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Bussmann®

ELECTRICAL PROTECTION HANDBOOK

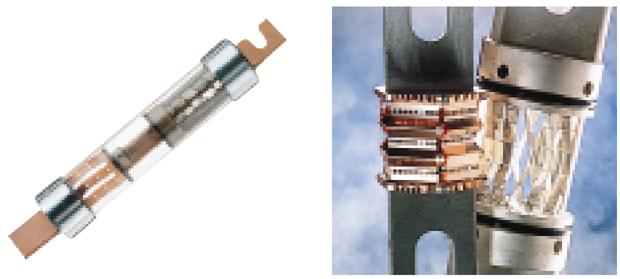
Selecting Protective Devices Based On the National Electrical Code

COOPER Bussmann

Fuseology

Circuit Protection

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



Fuses are constructed in an almost endless variety of configurations. These photos depict the internal construction of Bussmann Dual-Element and SEMI-TRON® fuses.

Overcurrents

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

Overloads

Overloads are most often between one and six times the normal current level. Usually, they are caused by harmless temporary surge currents that occur when motors are started-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 will generally prevent equipment damage. A sustained overload current results in overheating of conductors and other components and will cause deterioration of insulation, which may eventually result in severe damage and short-circuits if not interrupted.

Short-Circuits

Whereas overload currents occur at rather modest levels, the short-circuit or fault current can be many hundred times larger than the normal operating current. A high level fault may be 50,000 amperes (or larger). If not cut off within a matter of a few thousandths of a second, damage and destruction can become rampant–there can be severe insulation damage, melting of conductors, vaporization of metal, ionization of gases, arcing, and fires. Simultaneously, high level short-circuit currents can develop huge magnetic-field stresses. The magnetic forces between bus bars and other conductors can be many hundreds of pounds per linear foot; even heavy bracing may not be adequate to keep them from being warped or distorted beyond repair.

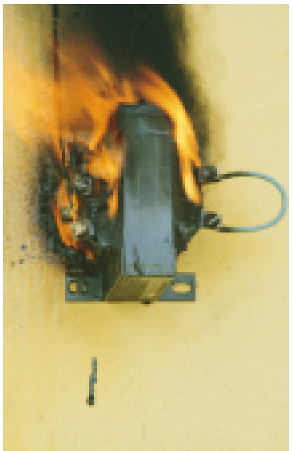
Fuses

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

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

The Louisiana Superdome in New Orleans is the world’s largest fully enclosed stadium. The overall electrical load exceeds 30,000,000 VA. Distribution circuits are protected with BUSS® LOW-PEAK® fuses.

Fuseology



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

Considerable damage to electrical equipment can result if the interrupting rating of a protective device is inadequate and is exceeded by a short-circuit current.

Voltage Rating

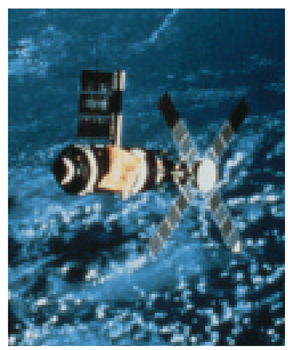
Most low voltage power distribution fuses have 250 volt or 600 volt ratings (other ratings are 125 volts and 300 volts). The voltage rating of a fuse must be at least equal to or greater than the circuit voltage. It can be higher but never lower. For instance, a 600 volt fuse can be used in a 208 volt 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 fault current conditions, the fuse may not clear the overcurrent safely. Special consideration is necessary for semiconductor fuse application, where a fuse of a certain voltage rating is used on a lower voltage circuit.

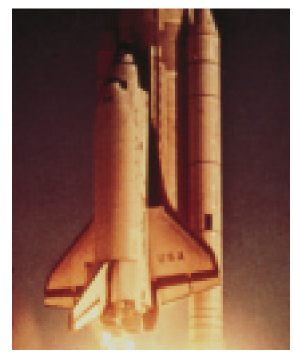
Ampere Rating

Every fuse has a specific ampere rating. In selecting the ampere rating of a fuse, consideration must be given to the type of load and code requirements. The ampere rating of a fuse normally should not exceed the current carrying capacity of the circuit. For instance, if a conductor is rated to carry 20 amperes, a 20 ampere fuse is the largest that should be used. However, there are some specific circumstances in which the ampere rating is permitted to be greater than the current carrying capacity of the circuit. A typical example is the motor circuit; 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 amperes. As a rule, the ampere 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.

Interrupting Rating - Safe Operation

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 10,000 amperes. (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 14,000 amperes or higher. In contrast, most modern, current-limiting fuses have an interrupting rating of 200,000 or 300,000 amperes and are commonly used to protect the lower rated circuit breakers. The National Electrical Code, Section 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.

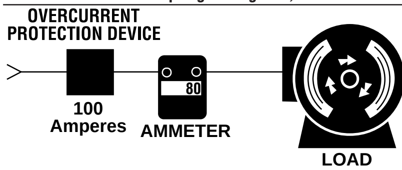
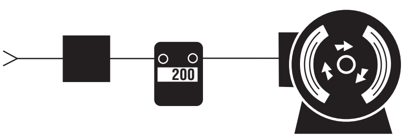
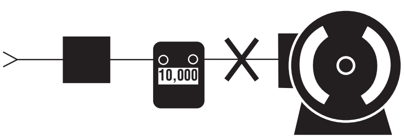
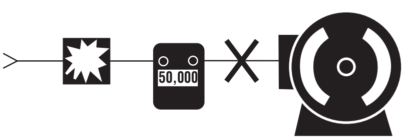




Fuses are a universal protective device. They are used in power distribution systems, electronic apparatus, vehicles. . .and as illustrated, our space program. The Space Shuttle has over 600 fuses installed in it protecting vital equipment and circuits.

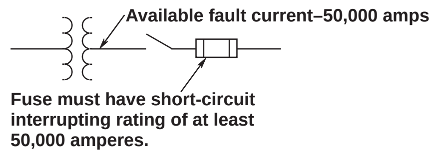
Fuseology

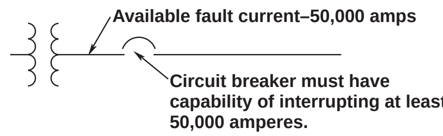
The table below depicts four different situations involving an overcurrent device with a normal current rating of 100 amperes and an interrupting rating of only 10,000 amperes.

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

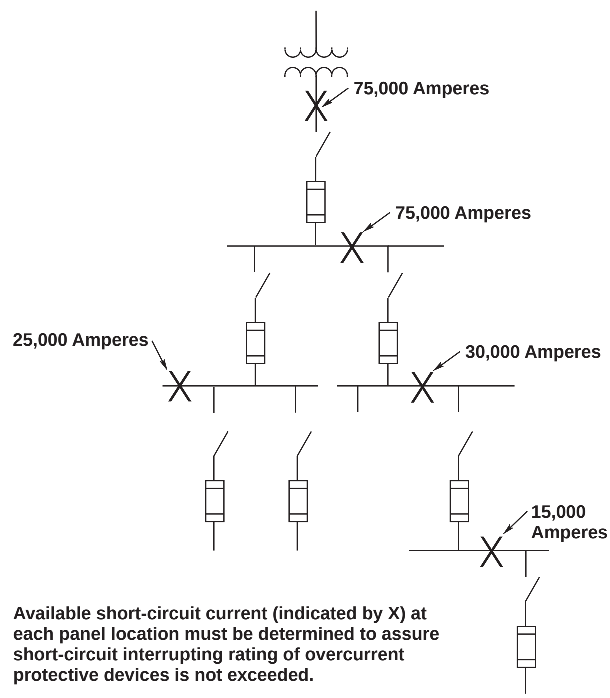
In the first three instances, the circuit current condition is within the safe operating capabilities of the overcurrent protective device. However, the fourth case involves a misapplication of the overcurrent device. A short-circuit on the load side of the device has resulted in a fault current of 50,000 amperes 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 amperes) would prevent this potentially dangerous situation.

The first paragraph of Section 110-9 requires that the overcurrent protective device be capable of interrupting the available fault current at its line terminals.





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. With modern fuses, these calculations normally are not necessary since the 200,000 ampere interrupting rating is sufficient for most applications.



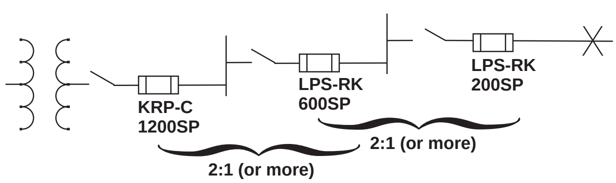
Available short-circuit current (indicated by X) at each panel location must be determined to assure short-circuit interrupting rating of overcurrent protective devices is not exceeded.

General Fuse Application Data For Compliance With NEC, Section 110-9.

	Guideline	Features	Benefits	Commonly Used Fuse Types
New Install-ations	1. Use modern, high interrupting rated fuses throughout electrical system.	300,000 ampere interrupting rating, on LOW-PEAK® YELLOW™ fuses. 200,000 ampere interrupting rating on other classes of modern current-limiting fuses.	Assure proper interrupting rating compliance currently and future. Usually a short-circuit current calculation study is unnecessary.	All modern current-limiting fuses (most have 200,000 ampere interrupting rating). LOW-PEAK® YELLOW™ fuses have a 300,000 ampere interrupting rating.
	2. Use current-limiting fuses to protect low withstand rated components.	Correct type and size current-limiting fuse can protect low withstand rated equipment against high short-circuit currents. (See fuse protection of circuit breakers).	Compliance with NEC 110-9.	LOW-PEAK® YELLOW™ Dual-Element T-TRON® Fast-Acting LIMITRON® Fast-Acting
System Up-Grading	3. Where available fault current has increased or is questionable, replace old style fuses such as One-Time and Renewable with modern high interrupting rated fuses.	200,000 ampere interrupting rating.	Provide safer electrical system protection with simple direct retrofit. Easily achieved since older style fuses can physically be replaced with modern fuses with no system modification.	LOW-PEAK® YELLOW™ Dual-Element FUSETRON® Dual-Element LIMITRON® Fast-Acting
	4. Where existing equipment may have questionable withstand rating due to deterioration, or the available fault current has increased, install modern current-limiting fuses.	Correct type and size current-limiting fuses can be put in switch, cut-in system or sometimes fuses can be cut in bus structure.	Provide sale electrical system protection. Small size of T-TRON® fuse permits easy cut-in strategy.	T-TRON® Fast-Acting LOW-PEAK® YELLOW™ Dual-Element LIMITRON® Fast-Acting LOW-PEAK® YELLOW™ Time-Delay

Selective Coordination - Prevention of Blackouts

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

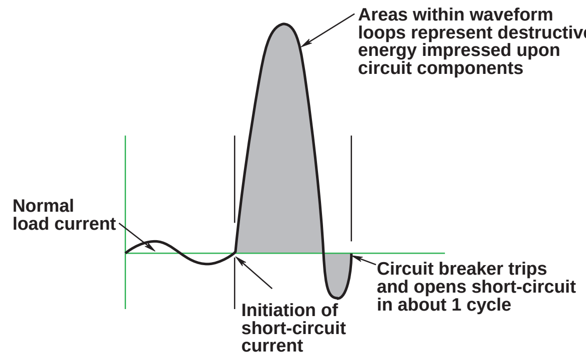


This diagram shows the minimum ratios of ampere ratings of LOW-PEAK® YELLOW™ fuses that are required to provide "selective coordination" (discrimination) of upstream and downstream fuses.

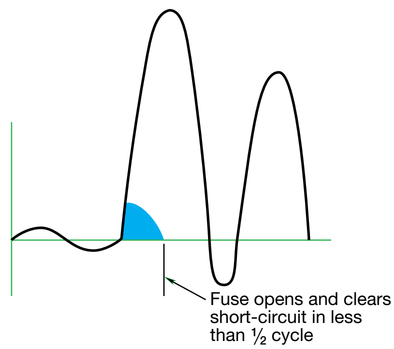
Unlike electro-mechanical inertial devices (circuit breakers), it is a simple matter to selectively coordinate fuses of modern design. By maintaining a minimum ratio of fuse-ampere ratings between an upstream and downstream fuse, selective coordination is assured. Minimum selectivity ratios for BUSS fuses are presented in a composite table (see the Selectivity Ratio Guide, page 15). Adherence to the tabulated selectivity ratios normally proves adequate.

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

Current-Limitation - Component Protection



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



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 is a “current-limiting” device. Most 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 40,000 amperes or higher in the first half cycle (.008 seconds, 60 hz) 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.

Fuseology

Operating Principles of BUSS® Fuses

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

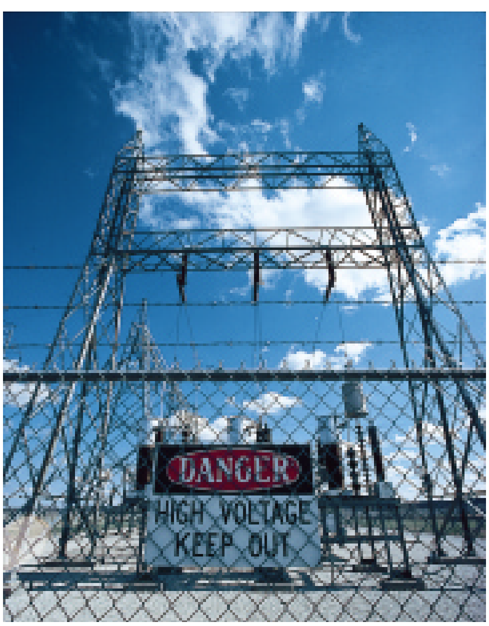
Non-Time-Delay Fuses

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

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

Single-element fuses of present day design have a very high speed of response to overcurrents. They provide excellent short-circuit component protection. However, temporary, harmless overloads or surge currents may cause nuisance openings unless these fuses are oversized. They are best used, therefore, in circuits not subject to heavy transient surge currents and the temporary overload of circuits with inductive loads such as motors, transformers, solenoids, etc. Because single-element, fast-acting fuses such as LIMITRON® and T-TRON® fuses have a high speed of response to short-circuit currents, they are particularly suited for the protection of circuit breakers with low interrupting ratings.

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



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

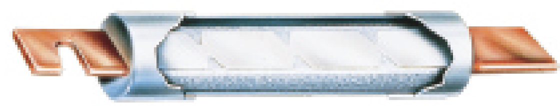


Figure 1. Cutaway view of typical single-element fuse.

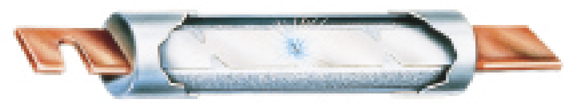


Figure 2. Under sustained overload, a section of the link melts and an arc is established.

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

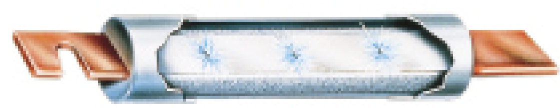


Figure 4. When subjected to a short-circuit current, several sections of the fuse link melt almost instantly.

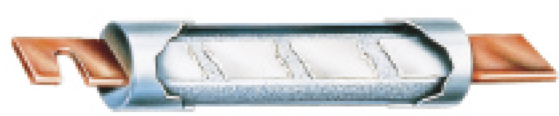


Figure 5. The "open" single-element fuse after opening a shorted circuit.

With continued growth in electrical power generation, the higher levels of short-circuit currents made available at points of consumption by electrical utilities have greatly increased the need for protective devices with high short-circuit interrupting ratings. Devices that can interrupt only moderate levels of short-circuit currents are being replaced by the modern fuse having the ability to cut-off short-circuit currents at levels up to 300,000 amperes.

Fuseology

Figure 6. The true dual-element fuse has distinct and separate overload and short-circuit elements.

Figure 7. Under sustained overload conditions, the trigger spring fractures the calibrated fusing alloy and releases the "connector".

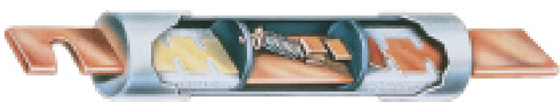


Figure 8. The "open" dual-element fuse after opening under an overload condition.

Figure 9. Like the single-element fuse, a short-circuit current causes the restricted portions of the short-circuit elements to melt and arcing to burn back the resulting gaps until the arcs are suppressed by the arc quenching material and increased arc resistance.

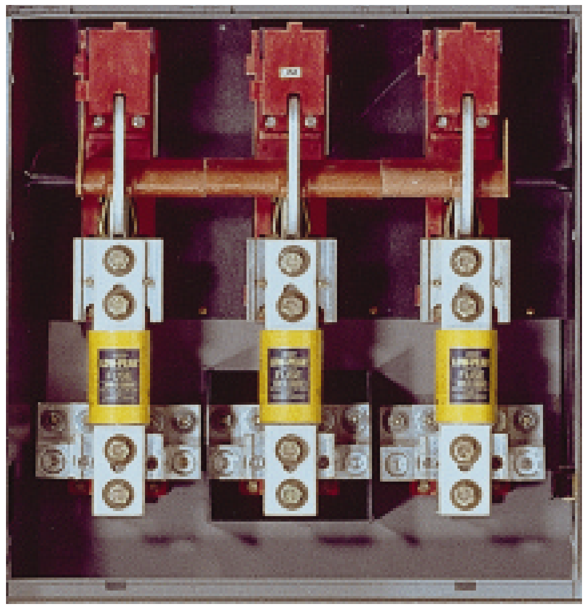
Figure 10. The "open" dual-element fuse after opening under a short-circuit condition.

Dual-Element, Time-Delay Fuses as Manufactured by Bussmann

Unlike single-element fuses, the dual-element, time-delay fuse can be applied in circuits subject to temporary motor overloads and surge currents to provide both high performance short-circuit and overload protection. Oversizing in order to prevent nuisance openings is not necessary. The dual-element, time-delay fuse contains two distinctly separate types of elements (Figure 6). Electrically, the two elements are series connected. The fuse links similar to those used in the non-time-delay fuse perform the short-circuit protection function; the overload element provides protection against low-level overcurrents or overloads and will hold an overload which is five times greater than the ampere rating of the fuse for a minimum time of 10 seconds.

As shown in Figure 6, the overload section consists of a copper heat absorber and a spring operated trigger assembly. The heat absorber bar is permanently connected to the heat absorber extension (left end of illustration) and to the short-circuit link on the opposite end of the fuse by the "S"-shaped connector of the trigger assembly. The connector electrically joins the short-circuit link to the heat absorber in the overload section of the fuse. These elements are joined by a "calibrated" fusing alloy. As depicted in Figure 7, an overload current causes heating of the short-circuit link connected to the trigger assembly. Transfer of heat from the short-circuit link to the heat absorbing bar in the mid-section of the fuse begins to raise the temperature of the heat absorber. If the overload is sustained, the temperature of the heat absorber eventually reaches a level which permits the trigger spring to "fracture" the calibrated fusing alloy and pull the connector free of the short-circuit link and the heat absorber. As a result, the short-circuit link is electrically disconnected from the heat absorber, the conducting path through the fuse is opened, and overload current is interrupted. A critical aspect of the fusing alloy is that it retains its original characteristic after repeated temporary overloads without degradation.

BUSS® dual-element fuses, typically LOW-PEAK® YELLOW™ and FUSETRON® fuses, utilize the spring-loaded design in the overload element.



Bussmann high performance fuses are used in tens of thousands of industrial plants, commercial buildings, and homes throughout the world.

Advantages of Bussmann Dual-Element, Time-Delay Fuses

Bussmann Dual-Element, Time-Delay fuses have four distinct advantages over single-element, non-time-delay fuses:

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

Motor Overload and Short-Circuit Protection

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

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

*Fuse Type	Maximum Fuse Size (Amperes)	Required Switch Size (Amperes)
Dual-Element, Time-Delay (LOW-PEAK® YELLOW™ or FUSETRON®)	40A*	60A
Single-Element, Non-Time-Delay (LIMITRON®)	100A†	100A

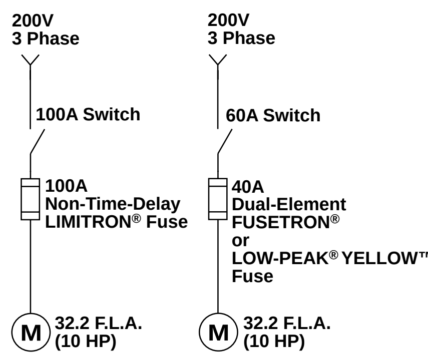
*Per N.E.C. Section 430-32.
†Per N.E.C. Section 430-52.

The preceding table shows that a 40 ampere, dual-element fuse will protect the 32.2 ampere motor, compared to the much larger, 100 ampere, single-element fuse that would be necessary. It is apparent that if a sustained, harmful overload of 300% occurred in the motor circuit, the 100 ampere, single-element fuse would never open and the motor could be damaged. The non-time-delay fuse, thus, only provides ground fault and short-circuit protection, requiring separate overload protection per the NEC. In contrast, the 40 ampere dual-element fuse provides ground fault, short-circuit and overload protection. The motor would be protected against overloads due to stalling, overloading, worn bearings, improper voltage, single-phasing, etc.

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

When *secondary* single-phasing occurs, the current in the remaining phases increases to a value of 170% to 200% of rated full-load current. When *primary* single-phasing occurs, unbalanced voltages that occur in the motor circuit cause excessive current. Dual-element fuses sized for motor overload protection can protect motors against the overload damage caused by single-phasing.

Permit the Use of Smaller and Less Costly Switches



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

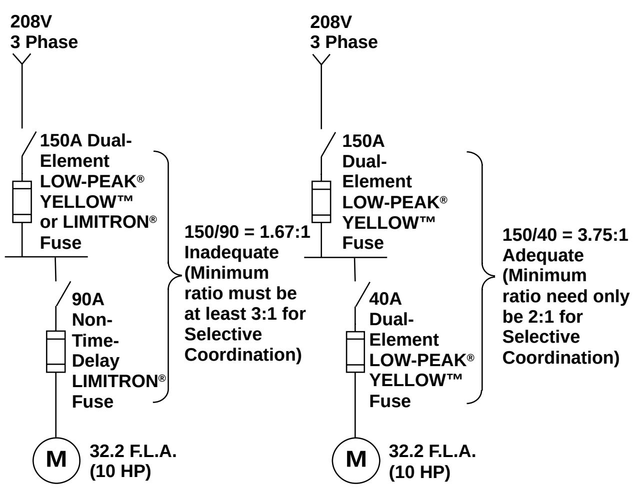
Better Short-Circuit Component Protection (Current-Limitation)
The non-time-delay, fast-acting fuse must be oversized in circuits in which surge or temporary overload currents occur. Response of the oversized fuse to short-circuit currents is slower. Current builds up to a higher level before the fuse opens. . .the current-limiting action of the oversized fuse is thus less than a fuse whose ampere rating is closer to the normal full-load current of the circuit. Therefore, oversizing sacrifices some component protection. Oversizing should not exceed NEC requirements.

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

Fuse Type	Fuse Name	Let-Through Current Versus Prospective Short-Circuit Currents (RMS Symmetrical) 25,000A	50,000A	100,000A
Dual-Element **(40A)**	FUSETRON®	2000A	3300A	4400A
	LOW-PEAK® YELLOW™	1800A	2200A	3000A
Non-Time-Delay **(100A)**	LIMITRON®	3100A	4100A	5000A

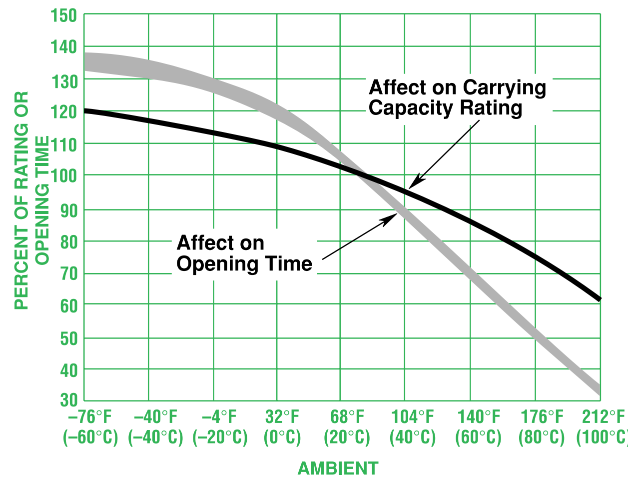
In the table above, it can be seen that the 40 ampere LOW-PEAK® YELLOW™ dual-element fuse used to protect a 10 HP (32.2 FLA) motor keeps short-circuit currents to approximately half the value of the non-time-delay fuse.

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



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

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



Affect of ambient temperature on operating characteristics of FUSETRON® and LOW-PEAK® YELLOW™ Dual-Element Fuses.

Classes of Fuses

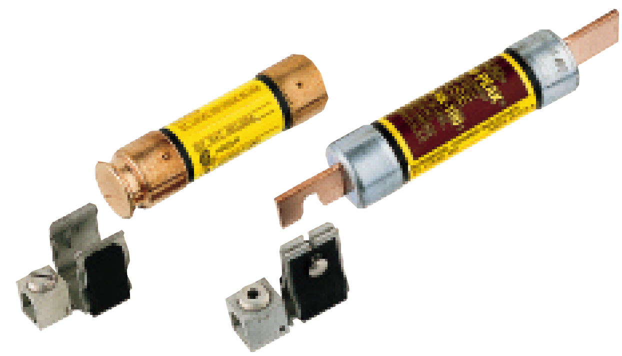
Safety is the industry mandate. However, proper selection, overall functional performance and reliability of a product are factors which are not within the basic scope of listing agency activities. In order to develop its safety test procedures, listing agencies develop basic performance and physical specifications or standards for a product. In the case of fuses, these standards have culminated in the establishment of distinct classes of low-voltage (600 volts or less) fuses, Classes RK1, RK5, G, L, T, J, H and CC being the more important.

The fact that a particular type of fuse has, for instance, a classification of RK1, does not signify that it has the identical function or performance characteristics as other RK1 fuses. In fact, the LIMITRON® non-time-delay fuse and the LOW-PEAK® YELLOW™ dual-element, time-delay fuse are both classified as RK1. Substantial difference in these two RK1 fuses usually require considerable difference in sizing. Dimensional specifications of each class of fuse does serve as a uniform standard.

Class R Fuses

Class R ("R" for rejection) fuses are high performance, $\frac{1}{10}$ to 600 ampere units, 250 volt and 600 volt, having a high degree of current-limitation and a short-circuit interrupting rating of up to 300,000 amperes (RMS symmetrical). BUSS® Class R's include Classes RK1 LOW-PEAK® YELLOW™ and LIMITRON® fuses, and RK5 FUSETRON® fuses. They have replaced BUSS® K1 LOW-PEAK® and LIMITRON® fuses and K5 FUSETRON® fuses. These fuses are identical, with the exception of a modification in the mounting configuration called a "rejection feature". This feature permits Class R to be mounted in rejection type fuseclips. "R" type fuseclips prevent older type Class H, ONE-TIME and RENEWABLE fuses from being installed. Since Class H fuses are not current-limiting and are recognized by regulatory agencies as having only a 10,000 ampere interrupting rating, serious damage could results if a Class R fuse were replaced by a Class H fuse. The use of Class R fuseholders is thus an important safeguard. The application of Class R fuses in such equipment as disconnect switches permits the equipment to have a high interrupting rating. NEC Articles 110-9 and 230-65 require that protective devices have adequate capacity to interrupt short-circuit currents. Article 240-60(b) requires fuseholders for current-limiting fuses to reject non-current-limiting type fuses.

In the above illustration, the fuse on the right has a grooved ring in one ferrule providing the rejection feature of the Class R fuse in contrast to the lower interrupting rating, non-rejection type.



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

Branch-Circuit Listed Fuses

Branch-circuit listed fuses are designed to prevent the installation of fuses that cannot provide a comparable level of protection to equipment.

The characteristics of branch-circuit fuses are:

1. They must have a minimum interrupting rating of 10,000 amps.
2. They must have a minimum voltage rating of 125 volts.
3. They must be size rejecting such that a fuse of a lower voltage rating cannot be installed in the circuit.
4. They must be size rejecting such that a fuse with a current rating higher than the fuseholder rating cannot be installed.

Fuseology

Medium Voltage Fuseology

General

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

1. GENERAL PURPOSE CURRENT-LIMITING FUSES
   A fuse capable of interrupting all currents from the rated interrupting current down to the current that causes melting of the fusible element in one hour.
2. BACK-UP CURRENT-LIMITING FUSE
   A fuse capable of interrupting all currents from the maximum rated interrupting current down to the rated minimum interrupting current.
3. EXPULSION FUSE
   A vented fuse in which the expulsion effect of gasses produced by the arc and lining of the fuseholder, either alone or aided by a spring, extinguishes the arc.

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

Construction

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

The tube must have a high burst strength to withstand the pressures generated during interruption. The most common materials used are fiberglass reinforced epoxy and melamine tubing.

End ferrule designs are usually dictated by the application. For example, a clip mounted fuse would have a silver-plated ferrule with a large surface area to insure good contact. In contrast, a stud mounted fuse may be cast bronze with very little surface area. In both designs it is very important that a good seal be provided between the tube and end ferrules. This is most commonly done with a gasket and magna-forming process, or with epoxy and screws.

Fuse elements are currently made from silver. Silver is the most common material used for high voltage fuse elements because of its predictable melting properties. To achieve this low current operation, it is necessary to either add a series element of different material or reduce the melting temperature of the silver by adding an "M" spot.

Finally, an arc quenching filler is added to aid in the interruption process. During interruption the arc quenching filler is changed into an insulating material called fulgurite.

Application

Many of the rules for applying expulsion fuses and current-limiting fuses are the same, but because the current-limiting fuse operates much faster on high fault currents, some additional rules must be applied.

Three basic factors must be considered when applying any fuse. These are: VOLTAGE, CONTINUOUS CURRENT CARRYING CAPACITY, INTERRUPTING RATING.

Voltage

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

Continuous Current-Carrying Capacity

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

Interrupting Rating

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

Additional Rules

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

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

Current-Limiting Fuses

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

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

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

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

Bussmann Power Distribution Fuses

LOW-PEAK®

(Time-Delay)
KRP-C_SP (600V)
601 to 6000A
300,000AIR
Current-Limiting
STD 248-10 CLASS L
UL Guide #JFHR
UL File #E56412

CSA Class #1422-02
CSA File #53787

The all-purpose silver linked fuse for both overload and short-circuit protection of high capacity systems (mains and large feeders). Time-delay (minimum of four seconds at five times amp rating) for close sizing. Unlike fast-acting fuses, time-delay fuses pass harmless surge currents of motors, transformers, etc., without overfusing or any sacrifice of short-circuit current limitation (component protection). The combination use of $\frac{1}{10}$ to 600 ampere LOW-PEAK YELLOW™ dual-element time-delay fuses and 601 to 6000A KRP-C LOW-PEAK YELLOW fuses is recommended as a total system specification. Easily selectively coordinated for blackout protection. Size of upstream fuse need only be twice that of downstream LOW-PEAK YELLOW fuses (2:1 ratio). LOW-PEAK YELLOW fuses can reduce bus bracing; protect circuit breakers with low interrupting rating as well as provide excellent overall protection of circuits and loads.

BIF No. 1008, 1009

LOW-PEAK®

(Dual-Element, Time-Delay)
LPS-RK_SP (600VAC, 300VDC)
LPN-RK_SP (250VAC, 125VDC)
$\frac{1}{10}$ to 600A
300,000AIR
Current-Limiting
STD 248-12 CLASS RK1
UL Guide #JFHR
UL File #E56412

CSA Class #1422-02
CSA File #53787

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

BIF No. 1001, 1002,1003, 1004

LOW-PEAK®

(Dual-Element, Time-Delay)
LPJ_SP (600V)
1 to 600A
300,000AIR
Current-Limiting
STD 248-8 CLASS J
UL Guide #JFHR
UL File #E56412

CSA Class #1422-02
CSA File #53787

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

BIF No. 1006, 1007

LOW-PEAK®

(Dual-Element, Time-Delay)
LP-CC
$\frac{1}{2}$ to 30A Current-Limiting
200,000AIR
STD 248-4 CLASS CC
UL Guide #JDDZ
UL File #E4273

CSA Class #1422-02
CSA File #53787

The Bussmann LOW-PEAK YELLOW Class CC fuse (LP-CC) was developed specifically for a growing need in the industry - a compact, space saving branch circuit fuse for motor circuits. Its superior performance characteristics of both time-delay and current-limitation make it the newest member of the LOW-PEAK YELLOW family of fuses.

BIF No. 1023

FUSETRON®

(Dual-Element, Time-Delay)
FRS-R (600VAC, 300VDC)
FRN-R (250VAC, 125VDC)
$\frac{1}{10}$ to 600A
200,000AIR
Current-Limiting
STD 248-12 CLASS RK5
UL Guide #JDDZ
UL File #E4273

CSA Class #1422-02
CSA File #53787

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

BIF No. 1017, 1018, 1019, 1020

DURALAG

(Dual-Element, Time-Delay)
Construction Grade Fuses
DLS-R (600VAC, 300VDC)
DLN-R (250VAC, 125VDC)
1 to 600A
200,000 AIR
Current-Limiting
STD 248-12 CLASS RK5
UL Guide #JDDZ
UL File # E4273

CSA Class #1422-02
CSA File #53787

Designed for contractor needs. Protects industrial equipment and large motors. Recommended for AC power distribution system mains, feeders and branch circuits. Industry standard time delay of 10 seconds at 5 times the fuse rating.

BIF No. 1021, 1022

LIMITRON®

(Fast-Acting)
KTU (600V)
601 to 6000A
200,000AIR
Current-Limiting
STD 248-10 CLASS L
UL Guide #JDDZ
UL File #E4273

CSA Class #1422-02
CSA File #53787

Silver-linked fuse. Single-element units with no time-delay. Very fast-acting with a high degree of current limitation; provide excellent component protection. Can be used for short-circuit protection only in circuits with inrush currents. Must be oversized to prevent opening by the temporary harmless overloads with some sacrifice of current limitation. In motor circuits, must be sized at approximately 300% of motor full-load current and thus will not provide the overload protection of LOW-PEAK YELLOW KRP-C_SP fuses.

BIF No. 1010

LIMITRON®

(Time-Delay)
KLU (600V)
601 to 4000A
200,000AIR
Current-Limiting
STD 248-10 CLASS L
UL Guide #JDDZ
UL File #E4273

CSA Class #1422-02
CSA File #53787

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

BIF No. 1013

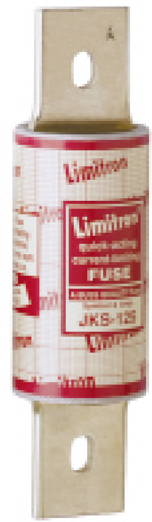
LIMITRON®

(Fast-Acting)
KTS-R (600V)
KTN-R (250V)
1 to 600A
200,000AIR
Current-Limiting
STD 248-12 CLASS RK1
UL Guide #JDDZ
UL File #E4273

CSA Class #1422-02
CSA File #53787

Single-element, fast-acting fuses with no time-delay. The same basic performance of the 601-6000A KTU fast-acting LIMITRON fuses. Provides a high degree of short-circuit current limitation (component protection). Particularly suited for circuits and loads with no heavy surge currents of motors, transformers, solenoids, and welders. LIMITRON fuses are commonly used to protect circuit-breakers with lower interrupting ratings. If used in circuits with surge currents (motors, etc.), must be oversized to prevent opening and, thus, only provide short-circuit protection. Incorporate Class R rejection feature. Can be inserted in non-rejection type fuseholders. Thus, can physically and electrically replace fast-acting Class H, K1, K5, RK5, and other RK1 fuses.

BIF No. 1044, 1043



LIMITRON®

(Fast-Acting)
JKS (600V)
1 to 600A
200,000AIR
Current-Limiting
STD 248-8 CLASS J
UL Guide #JDDZ
UL File #E4273

CSA Class #1422-02
CSA File #53787

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

BIF No. 1026, 1027

LIMITRON®

(Fast-Acting)
KTK-R (600V)
$\frac{1}{10}$ to 30A
200,000AIR
Current-Limiting
STD 248-4 CLASS CC
UL Guide #JDDZ,
UL File #E4273

CSA Class #1422-02
CSA File #53787

U.L. listed for branch circuit protection. A very small, high performance, fast-acting, single-element fuse for protection of branch circuits, motor control circuits, lighting ballasts, control transformers, street lighting fixtures. . .A diameter of only $\frac{13}{32}''$ and a length of $1\frac{1}{2}''$ give cost and space savings. A grooved ferrule permits mounting in “rejection” type fuseholders as well as standard non-rejection type holders.

BIF No. 1015

ONE-TIME

(General Purpose)
NOS (600V) NON (250V)
$\frac{1}{8}$ to 600A
Non-Current-Limiting

(NON $\frac{1}{8}$-60A) 50,000AIR
(NOS 1-60A) 50,000AIR
STD 248-9 CLASS K5
UL Guide #JDDZ
UL File #E4273
CSA Class #1421-01
CSA File #53787

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

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

BIF No. 1030

CC-TRON™

(Time-Delay)
FNQ-R (600V)
$\frac{1}{4}$ to 30A
200,000AIR
Current-Limiting
STD 248-4 CLASS CC
UL Guide #JDDZ
UL File #E4273

CSA Class #1422-01
CSA File #53787

Ideal for control transformer protection. Meets requirements of NEC 430-72 (b) & (c) and UL 508. Its miniature design and branch circuit rating allow it to be used for motor branch circuit and short circuit protection required by NEC 430-52.

