Benefits Offered By Fuses

High Interrupting Rating of 200,000 Amps or More
Modern current-limiting fuses have high interrupting ratings at no extra cost. Whether for the initial installation or system updates, a fusible system can maintain a sufficient interrupting rating. This helps with achieving high assembly short-circuit current ratings. See pages 6 to 8 for Fuseology Interrupting Rating details.

Type 2 Protection
Type 2 “No Damage” protection of motor starters when applied properly. See page 164 for details on Type 1 versus Type 2 protection.

High SCCR
High assembly short-circuit current ratings can be achieved. See pages 78 to 88 for Industrial Control Panels.

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

Flexibility
Increased flexibility in panel use and installation. Valuable time that was spent gathering information for proper application is drastically reduced with fuses since:
- Fuses can be installed in systems with available fault currents up to 200kA or 300kA covering the majority of installations that exist.
- Fuses can handle line-to-ground fault currents up to their marked interrupting rating where mechanical devices often have single pole interrupting capabilities far less than their marked IR (typically 8,660 amps for any marked IR) See pages 6 to 8 and 33 to 34 for Fuse Single Pole Interrupting Ratings and pages 29 to 34 for Circuit Breaker Single Pole Interrupting Capabilities.
- Fuses have a straight voltage rating instead of a slash voltage rating. A device with a slash voltage rating is limited to installation in ONLY a solidly grounded wye type system. Fuses can be installed in any type of installation independent of the grounding scheme used. See pages 5 to 6 for Slash Voltage Rating.

Reliability
Fuses provide reliable protection throughout the life of the installation. After a fault occurs, fuses are replaced with new factory calibrated fuses assuring the same level of protection that existed previous to the fault. Resettable devices may not provide the same level of protection following a fault and need to be tested for calibration and possibly replaced.

No Venting
Fuses do not VENT. Therefore fuses will not affect other components in the panel while clearing a fault. Additional guards or barriers which isolate devices that vent from other components are not required.

Helps Regulation Compliance
Eliminates invitation to reset into a fault and potential OSHA violation. Resetting or manually reenergizing a circuit without investigating the cause is prohibited in OSHA CFR29:1910-334. Fuses are not resettable and eliminate the invitation to reset. See page 132 for Is Resettablity of Value?

Workplace Safety
Superior current limitation provides enhanced workplace safety. See pages 116 to 126 for Electrical Safety.

Component Protection Via Current Limitation
Superior current limitation provides protection of circuit components for even the most susceptible components such as equipment grounding conductors. See pages 67 to 77 for Component Protection and pages 78 to 88 for Industrial Control Panels.

Selective Coordination
Achieving selective coordination is simple. Typically selective coordination can be achieved between current-limiting fuses by simply maintaining a minimum amp ratio between upstream and downstream fuses. This can aid in diagnostics within the building electrical system or machine panel as only the affected circuit is isolated. Selective coordination helps isolate faulted circuits from the rest of the system and prevents unnecessary power loss to portions of a building. See pages 9 and 88 to 105 for Selective Coordination.

Specify the Cooper Bussmann Low-Peak® System
- Safety Built-in rejection features
- Selective coordination with a minimum 2:1 ratio
- Maximum current-limiting protection for distribution equipment
- Type “2” Protection for motor starters
- Only one type of fuse throughout building
- Reduces inventory
- 300,000A interrupting rating
- May reduce arc-flash hazard

©2005 Cooper Bussmann
Overcurrents are often quite complicated. They cannot be absolutely fail-safe. Circuits are subject to destructive overcurrents. Harsh environments, general deterioration, accidental damage or damage from natural causes, excessive expansion or overloading of the electrical distribution system are factors which contribute to the occurrence of such overcurrents. Reliable protective devices prevent or minimize costly damage to transformers, conductors, motors, and the other many components and loads that make up the complete distribution system. Reliable circuit protection is essential to avoid the severe monetary losses which can result from power blackouts and prolonged downtime of facilities. It is the need for reliable protection, safety, and freedom from fire hazards that has made the fuse a widely used protective device.

**Overcurrents**

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

**Overloads**

Overloads are most often between one and six times the normal current level. Usually, they are caused by harmless temporary surge currents that occur when motors start up or transformers are energized. Such overload currents, or transients, are normal occurrences. Since they are of brief duration, any temperature rise is trivial and has no harmful effect on the circuit components. (It is important that protective devices do not react to them.) Continuous overloads can result from defective motors (such as worn motor bearings), overloaded equipment, or too many loads on one circuit. Such sustained overloads are destructive and must be cut off by protective devices before they damage the distribution system or system loads. However, since they are of relatively low magnitude compared to short-circuit currents, removal of the overload current within a few seconds to many minutes will generally prevent equipment damage. A sustained overload current results in overheating of conductors and other components and will cause deterioration of insulation, which may eventually result in severe damage and short circuits if not interrupted.

**Short Circuits**

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

Fuses are a universal protective device. They are used in power distribution systems, electronic apparatus, vehicles…and as illustrated, our space program. The Space Shuttle has over 600 fuses installed in it protecting vital equipment and circuits.

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

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

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

The NEC® addresses slash voltage ratings for circuit breakers in 240.86 restricting their use to solidly grounded systems where the line to ground voltage does not exceed the lower of the two values and the line voltage does not exceed the higher value.

430.83(E) was revised for the 2005 NEC® to address the proper application of motor controllers marked with a slash voltage rating. The words "solidly grounded" were added to emphasize that slash voltage rated devices are not appropriate for use on corner grounded delta, resistance grounded and ungrounded systems.

