NOTE: *Normally, in the case of a disconnect switch, the movable side of the knife blades is available to contact with the probe. In case of a circuit breaker, the load conductor termination should be contacted.*

12. Place the probe in the meter holder into good physical contact with phase B in the same relative physical location.
13. Repeat steps 11 and 12, except contact phases B and C.
14. Repeat steps 11 and 12, except contact phases A and C.

NOTE: *Tests for absence of voltage should be conducted at each point within the enclosure. If the compartment contains fuses, a voltage test should be conducted at both the line and load sides of each fuse, both between phases and between each phase conductor and ground. Each test should be taken at the fuse clip instead of at the fuse ferrule (endbell).*

15. Measure voltage between each point within the enclosure where contact is expected.
16. Verify that the voltmeter functions satisfactorily on a known energized voltage source.

NOTE: *If the meter is auto ranging, a nearby 110V receptacle is satisfactory. If the meter is not auto ranging, the known energized source must be within the same voltage range.*

X. Suggestions for Limiting Arc-Flash and Shock Hazards

There are many considerations creating an electrically safe workplace for employees. Electrical safety starts with the **design** of the electrical system. The selection and layout of the system components/equipment can have considerable impact on the probability of an incident and on the severity of hazard if an incident does occur. For existing electrical systems, it may be possible to improve electrical safety conditions for workers by **upgrading** components and also by following proper equipment **maintenance procedures.** Also, there are safe **work practices** in which the workers must be trained and qualified to perform. This includes understanding the electrical hazards, the types of PPE and work procedures that are necessary.

The following start with some work practice and maintenance suggestions and then moves to electrical system design and upgrade suggestions.

A. Avoidance is the surest electrical safety measure.

If workers do not "work on or near" exposed energized components, worker safety is enhanced. Management and workers should insist on putting equipment into **an electrically safe work condition** prior to commencing electrical work. Per OSHA 1910.333(a)(1) and *NFPA 70E* 130.1, workers shall not work on or near exposed live parts except for two demonstrable reasons:

A. De-energizing introduces additional or increased hazards (such as cutting ventilation to a hazardous location) or

B. Infeasible due to equipment design or operational limitations (such as when performing diagnostics and testing for startup or troubleshooting and this work can only be done when circuits are energized).

B. Avoidance: implement energized electrical work permit procedures requiring signature by management.

NFPA 70E 110.8(B)(2) & 130.1(A)(1)

If live parts are not placed in an electrically safe work condition (i.e., for the reasons of increased or additional hazards or infeasibility per 130.1) work to be performed shall be considered energized electrical work and shall be performed by written permit only.

NFPA 70E 130.1(A)(3) Exemptions to Work Permit

Work performed on or near live parts by qualified persons related to tasks such as testing, troubleshooting, voltage measuring, etc., shall be permitted to be performed without an energized electrical work permit provided appropriate safe work practices and personal protective equipment in accordance with Chapter 1 are provided and used.

70E-130(A)(2) provides the elements of energized electrical work permits that include a work description, justification of why the work must be done energized, a shock hazard analysis, a flash hazard analysis, the PPE required and more. One of the most important aspects is signature approval by an authorized person, which typically should be an owner or an executive. Experience by companies that effectively use energized electrical work permits is that most work gets performed under electrically safe work conditions. That is, the energized electrical work permits rarely get approved. Usually in the process of getting the electrical work permit approved, management finds a means to do the work under electrically safe work conditions. *NFPA 70E* has an example energized work permit form in Annex J.

C. Voltage testing - requires appropriate work practices and PPE

If a worker is troubleshooting an energized electrical circuit, clearly the worker needs to use safe work practices appropriate for the circuit voltage and energy level. This includes the worker wearing the appropriate PPE for the arc-flash hazard. However, the same precautions shall be taken while checking voltage on deenergized circuits that are not yet considered to be in an electrically safe work condition. (See the Electrically Safe Work Condition Section for the required steps.) Even though a circuit may be deenergized (disconnect opened), it is:

> *NFPA 70E 120.3(A)*
> *...not considered in an electrically safe work condition until all sources have been removed, the disconnecting means is under lockout/tagout, the absence of voltage is verified by an approved voltage testing device, and, where exposure to energized facilities exist, are temporarily grounded.*

Essentially the same requirement is in OSHA 1910.333(b) which considers de-energized circuits as *energized* until all the appropriate steps have been completed successful.

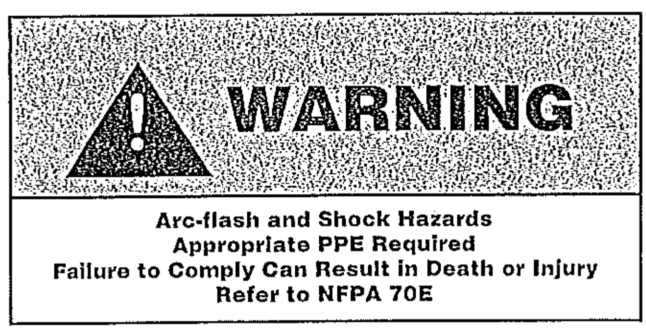
Therefore, voltage testing of each conductor, which is a necessary step while putting the equipment in an electrically safe work condition (completing the lockout/tagout procedure), is essentially considered as working on energized parts per OSHA 1910.333(b) and considered de-energized but not in an electrically safe work condition per *NFPA 70E* 120.3(A). *This means workers must utilize adequate personal protective equipment for the voltage level and arc-flash hazard level during the tests to verify the absence of voltage after the circuits are de-energized but not yet in an electrically safe work condition. Adequate PPE may also be required during load interruption and during visual inspection that verifies that all disconnecting devices are open.*

D. Do a flash hazard analysis for all equipment and affix NEC® 110.16 arc-flash warning label, including incident energy, flash protection boundary, and shock boundaries

> *NEC® 2002 - 110.16 Flash Protection*
>
> *Switchboards, panelboards, industrial control panels, and motor control centers in other than dwelling occupancies, that are likely to require examination, adjustment, servicing, or maintenance while energized, shall be field marked to warn qualified persons of potential electric arc-flash hazards. The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.*
>
> *FPN No. 1: NFPA 70E-2000, Electrical Safety Requirements for Employee Workplaces, provides assistance in determining severity of potential exposure, planning safe work practices, and selecting personal protective equipment.*
>
> *FPN No. 2: ANSI Z535.4-1998, Product Safety Signs and Labels, provides guidelines for the design of safety signs and labels for application to products.*

This requirement, which is new per the NEC® 2002, is intended to reduce the occurrence of serious injury or death due to arcing faults to workers who work on or near energized electrical equipment. The warning label should remind a qualified worker who intends to open the equipment for analysis or work that a serious hazard exists and that the worker should follow appropriate work practices and wear appropriate personal protective equipment (PPE) for the specific hazard (a nonqualified worker must not open or be near open energized equipment).

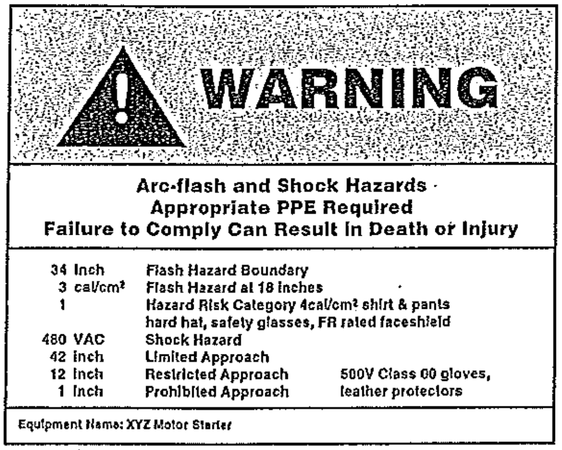
NEC® 110.16 only requires that this label state the existence of an arc-flash hazard.



