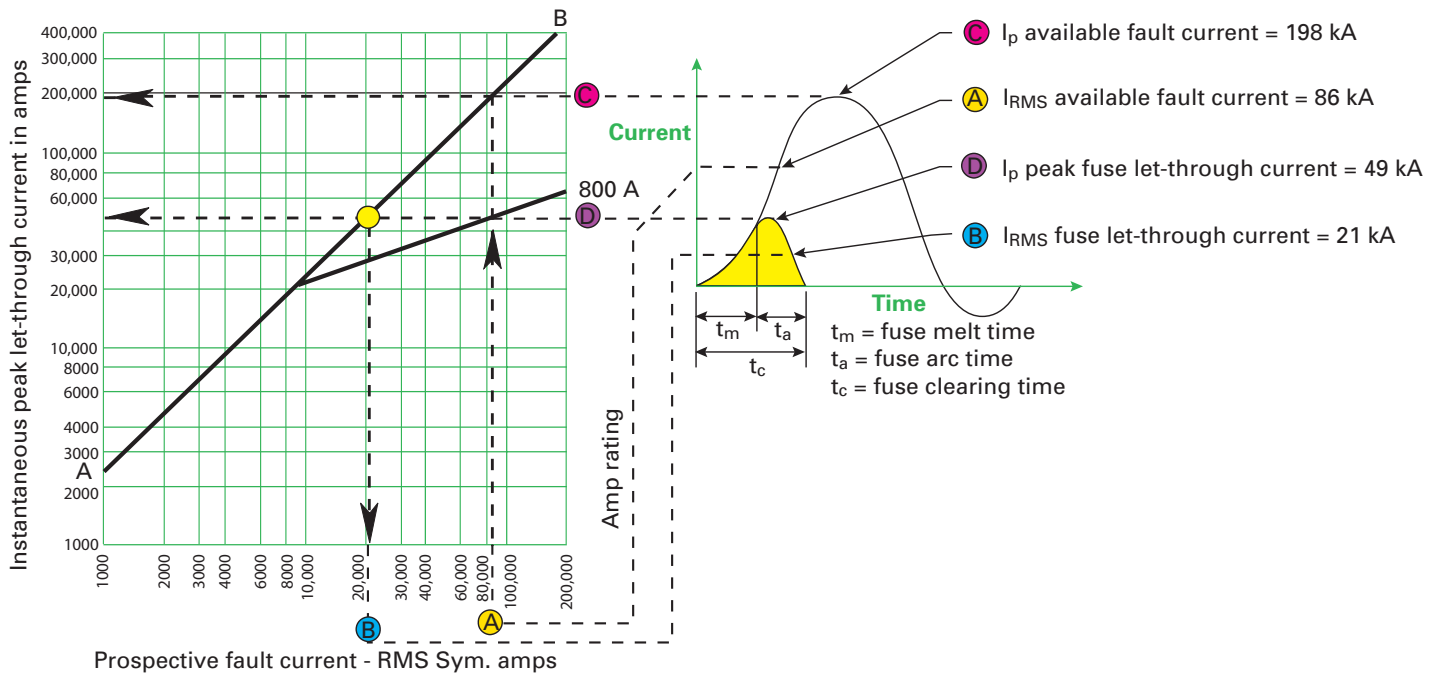


Figure 36: Current-limiting fuse let-through curve for a Bussmann series 800 A KRP-C-800SP Class L Low-Peak, time-delay fuse.

Prior to using the fuse let-through curves, it must be determined what let-through data is pertinent to equipment SCCRs (withstand ratings).

Equipment SCCR can be described as how much fault current the equipment can handle, and for how long. Based on standards presently available, the most important data that can be obtained from the fuse let-through curves and their physical effects are:

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

This typical example in Figure 37 shows the available fault current in an 800 A circuit and an 800 A Low-Peak current-limiting time-delay fuse.

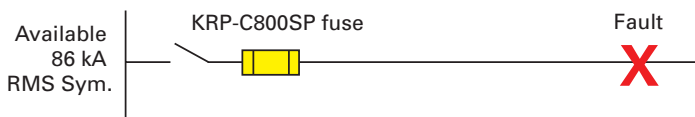


Figure 37: 800 A Low-Peak current-limiting time-delay fuse and associated let-through data

How to use the let-through curves

Using the example given, one can determine the pertinent let-through data for the KRP-C-800SP amp Low-Peak fuse. The let-through curve pertaining to the 800 A Low-Peak fuse is illustrated in Figure 36.

A. Determine the peak let-through current.

- Step 1. Enter the chart on the prospective short-circuit current scale at 86 kA and proceed vertically until the 800 A 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 kA (if a fuse had not been used, the peak current would have been 198 kA).

B. Determine the apparent prospective RMS Sym. let-through current.

- Step 1. Enter the curve on the prospective short-circuit current scale at 86 kA and proceed vertically until the 800 A fuse curve is intersected.
- Step 2. Follow horizontally until line A—B is intersected.
- Step 3. Proceed down to the prospective short-circuit current.
- Step 4. Read the prospective fault current — RMS Sym. amps as 21 kA. (The RMS Sym. let-through current would be 86 kA if there were no fuse in the circuit.)

The OCPD's role in electrical safety

OCPD selection and performance play a significant role in electrical safety. Extensive tests and analysis by industry have shown that the energy released during an arcing fault is related to two OCPD characteristics:

1. The time it takes the OCPD to open
2. The amount of fault current the OCPD lets through

For instance, the faster OCPD clears the fault, the lower the energy released. If the OCPD can also limit the current, thereby reducing the actual fault current magnitude that flows through the arc, the lower the energy released. The lower the energy released, the better for both worker safety and equipment protection.

Simple method for arc flash hazard analysis per 2018 NFPA 70B

The following is an example of identifying the arc flash hazard per 130.5(E) for the arc flash boundary (AFB) and 130.5(G) using the incident energy analysis method.

Various information about the system may be needed to complete this analysis, but two values are absolutely necessary:

1. The available 3Ø bolted fault current
2. The fuse type/amp rating

Consider the one-line diagram in Figure 38 and then follow the examples that take the steps needed to conduct an arc flash hazard analysis.

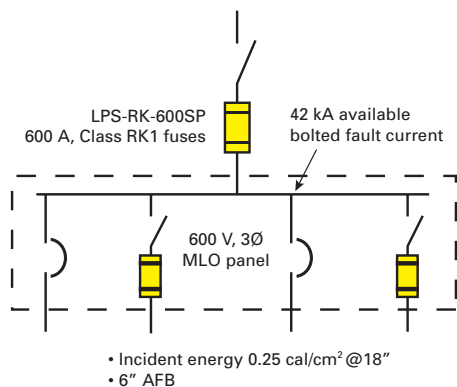


Figure 38: One-line diagram used in arc flash hazard analysis.

The following information utilizes the simplified fuse formulas based upon IEEE 1584-2002 Guide for Arc Flash Hazard Analysis and shown in 2018 NFPA 70E Annex D.4.6 and shows the steps necessary to conduct an arc flash hazard analysis when using Low-Peak fuses and Table 4: arc flash incident energy.

1. Determine the available bolted fault current on the lineside terminals of the equipment that will be worked on.
2. Identify the amp rating of the upstream Low-Peak fuse that's protecting the panel where work is to be performed.
3. Consult Table 4 to determine the Incident Energy Exposure (I.E.) level.
4. Determine the AFB that will require personal protective equipment (PPE) based upon the incident energy. This is simplified by using the column for AFB in Table 4.
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 Table 130.5(G).

Example 1: Arc flash hazard analysis using Busmann series current-limiting fuses (notes referenced appear on page 24)

The following is a simple method when using certain Busmann series fuses; this method is based on actual data from arcing fault tests (and resulting simplified formulas shown in NFPA 70E Annex D.4.6 and 2002 IEEE 1584) with Busmann series current-limiting fuses. Using this simple method, the first thing that must be done is to determine the incident energy exposure level. We have simplified this process when using LPS-RK, LPJ, TCF, LP-CC or KRP-C Low-Peak fuses, or JJN or JJS Limitron fuses and FCF fuses. In some cases the results are conservative; see Note 6.

In this example, the lineside OCPD in Figure 38 is an LPS-RK-600SP Low-Peak current-limiting fuse. Simply take the available 3Ø bolted fault current at the panel — in this case 42 kA — and locate it on the vertical column in Table 4. Then proceed directly to the right to the 401-600 A fuse column and identify the I.E. (incident energy) and AFB.

With 42 kA of 3Ø bolted available fault current, 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/cm². Notice the variables required are the available 3Ø bolted fault current and the Low-Peak current-limiting fuse amp rating. 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/cm² 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 Table 130.5(G) has requirements for the PPE based upon the incident energy exposure level. NFPA 70E Annex H is a resource for guidance in selecting PPE; specifically Tables H.2 and H.3.

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 levels based upon 1-600 A Low-Peak LPS-RK and 601-2000 A Low-Peak KRP-C- fuses

Incident Energy (I.E.) values expressed in Cal/cm², Arc Flash Boundary (AFB) expressed in inches.

Bolted fault current (kA)	1-100 A		101-200 A		201-400 A		401-600 A		601-800 A		801-1200 A		1201-1600 A		1601-2000 A	
	I.E.	AFB	I.E.	AFB	I.E.	AFB	I.E.	AFB	I.E.	AFB	I.E.	AFB	I.E.	AFB	I.E.	AFB
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

Table 4: Arc flash incident energy levels — see next page for applicable notes.

Notes for arc flash hazard analysis Table 4

1. 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.
2. This data is based upon the simplified fuse formulas in NFPA 70E Annex D.4.6 and 2002 IEEE 1584 guide for arc flash hazard analysis.
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).
4. The data is based on 32mm (1-1/4") electrode spacing, 600 V 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).
5. The data is based upon tests that were conducted at various fault currents for each Bussmann series Low-Peak KRP-C and LPS-RK fuse indicated in the charts. These tests were used to develop the formulas as shown in NFPA 70E Annex D.4.6 and 2002 IEEE 1584. Actual results from incidents could be different for a number of reasons, including:
 - System voltage
 - Short-circuit power factor
 - Distance from the arc
 - Arc gap
 - Enclosure size
 - Fuse manufacturer
 - Fuse class
 - Orientation of the worker
 - Grounding scheme
 - Electrode orientation

100 A LPS-RK fuses were the smallest fuses tested. Data for the fuses smaller than that is based upon the 100 A data. Arc flash values for actual 30 and 60 A fuses would be considerably less than 100 A fuses. However, it does not matter since the values for the 100 A fuses are already so low.

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.
7. Table 4 can also be used for LPJ, TCF, FCF, JJS and LP-CC fuses to determine the incident energy available and AFB.
8. These values from fuse tests take into account the translation from available 3-phase bolted fault current to the arcing fault current.
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.4.
10. Where the arcing current is less than the current-limiting range of the fuse when calculated per NFPA 70E Annex D.4.6 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.



Time-current characteristic curve (TCC)

Time-current characteristic curves (TCC) are graphical representations of the OCPD's operation under different overcurrent conditions as plotted by amps and time (see Figure 39). TCCs also provide a visual means for comparing OCPD operation and whether they will selectively coordinate, or not (see Selective coordination on page 26).

Figure 39 illustrates the TCCs for 400 A and 100 A dual-element, time-delay fuses in series as depicted in the one-line diagram. The graph's horizontal axis represents the RMS symmetrical current in amps. The vertical axis represents the time in seconds. Each fuse is represented by a band comprised of the minimum melt characteristic (solid blue line showing the lower operating characteristics) and the total clear characteristics (hash red line showing the higher operating characteristics). The area between these two lines represents the fuse's tolerance band under specific test conditions that, for a given overcurrent, a specific fuse, under the same circumstances, will open at a time within the its time-current tolerance band.

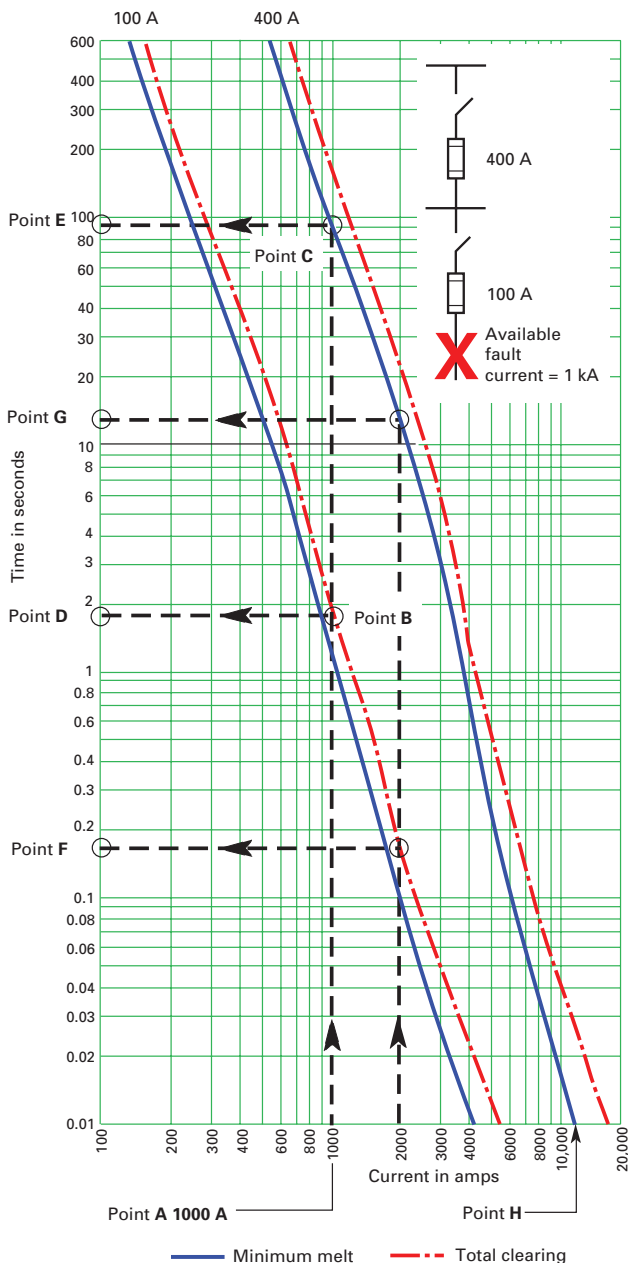


Figure 39: Minimum melt and total clearing curves for 100 A and 400 A dual-element, time-delay fuses.