BIF No. 1014

T-TRON®

(Fast-Acting)
JJS (600V) 1-800A
JJN (300V) 1-1200A
200,000AIR
Current-Limiting
STD 248-15 CLASS T
UL Guide #JDDZ
UL File #E4273

CSA Class #1422-02
CSA File #53787

The space-savers. Counterpart of the KTN-R/KTS-R LIMITRON fuses, but only one-third the size; thus, particularly suited for critically restricted space. A single-element fuse; extremely fast-acting. Provides a high degree of current limitation on short-circuits for excellent component protection. Must be oversized in circuits with inrush currents common to motors, transformers, and other inductive components (will give only short-circuit protection). Commonly applied in electric heat circuits, load centers, disconnect switches, meters, stacks, etc. The small size of T-TRON fuses permits them to be installed in panelboards and control centers for system upgrading to protect static equipment with lower withstand ratings.

BIF No. 1029, 1025

Bussmann Fuseblocks, Holders, and Disconnect Switches

Type SC

(Fast-Acting) 1/2-6A
(Time-Delay) 8-60A
SC (480V) 100,000AIR
STD 248-5 CLASS G
UL Guide #JDDZ
UL File #E4273
CSA Class #1422-01
CSA File #53787

A high performance general-purpose branch circuit fuse for lighting appliance, and motor branch circuits of 480 volts (or less). Fuse diameter is $\frac{13}{32}$"; lengths vary with ampere rating from $1\frac{5}{16}$ to $2\frac{1}{4}$" (serves as rejection feature and, thus, prevents dangerous oversizing).

BIF No. 1024

Plug Fuses

125V 10,000AIR

STD 248-11 Plug
UL Guide #JFHR, #JEFV
UL File #E56412, #E12112
(0-6$\frac{1}{4}$A), (7-30A)
CSA Class #1423-01
CSA File #53787
FUSTAT Type S fuses have a size limiting feature which prevents "overfusing." Dual element construction provides the time-delay necessary for motor running protection. Sizes from $\frac{1}{4}$ thru 30 amps.

STD 248-11Plug
UL Guide #JEFV
UL File #E12112

FUSETRON Type T fuses are similar to Type S fuses except for the Edison (light bulb type) base.

STD 248-11 Plug
UL Guide #JEFV
UL File #E12112

Type W fuses are non-time delay, used with non-inductive loads.

BIF No. 1032, 1034, 1036

Optima™ Overcurrent Protection Modules

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

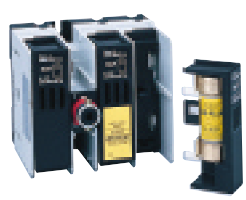
BIF No. 1102, 1103

Modular Fuseholder CH Series

Excellent for switchboard panels, control consoles, small motors, transformers and similar applications. Touchsafe design with optional open fuse indication lights.

BIF No. 1151

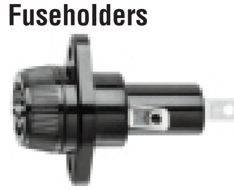
Compact Disconnect Switches



Bussmann disconnect switches used in manual control of single-phase or three-phase AC motors.

BIF No. 1120

Panel-Mount Fuseholders



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

BIF No. 2113

SAMI™ Fuse Covers with Option/Open Fuse Indication

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

BIF No. 1204

Power Distribution Blocks

For industrial controls, HVAC and other control automation panel applications. Available in 1, 2, or 3-pole versions and a wide range of input/output terminations.

BIF No. 1148

Fusible and Non-Fusible Disconnect Switches

Feature packed line of fusible and non-fusible disconnect switches for virtually every industrial application.

BIF No. 1139

Safety•J Fuseholder for Class J Fuses

Compact and touch-safe design that meets IP 20 Std. Fuse is removed/installed external to circuit. Open fuse indication available. Integral 35mm DIN Rail adapter.

BIF No. 1152

Fuseblocks

Buss fuseblocks are available in a wide range of sizes for power distribution, high speed semi-conductor protection and electronic applications. UL Listed, CSA certified. Classes H (K), R, T, J and CC fuses. Standard module and pyramid styles available.

General Data — Selection Chart

Buss Fuse Selection Chart (600 Volts or Less)

Interrupting Rating	Circuit	Load	Ampere Rating	Fuse Type	Symbol	Voltage Rating (AC)	Class	Interrupting Rating (kA)	Remarks
100,000A Interrupting Rating (RMS symmetrical) or Greater Current-Limiting		**Conventional Dimensions—Class RK1, RK5 (0-600A), L (601-6000A)**							
	Main, Feeder and Branch	All type loads (optimum overcurrent protection).	0 to 600A	LOW-PEAK® (dual-element, time-delay)	**LPN-RK_SP** **LPS-RK_SP**	250V 600V	RK1††	300	All-purpose fuses. Unequaled for combined short-circuit and overload protection. (Specification grade product)
			601 to 6000A	LOW-PEAK® (time-delay)	**KRP-C_SP**	600V	L	300	
		Motors, welder, transformers, capacitor banks (circuits with heavy inrush currents).	0 to 600A	FUSETRON® (dual-element, time-delay)	**FRN-R** **FRS-R**	250V 600V	RK5††	200	Moderate degree of current-limitation. Time-delay passes surge-currents.
			0 to 600A	DURA-LAG™ (dual-element, time-delay)	**DLN-R** **DLS-R**	250V 600V	RK5	200	
			601 to 4000A	LIMITRON® (time-delay)	**KLU**	600V	L	200	All-purpose fuse. Time-delay passes surge-currents.
		Non-motor loads (circuits with no heavy inrush currents). LIMITRON® fuses particularly suited for circuit breaker protection.	0 to 600A	LIMITRON® (fast-acting)	**KTN-R** **KTS-R**	250V 600V	RK1††	200	Same short-circuit protection as LOW-PEAK® fuses but must be sized larger for circuits with surge-currents; i.e., up to 300%.
			601 to 6000A		**KTU**	600V	L	200	A fast-acting, high performance fuse.
		Reduced Dimensions For Installation in Restricted Space—Class J(0-600A), T(0-1200A), CC(0-30A), G(0-60A)							
		All type loads (optimum overcurrent protection).	0 to 600A	LOW-PEAK® (dual-element, time-delay)	**LPJ_SP**	600V	J	300	All-purpose fuses. Unequaled for combined short-circuit and overload protection. (Specification grade product)
		Non-motor loads (circuits with no heavy inrush currents).		LIMITRON® (quick-acting)	**JKS**	600V	J	200	Very similar to KTS-R LIMITRON®, but smaller.
			0 to 1200A	T-TRON™ (fast-acting)	**JJN** **JJS**	300V 600V	T	200	The space saver (1/3 the size of KTN-R/KTS-R).
	Branch	Motor loads (circuits with heavy inrush currents.)	0 to 30A	LOW-PEAK® (time-delay)	**LP-CC**	600V	CC	200	Very compact (13/32″ × 1½″); rejection feature. Excellent for motor circuit protection.
		Non-motor loads (circuits with no heavy inrush currents.)	0 to 30A	LIMITRON® (fast-acting)	**KTK-R**	600V	CC	200	Very compact (13/32″ × 1½″); rejection feature. Excellent for outdoor highway lighting.
		Control transformer circuits and lighting ballasts; etc.	0 to 30A	TRON® (time-delay)	**FNQ-R**	600V	CC	200	Very compact (13/32″ × 1½″); rejection feature. Excellent for control transformer protection.
		General purpose; i.e., lighting panelboards.	0 to 60A	SC	**SC**	480V	G	100	Current limiting; 13/32″ dia. × varying lengths per amp rating.
10,000–50,000 AIC	General Purpose (non-current limiting fuses)	Miscellaneous	0 to 600A	ONE-TIME	**NON** **NOS**	250V 600V	H or K5†	10	Forerunners of the modern cartridge fuse.
		Plug fuses can be used for branch circuits and small component protection.	0 to 30A	FUSTAT® (dual-element, time-delay)	**S**	125V	S	10	Base threads of Type S differ with amp ratings. T and W have Edison base. T & S fuses recommended for motor circuits. W not recommended for circuits with motor loads.
				FUSETRON® (dual-element, time-delay)	**T**	125V	**	10	
				Buss Type W	**W**	125V	**	10	

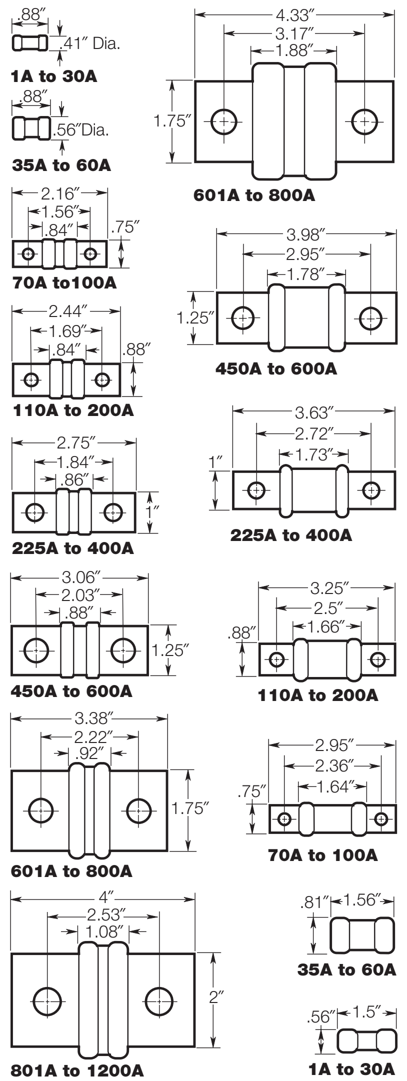
** U.L. Listed as Edison Base Plug Fuse.
†Some ampere ratings are available as U.L. Class K5 with a 50,000A interrupting rating.
††RK1 and RK5 fuses fit standard switches, fuseblocks and holders; however, the rejection feature of Class R switches and fuseblocks designed specifically for rejection type fuses (RK1 and RK5) prevent the insertion of the non-rejection fuses (K1, K5, and H).

General Data — Dimensions (Inches)

CLASS T

T-TRON™ Fuses

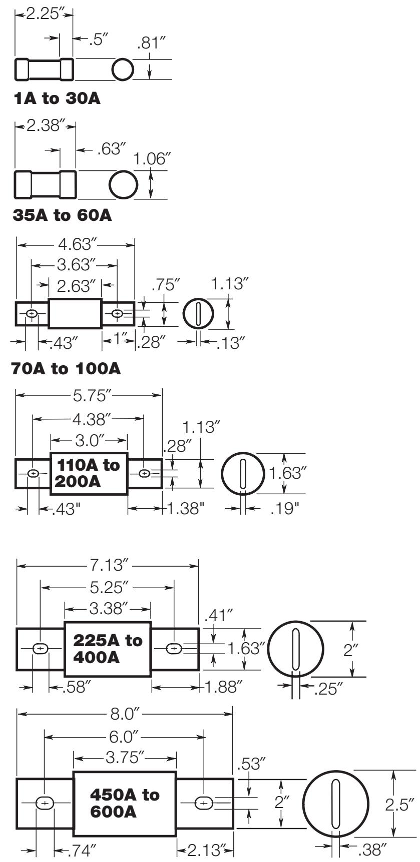
JJN **(300V)** JJS **(600V)**



CLASS J

LOW-PEAK® & LIMITRON® Fuses

LPJ & JKS **(600V)**



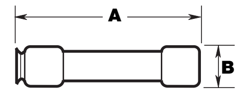
CLASS RK5 & RK1

FUSETRON®, LOW-PEAK® & LIMITRON® Fuses (250V & 600V)

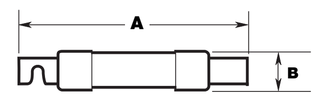
FRN-R & FRS-R; LPN-RK & LPS-RK; KTN-R & KTS-R

Basic dimensions are same as Class H (formerly NEC) ONE-TIME (NON & NOS) and SUPERLAG Renewable RES & REN fuses.

NOTE: These fuses can be used to replace existing Class H, RK1 and RK5 fuses relating to dimensional compatibility.



	250V		600V	
Ampere	**A**	**B**	**A**	**B**
1⁄10-30	2″	.56″	5″	.81″
35-60	3″	.81″	5.5″	1.06″



FUSETRON® & LIMITRON®

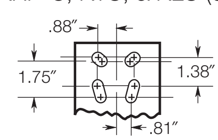
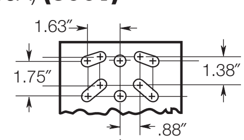
	250V		600V	
Ampere	**A**	**B**	**A**	**B**
70-100	5.88″	1.06″	7.88″	1.34″
110-200	7.13″	1.56″	9.63″	1.84″
225-400	8.63″	2.06″	11.63″	2.59″
450-600	10.38″	2.59″	13.38″	3.13″

LOW-PEAK® & FRS-R

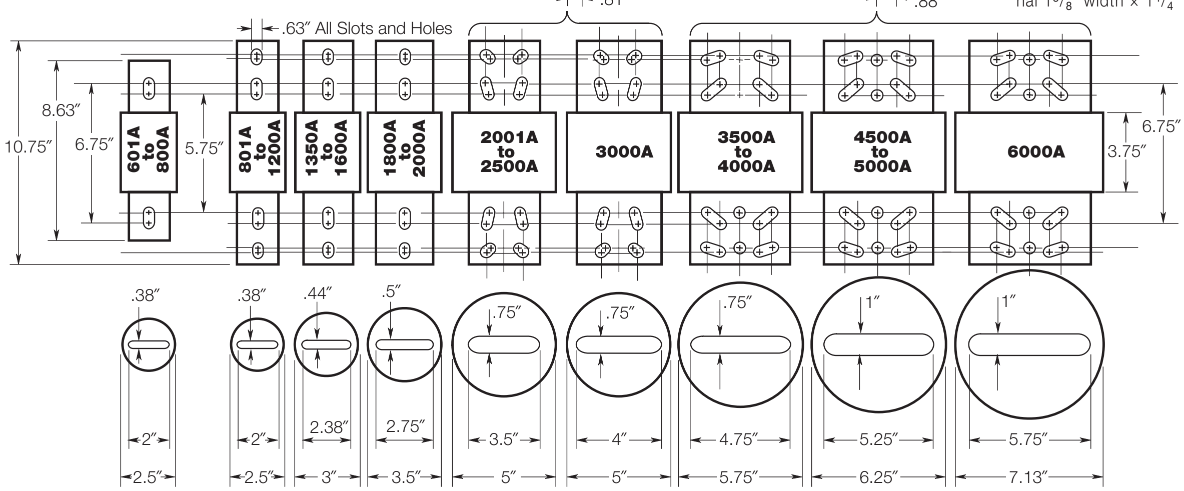
	250V		600V	
Ampere	**A**	**B**	**A**	**B**
70-100	5.88″	1.16″	7.88″	1.16″
110-200	7.13″	1.66″	9.63″	1.66″
225-400	8.63″	2.38″	11.63″	2.38″
450-600	10.38″	2.88″	13.38″	2.88″

CLASS L LOW-PEAK® & LIMITRON® Fuses

KRP-C, KTU, & KLU (601 - 4000A) **(600V)**

NOTE: KRP-CL (150A to 600A) fuses have same dimensions as 601A to 800A case size. KTU (400A to 600A) have same dimensions, except tube 3″ lgth. × 2″ dia.; terminal $1^5/_8$″ width × $1^1/_4$″ thick.



Conductor Protection

General

All conductors must be protected against overcurrents in accordance with their ampacities, as set forth in NEC Section 240-3. They must also be protected against short-circuit current damage, as required by Sections 240-1 (Note) and 110-10. The safest, most economical way to meet these requirements is through the use of current-limiting fuses.

Fuse ampere ratings must not be greater than the ampacity of the conductor. Section 240-3(b) states that if such conductor rating does not correspond to a standard size fuse, the next larger size fuse may be used, provided its rating does not exceed 800 amperes and the conductor is not part of a multi-outlet branch circuit supplying receptacles for cord and plug connected portable loads. When the ampacity of busway or cable bus does not correspond to a standard fuse size, the next larger standard fuse rating may be used, even though this rating may be greater than 800 amperes (364-10 and 365-5).

Standard fuse sizes per Section 240-6 are: 1, 3, 6, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 601, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, and 6000 amperes.

Note: The small fuse ampere ratings of 1, 3, 6, and 10 were added to provide more effective short-circuit and ground-fault protection for motor circuits, in accordance with Sections 430-40 and 430-52 and U.L. requirements for protecting the overload relays in controllers for very small motors.

Per Section 240-4

Flexible cords and extension cords shall have overcurrent protection rated at their ampacities. Supplementary fuse protection is an acceptable method of protection. For #18 fixture wire of 50 feet or more, a 6 amp fuse would provide the necessary protection. For #16 fixture wire of 100 feet or more, an 8 amp fuse would provide the necessary protection. For #18 extension cords, a 10 amp fuse would provide the necessary protection for a cord where only two conductors are carrying current, and a 7 amp fuse would provide the necessary protection for a cord where only three conductors are carrying current.

Location of Fuses in Circuit (Section 240-21)

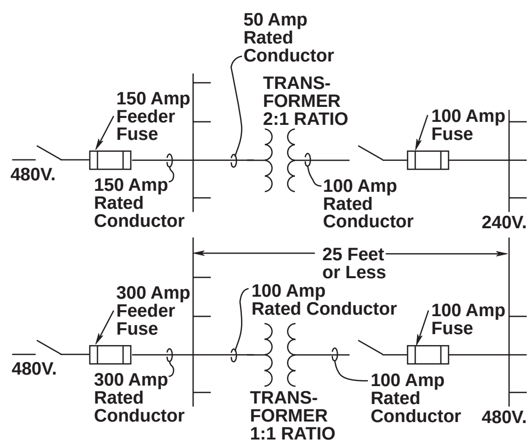
Fuses must be installed at the point where the conductor receives its supply, i.e., at the beginning or lineside of a branch circuit or feeder (240-21).

A) Fuses are not required at the conductor supply if a feeder tap conductor is not over ten feet long; is enclosed in raceway; does not extend beyond the switchboard, panelboard or control device which it supplies; and has an ampacity not less than the combined computed loads supplied, and not less than the rating of the device supplied, unless the tap conductors are terminated in a fuse not exceeding the tap conductor ampacity [240-21(b)]. For field installed taps, the ampacity of the tap conductor must be at least 10% of the overcurrent device rating. See "Note" following D.

B) Fuses are not required at the conductor supply if a feeder tap conductor is not over 25 feet long; is suitably protected from physical damage; has an ampacity not less than $\frac{1}{3}$ that of the feeder conductors or fuses from which the tap conductors receive their supply; and terminate in a single set of fuses sized not more that the tap conductor ampacity [240-21(c)]. See "Note" following D.

C) Fuses are not required at the conductor supply if a transformer feeder tap has primary conductors at least $\frac{1}{3}$ ampacity, and/or secondary conductors at least $\frac{1}{3}$ ampacity, when multiplied by the approximate transformer turns ratio of the fuse or conductors from which they are tapped; the total length of one primary plus one secondary conductor (excluding any portion of the primary conductor that is protected at its ampacity) is not over 25 feet in length; the secondary conductors terminate in a set of fuses rated at the ampacity of the tap conductors; and if the primary and secondary conductors are suitably protected from physical damage [240-21(d)].

D) Fuses are not required at the conductor supply if a feeder tap is not over 25 feet long horizontally and not over 100 feet long total length in high bay manufacturing buildings where only qualified persons will service such a system. Also, the ampacity of the tap conductors is not less than $\frac{1}{3}$ of the fuse rating from which they are supplied. The size of the tap conductors must be at least No. 6 AWG copper or No. 4 AWG aluminum. They may not penetrate walls, floors, or ceilings, and the taps are made no less than 30 feet from the floor [240-21(e)].



Note: Smaller conductors tapped to larger conductors can be a serious hazard. If not adequately protected against short-circuit conditions (as required in Sections 110-10 and 240-1), these unprotected conductors can vaporize or incur severe insulation damage. Molten metal and ionized gas created by a vaporized conductor can envelop other conductors (such as bare bus), causing equipment burndown. Adequate short-circuit protection is recommended for all conductors. When a tap is made to a switchboard bus for an adjacent panel, such as an emergency panel, the use of BUSS® cable limiters is recommended for protection of the tapped conductor. These current-limiting cable limiters are available in sizes designed for short-circuit protection of conductors from #12 to 1000 kcmil. BUSS® cable limiters are available in a variety of terminations to make adaption to bus structures or conductors relatively simple.

E) Transformer secondary conductors of separately derived systems do not require fuses at the transformer terminals when all of the following conditions are met. [240-21(j)]:
   1) Must be an industrial location.
   2) Secondary conductors must be less than 25 feet long.
   3) Secondary conductor ampacity must be at least equal to the secondary full-load current of transformer and sum of terminating, grouped, overcurrent devices.
   4) Secondary conductors must be protected from physical damage.

Note: Switchboard and panelboard protection (384-16) and transformer protection (450-3) must still be observed.

F) Outside conductors that are tapped to a feeder or connected to the secondary terminals of a transformer do not require fuse protection when all of the following are met:
   1) The conductors are protected from physical damage.
   2) The conductors terminate in a single set of fuses, no larger than the ampacity of the conductors.

Conductor Protection

3) The conductors are outside, except for point of termination.
4) The overcurrent device is near or a part of the disconnecting means.
5) The disconnecting means is readily accessible outdoors or, if indoors, nearest the point of the entrance of the conductors. [240-21(m)].

Branch Circuits–Lighting And/Or Appliance Load (No Motor Load)
The branch circuit rating shall be classified in accordance with the rating of the overcurrent protective device. Classifications for those branch circuits other than individual loads shall be: 15, 20, 30, 40, and 50 amperes (210-3).

Branch circuit conductors must have an ampacity of the rating of the branch circuit and not less than the load to be served (210-19).

The minimum size branch circuit conductor that can be used is No. 14 (210-19). For exceptions to minimum conductor size, see 210-19.

Branch circuit conductors and equipment must be protected by a fuse with an ampere rating which conforms to 210-20. Basically, the branch circuit conductor and fuse must be sized for non-continuous load (as calculated per Article 220) plus 125% of the continuous load (210-22 and 220-2). The fuse size must not be greater than the conductor ampacity (for exceptions, see 210-20). Branch circuits rated 15, 20, 30, 40, and 50 amperes with two or more outlets (other than receptacle circuits of 220-3b) must be fused at their rating and the branch circuit conductor sized according to Table 210-24 (see 210-24).

Feeder Circuits (No Motor Load)
The feeder fuse ampere rating and feeder conductor ampacity must be at least 100% of the non-continuous load plus 125% of the continuous load as calculated per Article 220 (220-10b). The feeder conductor must be protected by a fuse not greater than the conductor ampacity (for exceptions, see 240-3). Motor loads shall be computed in accordance with Article 430; see subsection on Motor Feeder Protection. For combination motor loads and other loads on feeders, see subsection on feeder combination motor, power, and lighting loads.

Service Equipment
Each ungrounded service entrance conductor shall have a fuse in series with a rating not higher than the ampacity of the conductor (for exceptions, see 230-90a-c). The service fuses shall be part of the service disconnecting means or be located immediately adjacent thereto (230-91).

Service disconnecting means can consist of one to six switches for each service or for each set of service entrance conductors permitted in Section 230-2. When more than one switch is used, the switches must be grouped together (230-71).

Service equipment must have adequate short-circuit ratings for the short-circuit currents available. (230-65)

Transformer Secondary Conductors
Secondary conductors need to be protected from damage by the proper overcurrent protective device. Although 240-3(i) provides an exception for conductors supplied by a single phase transformer with a 2-wire secondary, or a three-phase delta-delta transformer with a 3-wire, single voltage secondary, it is recommended that these conductors be protected. Primary overcurrent devices cannot adequately provide protection during internal transformer faults.

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

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

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

Equipment Protection

Listed or Labeled Equipment

Listed or labeled equipment must be installed in accordance with instructions included in the listing or labeling (110-3b). Be sure to observe maximum branch circuit fuse size labels. When the equipment label is marked with a *Maximum Fuse Ampere Rating* rather than marked with *Maximum Overcurrent Device Ampere Rating*, only fuses can be used for protection of this equipment.

Panelboards

A maximum of 42 fuses (excluding main fuses) are permitted to be installed in a lighting and appliance branch circuit panelboard (384-15). Each lighting and appliance branch circuit panelboard must be individually protected on the supply side by not more than two sets of fuses having a combined rating not greater than that of the panelboard (384-16). Exception No. 1: Individual protection is not required when the panelboard feeder has overcurrent protection not greater than that of the panelboard. Exception No. 2: Individual protection in existing installations is not required for individual residential occupancy service entrance panelboards (384-16a). Panels with snap switches rated at 30 amperes or less must be protected by fuses not larger than 200 amperes (384-16b). Fusible panelboards are available with heavy duty toggle switches rated more than 30 amperes; these panelboards are not restricted by this 200 ampere requirement.

When the load continues for more than 3 hours under normal operation, the total load on any fuse in the panelboard should not exceed 80% of the fuse rating (384-16c). Exception No. 1: Where the assembly including the overcurrent device is approved for continuous duty at 100% of its rating.

If the panelboard is supplied through a transformer, the fuses for the protection of the panelboard must be located on the transformer secondary (384-16d) except when the transformer is single-phase with a two-wire secondary and the fuse on the primary complies with Section 450-3(b)(1) and does not exceed the value determined by multiplying the panelboard rating by the secondary to primary voltage ratio (384-16d Exception).

Appliances

Appliance branch circuits shall be protected in accordance with Section 240-3. If a fuse rating is marked on an appliance, the branch circuit fuse rating cannot exceed that rating marked on the appliance (422-6)

For branch circuits which supply a single non-motor operated appliance rated more than 13.3 amperes, the fuse rating shall not exceed 150% of the appliance rating (422-28e).

Electric heating appliances using resistance heating elements rated more than 48 amperes shall have the heating elements subdivided such that each subdivision does not exceed 48 amps and each subdivision shall be protected by a branch circuit listed fuse not to exceed 60 amperes in rating. These fuses shall be factory installed by the heater manufacturer and they should be accessible (for Exceptions, refer to Section 422-28).

Fixed appliances are considered protected when supplied from 15, 20, 25, or 30 ampere branch circuits. Fixed cooking appliances are permitted to be protected by 40 or 50 ampere branch circuits (210-23). Household appliances with surface heating elements that have a maximum rating greater than 60 amperes must be divided into two or more circuits, each of which is protected by a fuse of no greater than 50 amperes.

Portable appliances are considered as protected when supplied from a 15, 20, or 30 ampere branch circuit (210-23).

Supplementary Protection

Supplementary overcurrent protection is recognized by the National Electrical Code for use in lighting fixtures, appliances, and other equipment or for internal control circuits and components of equipment. This type of protection should not be used as a substitute for branch circuit protection as described in Article 210. This type of protection is not required to be readily accessible as are branch circuit devices.

There are a wide variety of supplementary fuses and fuseholders which have small physical dimensions and are easily installed in or on equipment, appliances, or fixtures. The advantages of supplementary protection are closer fuse sizing for better individual protection, isolation of equipment on overcurrents so that the branch circuit fuse is not disturbed, ease in locating troubled equipment, and generally direct access to the fuse at the location of the equipment.

Air Conditioning and Refrigeration

Air conditioning and refrigeration equipment requirements are covered in Article 440 of the National Electrical Code. Hermetic motor-compressors are not rated in "full-load amperes" as are standard motors. Instead, different terms are used, such as Rated Load Current, Branch Circuit Selection Current, Maximum Continuous Current, Minimum Circuit Ampacity, and Maximum Overcurrent Protection. This equipment has overcurrent protection requirements that differ from that for ordinary motors covered in Article 430. Some highlights are presented here.

BRANCH CIRCUIT PROTECTION

Individual Motor-Compressor(s) and HVAC Equipment Having Motor-Compressor(s) and Other Loads (Such as Fan Motors, Electric Heaters, Coils, etc.).

Fuses sized for branch circuit protection only must not exceed 175% of the hermetic motor-compressor rated-load current or branch circuit selection current (whichever is larger). If this size fuse cannot withstand the motor starting current, a higher ampere rating is permitted, but in no case can the fuse size exceed 225% [Section 440-22(a)].

LOW-PEAK® YELLOW™ dual-element and FUSETRON® dual-element fuses are recommended for branch circuit protection of air conditioning and refrigeration hermetic motor-compressors because these fuses have an adequate time-delay for motor starting surges.

Refer to the nameplate on the equipment. The sizing (ampere rating) for the overcurrent protection has been determined by the manufacturer of the equipment. It is not necessary to apply any further multipliers to arrive at the proper size. This has already been done by the manufacturer. The nameplate will indicate MAXIMUM SIZE FUSE. . .or. . .MAXIMUM SIZE FUSE OR HACR TYPE CIRCUIT BREAKER.

The marked protective device rating is the maximum protective device rating for which the equipment has been investigated and found acceptable by nationally recognized testing laboratories. Where the marking specifies fuses, or "HACR" type circuit breakers, the equipment is intended to be protected only by the type of protective device specified.

See "Listed or Labeled Equipment" for requirement when nameplate states MAXIMUM SIZE FUSE. This is a critical requirement, and must be followed without exception to be in compliance with Section 110-3(b) of the Code. NEC Section 110-3(b) requires that listed or labeled equipment must be installed in accordance with any instructions included in the listing or labeling.

Disconnecting Means (Individual hermetic motor compressor)

The ampere rating of the disconnect shall be at least 115% of the compressors rated load current or branch-circuit selection current, whichever is greater [Section 440-12(a)(1)].

The horsepower rating can be obtained by referring to Table 430-151 of the NEC, which shows the conversions from locked rotor current to horsepower [Section 440-12(a)(2)].

Equipment Protection

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

The ampere rating of the disconnecting means must be at least 115% of the sum of all of the individual loads within the equipment. . .at rated load conditions [Section 440-12(b)(2)].

The horsepower rating of the disconnecting means must be at least equal to the sum of all of the individual loads within the equipment. . .at rated load conditions. . .and at locked rotor conditions [Section 440-12(b)(1)]. The equivalent horsepower rating of the compressor can be obtained by referring to Table 430-151 of the NEC.

Controller

The controller for a hermetic motor-compressor must have a continuous duty full-load current rating and locked-rotor current rating not less than the nameplate rated current or branch circuit selection current (whichever is larger), (Section 440-41). Where the controller serves a hermetic motor-compressor(s) plus other loads, the controller rating is determined according to Section 440-12(b), in much the same manner as determining the disconnecting means rating. It may be necessary to refer to Table 430-151 to convert locked rotor current values to horsepower.

The branch circuit protective device rating shall not exceed the maximum protective device rating shown on a manufacturer's heater table for use with a given motor controller [Section 440-22(c)]. Where the equipment is marked MAXIMUM SIZE FUSE ampere rating rather than stating MAXIMUM OVERCURRENT DEVICE ampere rating, only fuses can be used for the branch circuit protection.

Available Short-Circuit Current

As with most electrical equipment, HVAC equipment is tested and listed based upon circuits capable of delivering specific maximum values of short-circuit current. Because of this, it is important that the available fault current at the line side terminals of the equipment does not exceed these values. Where the available fault current does exceed the above levels, it will be necessary to "limit" the fault current to levels within the withstand rating of the equipment as tested. This is done by installing current-limiting overcurrent devices in the branch circuit that will limit the fault current to within the acceptable levels of the present standards. See information about Current Limitation.

Short-Circuit Test Currents

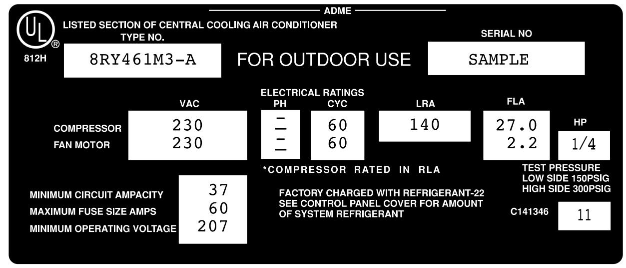
	SINGLE-PHASE			Circuit Capacity
110-120V	**200-208V**	**220-240V**	**254-277V**	**In Amperes**
9.8 or less	5.4 or less	4.9 or less	–	200
9.9 - 16.0	5.5 - 8.8	5.0 - 8.0	6.65 or less	1000
16.1 - 34.0	8.9 - 18.6	8.1 -17.0	–	2000
34.1 - 80.0	18.7 - 44.0	17.1 - 40.0	–	3500
Over 80.0	Over 44.0	Over 40.0	Over 6.65	5000
	THREE-PHASE			
200-208V	**220-240V**	**440-480V**	**550-600V**	
2.12 or less	2.0 or less	–	–	200
2.13 - 3.7	2.1- 3.5	1.8 or less	1.4 or less	1000
3.8 - 9.5	3.6 - 9.0	–	–	2000
9.6 - 23.3	9.1 - 22.0	–	–	3500
Over 23.3	Over 22.0	Over 1.8	Over 1.4	5000

Table showing values of available short-circuit current used in testing HVAC equipment.

Just as SERIES-RATED SYSTEMS must be installed per the listings of the various manufacturers equipment in order to meet the intent of Section 110-3(b) of the Code, so must HVAC equipment be properly installed to "Meet Code". To connect HVAC equipment to available fault currents that exceed the listed test levels could present a real hazard to personnel working on the equipment.

Room Air Conditioners

Room air conditioners (hermetic refrigerant motor-compressor) installed in the conditioned room are considered as single-motor units when the conditions of Section 440-62 are met. This condition also applies to conditioners containing a heating unit. Branch circuit requirements are determined by nameplate rating (440-62).



Electric Heat

Electric space heating equipment employing resistance type heating elements, rated more than 48 amperes, must have heating elements subdivided. Each subdivided load must not exceed 48 amperes, and the fuse for each load should not exceed 60 amperes (424-22b). If a subdivided load is less than 48 amperes, the fuse rating should be 125% of that load.

Exception: Boilers employing resistance type immersion electric heating elements in an ASME rated and stamped vessel may be subdivided into circuits not exceeding 120 amperes, and protected by a fuse at not more than 150 amperes (424-22b and 424-72a). If a subdivided load is less than 120 amperes, the fuse rating should be 125% of that load.

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

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

Capacitors

A fuse must be provided in each ungrounded conductor (no protection is required for a capacitor connected on the load-side of a motor running overcurrent device). The fuse rating must be as low as practical (460-8b). Generally, size dual-element, current-limiting fuses at 150% to 175% of the capacitor rated current and size non-time-delay, fast-acting, current-limiting fuses at 250% to 300% of the capacitor rated current.

Conductor ampacity must be at least 135% of the capacitor rated current (460-8a). The ampacity of conductors for a capacitor connected to motor circuit must be ⅓ the ampacity of the motor circuit conductors (460-8a).

Welders

AC Transformer, Motor-Generator, and DC Rectifier Arc Welders– each welder must be protected by a fuse rated at not more than 200% of the rated primary current. The fuse protecting the supply conductor can serve as the welder protection, if the fuse is rated at not more than 200% of the welder rated primary current (630-12a) and (630-22a). Conductors supplying one or more welders must be protected by a fuse rated at not more than 200% of the conductor rating (630-12b) and (630-22b).

Resistance welders must be protected by a fuse rated at not more than 300% of the rated primary current of the welder. The fuse protecting the supply conductor can serve as the welder protection if the fuse is rated at not more than 300% of the welder rated primary current (630-32a). Conductors supplying one or more welders must be protected by a fuse rated at not more than 300% of the conductor rating (630-32b).

Equipment Protection

For arc welder and resistance welder protection, FUSETRON® and LOW-PEAK® YELLOW™ dual-element fuses can be sized much closer than the above limits of 200% and 300%, respectively. Generally, the ampere rating of these dual-element fuses can be sized at 100% of the conductor ampacity as determined according to the respective duty cycle multipliers found in Sections 630-11a, 630-21a and 630-31a2. As an example, for a resistance welder rated on a 50% duty cycle, FUSETRON® or LOW-PEAK® YELLOW™ dual-element fuses can be sized at 71% of the welder rated primary current.

Hazardous (Classified) Locations

The characteristics of various atmospheric mixtures of hazardous gases, vapors and dusts depend on the specific hazardous material involved. It is necessary therefore that equipment be approved not only for the class of location but also for the specific gas, vapor or dust that will be present (500-2).

Class I, Divisions 1 and 2 (501-6a and 501-6b3)–Fuses may be used provided they are within enclosures approved for the purpose and location. In Division 2 locations, fuses are permitted in general enclosures if they are non-indicating, silver-sand, and current-limiting.

Approved cartridge fuses filled with a non-combustible material shall be permitted in lighting fixtures (501-6b5).

Class II, Division 1 (502-6a1)–Fuses must be provided with enclosures approved for Class II locations.

Class II, Division 2 (502-6b or 502-10b3)–Fuses must be provided with dust tight metal enclosures.

Class III (503-4)–Fuses must be provided with dust tight enclosures.

Mobile Homes

The branch circuit equipment may be combined with the disconnecting means as a single assembly. Such a combination may be designated as a distribution panel. Plug fuses must be Type S (550-6).

Branch circuit overcurrent devices must be rated (550-6b):

1. Not more than the circuit conductors,
2. Not more than 150% of the rating of a single appliance rated 13.3 amperes or more supplied by an individual branch circuit.
3. Not more than the *fuse* size marked on the air conditioner or other motor-operated appliance.

Ballasts

Each light fixture ballast should be individually protected by fuses. Fusing each fixture provides protection and isolation of a faulted ballast. When a ballast does fail, only the fuse for that fixture opens, and the remaining fixtures continue in normal operation. Without this individual ballast protection, a faulted ballast could cause the branch circuit protective device to open, thereby blacking out all fixtures. Additionally, special integrally protected ballasts, known as Class P Ballasts, are U.L. Listed under a 200A short-circuit test condition. This test is conducted utilizing a fuse as the branch protection. The starting current and continuous current characteristics for lighting ballast can vary considerably for various manufacturers. For proper fuse ampere rating, observe ballast manufacturer's recommendation.

There is a wide variety of supplementary and branch circuit fuses available for protection of light fixture ballasts including fluorescent lighting, mercury vapor lighting, and sodium lighting, indoor and outdoor.