It is suggested that the party responsible for the label include more information on the specific parameters of the hazard. In this way the qualified worker and his/her management can more readily assess the risk and better insure proper work practices, PPE and tools. The example label that follows includes more of the vital information that fosters safer work practices. The specific additional information that should be added to the label includes:

- Flash Protection Boundary
- Incident energy at 18 inches expressed in cal/cm^2
- PPE required
- Voltage shock hazard

- Limited shock approach boundary
- Restricted shock approach boundary
- Prohibited shock approach boundary



Put yourself in the place of an electrician who is given the assignment to troubleshoot a circuit that is energized or to check for the absence of voltage while putting equipment in an electrically safe work condition. How does he/she know the level of arc-flash hazard for that specific equipment? The more informative label provides sufficient information for a qualified electrician to use the proper level of PPE and appropriate work practices for the level of hazard.

Note: *If the label includes the specific hazard level data, the label must be updated when there are any electrical system changes that result in different hazard levels.*

E. Worker must be qualified for the task

This is especially important for tasks that involve working on or near circuits that are not in an electrically safe work condition.

NFPA 70E 110.6(D)(1) provides the training requirements for a qualified person. This clause is extensive but some training requirements include:

- Construction and operation of equipment
- Specific work methods
- Recognition and avoidance of electrical hazards
- Special precautionary techniques
- Personal protective equipment

A person working inside the limited approach boundary of exposed live parts must in addition be trained on:

- Identifying exposed energized parts
- Determining the voltage of exposed energized parts
- Determining the approach boundaries
- Decision making process to determine the hazard (including shock and arc-flash), PPE, and job planning to perform task

It is important to note that a person can be qualified for some equipment and methods but not others.

Before a qualified person is asked to perform work on or near energized parts, the supervisor should be sure the person is physically and mentally ready for the task that day.

F. Do not reset a circuit breaker or replace fuses until the cause is known and rectified.

> *OSHA 1910.334(b)(2) & NFPA 70E 130.6(K)*
>
> ***Reclosing circuits after protective device operation.*** *After a circuit is deenergized by a circuit protective device, the circuit may not be manually reenergized until it has been determined that the equipment and circuit can be safely energized. The repetitive manual reclosing of circuit breakers or reenergizing circuits through replaced fuses is prohibited. NOTE: When it can be determined from the design of the circuit and the overcurrent devices involved that the automatic operation of a device was caused by an overload rather than a fault condition, no examination of the circuit or connected equipment is needed before the circuit is reenergized.*

This is an important safety practice. If an overcurrent protective device opened under fault conditions, there is some damage at the point of the fault. If the fault is not located and rectified, reclosing on the fault again may result in an even more severe fault than the first fault. Also, if the protective device is a circuit breaker, it may have been damaged on the initial interruption. Reclosing a degraded circuit breaker on a fault may cause the circuit breaker to fail in an unsafe manner. See the next section, follow procedures for fuses and circuit breakers after interrupting a fault.

G. Follow procedures for fuses and circuit breakers after interrupting a fault

Fuses: Fuses that interrupt a circuit should be replaced with the proper fuse type and amps rating. When using modern current-limiting fuses, new factory calibrated fuses are installed in the circuit and the original level of overcurrent protection is maintained for the life of the circuit. Modern current-limiting fuses are always recommended. In most newer systems, the fuse mountings only accept modern current-limiting fuses that have a high interrupting rating. For older systems, where the fuse clips may accept older style fuses, it is recommended to only store and use modern current-limiting style fuses that also can be used in those clips. For example, if a facility has Class H fuse clips, only store and use LOW-PEAK® LPN-RK_SP and LPS-RK_SP fuses (Class RK1).

> *NFPA 70E 225.1*
>
> *Fuses shall be maintained free of breaks or cracks in fuse cases, ferrules, and insulators. Fuse clips shall be maintained to provide adequate contact with fuses.*

Fuses are typically used in conjunction with disconnects. Disconnects in most cases have no role in overcurrent protection. Disconnects should be periodically inspected and maintained. In applications where disconnects are used for interruption, such as when equipped with a ground fault protection relay or a feature that opens the disconnect when one fuse opens, the disconnect should be inspected and, if necessary, maintained after such an interruption.

Circuit Breakers: Circuit breakers need to be evaluated for suitability before being placed back into service by a person qualified for circuit breaker evaluations. This should involve visual inspection and electrical testing to specifications per manufacturer's procedures. It is advisable to electrically test a circuit breaker prior to putting it back in service. Low voltage power circuit breakers are designed so that a qualified person can examine and replace the internal parts of the circuit breaker. However, molded case circuit breakers and insulated case circuit breakers are not designed so that the internal parts can be examined and replaced in the field. Therefore, for these circuit breakers, visual inspection of the exterior and electrical testing are the only means to assess the suitability to be placed back in service.

> *NFPA 70E*
>
> *225.2 Molded-Case Circuit Breakers. Molded-case circuit breakers shall be maintained free of cracks in cases and cracked or broken operating handles.*
>
> *225.3 Circuit Breaker Testing. Circuit breakers that interrupt faults approaching their ratings shall be inspected and tested in accordance with the manufacturer's instructions.*

After a circuit breaker interrupts a fault, it may not be suitable for further service. UL 489, the product standard for molded case circuit breakers, only requires a circuit breaker to interrupt two short-circuit currents at its interrupting rating. Circuit breakers that are rated 100A or less do not have to operate after only one short-circuit operation under "bus bar" short-circuit conditions. It is possible for a fault to erode the circuit breaker's contacts, erode the arc chutes, or weaken the circuit breaker's case. If the fault current is high, circuit breaker manufacturers recommend that a circuit breaker should receive a thorough inspection with replacement, if necessary. Some difficulties in the evaluation process are not knowing a circuit breaker's service history, what level of fault current a circuit breaker interrupted, or what degradation occurred on the inside of the circuit breaker. That is why proper testing is recommended.

Another insightful quote is by Vince A. Baclawski, Technical Director, Power Distribution Products, NEMA; published in *EC&M Magazine*, pp. 10, January 1995:

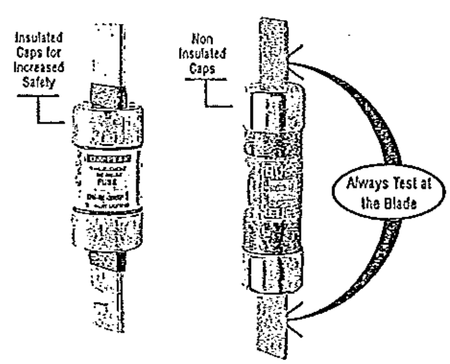
> *After a high level fault has occurred in equipment that is properly rated and installed, it is not always clear to investigating electricians what damage has occurred inside encased equipment. The circuit breaker may well appear virtually clean while its internal condition is unknown. For such situations, the NEMA AB4 "Guidelines for Inspection and Preventive Maintenance of MCCBs Used in Commercial and Industrial Applications" may be of help. Circuit breakers unsuitable for continued service may be identified by simple inspection under these guidelines. Testing outlined in the document is another and more definite step that will help to identify circuit breakers that are not suitable for continued service.*
>
> *After the occurrence of a short circuit, it is important that the cause be investigated and repaired and that the condition of the installed equipment be investigated. A circuit breaker may require replacement just as any other switching device, wiring or electrical equipment in the circuit that has been exposed to a short circuit. Questionable circuit breakers must be replaced for continued, dependable circuit protection.*

H. Testing fuses

When a person suspects that a fuse has opened, he or she should remove both indicating and non-indicating fuses from the circuit and check them for continuity.

To minimize exposure to electrical hazards, troubleshooting should be performed on de-energized equipment, where possible. Resistance measurements are as reliable as voltage measurements.