Fuses have an inverse time-current characteristic meaning the greater the overcurrent, the faster they open and interrupt. For example, the 100 A fuse in Figure 39 subjected to a 200 A overcurrent shows by its TCC that it will open and clear in approximately 200 seconds, and for a 2000 A overcurrent, its TCC shows it will open and clear in approximately 0.15 second.

In some cases, assessing coordination between two or more fuses is possible by comparing their TCCs. This method is limited to only the overcurrent range up to the point at which the upstream fuse crosses 0.01 second. For example: assume there is a 1 kA RMS symmetrical overcurrent on the 100 A fuse's loadside. To determine the time it would take this overcurrent to open both the 100 A and 400 A fuses:

- Find 1 kA on the horizontal axis (Point A)
- Follow the dotted line vertically to the intersection of the 100 A fuse's total clear curve (red line at Point B) and the 400 A fuse's minimum melt curve (blue line at 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 100 A fuse will take to open the 1 kA overcurrent. At 90 seconds, Point E represents the minimum time at which the 400 A fuse could open this overcurrent. These two fuses are coordinated for a 1 kA overcurrent.

For overcurrents up to approximately 11 kA (Point H), it can be determined that these two fuses selectively coordinate as there isn't any curve overlap and the current is less than where the 400 A upstream fuse crosses 0.01 second. When overcurrents exceed 11 kA, selective coordination cannot be determined by using TCCs and fuse selectivity ratio tables must be used. Using the Bussmann series fuse selectivity ratio table makes it simple to determine whether fuses selectively coordinate or not and eliminates the need for plotting and comparing fuse TCCs (see the Bussmann series fuse selectivity ratios table on page 26).



Technical assistance is available to all customers. Application support is available Monday-Friday, 7:00 a.m. - 5:00 p.m. Central Time. Toll-free phone: 855-287-7626 (855-BUSSMANN), email: FuseTech@Eaton.com.

Selective coordination

While important, selecting OCPDs based solely on their ability to carry system load current and interrupting the maximum fault current at their respective application points is not enough. As the demand for power system reliability increases, the OCPD's performance in the system becomes more and more critical as its function should, ideally, limit a power system outage to only that portion of the circuit which is faulted. The selected OCPD types and ratings (or settings) determine whether they are selectively coordinated upstream and downstream in a system so that only the nearest upstream OCPD will open for the full range of overcurrents and opening times, and leave the remainder of the system undisturbed to preserve service continuity.

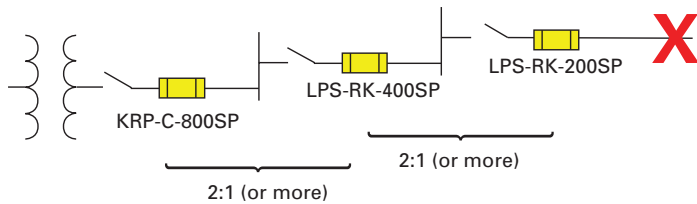


Figure 40: Low-Peak fuses applied with a simple 2:1 amp rating ratio achieves selective coordination.

Figure 40 shows the minimum amp rating ratios for Bussmann series Low-Peak fuses required to provide “selective coordination” (discrimination) between upstream and downstream fuses.

It's a simple matter to selectively coordinate a system using published fuse amp rating ratio tables and maintaining the minimum ratios between an upstream and downstream fuse. This will ensure selective coordination is achieved for all fault currents up to the fuse's interrupting rating.

Coordination, Selective (selective coordination)

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.

Selective coordination is mandatory per the NEC for the circuit paths of some vital loads on specific systems including:

- Elevator circuits — 620.62
- Critical operations data systems — 645.27
- Campus style fire pumps — 695.3
- Emergency systems — 700.32
- Legally required standby systems — 701.27
- Critical operations power systems — 708.54

Bussmann series fuse selectivity ratios

Circuit				Downstream / loadside fuse												
Amp rating range	Fuse type	Trade name (fuse class)	Bussmann fuse symbol	601-6000 A	601-4000 A	1-100 A	0-600 A			601-6000 A	0-600 A	0-1200 A	0-600 A	0-60 A	0-30 A	
				Time-delay	Time-delay	Time-delay	Dual-element, time-delay			Fast-acting	Fast-acting	Fast-acting	Fast-acting	Time-delay		
				Low-Peak (L)	Limitron (L)	CUBEFuse (CF ²)	Low-Peak (J)	Low-Peak (RK1)	Fusetron (RK5)	Limitron (L)	Limitron (RK1)	Limitron (T)	Limitron (J)	SC (G)	(CC)	
				KRP-C_SP	KLU	TCF	LPJ-SP	LPN-RK_SP LPS-RK_SP	FRN-R FRS-R	KTU	KTN-R KTS-R	JJN JJS	JKS	SC	LP-CC FNQ-R KTK-R	
Upstream / lineside fuse	601 to 6000 A	Time-delay	Low-Peak (L)	KRP-C_SP	2:1	2.5:1	2:1	2:1	2:1	—	—	—	—	—	2:1	
	601 to 4000 A	Time-delay	Limitron (L)	KLU	2:1	2:1	2:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	2:1	
	0 to 600 A	Dual-element	Low-Peak (RK1)	LPN-RK_SP LPS-RK_SP	—	—	2:1	2:1	2:1	8:1	—	3:1	3:1	3:1	4:1	2:1
	0 to 600 A	Dual-element	Low-Peak (J)	LPJ-SP	—	—	2:1	2:1	2:1	8:1	—	3:1	3:1	3:1	4:1	2:1
	0 to 100 A	Dual-element	CUBEFuse (CF ²)	TCF	—	—	2:1	2:1	2:1	8:1	—	3:1	3:1	3:1	4:1	2:1
	0 to 600 A	Dual-element	Fusetron (RK5)	FRN-R FRS-R	—	—	1.5:1	1.5:1	1.5:1	2:1	—	1.5:1	1.5:1	1.5:1	1.5:1	2:1
	601 to 6000 A	Fast-acting	Limitron (L)	KTU	2:1	2.5:1	3:1	3:1	3:1	6:1	2:1	2:1	2:1	2:1	2:1	2:1
	0 to 600 A	Fast-acting	Limitron (RK1)	KTN-R KTS-R	—	—	3:1	3:1	3:1	8:1	—	3:1	3:1	3:1	4:1	—
	0 to 1200 A	Fast-acting	Limitron (T)	JJN JJS	—	—	3:1	3:1	3:1	8:1	—	3:1	3:1	3:1	4:1	—
	0 to 600 A	Fast-acting	Limitron (J)	JKS	—	—	3:1	3:1	3:1	8:1	—	3:1	3:1	3:1	4:1	—
0 to 60 A	Time-delay	SC (G)	SC	—	—	3:1	3:1	3:1	4:1	—	2:1	2:1	2:1	2:1	—	

General notes: Ratios given in this table apply to only Bussmann fuses. When fuses are within the same case size, consult Bussmann.

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 Bussmann.
2. Time-delay Class CF TCF CUBEFuse OCPDs are 1 to 100 A Class J performance; dimensions and construction are a unique, finger-safe design.

Table 5: This selectivity ratio table identifies the fuse amp rating ratios that ensure selective coordination.

Fuse types and classes

Low voltage, branch circuit fuses

The NEC defines the branch circuit OCPD as 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. They're also the only OCPDs the NEC permits to be installed in a building's electrical system. The definition found in Article 100 is as follows:

"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."

Per this definition, branch circuit OCPDs are suitable to protect branch and feeder circuits and service conductors at any point in the electrical system, and must be capable of protecting against the full range of overcurrents, including overloads and faults. In addition, the OCPD must have an interrupting rating sufficient for the application per NEC 110.9. Branch circuit OCPDs meet common, minimum standard requirements for spacing and operating time-current characteristics defined by UL.

Table 6 illustrates acceptable OCPDs that can be used for branch circuit protection.

Device type	Acceptable devices	Bussmann series fuses
UL 248 branch circuit fuses	Class CC	LP-CC, FNQ-R, KTK-R
	Class CF	TCF, FCF
	Class G	SC
	Class H(K)	NON, NOS
	Class J	LPJ-, JKS, DFJ
	Class L	KRP-C, KLU, KTU
	Class RK1	LPN-RK, LPS-RK, KTN-R, KTS-R
	Class RK5	FRN-R, FRS-R
	Class T	JJN, JJS
UL 489 circuit breakers	Molded case CBs	—
UL 1066 circuit breakers	Insulated case CBs	—
	Low voltage power CBs	—

Table 6: Acceptable OCPDs for branch circuit protection.

The UL 248 fuse standards cover distinct low-voltage (600 volts or less) fuse classes. Of these, modern current-limiting fuse Classes CC, CF, G, J, L, R and T are the most important. The branch circuit current-limiting fuses' rejection feature helps ensure electrical system safety over its life because it prevents installing other fuse types or larger case sizes. Thus, fuses that cannot provide a comparable minimum protection level for critical ratings and performance cannot be inadvertently installed.

This is inherent in all current-limiting fuse classes. Each fuse class must meet:

- Maximum let-through limits (I_p and I^2t) during fault conditions
- Minimum voltage ratings
- Minimum 200 kA interrupting ratings for Class CC, CF, J, L, R and T
- Physical rejection of
 - Different fuse classes and case sizes*
 - Non current-limiting fuses (see Figures 41 and 42)

* Branch circuit fuse blocks and holders are made to hold a fuse class case size that corresponds to a particular amp range. This prevents fuses from the same class with a larger case size from being installed and helps prevent overfusing. There are instances where it is desirable to install a class fuse with a smaller case size than the block or holder. For these situations, it is permitted to use fuse reducers.

These product standards ensure branch circuit fuses provide specific, minimum circuit protection when current-limiting fuses and equipment are used. A given fuse class will ensure the voltage and interrupting rating, and degree of current limitation for the electrical system's life.

For example, by using Class J fuses and equipment, only Class J fuses can be installed. This ensures the voltage rating is always 600 V (whether the system is 120, 208, 480, or 575 V), the interrupting rating is at least 200 kA, and the fault current protection provided by its current-limiting, let-through characteristics. If the fuse needs replacing, only a Class J fuse can be installed.



Figure 41: Low-Peak Class J fuses achieve rejection by their unique physical size that is unlike other UL class fuses.

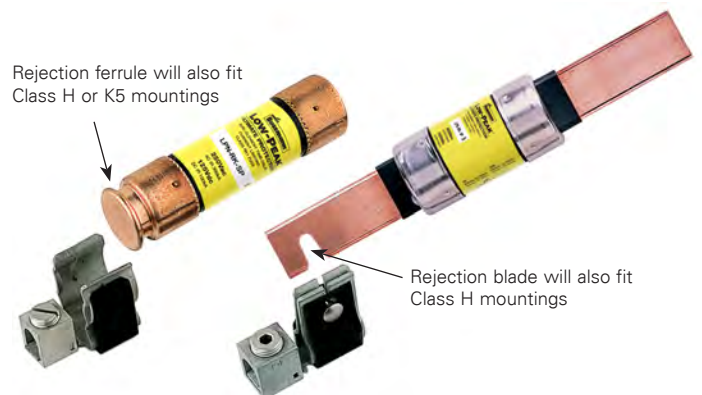


Figure 42: Class R fuse rejection clips (restriction on the ferrule or notch on the blade) that will only accept Class R fuses.

Bussmann series branch circuit power distribution fuses

Class CC

Time-delay, Low-Peak LP-CC

- 600 Vac, 1/2 to 30 A current-limiting 200 kA IR AC
- UL Std. 248-4 Class CC, Guide JDDZ, File E4273, 1/2-2.8 A (300 Vdc 20 kA IR), 3-15 A (150 Vdc 20 kA IR), 20-30 A (300 Vdc 20 kA IR), CSA Class 1422-02, CSA File #53787

The Bussmann series Low-Peak LP-CC was developed specifically for a growing need in the industry to have a compact, space saving branch circuit fuse for motor circuits (see data sheet no. 1023).



Time-delay, Limitron FNQ-R

- 600 Vac, 1/4 to 30 A, current-limiting 200 kA IR AC
- UL Std. 248-4 Class CC, Guide JDDZ, UL File E4273, CSA Class 1422-01, CSA File 53787

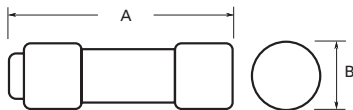
Ideal for control transformer protection, the FNQ-R can be sized to meet requirements of NEC 430.72 and UL 508. Its small size and branch circuit rating allow it to be used for motor branch circuit and short-circuit protection required by NEC 430.52 (see data sheet no. 1014)



Fast-acting, Limitron KTK-R

- 600 Vac, 1/10 to 30 A, current-limiting 200 kA IR AC
- UL Std. 248-4 Class CC, Guide JDDZ, UL File E4273, CSA Class 1422-02 CSA File 53787

KTK-R fuses are small, high performance, fast-acting, single-element fuses for protecting branch circuits, motor control circuits, lighting ballasts and street lighting fixtures (see data sheet no. 1015).



Dimensions — in (mm)

Amp range	A	B
Up to 30	1.5 (38)	0.41 (10)



Class CF

The UL Class CF CUBEFuse provides the same electrical performance as UL Class J fuses. Available in time-delay or fast-acting versions, the CUBEFuse is the world's first finger-safe fuse with the smallest installed footprint of any power class fuse and meets IEC 60529 requirements for IP20 finger-safe protection.



The CUBEFuse mounts in 35mm DIN-Rail and panel mountable amp rating rejecting holders (30, 60 and 100 A) that will not accept a fuse rating greater than the holder's. Additionally, the CUBEFuse can be mounted in the UL 98 Compact Circuit Protector available in 1-, 2- and 3-pole factory configured units in the same 30, 60 and 100 amp rating rejection increments.

Time-delay, Low-Peak CUBEFuse TCF

- 600 Vac, 1 to 100 A, dual-element, current-limiting 300 kA IR AC
- UL Listed Class CF, Std. 248-8 Class J performance, Guide JDDZ, File E4273, 300 kA IR AC, (300 Vdc – 100, kA IR), CSA Class 1422-02, CSA File 53787, 200 kA IR AC, (300 Vdc, 100 kA IR)

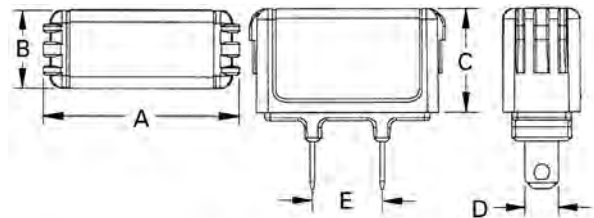
The Low-Peak TCF CUBEFuse provides Type 2 “No Damage” motor starter protection when sized properly. Available with optional open fuse indication (6 to 100 A) (see data sheet no. 9000).