Transformer Protection

Transformers–600 Volts or Less

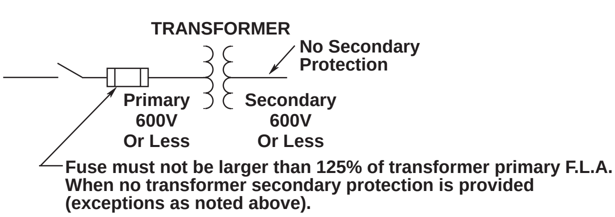
The requirements of Section 450-3 cover only transformer protection. In practice, other components must be considered in applying circuit overcurrent protection. For circuits with transformers, requirements for conductor protection per Articles 240 and 310 and for panelboards per Article 384, must be observed. Refer to Sections 240-3(i), 240-21(b) (d) and (j), and 384-16(d).

Primary Fuse Protection Only (450-3b1) (See Figure below) If secondary fuse protection is not provided (as discussed in the next Section) then the primary fuses must not be sized larger than 125% of the transformer primary full-load amperes except if the transformer primary F.L.A. is that shown in Section 450-3(b)1.

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

Primary Fuse Only

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

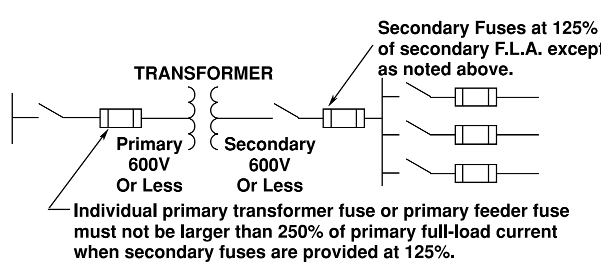


Note: Section 450-3 requirements pertain only to transformer protections. Additional circuit overcurrent protection for conductors or panelboards may be required per Articles 240, 310, 384, 430-72.

**Primary Fuse (600 Volts or less) and Secondary Fuse (600 Volts or less) (450-3b2)*. If secondary (600 Volts or less) fuses are sized not greater than 125% of transformer secondary current, individual transformer fuses are not required in the primary (600 Volt or less) provided the primary feeder fuses are not larger than 250% of the transformer rated primary current. [See 450-3b(2) for overcurrent protection requirements of thermally protected transformers].

Primary and Secondary Fuses

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



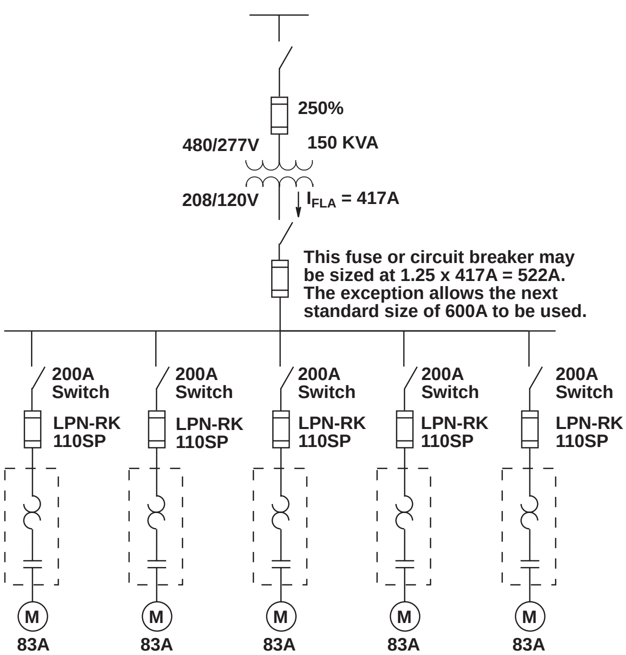
Transformer Protection

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

There is a wide fuse ampere rating range available to properly protect transformers. FUSETRON® and LOW-PEAK® YELLOW™ dual-element fuses can be sized on the transformer primary and/or secondary rated at 125% of the transformer F.L.A. These dual-element fuses have sufficient time-delay to withstand the high magnetizing inrush currents of transformers. There is a wide ampere rating selection in the 0 to 15 ampere range for these dual-element fuses to provide protection for even small control transformers.

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

This Design 1 utilizes a single secondary overcurrent device. It provides the greatest degree of selective coordination, transformer protection, secondary cable protection, and switchboard/panelboard/load center protection. The transformer cannot be overloaded to a significant degree if future loads are added (improperly) in the future.

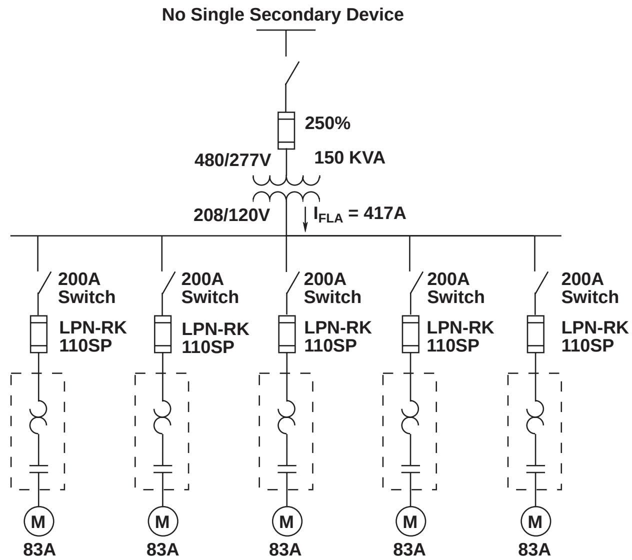


Design 1

If the single secondary overcurrent device is eliminated, much of the protection described above will be reduced.

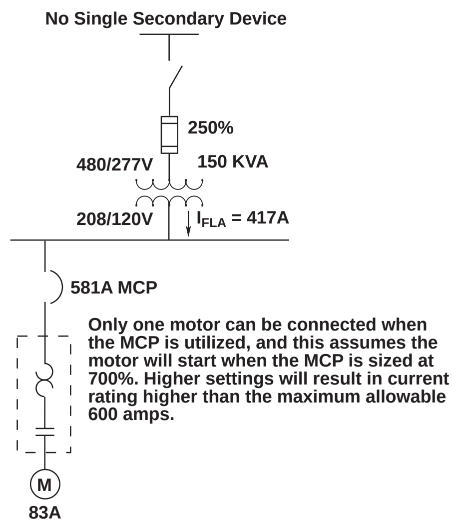
Note: With this arrangement the transformer's full capacity is utilized.

If the single secondary main is eliminated (Design 2), and dual-element fuses are utilized as branch circuit protection, the transformer can continue to be loaded with the five 83 amp motors because 5 × 110 = 550 amps, (less than the maximum 600 amps).



Design 2

If the single secondary main is eliminated and MCP's are utilized as branch circuit protection (Design 3), the transformer will be seriously under-utilized because only one motor can be connected. For one motor, 1 × 700% of 83 = 581 amps. For two motors, 2 × 700% of 83 = 1162 amps. Since the sum of the devices cannot exceed 600 amps, only one motor can be connected when the motor circuit is protected by an MCP.

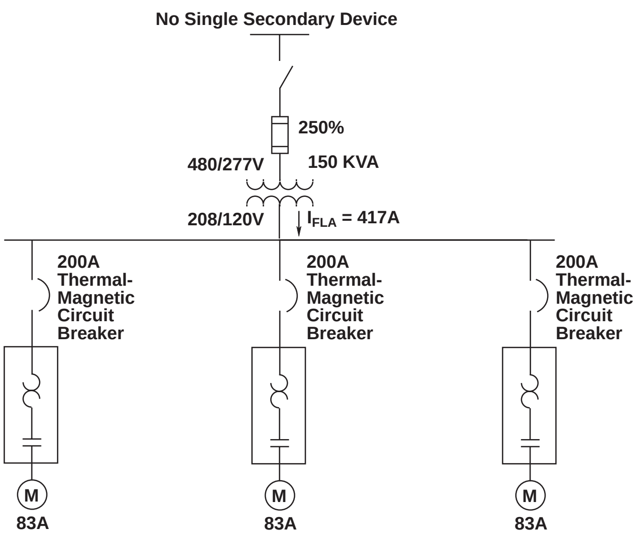


Design 3

Using the same procedure, if the single secondary main is eliminated and thermal magnetic circuit breakers are utilized (Design 4) as branch circuit protection per Section 450-152, only three of the motors can be connected because the thermal magnetic breakers will have been sized at approximately 250% of the motor F.L.A. (83 × 250% = 207.5A.)

Note: If sized less than permitted by Section 430-152, nuisance tripping may result since the new energy efficient motors have higher inrush currents.

Transformer Protection



Design 4

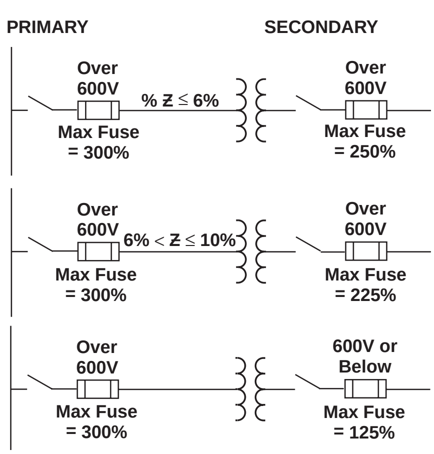
Using a 200 ampere circuit breaker would allow only three (600 ÷ 200) motors to be connected. To add two additional motors of the same type as shown in Design 1 and Design 2 requires a larger transformer - one that would have a 1000 ampere or more secondary capability. A 300 KVA 208V transformer has a 830 ampere secondary rating which is not sufficient. Therefore, the next standard size 3Ø transformer is a 400 KVA with a 1110 ampere capacity to meet the new rule.

Normal magnetizing inrush currents can range from 10 times to 12 times the transformer full load current, for up to 6 cycles, and as high as 25 times transformer full load current at .01 seconds.

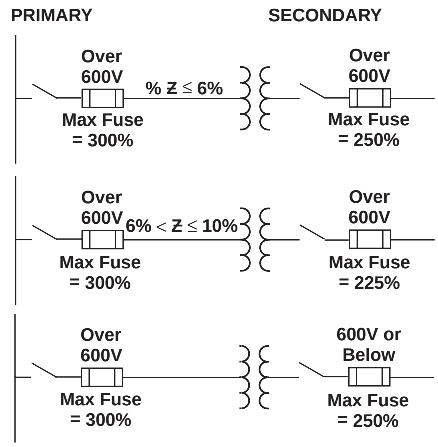
Some transformers may have inrush magnitudes substantially greater. Severe inrush should be compared with melting times to assure that unnecessary opening of the device does not occur.

Transformers–Over 600 Volts
Primary and Secondary Protection

In unsupervised locations, with primary over 600 volts, the primary fuse can be sized at a maximum of 300%. If the secondary is also over 600 volts, the secondary fuses can be sized at a maximum of 250% for transformers with impedances not greater than 6% or 225% for transformers with impedances greater than 6% and not more than 10%. If the secondary is 600 volts or below, the secondary fuses can be sized at a maximum of 125%. Where these settings do not correspond to a standard fuse size, the next higher standard size is permitted.



In supervised locations, the maximum settings are as shown above except for secondary voltages of 600 volts or below, where the secondary fuses can be sized at a maximum of 250%.



Primary Protection Only

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

Note: The use of "Primary Protection Only" does not remove the requirements for compliance with Articles 240 & 384. See (FPN) in Section 450-3, which references Sections 240-3, 240-21, and 240-100 for proper protection for secondary conductors.

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

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

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

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

Application

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

Transformer Protection

Example:
The transformer manufacturer states that an 800VA 2400 Volt, single phase potential transformer has a magnetizing inrush current of 12× lasting for 0.1 second.

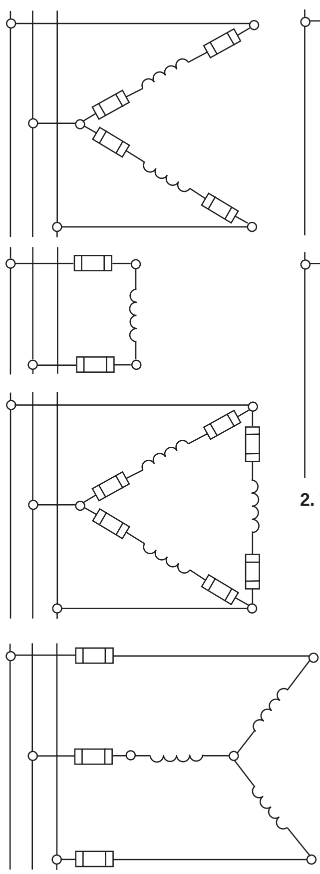
A. I_{FL} = 800VA/2400V = 0.333 ampere
Inrush Current = 12 × 0.333 = 4 amperes

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

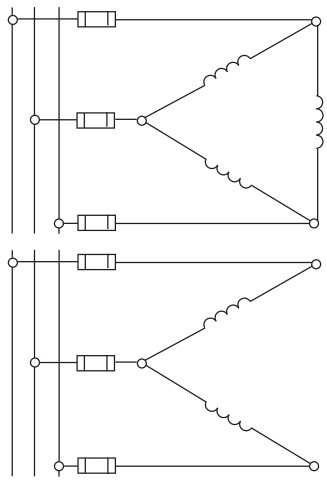
B. Using the rule of thumb–300% of 0.333 amperes is 0.999 amperes.

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

Typical Potential Transformer Connections
The typical potential transformer connections encountered in industry can be grouped into two categories:



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



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

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

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

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

Bussmann, Medium Voltage Fuse. E-Rated

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

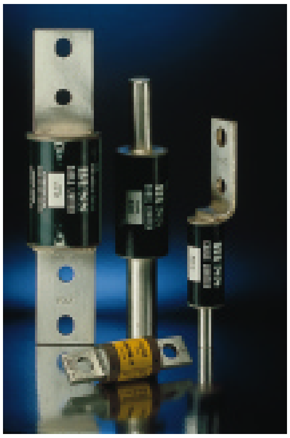
A fuse with an ‘X’ rating does not meet the electrical interchangeability for an ‘E’ rated fuse but offers the user other ratings that may provide better protection for his particular application.

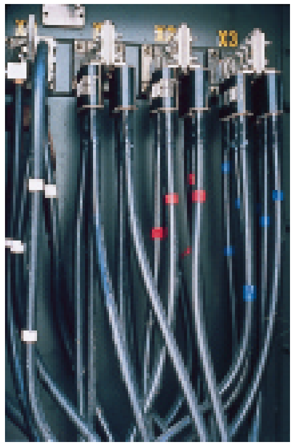
Application
Transformer protection is the most popular application of E-Rated fuses. The fuse is applied to the primary of the transformer and is used solely to prevent rupture of the transformer due to short-circuits. It is important, therefore, to size the fuse so that it does not clear on system inrush or permissible overload currents. See section on transformers over 600 volts for applicable sizing recommendations. Magnetizing inrush must also be considered when sizing a fuse. In general, power transformers have a magnetizing inrush current of 12× the full-load rating for a duration of 1⁄10 second.

Three-Phase Transformers (Or Transformer Bank)

Transformer KVA Rating	System Voltage 2.4 kV Full-load Fuse Amperes		4.16 kV Full-load Fuse Amperes		4.8 kV Full-load Fuse Amperes	
9	2.17	**JCX-7E**	1.25	**JCY-5E**	1.08	**JCY-5E**
15	3.6	**JCX-10E**	2.08	**JCY-7E**	1.8	**JCY-7E**
30	7.3	**JCX-20E**	4.2	**JCY-15E**	3.6	**JCY-10E**
45	10.8	**JCX-25E**	6.2	**JCY-15E**	5.4	**JCY-15E**
75	18.0	**JCX-40E**	10.4	**JCY-25E**	9.0	**JCY-20E**
112.5	27.0	**JCX-65E**	15.6	**JCY-40E**	13.5	**JCY-30E**
150	36.0	**JCX-65E**	20.8	**JCY-40E**	18.0	**JCY-40E**
225	54.0	**JCX-100E**	31.2	**JCY-65E**	27.0	**JCY-65E**
300	72.0	**JCX-125E**	41.6	**JCY-80E**	36.0	**JCY-65E**
500	120.0	**JCX-200E**	69.4	**JCY-125E**	60.0	**JCY-100E**
750	—	—	104.0	**JCY-150E**	90.0	**JCY-125E**
1000	—	—	139.0	**JCY-200E**	120.0	**JCY-200E**
Single-Phase Transformers						
3	1.25	**JCX-5E**	0.72	**JCY-3E**	0.63	**JCY-3E**
5	2.08	**JCX-7E**	1.20	**JCY-5E**	1.04	**JCY-5E**
10	4.17	**JCX-15E**	2.40	**JCY-7E**	2.08	**JCY-7E**
15	6.25	**JCX-15E**	3.61	**JCY-10E**	3.13	**JCY-10E**
25	10.4	**JCX-25E**	6.01	**JCY-15E**	5.21	**JCY-15E**
37.5	15.6	**JCX-40E**	9.01	**JCY-20E**	7.81	**JCY-20E**
50	20.8	**JCX-40E**	12.0	**JCY-25E**	10.4	**JCY-25E**
75	31.3	**JXC-65E**	18.0	**JCY-40E**	15.6	**JCY-30E**
100	41.7	**JCX-80E**	24.0	**JCY-80E**	20.8	**JCY-40E**
167	70.0	**JCX-100E**	40.0	**JCY-100E**	35.0	**JCY-65E**
250	104.0	**JCX-150E**	60.0	**JCY-125E**	52.0	**JCY-100E**
333	139.0	**JCX-200E**	80.0	**JCY-125E**	69.5	**JCY-100E**
500	—	—	120.0	**JCY-200E**	104.0	**JCY-150E**
667	—	—	—	—	139.0	**JCY-200E**

Cable Limiter Applications





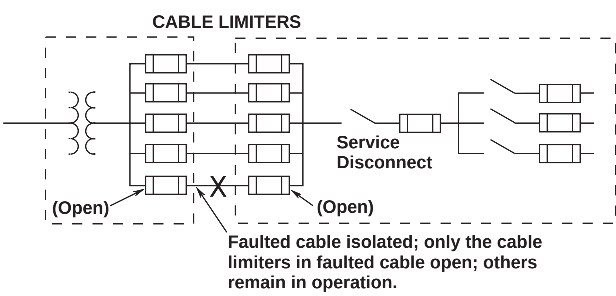
Cable Limiters

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

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

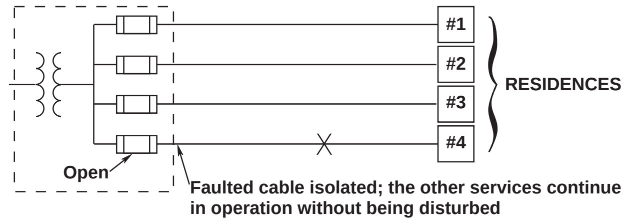
In institutional, commercial, and industrial systems, cable limiters are most often used at both ends of each cable on multiple cables per phase applications between the transformer and switchboard, as illustrated in the diagram and photographs below.

COMMERCIAL/INDUSTRIAL SERVICE ENTRANCE (Multiple cables per phase)



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

RESIDENTIAL SERVICE ENTRANCE (Single cables per phase)



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

1. Isolation of one or more faulted cables. Only the affected cable(s) are removed from service by the cable limiters at each end opening, (assuming 3 or more cables per phase, with cable limiters on each end).
2. The isolation of a faulted cable permits the convenient scheduling of repair service.
3. The hazard of equipment burndown due to a fault on the line-side of the main overcurrent protective device is greatly reduced. Typically, without cable limiters, a fault between the transformer and service switchboard is given little or no protection.
4. Their current-limiting feature can be used to provide protection against high short-circuit currents. Often, the available fault current exceeds the interrupting rating of service circuit breakers or the short-circuit current withstand of the metering. Cable limiters can provide the necessary degree of protection to meet the requirements of Sections 110-9, 110-10, and 230-65. There are many different cable limiters available for cables from #12 to 1,000 kcmil and many different type terminations. Below is the listing of those most commonly used.

Copper Cable Limiter — 600 Volts

Catalog Symbol	Cable Size	Catalog Symbol	Cable Size
KCY	#4	**KCF**	4/0
KCZ	#3	**KCH**	250 kcmil
KCA	#2	**KCJ**	350 kcmil
KCB	#1	**KCM**	500 kcmil
KCC	1/0	**KCV**	600 kcmil
KCD	2/0	**KCR**	750 kcmil
KCE	3/0	**KCS**	1000 kcmil
Tubular Terminal and Offset Bolt-Type Terminal			
KQV	#12	**KDD**	2/0
KQT	#10	**KDE**	3/0
KFZ	#8	**KDF**	4/0
KIG	#6	**KDH**	250 kcmil
KDY	#4	**KDJ**	350 kcmil
KDA	#2	**KDM**	500 kcmil
KDB	#1	**KDU**	600 kcmil
KDC	1/0	**KDR**	750 kcmil
Compression Connector Rod Terminal and Tubular Terminal			
KEX	4/0	**KQO**	350 kcmil
KFH-A	250 kcmil	**KDT**	500 kcmil
***Center Bolt-Type Terminal and Off-Set Bolt-Type Terminal**			
KPF	4/0	**KDP**	500 kcmil
KFT	250 kcmil	**KFM**	750 kcmil
KEW	350 kcmil		

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

High Speed Fuse Applications

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

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

Section 430-52 recognizes the use of these types of fuses in motor applications:

"Suitable fuses shall be permitted in lieu of devices listed in Table 430-152 for an adjustable speed drive system provided that the marking for replacement fuses is provided adjacent to the fuses."

There are several criteria that can be used to judge the performance of semiconductor fuses. Among these are the current-limiting short-circuit capability and DC interrupting capability. From a design standpoint, I^2t is most often used to evaluate the current-limiting short-circuit performance. I^2t (RMS amperes- squared seconds) is a parameter that indicates the heating effect associated with a current pulse. Typically the semiconductor data sheet specifies a maximum I^2t withstand for a semiconductor device. To offer short-circuit protection to the semiconductor device, the fuse selected should have an I^2t let-through less than the I^2t withstand rating of the semiconductor device. Semiconductor fuses have excellent current-limiting ability, as indicated by their low I^2t let-through and peak current let-through.

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

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

Ratios Of Circuit Currents

Circuit Diagram* No.	Relative Circuit Currents $\frac{I_1RMS}{I_1average}$	$\frac{I_2RMS}{I_1average}$	$\frac{I_3RMS}{I_1average}$	$\frac{I_2RMS}{I_1RMS}$
1	1.57	–	–	–
2	1.11	0.79	–	0.71
3	1.11	0.79	1.11	0.71
4	1.02	0.59	–	0.58
5	1.00	0.58	0.82	0.58
6	1.00	0.41	–	0.41
7	–	–	–	0.71
8	–	–	–	0.71

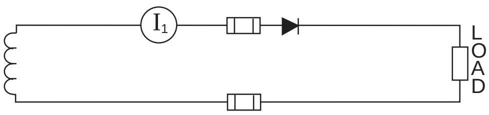
*For example, in Diagram No. 1,

$$\frac{I_{1RMS}}{I_{1average}} = 1.57$$

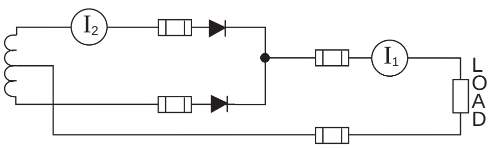
The new "square bodied" high speed fuse is applied for short-circuit protection of power semiconductors. Voltage ratings through 20,000V, and current ratings through 6000A single body are available. Semitron fuses have interrupting ratings up to 300,000A RMS. Miniature switches are quite frequently used on square bodied high speed fuses for visual indication or for signaling purposes when the fuse has opened. Hockey puck versions are available with both U.S. and metric threads.

High Speed Fuse Applications

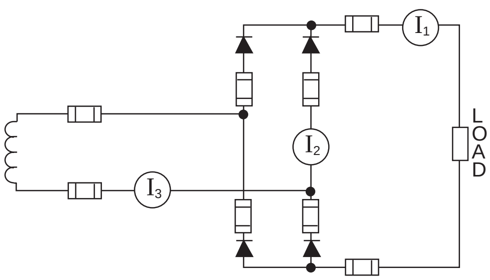
TYPICAL CIRCUITS



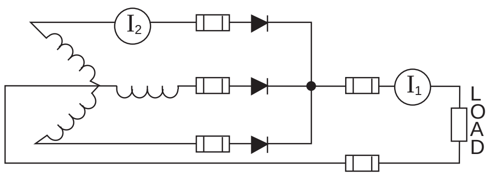
1. Single-Phase, Half-Wave.



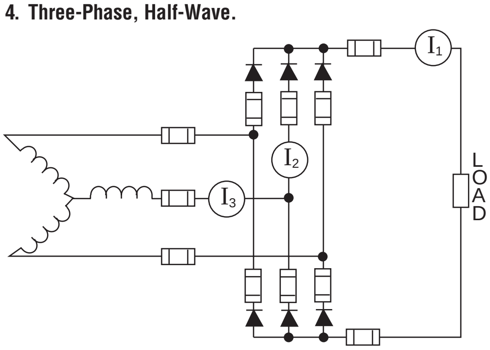
2. Single-Phase, Full-Wave, Center-Tap.



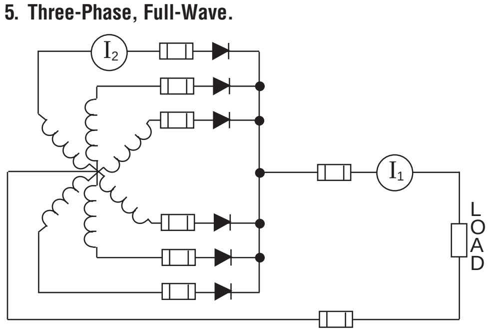
3. Single-Phase, Full-Wave, Bridge.



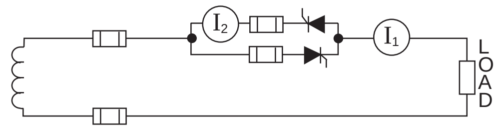
4. Three-Phase, Half-Wave.



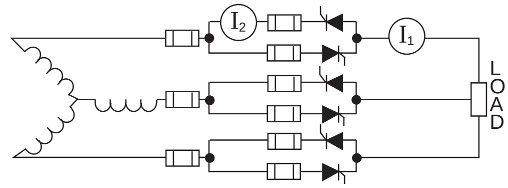
5. Three-Phase, Full-Wave.



6. Six-Phase, Single-Wave.



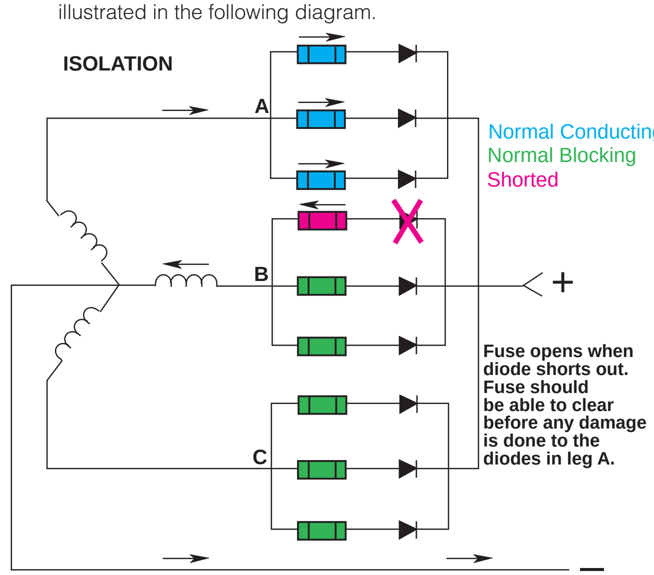
7. Single-Phase, Anti-Parallel, AC Control.



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

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

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



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

3Ø Short-Circuit Calculations

Why Short-Circuit Calculations

Several sections of the National Electrical Code relate to proper overcurrent protection. Safe and reliable application of overcurrent protective devices based on these sections mandate that a short-circuit study and a selective coordination study be conducted.

These sections include, among others:

- 110-9 Interrupting Rating
- 110-10 Component Protection
- 230-65 Service Entrance Equipment
- 240-1 Conductor Protection
- 250-95 Equipment Grounding Conductor Protection
- 517-17 Health Care Facilities - Selective Coordination

Compliance with these code sections can best be accomplished by conducting a short-circuit study and a selective coordination study.

The protection for an electrical system should not only be safe under all service conditions but, to insure continuity of service, it should be selectively coordinated as well. A coordinated system is one where only the faulted circuit is isolated without disturbing any other part of the system. Overcurrent protection devices should also provide short-circuit as well as overload protection for system components, such as bus, wire, motor controllers, etc.

To obtain reliable, coordinated operation and assure that system components are protected from damage, it is necessary to first calculate the available fault current at various critical points in the electrical system.

Once the short-circuit levels are determined, the engineer can specify proper interrupting rating requirements, selectively coordinate the system and provide component protection.

General Comments on Short-Circuit Calculations

Short-circuit calculations should be done at all critical points in the system. These would include:

- Service Entrance
- Panel Boards
- Motor Control Centers
- Motor Starters
- Transfer Switches
- Load Centers

Normally, short-circuit studies involve calculating a bolted 3-phase fault condition. This can be characterized as all three phases "bolted" together to create a zero impedance connection. This establishes a "worst case" condition, that results in maximum thermal and mechanical stress in the system. From this calculation, other types of fault conditions can be obtained.

Sources of short-circuit current that are normally taken under consideration include:

- Utility Generation
- Local Generation
- Synchronous Motors
- Induction Motors

Capacitor discharge currents can normally be neglected due to their short time duration. Certain IEEE (Institute of Electrical and Electronic Engineers) publications detail how to calculate these currents if they are substantial.

Interrupting Rating, Interrupting Capacity and Short-Circuit Currents

Interrupting rating can be defined as "the maximum short-circuit current that a protective device can safely clear, under specified test conditions."

Interrupting capacity can be defined as "the actual short-circuit current that a protective device has been tested to interrupt."

The National Electrical Code requires adequate interrupting ratings in Sections 110-9 and 230-65.

Section 110-9 Interrupting Rating. Equipment intended to break current at fault levels shall have an interrupting rating sufficient for the system voltage and the current which is available at the line terminals of the equipment.

Section 230-65. Available Short-Circuit Current. Service equipment shall be suitable for the short-circuit current available at its supply terminals.

Low voltage fuses have their interrupting rating expressed in terms of the symmetrical component of short-circuit current, I_S. They are given an RMS symmetrical interrupting rating at a specific power factor. This means that the fuse can interrupt any asymmetrical current associated with this rating. Thus only the symmetrical component of short-circuit current need be considered to determine the necessary interrupting rating of a low voltage fuse. For listed low voltage fuses, interrupting rating equals its interrupting capacity.

Low voltage molded case circuit breakers also have their interrupting rating expressed in terms of RMS symmetrical amperes at a specific power factor. However, it is necessary to determine a molded case circuit breaker's interrupting capacity in order to safely apply it. The reader is directed to Buss® bulletin PMCB II for an understanding of this concept.

Procedures and Methods

To determine the fault current at any point in the system, first draw a one-line diagram showing all of the sources of short-circuit current feeding into the fault, as well as the impedances of the circuit components.

To begin the study, the system components, including those of the utility system, are represented as impedances in the diagram.

The impedance tables include three-phase and single-phase transformers, cable, and busway. These tables can be used if information from the manufacturers is not readily available.

It must be understood that short-circuit calculations are performed without current-limiting devices in the system. Calculations are done as though these devices are replaced with copper bars, to determine the maximum "available" short-circuit current. This is necessary to project how the system and the current-limiting devices will perform.

Also, current-limiting devices do not operate in series to produce a "compounding" current-limiting effect. The downstream, or load side, fuse will operate alone under a short-circuit condition if properly coordinated.

3Ø Short-Circuit Calculations

The application of the point-to-point method permits the determination of available short-circuit currents with a reasonable degree of accuracy at various points for either 3Ø or 1Ø electrical distribution systems. This method can assume unlimited primary short-circuit current (infinite bus).

Basic Point-to-Point Calculation Procedure

Step 1. Determine the transformer full load amperes from either the nameplate or the following formulas:

3Ø Transformer $$I_{f.l.} = \frac{KVA \times 1000}{E_{L-L} \times 1.732}$$

1Ø Transformer $$I_{f.l.} = \frac{KVA \times 1000}{E_{L-L}}$$

Step 2. Find the transformer multiplier.

$$\text{Multiplier} = \frac{100}{{}^{*}\%Z_{trans}}$$

* **Note.** Transformer impedance (Z) helps to determine what the short circuit current will be at the transformer secondary. Transformer impedance is determined as follows: The transformer secondary is short circuited. Voltage is applied to the primary which causes full load current to flow in the secondary. This applied voltage divided by the rated primary voltage is the impedance of the transformer.

Example: For a 480 volt rated primary, if 9.6 volts causes secondary full load current to flow through the shorted secondary, the transformer impedance is 9.6/480 = .02 = 2%Z.

In addition, U.L. listed transformer 25KVA and larger have a ± 10% impedance tolerance. Short circuit amperes can be affected by this tolerance.

Step 3. Determine the transformer let-through short-circuit current**.

$$I_{S.C.} = I_{f.l.} \times \text{Multiplier}$$

** **Note.** Motor short-circuit contribution, if significant, may be added to the transformer secondary short-circuit current value as determined in Step 3. Proceed with this adjusted figure through Steps 4, 5 and 6. A practical estimate of motor short-circuit contribution is to multiply the total motor current in amperes by 4.

Step 4. Calculate the "f" factor.

3Ø Faults $$f = \frac{1.732 \times L \times I_{3Ø}}{C \times E_{L-L}}$$

1Ø Line-to-Line (L-L) Faults on 1Ø Center Tapped Transformer $$f = \frac{2 \times L \times I_{L-L}}{C \times E_{L-L}}$$

1Ø Line-to-Neutral (L-N) Faults on 1Ø Center Tapped Transformer $$f = \frac{2 \times L \times I_{L-N}^{\dagger}}{C \times E_{L-N}}$$

Where:

L = length (feet) of conductor to the fault.

C = constant from Table of "C" values for conductors and busway. For parallel runs, multiply C values by the number of conductors per phase.

I = available short-circuit current in amperes at beginning of circuit.

† **Note.** The L-N fault current is higher than the L-L fault current at the secondary terminals of a single-phase center-tapped transformer. The short-circuit current available (I) for this case in Step 4 should be adjusted at the transformer terminals as follows: At L-N center tapped transformer terminals, **$I_{L-N} = 1.5 \times I_{L-L}$ at Transformer Terminals.**

At some distance from the terminals, depending upon wire size, the L-N fault current is lower than the L-L fault current. The 1.5 multiplier is an approximation and will theoretically vary from 1.33 to 1.67. These figures are based on change in turns ratio between primary and secondary, infinite source available, zero feet from terminals of transformer, and 1.2 x %X and 1.5 x %R for L-N vs. L-L resistance and reactance values. Begin L-N calculations at transformer secondary terminals, then proceed point-to-point.

Step 5. Calculate "M" (multiplier).

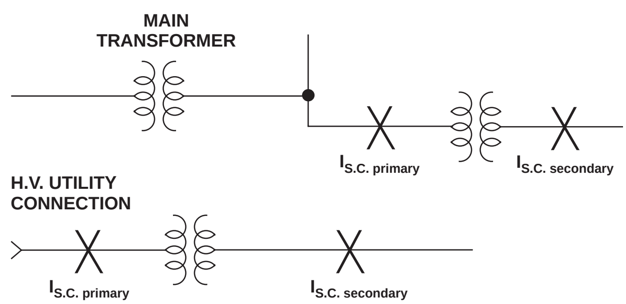
$$M = \frac{1}{1 + f}$$

Step 6. Calculate the available short-circuit symmetrical RMS current at the point of fault.

$$I_{S.C.\ sym\ RMS} = I_{S.C.} \times M$$

Calculation of Short-Circuit Currents at Second Transformer in System

Use the following procedure to calculate the level of fault current at the secondary of a second, downstream transformer in a system when the level of fault current at the transformer primary is known.