I. Properly test knife-blade fuses



A continuity test across any knife-blade fuse should be taken only along the fuse blades. Do not test a knife-blade fuse with meter probes to the fuse caps.

A common mistake when electricians are testing *knife-blade* fuses (have blades on ends as shown in illustration) 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 amps 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 by simply taking readings at the end caps. A portion of all testing-related injuries could be avoided by proper testing procedures. Bussmann® hopes to reduce such injuries by informing electricians of proper procedures.

J. Good housekeeping upon completion of electrical work

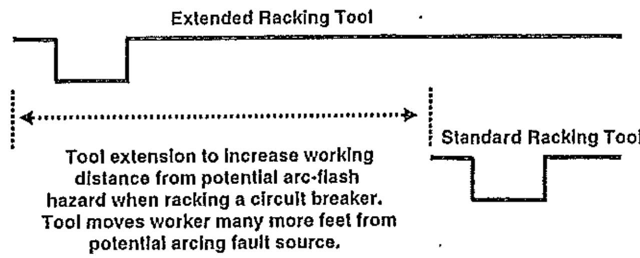
When electrical workers have completed work on equipment, it is important that prior to reenergization, all tools, scrap wire, and other debris be removed. This may avoid an incident when the doors are opened in the future. There are incidents where a worker opens an enclosure door on equipment and a tool, skinned conductor, or knockout becomes dislodged and falls across exposed energized parts creating an arcing fault.

K. Under normal operation, keep electrical equipment doors closed

When equipment is thermally affected by the ambient temperature or electrical loading, the remedy is not leaving the electrical equipment doors open. This is a serious safety hazard for personnel and property.

L. Move people outside the flash protection boundary

Numerous injuries and deaths occur when workers rack circuit breakers or switch medium voltage switches and circuit breakers. Systems should be designed with a remote open/close operating feature for medium voltage switches and circuit breakers. Let the worker remotely control a motorized unit so he/she does not have to be directly in harms way. Also, provide extended length racking tools as in the illustration.



M. Overcurrent protection reliability, maintenance requirements, and the effect maintenance has on arc-flash hazard

> *NFPA 70E 210.5 Protective Devices*
>
> *Protective devices shall be maintained to adequately withstand and interrupt available fault current.*

The reliability of overcurrent protective devices can directly impact arc-flash hazards. The opening time of overcurrent protective devices is critical in the resultant arc-flash energy released when an arcing fault occurs. The longer an overcurrent protective device takes to clear a given arcing fault current, the greater the arc-flash hazard. When an arcing fault occurs, or for that matter, when any fault current occurs, the overcurrent protective device must be able to operate as intended. Therefore, the reliability of overcurrent protective devices is critical — they need to open as originally specified, otherwise the flash hazard can escalate to higher levels than expected.

Two different types of overcurrent protection technologies provide different choices in reliability and maintenance requirements. This choice can impact the flash hazard. Either:

(1) Use overcurrent protective devices that are reliable and do not require maintenance, or

(2) If the overcurrent protective devices require periodic maintenance, then maintenance must be performed as required per the manufacturer's instructions and industry standards.

Current-limiting fuses

Modern fuses are reliable and retain their ability to open as originally designed under overcurrent conditions. When a fuse is replaced, a new factory calibrated fuse is put into service — the circuit has reliable protection with performance equal to the original specification. Modern current-limiting fuses do not require maintenance other than visual examination and insuring that there is no damage from external thermal conditions or liquids. Under overcurrent conditions, fuse short-circuit element operation is reliable.

Circuit breakers

Circuit breakers are mechanical overcurrent protective devices, which require periodic exercise, maintenance, testing, and possible replacement. A circuit breaker's reliability and operating speed are dependent upon its original specification and its condition. A specific circuit breaker's condition is dependent on many variables, some of which are not typically recorded and saved; length of service, number of manual operations under load, number of operations due to overloads, number of fault interruptions, humidity, condensation, corrosive substances in the air, vibrations, invasion by foreign materials or liquids, damage due to thermal conditions such as loose connections, erosion of contacts, and erosion of arc chutes. To help keep a circuit breaker within original specification, a circuit breaker manufacturer's instructions for maintenance must be followed.

Failure to do periodic maintenance on a circuit breaker or maintenance after interrupting a fault may result in longer interruption times or the inability to interrupt overcurrents; this can drastically affect the potential arc-flash energy that can be released.

Protective Devices Maintenance as It Applies to the Arc-Flash Hazard, is a technical paper by Dennis Neitzel, AVO Training Institute that is available on www.bussmann.com under Electrical Safety. This paper is a good resource on this topic. Excerpts from this paper:

> *Where proper maintenance and testing (on circuit breakers) are not performed, extended clearing times could occur creating an unintentional time delay that will effect the results of flash hazard analysis...*
>
> *Fuses, although they are protective devices, do not have operating mechanisms that would require periodic maintenance; therefore, this article will not address them. ...*
>
> *Circuit breakers installed in a system are often forgotten. Even though the breakers have been sitting in place supplying power to a circuit for years, there are several things that can go wrong. The circuit breaker can fail to open due to a burned out trip coil or because the mechanism is frozen due to dirt, dried lubricant, or corrosion. The overcurrent device can fail due to inactivity or a burned out electronic component. Many problems can occur when proper maintenance is not performed and the breaker fails to open under fault conditions. This combination of events can result in fires, damage to equipment or injuries to personnel.*

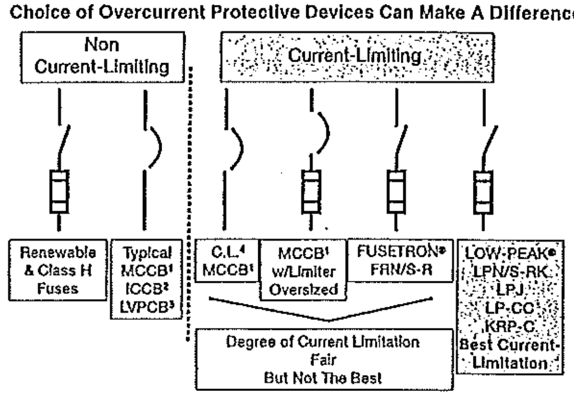
N. Designing systems: overcurrent protective device selection

Use the most current-limiting overcurrent protective devices possible. There are a variety of choices in the market for overcurrent protective devices. A fuse or circuit breaker that is not marked "current-limiting" has not been tested and listed as a current-limiting overcurrent protective device. For those that are marked "current-limiting," there are different degrees of current-limitation to consider — some are considerably more current-limiting than others.

One of the most important decisions for impacting the flash hazard can be the type, amps rating, and current-limiting ability of the overcurrent protective devices. It has been demonstrated that the magnitude of fault current and the length of time the current flows is directly related to the energy released by an arcing fault. Overcurrent protective devices that limit the magnitude of the fault current that flows and reduce the time duration of the fault current, can reduce the energy that is released by an arcing fault. In the discussion that follows, the types of devices are divided between (1) non current-limiting and (2) current-limiting. The typical six general choices are shown in the figure below and are discussed in the paragraph after the figure.

Figure X(N)(1)

Choice of Overcurrent Protective Devices Can Make A Difference



[1] MCCB - Molded Case Circuit Breaker
[2] ICCB - Insulated Case Circuit Breaker
[3] LVPCB - LV Power Circuit Breaker
[4] C.L. - Current-Limiting

1. Non current-limiting overcurrent protective devices

Renewable & Class H fuses are outdated type fuses that are not considered current-limiting that also have a low interrupting rating. These fuses are not recommended to assist in reducing arc-flash hazards because they let-through too much fault current for too long a time, and their interrupting rating is too low.