Fast-acting, CUBEFuse FCF

- 600 Vac/dc, 1 to 100 A, current-limiting 300 kA (up to 60 A) 200 kA (70 to 100 A) IR, 50 kA IR DC
- UL Listed Class CF, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787, 200 kA IR AC

The fast-acting FCF CUBEFuse is a non-indicating fuse specifically designed to meet the needs of UPS and critical power applications (see data sheet no. 2147)



Dimensions — in (mm)

Amp range	A	B	C	D	E
1-15				0.23 (6)	
17-1/2	1.88 (48)	0.75 (19)	1.0 (25)	0.27 (7)	
20				0.31 (8)	0.63 (16)
25-30				0.36 (9)	
35-40	2.13 (54)		1.13 (29)	0.44 (11)	
60		1.0 (25)			
70				0.49 (12)	0.58 (15)
80-90	3.01 (76)		1.26 (32)		
100				0.57 (14)	

Quik-Spec Coordination Panelboard (QSCP)

The Bussmann series Quik-Spec™ Coordination Panelboard uses the CUBEFuse for its branch circuit OCPD. The QSCP makes selective coordination easy in an all-fused system utilizing the fuse selectivity ratios table.

Features

- Addresses NEC selective coordination requirements
- Flexible configurations — up to 400 A, 600 Vac or less
- Same size footprint as traditional circuit breaker panelboards
- Finger-safe construction for greater safety
- Saves time
- Easy-to-spec
- Amp rating rejection branch switches help prevent overfusing
- Built-in spare fuse storage



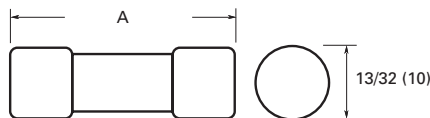
(See data sheet no. 1160 and application note no. 3148.)

Class G

Fast-acting (up to 6 A) and time-delay (7 to 60 A) general purpose SC

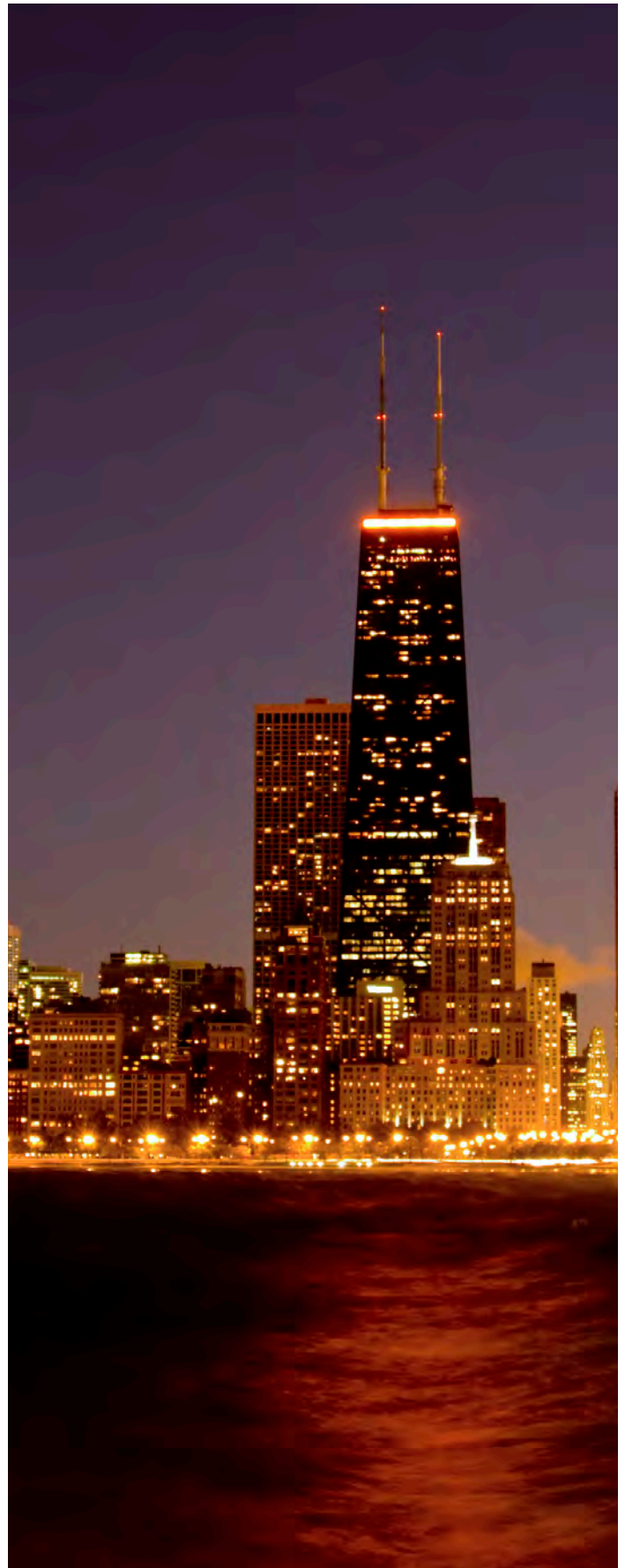
- 600 Vac (1/2 to 20 A), 480 Vac (25 to 60 A), 170 Vdc (1/2 to 20 A), 300 Vdc (25-60 A), current-limiting 100 kA IR AC, 10 kA IR DC
- UL Std. 248-5 Class G, Guide JDDZ, File E4273 0-20 A (170 Vdc 10 kA IR), 25-30 A (300 Vdc 10 kA IR), 35-60 A (300 Vdc 10 kA IR), CSA Class 1422-01, CSA File 53787

A high performance general-purpose branch circuit fuse for lighting, appliance and motor branch circuits. SC fuse lengths vary with amp rating from 1-5/16 to 2-1/4 inches to serve as a rejection feature and help prevent oversizing (see data sheet no. 1024).



Dimensions — in (mm)

Fuse amp rating	A
1/2 to 15	1-5/16 (33)
20	1-13/32 (36)
25-30	1-5/8 (41)
35-60	2-1/4 (57)



Class J

Time-delay Low-Peak LPJ-SP

- 600 Vac, 1 to 600 A, dual-element, current-limiting, 300 kA IR AC
- UL Std. 248-8 Class J, Guide JFHR, File E56412, 300 kA IR AC, 1 to 600 A (300 Vdc, 100 kA IR), CSA Class 1422-02, CSA File 53787

Space saving LPJ fuses have the time-delay “advantage” that permits them to pass temporary, harmless overloads while offering back-up overload, and short-circuit protection. Ideal for IEC starters, they provide Type 2 “No Damage” protection when properly sized (see data sheet no. 1006, up to 60 A, and no. 1007, 70 to 600 A).



Fast-acting Limitron JKS

- 600 Vac, 1 to 600 A, current-limiting, 200 kA IR AC
- UL Std. 248-8 Class J, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787

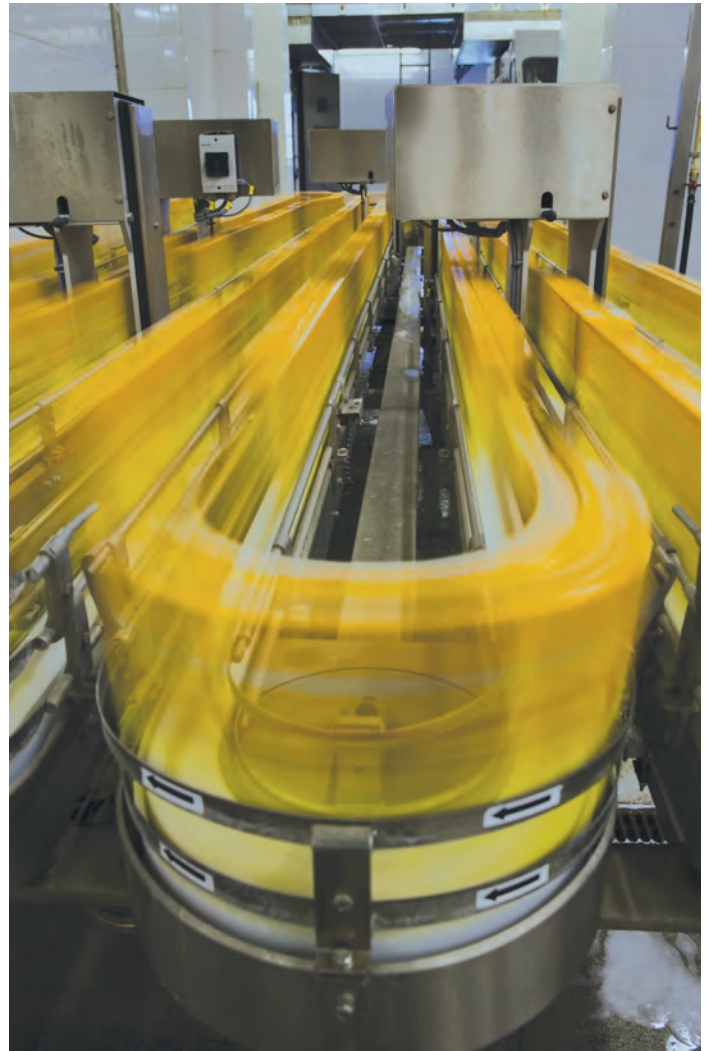
JKS Limitron fuses are essentially the same as RK1 Limitron fuses, but smaller in physical size. JKS fuses are single-element units with no intentional time-delay and are thus best applied in circuits free of the temporary overloads from motors and transformers. The smaller dimensions of Class J fuses prevent their replacement with conventional fuses (see data sheet no. 1026, up to 60 A, and no. 1027, 70 to 600 A).



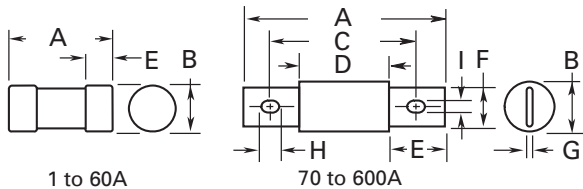
High speed Drive Fuse DFJ

- 600 Vac, 450 Vdc (15 to 600 A), 1 to 600 A, current-limiting 200 kA IR AC, 100 kA DC
- UL Std. 248-8 Class J, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787

The DFJ high speed fuse offers the advantage of meeting NEC and UL branch circuit protection requirements. Designed specifically for protecting drives, soft starters, solid state relays and other power electronics, the DFJ is capable of limiting fault currents like a semiconductor fuse. The DFJ fits into all standard Class J fuse holders and blocks (see data sheet no. 1048).



Innovative Bussmann series products, like the patented Class J power distribution fuse block above, combine fuse block and power distribution block into one assembly to reduce component count and speed equipment assembly.



Dimensions — in (mm)

Amp range	A	B	C	D	E	F	G	H	I
1-30	2.25 (57)	0.81 (21)	—	—	0.5 (13)	—	—	—	—
35-60	2.38 (60)	1.06 (27)	—	—	0.63 (16)	—	—	—	—
70-100	4.63 (118)	1.13 (29)	3.63 (92)	2.63 (67)	1.0 (25)	0.75 (19)	0.13 (3)	0.41 (10)	0.28 (7)
110-200	5.75 (146)	1.63 (41)	4.38 (111)	3.0 (76)	1.38 (35)	1.13 (29)	0.19 (5)	0.38 (10)	0.28 (7)
225-400	7.12 (181)	2.11 (54)	5.25 (133)	3.26 (83)	1.87 (48)	1.62 (41)	0.25 (6)	0.56 (14)	0.4 (10)
450-600	8.0 (203)	2.6 (66)	6.0 (152)	3.31 (84)	2.12 (54)	2.0 (51)	0.53 (14)	0.72 (18)	0.53 (14)

Class L

Time-delay, Low-Peak KRP-C

- 600 Vac, 601 to 6000 A, current-limiting, 300 kA IR AC
- UL Std. 248-10 Class L, Guide JFHR, File E56412, 300 kA IR AC, 601-2000 and 3000 A (300 Vdc 100 kA IR), CSA Class 1422-02, CSA File 53787

The KRP-C is an all purpose fuse with both overload and short-circuit protection of high capacity systems. Its minimum time-delay of four seconds at five times amp rating permits sizing closer to loads. The use of downstream 1/10 to 600 A Low-Peak dual-element time-delay fuses and upstream 601 to 6000 A KRP-C Low-Peak fuses is recommended for easy selective coordination and blackout protection with a simple 2:1 amp rating ratio. Low-Peak fuses can also reduce bus bracing and provide excellent overall protection of circuits and loads (see data sheet no. 1008, 601 to 2000 A, and no. 1008, 2001 to 6000 A).



Fast-acting, Limitron KTU

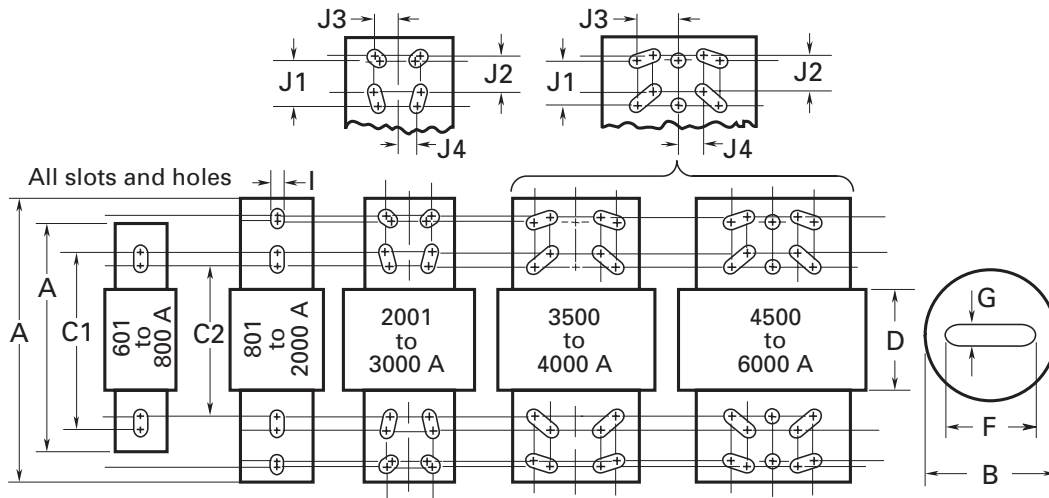
- 600 Vac, 601 to 6000 A current-limiting, 200 kA IR AC
- UL Std. 248-10 Class L, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787

The KTU is a single-element fuse with no intentional time-delay that's very fast-acting with a high degree of current limitation to provide excellent component protection. In motor circuits, the KTU is sized at approximately 300% of motor full-load amps (see data sheet no. 1010).