Procedure for Second Transformer in System

Step 1. Calculate the "f" factor ($I_{S.C.\ primary}$ known)

3Ø Transformer ($I_{S.C.\ primary}$ and $I_{S.C.\ secondary}$ are 3Ø fault values)

$$f = \frac{I_{S.C.\ primary} \times V_{primary} \times 1.73\ (\%Z)}{100{,}000 \times KVA_{trans}}$$

1Ø Transformer ($I_{S.C.\ primary}$ and $I_{S.C.\ secondary}$ are 1Ø fault values: $I_{S.C.\ secondary}$ is L-L)

$$f = \frac{I_{S.C.\ primary} \times V_{primary} \times (\%Z)}{100{,}000 \times KVA_{trans}}$$

Step 2. Calculate "M" (multiplier).

$$M = \frac{1}{1 + f}$$

Step 3. Calculate the short-circuit current at the secondary of the transformer. (See Note under Step 3 of "Basic Point-to-Point Calculation Procedure".)

$$I_{S.C.\ secondary} = \frac{V_{primary}}{V_{secondary}} \times M \times I_{S.C.\ primary}$$

3Ø Short-Circuit Calculations

System A

Available Utility
Infinite Assumption

1500 KVA Transformer,
480V, 3Ø, 3.5%Z,
3.45%X, 56%R

$I_{f.l.}$ =1804A

25' - 500kcmil
6 Per Phase
Service Entrance
Conductors in Steel Conduit

2000A Switch

KRP-C-2000SP Fuse

Fault X_1

400A Switch

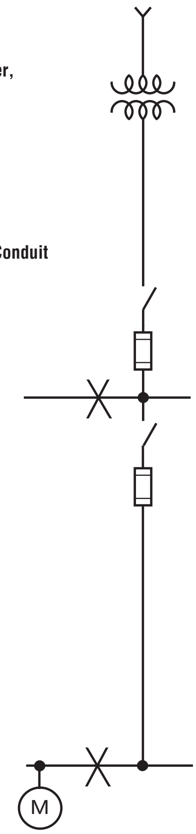
LPS-RK-400SP Fuse

50' - 500 kcmil
Feeder Cable
in Steel Conduit

Fault X_2

Motor Contribution

One-Line Diagram



Fault X_1

Step 1. $I_{f.l.} = \frac{1500 \times 1000}{480 \times 1.732} = 1804A$

Step 2. $\text{Multiplier} = \frac{100}{3.5} = 28.57$

Step 3. $I_{S.C.} = 1804 \times 28.57 = 51{,}540A$

Step 4. $f = \frac{1.732 \times 25 \times 51{,}540}{6 \times 22{,}185 \times 480} = 0.0349$

Step 5. $M = \frac{1}{1 + .0349} = .9663$

Step 6. $I_{S.C.sym\ RMS} = 51{,}540 \times .9663 = 49{,}803A$

$I_{S.C.motor\ contrib} = 4 \times 1{,}804 = 7{,}216A$

$I_{totalS.C.\ sym\ RMS\ (fault\ X_1)} = 49{,}803 + 7{,}216 = 57{,}019A$

Fault X_2

Step 4. Use $I_{S.C.sym\ RMS}$ @ Fault X_1 to calculate "f"

$f = \frac{1.732 \times 50 \times 49{,}803}{22{,}185 \times 480} = .4050$

Step 5. $M = \frac{1}{1 + .4050} = .7117$

Step 6. $I_{S.C.sym\ RMS} = 49{,}803 \times .7117 = 35{,}445A$

$I_{sym\ motor\ contrib} = 4 \times 1{,}804 = 7{,}216A$

$I_{total\ S.C.\ sym\ RMS\ (fault\ X_2)} = 35{,}445 + 7{,}216 = 42{,}661A$

System B

Available Utility
Infinite Assumption

1000 KVA Transformer,
480V, 3Ø,
3.5%Z

$I_{f.l.}$= 1203A

30' - 500 kcmil
4 Per Phase
Copper in PVC Conduit

1600A Switch

KRP-C-1500SP Fuse

Fault X_1

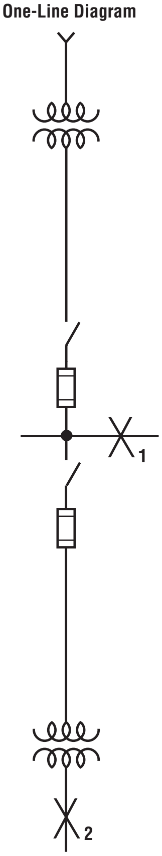
400A Switch

LPS-RK-350SP Fuse

20' - 2/0
2 Per Phase
Copper in PVC Conduit

225 KVA transformer,
208V, 3Ø
1.2%Z

One-Line Diagram



Fault X_1

Step 1. $I_{f.l.} = \frac{1000 \times 1000}{480 \times 1.732} = 1203A$

Step 2. $\text{Multiplier} = \frac{100}{3.5} = 28.57$

Step 3. $I_{S.C.} = 1203 \times 28.57 = 34{,}370A$

Step 4. $f = \frac{1.732 \times 30 \times 34{,}370}{4 \times 26{,}706 \times 480} = .0348$

Step 5. $M = \frac{1}{1 + .0348} = .9664$

Step 6. $I_{S.C.sym\ RMS} = 34{,}370 \times .9664 = 33{,}215A$

Fault X_2

Step 4. $f = \frac{1.732 \times 20 \times 33{,}215}{2 \times 11{,}423 \times 480} = .1049$

Step 5. $M = \frac{1}{1 + .1049} = .905$

Step 6. $I_{S.C.sym\ RMS} = 33{,}215 \times .905 = 30{,}059A$

Fault X_2

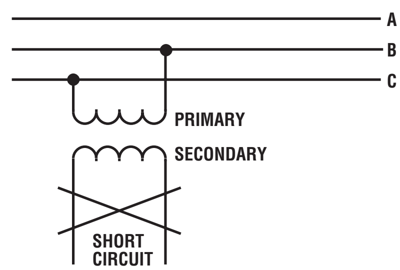
$f = \frac{30{,}059 \times 480 \times 1.732 \times 1.2}{100{,}000 \times 225} = 1.333$

$M = \frac{1}{1 + 1.333} = .4286$

$I_{S.C.\ sym\ RMS} = \frac{480 \times .4286 \times 30{,}059}{208} = 29{,}731A$

1Ø Short-Circuit Calculations

Short-circuit calculations on a single-phase center tapped transformer system require a slightly different procedure than 3Ø faults on 3Ø systems.



1. It is necessary that the proper impedance be used to represent the primary system. For 3Ø fault calculations, a single primary conductor impedance is only considered from the source to the transformer connection. This is compensated for in the 3Ø short-circuit formula by multiplying the single conductor or single-phase impedance by 1.73.

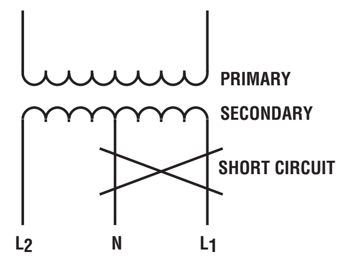
However, for single-phase faults, a primary conductor impedance is considered from the source to the transformer and back to the source. This is compensated in the calculations by multiplying the 3Ø primary source impedance by two.

2. The impedance of the center-tapped transformer must be adjusted for the half-winding (generally line-to-neutral) fault condition.

The diagram at the right illustrates that during line-to-neutral faults, the full primary winding is involved but, only the half-winding on the secondary is involved. Therefore, the actual transformer reactance and resistance of the half-winding condition is different than the actual transformer reactance and resistance of the full winding condition. Thus, adjustment to the %X and %R must be made when considering line-to-neutral faults. The adjustment multipliers generally used for this condition are as follows:

1.5 times full winding %R on full winding basis.

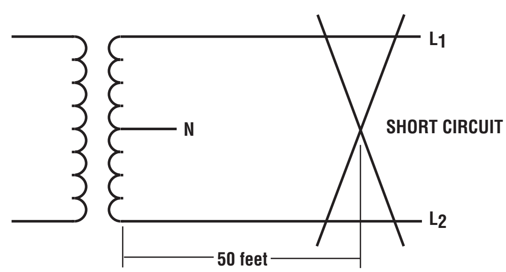
1.2 times full winding %X on full winding basis.



Note: %R and %X multipliers given in "Impedance Data for Single Phase Transformers" Table may be used, however, calculations must be adjusted to indicate transformer KVA/2.

3. The impedance of the cable and two-pole switches on the system must be considered "both-ways" since the current flows to the fault and then returns to the source. For instance, if a line-to-line fault occurs 50 feet from a transformer, then 100 feet of cable impedance must be included in the calculation.

The calculations on the following pages illustrate 1Ø fault calculations on a single-phase transformer system. Both line-to-line and line-to-neutral faults are considered.



Note in these examples:

a. The multiplier of 2 for some electrical components to account for the single-phase fault current flow,

b. The half-winding transformer %X and %R multipliers for the line-to-neutral fault situation, and

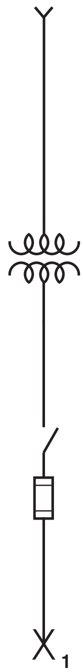
c. The KVA and voltage bases used in the per-unit calculations

1Ø Short-Circuit Calculations

Line-to-Line Fault @ 240V — Fault X_1

One-Line Diagram

Available Utility
Infinite Assumption



75KVA, 1Ø Transformer,
1.22%X, .68%R
1.40%Z
120/240V

Negligible Distance

400A Switch

LPN-RK-400SP Fuse

25' - 500kcmil

Magnetic Conduit

Fault X_1

Step 1. $I_{f.l.} = \frac{75 \times 1000}{240} = 312.5A$

Step 2. $\text{Multiplier} = \frac{100}{1.40} = 71.43$

Step 3. $I_{S.C.} = 312.5 \times 71.43 = 22{,}322A$

Step 4. $f = \frac{2 \times 25 \times 22{,}322}{22{,}185 \times 240} = .2096$

Step 5. $M = \frac{1}{1 + .2096} = .8267$

Step 6. $I_{S.C.\ L\text{-}L\ (X_1)} = 22{,}322 \times .8267 = 18{,}453A$

Line-to-Neutral Fault @ 120V — Fault X_1

One-Line Diagram

Available Utility
Infinite Assumption

75KVA, 1Ø Transformer,
1.22% X, .68%R,
1.40%Z
120/240V

Negligible Distance

400A Switch

LPN-RK-400SP Fuse

25' - 500kcmil

Magnetic Conduit

Fault X_1

Step 1. $I_{f.l.} = \frac{75 \times 1000}{240} = 312.5A$

Step 2. $\text{Multiplier} = \frac{100}{1.40} = 71.43$

Step 3. $I_{S.C.\ (L\text{-}L)} = 312.5 \times 71.43 = 22{,}322A$

$I_{S.C.\ (L\text{-}N)} = 22{,}322 \times 1.5 = 33{,}483A$

Step 4. $f = \frac{2^{*} \times 25 \times 22{,}322 \times 1.5}{22{,}185 \times 120} = .6288$

Step 5. $M = \frac{1}{1 + .6288} = .6139$

Step 6. $I_{S.C.\ L\text{-}N\ (X_1)} = 33{,}483 \times .6139 = 20{,}555A$

* Assumes the neutral conductor and the line conductor are the same size.

Short-Circuit, Impedance and Reactance Data

TRANSFORMERS

Short-Circuit Currents Available from Various Size Transformers

Voltage And Phase	KVA	Full Load Amps	% Impedance†† (Nameplate)	Short-Circuit Amps†
120/240 1 ph.*	25	104	1.58	11,574
	37½	156	1.56	17,351
	50	209	1.54	23,122
	75	313	1.6	32,637
	100	417	1.6	42,478
	167	695	1.8	60,255
120/208 3 ph.**	25	69	1.6	4,791
	50	139	1.6	9,652
	75	208	1.11	20,821
	100	278	1.11	27,828
	150	416	1.07	43,198
	225	625	1.12	62,004
	300	833	1.11	83,383
	500	1388	1.24	124,373
	750	2082	3.5	66,095
	1000	2776	3.5	88,167
	1500	4164	3.5	132,190
	2000	5552	5.0	123,377
	2500	6950	5.0	154,444
277/480 3 ph.	112½	135	1.0	15,000
	150	181	1.2	16,759
	225	271	1.2	25,082
	300	361	1.2	33,426
	500	601	1.3	51,362
	750	902	3.5	28,410
	1000	1203	3.5	38,180
	1500	1804	3.5	57,261
	2000	2406	5.0	53,461
	2500	3007	5.0	66,822

* Single-phase values are L-N values at transformer terminals. These figures are based on change in turns ratio between primary and secondary, 100,000 KVA primary, zero feet from terminals of transformer, 1.2 (%X) and 1.5 (%R) multipliers for L-N vs. L-L reactance and resistance values and transformer X/R ratio = 3.

** Three-phase short-circuit currents based on "infinite" primary.

†† U.L. listed transformers 25 KVA or greater have a ±10% impedance tolerance. Short-circuit amps reflect a "worst case" condition.

† Fluctuations in system voltage will affect the available short-circuit current. For example, a 10% increase in system voltage will result in a 10% increase in the available short-circuit currents shown in the table.

Impedance Data for Single-Phase Transformers

kVA 1Ø	Suggested X/R Ratio for Calculation	Normal Range of Percent Impedance (%Z)*	Impedance Multipliers** For Line-to-Neutral Faults for %X	for %R
25.0	1.1	1.2–6.0	0.6	0.75
37.5	1.4	1.2–6.5	0.6	0.75
50.0	1.6	1.2–6.4	0.6	0.75
75.0	1.8	1.2–6.6	0.6	0.75
100.0	2.0	1.3–5.7	0.6	0.75
167.0	2.5	1.4–6.1	1.0	0.75
250.0	3.6	1.9–6.8	1.0	0.75
333.0	4.7	2.4–6.0	1.0	0.75
500.0	5.5	2.2–5.4	1.0	0.75

* National standards do not specify %Z for single-phase transformers. Consult manufacturer for values to use in calculation.

** Based on rated current of the winding (one–half nameplate kVA divided by secondary line-to-neutral voltage).

Note: U.L. Listed transformers 25 KVA and greater have a ± 10% tolerance on their impedance nameplate.

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Impedance Data for Single-Phase and Three-Phase Transformers-Supplement†

kVA 1Ø	kVA 3Ø	%Z	Suggested X/R Ratio for Calculation
10	—	1.2	1.1
15	—	1.3	1.1
	75	1.11	1.5
	150	1.07	1.5
	225	1.12	1.5
	300	1.11	1.5
333	—	1.9	4.7
	500	1.24	1.5
500	—	2.1	5.5

†These represent actual transformer nameplate ratings taken from field installations.

Note: U.L. Listed transformers 25KVA and greater have a ±10% tolerance on their impedance nameplate.

“C” Values for Conductors and Busway

“C” Values for Conductors and Busway

AWG or kcmil	Three Single Conductors						Three-Conductor Cable					
	Conduit						Conduit					
	Steel			Nonmagnetic			Steel			Nonmagnetic		
	600V	5KV	15KV	600V	5KV	15KV	600V	5KV	15KV	600V	5KV	15KV
Copper												
14	389	389	389	389	389	389	389	389	389	389	389	389
12	617	617	617	617	617	617	617	617	617	617	617	617
10	981	981	981	981	981	981	981	981	981	981	981	981
8	1557	1551	1557	1558	1555	1558	1559	1557	1559	1559	1558	1559
6	2425	2406	2389	2430	2417	2406	2431	2424	2414	2433	2428	2420
4	3806	3750	3695	3825	3789	3752	3830	3811	3778	3837	3823	3798
3	4760	4760	4760	4802	4802	4802	4760	4790	4760	4802	4802	4802
2	5906	5736	5574	6044	5926	5809	5989	5929	5827	6087	6022	5957
1	7292	7029	6758	7493	7306	7108	7454	7364	7188	7579	7507	7364
1/0	8924	8543	7973	9317	9033	8590	9209	9086	8707	9472	9372	9052
2/0	10755	10061	9389	11423	10877	10318	11244	11045	10500	11703	11528	11052
3/0	12843	11804	11021	13923	13048	12360	13656	13333	12613	14410	14118	13461
4/0	15082	13605	12542	16673	15351	14347	16391	15890	14813	17482	17019	16012
250	16483	14924	13643	18593	17120	15865	18310	17850	16465	19779	19352	18001
300	18176	16292	14768	20867	18975	17408	20617	20051	18318	22524	21938	20163
350	19703	17385	15678	22736	20526	18672	22646	21914	19821	24904	24126	21982
400	20565	18235	16365	24296	21786	19731	24253	23371	21042	26915	26044	23517
500	22185	19172	17492	26706	23277	21329	26980	25449	23125	30028	28712	25916
600	22965	20567	17962	28033	25203	22097	28752	27974	24896	32236	31258	27766
750	24136	21386	18888	28303	25430	22690	31050	30024	26932	32404	31338	28303
1000	25278	22539	19923	31490	28083	24887	33864	32688	29320	37197	35748	31959
Aluminum												
14	236	236	236	236	236	236	236	236	236	236	236	236
12	375	375	375	375	375	375	375	375	375	375	375	375
10	598	598	598	598	598	598	598	598	598	598	598	598
8	951	950	951	951	950	951	951	951	951	951	951	951
6	1480	1476	1472	1481	1478	1476	1481	1480	1478	1482	1481	1479
4	2345	2332	2319	2350	2341	2333	2351	2347	2339	2353	2349	2344
3	2948	2948	2948	2958	2958	2958	2948	2956	2948	2958	2958	2958
2	3713	3669	3626	3729	3701	3672	3733	3719	3693	3739	3724	3709
1	4645	4574	4497	4678	4631	4580	4686	4663	4617	4699	4681	4646
1/0	5777	5669	5493	5838	5766	5645	5852	5820	5717	5875	5851	5771
2/0	7186	6968	6733	7301	7152	6986	7327	7271	7109	7372	7328	7201
3/0	8826	8466	8163	9110	8851	8627	9077	8980	8750	9242	9164	8977
4/0	10740	10167	9700	11174	10749	10386	11184	11021	10642	11408	11277	10968
250	12122	11460	10848	12862	12343	11847	12796	12636	12115	13236	13105	12661
300	13909	13009	12192	14922	14182	13491	14916	14698	13973	15494	15299	14658
350	15484	14280	13288	16812	15857	14954	15413	16490	15540	17635	17351	16500
400	16670	15355	14188	18505	17321	16233	18461	18063	16921	19587	19243	18154
500	18755	16827	15657	21390	19503	18314	21394	20606	19314	22987	22381	20978
600	20093	18427	16484	23451	21718	19635	23633	23195	21348	25750	25243	23294
750	21766	19685	17686	25976	23701	20934	26431	25789	23750	29036	28262	25976
1000	23477	21235	19005	28778	26109	23482	29864	29049	26608	32938	31919	29135

Note: These values are equal to one over the impedance per foot for impedances found in IEEE std. 241-1990, IEEE Recommended Practice for Commercial Building Power Systems.

Ampacity	Busway				
	Plug-In	Feeder		High Impedance	
	Copper	Aluminum	Copper	Aluminum	Copper
225	28700	23000	18700	12000	—
400	38900	34700	23900	21300	—
600	41000	38300	36500	31300	—
800	46100	57500	49300	44100	—
1000	69400	89300	62900	56200	15600
1200	94300	97100	76900	69900	16100
1350	119000	104200	90100	84000	17500
1600	129900	120500	101000	90900	19200
2000	142900	135100	134200	125000	20400
2500	143800	156300	180500	166700	21700
3000	144900	175400	204100	188700	23800
4000	—	—	277800	256400	—

Note: These values are equal to one over the impedance per foot for impedance in a survey of industry.

Voltage Drop Calculations

Ratings of Conductors and Tables to Determine Volt Loss

With higher rating on new installations, it is extremely important to bear *volt loss* in mind, otherwise some very unsatisfactory problems are likely to be encountered.

The actual conductor used must also meet the other sizing requirements such as full-load current, ambient temperature, number in a raceway, etc.

How to Figure Volt Loss

Multiply *distance* (length in feet of one wire) by the *current* (expressed in amperes) by the *figure* shown in table for the kind of current and the size of wire to be used, by one over the number of conductors per phase.

Then, put a decimal point in front of the last 6 digits–you have the *volt loss* to be expected on that circuit.

Example – No. 6 copper wire in 180 feet of iron conduit–3 phase, 40 amp load at 80% power factor.

Multiply feet by amperes: 180 x 40 = 7200

Multiply this number by number from table for No. 6 wire three-phase at 80% power factor: 7200 x 745 = 5364000

Multiply by $\frac{1}{\#/\text{phase}}$ 5364000 x $\frac{1}{1}$ = 5364000

Place decimal point 6 places to left.

This gives volt loss to be expected: 5.364 volts

(For a 240 volt circuit the % voltage drop is $\frac{5.364}{240}$ x 100 or 2.23%).

These Tables take into consideration *reactance on AC circuits* as well as resistance of the wire.

Remember on short runs to check to see that the size and type of wire indicated has sufficient ampere capacity.

How to Select Size of Wire

Multiply *distance* (length in feet of one wire) by the *current* (expressed in amperes), by one over the number of conductors per phase.

Divide that figure into the permissible *volt loss* multiplied by 1,000,000.

Look under the column applying to the type of current and power factor for the figure nearest, but not above your result–you have the size of wire needed.

Example – Copper in 180 feet of steel conduit–3 phase, 40 amp load at 80% power factor–volt loss from local code equals 5.5 volts.

Multiply feet by amperes by $\frac{1}{\#/\text{phase}}$ 180 x 40 x $\frac{1}{1}$ = 7200.

Divide permissible volt loss multiplied by 1,000,000 by this number: $\frac{5.5 \times 1{,}000{,}000}{7200}$ = 764.

Select number from Table, three-phase at 80% power factor, that is nearest but not greater than 764. This number is 745 which indicates the size of wire needed: No. 6.

Line-to-Neutral

For line to neutral voltage drop on a 3 phase system, divide the three phase value by 1.73. For line to neutral voltage drop on a single phase system, divide single phase value by 2.

Open Wiring

The volt loss for open wiring installations depends on the separation between conductors. The volt loss is approximately equal to that for conductors in non-magnetic conduit.

Section 310-15 offers a method to calculate conductor ampacity.

Installation in Conduit, Cable or Raceway

NEC Tables 310-16 through 310-19 give allowable ampacities (current-carrying capacities) for not more than three conductors in a conduit, cable, or raceway. Where the number of conductors exceeds three the allowable ampacity of each conductor must be reduced as shown in the following tables:

Installation in Conduit, Cable or Raceway

The Number of Conductors In One Conduit, Raceway Or Cable	Percentage of Values In Tables 310-16 And 310-18, Note 8
4 to 6	80%
7 to 9	70%
10 to 20	50%
21 to 30	45%
31 to 40	40%
41 and over	35%

Conditions Causing Higher Volt Loss

The voltage loss is increased when a conductor is operated at a higher temperature because the resistance increases.

If type RH, RHW, THW, or THWN wire (75°C wire) is loaded to near its full rating, or if room temperature is 15°C higher than normal, add the following percentages to get the volt loss.

Conditions Causing Higher Volt Loss

	Direct	Single Or Three Phase–Power Factor				
Wire Size	Current	100%	90%	80%	70%	60%
#14 to #4	5.0%	5.0%	4.8%	4.7%	4.7%	4.6%
#2 to #000	5.0%	5.0%	4.2%	3.8%	3 5%	3.3%
#0000 to 500 kcmil	5.0%	5.0%	3.1%	2.6%	2.4%	2.0%
600 kcmil to 1000 kcmil	5.0%	5.0%	2.5%	2.2%	1.6%	1.3%

Room Temperature Affects Ratings

The ampacities (carrying capacities) of conductors are based on a room temperature of 86°F or 30°C. If room temperature is higher, the ampacities are reduced by using the following multipliers; (for 0-2000 volt, insulated conductors not more than 3 conductors in raceway or direct buried, Table 310-16).

Room Temperature Affects Ratings

Room Temperature °C	TW °F	Ampacity Multiplier THW, THWN (60°C Wire)	THHN, XHHW* (75°C Wire)	(90°C Wire)
31-40	88-104	.82	.88	.91
41-45	105-113	.71	.82	.87
46-50	114-122	.58	.75	.82
51-60	123-141	–	.58	.71
61-70	142-158	–	.35	.58
71-80	159-176	–	–	.41

If type RHH, THHN or XHHW wire (90°C. wire) is loaded to near its full rating or if room temperature is 30°C. higher than normal add *twice* the above percentages to get the volt loss.

Voltage Drop Calculations

Copper Conductors–Ratings and Volt Loss†

Conduit	Wire Size	Ampacity Type T, TW (60°C Wire)	Type RH, THWN, RHW, THW (75°C Wire)	Type RHH, THHN, XHHW (90°C Wire)	Direct Current	Volt Loss (See Explanation p. 35) Three-Phase (60 Cycle, Lagging Power Factor.) 100%	90%	80%	70%	60%	Single-Phase (60 Cycle, Lagging Power Factor.) 100%	90%	80%	70%	60%
Steel Conduit	14	20*	20*	25*	6140	5369	4887	4371	3848	3322	6200	5643	5047	4444	3836
	12	25*	25*	30*	3860	3464	3169	2841	2508	2172	4000	3659	3281	2897	2508
	10	30	35*	40*	2420	2078	1918	1728	1532	1334	2400	2214	1995	1769	1540
	8	40	50	55	1528	1350	1264	1148	1026	900	1560	1460	1326	1184	1040
	6	55	65	75	982	848	812	745	673	597	980	937	860	777	690
	4	70	85	95	616	536	528	491	450	405	620	610	568	519	468
	3	85	100	110	490	433	434	407	376	341	500	501	470	434	394
	2	95	115	130	388	346	354	336	312	286	400	409	388	361	331
	1	110	130	150	308	277	292	280	264	245	320	337	324	305	283
	0	125	150	170	244	207	228	223	213	200	240	263	258	246	232
	00	145	175	195	193	173	196	194	188	178	200	227	224	217	206
	000	165	200	225	153	136	162	163	160	154	158	187	188	184	178
	0000	195	230	260	122	109	136	140	139	136	126	157	162	161	157
	250	215	255	290	103	93	123	128	129	128	108	142	148	149	148
	300	240	285	320	86	77	108	115	117	117	90	125	133	135	135
	350	260	310	350	73	67	98	106	109	109	78	113	122	126	126
	400	280	335	380	64	60	91	99	103	104	70	105	114	118	120
	500	320	380	430	52	50	81	90	94	96	58	94	104	109	111
	600	335	420	475	43	43	75	84	89	92	50	86	97	103	106
	750	400	475	535	34	36	68	78	84	88	42	79	91	97	102
	1000	455	545	615	26	31	62	72	78	82	36	72	84	90	95
Non-Magnetic Conduit (Lead Covered Cables or Installation in Fibre or Other Non-Magnetic Conduit, Etc.)	14	20*	20*	25*	6140	5369	4876	4355	3830	3301	6200	5630	5029	4422	3812
	12	25*	25*	30*	3464	3464	3158	2827	2491	2153	4000	3647	3264	2877	2486
	10	30	35*	40*	2420	2078	1908	1714	1516	1316	2400	2203	1980	1751	1520
	8	40	50	55	1528	1350	1255	1134	1010	882	1560	1449	1310	1166	1019
	6	55	65	75	982	848	802	731	657	579	980	926	845	758	669
	4	70	85	95	616	536	519	479	435	388	620	599	553	502	448
	3	85	100	110	470	433	425	395	361	324	500	490	456	417	375
	2	95	115	130	388	329	330	310	286	259	380	381	358	330	300
	1	110	130	150	308	259	268	255	238	219	300	310	295	275	253
	0	125	150	170	244	207	220	212	199	185	240	254	244	230	214
	00	145	175	195	193	173	188	183	174	163	200	217	211	201	188
	000	165	200	225	153	133	151	150	145	138	154	175	173	167	159
	0000	195	230	260	122	107	127	128	125	121	124	147	148	145	140
	250	215	255	290	103	90	112	114	113	110	104	129	132	131	128
	300	240	285	320	86	76	99	103	104	102	88	114	119	120	118
	350	260	310	350	73	65	89	94	95	94	76	103	108	110	109
	400	280	335	380	64	57	81	87	89	89	66	94	100	103	103
	500	320	380	430	52	46	71	77	80	82	54	82	90	93	94
	600	335	420	475	43	39	65	72	76	77	46	75	83	87	90
	750	400	475	535	34	32	58	65	70	72	38	67	76	80	83
	1000	455	545	615	26	25	51	59	63	66	30	59	68	73	77

* The overcurrent protection for conductor types marked with an (*) shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper; or 15 amperes for 12 AWG and 25 amperes for 10 AWG aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

† Figures are L-L for both single-phase and three-phase. Three-phase figures are average for the three-phase.

Voltage Drop Calculations

Aluminum Conductors—Ratings and Volt Loss†

Conduit	Wire Size	Ampacity Type T, TW (60°C Wire)	Type RH, THWN, RHW, THW (75°C Wire)	Type RHH, THHN, XHHW (90°C Wire)	Direct Current	Volt Loss (See Explanation p.35) Three-Phase (60 Cycle, Lagging Power Factor.) 100%	90%	80%	70%	60%	Single-Phase (60 Cycle, Lagging Power Factor.) 100%	90%	80%	70%	60%
Steel Conduit	12	20*	20*	25*	6360	5542	5039	4504	3963	3419	6400	5819	5201	4577	3948
	10	25	30*	35*	4000	3464	3165	2836	2502	2165	4000	3654	3275	2889	2500
	8	30	40	45	2520	2251	2075	1868	1656	1441	2600	2396	2158	1912	1663
	6	40	50	60	1616	1402	1310	1188	1061	930	1620	1513	1372	1225	1074
	4	55	65	75	1016	883	840	769	692	613	1020	970	888	799	708
	3	65	75	85	796	692	668	615	557	497	800	771	710	644	574
	2	75	90	100	638	554	541	502	458	411	640	625	580	529	475
	1	85	100	115	506	433	432	405	373	338	500	499	468	431	391
	0	100	120	135	402	346	353	334	310	284	400	407	386	358	328
	00	115	135	150	318	277	290	277	260	241	320	335	320	301	278
	000	130	155	175	259	225	241	234	221	207	260	279	270	256	239
	0000	150	180	205	200	173	194	191	184	174	200	224	221	212	201
	250	170	205	230	169	148	173	173	168	161	172	200	200	194	186
	300	190	230	255	141	124	150	152	150	145	144	174	176	173	168
	350	210	250	280	121	109	135	139	138	134	126	156	160	159	155
	400	225	270	305	106	95	122	127	127	125	110	141	146	146	144
	500	260	310	350	85	77	106	112	113	113	90	122	129	131	130
	600	285	340	385	71	65	95	102	105	106	76	110	118	121	122
	750	320	385	435	56	53	84	92	96	98	62	97	107	111	114
	1000	375	445	500	42	43	73	82	87	89	50	85	95	100	103
Non-Magnetic Conduit (Lead Covered Cables or Installation in Fibre or Other Non-Magnetic Conduit, Etc.)	12	20*	20*	25*	6360	5542	5029	4490	3946	3400	6400	5807	5184	4557	3926
	10	25	30*	35*	4000	3464	3155	2823	2486	2147	4000	3643	3260	2871	2480
	8	30	40	45	2520	2251	2065	1855	1640	1423	2600	2385	2142	1894	1643
	6	40	50	60	1616	1402	1301	1175	1045	912	1620	1502	1357	1206	1053
	4	55	65	75	1016	883	831	756	677	596	1020	959	873	782	668
	3	65	75	85	796	692	659	603	543	480	800	760	696	627	555
	2	75	90	100	638	554	532	490	443	394	640	615	566	512	456
	1	85	100	115	506	433	424	394	360	323	500	490	455	415	373
	0	100	120	135	402	346	344	322	296	268	400	398	372	342	310
	00	115	135	150	318	277	281	266	247	225	320	325	307	285	260
	000	130	155	175	252	225	234	223	209	193	260	270	258	241	223
	0000	150	180	205	200	173	186	181	171	160	200	215	209	198	185
	250	170	205	230	169	147	163	160	153	145	170	188	185	177	167
	300	190	230	255	141	122	141	140	136	130	142	163	162	157	150
	350	210	250	280	121	105	125	125	123	118	122	144	145	142	137
	400	225	270	305	106	93	114	116	114	111	108	132	134	132	128
	500	260	310	350	85	74	96	100	100	98	86	111	115	115	114
	600	285	340	385	71	62	85	90	91	91	72	98	104	106	105
	750	320	385	435	56	50	73	79	82	82	58	85	92	94	95
	1000	375	445	500	42	39	63	70	73	75	46	73	81	85	86

* The overcurrent protection for conductor types marked with an (*) shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper; or 15 amperes for 12 AWG and 25 amperes for 10 AWG aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

† Figures are L-L for both single-phase and three-phase. Three-phase figures are average for the three-phase.

Selective Coordination

What Is Selective Coordination?

Today, more than ever, one of the most important parts of any installation - whether it is an office building, an industrial plant, a theater, a high-rise apartment or a hospital - is the electrical distribution system. Nothing will 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.

It is not enough to select protective devices based solely on their ability to carry the system load current and interrupt the maximum fault current at their respective levels. A properly engineered system will allow ONLY the protective device nearest the fault to open, leaving the remainder of the system undisturbed and preserving continuity of service.

We may then define selective coordination as "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."

Popular Methods of Performing a Selective Coordination Study

Currently two methods are most often used to perform a coordination study:

1. Overlays of time-current curves, which utilize a light table and manufacturers' published data, then hand plot on log-log paper.

2. Computer programs that utilize a PC and allow the designer to select time-current curves published by manufacturers and transfer to a plotter or printer, following proper selections.

This text will apply to both methods.

Overloads and Low Level Fault Currents

This information is presented as an aid to understanding time-current characteristic curves of fuses and circuit breakers, and will discuss the major considerations in properly applying electrical protective devices. A thorough understanding of time-current characteristic curves of overcurrent protective devices is essential to provide a Selectively Coordinated System.

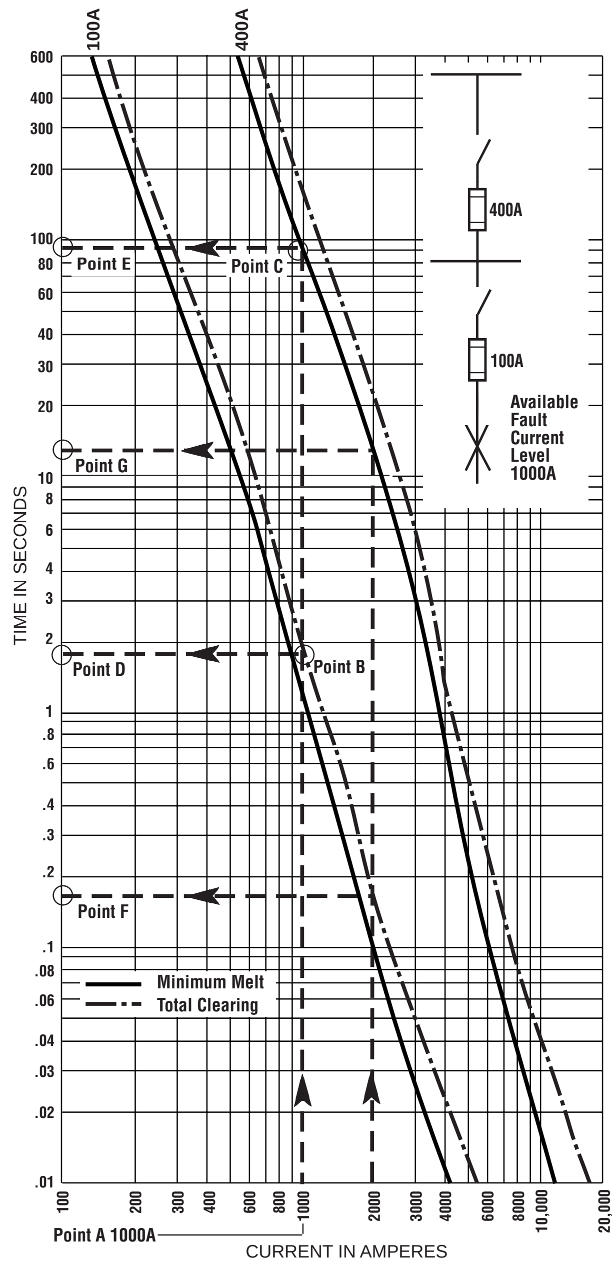
It should be noted that the study of time-current curves indicates performance during overload and low level fault conditions. The performance of overcurrent devices that operate under medium to high level fault conditions are not reflected on standard curves. Other engineering methods must be utilized.

Fuse Curves

The figure to the right illustrates the time-current characteristic curves for two sizes of time-delay, dual-element fuses in series, as depicted in the one-line diagram. The horizontal axis of the graph represents the RMS symmetrical current in amperes. The vertical axis represents the time, in seconds, until the fault occurs.

For example: Assume an available fault current level of 1000 amperes RMS symmetrical on the load side of the 100 ampere fuse. To determine the time it would take this fault current to open the two fuses, first find 1000 amperes on the horizontal axis (Point A), follow the dotted line vertically to the intersection of the total clear curve of the 100 ampere time-delay dual-element fuse (Point B) and the minimum melt curve of the 400 ampere time-delay dual-element fuse (Point C). Then, horizontally from both intersection points, follow the dotted lines to Points D and E. At 1.75 seconds, Point D represents the maximum time the 100 ampere time-delay dual-element fuse will take to open the 1000 ampere fault. At 88 seconds, Point E represents the minimum time at which the 400 ampere time-delay dual-element fuse could open this available fault current. Thus, selective operation is assured.

The two fuse curves can be examined by the same procedure at various current levels along the horizontal axis (for example, see Points F and G at the 2000 ampere fault level). It can be determined that the two fuses are selectively coordinated, since the 100 ampere time-delay dual-element fuse will open before the 400 ampere time-delay dual-element fuse can melt.



Selective Coordination — Reading Time-Current Curves

Circuit Breaker Curves

The following curve illustrates a typical thermal magnetic molded case circuit breaker curve with an overload region and an instantaneous trip region (two instantaneous trip settings are shown). Circuit breaker time-current characteristic curves are read similar to fuse curves. The horizontal axis represents the current, and the vertical axis represents the time at which the breaker interrupts the circuit.

When using molded case circuit breakers of this type, there are four basic curve considerations that must be understood. These are:

1. Overload Region
2. Instantaneous Region
3. Unlatching Time
4. Interrupting Rating

1. Overload Region - The opening of a molded case circuit breaker in the overload region is generally accomplished by a thermal element, while a magnetic coil is generally used on power breakers. Electronic sensing breakers will utilize CT's. As can be seen, the overload region has a wide tolerance band, which means the breaker should open within that area for a particular overload current.

2. Instantaneous Region - The instantaneous trip setting indicates the multiple of the full load rating at which the circuit breaker will open as quickly as possible. The instantaneous region is represented in the following curve and is shown to be adjustable from 5× to 10× the breaker rating. When the breaker coil senses an overcurrent in the instantaneous region, it releases the latch which holds the contacts closed.

The unlatching time is represented by the curve labeled "average unlatching time for instantaneous tripping". After unlatching, the overcurrent is not halted until the breaker contacts are mechanically separated and the arc is extinguished. Consequently, the final overcurrent termination can vary over a wide range of time, as is indicated by the wide band between the unlatching time curve and the maximum interrupting time curve.

The instantaneous trip setting for larger molded case and power breakers can usually be adjusted by an external dial. Two instantaneous trip settings for a 400 amp breaker are shown. The instantaneous trip region, drawn with the solid line, represents an I.T. = 5×, or five times 400 amperes = 2000 amperes. At this setting, the circuit breaker will trip instantaneously on currents of approximately 2000 amperes or more. The ± 25% band represents the area in which it is uncertain whether the overload trip or the instantaneous trip will operate to clear the overcurrent.