Non Current-limiting Circuit Breakers: The typical **molded case circuit breaker, insulated case circuit breaker** and **low voltage power circuit breaker** are not listed as current-limiting and are much like the renewable and Class H fuses. Therefore these devices do not significantly reduce the level of fault currents and they take longer to open. These devices can permit large amounts of energy to be released during an arcing fault. For instance, even if the fault current is in the instantaneous setting range of a circuit breaker, the higher the fault current the more the energy that is released. Circuit breakers require periodic maintenance and/or replacement to better insure they will operate as intended. If not maintained properly, circuit breaker clearing times can extend beyond their specifications and the arc-fault energy can be significantly greater than expected.

2. Current-limiting overcurrent protective devices

The four types of devices depicted on the right in Figure X(N)(1) are all current limiting. Current limiting devices provide the benefit of reducing the arc-fault energy released for higher fault currents by reducing both the current magnitude and time duration (when the fault current is within their current-limiting range). However, there are different degrees of current-limitation. And different devices become current-limiting at different levels of fault current. If the fault current is in the current-limiting range of current-limiting fuses, the energy released during an arc-fault typically does not increase as the fault current increases. This is a very important criterion.

Current-limiting molded case circuit breakers are a better choice than standard molded case circuit breakers. The cost is three to four times as much as standard molded case circuit breakers. The degree of current-limitation is typically fair, but can vary significantly. UL 489, the Molded Case Circuit Breaker Standard, does not establish different short-circuit let-through Ip and I^2t values for various amps rated circuit breakers like UL 248, the Fuse Standards. Periodic maintenance and testing is necessary for all circuit breakers to help ensure that they will operate as intended. If not maintained properly, their clearing times can extend beyond their specifications and the arc-fault energy can be significantly greater than expected.

Standard circuit breakers that incorporate fuses as limiters are another current-limiting alternative. The cost is higher than that of standard circuit breakers. The limiter is intended only to provide current-limiting short circuit protection. However, the fuse limiters are oversized; so that the circuit breaker operates for lower level short-circuit currents. Therefore, these fuse limiters provide far less protection than current-limiting fuses sized to the load such as when the circuit is a fusible switch system.

The result with the circuit breaker/limiter alternative is typically higher arcing fault energy releases. For instance, the circuit breaker limiter may be sized at two to ten times the equivalent current-limiting fuses that would be used instead of a circuit breaker. As an example, a 600A circuit breaker with fuse limiters may have limiters that are equivalent to 1600A or greater fuses. 600A LOW-PEAK® Fuses would typically provide much lower arc-flash incident energy than a limiter that is equivalent to a 1600A fuse. Properly sized LOW-PEAK® Fuses enter the current-limiting range sooner and let-through less fault energy than a 1600A limiter.

FUSETRON® dual-element, time delay fuses FRS-R and FRN-R (Class RK5) provide current-limiting protection. The level of current limiting ability is good. A better choice for applications using Class R fuse clips is the LOW-PEAK® LPS-RK_SP & LPN-RK_SP (Class RK1) because these fuses are more current-limiting and enter their current-limiting range at lower fault levels.

LOW-PEAK® fuses, LPJ_SP (Class J), **LPS-RK_SP & LPN-RK_SP** (Class RK1), **LP-CC** (Class CC) and **KRP-C_SP** (Class L) and **TRON JJN/JJS fuses** (Class T), offer the best practical current-limiting protection. They have a significantly better degree of current limitation than the other alternatives discussed. In addition, they typically enter their current-limiting range at lower currents than the other fuses or limiter alternatives. The LOW-PEAK® family of fuses is the most current-limiting type fuse family for general protection and motor circuit protection.

The table below illustrates the potential benefits of using fuses that have greater current-limiting ability. In evaluating arc-flash protection, the overcurrent protective device's I^2t let-through is a direct indicator of the arc-flash energy that would be released. This table compares the UL 248 Fuse Standards and UL 489 Molded Case Circuit Breaker Standard maximum permitted I^2t let-through limits. These values shown are the maximum limits. Commercially available products will have values less than shown.

UL Standard Maximum I^2t (amp²seconds) Let-Through Limits for 50,000A Short-Circuit Test

Device Amps Rating	Fuse Class J 600V	Fuse Class RK1 600V	Fuse Class RK5 600V	Current Limiting Molded Case Circuit Breaker	Molded Case Circuit Breaker
600A	2,500,000	3,000,000	10,000,000	20,750,000	No Limit
400A	1,000,000	1,200,000	5,200,000	20,750,000	No Limit
200A	200,000	400,000	1,600,000	20,750,000	No Limit

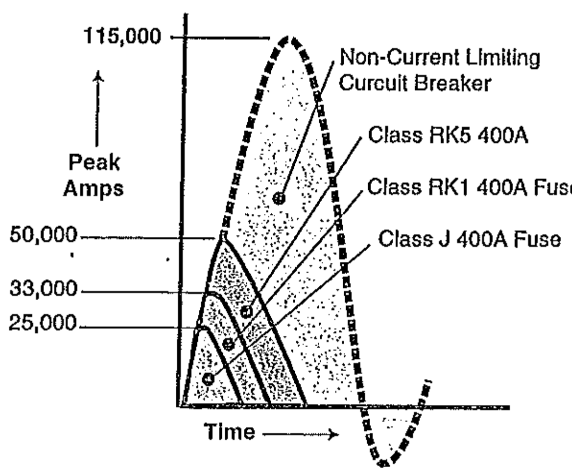
Note: *I^2t is proportional to thermal energy. I^2t is a measurable value that is used to evaluate fault protection performance of overcurrent protective devices. The lower the I^2t that an overcurrent protective device lets-through, the lower the thermal energy released.*

The UL 248 Fuse Standards set short-circuit I^2t let-through limits for current-limiting fuse types such as Classes J, RK1, and RK5. Different limits are set for each fuse major amps rating case size such as 30, 60, 100, 200, 400, and 600A. Fuses that are tested and listed as current-limiting are marked "current-limiting".

UL 489 Standard for Molded Case Circuit Breakers does not have I^2t let-through limits for circuit breakers that are not tested and listed as current limiting; these circuit breakers will not have a marking stating "current-limiting". Circuit breakers that are marked "current-limiting" have I^2t let-through limits, which is the lower of either what the manufacturer claims or the symmetrical short-circuit calibration wave for a $\frac{1}{2}$ cycle without the circuit breaker in the circuit. UL 489 does not require current-limiting circuit breaker I^2t let-through limits to apply when the circuit breakers are tested under "bus bar" test conditions. UL 489 does not require different I^2t let-through limits for different circuit breaker amps ratings or frame sizes.

Figure X(N)(2)

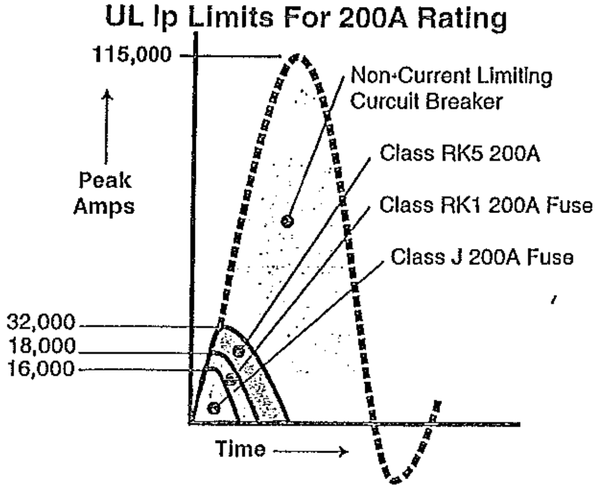
Illustrates Different Levels of Protection UL Ip Limits For 400A Rating



50,000 Sym. Amps Available

Figure X(N)(3)

Illustrates Different Levels of Protection UL Ip Limits For 200A Rating



50,000 Sym. Amps Available

Figures X(N)(2) and X(N)(3) illustrate another way to gain an understanding of the importance of using overcurrent protective devices that have better current-limiting ability. The dotted line represents the asymmetrical fault current that could flow with 50,000 symmetrical amps available — the peak current could reach 115,000A. Figure X(N)(2) shows the UL Ip limit for a 400A Class RK5 fuse is 50,000A, for a 400A RK1 fuse the Ip limit is 33,000A and for a 400 Class J fuse it is 25,000A. The limits for 200A UL fuses are less and illustrated in Figure X(N)(3).