Time-delay, Limitron KLU

- 600 Vac, 601 to 4000 A, current-limiting, 200 kA IR AC
- UL Std. 248-10 Class L, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787

The KTU has a minimum five second delay at 500% of rated current. The KTU is not as current-limiting as KRP-C or KTU fuses (see data sheet no. 1013).



Dimensions — in (mm)

Amp range	A	B	C1	C2	D	F	G	I	J1	J2	J3	J4
601-800	8.63 (219)	2.4 (61)										
801-1200						2.00 (51)	0.38 (10)					
1350-1600		3.0 (76)				2.38 (60)	0.44 (11)					
1800-2000		3.5 (89)				2.75 (70)	0.5 (13)					
2001-2500	10.75 (273)	4.8 (122)	6.75 (172)	5.75 (146)	3.75 (95)	3.50 (89)		0.63 (16)				
3000		5.0 (127)				4.00 (102)	0.75 (19)					
3500-4000		5.75 (146)				4.75 (121)			1.75 (45)	1.38 (35)		
4500-5000		6.25 (159)				5.25 (133)					1.63 (41)	0.88 (22)
6000		7.13 (181)				5.75 (146)	1.0 (25)					

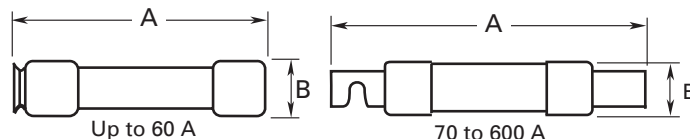
Class RK1

Time-delay, Low-Peak LPN-RK and LPS-RK

- LPN-RK (250 Vac) and LPS-RK (600 Vac), up to 600 A, current-limiting, dual-element, 300 kA IR AC, 100 kA IR DC
- UL Std. 248-12 Class RK1, Guide JFHR, File E56412, CSA Class 1422-02, CSA File 53787 — LPN-RK 0-60 A (125 Vdc, 50 kA IR), 70-600 A (250 Vdc, 50 kA IR), LPS-RK 0-600 A (300 Vdc, 50 kA IR)

Low-Peak RK1 fuses provide a very high degree of fault current limitation of Limitron fuse plus the overload protection of the Fusetron fuse in all types of circuits and loads.

They can be closely sized to motor full load amps for reliable backup protection. Close sizing to loads permits using smaller and more economical switches (and fuses), better selective coordination, and a greater degree of current limitation for component protection. RK1 Low-Peak fuses are rejection type but also fit non-rejection type fuse holders to easily replace lower-rated Class H(K) fuses in existing installations (see LPN-RK data sheet no. 1001, up to 60 A, and no. 1002, 70 to 600 A, and LPS-RK data sheet no. 1003, up to 60 A, and no. 1004, 70 to 600 A).



Basic dimensions are same as Class H(K), general purpose (NON and NOS) fuses. **Note:** relating to dimensional compatibility these fuses can replace existing Class H, RK1 and RK5 fuses.

Dimensions — in (mm)

Amp range	250 V fuses		600 V fuses	
	A	B	A	B
Up to 30	2 (51)	0.56 (14)	5.0 (127)	0.81 (21)
35-60	3 (76)	0.81 (21)	5.5 (140)	1.06 (27)
RK5 FRN-R, FRS-R, — RK1 KTN-R, KTS-R				
70-100	5.88 (149)	1.06 (27)	7.88 (200)	1.34 (34)
110-200	7.13 (181)	1.56 (40)	9.63 (245)	1.84 (47)
225-400	8.63 (219)	2.38 (61)	11.63 (295)	2.59 (66)
450-600	10.38 (264)	2.88 (73)	13.38 (340)	3.13 (80)
RK1 LPN-RK, LPS-RK				
70-100	5.88 (149)	1.16 (30)	7.88 (200)	1.16 (30)
110-200	7.13 (181)	1.66 (42)	9.63 (245)	1.66 (42)
225-400	8.63 (219)	2.38 (61)	11.63 (295)	2.38 (61)
450-600	10.38 (264)	2.88 (73)	13.38 (340)	2.88 (73)

Fast-acting, Limitron KTN-R and KTS-R

- KTN-R (250 Vac) and KTS-R (600 Vac), up to 600 A, current-limiting, 200 kA IR AC
- UL Std. 248-12 Class RK1, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787

KTN-R and KTS-R single-element, fast-acting fuses have no intentional time-delay and provide a high degree of fault current limitation (component protection). They are well suited for circuits and loads without the in-rush currents. RK1 Limitron fuses are rejection type but also fit non-rejection type fuse holders to easily replace lower-rated Class H(K) fuses in existing installations (see KTN-R data sheet no. 1043, and KTS-R data sheet no. 1044).



Bussmann series modular Class R fuse blocks feature a snap-together construction to create the required number of poles. Either DIN-Rail or panel mount, these blocks are available with optional covers that provide a lockout/tagout provision for enhanced electrical safety. Also available in power distribution fuse block versions.

Class RK5 — Time-delay, Fusetron FRN-R and FRS-R

- FRN-R (250 Vac) and FRS-R (600 Vac), up to 600 A, current-limiting, dual-element, 200 kA IR AC, 20 kA IR DC
- UL Std. 248-12 Class RK5, Guide JDDZ, File E4273, CSA Class 1422-02, CSA File 53787 — FRN-R and FRS-R, up to 600 A, 200 kA IR AC, FRN-R 125 Vdc, 20 kA IR DC (up to 60 A and 110 to 200 A), 250 Vdc, 20 kA IR DC (225 to 600 A), FRS-R 300 Vdc, 20 kA IR DC (up to 30 A and 65 to 600 A), 250 Vdc, 20 kA IR DC (35 to 60 A)

FRN-R and FRS-R RK5 time-delay fuses provide excellent overload protection for loads with inrush current like motors, transformers and solenoids. Fusetron fuses are not as fast-acting on short-circuits as Low-Peak fuses, and do not give as high a degree of component short-circuit protection.

Like the Low-Peak fuse, Fusetron fuses can be sized closer to loads to permit using smaller size and less costly switches. RK5 Fusetron fuses are rejection type but also fit non-rejection type fuse holders to easily replace lower-rated Class H(K) fuses in existing installations (see FRN-R data sheet no. 1017, up to 60 A, and no. 1018, 70 to 600 A, and FRS-R data sheet no. 1019, up to 60 A, and no. 1020, 70 to 600 A).



Class H(K)

General purpose, NON and NOS

- NON (250 Vac) and NOS (600 Vac) up to 600 A, non-current-limiting, 50 kA IR AC up to 60 A) and 10 kA (65 to 600 A)
- UL Std. 248-9 Class K5, Std. 248-9, UL Std. 248-6 Class H, Guide JDDZ, File E4273, CSA Class 1421-01, CSA File 53787 (NON 65-600 A) 10 kA IR AC, (NOS 70-600 A) 10 kA IR AC.

NON and NOS Class H(K) general purpose fuses are not considered current-limiting fuses, do not incorporate intentional time-delay and are used in circuits with low available fault currents. We recommend upgrading to Class R fuses that can be installed without the need to change fuse blocks or holders (see NON/NOS data sheet no. 1030).

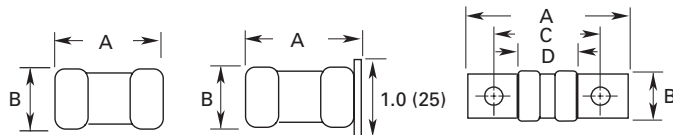


Class T

Fast-acting, Limitron JJN and JJS

- JJN (300 Vac up to 1200 A) and JJS (600 Vac up to 800 A), current-limiting, 200 kA IR AC
- UL Std. 248-15 Class T, Guide JDDZ, File E4273, JJN 15-600 A (160 Vdc, 20 kA IR), JJN 601-1200 A (170 Vdc 100 kA IR), CSA Class 1422-02, CSA File 53787

JJN and JJS fuses are the space-saving counterparts to KTN-R/KTS-R Limitron fuses. At one-third the size, they are well suited for applications where space is very restricted. These single-element fuses are extremely fast-acting and provide a high degree of current limitation on short-circuits for excellent component protection. These fuses will give only short-circuit protection and must be oversized for circuits with inrush currents common to motors, transformers and other inductive components (see JJN data sheet no. 1025, and JJS data sheet no. 1029).



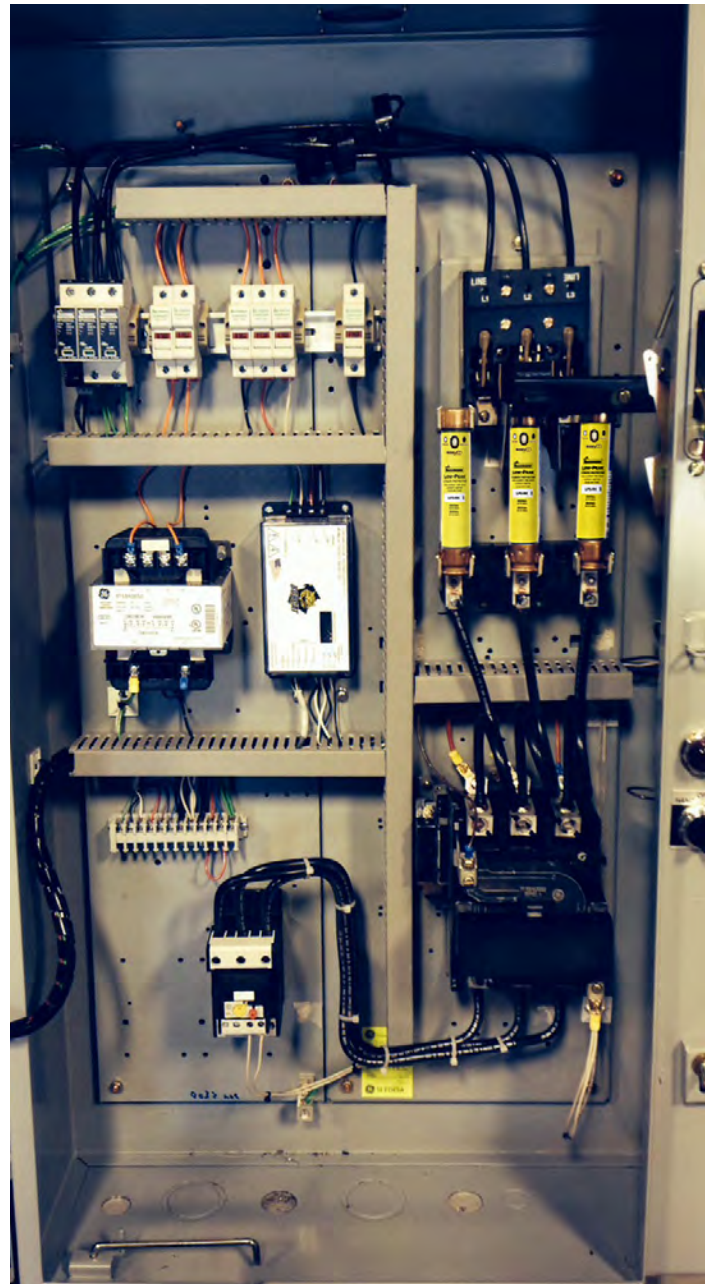
JJN up to 60 A
JJS up to 30 A

JJS 35 to 60 A

JJN 70 to 1200 A
JJS 70 to 800 A

Dimensions — in (mm)

Amp range	A	B	C	D
300 V JJN				
Up to 30	0.88 (22)	0.41 (10)	—	—
35-60	0.88 (22)	0.56 (14)	—	—
70-100	2.16 (55)	0.75 (19)	1.56 (40)	0.84 (21)
110-200	2.44 (62)	0.88 (22)	1.69 (43)	0.84 (21)
225-400	2.75 (70)	1.00 (25)	1.84 (47)	0.86 (22)
450-600	3.06 (78)	1.25 (32)	2.03 (52)	0.88 (22)
601-800	3.38 (86)	1.75 (45)	2.22 (56)	0.89 (23)
801-1200	4.00 (102)	2.00 (51)	2.53 (64)	1.08 (27)
600 V JJS				
Up to 30	1.50 (38)	0.56 (14)	—	—
35-60	1.56 (40)	0.81 (21)	—	—
70-100	2.95 (75)	0.75 (19)	2.36 (60)	1.64 (42)
110-200	3.25 (83)	0.88 (22)	2.50 (64)	1.66 (42)
225-400	3.63 (92)	1.00 (25)	2.72 (69)	1.73 (44)
450-600	3.98 (101)	1.25 (32)	2.96 (75)	1.78 (45)
601-800	4.33 (110)	1.75 (45)	3.17 (81)	1.88 (48)



Busmann series branch circuit fuse selection chart (600 V or Less)