The dashed portion represents the same 400 ampere breaker with an I.T. = 10×, or 10 times 400 amperes = 4000 amperes. At this setting the overload trip will operate up to approximately 4000 amperes (±10%). Overcurrents greater than 4000 amperes (±10%) would be cleared by the instantaneous trip.

3. Unlatching Times - As explained above, the unlatching time indicates the point at which the breaker senses an overcurrent in the instantaneous region and releases the latch holding the contacts. However, the fault current continues to flow through the breaker and the circuit to the point of fault until the contacts can physically separate and extinguish the arc. Once the unlatching mechanism has sensed an overcurrent and unlatched, the circuit breaker will open. The final interruption of the current represented on the breaker curve in the instantaneous region occurs after unlatching, but within the maximum interruption time.

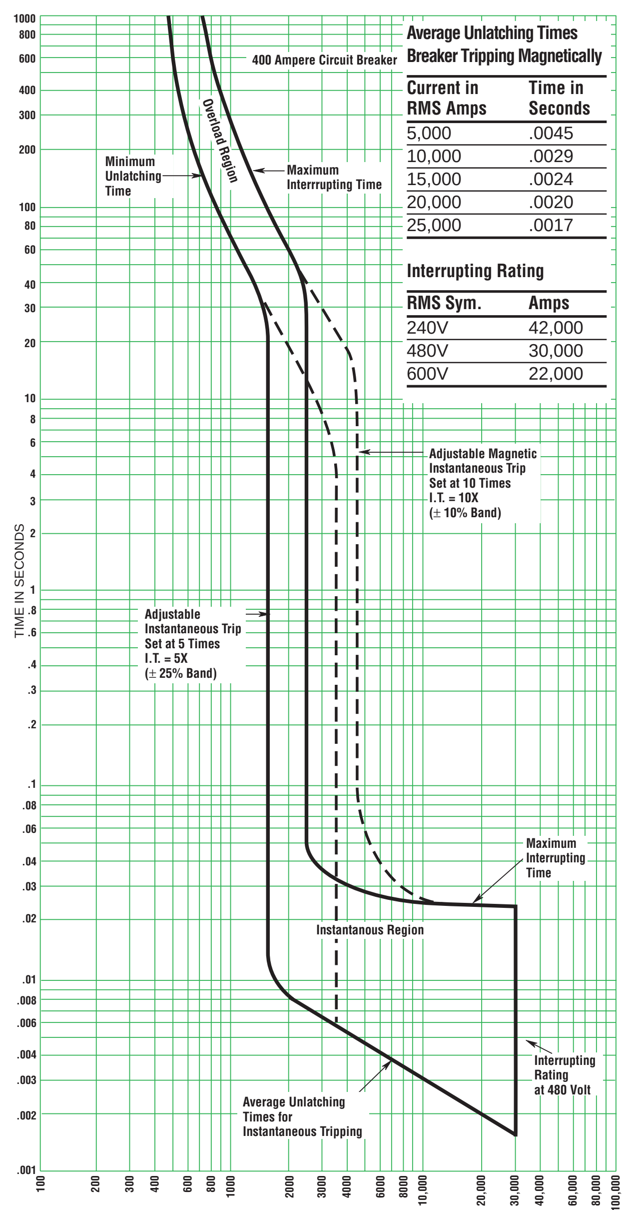
The relatively long delay between unlatching and the actual interruption of the overcurrent in the instantaneous region is the primary reason that molded case breakers are very difficult to coordinate. This is an inherent problem since the breaking of current is accomplished by mechanical means.

4. Interrupting Rating - The interrupting rating of a circuit breaker is a critical factor concerning protection and safety. The interrupting rating of a circuit breaker is the maximum fault current the breaker has been tested to interrupt in accordance with testing laboratory standards. Fault currents in excess of the interrupting rating can result in destruction of the breaker and equipment and possible injury to personnel. In other words, when the fault level exceeds the circuit breaker interrupting rating, the circuit breaker is no longer a protective device.

The interrupting rating at 480 volts is 30,000 amperes. The interrupting ratings on circuit breakers vary according to breaker type and voltage level.

When drawing circuit breaker time-current curves, determine the proper interrupting rating from the manufacturer's literature and represent this interrupting rating on the drawing by a vertical line at the right end of the curve.

Typical Circuit Breaker Time-Current Characteristic Curve



Average Unlatching Times Breaker Tripping Magnetically

Current in RMS Amps	Time in Seconds
5,000	.0045
10,000	.0029
15,000	.0024
20,000	.0020
25,000	.0017

Interrupting Rating

RMS Sym.	Amps
240V	42,000
480V	30,000
600V	22,000

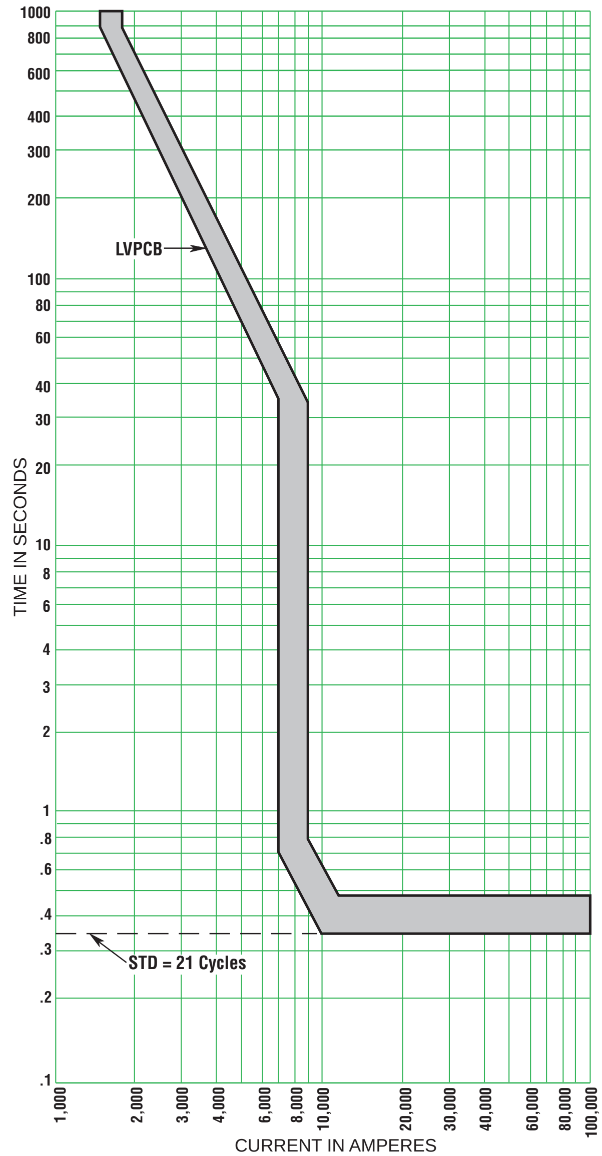
Selective Coordination — Reading Time-Current Curves

Short-Time-Delay And Instantaneous Override - Circuit breaker short-time-delay (STD) mechanisms allow an intentional delay to be installed on low voltage power circuit breakers. Short-time-delays allow the fault current to flow for several cycles, which subjects the electrical equipment to unnecessarily high mechanical and thermal stress. Most equipment ratings, such as short-circuit ratings for bus duct and switchboard bus, do not apply when short-time-delay settings are employed. The use of short-time-delay settings on circuit breakers requires the system equipment to be reinforced to withstand the available fault current for the duration of the short-time-delay. Ignoring equipment ratings in relation to the protective device opening time and let-through characteristics can be disastrous.

An insulated case circuit breaker (ICCB) may also be equipped with short-time-delay. However, ICCB's will have a built-in override mechanism. This is called the instantaneous override function, and will override the STD for medium to high level faults. This override may "kick in" for faults as low as 12× the breaker's ampere rating. This can result in non-selective tripping of the breaker and load side breakers where overlaps occur. This can be seen in the example. As the overlap suggests, for any fault condition greater than 21,000 amperes, both devices will open, causing a blackout.

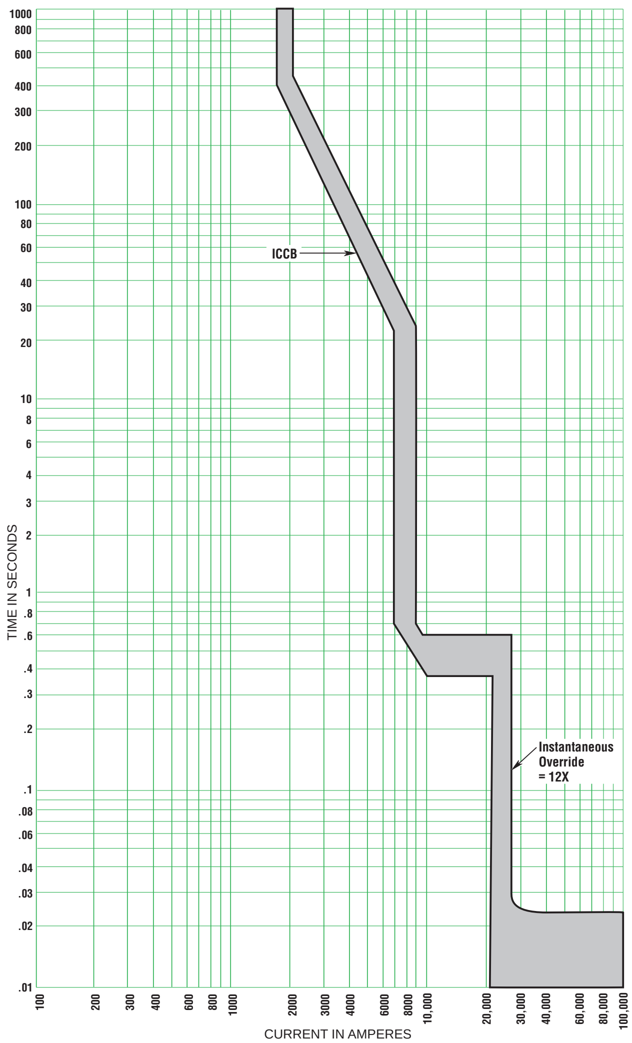
Note: Choosing overcurrent protective devices strictly on the basis of voltage, current, and interrupting rating **will not** assure component protection from short-circuit currents. The interrupting rating of a protective device pertains **only** to that device and has absolutely no bearing on its ability to protect connected downstream components. High interrupting rated electro-mechanical overcurrent protective devices, such as circuit breakers, especially those that are not current-limiting, may not be capable of protecting wire, cable or other components within the higher short-circuit ranges. Quite often, the component is completely destroyed under short-circuit conditions while the protective device is opening the faulted circuit.

Low Voltage Power Circuit Breaker

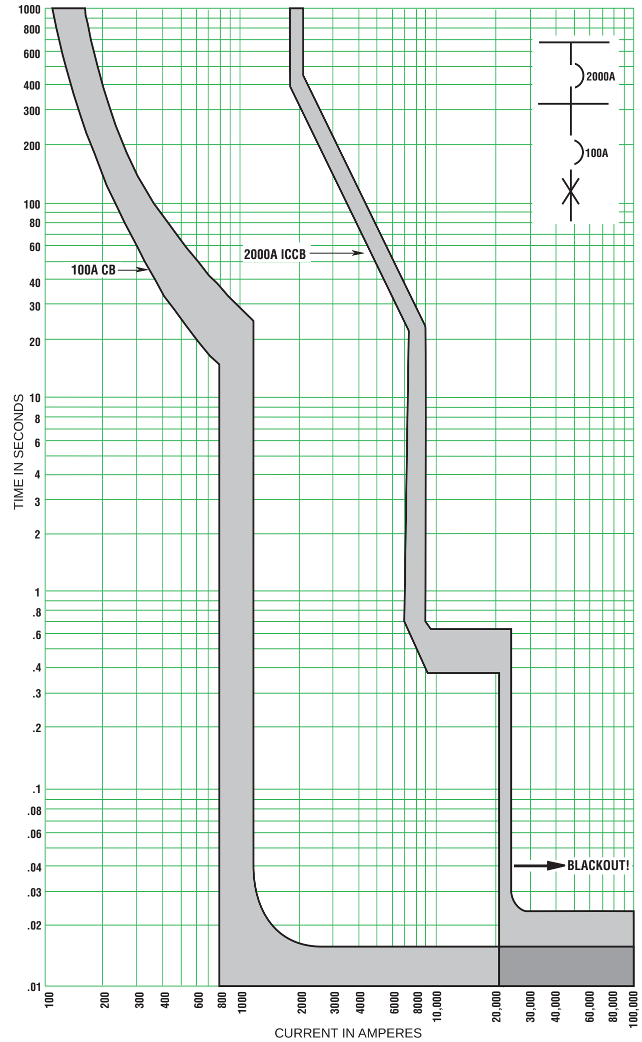


Selective Coordination — Reading Time-Current Curves

Insulated Case Circuit Breaker



Instantaneous Override Opens at 21,000 Amps



Selective Coordination — Current-Limiting Fuses

Medium to High Level Fault Currents

The available short-circuit current will reach a peak value of I_p during the first half cycle unless a protective device limits the peak fault current to a value less than I_p. A current-limiting fuse will reduce the available peak current to less than I_p, namely I_p, and will clear the fault in approximately one-half cycle or less. Note that t_c is the total clearing time of the fuse, t_m the melting time and t_a the arcing time of the fuse. Where high values of fault current are available, the sub-cycle region becomes the most critical region for selective operation of current-limiting fuses.

The area under the current curves indicates the energy let-through. If no protective device were present, or if mechanical type overcurrent devices with opening times of one-half cycle or longer were present, the full available short-circuit energy would be delivered to the system. The amount of energy delivered is directly proportionate to the square of the current. So we can see how important it is to have fuses which can limit the current being delivered to the system to a value less than the available current. The amount of energy being produced in the circuit while the fuse is clearing is called the total clearing energy and is equal to the melting energy plus the arcing energy.

Selectivity between two fuses operating under short-circuit conditions exists when the total clearing energy of the load side fuse is less than the melting energy of the line side fuse.

An engineering tool has been developed to aid in the proper selection of fuses for selective coordination. This Selectivity Ratio Guide (SRG) is shown below.

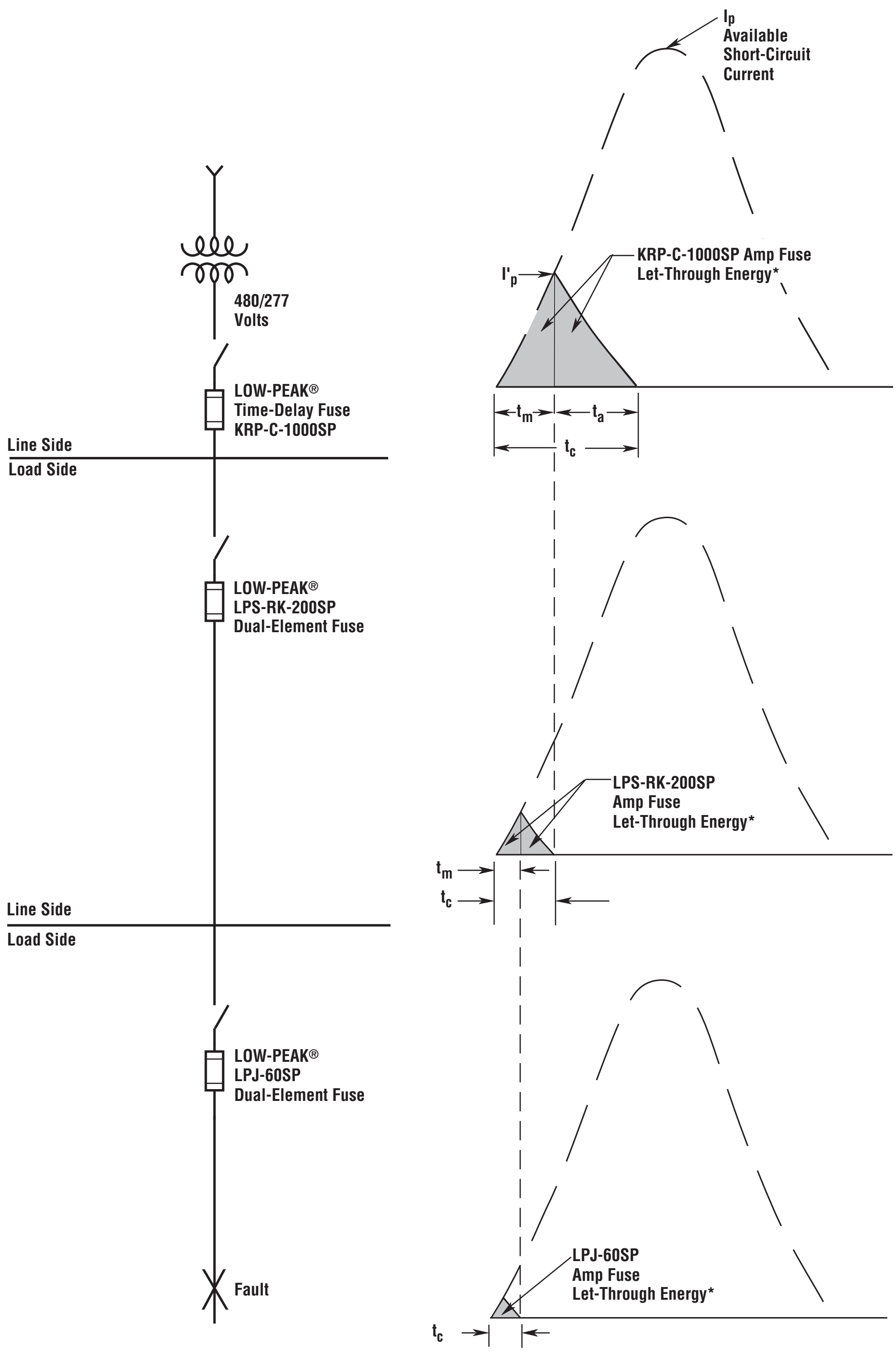
*** Selectivity Ratio Guide (Line-Side to Load-Side) for Blackout Prevention**

Circuit (Line-Side Fuse)				Load-Side Fuse									
Current Rating				601-6000A	601-4000A	0-600A			601-6000A	0-600A	0-1200A	0-600A	0-60A
	Type			Time-Delay	Time-Delay	Dual-Element Time-Delay			Fast-Acting	Fast-Acting			Time-Delay
		Trade Name		LOW-PEAK® YELLOW™	LIMITRON®	LOW-PEAK® YELLOW™		FUSETRON®	LIMITRON®	LIMITRON®	T-TRON®	LIMITRON®	SC
		Class		(L)	(L)	(RK1)	(J)**	(RK5)	(L)	(RK1)	(T)	(J)	(G)
		Buss Symbol		**KRP-CSP**	**KLU**	**LPN-RKSP LPS-RKSP**	**LPJ-SP**	**FRN-R FRS-R**	**KTU**	**KTN-R KTS-R**	**JJN JJS**	**JKS**	**SC**
601 to 6000A	Time-Delay	LOW-PEAK® YELLOW™ (L)	**KRP-CSP**	2:1	2.5:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	N/A
601 to 4000A	Time-Delay	LIMITRON® (L)	**KLU**	2:1	2:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	N/A
0 to 600A	Dual-Element	LOW-PEAK® YELLOW™ (RK1)	**LPN-RKSP LPS-RKSP**	–	–	2:1	2:1	8:1	–	3:1	3:1	3:1	4:1
		(J)	**LPJ-SP****	–	–	2:1	2:1	8:1	–	3:1	3:1	3:1	4:1
		FUSETRON® (RK5)	**FRN-R FRS-R**	–	–	1.5:1	1.5:1	2:1	–	1.5:1	1.5:1	1.5:1	1.5:1
601 to 6000A		LIMITRON® (L)	**KTU**	2:1	2.5:1	2:1	2:1	6:1	2:1	2:1	2:1	2:1	N/A
0 to 600A	Fast-Acting	LIMITRON® (RK1)	**KTN-R KTS-R**	–	–	3:1	3:1	8:1	–	3:1	3:1	3:1	4:1
0 to 1200A		T-TRON® (T)	**JJN JJS**	–	–	3:1	3:1	8:1	–	3:1	3:1	3:1	4:1
0 to 600A		LIMITRON® (J)	**JKS**	–	–	2:1	2:1	8:1	–	3:1	3:1	3:1	4:1
0 to 60A	Time-Delay	SC (G)	**SC**	–	–	3:1	3:1	4:1	–	2:1	2:1	2:1	2:1

* **Note:** At some values of fault current, specified ratios may be lowered to permit closer fuse sizing. Plot fuse curves or consult with Bussmann.
General Notes: Ratios given in this Table apply only to Buss fuses. When fuses are within the same case size, consult Bussmann.
** Consult Bussmann for latest LPJ-SP ratios.

For the next example, the Selectivity Ratio Guide suggests that the minimum ratio between line side and load side fuse should be at least 2:1. The one-line shows LOW-PEAK® fuses KRP-C1000SP feeding a LPS-RK200SP. The ratio of ampere ratings is 5:1 (1000:200) which indicates coordination between these fuses. Continuing further into the system the LPS-RK-200SP feeds a LPJ60SP. This ratio of ampere ratings is 3.33:1 (200:60), which also indicates a selectively coordinated system.

Selective Coordination — Current-Limiting Fuses



Requirements for selectivity—Total clearing energy of load side fuse is less than melting energy of line side fuse.

*Area under the curves indicates let-through energy.

Medium to High Level Fault Currents

The following curve illustrates a 400 ampere circuit breaker ahead of a 90 ampere breaker. Any fault above 1500 amperes on the load side of the 90 ampere breaker will open both breakers. The 90 ampere breaker will generally unlatch before the 400 ampere breaker. However, before the 90 ampere breaker can separate its contacts and clear the fault current, the 400 ampere breaker has unlatched and also will open.

Assume a 4000 ampere short-circuit exists on the load side of the 90 ampere circuit breaker. The sequence of events would be as follows:

1. The 90 ampere breaker will unlatch (Point A) and free the breaker mechanism to start the actual opening process.

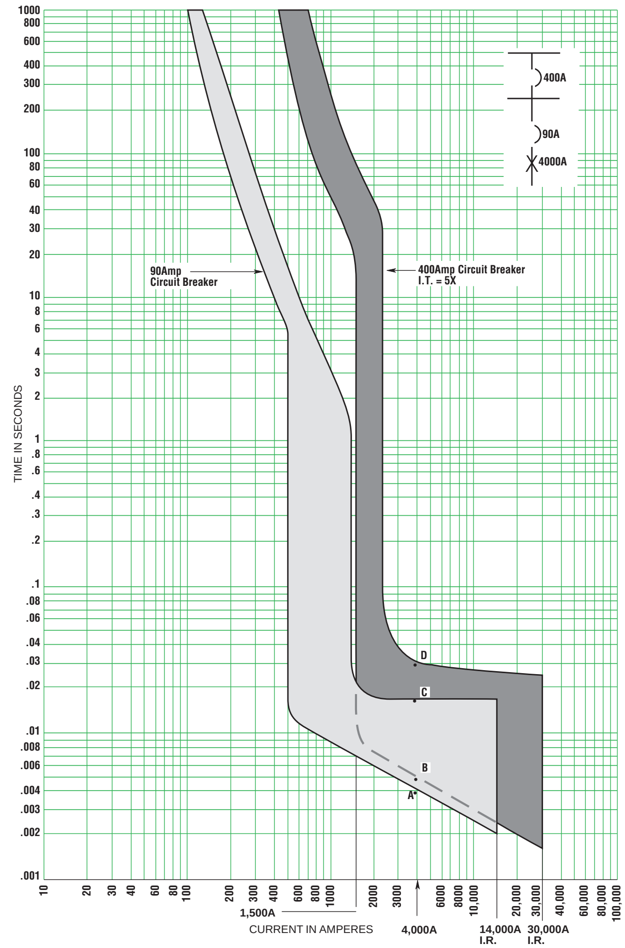
2. The 400 ampere breaker will unlatch (Point B) and it, too, would begin the opening process. Once a breaker unlatches, it will open. At the unlatching point, the process is irreversible.

3. At Point C, the 90 ampere breaker will have completely interrupted the fault current.

4. At Point D, the 400 ampere breaker also will have completely opened the circuit.

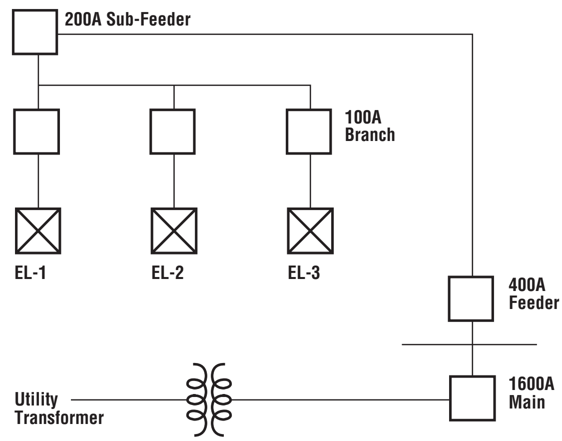
Consequently, this is a **non-selective** system, causing a complete blackout to the load protected by the 400 ampere breaker.

As printed by one circuit breaker manufacturer, "One should not overlook the fact that when a high fault current occurs on a circuit having several circuit breakers in series, the instantaneous trip on all breakers may operate. Therefore, in cases where several breakers are in series, the larger upstream breaker may start to unlatch before the smaller downstream breaker has cleared the fault. This means that for faults in this range, a main breaker may open when it would be desirable for only the feeder breaker to open."

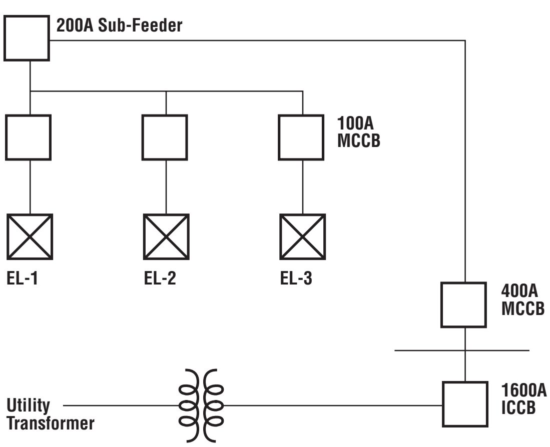


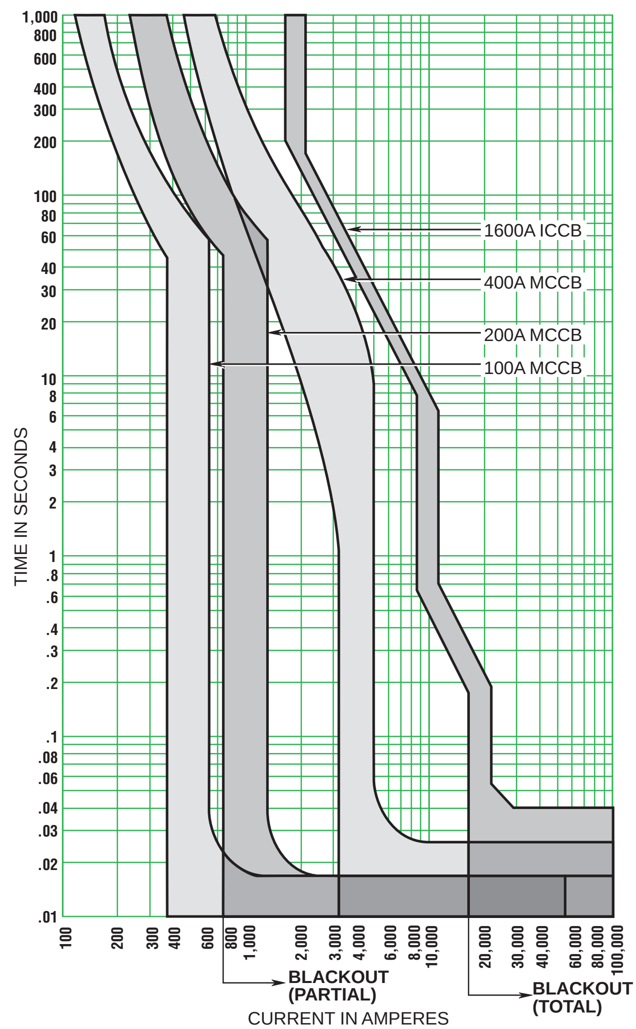
Selective Coordination — Elevator Circuits

The 1996 NEC®, Section 620-62 states: **Where more than one driving machine disconnecting means is supplied by a single feeder, the overcurrent protective devices in each disconnecting means shall be selectively coordinated with any other supply side overcurrent protective devices.** This wording is unprecedented in the NEC in that absolute selective coordination is indeed required. A design engineer must specify main, feeder, sub-feeder, and branch circuit protective devices that are selectively coordinated for all values of overloads and short-circuits.



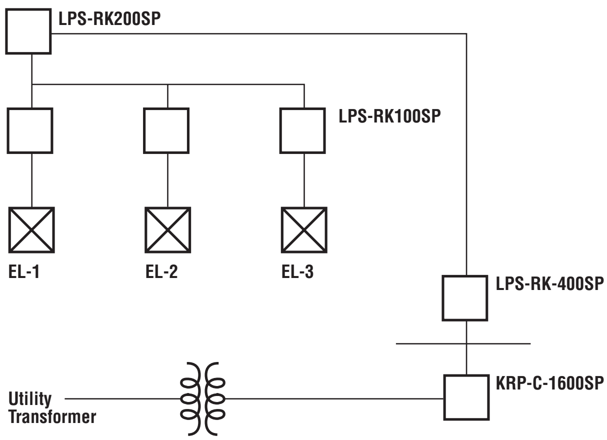
The following design consists of an insulated case circuit breaker (ICCB) and molded case circuit breakers (MCCBs). It shows a lack of coordination for any value of current in excess of 750 amperes. Faults in excess of 16,000 amperes cause a total system blackout, violating Section 620-62.

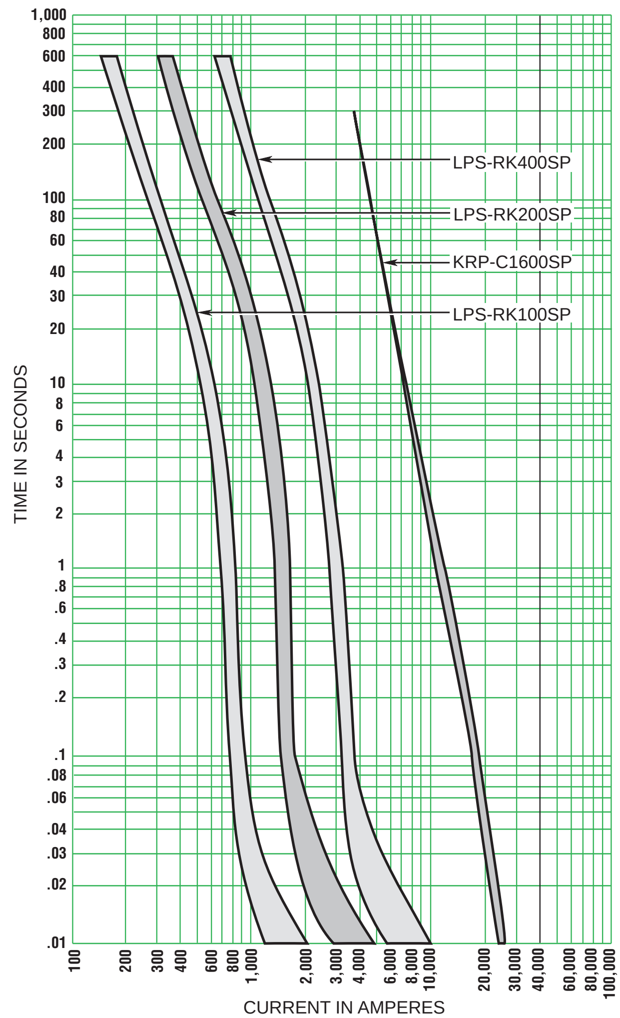




Selective Coordination — Elevator Circuits

This design consists of Class RK1 LOW-PEAK® fuses. It complies with Section 620-62 because the fuses selectively coordinate.





Conclusions

Unnecessary power OUTAGES, such as the BLACKOUTS we so often experience, can be reduced by isolating a faulted circuit from the remainder of the system through the proper selection of MODERN CURRENT-LIMITING FUSES.

The SELECTIVITY RATIO GUIDE may be used for an easy check on fuse selectivity regardless of the short-circuit current levels involved. Where medium and high voltage primary fuses are involved, the time-current characteristic curves of the fuses in question should be plotted on standard NEMA log-log graph paper for proper study.

Component Protection

Introduction

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

In the past several years, there have been numerous reports in newspapers, magazines and insurance company files about destroyed electrical systems. Recognizing this as a serious problem to safety of life and property, much more emphasis has been placed on COMPLIANCE with THE NATIONAL ELECTRICAL CODE.

The National Electrical Code covers COMPONENT PROTECTION in several sections. The first section to note is Section 110-10.

Component Protection and the National Electrical Code

Section 110-10. Circuit Impedance and Other Characteristics. The overcurrent protective devices, the total impedance, the component short-circuit withstand ratings, and other characteristics of the circuit to be protected shall be so selected and coordinated as to permit the circuit protective devices used to clear a fault without the occurrence of extensive damage to the electrical components of the circuit. This fault shall be assumed to be either between two or more of the circuit conductors, or between any circuit conductor and the grounding conductor or enclosing metal raceway.

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

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

After calculating the fault levels throughout the electrical system, the next step is to check the withstand rating of wire and cable, but circuit breakers, transfer switches, starters, etc. not only under overload conditions but also under short-circuit conditions.

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

CAUTION: Choosing overcurrent protective devices strictly on the basis of voltage, current, and interrupting rating alone will not assure component protection from short-circuit currents. High interrupting capacity electro-mechanical overcurrent protective devices, especially those that are not current-limiting, may not be capable of protecting wire, cable or other components within high short-circuit ranges. The interrupting rating of a protective device pertains only to that device and has absolutely no bearing on its ability to protect connected downstream components. Quite often, an improperly protected component is completely destroyed under short-circuit conditions while the protective device is opening the faulted circuit.

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

CURRENT-LIMITATION

A Definition of Current-Limitation

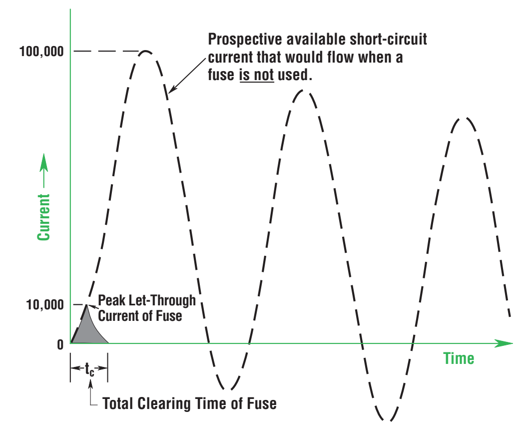
Today, most electrical distribution systems are capable of delivering very high short-circuit currents, some in excess of 200,000 amperes. If the components are not capable of handling these short-circuit currents, they could easily be damaged or destroyed. The current-limiting ability of today's modern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

Section 240-11 of the NEC offers the following definition of a current-limiting device:

"A current-limiting overcurrent protective device is a device which, when interrupting currents in its current-limiting range, will reduce the current flowing in the faulted circuit to a magnitude substantially less than that obtainable in the same circuit if the device were replaced with a solid conductor having comparable impedance."

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

Current-Limiting Effect of Fuses



Thus, the current-limiting fuse in this example would limit the let-through energy to a fraction of the value which is available from the system. In the first major loop of fault current, standard non-current-limiting, electro-mechanical protective devices would let-through approximately 100 times* as much destructive energy as the fuse would let-through.

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

Component Protection

Analysis of Current-Limiting Fuse Let-Through Charts

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

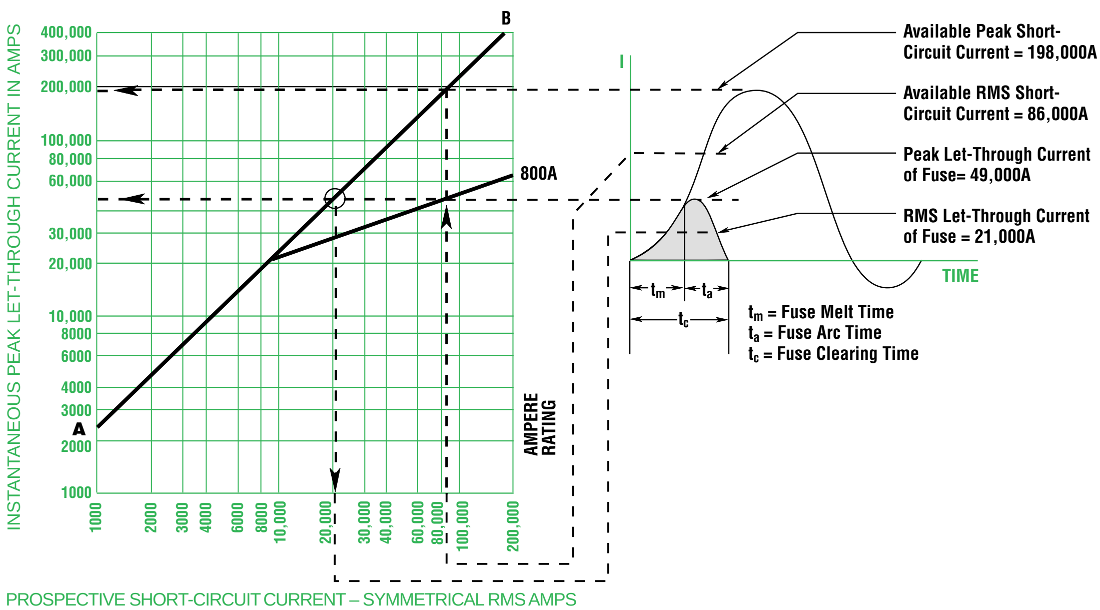
Fuse let-through charts are plotted from actual test data. The test circuit that establishes line A-B corresponds to a short-circuit power factor of 15%, which is associated with an X/R ratio of 6.6. The fuse curves represent the cutoff value of the prospective available short-circuit current under the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

The let-through data has been generated by actual short-circuit tests of current-limiting fuses. It is important to understand how the curves are generated, and what circuit parameters affect the let-through curve data. Typically, there are three circuit parameters that can affect fuse let-through performance for a given available short-circuit current. These are:

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

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

Analysis of a Current-Limiting Fuse



Component Protection

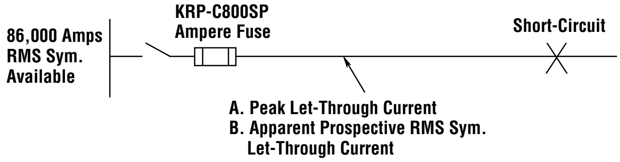
Prior to using the Fuse Let-Through Charts, it must be determined what let-through data is pertinent to equipment withstand ratings.