Recommendation: Design new systems with LOW-PEAK® Fuses and TRON Fuses. LPJ_SP Fuses are Class J which provide an advantage in that Class J fuses are physically size rejecting. No other class fuse can be inserted in a Class J mounting. LPS-RK_SP and LPN-RK_SP Fuses are Class RK1 and should be installed in Class R clips that only accept Class R fuses. Class RK5 fuses can also be inserted in Class R clips. KRP-C_SP Fuses are Class L which are physically size rejecting. TRON JJN or JJS Fuses are Class T and are also physically size rejecting.

O. For circuits above 600A, specify switches with shunt-trip that will open the switch when a fuse opens

There are options for some fused switches that open the switch when one of the fuses opens. This option can be included on new switches or can be retrofitted on some existing switches. Tests have shown on larger amps rated circuits that this option may reduce the arc-flash hazard level. This is an electro-mechanical option, which may require maintenance after an operation.

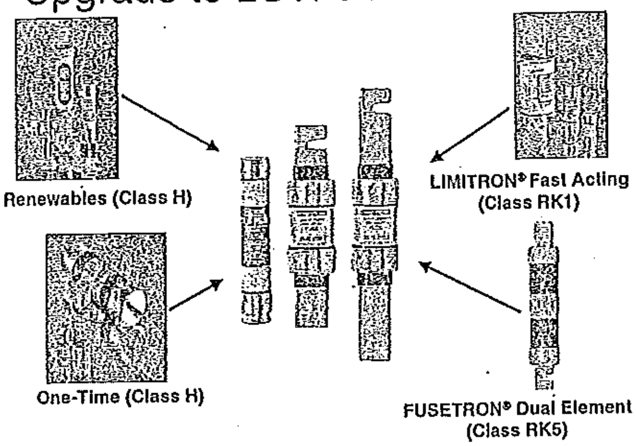
P. Improving existing fusible systems that have class H, R, J, CC, or L fuse clips, upgrade to LOW-PEAK® fuses

If the electrical system is an existing fusible system, consider replacing the existing fuses with the LOW-PEAK® family of fuses. If the existing fuses in the clips are not the most current-limiting type fuses, upgrading to the LOW-PEAK® family of fuses can reduce the hazards associated with arc-flash. To assist the process visit www.bussmann.com for the LOW-PEAK® upgrade service. Submit the electronic listing of 600V and less fuse part numbers for all manufacturers at your facility and receive a listing of the LOW-PEAK® fuse part numbers for the upgrade.

Owners of existing fusible systems should consider upgrading to LOW-PEAK® fuses, Classes RK1, L, J and CC. An assessment of many facilities will uncover that the installed fuse types are not as current-limiting as desired or that fuses were installed decades ago and new, better current-limiting fuses are now available.

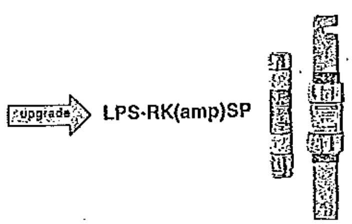
LOW-PEAK® Fuses LPS_ RK_SP/LPN-RK_SP (Class RK1), LPJ_SP (Class J), LP-CC (Class CC) and KRP-C_SP (Class L) offer the best practical current-limiting protection. The LOW-PEAK® family of fuses are the most current-limiting type fuse family for general protection and motor circuit protection.

Upgrade to LOW-PEAK® Fuses



LOW-PEAK® Upgrade Example For 600V Classes H & R Fuse Clips

A6D	KTS-R
A6K-R	LES
A6K-R	LES-R
A6X type 1	LES-RK
ATS-DE	LKS
CHR	LLS-RK
CTS-R	LOS-RK
DES	NLS
DES-R	NOS
DLS	NRS
DLS-R	OTS
ECS-R	RES
ERS	RFS
FLS	RHS
FLS-R	RLS
FRS	SCLR
FRS-R	TRS
FTS-R	TRS-R
GDS	656
HA	10KOTS
KLS-R	50KOTS
KOS	



This is an upgrade example for 600V rated Class H and Class R fuse clips. All of these part numbers in the two left columns that are 600V rated Class H and Class R fuses from Bussmann® and other manufacturers can be replaced with the LOW-PEAK® LPS-RK (amp)SP fuses. There are several benefits in upgrading in this manner. One benefit is better arc-flash protection.

Q. Specify Type 2 ("no damage") protection for motor controllers

Motor starters are very susceptible to damage due to short-circuit currents. If a worker needs to work within a motor starter enclosure while energized, it can be a serious safety hazard. Specifying Type 2 motor starter protection can reduce the risk.

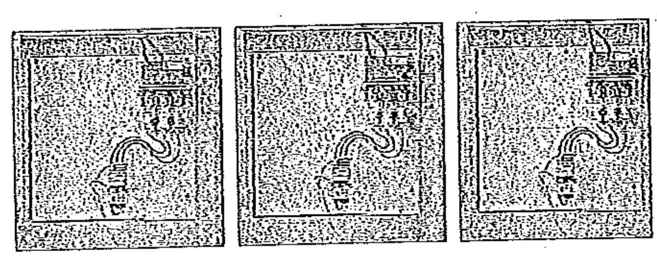
The engineer or person with the responsibility to specify or choose the type of equipment can choose the level of motor starter protection desired: Type 1 or Type 2.

A choice of motor starter protection is available: both UL 508E (outline of investigation) and IEC 60947-4-1 differentiate between two types of protection for motor circuits. The overcurrent protective device makes the difference.

Type 1 – "Requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons (with enclosure door closed) or installation and might not be suitable for further service without repair and replacement of parts." Damage is allowed, requiring partial or complete component replacement. It is possible for the overload devices to vaporize and the contacts to weld. Short-circuit protective devices interrupt the fault current, but are not required to provide component protection. The requirements for Type 1 protection are similar to the requirements for listing to UL 508. See photos below. If a worker has any unprotected body parts near such an event, he/she may be injured.

Photos of Type 1 Protection: Test photos of before, during and after of: MCP intended to provide motor branch circuit protection for 10HP, IEC Starter with 22,000A available at 480V. The heater elements vaporized and the contacts were severely welded. This could be a hazard if the door is open and a worker is near.

Type 2 – "Requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons (with enclosure door closed) or installation and shall be suitable for further use." No damage is allowed to either the contactor or overload relay. Light contact welding is permitted, but contacts must be easily separable. "No damage" protection for NEMA and IEC motor starters can only be provided by a current-limiting device. See photos below.



Photos of Type 2 Protection: Test photos of before, during and after of same test circuit and same type starter during short-circuit interruption as in Photo 1, 2 and 3. The difference is LOW-PEAK® LPJ_SP current-limiting fuses provide the motor branch circuit protection. This level of protection reduces the risk for workers.