Circuit	Load	Amp rating	Fuse type	Catalog symbol	Voltage rating (AC)	Fuse class	Interrupting rating (kA)	Remarks	
Main, feeder and branch	Conventional dimensions—Class RK1, RK5 (0-600 A), L (601-6000 A)								
	All type loads (optimum overcurrent protection)	Up to 600 A	Low-Peak (dual-element, time-delay)	LPN-RK_SP	250 V	RK1††	300	All-purpose fuses. Unequaled for combined short-circuit and overload protection.	
		601 to 6000 A	Low-Peak (time-delay)	KRP-C_SP	600 V				L
	Motors, welder, transformers, capacitor banks (circuits with heavy inrush currents)	Up to 600 A	Fusetron (dual-element, time-delay)	FRN-R	250 V	RK5††	200	Moderate degree of current limitation. Time-delay passes in-rush currents.	
		601 to 4000 A	Limitron (fast-acting)	FRS-R	600 V				L
	Non-motor loads (circuits with no heavy inrush currents). Limitron fuses particularly suited for circuit breaker protection. Up to 600 A	Up to 600 A	Limitron (fast-acting)	KTN-R	250 V	RK1††	200	Same short-circuit protection as Low-Peak fuses but must be sized larger for circuits with inrush currents; i.e., up to 300%.	
				KTS-R	600 V				
		601 to 6000 A	KTU	600 V	L	200	A fast-acting, high performance fuse.		
	Reduced dimensions for installation in restricted space—CUBEFuse Class CF (0-100 A), Class J (0-600 A), T (0-1200 A), CC (0-30 A), G (0-60 A)								
	100 kA IR (RMS Sym.) or greater, current-limiting	All type loads (optimum overcurrent protection)	Up to 100 A	CUBEFuse (finger-safe, dual-element, time-delay)	TCF	600 V	(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)		Up to 600 A	Low-Peak (dual-element, time-delay)	LPJ	600 V	J	300	All-purpose fuses. Unequaled for combined short-circuit and overload protection. (Specification grade product)	
Power electronic applications such as drives and SSRs		Up to 600 A	Drive fuse (high speed Class J)	DFJ	600 V	J	200	Where branch circuit protection is needed with high speed fuse characteristics.	
Non-motor loads (circuits with no heavy inrush currents)		Up to 600 A	Limitron (fast-acting)	JKS	600 V	J	200	Very similar to KTS-R Limitron, but smaller.	
		Up to 1200 A	Limitron fast-acting	JJN	300 V	T	200	The space saver (1/3 the size of KTN-R).	
		Up to 800 A	Limitron fast-acting	JJS	600 V	T	200	The space saver (1/3 the size of KTS-R).	
Branch	Motor loads (circuits with heavy inrush currents)	Up to 30 A	Low-Peak (time-delay)	LP-CC	600 V	CC	200	Very compact (13/32" x 1-1/2"); rejection feature. Excellent for motor circuit protection.	
	Limitron (fast-acting)		KTK-R	600 V	CC	200	Very compact (13/32" x 1-1/2"); rejection feature. Excellent for outdoor highway lighting.		
	Control transformer circuits and lighting ballasts; etc	Up to 60 A	Limitron (time-delay)	FNQ-R	600 V	CC	200	Very compact (13/32" x 1-1/2"); rejection feature. Excellent for control transformer protection.	
	General purpose; i.e., lighting panelboards		General purpose (1/2-6 A fast-acting, 7-60 A time-delay)	SC	600 (0-20 A) 480 V (25-60 A)	G	100	Current limiting; 13/32" dia. x varying lengths per amp rating.	
10-50 kA IR General Purpose (non-current-limiting fuses)	Miscellaneous	Up to 600 A	General purpose	NON NOS	250 V 600 V	H or K5†	10	Forerunners of the modern cartridge fuse.	
	Plug fuses can be used for branch circuits and small component protection.	Up to 30 A	Type S (dual-element, time-delay)	S	125 V	S	10	Base threads of Type S differ with amp ratings (size rejecting). T and W are Edison base. T and S Type fuses recommended for motor circuits. W not recommended for circuits with motor loads.	
			Type T (dual-element, time-delay)	T	125 V	**	10		
Up to 12 A	Type W (fast-acting)	W	125 V	**	10				

** UL Listed as Edison base plug fuse.

† Some amp ratings are available as UL Class K5 with a 50 kA 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) prevents 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 catalog numbers.

Table 7: Branch circuit fuse selection chart.

Supplemental/application limited OCPDs

The supplemental or application limited OCPDs in Figure 43 are not branch circuit rated (cannot be installed in a building’s electrical system) and serve specific functions within a circuit. Two application limited OCPD examples include motor circuit protectors and supplemental protective devices.

Application limited OCPDs cannot be used in place of branch circuit OCPDs, however a branch circuit rated OCPD can be used in lieu of an application limited OCPD.

Understanding the differences between these devices is important to ensure their proper application. Not using a branch circuit OCPD where required could result in potentially serious electrical safety hazards to people or damage to property. In addition, NEC violations could be tagged by the authority having jurisdiction (AHJ), resulting in project delays and unplanned delays and costs.



Figure 43: Supplemental OCPDs cannot be used for branch circuit protection.

Supplemental OCPDs are not general use devices and must be evaluated for appropriate application in every instance where they are used. Supplemental OCPDs are extremely application oriented, and prior to application, the differences and limitations of these devices must be investigated and found acceptable.

Bussmann series supplemental fuses

The following pages contain examples of fast-acting and time-delay fuses with their specifications that must be considered before a correct selection can be determined for a particular application. Of particular note with these fuses are the following:

- Agency information is not applicable to all ratings
- Specific fuse amp ratings may have different voltage ratings and corresponding interrupting ratings
- Construction may vary, depending on amp rating, and affect the available mounting means (see FNA, page 37)
- Some are pin-indicating to provide a visual notification means or activating a microswitch for remote monitoring systems
- Their labels are color coded to indicate maximum voltage rating that can coincide within an amp range inside a fuse family

All these factors must be reviewed to be sure the appropriate supplemental fuse is specified and meets the application’s requirements for:

- Operation (time-delay or fast-acting)
- Voltage rating (by fuse amp rating)
- Amp rating
- Interrupting rating at applied amp rating and system voltage
- Special needs (pin-indication)

Exceptions in the Code for applying supplemental OCPDs

There are exceptions that do allow using a supplemental, application specific OCPD in a branch circuit, but defined NEC conditions must be met.

(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. Examples include:

- High speed fuses that are not branch circuit OCPDs, but can be used for fault current 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 for fault current protection of motor branch circuits, if applied in combination with a listed combination starter for which the MCP has been tested and found acceptable [per 430.52(C)(3)].
- Self-protected starters listed only for motor branch circuit protection; they cannot be used on other branch circuit types or for main or feeder protection.
- When considering supplemental, application specific OCPDs, special attention must be paid to the circuit type, NEC requirements and the device’s product listing or recognition.

(2) Supplemental 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.



BAF fast-acting 13/32" x 1-1/2"

Fast-acting, supplemental fuse. Green color code (250 Vac max) (see data sheet no. 2011).

For superior protection, Eaton recommends upgrading to Bussmann series Low-Peak Class CC fuses (see data sheet no. 1023).

Ratings

Fuse amp range	IR at system voltage		Agency information	
	250 Vac	125 Vac	UL	CSA
1/4 to 1	35 A	10 kA	-	X
1-1/2 to 2-1/2	100 A	10 kA	-	X
3	100 A	10 kA	X	X
4 to 10	200 A	10 kA	X	X
12 to 15	750 A	10 kA	X	X
20 to 30	200 A	10 kA	-	-

Agency information

- UL Listed, Std. 248-14, 250 Vac (3 to 15 A) Guide JDYX, File E19180, CSA Certified, 250 Vac (1/4 to 15 A) Class 1422-01, File 53787

BBS fast-acting 13/32" x 1-3/8"

Fast-acting supplemental fuse. Color codes black (600 Vac max 1/10 to 6 A), green (250 Vac max 7 to 10 A), and purple (48 Vac max 12 to 30 A) (see data sheet no. 2010).

For superior protection, Eaton recommends upgrading to Bussmann series Low-Peak Class CC fuses (see data sheet no. 1023).

Ratings

Fuse amp range	IR at system voltage			Agency information	
	600 Vac	250 Vac	48 Vac	UL	CSA
1/10 to 6	10 kA	—	—	X	X
7 to 10	—	10 kA	—	X	X
12 to 30*	—	—	—	—	—

* For interrupting rating, contact factory.

Agency information

- UL Listed, Std. 248-14 (1/10-6 A@600 Vac, 7-10 A@250 Vac), Guide JDYX, File E19180, CSA Certified, C22.2 No. 248.14 (1/10-6 A @ 600 Vac, 7-10 A @ 250 Vac), Class 1422-01, File 53787, CE



KLM fast-acting 13/32" x 1-1/2"

Fast-acting supplemental fuse. Color code black (600 Vac/dc max) (see data sheet no. 2020).

For superior protection, Eaton recommends upgrading to Bussmann series Low-Peak Class CC fuses (see data sheet no. 1023).

For protecting PV systems, use PVM 10x30mm PV fuses (see data sheet no. 10121).

Ratings

Fuse amp range	IR at rated voltage		Agency information	
	600 Vac	600 Vdc	UL	CSA
1/10 to 30	100 kA	50 kA	X	X

Electrical characteristics

% of amp rating	Opening time
110%	4 hours minimum
135%	AC opens within 1 hour

Agency information

- UL Listed, Std. 248-14, Guide JDYX, File E19180, CSA Certified, C22.2 No. 248.14, Class 1422-01, File 53787, RoHS compliant, CE

KTK fast-acting 13/32" x 1-1/2"

Fast-acting supplemental fuse. Black color code (600 Vac max) (see data sheet no. 1011).

For superior protection, Eaton recommends upgrading to Bussmann series Low-Peak Class CC fuses (see data sheet no. 1023).

Ratings

Fuse amp range	IR at rated voltage	Agency information	
	600 Vac	UL	CSA
1/10 to 30	100 kA	X	X

Agency information

- UL Listed, Std. 248-14, Guide JDYX, File E19180, CSA Certified, C22.2 No. 248.14, Class 1422-01, File 53787, HRC-MISC, RoHS compliant, CE



MIC fast-acting 13/32" x 1-1/2" pin-indicating

Fast-acting, pin-indicating supplemental fuse. Green color code (250 Vac max 1 to 15 A), grey (32 Vac max 20 to 30 A) (see data sheet no. 10246).



Ratings

Fuse amp range	IR at voltage rating		Agency information	
	250 Vac	32 Vac	UL	CSA
1	35 A	—	X	—
2 to 3	100 A	—	X	—
5 to 10	200 A	—	X	—
15	750 A	—	X	—
20 to 30	—	10 kA	—	—

Electrical characteristics

% of fuse rating	Opening time
110%	Indefinitely
135%	1 hour max

Agency information

- UL Listed, Std. 248-14, 1-15 A, Guide JDYX, File E19180, CE

FNA time-delay 13/32" x 1-1/2" pin-indicating

Pin-indicating time-delay supplemental fuse. Color coded green (250 Vac max 1/10 to 6 A), blue (125 Vac max 6-1/4 to 15 A) and grey (32 Vac max 20 to 30 A) (see data sheet no. 2029).



Dual-tube construction 12 A and up

Ratings

Fuse amp range	IR at system voltage			Agency information	
	250 Vac	125 Vac	32 Vac	UL	CSA
1/10 to 8/10	35 A	10 kA	-	X	X
1 to 6	200 A	10 kA	-	X	X
6-1/4 to 15	-	10 kA	-	X	X
20 to 30	-	-	1 kA	-	-

Agency information

- UL Listed, 1/10 to 8/10 A @ 125/250 Vac, 1-15 A @ 125 Vac, Guide JDYX, File E19180, CSA Certified, 1/10 to 10 A @ 125 Vac, Class 1422-01, File 53787, CE

FNM time-delay 13/32" x 1-1/2"

Time-delay supplemental fuse. Color code green (250 Vac max) (see data sheet no. 2028).

For superior protection, Eaton recommends upgrading to Bussmann series Low-Peak Class CC fuses (see data sheet no. 1023).



Ratings

Fuse amp range	IR at system voltage		Agency information	
	250 Vac	125 Vac	UL	CSA
1/10 to 1	35 A	10 kA	X	X
1-1/8 to 3-1/2	100 A	10 kA	X	X
4 to 10	200 A	10 kA	X	X
12 to 30	10 kA	-	X	X

Agency information

- UL Listed, Std. 248-14, Guide JDYX; File E19180, CSA Certified, Class 1422-01, File 53787, RoHS compliant, CE

FNQ time-delay 13/32" x 1-1/2"

Time-delay supplemental fuse. Color code orange (500 Vac max) (see data sheet no. 1012).

For superior protection, Eaton recommends upgrading to Bussmann series Limitron FNQ-R Class CC fuses (see data sheet no. 1014).



Ratings

Fuse amp range	IR at rated voltage	Agency information	
	500 Vac	UL	CSA
1/10 to 30	10 kA	X	X

Agency information

- UL Listed, Std. 248-14, Guide JDYX, File E19180, CSA Certified, C22.2 No. 248.14, Class 1422-01, File 53787, HRC-MISC, RoHS compliant, CE



Bussmann series finger-safe CH modular fuse holders for supplemental, PV and Class CC fuses feature a snap-together construction to create the required number of poles. These DIN-Rail mount holders are available with optional open fuse indication and PLC remote fuse monitoring for faster troubleshooting, and accessories like comb busbars for easy ganging.

Applying supplemental OCPDs in branch circuits

The NEC defines a supplemental OCPD as “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.”

Supplemental OCPDs can:

- Only be used for additional protection when installed on the branch circuit overcurrent device’s loadside
- Not be applied where branch circuit OCPDs are required
- Be properly used in appliance applications and for additional (supplemental) protection where branch circuit overcurrent protection is already provided. In appliance applications, the supplemental device inside the appliance provides protection for internal circuits and supplements the branch circuit OCPD’s protection.

Using supplemental OCPDs is permitted by 240.10 for lighting and appliances shown in Figure 44. The supplemental protection is in addition to that provided by the branch circuit OCPD protecting the branch circuit located in the lighting panel in Figure 44.

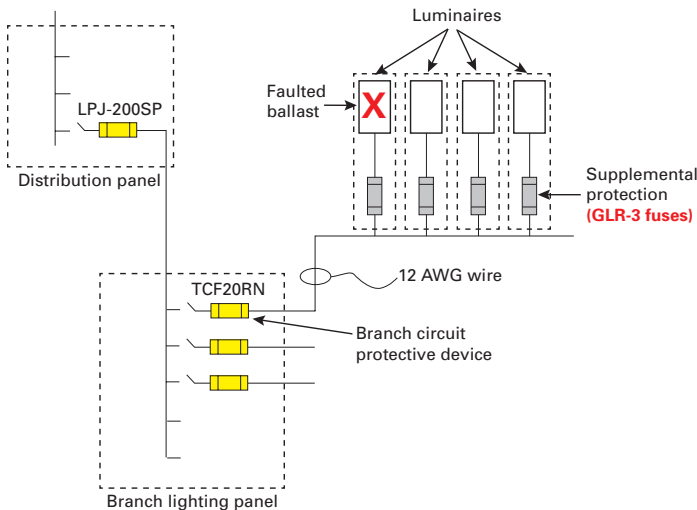


Figure 44: Supplemental OCPDs may be used per 240.10, but will not be considered as protecting a branch circuit.