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

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

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

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

If a device has a slash voltage rating limitation, product standards require these devices, such as circuit breakers, manual motor controllers, self protected starters, or supplementary protectors to be marked with the rating such as 480Y/277V. If a machine or equipment electrical panel utilizes a slash voltage rated device inside, it is recommended that the equipment nameplate or label designate this slash voltage rating as the equipment voltage rating. UL508A industrial control panels requires the electrical panel voltage marking to be slash rated if one or more devices in the panel are slash voltage rated.
Slash voltage devices are limited in application to solidly grounded, wye systems due to the nature of the way that these devices are tested, listed and labeled. Any piece of equipment that utilizes a slash voltage rated overcurrent protective device is therefore, limited to installation only in a solidly grounded, wye system and should require marking that notes this limitation.

Equipment that utilizes straight voltage rated overcurrent protective devices provides more value and utilization to the owner or potential future owners than equipment that utilizes slash voltage rated devices. In today’s business environment, machinery and equipment may be moved several times during its useful life. Equipment utilizing slash voltage rated overcurrent devices is not suitable for many electrical systems found in industrial environments.

**Amp Rating**

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

**Testing Knife-Blade Fuses**

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

In a continuing effort to promote safer work environments, Cooper Bussmann has introduced newly designed versions of knife-blade Fusetron® fuses (Class RK5) and knife-blade Low-Peak fuses (Class RK1) for some of the amp ratings. The improvement is that the end caps are insulated to reduce the possibility of accidental contact with a live part. With these improved fuses, the informed electrician knows that the end caps are isolated. With older style non-insulated end caps, the electrician doesn’t really know if the fuse is “hot” or not. A portion of all testing-related injuries could be avoided by proper testing procedures. Cooper Bussmann hopes to reduce such injuries by informing electricians of proper procedures.

**Interrupting Rating**

A protective device must be able to withstand the destructive energy of short-circuit currents. If a fault current exceeds a level beyond the capability of the protective device, the device may actually rupture, causing additional damage. Thus, it is important when applying a fuse or circuit breaker to use one which can sustain the largest potential short-circuit currents. The rating which defines the capacity of a protective device to maintain its integrity when reacting to fault currents is termed its “interrupting rating”. The interrupting rating of most branch-circuit, molded case, circuit breakers typically used in residential service entrance panels is 10,000A. (Please note that a molded case circuit breaker’s interrupting capacity will typically be lower than its interrupting rating.) Larger, more expensive circuit breakers may have interrupting ratings of 14,000A or higher. In contrast, most modern, current-limiting fuses have an interrupting rating of 200,000 or 300,000A and are commonly used to protect the lower rated circuit breakers. The National Electrical Code® 110.9, requires equipment intended to break current at fault levels to have an interrupting rating sufficient for the current that must be interrupted. The subjects of interrupting rating and interrupting capacity are treated later in more detail.
Fuseology

Interrupting Rating

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

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

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

This last group depicts the same test circuit as the previous two tests, which is 50,000A available at 480V. This time the test was performed with modern current-limiting fuses. These happen to be Cooper Bussmann Low-Peak fuses with a 300,000A interrupting rating. Notice that the fault was cleared without violence.
The table below depicts four different situations involving an overcurrent device with a normal current rating of 100A and an interrupting rating of only 10,000A.

<table>
<thead>
<tr>
<th>Circuit with Overcurrent Protective Device</th>
<th>Application And Action of Protective Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit Conditions</td>
<td>Circuit interrupting rating of at least 50,000A</td>
</tr>
<tr>
<td>100 Amps AMMETER LOAD</td>
<td>Proper</td>
</tr>
<tr>
<td>Overload Current Greater Than Device's Amp Rating</td>
<td>Proper-Safe Interruption of Current</td>
</tr>
<tr>
<td>Short-Circuit Current Within Device Interrupting Rating</td>
<td>Improper: Explosion or Rupture Could Result</td>
</tr>
<tr>
<td>Short-Circuit Current Exceeds Device Interrupting Rating</td>
<td>Improper: Explosion or Rupture Could Result</td>
</tr>
</tbody>
</table>

As depicted in the diagram that follows, when using overcurrent protective devices with limited interrupting rating, it becomes necessary to determine the available short-circuit currents at each location of a protective device. The fault currents in an electrical system can be easily calculated if sufficient information about the electrical system is known. (See the Point-to-Point Method for Short Circuit Calculations, pages 192 to 198.) With modern fuses, these calculations normally are not necessary since the 200,000A or 300,000A interrupting rating is sufficient for most applications.

Also, if using circuit breakers or self-protected starters, it may be necessary to evaluate the devices’ individual pole interrupting capability for the level of fault current that a single pole of a multi-pole device may have to interrupt. This is covered in-depth in the “Single-Pole Interrupting Capability” section on pages 29 to 34.

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

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

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

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

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

Unlike electro-mechanical inertial devices (circuit breakers), it is a simple matter to selectively coordinate fuses of modern design. By maintaining a minimum ratio of fuse-amp ratings between an upstream and downstream fuse, selective coordination is achieved. Minimum selectivity ratios for Cooper Bussmann fuses are presented in the Selectivity Ratio Guide in “Fuse Selective Coordination” section. Adherence to the tabulated selectivity ratios normally proves adequate.

This book has an indepth discussion on coordination. See sections “Fuse Selective Coordination” and “Circuit Breaker Coordination.”

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

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

See Current-Limitation section and Fuse Let-Through Charts Analysis section for in-depth discussion. See Fuse Current-Limiting Let-Through Charts section for Cooper Bussmann fuse data.