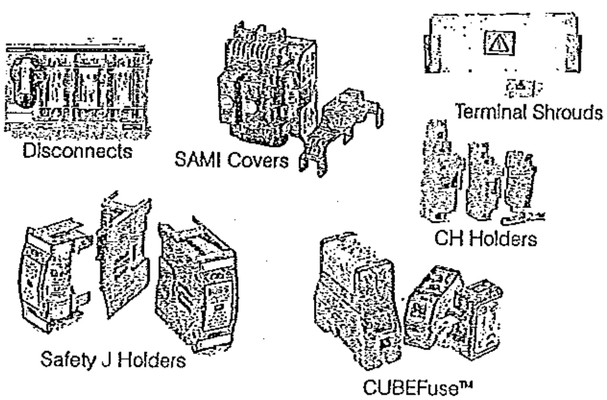
The fuses that typically meet the requirements for Type 2 "no damage" protection that are the result of the controller manufacturers testing are LOW-PEAK® LPJ_SP fuses (Class J), LP-CC fuses (Class CC) and LPS-RK_SP/LPN-RK_SP fuses (Class RK1). As discussed in the two previous section, these are very current-limiting fuses which can protect the sensitive controller components.

For more discussion on this subject and some Type 2 Tables by motor starter manufacturers, see Cooper Bussmann's publication SPD, section *Type 2 "No Damage" Motor Starter Protection* which can be found on www.bussmann.com.

R. Finger-safe products and terminal covers

Although most electrical workers and others are aware of the hazard due to electrical shock, it still is a prevalent cause of injury and death. One of the best ways to help minimize the electrical shock hazard is to utilize finger-safe products and non-conductive covers or barriers. Finger-safe products and covers reduce the chance that a shock or arcing fault can occur. If all the electrical components are finger-safe or covered, a worker has a much lower chance of coming in contact with a live conductor (shock hazard). Also, the risk that a conductive part falling across bare, live conductive parts and creating an arcing fault is greatly reduced (arc-flash hazard).

Shown below are several items to help minimize shock hazard and minimize the initiation of an arcing fault: the new Cooper Bussmann CUBEFuse™ (1 to 100A) that are IP-20 finger-safe and very current-limiting protective devices. SAMI™ fuse covers for covering fuses, Safety J fuse holders for LPJ fuses, CH fuse holders available for a variety of Cooper Bussmann fuses and Cooper Bussmann disconnect switches, with fuse and terminal shrouds. All these devices can reduce the chance that a worker, tool or other conductive item will come in contact with a live part.



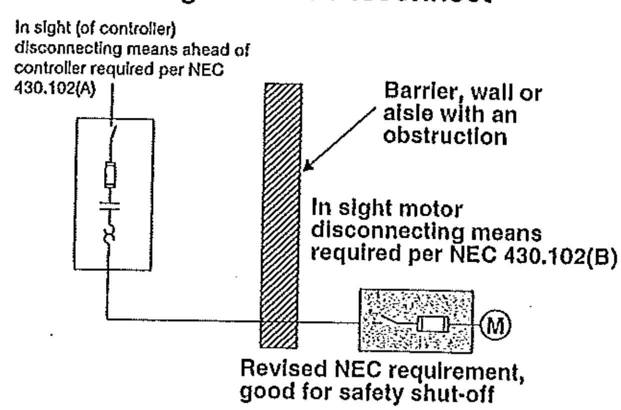
S. Isolate the circuit: install in-sight fusible disconnect for each motor

Electrical systems must be designed to support preventive maintenance, with easy access to the equipment. Designers must isolate equipment for repair with a disconnecting means that provides for adequate implementation of lockout/tagout procedures.
A sound design provides disconnecting means at all motor loads in addition to the disconnecting means required at the controller that can be locked in the open position. Disconnecting means at the motor provide improved isolation and safety for maintenance and for use in case of an emergency.

Install HP-rated fusible disconnects (with permanently installed lockout provision) within sight and within 50 feet of every motor or driven machine. This measure fosters safer work practices and can be used for an emergency disconnect if there is an incident. An in sight motor disconnect is more likely to be used by a worker for the lockout procedure to put equipment in an electrically safe work condition prior to doing work on the equipment.

The 1999 NEC® required a disconnect in sight of a motor or machine. However, there was an exception that if the disconnect at the controller could be locked out, then the in-sight disconnect could be omitted. 430.102 changed in the 2002 NEC®, resulting in a tighter requirement that provides for better worker safety. An in-sight motor disconnect is required even if the disconnect ahead of the controller can be locked out. There are exceptions for some specific industrial applications.

In-Sight Motor Disconnect



T. Isolate the circuit-selective coordination

Today, more than ever, one of the most important parts of any installation is the electrical distribution system. Nothing can stop all activity, paralyze production, inconvenience and disconcert people, and possibly cause a panic more effectively than a major power failure.

Isolation of a faulted circuit from the remainder of the installation is *mandatory* in today's modern electrical systems. Power blackouts cannot be tolerated.

Isolating the faulted circuit can also be a serious safety issue. According to the *NEC*®, Article 240.12, where an orderly shutdown is required to minimize hazards to personnel and equipment, a system of coordinated short-circuit protection shall be permitted.

Therefore, selecting protective devices based solely on their ability to carry the system load current and interrupt the maximum fault current at their respective levels is not enough. A properly engineered system allows *only* the protective device nearest the fault to open, leaving the remainder of the system undisturbed and preserving continuity of service.

Selective coordination is considered the act of isolating a faulted circuit from the remainder of the electrical system, thereby eliminating unnecessary power outages. The faulted circuit is isolated by the selective operation of only that overcurrent protective device closest to the overcurrent condition. For more information pick Selective Coordination under Application Info. at www.bussmann.com.

U. High impedance-grounded wye systems

Some users are designing their 480V electrical systems with high impedance grounded wye systems. This type of system can reduce the probability that arcing faults will occur. With high-impedance-grounded wye systems, if a worker's screwdriver slips, simultaneously touching an energized bare phase termination and the enclosure, a high energy arc-fault would not be initiated. However, this type of system does not totally eliminate the hazard. If the worker's screwdriver simultaneously touches the energized bare terminations of two phases, an arcing fault may occur. If high impedance grounded wye systems are being designed or an existing solidly grounded wye system is being retrofitted to this type system, it is imperative to consider the single-pole interrupting capabilities of any circuit breakers and self-protected starters that may be considered or already installed. In addition, any slash voltage-rated circuit breakers or other mechanical devices may not be suitable. For an in-depth discussion on this subject, see Cooper Bussmann's publication SPD, sections *Single-Pole Interrupting Capability* and *Slash Voltage Rating* which can be found on www.bussmann.com.

V. Do not use short-time delay settings on circuit breakers

Some circuit breakers are equipped with a short-time delay mechanism, which is intended to delay operation of the circuit breaker with an intentional delay under fault conditions. Short time delay breakers are used on feeders and mains so that downstream molded case breakers may clear a fault without tripping the larger upstream circuit breaker. In many cases a circuit breaker with a short-time delay setting will not have an instantaneous setting. So a fault is permitted to flow for an extended time. Under fault conditions, a short-time delay sensor intentionally delays signaling the circuit breaker to open for the time duration setting of the short-time delay. For instance, a low voltage power circuit breaker with a short-time delay and without instantaneous trip permits a fault to flow for the length of time of the short-time delay setting, which might be 6, 12, 18, 24, or 30 cycles.

There is an adverse consequence associated with using circuit breakers with short-time delay settings. If an arcing fault occurs on the circuit protected by a short-time delay setting, a tremendous amount of damaging fault energy can be released while the system waits for the circuit breaker short-time delay to time out. The longer an overcurrent protective device takes to open, the greater the flash hazard due to arcing faults. Research has shown that the arc-flash hazard increases with the time duration the current is permitted to flow.

System designers and users should understand that using circuit breakers with short-time delay settings can greatly increase the arc-flash energy. If an incident occurs when a worker is at or near the arc-flash, the worker may be subjected to considerably more arc-flash energy than if an instantaneous trip circuit breaker or, better yet, a current-limiting circuit breaker or current-limiting fuses were protecting the circuit.