Branch circuit OCPDs are permitted for supplemental protection and can replace a supplemental OCPD (see Figure 45). Rather than using a supplemental OCPD for supplemental luminaire protection, a branch circuit OCPD is used. The fact that a branch circuit OCPD (a KTK-R-3 fuse) is used where a supplemental device is permitted does not turn the circuit between the lighting panel and the fixture from a branch circuit into a feeder circuit. In the case of Figure 45, the branch circuit starts on the 20 A fuse’s loadside in the lighting panel.

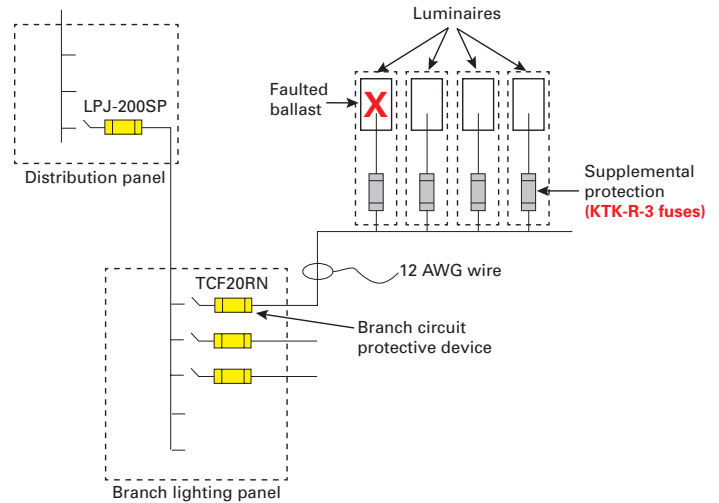


Figure 45: Branch circuit OCPDs can be used for supplemental protection.

Another difference and limitation is that supplemental OCPDs may have creepage and clearance spacing that are considerably less than a branch circuit OCPD. Two such creepage and clearance spacing differences include:

- A supplemental protector, recognized to UL 1077, has 3/8 inch through air spacing requirements between terminals and 1/2 inch over surface at 480 V.
- A branch circuit rated UL 489 molded case circuit breaker with 1 inch through air and 2 inches over surface has spacing requirements between terminals at 480 V.

Further, branch circuit OCPDs have standard overload characteristics to protect branch and feeder circuits, and service entrance conductors. Supplemental OCPDs do not have standard overload (time-current) characteristics and may differ considerably from standard branch circuit overload characteristics. Also, supplemental OCPDs have interrupting ratings that range from 32 A to 100 kA. When supplemental OCPDs are considered for proper use, it’s important to be sure the interrupting rating equals or exceeds the available fault current, and that the device has the proper voltage rating for the installation (including compliance with slash voltage rating requirements, if applicable).



10 Reasons why supplemental protectors are not allowed to protect branch circuits

1. Supplemental protectors are not intended to be used, nor are they evaluated for branch circuit protection in UL 1077.
2. Compared to branch circuit OCPDs, supplemental protectors have drastically reduced spacings, and often depend upon a separate, upstream branch circuit OCPD.
3. Supplemental protectors do not have standard calibration limits or overload characteristic performance levels, and cannot ensure proper protection for branch circuits.
4. Multi-pole supplemental protectors used in three-phase systems are not evaluated for protection against all overcurrent types nor tested to protect circuits from all fault types (e.g., line-to-ground faults on B-phase grounded systems).
5. Most supplemental protectors are fault current tested with an upstream branch circuit OCPD and rely upon this device for proper performance.
6. Supplemental protectors do not require testing for closing into a fault.
7. Supplemental protector re-calibration (for supplemental protection by circuit breakers) is not required and depends upon the manufacturer's preference. There is no performance assurance following a fault or resetting the device. The product standard does not require supplemental devices to be re-calibrated and operational after interrupting a fault.
8. Considerable damage to a supplemental OCPDs is allowed following short-circuit testing.
9. Supplemental protectors are not intended for use as a disconnecting means.
10. Supplemental protectors are not evaluated for fault current performance such as energy let-through limits or protecting test circuit conductors.



Medium voltage fuses

Medium voltage fuses generally have ratings that range from 2.5 kV to 38 kV and are designated under one of three ANSI/IEEE C37.40 defined classifications:

- **General Purpose Current-Limiting:** A fuse capable of interrupting all currents from the rated interrupting current down to the current that causes the fusible element to melt in one hour
- **Back-up Current-Limiting:** A fuse capable of interrupting all currents from the maximum rated interrupting current down to the rated minimum interrupting current
- **Expulsion:** A vented fuse in which the expulsion effect of gasses (produced by the arc and housing, either alone or aided by a spring) extinguish the arc

The general purpose and back-up current-limiting fuses are constructed in a sealed, non-venting design that, when the element melts from a current within the fuse's interrupting rating, produces arc voltages exceeding the system voltage which, in turn, forces the current to zero. The arc voltages are produced by a series of high resistance arcs within the fuse's element to create a fuse that typically interrupts high fault currents within the first 1/2 cycle.

The expulsion fuse, in contrast, depends on the interruption process being initiated by a single arc that acts as a catalyst to create and cause a de-ionizing gas to escape from its housing.

The arc is then elongated, either by the gases' force or a spring so that, at some point, the arc elongates sufficiently enough to prevent a restrike after the AC current cycle passes through zero volts and may take many cycles to clear.

Application

Many rules for applying expulsion and current-limiting fuses are the same, with some additional rules applied to current-limiting fuses because they operate much faster on high fault currents. The three basic factors to consider when applying any medium voltage fuse are:

- Voltage rating
- Continuous current carrying capacity
- Interrupting rating

Voltage rating

As a rule, medium voltage fuses should be applied on systems as close to their voltage rating as possible (unlike low voltage fuses that can be applied on a system at or below their rating). This is particularly important with current-limiting fuses that function by creating multiple high resistance arcs that will drive up the fuse's peak arcing voltage. The arcing voltage should never exceed the system basic insulation level (BIL) and create a safety hazard.

Continuous current carrying capacity

Continuous current values shown on the fuse label represent the continuous current the fuse can carry without exceeding the temperature rise 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 cause damage to the fuse from excessive heat. This is the main reason motor circuit protection uses overload relays in series with back-up current-limiting fuses.

Interrupting rating

As with all fuses, medium voltage fuses need to have an interrupting rating equal to or greater than the available fault current.

Rules for medium voltage current-limiting fuses

To ensure proper current-limiting fuse application, it's important to apply the following:

- As stated earlier, current-limiting fuses produce arc voltages that exceed the system voltage. Care must be taken to ensure the peak voltages do not exceed the system's basic insulation level (BIL). If the fuse voltage rating is not permitted to exceed system voltage by 140%, there should not be a problem. This does not mean that a higher rated fuse cannot be used, but points out that one must ensure the system's BIL will handle the peak arc voltage produced.
- As with the expulsion fuse, current-limiting fuses must be properly coordinated with other system OCPDs. 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 second or greater.

When other current-limiting OCPDs are on the system, it becomes necessary to use I^2t (the thermal energy required to melt a specific fuse element at rated current under test condition, expressed "current squared times seconds" or as A^2s "amps squared times seconds" values for coordination at currents causing the fuse to interrupt in less than 0.01 second. These may be supplied as minimum and maximum values, or minimum melting and total clearing I^2t curves. In either case, apply the following:

- The fuse's minimum melting I^2t should be greater than the downstream current-limiting device's total clearing I^2t .
- The fuse's total clearing I^2t should be less than the upstream current-limiting device's minimum melting I^2t .

Applying R-Rated fuses

The current-limiting fuse should be selected so that the overload relay's curve crosses the fuse's minimum melting curve at a current greater than 110% of the motor's locked rotor current.

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-Rated fuse size.

Example:

A 2300 V motor has a 100 amp full load current rating and 600 amps locked rotor current. The preliminary choice is

$$\frac{6.6 \times 100}{100} = 6.6$$

When rounded up to the next standard R-Rated size, it becomes a 9R fuse, but this must be checked against the appropriate time-current characteristics curves, shown in Figure 46.

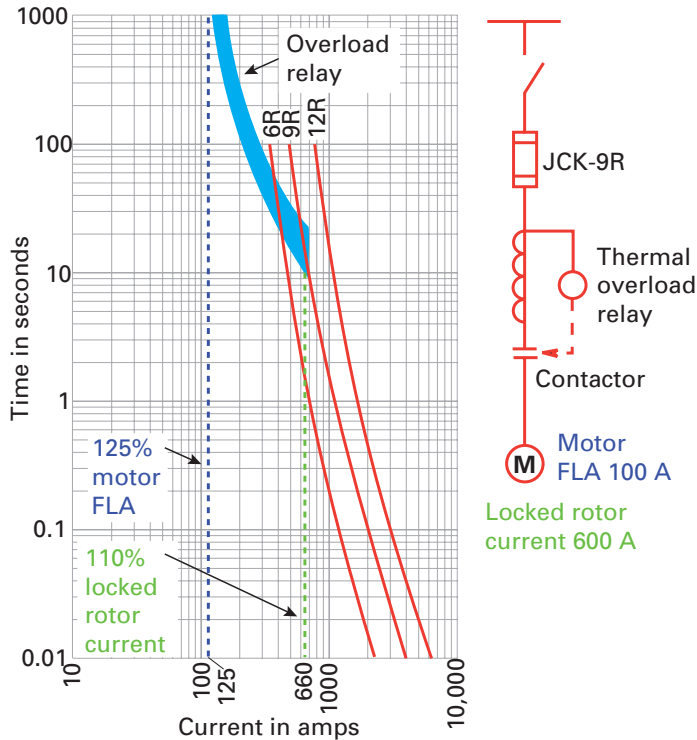


Figure 46: Special care must be taken to ensure the fuse amp rating is compatible with the motor’s overload relay.

The overload relay in this example has the time-current characteristic shown in Figure 46. To ensure the proper fuse is selected, one must plot 110% of the locked rotor current and the range (6R, 9R, 12R) of R-Rated fuses on the same graph as the overload relay.

The selected fuse should be the smallest whose minimum melting characteristic crosses the overload relay at a current greater than 110% of the motor’s locked rotor current. In this example, it would be a 2400 V 9R fuse determined in the given formula. This agrees with the quick selection choice. Depending on the type of installation and starter being used, a JCK-9R, JCK-A-9R, or 2BCLS-9R would be the correct choice.

Additional rules

When choosing an expulsion fuse, it’s important that it be properly coordinated with other upstream and downstream OCPDs. To accomplish this, one must consider the devices’ melting and clearing characteristics. Two curves, the minimum melting and the total clearing curve, provide this information. To ensure proper coordination, the following should apply:

- The total clearing curve for any downstream protective device must be below a curve representing 75% of the applied fuse’s minimum melting curve
- The total clearing curve for the applied fuse must lie below a curve representing 75% of the minimum melting curve for any upstream protective device

R-Rated medium voltage fuses and motor circuits

R-Rated medium voltage fuses are back-up current-limiting fuses used in junction with medium voltage motors and controllers. These fuses are only for short-circuit protection and do not protect themselves or other components during extended overloads. They offer a high level of fault current interruption in a self-contained, non-venting package that can be mounted indoors or in an enclosure. All Bussmann series R-Rated fuses come with open fuse indication, with some available with a Hookeye option for use with a hookstick for non-loadbreak isolation.

R-Rated fuses do not have “amp ratings,” but rather an R-rating when they meet the following requirements:

- The fuse will safely interrupt any current between its minimum and maximum interrupting rating
- The fuse will melt in a range of 15 to 35 seconds at a value of 100 times the “R” number (ANSI C37.46).

Application

Medium voltage motors are efficiently protected by overload relays applied in conjunction with back-up current-limiting fuses that open the circuit under high fault conditions. The overload relay is chosen to interrupt currents below the fuse’s minimum interrupting rating. Since multiple devices are used to provide motor protection, it is very important that they be properly coordinated. The motor starter manufacturer typically designates the proper fuse R-rating, overload relay and contactor.



The Eaton Bussmann Division’s Paul P. Gubany Center for High Power Technology is the electrical industry’s most comprehensive facility for testing and certifying device and equipment SCCRs. Capable of performing electrical tests up to 600 V three-phase, 300 kA of short-circuit current for meeting ANCE, ANSI, CE, CSA, ETL, IEC and UL testing requirements.

R-Rated for motor circuits

- 2.4 kV: 2CLS, 2ACLS, JCK, JCK-A, 2HCLS, 2BCLS — 25 to 450 A
- 4.8 kV: 5CLS, JCL, 5LCLS, JCL-A, 5ACLS, 5HCLS, 5BCLS, 5MCLS — 30 to 800 A
- 7.2 kV: 8CLS, 7CLS, 8ACLS, 7ACLS, 7BCLS — 70 to 800 A
- 50 kA IR Sym.
- 80 kA IR Asym.



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

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 series R-Rated fuses offer a high level of fault current interruption in a self-contained, non-venting package that can be mounted indoors or in an enclosure.

Available styles include standard, AMPGARD™ Hookeye, hermetically sealed and bolt-on with open fuse indication standard on all fuses (see data sheet no. 6001).

E-Rated for transformer and feeder protection

- 2.75 kV: 2CLE, JCX — 1 to 450 A (see data sheet no. 10350)
- 5.5 kV: AHLE, BHLE, HCL, 5CLE, 5HLE, JCY, MV055F — 1 to 1350 A (see data sheet no. 10351)
- 8.3 kV: 8CLE, 8HLE, 8AHLE, 8BHLE, 8HCL — 10 to 350 A (see data sheet no. 10352)
- 15.5 kV: 15CLE, 15HLE, 15LHLE, MV155F, 15BHLE, 15HCL — 10 to 300 A (see data sheet no. 10353)
- 5.5 to 38 kV (DIN dimensioned for switchgear): 55GDMSJ, 55GFMSJ, 155GQJSJ, 175GDMSJ, 175GFMSJ, 175GXMSJ, 175GXQJSJ, 258GDQJSJ, 258GXQJSJ, 258GXZSJ, 38GFZSJ — 10 to 450 A (see data sheet no. 10638)
- 25 to 65 kA IR catalog number dependent



E-Rated medium voltage fuses are general purpose current-limiting fuses. The E-rating defines the fuse's melting time-current characteristic and the ratings are used to allow electrical interchangeability among different manufacturers. A general purpose E-Rated fuse must meet these requirements:

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

Bussmann series E-Rated fuses provide primary protection for 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 fault current (I^2t) that the system components must withstand.