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

A. Peak let-through current - mechanical forces
B. Apparent prospective RMS symmetrical let-through current - heating effect

This is a typical example showing the short-circuit current available to an 800 ampere circuit, an 800 ampere LOW-PEAK® current-limiting time-delay fuse, and the let-through data of interest.

800 Ampere LOW-PEAK® Current-Limiting Time-Delay Fuse and Associated Let-Through Data



How to Use the Let-Through Charts

Using the example given, one can determine the pertinent let-through data for the KRP-C800SP ampere LOW-PEAK® fuse. The Let-Through Chart pertaining to the 800 ampere LOW-PEAK® fuse is illustrated.

A. Determine the PEAK LET-THROUGH CURRENT.

Step 1. Enter the chart on the Prospective Short-Circuit current scale at 86,000 amperes and proceed vertically until the 800 ampere 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 49,000 amperes. (If a fuse had not been used, the peak current would have been 198,000 amperes.)

B. Determine the APPARENT PROSPECTIVE RMS SYMMETRICAL LET-THROUGH CURRENT.

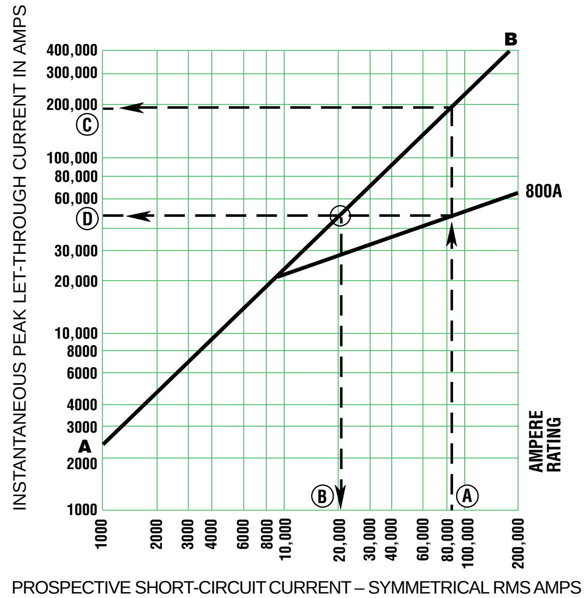
Step 1. Enter the chart on the Prospective Short-Circuit current scale at 86,000 amperes and proceed vertically until the 800 ampere fuse curve is intersected.

Step 2. Follow horizontally until line A-B is intersected.

Step 3. Proceed vertically down to the Prospective Short-Circuit Current.

Step 4. Read the APPARENT PROSPECTIVE RMS SYMMETRICAL LET-THROUGH CURRENT as 21,000 amperes. (The RMS SYMMETRICAL LET-THROUGH CURRENT would be 86,000 amperes if there were no fuse in the circuit.)

Current-Limitation Curves — Bussmann LOW-PEAK® Time-Delay Fuse KRP-C800SP



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

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

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

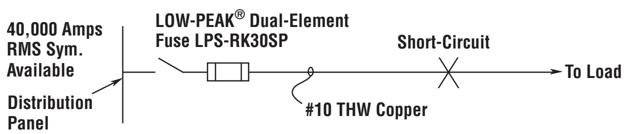
The following components will be analyzed by establishing the short-circuit withstand data of each component and then selecting the proper current-limiting fuses for protection:

- Wire and Cable
- Bus (Busway, Switchboards, Motor Control Centers and Panelboards)
- Low-Voltage Motor Controllers
- Ballasts
- Circuit Breakers
- Transfer Switches
- HVAC Equipment

Component Protection — Wire and Cable

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

Short-Circuit Protection of Wire and Cable



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

The short-circuit withstand of the #10 THW copper conductor is 4,300 amperes for one cycle (.0167 seconds). Short-circuit protection of this conductor requires the selection of an overcurrent device which will limit the 40,000 amperes RMS symmetrical available to a value less than 4,300 amperes, and clear the fault in one cycle or less.

The LOW-PEAK® dual-element fuse let-through chart shows that the LPS-RK30SP LOW-PEAK® dual-element fuse will let-through an apparent prospective RMS current of less than 1,800 amperes, when 40,000 amperes is available (and would clear the fault in less than 1/2 cycle).

Short-Circuit Currents for Insulated Cables

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

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

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

Thus, if the protective device requires one cycle to open (such as a circuit breaker) then 1/0 THW copper cables must be specified for the 30 ampere circuit in order to prevent damaging temperature rise to the insulation.

Using the formula shown on the ICEA protection table will allow the engineer to calculate withstand ratings of cable not shown on these pages. It may be advantageous to calculate withstand ratings below one cycle, when the opening time of the current-limiting device is known.

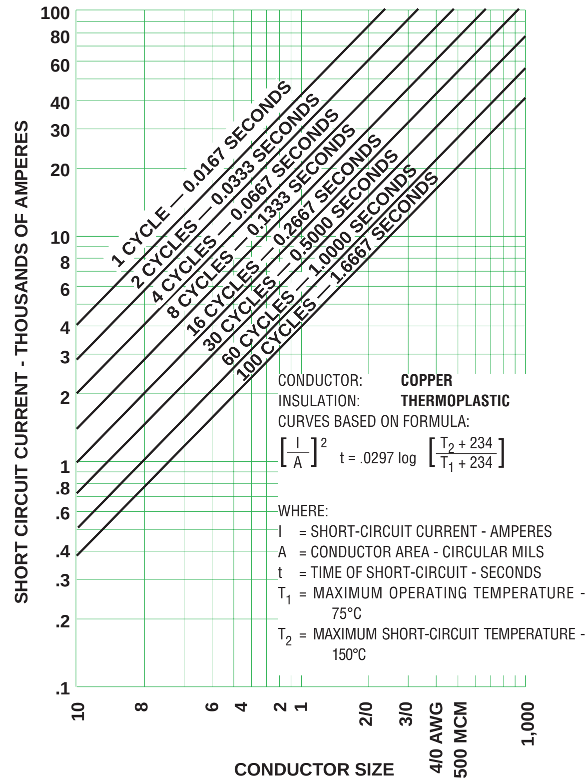
An example of additional withstand ratings for 75°C copper wire is shown below.

Copper, 75° Thermoplastic Insulated Cable Damage Table (Based on 60 HZ)

Copper Wire Size 75°C Thermoplastic	Maximum Short-Circuit Withstand Current in Amperes 1/8 Cycles*	1/4 Cycles*	1/2 Cycles*	1 Cycle	2 Cycles	3 Cycles
#14*	4,800	3,400	2,400	1,700	1,200	1,000
#12*	7,600	5,400	3,800	2,700	1,900	1,550
#10	12,000	8,500	6,020	4,300	3,000	2,450
#8	19,200	13,500	9,600	6,800	4,800	3,900
#6	30,400	21,500	16,200	10,800	7,600	6,200
#4	48,400	34,200	24,200	17,100	12,100	9,900

* Extrapolated data.

Short-Circuit Current Withstand Chart for Copper Cables with Thermoplastic Insulation
Allowable Short-Circuit Currents for Insulated Copper Conductors*



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

Protecting Equipment Grounding Conductors

Safety issues arise when the analysis of equipment grounding conductors is discussed. Table 250-95 of the NEC offers minimum sizing for equipment grounding conductors.

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

In addition to this and the ICEA charts, a third method promoted by Onderdonk allows the calculation of the energy necessary to cause the conductor to melt (75°C to 1,083°C).

The following table offers a summary of these values associated with various size copper conductors.

It becomes obvious that the word "Minimum" in the heading of table 250-95 means just that - the values in the table are a minimum - they may have to be increased due to the available short-circuit current and the current-limiting, or non-current-limiting ability of the overcurrent protective device.

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

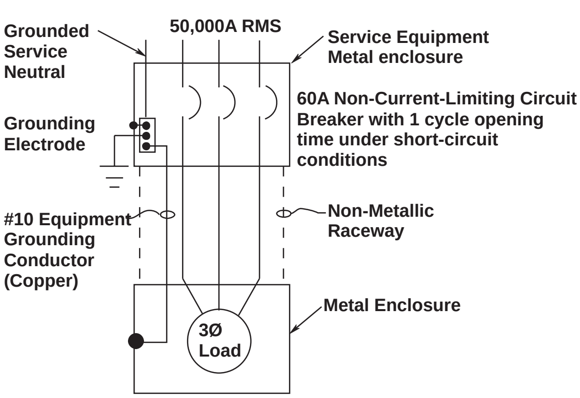
Component Protection — Wire and Cable

Comparison of Equipment Grounding Conductor Short-Circuit Withstand Ratings

Conductor Size	5 Sec. Rating (Amps) ICEA P32-382 Insulation Damage 150°C	5 Sec. Rating (Amps) Soares 1 Amp/30 cm Validity 250°C	5 Sec. Rating (Amps) Onderdonk Melting Point 1,083°C	I²t Rating x10⁶ (Ampere Squared Seconds) ICEA P32-382 Insulation Damage 150°C	I²t Rating x10⁶ Soares 1 Amp/30 cm Validity 250°C	I²t Rating x10⁶ Onderdonk Melting Point 1,083°C
14	97	137	253	.047	.094	.320
12	155	218	401	.120	.238	.804
10	246	346	638	.303	.599	2.03
8	391	550	1,015	.764	1.51	5.15
6	621	875	1,613	1.93	3.83	13.0
4	988	1,391	2,565	4.88	9.67	32.9
3	1,246	1,754	3,234	7.76	15.4	52.3
2	1,571	2,212	4,078	12.3	24.5	83.1
1	1,981	2,790	5,144	19.6	38.9	132.0
1/0	2,500	3,520	6,490	31.2	61.9	210.0
2/0	3,150	4,437	8,180	49.6	98.4	331.0
3/0	3,972	5,593	10,313	78.9	156.0	532.0
4/0	5,009	7,053	13,005	125.0	248.0	845.0
250	5,918	8,333	15,365	175.0	347.0	1,180.0
300	7,101	10,000	18,438	252.0	500.0	1,700.0
350	8,285	11,667	21,511	343.0	680.0	2,314.0
400	9,468	13,333	24,584	448.0	889.0	3,022.0
500	11,835	16,667	30,730	700.0	1,389.0	4,721.0
600	14,202	20,000	36,876	1,008.0	2,000.0	6,799.0
700	16,569	23,333	43,022	1,372.0	2,722.0	9,254.0
750	17,753	25,000	46,095	1,576.0	3,125.0	10,623.0
800	18,936	26,667	49,168	1,793.0	3,556.0	12,087.0
900	21,303	30,000	55,314	2,269.0	4,500.0	15,298.0
1,000	23,670	33,333	61,460	2,801.0	5,555.0	18,867.0

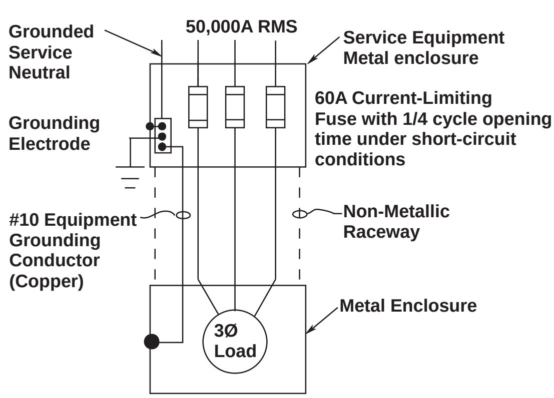
Take the example below. The EGC must be protected from damage. It can withstand 4,300 amperes of current for 1 cycle. The 1 cycle opening time of the circuit breaker will cause damage to the #10 EGC. However, a current-limiting fuse will limit the current to within the withstand rating of the EGC. An LPS-RK60SP will limit the line to ground current to approximately 3300 amperes, providing protection.

VIOLATION



Would need to increase Equipment Grounding Conductor to 2/0, per ICEA Std. P-32-382.

COMPLIANCE



Conforms to Section 110-10 and 250-95.

Component Protection —
Bus Short-Circuit Rating and Bracing Requirements

Bus Short-Circuit Rating Requirements When Protected by Current-Limiting Fuses

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

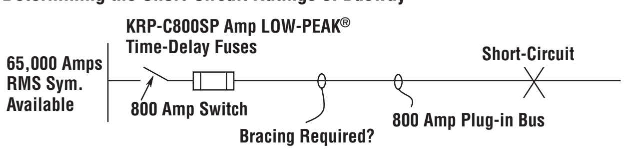
Since the short-circuit ratings of busways are established on the basis of minimum three-cycle duration tests, these ratings will not apply unless the protective device used will remove the fault within three cycles or less.*

BUSWAYS MAY BE USED ON CIRCUITS HAVING AVAILABLE SHORT-CIRCUIT CURRENTS GREATER THAN THE BUSWAY RATING WHEN PROPERLY COORDINATED, AND RATED WITH CURRENT-LIMITING DEVICES.*

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

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

Determining the Short-Circuit Ratings of Busway



The 800 ampere plug-in bus could be subjected to 65,000 amperes at its line side; however, the KRP-C800SP ampere LOW-PEAK® time-delay fuse would limit this available current. When protected by KRP-C800SP ampere LOW-PEAK® time-delay fuses, the 800 ampere bus need only be braced for 19,000 amperes RMS symmetrical. This would allow a standard 22,000 ampere RMS symmetrical (3-cycle) rated bus to be specified, whereas, if a non-current-limiting type protective device were specified, the bracing requirements would have been 65,000 amperes for three cycles.

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

When applying air frame circuit breakers with short-time-delay (STD), the engineer must specify additional short-circuit bracing based on the STD time setting. For example, an 800 ampere air frame circuit breaker may have an intentional 18 cycle STD to selectively coordinate with downstream breakers. It is imperative that the 800 ampere busway also be braced for this 18 cycles to avoid damage or destruction.

*NEMA Pub. No. BU1-1988.

The busway short-circuit short-time rating has a mechanical limit. Exceeding this limit invites mechanical damage due to the high magnetic forces associated with the peak current of the fault. The mechanical limit typically applies for high faults near and below the busway short-circuit rating. Allowable durations of short-circuit current, longer than the 3-cycles at 60 Hz (0.05 seconds) required at the maximum short-circuit rating, are obtained from a constant I^2t "mechanical damage limit" curve.

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

The following examples compare busway short-circuit overcurrent protection by low voltage circuit breakers and current-limiting fuses. This study looks at the development of the busway mechanical withstand curves and the time-current curves of the breakers and fuses.

In this example, the 800 ampere plug-in busway has a 65 kA short-circuit rating.

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

Assume the available short-circuit current at the busways is equal to the 65 kA rating. The overcurrent devices are assumed to have the proper interrupting capacity.

In order to coordinate selectively with circuit breakers that are instantaneously tripped, the power circuit breaker protecting the busway does not have an instantaneous trip.

There is a problem with the protection of this busway. The short-time-delay needed to achieve coordination results in a lack of protection of the 800 ampere busway. A short-circuit on this busway can result in damage. As noted on the curve, a 65,000 ampere fault will intersect the mechanical damage curve before the breaker trips.

This busway would have to be braced to withstand 65,000 amperes of short-circuit current for a minimum of 12 cycles.

A plot of the same system utilizing LOW-PEAK® Class L and Class RK1 fuses is also shown. Current-limitation by the KRP-C800SP will offer short-circuit protection for the busway, as it lets through 19,000 amperes.

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

NEMA (Standard Short-Circuit Ratings of Busway*)

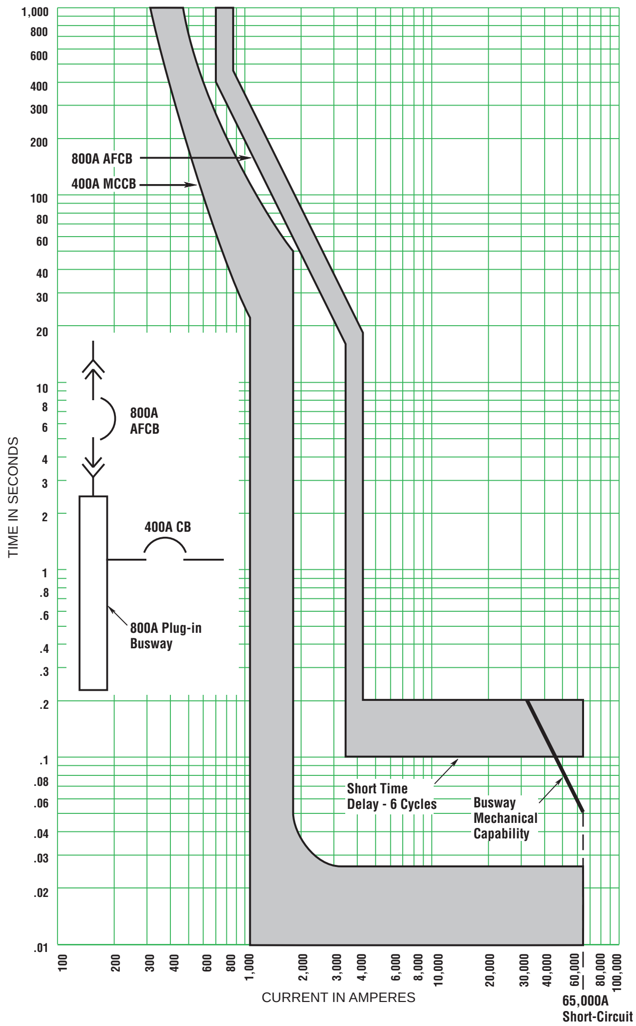
Continuous Current Rating of Busway (Amperes)	Short-Circuit Current Ratings (Symmetrical Amperes) Plug-In Duct	Feeder Duct
100	10,000	–
225	14,000	–
400	22,000	–
600	22,000	42,000
800	22,000	42,000
1000	42,000	75,000
1200	42,000	75,000
1350	42,000	75,000
1600	65,000	100,000
2000	65,000	100,000
2500	65,000	150,000
3000	85,000	150,000
4000	85,000	200,000
5000	–	200,000

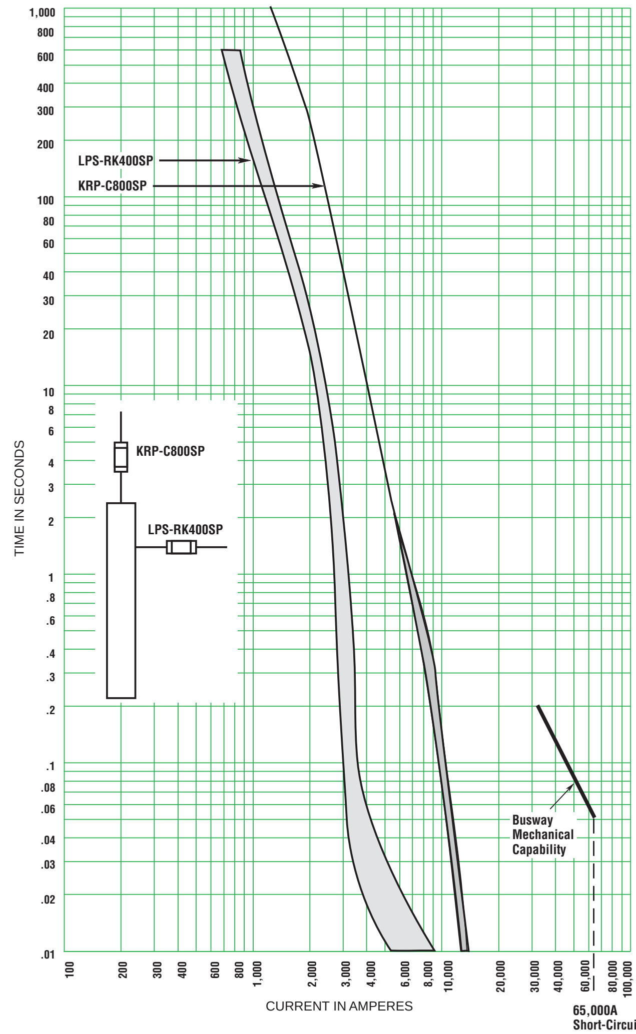
This table pertains to feeder and plug-in busway. For switchboard and panelboard standard ratings refer to manufacturer.

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

*Reprinted with permission of NEMA, Pub. No. BU1-1988.

Component Protection —
Bus Short-Circuit Rating and Bracing Requirements

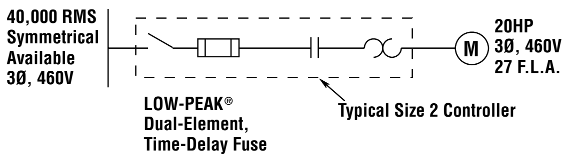




Component Protection — Low Voltage Motor Controllers

The diagram below shows a Size 2, combination motor controller supplying a 460 volt, 3Ø, 20HP motor. The short-circuit withstand of this and other motor controllers are established so that they may be properly protected from short-circuit damage.

Short-Circuit Protection of Motor Controller



There are several independent organizations engaged in regular testing of motor controllers under short-circuit conditions. One of these, Underwriter's Laboratories, tests controllers rated one horsepower or less and 300 volts or less with 1000 amperes short-circuit current available to the controller test circuit. Controllers rated 50HP or less are tested with 5000 amperes available and controllers rated above 50HP to 200HP are tested with 10,000 amperes available. See the table below for these values.*

Motor Controller HP Rating	Test Short-Circuit Current Available
1HP or less and 300V or less	1,000A
50HP or less	5,000A
Greater than 50HP to 200HP	10,000A
201HP to 400HP	18,000A
401HP to 600HP	30,000A
601HP to 900HP	42,000A
901HP to 1600HP	85,000A

It should be noted that these are basic short-circuit requirements. Higher, combination ratings are attainable if tested to an applicable standard. However, damage is usually allowed.

Type 1 vs. Type 2 Protection

U.L. has developed a short-circuit test procedure designed to verify that motor controllers will not be a safety hazard and will not cause a fire.

Compliance to the standard allows deformation of the enclosure, but the door must not be blown open and it must be possible to open the door after the test. In the standard short-circuit tests, the contacts must not disintegrate, but welding of the contacts is considered acceptable. When testing with fuses, damage to the overload relay is not allowed, and it must perform in accordance with the calibration requirements. Tests with circuit breakers allow the overload relay to be damaged with burnout of the current element completely acceptable.

For short-circuit ratings in excess of the standard levels listed in U.L. 508, the damage allowed is even more severe. Welding or complete disintegration of contacts is acceptable and complete burnout of the overload relay is allowed. Therefore, a user cannot be certain that the motor starter will not be damaged just because it has been U.L. Listed for use with a specific branch circuit protective device. U.L. tests are for safety, but do allow a significant amount of damage as long as it is contained within the enclosure.

*From Industrial Control Equipment, U.L. 508.

In order to properly select a branch circuit protective device that not only provides motor branch circuit protection, but also protects the circuit components from damage, the designer must look beyond mere safety standards. Coordination of the branch circuit protective device and the motor starter is necessary to insure that there will be no damage or danger to either the starter or the surrounding equipment. There is an IEC (International Electrotechnical Commission) Standard that offers guidance in evaluating the level of damage likely to occur during a short-circuit with various branch circuit protective devices. IEC Publication 947, "Low Voltage Switchgear and Control, Part 4-1: Contractors and Motor Starters", addresses the coordination between the branch circuit protective device and the motor starter. It also provides a method to measure the performance of these devices should a short-circuit occur. IEC defines two levels of protection (coordination) for the motor starter:

Type 1. Considerable damage to the contactor and overload relay is acceptable. Replacement of components or a completely new starter may be needed. There must be no discharge of parts beyond the enclosure.

Type 2. No damage is allowed to either the contactor or overload relay. Light contact welding is allowed, but must be easily separable.

Where Type 2 protection is desired, the controller manufacturer must verify that Type 2 protection can be achieved by using a specified protective device. U.S. manufacturers have recently begun having both their NEMA and IEC motor controllers verified to meet the Type 2 requirements outlined in IEC 947-4. As of this writing only current-limiting fuses have been able to provide the current-limitation necessary to provide verified Type 2 protection. In many cases, Class J, Class RK1, or Class CC fuses are required, because Class RK5 fuses and circuit breakers aren't fast enough under short-circuit conditions to provide Type 2 protection.

Section 430-52 of the National Electrical Code allows dual-element, time-delay fuses and other overcurrent protective devices to be sized for branch circuit protection (short-circuit protection only). Controller manufacturers often affix labels to the inside of the motor starter cover which recommend the maximum size fuse for each overload relay size.

A paragraph in Section 430-52 states:

"Where maximum branch circuit protective device ratings are shown in the manufacturer's overload relay table for use with a motor controller or are otherwise marked on the equipment, they shall not be exceeded even if higher values are allowed as shown above."**

This paragraph means that the branch circuit overcurrent protection for overload relays in motor controllers must be no greater than the maximum size as shown in the manufacturer's overload relay table. These maximum branch circuit sizes must be observed even though other portions of Section 430-52 allow larger sizing of branch circuit overcurrent protection.

The reason for this maximum overcurrent device size is to provide short-circuit protection for the overload relays and motor controller.

**"Above" refers to other portions of Section 430-52 not shown here.

Component Protection — Ballasts

The National Electrical Code requires integral thermal protection for ballasts in Section 410-73(e).

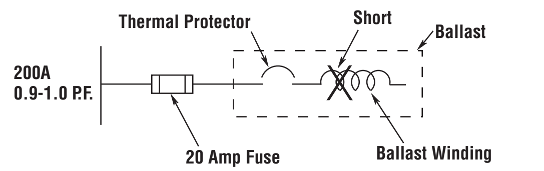
Testing agencies list ballasts for general use in lighting fixtures which pass specific thermal and short-circuit tests. The ballast must incorporate a thermal protector to sense certain over-temperature conditions and must also be able to withstand 200 amperes of short-circuit current when tested with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

Most systems today will deliver more than 200 amperes of short-circuit current to a row of fixtures. The fixtures should, therefore, be specified to incorporate individual ballast fusing within the fixture and external to the ballast.

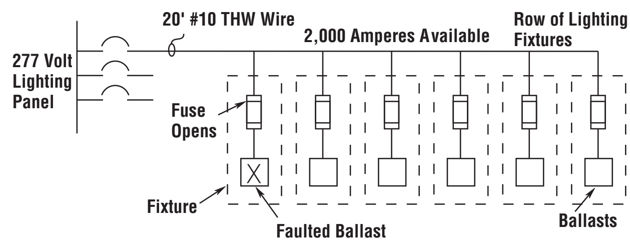
Fusing each fixture will also provide isolation of the faulted ballast and reduce costly and dangerous blackouts. When a ballast does fail, only the fuse protecting that individual fixture opens - the remaining fixtures continue in normal operation. Without this individual ballast protection, a faulted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

Note: Refer to fixture manufacturer for recommended fuse size.

Underwriters’ Laboratories Short-Circuit Test for Ballast Protectors



Fusing Fixture Ballasts to Provide Short-Circuit Protection and Isolation of Faulted Ballast. Good Ballasts Remain on the Line



Component Protection — Circuit Breakers

As has been discussed previously, the two parameters I_{RMS} and I_p, must be compared to the equipment withstand rating. The rule is simple: if the RMS and peak let-through value of the fuse are less than the equipment withstand rating, the equipment will be protected. This philosophy holds true for various static components, such as wire and cable, busway, and motor starters. This basic protection requirement is mandated in NEC Section 110-10. It will also be true for non-current-limiting circuit breakers when their opening time is greater than one-half cycle.

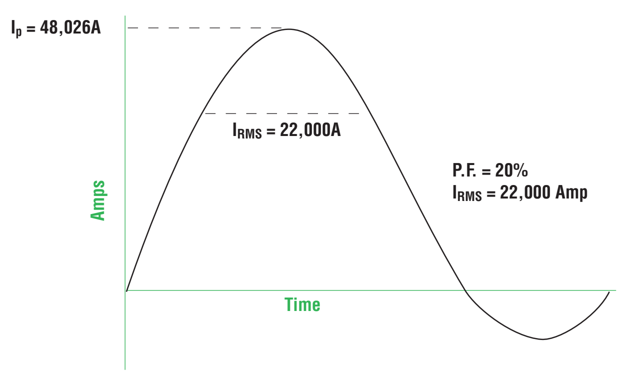
In the past, as long as the fuse let-through values were less than the breaker’s interrupting rating, the system was considered sound. THIS METHOD HAS A SOLID HISTORY OF SUCCESSFUL APPLICATIONS. However, due to changes in circuit breaker design, the method may not always work with today’s circuit breakers. Selecting a current-limiting fuse to protect a downstream molded case circuit breaker has now become an increasingly more complex problem.

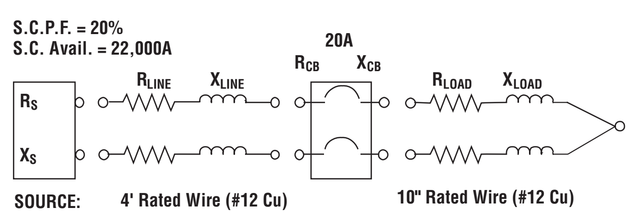
Quicker Operating Circuit Breakers

Simply put, if the total clearing energy of a quicker acting molded case circuit breaker is less than the melting energy of a larger upstream fuse, the molded case circuit breaker will interrupt the full value of the system fault without the benefit of the fuse’s current-limiting effect. This situation can have catastrophic effects on the circuit breaker as it tries to interrupt faults beyond its interrupting capacity. Currently, there is no available engineering method to predict protection of these faster breakers.

Molded Case Circuit Breakers - Agency Test Procedures

Some agency standards allow a unique test set-up for testing circuit breaker interrupting ratings. The Graph at the right illustrates a typical calibrated test circuit waveform for a 20A, 240-volt, two-pole molded case circuit breaker, with a marked interrupting rating of 22,000 amperes RMS symmetrical. The Figure also illustrates the calibration required by the standard, and the maximum peak current available at a 20% power factor. However, agency standards allow for a random close during the short-circuit test, so the peak available current may be as low as 1.414 times the RMS current for one- and two-pole circuit breakers. For three-pole circuit breakers, one pole may see a peak of only 1.414 × RMS. The conservative approach would therefore assume a 1.414 multiplier also for three-pole breakers.



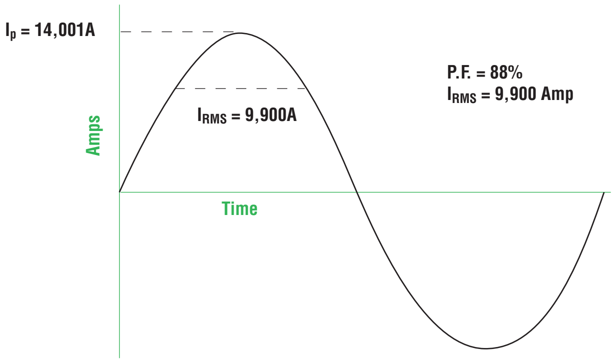


Note: For calculations, R_{CB} and X_{CB} are assumed negligible.

Standard interrupting rating tests will allow for a maximum 4-foot rated wire on the line side, and a 10-inch rated wire on the load side of the circuit breaker. Performing a short-circuit analysis of this test circuit results in the following short-circuit parameters, as seen by the circuit breaker.

Actual short-circuit RMS current = 9,900 amperes RMS symmetrical
Actual short-circuit power factor = 88%
Actual short-circuit peak current = 14,001 amperes

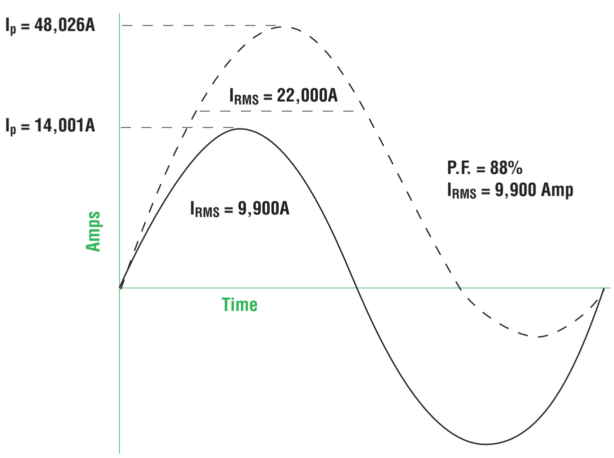
A graphic analysis of this actual short-circuit follows.



Agency standards allow for a random close during the short-circuit test, so the peak available current may be as low as 1.414 times the RMS symmetrical current.

Thus, the circuit breaker is actually tested to interrupt 9,900 amperes at 88% power factor, not 22,000 amperes at 20% power factor.

The following graph shows the waveforms superimposed for comparison. Henceforth, this RMS test value will be identified as the circuit breaker interrupting capacity. (Don't confuse this with the circuit breaker marked interrupting rating.)



The following definitions should be noted:

Interrupting Rating (CB): The marked rating shown on the Circuit Breaker. It has been established by testing.*

Interrupting Capacity (CB): Actual test I_p and I_{RMS} the circuit breaker sees during the tests for standard circuit breaker applications.*

Equally important, the short-circuit power factor is greatly affected due to the high R values of the small, rated wire. This results in a lower peak value that the circuit breaker must tolerate during the first one-half cycle.

Following is a partial table showing the actual I_p and I_{RMS} values to which a circuit breaker may be tested.

240V - 2-Pole CB Interrupting Capacities (KA)

CB Rating	10kA		14kA		18kA	
	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}
15	7.2	5.1	8.7	6.1	9.3	6.6
20	8.9	6.3	11.4	8.1	12.6	8.9
25	10.7	7.5	14.2	10.1	16.5	11.7
30	10.7	7.5	14.2	10.1	16.5	11.7
40	11.7	8.3	16.0	11.3	19.2	13.6
50	11.7	8.3	16.0	11.3	19.2	13.6
60	12.5	8.8	17.3	12.2	21.3	15.1
70	13.0	9.2	18.1	12.8	22.6	16.0
80	13.0	9.2	18.1	12.8	22.6	16.0
90	13.2	9.3	18.3	12.9	23.0	16.3
100	13.2	9.3	18.3	12.9	23.0	16.3

After reviewing the values to which the circuit breaker can be tested (its interrupting capacity) it becomes obvious that a circuit breaker's interrupting rating cannot be considered its short-circuit withstand rating (especially for breakers with higher interrupting ratings).

"Fully Rated System": A fully rated system is a combination of overcurrent devices that have an interrupting rating equal to or greater than the available short-circuit current.

"Series Rated System": Although there is no official definition, a series rated system can be described as a combination of circuit breakers or fuses and breakers that can be applied at available fault levels above the interrupting rating of the load side circuit breakers, but not above that of the main or line side device (formerly known as a Cascaded System).

Bussmann's recommendation is to use fully rated overcurrent devices. But, when a series rated system is desired, the recommended alternative is to use listed switchboards, panelboards, and load centers which have been tested listed and marked for use with recognized combinations of line side fuses and load side circuit breakers.

* These definitions paraphrase those given in the IEEE Standard Dictionary of Electrical and Electronic Terms, page 462, 1984 edition.

Component Protection — Transfer Switches

Transfer switches are designed to transfer power sources under load in order to feed a system, typically an emergency system, on critical loads. These devices are tested to meet basic short-circuit testing requirements. Transfer switches are often tested per U.L. Standard 1008.

Transfer switches should always be evaluated on the basis of the maximum available short-circuit currents. The automatic transfer switch must withstand: a) the magnetic stresses imposed by the instantaneous peak current available at the point of application, and b) the thermal stresses imposed by the available RMS short-circuit current. The short-circuit current withstand rating of the transfer switch must be equal to or greater than the available short-circuit current at the point of application.

When properly coordinated with current-limiting devices, automatic transfer switches can be used on circuits having available short-circuit currents greater than their unprotected withstand short-circuit current rating. Modern current-limiting fuses, when properly sized, limit the short-circuit current to within the withstand rating of a transfer switch.

Transfer switches must withstand minimum short-circuit currents at specified power factors, as listed in U.L. Standard 1008, until the overcurrent protective devices open.

U.L. 1008 Minimum Withstand Test Requirement

Automatic Transfer Switch Rating	U.L. Minimum Current Amps	U.L. Test Current Power Factor
100 Amps or less	5,000	40% to 50%
101-400 Amps	10,000	40% to 50%
401 Amps and greater	20 times rating but not less than 10,000 Amps	40% to 50% for current of 10,000 Amps. OR 25% to 30% for currents of 20,000 Amps or less. OR 20% or less for current greater than 20,000 Amps.

Transfer switch manufacturers generally publish the withstand rating data for their products. When the available short-circuit current exceeds the withstand rating of the transfer switch, current-limitation is required. Properly sized modern current-limiting fuses ahead of the transfer switch limit the available short-circuit current to within the withstand rating of a transfer switch, thereby protecting the transfer switch. The transfer switch manufacturer will mark the equipment with the fuse class and rating required to achieve these higher short-circuit ratings.