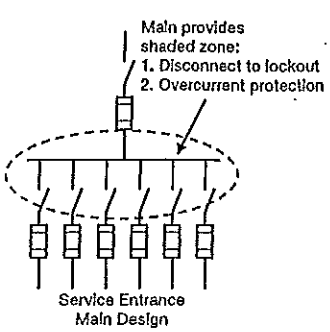
Note: *Designers typically use short-time delays to achieve fault coordination with downstream circuit breakers. If selective coordination and fast fault opening time are design objectives, there are other, better alternatives. For instance, systems designed with current-limiting fuses can usually achieve both objectives.*

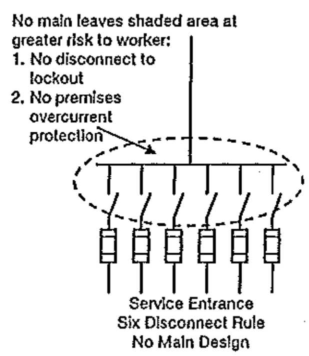
W. Specify a main on a service

Do not utilize the six disconnect rule for service entrances permitted in the National Electrical Code in lieu of a single main disconnect. Some designers use the six disconnect rule to lower the cost of the service equipment, but this can increase the hazards for workers. With a main overcurrent protective device and disconnect, the main bus and line terminals of the feeders are provided better protection. See Figure below.

For instance, if a worker must work in the enclosure of one of the feeders, this compartment should be placed in an electrically safe work condition. In achieving that process, the main disconnect should be locked out. In this way, the feeder device compartment will have no energized conductors.

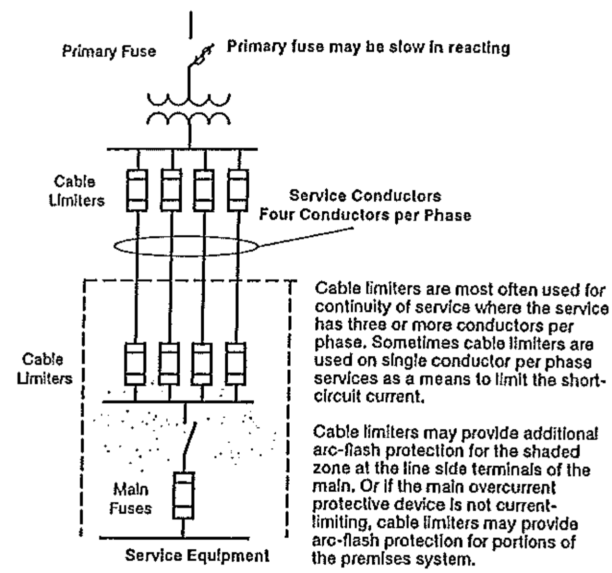
If a worker is in a feeder compartment while energized, the main overcurrent protective device provides the protection against arc-faults on the feeder device line terminals and the equipment main bus. It is necessary to assess the arc-fault hazard with the main device; large amps rated overcurrent protective devices may permit high arc-flash incident energies. But for most cases, the main overcurrent protective device will provide better protection than the utility overcurrent protective device, which is located on the service transformer primary (not shown in figure below).





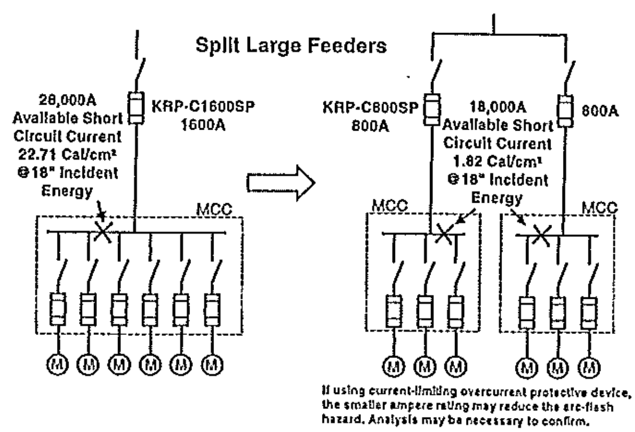
X. Utilize cable limiters on service conductors

Limit the arc-flash energy for faults ahead of the main. Cable limiters can provide an added safety factor for the service entrance conductors and where they terminate to the service equipment.



Y. Break up large loads into smaller circuits.

In the design stage, it is suggested not to utilize large amps-rated circuits. In some cases, larger amps-rated fuses and circuit breakers let-through too much energy for a practical PPE arc rating. As an example, break up a 3000A circuit to three 1000A circuits. Or another example, it is generally better to have two 800A circuits than one 1600A circuit. It is even better to have the loads divided so that the circuits are protected by LOW-PEAK® fuses of 600A and less. For specific situations, do an analysis of the arc-flash hazard; there are variables that can affect the outcome. This is especially beneficial when using current-limiting protective devices; since the lower amps-rated devices are typically more current-limiting and, thus, can better reduce the arc-flash hazard. See the following example.



Z. If using circuit breakers, specify zone-selective interlocking

If using circuit breakers, in order to achieve coordination, circuit breakers with short-time delay are typically specified. However, short-time delay settings can permit extremely hazardous incident energy levels. Another option with circuit breakers is to use zone-selective interlocking. In this scheme, the circuit breakers with this option have communication wiring between the circuit breakers and the circuit breakers' sensing elements communicate. For instance, the main and feeder circuit breakers might be equipped with zone-selective interlocking. For faults on the load side of the feeder circuit breaker. the main circuit breaker, if signaled by the feeder circuit breaker, might be set to have a short-time delay of 24 cycles. This allows for the main circuit breaker to wait for the feeder to open for faults on the feeder circuit. However, if the fault is on the main circuit, then the main circuit breaker will not receive a signal from a feeder circuit breaker and the main circuit breaker will open without an intentional delay.

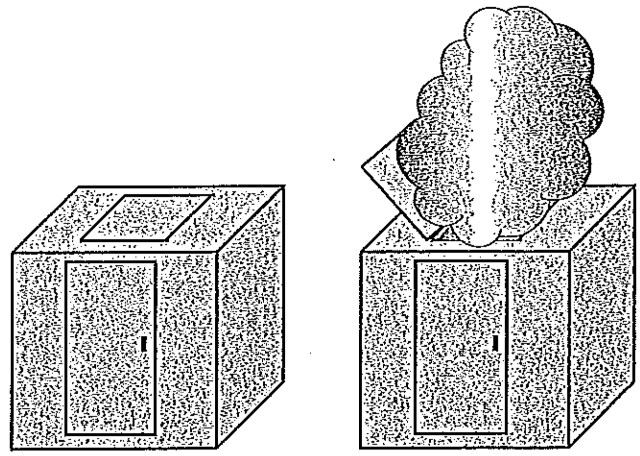
AA. "Smart" equipment

By using digital technologies, remotely perform voltage testing and check current readings and other parameters. Utilizing this design method shifts some troubleshooting from "working on or near" exposed energized components to the remote computer screen with the equipment doors closed and latched. These schemes can reduce the associated electrical hazards and reduce the required PPE.

BB. Utilize arc resistant (arc diverting) medium voltage switchgear

Some medium voltage switchgear is designed to better withstand internal arcing faults than standard equipment. This equipment is typically designed with stronger door hinges and latches, better door gaskets and hinged enclosure top panels. The concept is to divert the resultant explosive hot gases and pressures from an internal arcing fault via the hinged enclosure top panels. If the switchgear is installed indoors then ductwork or a similar means of exhausting the hot gases to the outside of the building is required.