E-Rated for potential and small transformers

- 2.475 kV: 2NCLPT —
0.25 to 5 A
- 3.6 kV: 3.6ABCNA,
3.6ABWNA, 3.6CAV —
2 to 10 A
- 5.5 kV: JCW, 5CLPT, 5NCLPT,
5.5ABWNA, 5.5AMWNA,
5.5CAV, 5.5CAVH —
0.5 to 15 A
- 7.2 kV: 7.2ABWNA, 7.2ABCNA,
7.2AMWNA, 7.2CAV —
0.5 to 10 A
- 8.3 kV: 8CLPT, CLPT, 8NCLPT —
0.5 to 10 A
- 12 kV: 12ABCNA, 12CAV —
2 to 3.15 A
- 15.5 kV: 15CLPT, 15NCLPT, 15.5CAV, 15.5CAVH —
0.5 to 10 A
- 17.5 kV: 17.5ABGNA, 17.5CAV —
2 to 10 A
- 24 kV: 24ABGNA, 24CAV —
2 to 4 A
- 25.5 kV: 25CLPT —
0.5 to 1 A
- 36 kV: 36ABGNA, 36CAV —
2 to 4 A
- 38 kV: 38CAV, 38CAVH, 38CLPT —
0.5 to 4 A
- 25 to 80 kA IR Sym., catalog number dependent.



Low amp, E-Rated medium voltage fuses are general purpose current-limiting fuses defined by their melting time-current characteristic that permits their electrical interchangeability with fuses having the same E-rating. To be E-Rated, the fuse responsive element shall melt in 300 seconds at a RMS current within the range of 200% to 240% of the fuse's continuous current rating. (For fuses rated 100E or less)(ANSI C37.46).

Bussmann series low amp, E-Rated fuses 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 that can be mounted indoors or in an enclosure (see data sheet no. 6002).



High speed fuses

High speed fuses are often called “semiconductor fuses” and sometimes feature a diode symbol on their label. This does not mean there’s a diode in the fuse’s construction. The symbol is there to indicate the fuse is primarily used to protect solid state devices.

In general terms, high speed fuses are not full range fuses. They are applied for short-circuit protection that requires a very “high speed” response to faults. As such, their proper specification and selection requires greater attention to application details and correction factors too numerous to cover in this section. More information on this subject is available in the Bussmann series high speed fuse application guide, publication no. 10507.

Protecting solid-state power equipment often differs significantly from electrical equipment and requires the unique operating characteristics only offered by high speed fuses. Because power diodes and silicon controlled rectifiers (SCRs) cannot withstand heavy fault current, they require ultra-fast current-limiting fuses. The circuits in which these fuses are applied have certain requirements that are generally more stringent than those for typical 60 cycle AC power distribution systems.

The diodes or SCRs in solid-state power equipment have relatively low fault current withstand capabilities. Their thin silicon material has a very low transient thermal capacity that makes them highly susceptible to damage from the heat produced by low, moderate and high faults that can occur in a very short time. Thus, it’s essential to restrict fault energy with a high speed fuse.

NEC 430.52(C)(5) recognizes using high speed fuses for motor protection

There are several criteria used to judge high speed fuse performance. Among these are the current-limiting/short-circuit capability and the ability to quickly interrupt DC currents found in rectifiers and drives. From a design standpoint, I^2t is most often used to evaluate the current-limiting/short-circuit performance. I^2t (RMS amps-squared seconds) indicates the heating affect associated with a current pulse. A semiconductor’s data sheet often specifies its maximum I^2t withstand capability. If the selected fuse has an I^2t let-through less than the semiconductor’s I^2t withstand rating, it is protected.

High speed fuses are often applied where DC interrupting capabilities are essential, with some high speed fuses specifically designed and rigorously tested to have excellent DC operating characteristics.

Specialized knowledge about circuit types is essential for proper application. Included in Figures 47 through 54 are common circuits protected by high speed fuses.

Typical circuits

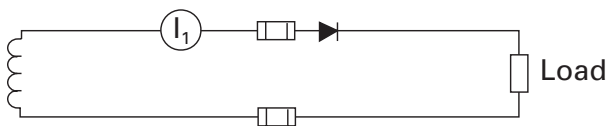


Figure 47: Single-phase, half-wave.

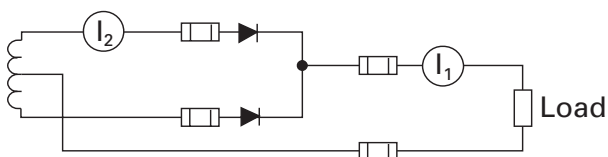


Figure 48: Single-phase, full-wave, center-tap.

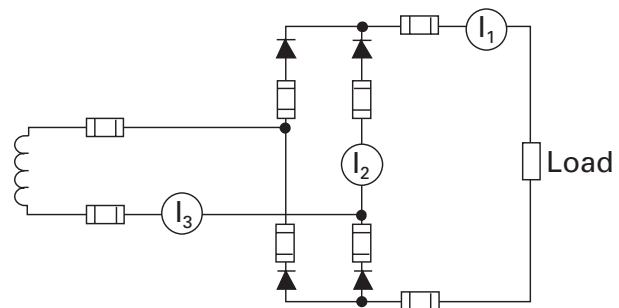


Figure 49: Single-phase, full-wave, bridge.

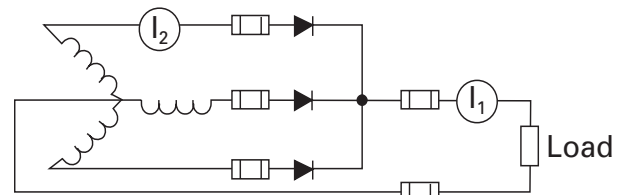


Figure 50: Three-phase, half-wave.

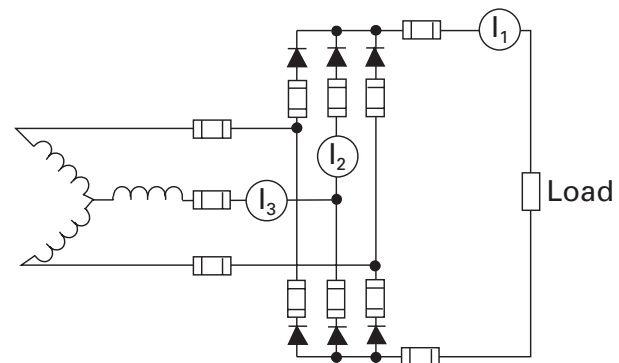


Figure 51: Three-phase, full-wave.

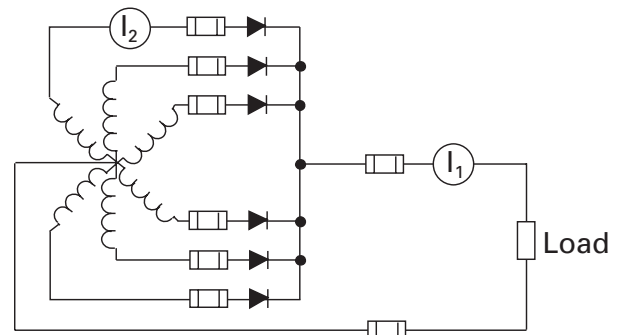


Figure 52: Six-phase, single wave.

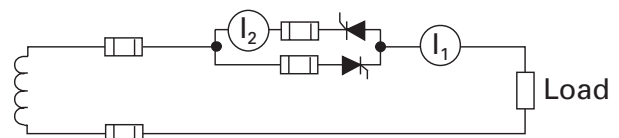


Figure 53: Single-phase, anti-parallel, AC control.

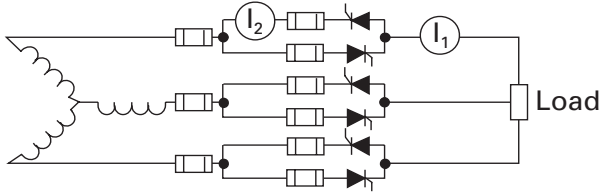
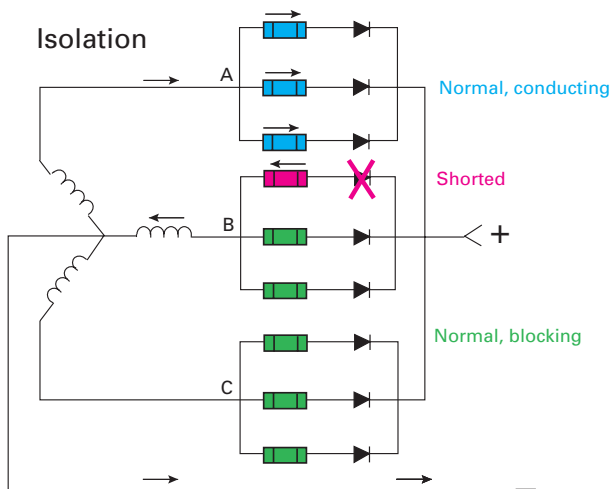


Figure 54: Three-phase, anti-parallel, AC control.

Not all systems with diodes or SCRs have the fuse provide full protection and they are applied to achieve varying design objectives:

1. Prevent device rupture — The fuse merely needs to interrupt current before the diode or SCR ruptures.
2. Isolate failed device — Used typically where only three or more diodes or SCRs are used per conduction path. An individual fuse is not intended to protect an individual device, but rather its purpose is to isolate 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 Figure 55.



Fuse on shorted diode in leg B should be able to open and clear before any damage is done to the diodes in leg A

Figure 55: High speed fuses can be applied to simply isolate faulted circuit paths and allow the remainder of the device to operate.

3. Protect the device (faults) — In this case, the fuse is applied to protect the diode or SCR against faults external to the SCR or diode. Typically, the fuse is selected to give a much lower let-through current than that required for design objectives 1 and 2 shown above.

CHSF — UL compact high speed fuse

CHSF

- 50 to 400 A
- 500 Vac/dc
- 200 kA IR
- Operating class aR, UL Recognized, Guide JFHR2, File E56412, CSA Component Acceptance, Class 1422-30, File 53787, IEC aR (self certified), RoHS compliant, CE



Bussmann series compact high speed fuses feature space-saving case sizes for protecting semiconductor devices while providing superior current cycling performance to help withstand demanding applications.

The CHSF fuse requires up to 48% less enclosure space to help reduce the overall assembly size. Its innovative design allows for a significantly smaller package without compromising heat rise performance, preventing extensive equipment redesign.

With a bolt-on design the CHSF provides design flexibility for installation in fuse blocks or direct mounting on busbars and meets JASO D622 spec for thermal shock, humidity, and vibration (see data sheet no. 10414).

DFJ — UL Class J full range high speed fuse

- 1 to 600 A
- 600 Vac/450 Vdc
- IR
 - 200 kA RMS Sym.
 - 100 kA DC
- Operating class aR, UL Listed, Std 248-8, Class J, Guide JDDZ, File E4273, CSA Certified, C22-2 No 248.8, Class 1422-02, File 53787



UL Class J high speed, full range current-limiting fuses provide maximum protection for AC and DC drives and controllers.

The UL Class J DFJ fuse has the lowest I²t of any branch circuit fuse to protect power semiconductor devices that utilize diodes, GTOs, SCRs and SSRs.

The DFJ fuse combines the performance of high speed fuses in a full range Class J branch circuit package, allowing the use of readily available Class J fuse blocks, holders and switches. The DFJ uses standard Class J holders and blocks (see data sheet no. 1048).

British style (BS88)

CT, ET, EET, FE, FEE, FM, FMM, LCT, LET, LMT, LMMT, MT, MMT

- 6 to 900 A
- 240 to 690 V
- 200 kA IR AC
- UL Recognized
- Designed and tested to BS88: Part 4 and IEC 60269: Part 4



A wide range of British style semiconductor fuses that use innovative arc-quenching techniques and high grade materials to provide:

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

Found in equipment manufactured in the United Kingdom or British Commonwealth countries. North American manufacturers have begun to specify BS88 fuses — particularly in UPS applications at 240 volts or less — to take advantage of their size, performance and cost benefits.

See Bussmann series full line product catalog 1007 for complete product offering.

Ferrule

FWA, FWX, FWH, FWC, FWP, FWK, FWJ, FWL, FWS

- 1 to 100 A
- 150 to 2000 V
- 200 kA IR AC
- UL Recognized
- Designed and tested to IEC 60269:Part 4



Bussmann series full line of ferrule style (cylindrical and clip-mounted) high-speed fuses are 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.

See Bussmann series full line product catalog 1007 for complete product offering.



Square body

170M

- 10 to 7500 A
- 690 to 1300 V
- 200 kA IR AC
- UL Recognized
- Designed and tested to IEC 60269: Part 4

Complete range of square body high-speed fuses and accessories suited for high power applications requiring a compact design with superior performance. End fitting options include:

- DIN 43 653
- DIN 43 620
- Flush end (Metric/US)
- French style
- US style

See Bussmann series full line product catalog 1007 for complete product offering.

North American

FWA, FWH, FWJ, FWP, FWX, KAC, KBC

- 1 to 4000 A
- 130 to 1000 V
- 200 kA IR AC
- UL Recognized

North American The Bussmann series high speed fuses have a complete range of blade and flush-end styles, and accessories designed to provide:

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

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

See Bussmann series full line product catalog 1007 for complete product offering.



Photovoltaic (PV)

Unlike a grid connected AC system, the available fault current within a PV system is limited, requiring the OCPD to operate effectively on higher DC voltage and low fault current. For this reason, PV-specific fuses were developed.

The International Electrotechnical Commissions and Underwriters Laboratories recognize that PV system protection is different and is reflected in IEC 60269-6 (gPV) and UL 248-19 with PV OCPDs for protecting strings and arrays specifically designed to meet these standards:

- Fully tested to the requirements of IEC 60269-6 and exceeding the requirements of operating at 1.45 x In (1.45 times the nominal current).
- Meet the requirements of UL 248-19 that are very similar to the IEC standards, except they operate at 1.35 x In (1.35 times the nominal current).

These IEC and UL ratings do not reflect a continuous service rating. The assigned service rating should be reduced as ambient temperatures increase. To ensure PV fuse longevity, they should not be subjected to a continuous current of more than 80% of the assigned IEC and UL ratings.