Component Protection — HVAC Equipment

Heating and cooling equipment must meet short-circuit test requirements in U.L. Standard 1995 and CSA-C22.2 No. 236-M90. Short-circuit tests are conducted at various levels, up to a maximum of only 5000 amperes, depending on the rated current and voltage of the equipment.

Where available fault currents exceed the values given in Table 55.1 of U.L. 1995 it is necessary to specify a current-limiting device to reduce the available current down to within the withstand capabilities of the equipment.

Class J and Class RK1 dual-element current-limiting fuses will offer the best component short-circuit protection and current-limiting characteristics for this type of equipment.

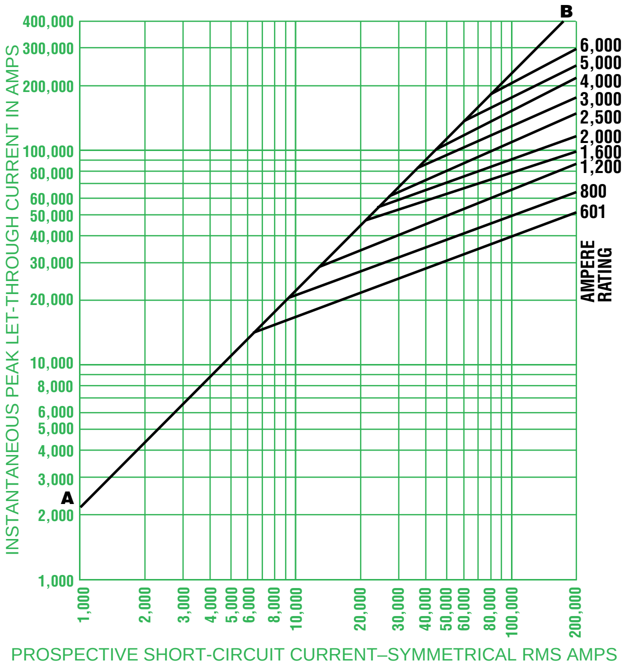
Short-Circuit Test Currents*

Product Ratings, A				
	Single-Phase			**Circuit Capacity,**
110-120V	**200-208V**	**220-240V**	**254-277V**	**A**
9.8 or less	5.4 or less	4.9 or less	–	200
9.9-16.0	5.5-8.8	5.0-8.0	6.65 or less	1000
16.1-34.0	8.9-18.6	8.1-17.0	–	2000
34.1-80.0	18.7-44.0	17.1-40.0	–	3500
Over 80.0	Over 44.0	Over 40.0	Over 6.65	5000
	3-Phase			**Circuit Capacity,**
200-208V	**220-240V**	**440-480V**	**550-600V**	**A**
2.12 or less	2.0 or less	–	–	200
2.13-3.7	2.1-3.5	1.8 or less	1.4 or less	1000
3.8-9.5	3.6-9.0	–	–	2000
9.6-23.3	9.1-22.0	–	–	3500
Over 23.3	Over 22.0	Over 1.8	Over 1.4	5000

*Table 55.1 of U.L. Standard 1995.

Component Protection — Let-Through Charts

LOW-PEAK® YELLOW™ Class L Time-Delay Fuses
KRP-C_SP

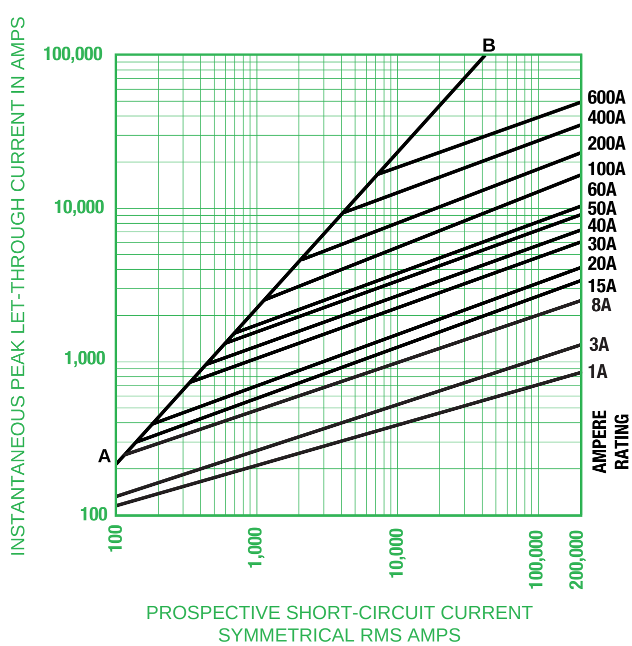


KRP-C_SP Fuse – RMS Let-Through Currents (kA)

Prosp. Short C.C.	Fuse Size 601	800	1200	1600	2000	2500	3000	4000	5000	6000
	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}
5,000	5	5	5	5	5	5	5	5	5	5
10,000	7	10	10	10	10	10	10	10	10	10
15,000	9	11	14	15	15	15	15	15	15	15
20,000	10	12	15	20	20	20	20	20	20	20
25,000	11	13	17	22	25	25	25	25	25	25
30,000	11	14	18	24	26	29	30	30	30	30
35,000	12	15	18	25	28	30	35	35	35	35
40,000	13	16	19	26	29	32	38	40	40	40
50,000	14	17	22	28	31	35	43	48	50	50
60,000	15	18	24	30	33	38	46	52	60	60
70,000	16	19	25	31	35	41	48	56	65	70
80,000	16	20	27	32	37	43	52	59	70	80
90,000	17	21	28	34	38	46	54	63	74	85
100,000	18	22	29	35	39	48	57	65	78	89
150,000	21	25	34	39	46	57	70	83	96	113
200,000	23	28	37	43	50	65	78	96	109	130

Note: For I_{RMS} value at 300,000 amperes, consult Factory.

LOW-PEAK® YELLOW™ Class J, Dual-Element Time-Delay Fuses
LPJ_SP



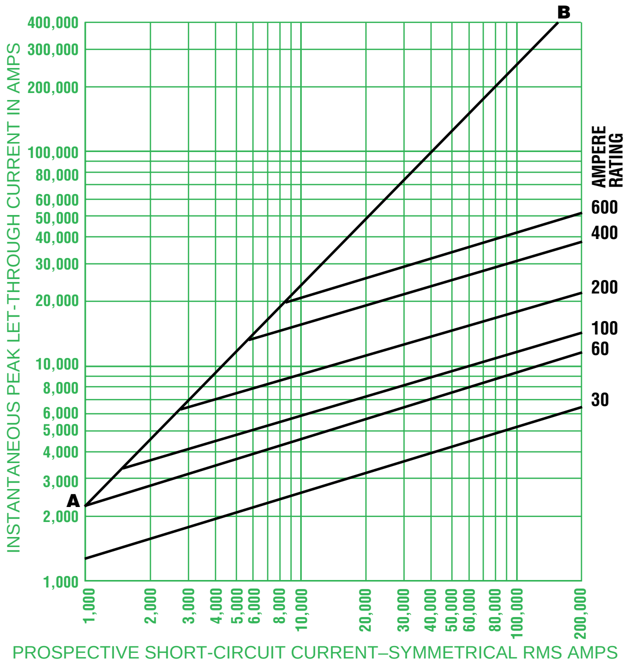
LPJ_SP Fuse – RMS Let-Through Currents (kA)

Prosp. Short C.C.	Fuse Size 15	30	60	100	200	400	600
	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}
1,000	0	0	1	1	1	1	1
3,000	0	1	1	2	2	3	3
5,000	0	1	1	2	3	4	5
10,000	1	1	2	2	4	6	8
15,000	1	1	2	3	4	6	9
20,000	1	1	2	3	4	7	10
25,000	1	1	2	3	5	8	11
30,000	1	2	2	4	5	8	12
35,000	1	2	3	4	5	8	13
40,000	1	2	3	4	6	9	13
50,000	1	2	3	4	6	9	14
60,000	1	2	3	5	6	10	15
80,000	1	2	3	5	7	11	16
100,000	1	2	4	5	8	12	17
150,000	1	2	4	6	9	14	19
200,000	2	3	4	7	10	16	21

Note: For I_{RMS} value at 300,000 amperes, consult Factory.

Component Protection — Let-Through Charts

LOW-PEAK® YELLOW™ Class RK1 Dual-Element Time-Delay Fuses LPN-RK_SP

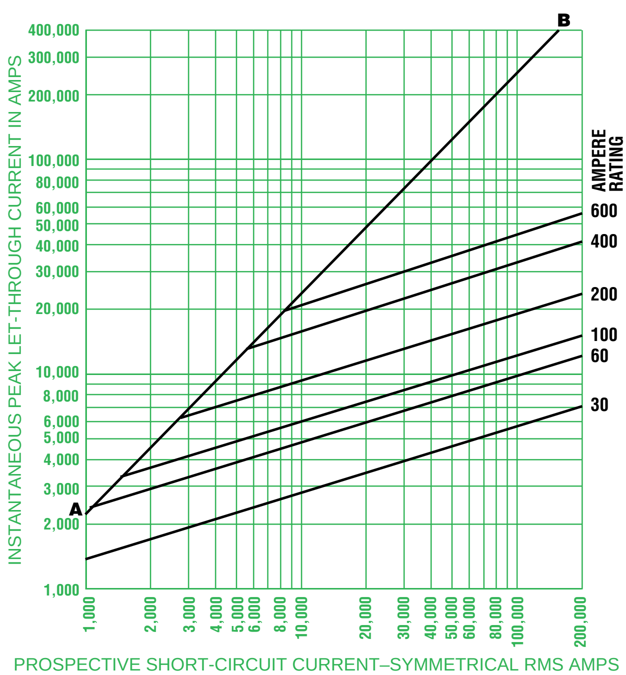


LPN-RK_SP – RMS Let-Through Currents (kA)

Prosp. Short C.C.	Fuse Size 30 I_{RMS}	60 I_{RMS}	100 I_{RMS}	200 I_{RMS}	400 I_{RMS}	600 I_{RMS}
1,000	1	1	1	1	1	1
2,000	1	1	2	2	2	2
3,000	1	1	2	3	3	3
5,000	1	2	2	3	5	5
10,000	1	2	2	4	7	9
15,000	1	2	3	4	7	10
20,000	1	2	3	5	8	11
25,000	1	3	3	5	9	12
30,000	2	3	3	5	9	13
35,000	2	3	4	6	10	13
40,000	2	3	4	6	10	13
50,000	2	3	4	6	10	14
60,000	2	3	4	7	11	15
70,000	2	3	4	7	12	16
80,000	2	4	5	7	12	17
90,000	2	4	5	7	13	17
100,000	2	4	5	8	13	17
150,000	2	4	5	8	16	20
200,000	3	5	6	9	18	22

Note: For I_{RMS} value at 300,000 amperes, consult Factory.

LOW-PEAK® YELLOW™ Class RK1 Dual-Element Time-Delay Fuses LPS-RK_SP



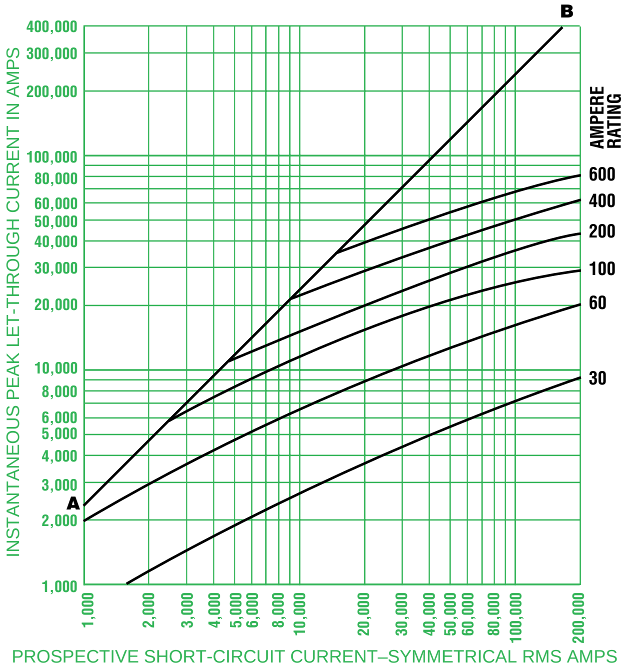
LPS-RK_SP – RMS Let-Through Currents (kA)

Prosp. Short C.C.	Fuse Size 30 I_{RMS}	60 I_{RMS}	100 I_{RMS}	200 I_{RMS}	400 I_{RMS}	600 I_{RMS}
1,000	1	1	1	1	1	1
2,000	1	1	2	2	2	2
3,000	1	1	2	3	3	3
5,000	1	2	2	3	5	5
10,000	1	2	3	4	7	9
15,000	1	2	3	5	8	10
20,000	1	3	3	5	8	11
25,000	2	3	3	5	9	12
30,000	2	3	4	6	10	13
35,000	2	3	4	6	10	13
40,000	2	3	4	6	10	14
50,000	2	3	4	7	11	15
60,000	2	3	4	7	12	16
70,000	2	4	5	7	13	17
80,000	2	4	5	8	13	17
90,000	2	4	5	8	13	18
100,000	2	4	5	8	14	19
150,000	3	5	6	9	16	22
200,000	3	5	7	10	17	23

Note: For I_{RMS} value at 300,000 amperes, consult Factory.

Component Protection — Let-Through Charts

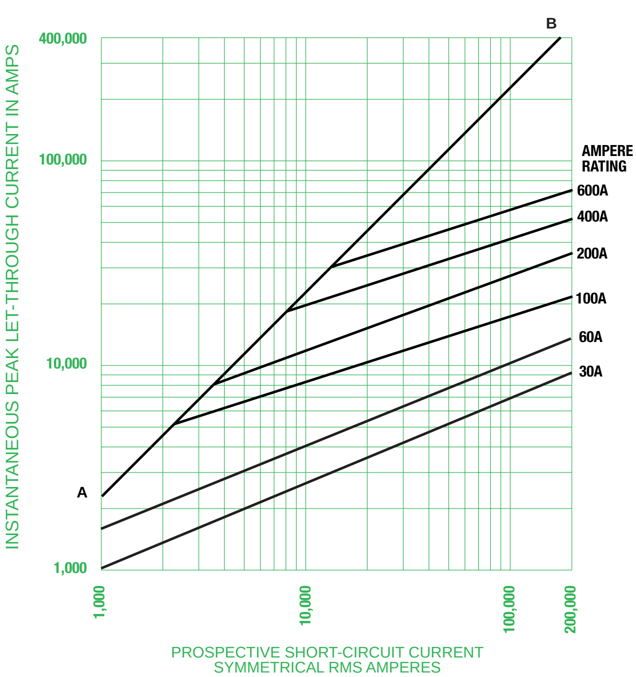
FUSETRON® Class RK5 Dual-Element Time-Delay Fuses
FRN-R



FRN-R – RMS Let-Through Currents (kA)

Prosp. Short C.C.	Fuse Size 30 I_{RMS}	60 I_{RMS}	100 I_{RMS}	200 I_{RMS}	400 I_{RMS}	600 I_{RMS}
5,000	1	2	3	5	5	5
10,000	1	3	5	7	9	10
15,000	1	3	6	8	11	14
20,000	2	4	7	8	12	16
25,000	2	4	7	9	13	17
30,000	2	4	7	10	14	19
35,000	2	5	8	11	15	20
40,000	2	5	8	11	15	20
50,000	2	5	9	12	16	22
60,000	2	6	9	12	17	23
70,000	3	6	10	13	18	24
80,000	3	6	10	13	19	25
90,000	3	7	10	14	19	26
100,000	3	7	10	14	20	27
150,000	3	8	11	16	23	30
200,000	4	8	12	17	24	32

FUSETRON® Class RK5 Dual-Element Time-Delay Fuses
FRS-R

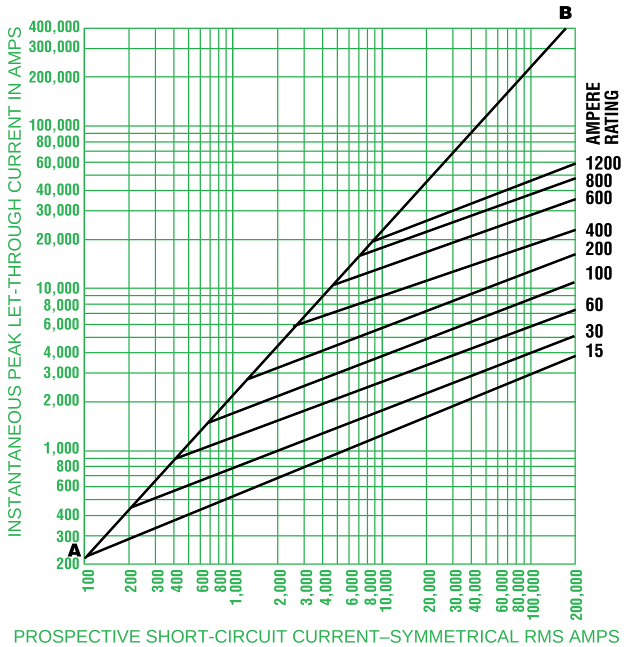


FRS-R – RMS Let-Through Currents (kA)

Prosp. Short C.C.	Fuse Size 30 I_{RMS}	60 I_{RMS}	100 I_{RMS}	200 I_{RMS}	400 I_{RMS}	600 I_{RMS}
5,000	1	2	3	5	5	5
10,000	2	3	5	7	10	10
15,000	2	3	5	8	13	15
20,000	2	3	6	10	14	17
25,000	3	4	6	10	16	19
30,000	3	4	7	11	17	20
35,000	3	4	7	12	18	22
40,000	3	5	8	12	19	23
50,000	3	5	8	13	20	24
60,000	4	5	9	14	21	26
70,000	4	6	9	15	22	27
80,000	4	6	9	15	23	28
90,000	4	6	10	16	23	29
100,000	4	7	10	16	24	30
150,000	5	7	11	18	26	33
200,000	6	8	11	19	27	35

Component Protection — Let-Through Charts

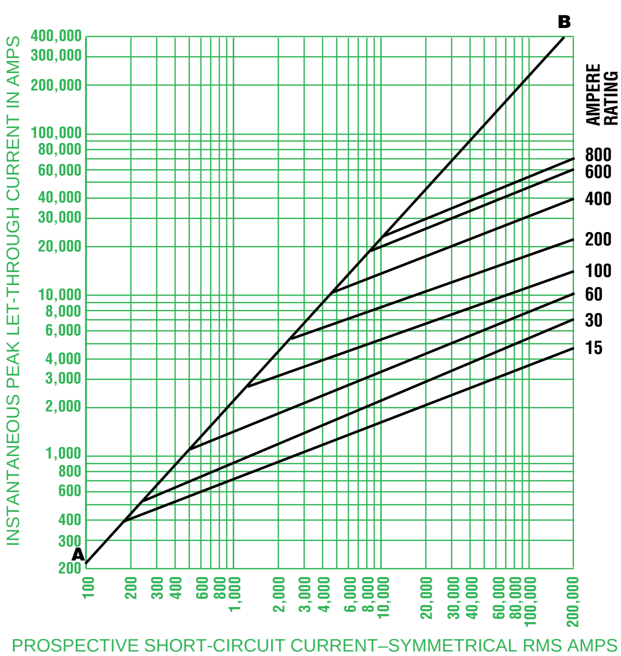
TRON® Class T Fast-Acting Fuses
JJN



JJN – RMS Let-Through Current (kA)

Prosp. Short C.C.	Fuse Size 15	30	60	100	200	400	600	800	1200
	IRMS	IRMS	IRMS	IRMS	IRMS	IRMS	IRMS	IRMS	IRMS
500	0	0	0	1	1	1	1	1	1
1,000	0	0	1	1	1	1	1	1	1
5,000	0	1	1	1	2	3	5	5	5
10,000	1	1	1	2	2	4	6	7	9
15,000	1	1	1	2	3	4	6	9	10
20,000	1	1	1	2	3	5	7	10	11
25,000	1	1	2	2	3	5	7	10	12
30,000	1	1	2	2	3	5	8	11	13
35,000	1	1	2	3	4	6	8	11	13
40,000	1	1	2	3	4	6	9	11	13
50,000	1	1	2	3	4	7	9	12	15
60,000	1	1	2	3	4	7	10	13	16
70,000	1	1	2	3	5	7	10	14	17
80,000	1	2	2	3	5	8	11	15	17
90,000	1	2	2	3	6	8	11	15	18
100,000	1	2	2	4	6	8	12	16	19
150,000	1	2	3	4	6	9	13	17	22
200,000	2	2	3	4	7	9	15	19	23

TRON® Class T Fast-Acting Fuses
JJS

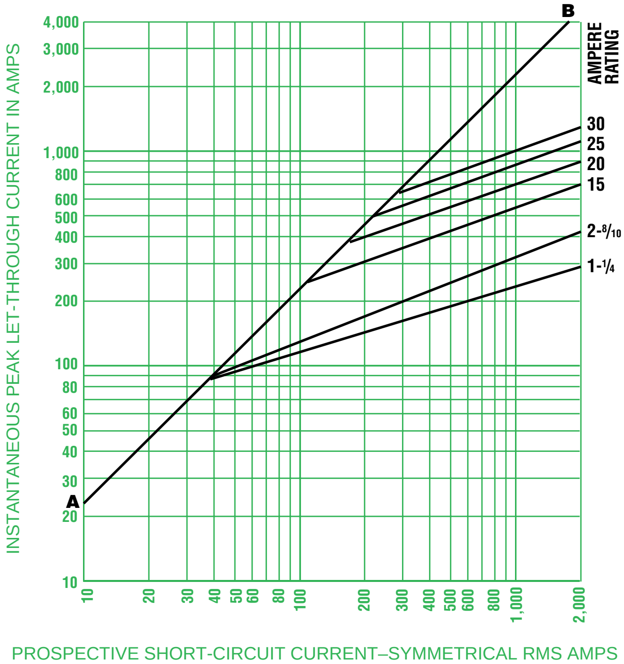


JJS – RMS Let-Through Current (kA)

Prosp. Short C.C.	Fuse Size 15	30	60	100	200	400	600	800
	IRMS	IRMS	IRMS	IRMS	IRMS	IRMS	IRMS	IRMS
500	0	0	0	1	1	1	1	1
1,000	0	0	1	1	1	1	1	1
5,000	1	1	1	2	3	4	5	5
10,000	1	1	1	2	3	6	8	9
15,000	1	1	2	3	4	7	10	11
20,000	1	1	2	3	4	7	10	12
25,000	1	1	2	3	5	7	11	13
30,000	1	1	2	3	5	8	12	14
35,000	1	1	2	3	5	9	13	15
40,000	1	2	2	4	5	9	13	15
50,000	1	2	2	4	6	10	14	17
60,000	1	2	3	4	6	10	16	18
70,000	1	2	3	4	7	11	17	19
80,000	1	2	3	4	7	11	17	20
90,000	1	2	3	4	7	12	18	21
100,000	2	2	3	5	7	12	19	22
150,000	2	3	4	6	8	14	22	25
200,000	2	3	4	6	9	16	24	28

Component Protection — Let-Through Charts

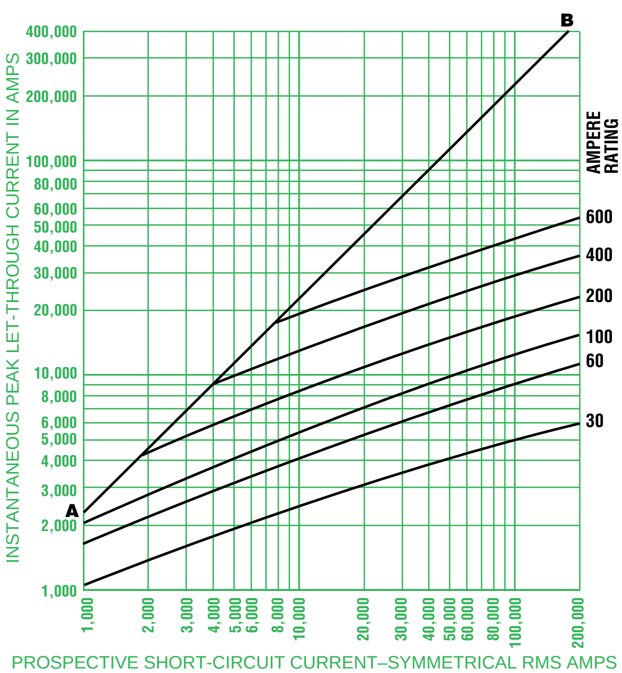
LOW-PEAK® YELLOW™ Class CC Time-Delay Fuses
LP-CC



LP-CC – RMS Let-Through Currents (kA)

Prosp. Short C.C.	Fuse Size 1¼	2⁸⁄₁₀	15	20	25	30
	IRMS	IRMS	IRMS	IRMS	IRMS	IRMS
1,000	100	135	240	305	380	435
3,000	140	210	350	440	575	580
5,000	165	255	420	570	690	710
10,000	210	340	540	700	870	1000
20,000	260	435	680	870	1090	1305
30,000	290	525	800	1030	1300	1520
40,000	315	610	870	1150	1390	1700
50,000	340	650	915	1215	1520	1820
60,000	350	735	1050	1300	1650	1980
80,000	390	785	1130	1500	1780	2180
100,000	420	830	1210	1600	2000	2400
200,000	525	1100	1600	2000	2520	3050

LIMITRON® Class J Fast-Acting Fuses
JKS



JKS – RMS Let-Through Currents (kA)

Prosp. Short C.C.	Fuse Size 30	60	100	200	400	600
	IRMS	IRMS	IRMS	IRMS	IRMS	IRMS
5,000	1	1	2	3	4	5
10,000	1	2	3	4	6	9
15,000	1	2	3	4	7	10
20,000	1	2	3	5	8	11
25,000	2	3	3	6	9	12
30,000	2	3	3	6	9	13
35,000	2	3	4	6	9	13
40,000	2	3	4	7	10	14
50,000	2	3	4	7	10	15
60,000	2	3	5	7	11	16
70,000	2	3	5	8	11	17
80,000	2	3	5	8	12	17
90,000	2	4	6	9	13	18
100,000	2	4	6	9	13	18
150,000	2	5	6	9	14	22
200,000	3	5	7	10	16	24

Flash Protection

MEETING NFPA 70E REQUIREMENTS FOR FLASH PROTECTION

Introduction

On January 7, 1976 a new electrical standards development committee was formed to assist the Occupational Safety and Health Administration (OSHA) in preparing electrical safety standards. This committee was needed for a number of reasons.

First, when adopted by Congress, OSHA incorporated the 1971 National Electrical Code®. OSHA refrained from adopting later editions due to the danger that the NEC® requirements would be significantly changed due to the required public comment.

Second, the NEC is an installation manual, while OSHA addresses employee safety in the workplace.

Third, not all sections in the NEC are safety related.

Fourth, many safety related work and maintenance practices are not covered, or not adequately covered, in the NEC.

As a result, the idea of a new standard was conceived. It consisted of four parts;

Part I	Installation Safety Requirements
Part II	Safety-Related Work Practices
Part III	Safety-Related Maintenance Requirements
Part IV	Safety Requirements for Special Equipment

Since each part was independent of the others, it was decided that they would be published as they were completed. The new standard (NFPA 70E, Standard for Electrical Safety Requirements for Employee Workplaces) was first published in 1979 and consisted of only Part I.

The second edition, published in 1981, consisted of the original Part I and a new Part II. The third edition was published in 1988. It included a revision of the original Parts I and II and a new Part III. The fourth edition (1995) is a major rewrite of existing text. Part IV will be developed at a later date.

The following will explore some of the new requirements in Part II as they pertain to the protection of workers against burns caused by electric arcs.

I. ARC BASICS

When a maintenance worker, that is "working a panel hot," goes to ground or phase to phase with a screwdriver, an arc is often formed. The temperature at the ends of an arc can reach approximately 35,000˚F, or about four times as hot as the surface of the sun. These temperatures can easily cause serious or fatal burns to exposed skin and/or ignite clothing.

II. SAFE WORKING DISTANCE FORMULA

Because employees were being seriously burned by electric arcs, NFPA 70E adopted formulas to define the safe working distance from a potential arc. The formulas for this calculation are based upon the work and a technical paper by Ralph Lee, "The Other Electrical Hazard: Electrical Arc Blast Burns," IEEE Transactions on Industrial Applications, Volume IA-18. No.3, May/June 1982.

Lee's work showed, for example, that skin temperature above 96˚C for .1 sec. resulted in total destruction of the tissue (incurable burn) and that skin temperature below 80˚C for .1 sec. allowed for skin which could be cured (just curable burn). At a distance of 3 feet, the arc energy required to produce these temperatures was determined to be 23MW and l7MW respectively. He also found that the maximum arc energy occurred when it represented 50% of the available three phase bolted fault. Therefore, the arc from a 46MVA available source for .1 second could cause an "incurable burn" at a distance of 3 feet. And, the arc from a 34 MVA available fault for .1 seconds at 3 feet would result in a "just curable" burn.

Following are the formulas developed by Mr. Lee and incorporated into NFPA 70E.

$D_C = (2.65 \times MVA_{bf} \times t)^{1/2}$

$D_f = (1.96 \times MVA_{bf} \times t)^{1/2}$*

where

D_C = distance in feet for a "just curable" burn

D_f = distance in feet for an "incurable burn"*

MVA_{bf} = bolted three phase MVA at point of short-circuit
= 1.73 × $VOLTAGE_{L-L}$ × AVAILABLE SHORT-CIRCUIT CURRENT × 10^{-6}

t = time of exposure in seconds

*Not included in NFPA 70E.

Example 1:

Assume an available 40896 ampere bolted 3 phase fault on a 480 volt system with a clearing time of 6 cycles (.1 second). Find the distance in feet for a just curable burn.

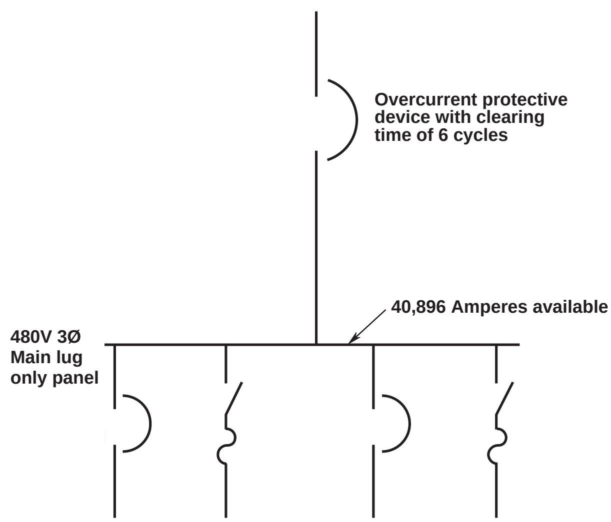
$D_C = (2.65 \times MVA_{bf} \times t)^{1/2}$ ft

$D_C = (2.65 \times 1.732 \times 480 \times 40896 \times 10^{-6} \times .1)^{1/2}$ ft

$D_C = (9.00)^{1/2}$ ft

$D_C = 3$ ft

This means that any exposed skin, closer than 3 feet to this available fault, for .1 seconds or longer, may not be curable, should an arcing fault occur. If the employee must work on this equipment where parts of his/her body would be closer than 3 feet from the possible arc, suitable protective equipment must be utilized so that the employee injury is minimized.



Example 2:

Assume that the same criteria exists as for Example 1 except that the equipment is being protected by a LPJ-200SP LOW-PEAK® YELLOW™ upstream fuse. The opening time is assumed at ¼ cycle (.004 seconds) and the equivalent RMS let-through current is read off a chart as 6,000 amperes.

$D_C = (2.65 \times MVA_{bf} \times t)^{1/2}$ ft

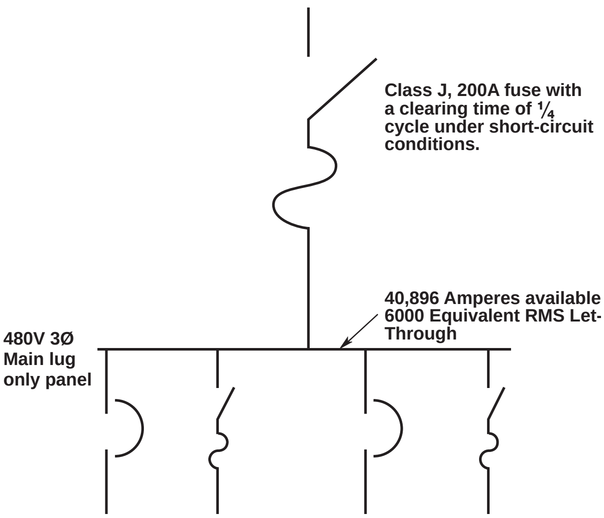
$D_C = (2.65 \times 1.732 \times 480 \times 6000 \times 10^{-6} \times .004)^{1/2}$

$D_C = (.0528)^{1/2}$ ft

$D_C = .229$ ft (or 2.75 inches)

Thus, the flash protection boundary was significantly decreased, from 3 feet (Example 1) to 2.75 inches (Example 2), by limiting the short-circuit current from 40,896 to 6000 amperes and by reducing the exposure time from 6 cycles to ¼ cycle.

The user also needs to examine the flash protection boundary for low levels of arcing faults. Low level faults, below the current-limiting threshold of a fuse or the instantaneous trip of a circuit breaker will often produce a greater flash protection boundary than higher level faults.



III. PROTECTIVE EQUIPMENT

Employees must wear, and be trained in the use of, appropriate protective equipment for the possible electrical hazards with which they are faced. Examples of equipment could include head, face, neck, chin, eye, ear, body, and extremity protection as required. All protective equipment must meet the requirements as shown in Table 3-3.6 of NFPA 70E-1995.

Protective equipment, sufficient for protection against an electrical flash, would be required for any part of the body which could be within 3 feet of the fault in Example 1. Such equipment would likely include a hard hat, face shield, flame retardant neck protection, ear protectors, Nomex™ suit, insulated rubber gloves with leather protectors, and insulated footwear.

IV. EXPOSURE TIME & FAULT CURRENT

Much equipment is manufactured with an integral main overcurrent device/disconnecting means. If it is possible to create a fault on the line side of the main, the opening time and let-through characteristics of the overcurrent device which feeds the main device should be considered.

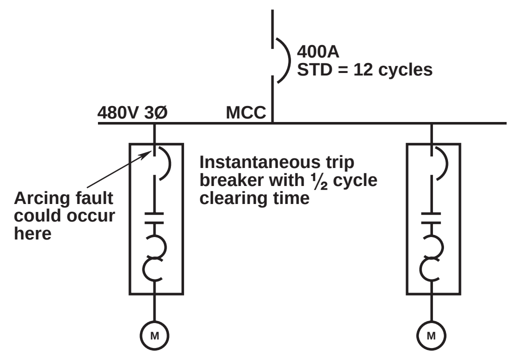
Example 3

A 10HP motor starter utilizes an instantaneous trip breaker for the main overcurrent device/disconnecting means. Even though it has an opening time of approximately ½ cycle (.0083 sec), the ½ cycle time cannot be used for the flash distance calculation if it is possible for a fault to be created on the line side of the instantaneous trip breaker (and it's almost always possible to create a fault on the line side). Assuming that this starter is fed from a 400 ampere air frame circuit breaker with short-time-delay set at 12 cycles (.2 sec.), the time which must be used in the flash distance calculation would be .2 seconds. That's the time it would take for the 400 ampere device on the line side to clear a fault if the fault occurred on the line side of the instantaneous trip breaker. The full available fault current, at the line side of the instantaneous trip breaker, would be used in the formula, because the 400 amp breaker would not be current-limiting.

The Standard suggests clearing times for current-limiting fuses of ¼ cycle and for 5KV and 15KV circuit breakers of 6 cycles. Industry accepted values for other devices are as follows:

TYPE OF DEVICE	TIME (Seconds)
Standard molded case circuit breakers (600 volt & below)	
without short-time-delay (STD)	.0083-.0167
with short-time-delay (STD)	STD Setting
Insulated case circuit breakers (600 volt & below)	
without short-time-delay	.033
with short-time-delay	STD Setting
Low voltage power (air frame) circuit breakers (600 volt & below)	
without short-time-delay	.05
with short-time-delay	STD Setting
Current-limiting molded case circuit breaker (600V & below)	.004

Where equivalent RMS let-through data is available, it can be used in the flash distance formula. Where data is unavailable, the full available short-circuit must be used.



V. OTHER ARC HAZARDS

In addition to the extreme heat generated by the arc, molten metal is often expelled. This metal can easily burn skin, eyes, and clothing. Although natural fibers, such as cotton, have been found to provide excellent resistance to ignition, the modern Aramid fibers will not ignite, and may therefore provide the best protection. Safety glasses with side shields and gloves are an absolute necessity to protect the eyes and hands against molten metal.

There are also tremendous pressures developed during an arcing fault. In Ralph Lee's paper "Pressures Developed by Arcs" IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL.IA-23, No. 4, JULY/AUGUST 1987, he calculates that the pressure developed at two feet from a 25,000 amp arc is 160 pounds per square foot.

That is equivalent to a total pressure on a typical worker's body of about 480 pounds, more than enough to blow the worker off a ladder or scaffolding. On a somewhat positive note, because the arc pressure blows the worker away, it tends to reduce the time that the person is exposed to the extreme heat of the arc.

Finally, a short-circuit created within an open enclosure may create such enormous explosive forces that shrapnel is expelled toward the workman. The greater the available short-circuit current the greater the explosive forces. Equipment listed to a nationally recognized safety standard does not assure shrapnel protection because the equipment was tested with the doors closed. Once the doors are opened, equipment listings are void. Current-limitation is an important factor in the protection of the worker from the potentially dangerous shrapnel.

Ground Fault Protection

Ground fault protection is equipment protection from the effects of ground faults. The National Electrical Code (N.E.C.) has specific ground fault equipment protection requirements in Sections 215-10, 230-95, 240-13 and 517-17. Ground fault relays (or sensors) are used to sense low magnitude ground faults. When the ground fault current magnitude and time reach the G.F. relay pick up setting, the control scheme signals the circuit disconnect to open.