Note: This equipment is rated to withstand specific levels of internal arc-faults with all the doors closed and latched. The rating does not apply with any door opened. So it is not applicable when a worker is working on the equipment with an open door or panel. Also, the term "arc resistant" is a bit misleading. The internal switchgear must withstand an internal arcing fault and, therefore, the sheet metal, etc., must resist or withstand a specified arc-fault. However, a major feature of this equipment is diverting the arc-fault byproducts (hot ionized gases and blast) via the hinged enclosure top panels. This feature helps to prevent the arc-fault from blowing open the doors or side panels and venting the arc-fault byproducts where a worker may be standing.

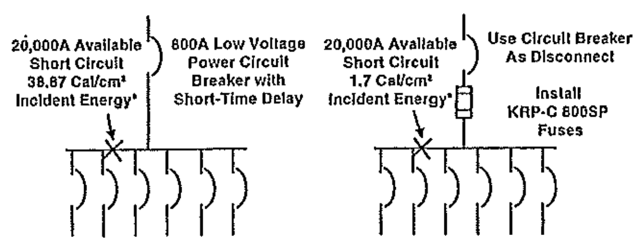


Before Arc Fault　　During Arc Fault

CC. Retrofit existing non-current-limiting feeders that have high fault potential with LOW-PEAK® fuses by cutting in fusible switches

There is a large legacy of installed circuit breakers that may be slow in operating, have not been maintained properly or may not even operate on overcurrents. It may be expensive to remove the existing gear and install new fusible or circuit breaker gear. A solution might be to use the circuit breaker as a disconnect and retrofit LOW-PEAK® fuses properly sized for the load.

Retrofit Potential: Feeders to MCCs, Busways, and Panels

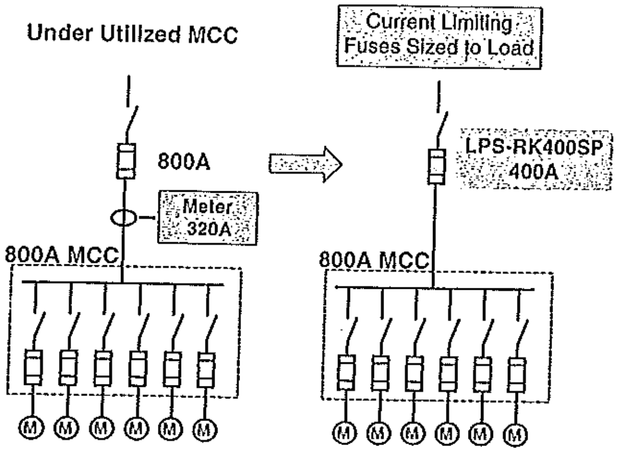


**If the feeder circuit breaker has not been maintained properly, the incident energy may be much greater.*

DD. Retrofit under-utilized circuits with lower-amps rated LOW-PEAK® fuses

Sometimes circuits are under-utilized. In this case, it is recommended to meter for the actual current under the maximum load condition, then install LOW-PEAK® fuses sized for this load (see typical fuse sizing calculation method on page 176 of the SPD publication). For instance, if an 800A feeder to a motor control center draws only 320A, install 400A LOW-PEAK® fuses.

Size Fuses for Actual Loads



EE. Proper interrupting rating

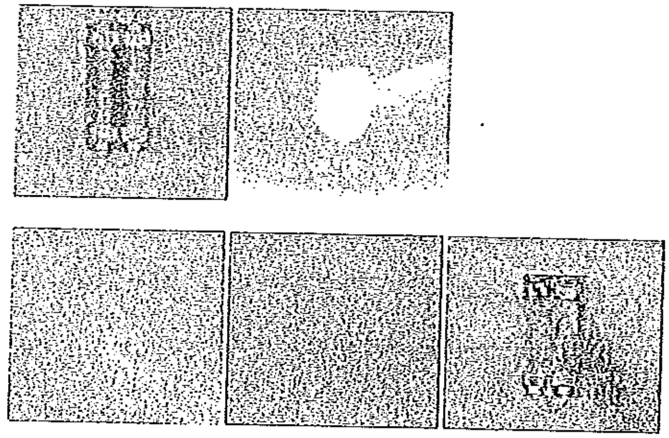
Interrupting rating is the maximum current that a fuse or circuit breaker can safely interrupt under standard test conditions. "Safely interrupts" pertains to the condition of the fuse or circuit breaker during and after the interruption.

Many people in the electrical industry still do not understand what interrupting rating means, they do not appreciate the consequences of improper interrupting rating, or they have yet to figure out or care that available short-circuit currents in electrical systems can increase beyond a device's interrupting rating over time due to system changes. An overcurrent protective device that attempts to interrupt a fault current beyond its interrupting rating can violently rupture. An overcurrent protective device applied with inadequate interrupting rating is a serious safety hazard. This in itself can be an arc-flash and arc-blast hazard, plus the violent rupturing can cause an arcing fault in other parts of the equipment.

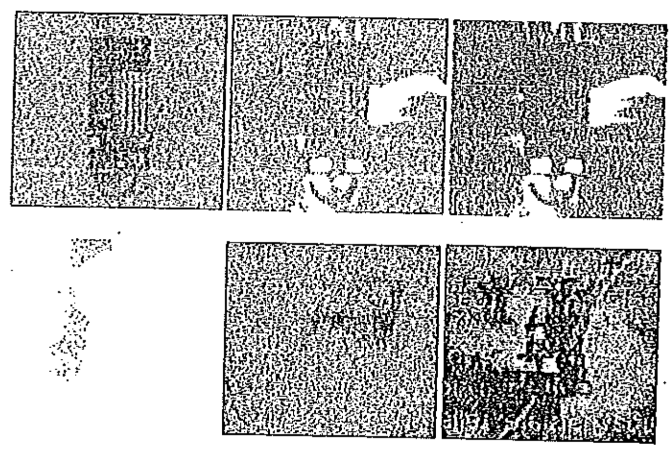
Be absolutely sure to use overcurrent protective devices that have adequate interrupting ratings at their point of application for the maximum available short-circuit current. Consideration for interrupting rating should be for the life of the system. All too often, transformers are replaced or systems are upgraded and the available short-circuit currents increase.

Modern current-limiting fuses have interrupting ratings of 200,000 and 300,000A, which virtually eliminates this hazard contributor. However, renewable and Class H fuses only have a 10,000A interrupting rating.

Circuit breakers have varying interrupting ratings, so they need to be assessed accordingly. If systems changes occur, it is important to reassess whether the installed circuit breakers still have sufficient interrupting ratings. Plus, circuit breakers must be periodically maintained and, possibly, tested to verify their ability to interrupt as intended.

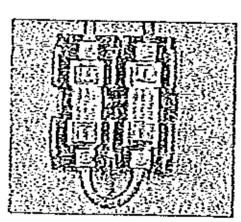


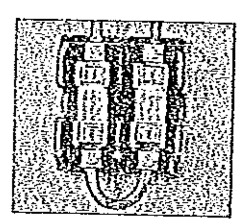
The photos above show what happens when Class H fuses, which have an interrupting rating of only 10,000A, are subjected to a 50,000A fault. Obviously, this is a misapplication, but this emphasizes how important proper interrupting rating is for arc-flash protection and proper application of overcurrent protective devices. In a fraction of a second the fuses can violently rupture. This could be a very serious safety hazard for a worker. This is a violation of NEC 110.9.



The photos above show what happens when a circuit breaker with an interrupting rating of 14,000A is subjected to the same 50,000A fault. This also is a misapplication, but illustrates the sudden violence that occurs. In a fraction of a second, the circuit breaker violently ruptured, which could be a very serious safety hazard for a worker. This violates NEC 110.9.

The photos below show a proper application that meets NEC 110.9. Note there is no violence or emitted byproducts. In this case, LOW-PEAK® LPJ fuses safely interrupt this the 50,000A available short-circuit current. The LPJ fuses have an interrupting rating of 300,000A.


Before test.


During and after test.