Photovoltaic system trends

As with any electrical system, primary goals in a photovoltaic system are efficiency and economies. To do this requires:

- Using smaller, less costly conductors and system components
- Simplifying system design (e.g., in-line holders that combine fuse and holder in one assembly)
- Operating at higher system voltages

Additionally, circuit protection comes into play on the balance of system components from the DC (direct current) side (arrays, combiner boxes, recombiner boxes and inverters - where high speed fuses are needed) to the AC (alternating current) side and, ultimately, connecting to a building's electrical system or the grid.

For more information on selecting and sizing PV fuses, see the solar circuit protection application guide, publication no. 10191.

PVM 600 Vdc 13/32" x 1-1/2" midget

A range of UL 248-19 fast-acting 600 Vdc 13/32" x 1-1/2" (10x38mm) 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) (see data sheet no. 2153).



Ratings

- Volts 600 Vdc
- Amps 4-30 A
- IR 50 kA DC (4-30 A)

Agency information

- UL Listed 248-19, Guide JFGA, File E335324, CSA Component Certified C22.2, RoHS compliant

PVS-R 600 Vac/dc Class RK5

A range of UL 248-19 fast-acting 600 Vdc Class RK5 fuses specifically designed to protect photovoltaic power systems in extreme ambient temperature, high cycling and low level fault current conditions (reverse current, multi-array fault) (see data sheet no. 4203)



Ratings

- Volts
 - 600 Vac to UL 248-12 and 600 Vdc to UL 248-19
- Amps 20-400 A
- IR
 - 200 kA RMS Sym. AC
 - 20 kA DC (20-60 A)
 - 10 kA DC (70-400 A)

Agency information

- UL Listed, Std. 248-12, Class RK5, Guide JFGA, File E335324. Photovoltaic to UL 248-19, CSA Component Certified C22.2

PV 1000 Vdc 10x38mm PV fuses

A range 10x38mm, 1000 Vdc PV fuses for the protection and isolation of photovoltaic strings that are specifically designed for use in PV systems with extreme ambient temperature, high cycling and low fault current conditions (reverse current, multi-array fault) string arrays. For application flexibility, the PV 10x38mm fuse is available as a cylindrical fuse as well as bolt-on, single and dual PCB tab and in-line crimp terminal versions (see data sheet no. 10121).



Ratings

- Volts 1000 Vdc
- Amps 1-20 A
- IR 50 kA

Terminals and conductors

- Crimp connection for single, 75°C/90°C Cu Stranded 12-8 AWG PV wire

Agency information

- UL Listed to 248-19†, Guide JFGA, File E335324, IEC 60269-6 (gPV), CSA File 53787, Class 1422-30 (1-15 A), 20 A Pending, CCC (1-20 A), RoHS Compliant

† Except crimp terminal version that is UL Recognized to UL 248-19, Guide JFGA2, File E335324.



HPV 1000 Vdc in-line PV fuse assembly

A single-pole, non-serviceable photovoltaic in-line fuse holder and fuse assembly in an IP67 dust tight, submersible insulating boot for use in photovoltaic wire harnesses (see data sheet no. 2157).

Ratings

- Volts 1000 Vdc
- Amps 1-20 A
- IR 33 kA



Agency information

- UL Listed to 4248-1 and 4248-19, File E 348242, CSA Component Acceptance, Class 6225 30, File # 47235, IP67 submersible, RoHS compliant, CE

PV 1000/1100 Vdc 14x51mm

A range of 14x51mm PV fuses specifically designed for protecting and isolating photovoltaic strings. These fuses are capable of interrupting low overcurrents associated with faulted PV systems (reverse current, multi-array fault) (see data sheet no. 720132).

Ratings

- Volts
 - 1000 Vdc (25 and 32 A)
 - 1100 Vdc (15 and 20 A)
- Amps 15-32 A
- IR 10 kA



Agency information

- UL Listed, Guide JFGA, File E335324. Photovoltaic to, UL 248-19, IEC 60269-6 gPV, CSA Pending, CCC Pending, RoHS compliant

NH 1000 Vdc blade and bolt-on

A range of 1000 Vdc NH size PV fuses specifically designed for protecting and isolating array combiners/re-combiners, disconnects and inverters (see data sheet no. 720133).

Ratings

- Volts 1000 Vdc
- Amps 32-400 A
- IR 50 kA



Agency information

- UL Listed, Guide JFGA, File E335324, Photovoltaic to UL 248-19, IEC 60269-6 gPV, CSA Class 1422-30, File 53787 (32-160 A), UL Listed, IEC gPV, CSA, CCC Pending, RoHS compliant

PV 1500 Vdc 10x85mm

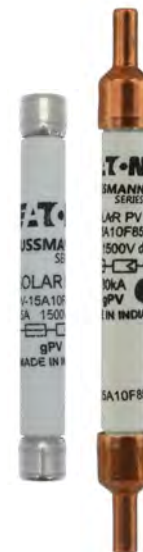
A range of 10x85mm PV fuses specifically designed for protecting and isolating photovoltaic strings. These fuses are capable of interrupting low overcurrents associated with faulted PV systems (reverse current, multi-array fault). Also available with crimp terminals (see data sheet no. 10658).

Ratings

- Volts 1500 Vdc
- Amps 2.25-25 A
- IR 30 kA, 1 ms

Agency information

- UL 248-19, IEC 60269, RoHS compliant



PV15M-4A-CT 1500 Vdc in-line crimp terminal fuse

Bussmann series PV15M-4A-CT is a 1500 Vdc in-line photovoltaic fuse with crimp terminals for use in wire harnesses and other applications where an in-line PV fuse is desirable. This in-line fuse can be electrically insulated with customer-supplied overmolding or approved heat-shrink (see data sheet no. 10639).

Ratings

- Volts 1500 Vdc
- Amps 4 A
- IR 15 kA DC
- Time constant 1~3 ms

Agency information

- UL Recognized, 248-19, File E484317 Vol. 1 Sec. 1, CSA pending, RoHS compliant



PV XL 1000 Vdc and 1500 Vdc

A range of XL size PV fuses specifically designed for protecting and isolating photovoltaic array combiners and disconnects. These fuses are capable of interrupting low overcurrents associated with faulted PV systems (reverse current, multi-array fault). Optional microswitches available for use in monitoring systems (see data sheet no. 10201).

Ratings

- Volts
 - 1000 Vdc (60-630 A)
 - 1500 Vdc (50-400 A)
- Amps
 - 63-630 A (1000 Vdc)
 - 50-400 A (1500 Vdc)
- IR
 - 50 kA (1000 Vdc 63-160 A 01XL and 350-630 A 3L)
 - 30 kA (1000 Vdc 200 A 1XL, 160-355 A 2XL)
 - 30 kA (1500 Vdc 50-160 A 01XL, 100-200 A 1XL, 125-250 A 2XL, 250-400 A 3L)



Agency information

- UL 248-19, Guide JFGA, File E335324, IEC 60269-6 gPV, CSA Class 1422-30, File 53787, RoHS compliant

Glossary — common electrical terminology

Ampere (amp) — The measurement of intensity of rate of flow of electrons in an electrical 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, I²t — The measure of heat energy developed within a circuit during the fuse's clearing. It can be expressed as "Melting I²t," "Arcing I²t" or the sum of them as "Clearing I²t." "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 fuse — 600 V, 200 kA amp interrupting rating, branch circuit fuses with overall dimensions of 13/32" x 1-1/2". 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 13/32" x 1-1/2" fuses. They are available from 1/10 through 30 amps.

Class CF fuse — A finger-safe UL Listed branch circuit rated fuse. Available in time-delay or fast-acting versions, the Class CF fuse has Class J electrical performance and is available in ratings from 1 to 100 A in 30, 60 and 100 A case sizes.

Class G fuse — A size rejecting branch circuit fuse in ratings from 1/2 through 20 amps (600 Vac) and 25 through 60 amps (480 Vac) with a 100 kA interrupting rating. The size rejecting feature helps to eliminate overfusing. The fuse diameter is 13/32" while the length varies from 1-5/16" to 2-1/4".

Class H fuse — 250 V and 600 V, 10 kA interrupting rating branch circuit fuses that may be renewable or non-renewable. These are available in ratings from 70 through 600 amps.

Class J fuse — These rejection style fuses are rated to interrupt a minimum of 200 kA AC. They are labeled as "current-limiting," are rated for 600 Vac 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 I²t and I_p maximums. These are dimensionally the same as Class H fuses, and they can have interrupting ratings of 50 kA, 100 kA, or 200 kA. While these fuses are current-limiting, they are not marked "current-limiting" on their label since they do not have a rejection feature.

Class L fuse — These fuses are rated for 601 through 6000 amps, and are rated to interrupt a minimum of 200 kA AC. They are labeled "current-limiting" and are rated for 600 Vac. 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 fuse — These are high performance fuses rated 1/10 through 600 amps in 250 V and 600 V ratings. All are marked "current-limiting" on their label and all have a minimum of 200 kA interrupting rating. They have identical outline dimensions with the Class H fuses but have a rejection feature that 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 fuse — An industry class of 300 V and 600 V fuses in ratings from 1 through 1200 amps (300 V) and 1 through 800 amps (600 V). 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 kA RMS.

Classes of fuses — The industry has developed basic physical specifications and electrical performance requirements for fuses with voltage ratings of 600 V 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 UL branch circuit fuse classes are CC, CF, G, H, J, K, L, RK1, RK5 and T.

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 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 — A 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 — The part of the electrical system that actually uses the energy or does the work required.

Fast-acting fuse — A fuse that 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.

Fault current — Fault currents can be short-circuit currents, ground fault currents or arcing fault currents.

Fuse — An overcurrent protective device with a fusible link that operates and opens the circuit on an overcurrent condition.

High speed fuse — A fuse 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 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 NEC. 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.

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 fuse — Generic term used to describe a Class H non-renewable cartridge fuse, with a single-element.

Overcurrent — Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short-circuit or ground fault. (Ref. NEC Article 100.)

Overload — Operation of equipment in excess of normal, full load rating, or of a conductor in excess of rated ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short-circuit or ground fault, is not an overload. (Ref. NEC Article 100.)



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 (600 V and 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 affect in the resistance as the periodic current does.

Semiconductor fuse — Fuses used to protect solid-state devices. See "high speed fuse."

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 (SCCR) — This term applies to components (single devices) and assemblies (equipment). For the component, it is the maximum fault current it can sustain without the occurrence of excessive damage. For equipment, it is the assembly's rating, generally limited by the lowest component SCCR in the circuit as determined by an approved method such as UL 508A, Supplement SB.

Short-circuit withstand — The maximum current that an unprotected electrical component can sustain for a specified period of time without the occurrence of extensive damage. Typically applies to devices or components that do not have a marked short-circuit current rating, such as conductors, transfer switches or semiconductor devices.

Single-phasing — The condition that 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, may cause overheating and failure.

Threshold current — The symmetrical RMS (root mean square) 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 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.

Summary — the power of the modern, current-limiting fuse

Highest interrupting ratings up to 300 kA

- Provides flexibility for use in any system with available fault currents up to 300 kA without fear of misapplication
- Provides a no-worry solution in the case system changes (utility transformer or equipment relocation) result in higher available fault current
- Saves time by eliminating the need for fault current studies when using 300 kA IR Low-Peak fuses
- Improves compliance with NEC 110.9 and removes the fear of misapplication
- Helps achieve high equipment short-circuit current ratings as the fuse will not be the limiting factor
- Peace of mind as a fuse's interrupting rating is always at least equal to or, in many cases, greater than the available fault current at the line terminals

Current limitation

- Enhances workplace safety by reducing the incident energy and arc flash hazards personnel may be exposed to under fault conditions
- Protects components and equipment from extreme thermal and mechanical forces associated with a fault event
- Helps compliance with NEC 110.10 by protecting equipment and components from extensive fault current damage when properly sized
- Helps achieve high equipment short-circuit current ratings by drastically reducing peak let-through current
- Type 2 “No Damage” (versus Type 1) protection with properly sized fuses reduces downtime and improves system protection

Physical rejection

- Provides a safe and reliable system by ensuring the same class fuse with the same voltage and interrupting rating is installed
- Reduces the risk that the wrong fuse type with different performance characteristics and lower interrupting ratings can be installed and compromise the protection level

Enclosed non-venting design

- Fuses do not vent, so they eliminate the venting that's inherent on some mechanical OCPDs that could cause unnecessary damage to other system components
- Reduces cost by eliminating the need for additional system guards or barriers to protect from venting

Enclosed, fixed, thermal design

- Improved fault protection integrity by not relying on springs, levers and latches to open the circuit
- Reduced operating costs by eliminating the need for device maintenance or calibration
- Minimizes possible misapplication and confusion by eliminating the need to adjust and change device settings in the field

Factory calibrated replacements

- Improved system reliability throughout the system's life by ensuring the same protection level is installed after a fault
- Maintained system integrity as replacement fuses utilize the latest design and performance improvements
- Helps comply with OSHA 1910.334(b)2 by eliminating the invitation for an operator to reset a device after a fault occurs without first determining its cause (resetting circuit breakers or replacing fuses in a circuit without investigating and fixing the cause is prohibited by federal law)

Straight voltage rating

- Straight voltage rated fuses provide flexibility in any system regardless of its grounding (a slash voltage rated OCPD is limited to installation in ONLY a solidly grounded Wye system)

Finger-safe designs

- Increase system and personnel safety by utilizing the latest in finger-safe fuse technology covering blocks, holders, disconnect switches and power distribution fuse blocks.
- Of special note is the finger-safe Bussmann series CUBEFuse that's used with the patented UL 98 Listed Bussmann series Compact Circuit Protector (CCP) switch — together they provide a finger-safe fused switch that's horsepower rated and can be used on branch circuits



A common sight for generations, this tin of BUSS fuses proudly displays the overcurrent protection slogan “Electricity’s Safety Valve.”

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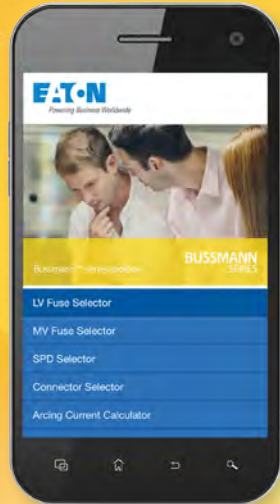
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- > Arcing Current Calculator
- > Low Voltage Fuse Selector
- > Medium Voltage Fuse Selector
- > Motor Protection Selector
- > Surge Protective Device Selector
- > Connector Selector
- > Competitor Cross Reference
- > Distributor Locator
- > SCCR Protection Suite
- > OSCAR™ 2.1 Online Compliance Software
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