Ground fault relays can **only** offer protection for equipment from the effects of **low** magnitude ground faults. Equipment protection against the effects of higher magnitude ground faults is dependent on the speed of response of the conventional overcurrent protective devices (fuses or circuit breakers.)

What It Is Not

Ground Fault Protection IS NOT:

- People protection. It will not prevent shock
- Ground fault prevention
- Protection from 3-phase, phase-phase, or phase-neutral faults
- Protection from high level ground faults
- A guarantee of a selectively coordinated system. In fact, coordination may be compromised.

Reliability

Ground fault relays are not simple and the ultimate reliability depends on the reliability of each element such as solid state sensor, monitor, control wiring, control power source, shunt trip, and circuit disconnecting means. If one element is incorrectly wired, inoperative, miscalibrated, or damaged, the low level ground fault protection may be negated. If the system neutral is incorrectly or accidentally grounded on the load side of the sensor, a ground fault can have a return path over the neutral and never trip the relay. Unfortunately, a nuisance outage often encourages the building owner or maintenance crew to disconnect the ground fault relay so that the power “stays on”.

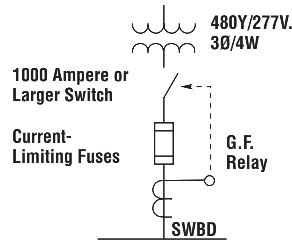
Ground fault relays are not maintenance free devices. Ground fault relay equipment relies on sensing equipment, shunt trips, switching devices, control circuits, etc. Complete periodic maintenance and electrical testing of the equipment by qualified personnel is necessary since it has components and mechanisms which can fail, malfunction, and/or lose calibration.

NATIONAL ELECTRICAL CODE - SECTION 230-95

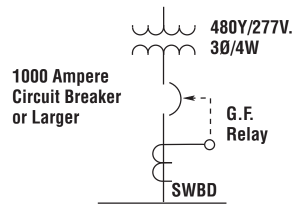
230-95. Ground Fault Protection of Material

This Section means that 480Y/277 volt, solidly grounded “wye” only connected service disconnects, 1000 amperes and larger, must have ground fault protection in addition to conventional overcurrent protection. Ground fault protection, however, is not required on a service disconnect for a continuous process where its opening will increase hazards. All delta connected services are not required to have ground fault protection. The maximum setting for the ground fault relay (or sensor) can be set to pick up ground faults at a maximum of 1200 amperes and actuate the main switch or circuit breaker to disconnect all phase conductors. A ground fault relay with a deliberate time-delay characteristic of up to 1 second, may be specified, for currents greater than or equal to 3000 amperes. (The use of such a relay greatly enhances system coordination and minimizes power outages).

Ground fault protection in itself will not limit the line-to-ground or phase-to-phase short-circuit current. When mechanical protective devices such as conventional circuit breakers are used with GFP, all of the available short-circuit current will flow to the point of fault, limited only by circuit impedance. Therefore, it is recommended that current-limiting overcurrent protective devices be used in conjunction with GFP relays.



This system offers:
1. Some degree of arcing and low magnitude ground fault protection by the ground fault relay operating the switch.
2. Current-limitation for high magnitude ground faults and short-circuits by current-limiting fuses, which provides component protection for the switchgear.

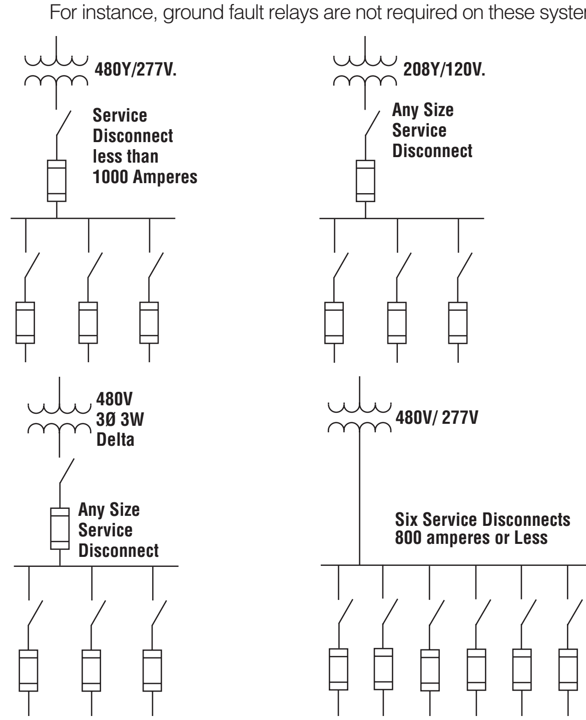


This system offers:
1. Some degree of arcing and low magnitude ground fault protection by the ground fault relay operating the circuit breaker.
Note: This system DOES NOT provide current-limitation for high magnitude ground faults and short-circuits.

Services where Ground Fault Relays are NOT Required

There are many services and feeders where Section 230-95 does not require ground fault protection including:
1. Continuous industrial process where a non-orderly shut down would increase hazards.
2. All services or feeders where the disconnect is less than 1000 amperes.
3. All 208Y/120 volt, 3ø, 4W (wye) services or feeders.
4. All single-phase services or feeders including 240/120 volt.
5. High or medium voltage services or feeders. (See NEC Sections 240-13 and 215-10 for feeder requirements.)
6. All services or feeders on delta systems (grounded or ungrounded) such as 240 volt, 3ø, 3W delta, or 240 volt, 3ø, 4W delta with midpoint tap.
7. Service with six disconnects or less (Section 230-71) where each disconnect is less than 1000 amperes. A 4000 ampere service could be split into 5-800 ampere switches.
8. Resistance or impedance grounded systems.

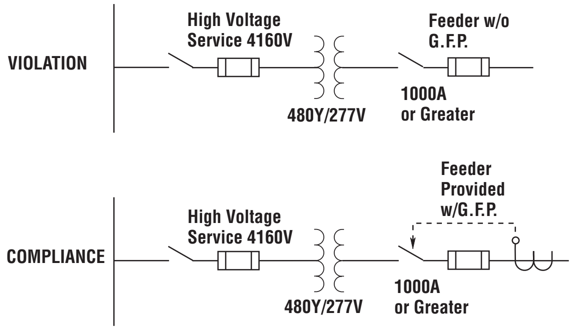
For instance, ground fault relays are not required on these systems.



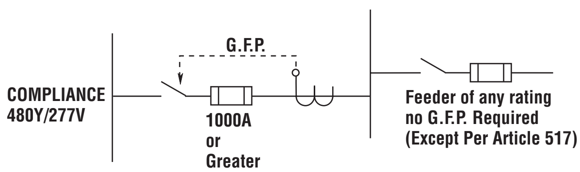
Ground Fault Protection

215-10. Ground Fault Protection of Equipment

Equipment classified as a feeder disconnect must have ground fault protection as specified in Section 230-95.



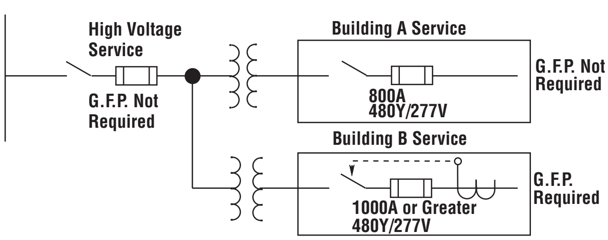
GFP will not be required on feeder equipment when it is provided on the supply side of the feeder (except for certain Health Care facilities requirements, Article 517).



This requirement for GFP on feeders may subject the system to blackouts due to downstream ground faults as discussed previously. A selective coordination analysis is required to assure that needless blackouts do not occur.

240-13. Ground Fault Protection of Equipment

Equipment ground fault protection of the type required in Section 230-95 is now required for each disconnect rated 1000A or more, 480Y/277V systems, that will serve as a main disconnect for a separate building or structure. Refer to sections 215-10 and 230-95.



Note: GFP without current-limitation may not protect system components. See Section 110-10 and 250-1(FPN).

This requirement for GFP on equipment may subject the system to blackouts due to downstream ground faults, as discussed previously. A selective coordination analysis is required to assure that needless blackouts do not occur.

FOR HEALTH CARE FACILITIES

517-17. Ground Fault Protection

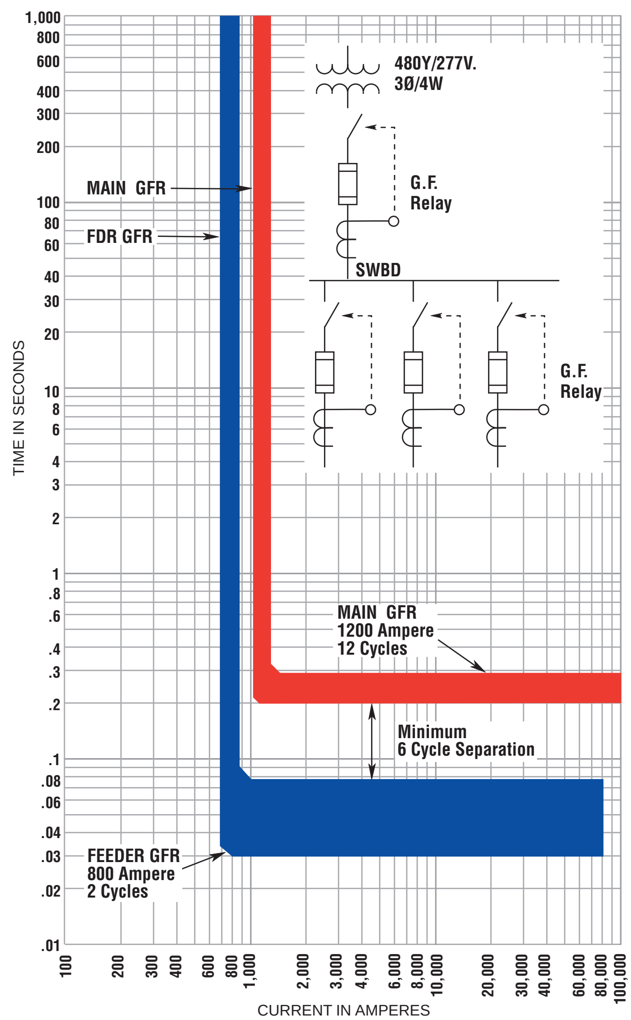
If ground fault protection is placed on the main service of a health care facility, ground fault relays must also be placed on the feeders. The separation between ground fault relay time bands for any feeder and main ground fault relay must be at least 6 cycles in order to achieve coordination between these two ground fault relays. In health care facilities where no ground fault relay is placed on the main, no ground fault relays are necessary on the feeders. Therefore, if the requirements of Section 230-95 do not require a ground fault relay and no ground fault relay is placed on the main service disconnect, then no ground fault relays are required on the feeders either (unless required by Sections 215-10 and 240-13).

A ground fault relay time band includes the disconnect operating time and any tolerances in the G.F. relay control signal.

Health Care Facility

1. When a ground fault relay is placed on the main service of a health care facility then,

2. Ground fault relays must also be placed on the feeders, and the feeder ground fault relay time band must have a 6 cycle separation from the main ground fault relay.



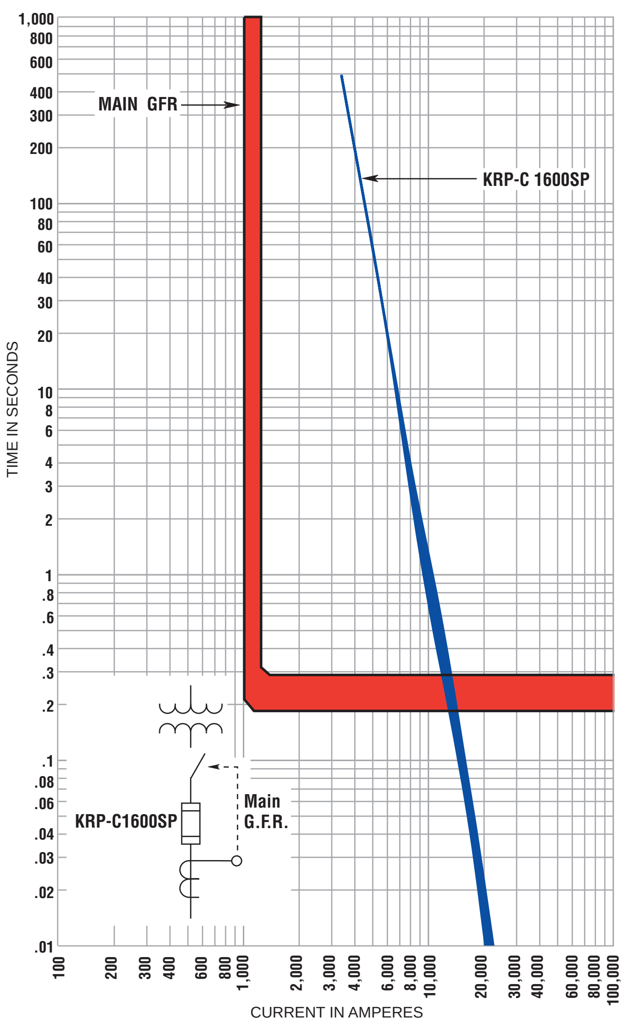
Note: Merely providing coordinated ground fault relays does not prevent a main service blackout caused by feeder ground faults. The overcurrent protective devices must also be selectively coordinated. The intent of Section 517-17 is to achieve "100 percent selectivity" for all magnitudes of ground fault current and overcurrents. 100% selectivity requires that the overcurrent protective devices also be selectively coordinated for medium and high magnitude ground fault currents because the conventional overcurrent devices may operate at these levels.

Ground Fault Protection

Analysis of Ground Fault Relay Curves and Overcurrent Device Curves

To a fuse or circuit breaker, ground fault current is sensed just as any other current. If the ground fault current is high enough, the fuse or circuit breaker responds before the ground fault relay (this depends on the ground fault relay setting, overcurrent device characteristics, speed of response of the overcurrent device, and ground fault current magnitude). Therefore, when analyzing ground fault protection it is necessary to study the characteristics of the ground fault relay and overcurrent protective device as a combination.

The combination of the ground fault relay and overcurrent device have a ground fault "effective curve". This is a composite of the ground fault relay and overcurrent protective device curves. When analyzing line-to-ground faults, the "effective" curve of the ground fault relay and conventional overcurrent protective device must be examined.

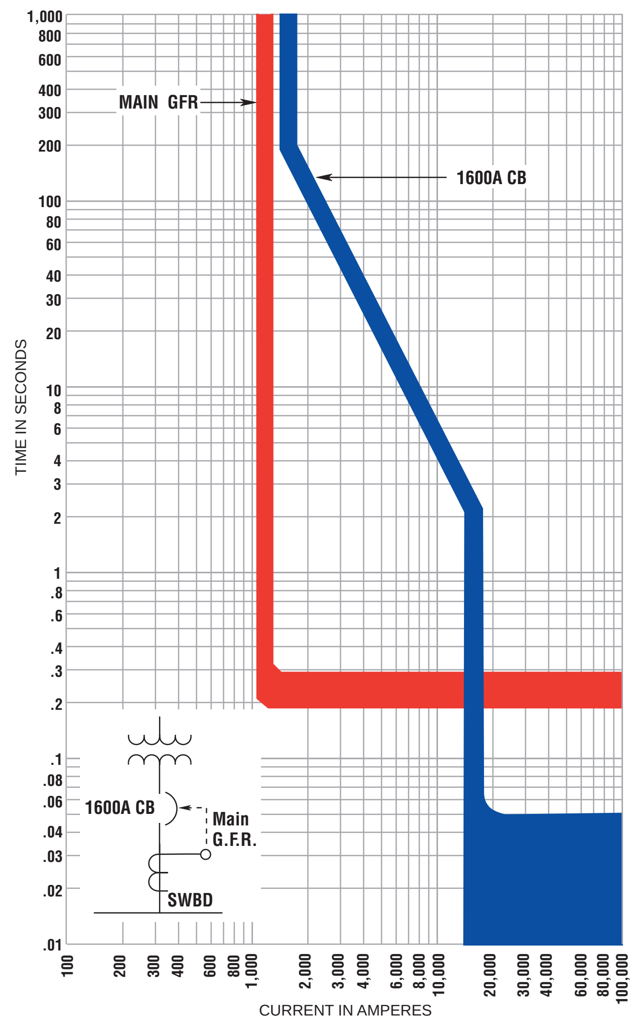


"Effective" time current curve for line to ground fault with 1600 ampere fuse and ground fault protection scheme set at 1200 amperes (switch clearing time of 4 cycles).

The graph above is the "effective" ground fault curve for a 1600 ampere fuse in combination with a ground fault relay scheme set at 1200 amperes pick-up and 12 cycle delay.

The graph below is the "effective" ground fault curve for a 1600 ampere circuit breaker in combination with a ground fault relay scheme set at 1200 amperes and 12 cycle delay.

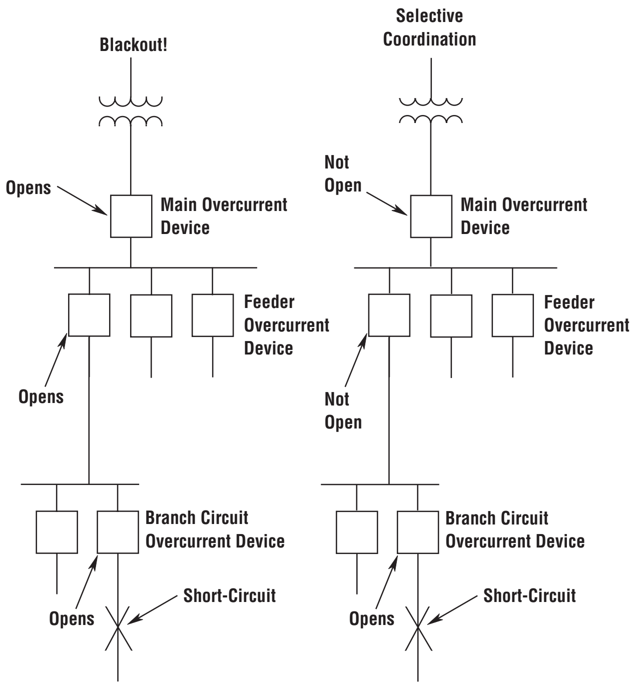
Notice that for ground faults above approximately 14,000 amperes the fused bolted pressure switch combination has the advantage of faster response and above 22,000 amperes the fused switch has the advantage of current-limitation.



"Effective" time current curve for line to ground fault with 1600 ampere circuit breaker and ground fault sensor setting at 1200 amperes.

Ground Fault Protection

Coordination is the act of isolating a faulted circuit from the remainder of the electrical system, thereby eliminating unnecessary power outages. However, the term coordination is sometimes interpreted to mean a “degree of coordination” where more than one protective device is allowed to open under a given short-circuit condition. Therefore, the term selective coordination or selectivity is used to mean positive coordination over the entire range of possible fault currents, assuring that the faulted circuit is cleared and that other parts of the system are not affected.



This system does not have selective coordination. A short-circuit on a branch circuit causes the main overcurrent device to open thereby causing a BLACKOUT.

This system has selective coordination. Only the nearest overcurrent device opens on any short-circuit.

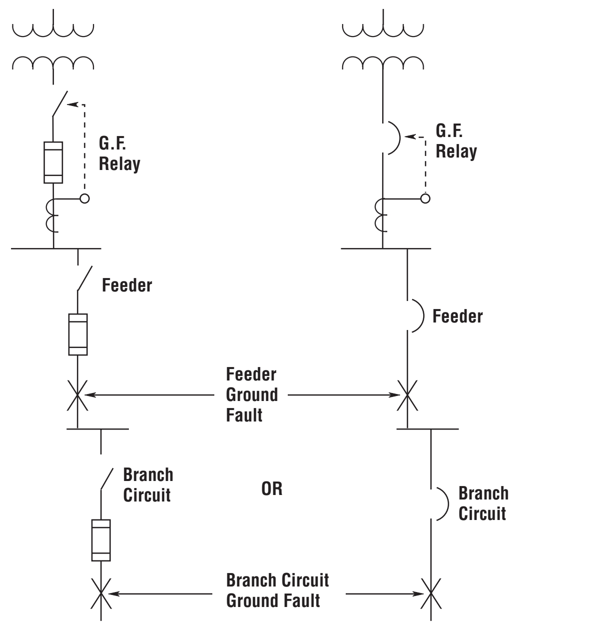
Modern current-limiting fuses can be selectively coordinated simply by maintaining at least a minimum ampere rating ratio between two fuses in series. This ratio is dependent on the fuse types used.

When ground fault relays are used in a system, selective coordination considerations are more difficult. The relay curve must be studied in reference to the overcurrent protective devices in the system. The topic of selective coordination that follows has been separated into two parts:

A. One step ground fault relaying.
B. Two step ground fault relaying.

A. One Step Ground Fault Relaying

When a ground fault occurs on a feeder or branch circuit it is highly desirable for the feeder or branch circuit overcurrent device to clear that fault before the main device opens, thus preventing an unnecessary system blackout. However, this is not always the case when a ground fault relay is located on the main or when the overcurrent protective devices are not selectively coordinated.



To avoid unnecessary service disruptions (or BLACKOUTS):

1. the characteristics of the feeder and/or branch circuit overcurrent devices must be analyzed with relation to the main ground fault relay characteristics and;

2. the characteristics of the main overcurrent device must be analyzed with relation to the feeder and branch circuit overcurrent protective devices.

Selective coordination should be investigated for low and high magnitude ground faults. Generally on low magnitude ground faults the feeder overcurrent device must be selective with the main ground fault relay. For high magnitude ground faults it is necessary also to consider selective coordination between the main overcurrent device and feeder overcurrent device.

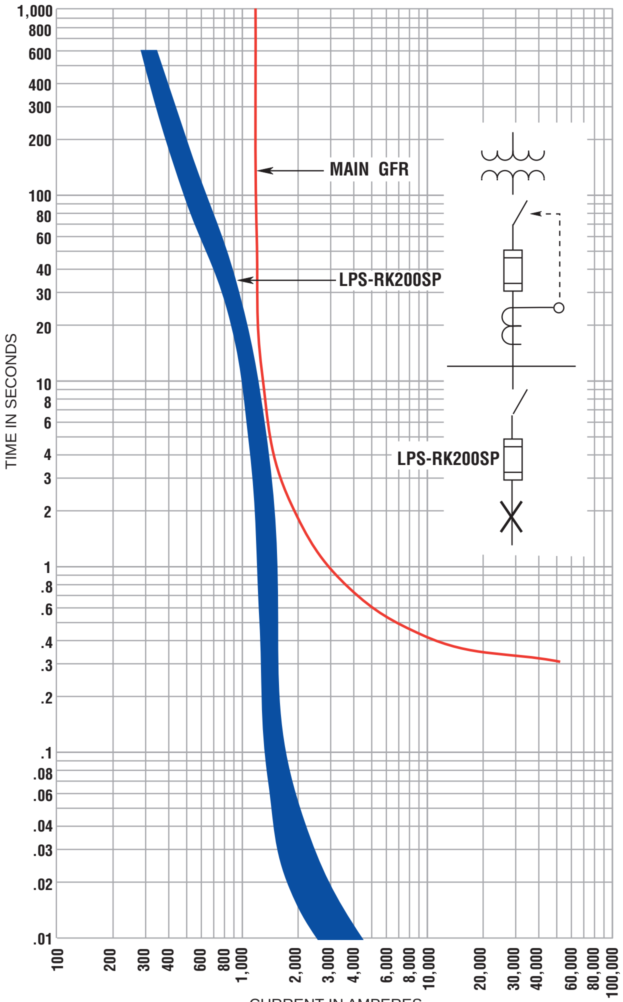
Ground Fault Protection

Low Magnitude Ground Faults on Feeders - One Step Ground Fault Relaying.

For low magnitude feeder ground faults, the feeder overcurrent protective device can clear the circuit without disrupting the main service if the feeder overcurrent device lies to the left of the ground fault relay and does not cross at any point.

In the following two graphs, the ground fault relay located on the main has an operating time-delay of 18 cycles and 1200 ampere pickup. It's inverse-time characteristic with the maximum 1 second opening time at 3000 amperes improves selective coordination with downstream devices.

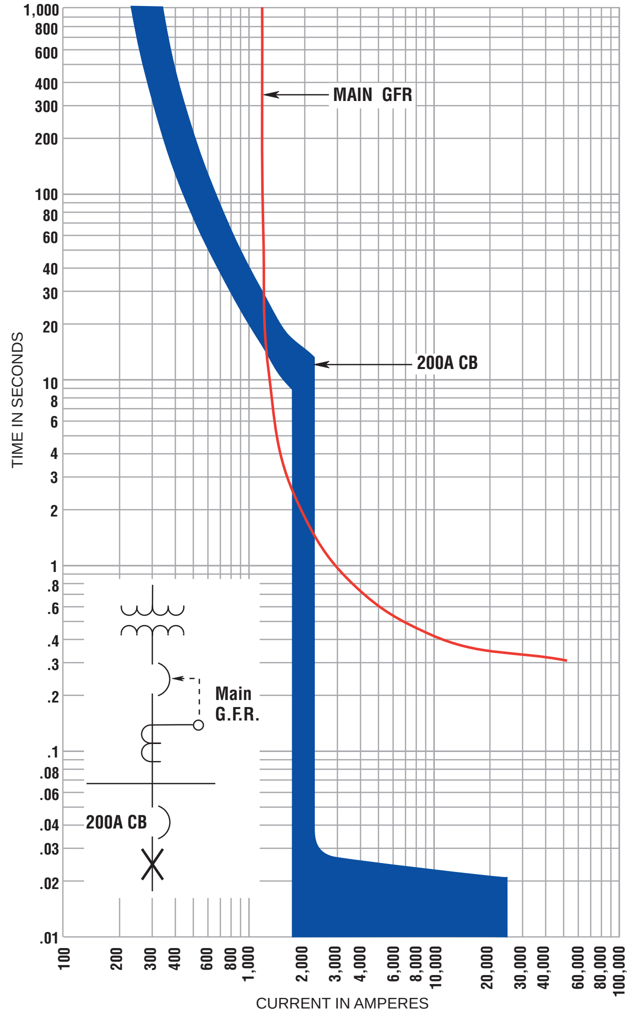
Fuse System



Selective coordination considerations for low magnitude feeder ground faults. Longer G.F. relay delay permits larger feeder fuse to coordinate with main relay.

The graph above illustrates that an inverse-time main ground fault relay may permit a larger size feeder fuse to selectively coordinate with the ground fault relay. In this case the inverse time ground fault relay is set at 1200 amperes, 18 cycle delay. A LPS-RK200SP ampere feeder fuse coordinates with this main ground fault relay.

Circuit Breaker System



Coordination considerations for low magnitude feeder ground faults. Consider main ground fault relay and feeder overcurrent device. A lack of coordination exists for ground faults between 1200 amperes and 1800 amperes.

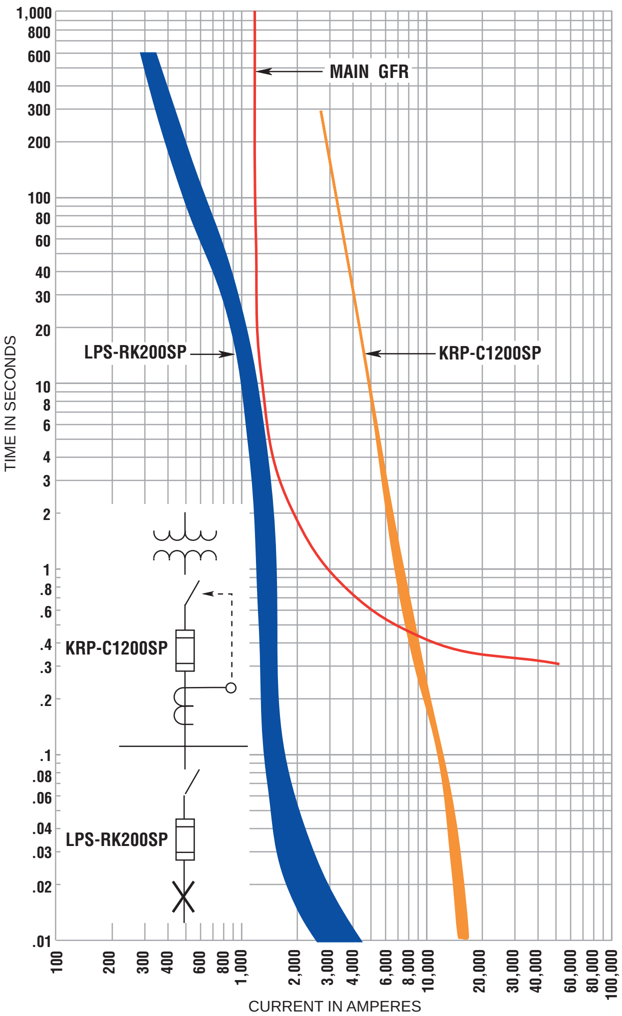
The graph above illustrates that for some low magnitude ground faults a 200 ampere circuit breaker will not coordinate with the ground fault relay. This and circuit breakers of larger sizes will not be selective with the ground fault relay and total service disruption can be caused by a feeder or branch circuit ground fault.

Ground Fault Protection

High Magnitude Ground Faults on Feeders - One Step Ground Fault Relaying

For higher magnitude ground faults, it is generally necessary to consider the characteristics of the main overcurrent protective device as well as the ground fault relay. Conventional overcurrent protective devices, fuses or circuit breakers, cannot differentiate between a high magnitude ground fault or a high magnitude phase-to-phase short-circuit. Therefore, when a high magnitude feeder ground fault occurs the main overcurrent device must be considered in relation to the feeder overcurrent device. To achieve selective coordination and prevent a blackout for high magnitude ground faults, the feeder overcurrent device must be selective with the main overcurrent device.

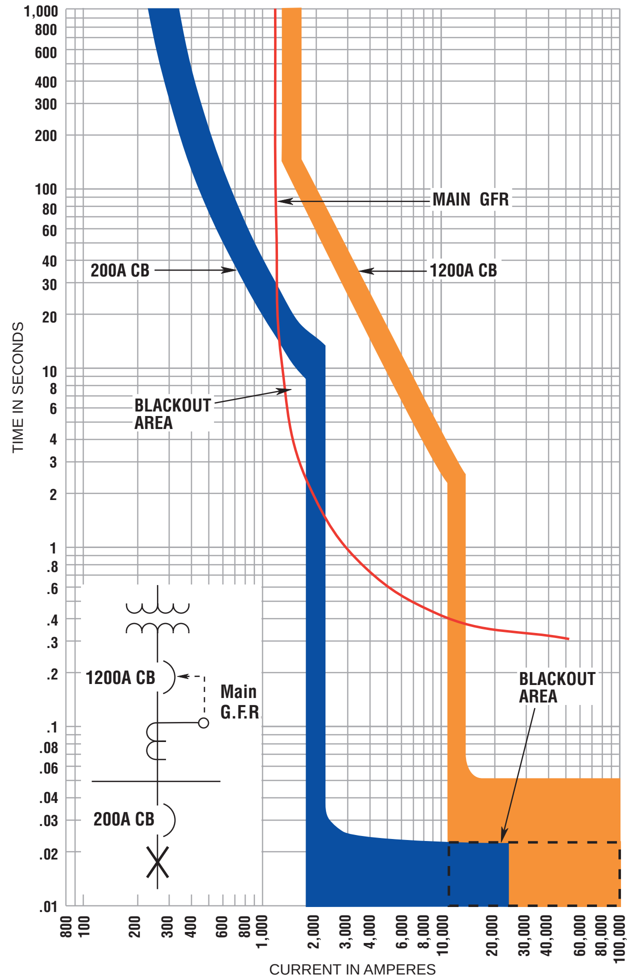
Fuse System



Selective coordination considerations for high magnitude feeder ground faults requires analysis of main and feeder overcurrent devices. In this case the fuses are selectively coordinated so that an unnecessary black-out does not occur.

The graph above illustrates that for high magnitude feeder ground faults the LPS-RK200SP ampere fuse opens before the main service KRP-C1200SP ampere fuse. This is referred to as selective coordination for ground faults. This assures that any high magnitude ground faults on the branch circuits or feeders will be isolated without disrupting the main service.

Circuit Breaker System



Selective coordination considerations for high magnitude feeder ground faults requires analysis of main and feeder overcurrent devices. In this case feeder ground faults greater than 11,000 amperes will cause the main circuit breaker to open unnecessarily creating a BLACKOUT! Thus the entire service is blacked-out because of a lack of coordination. The ground fault relay is not of concern because it has an 18 cycle delay.

The graph above illustrates that for feeder ground faults above 11,000 amperes the main service 1200 ampere circuit breaker as well as the 200 ampere circuit breaker will open. This is because an 11,000 ampere or greater fault current unlatches both the 200 ampere and 1200 ampere circuit breakers. This condition will create a service blackout when a feeder ground fault occurs.

Ground Fault Protection

This fact is commonly overlooked when applying ground fault relays. Generally, the short-time-delay on the ground fault relay is thought to provide coordination for higher magnitude feeder ground faults. However, as shown by this example the main circuit breaker operates to cause an unnecessary blackout.

Note: Circuit breakers with short-time-delay trip units were not considered in this section. The reason is that a short-time-delay on a circuit breaker defeats the original purpose of protection. Short-circuit currents and high magnitude ground fault currents, when intentionally permitted to flow for several cycles, dramatically increase the burn time and damage to the system.

Electrical systems are not designed to withstand, for long periods, the torturous forces that fault currents produce. Circuit breaker short-time-delay trip units with typical delays of 6, 18, 24, or 30 cycles greatly exceed the short-circuit withstandability of system components. According to NEMA standards, the duration for equipment short-circuit current testing is four cycles for switchboard bus (PB-2,1989) and three cycles for busway (BU1-1988). The short-circuit current withstandability for insulated conductors decreases as the overcurrent device operating time increases (reference Insulated Cable Engineers Association Publication P-32-382, "Short-Circuit Characteristics of Cable"). Short-circuit currents and high magnitude ground fault currents must be interrupted as rapidly as possible (preferably with current-limiting devices) to minimize equipment damage.

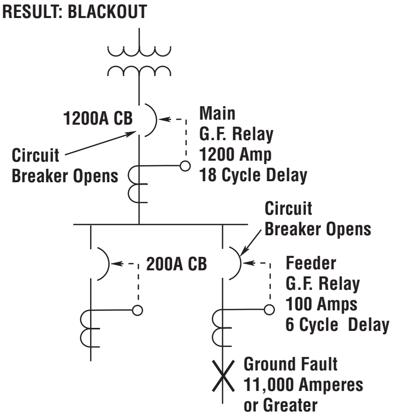
Whenever insulated case and molded case circuit breakers have a short-time-delay feature they also have an instantaneous override This requires the sensing mechanism (typically solid state) to override the short-time-delay feature for high ground fault or line-line faults. The result is a lack of coordination with the feeder breakers for any fault current above the instantaneous override setting. Selective coordination is therefore very difficult to achieve.

B. Two Step Ground Fault Relaying

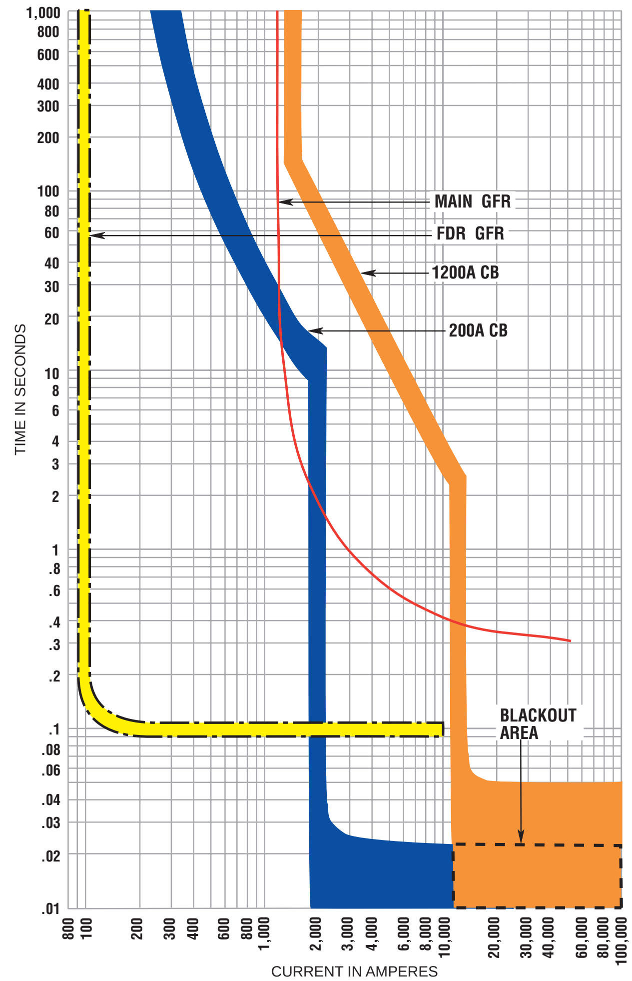
Two step ground fault relaying includes ground fault relays on the main service and feeders.

In many instances, this procedure can provide a higher degree of ground fault coordination to prevent unnecessary service blackouts. Yet it is mistakenly believed by many that two step ground fault relays assure ground fault coordination. For complete selective coordination of all ground faults, the conventional overcurrent protective devices must be selectively coordinated as well as the ground fault relays. The fact is that even with this two step relay provision, ground fault coordination is not assured on many systems designed with mechanical overcurrent protective devices which incorporate instantaneous unlatching mechanisms.

RESULT: BLACKOUT



The system above illustrates the typical problem concerning this point. The main ground fault relay is set at 1200 amperes, 18 cycle delay and the feeder ground fault relay is set at 100 amperes, 6 cycle delay. These ground fault relay settings could mistakenly be interpreted to mean that feeder ground faults would be cleared by only the feeder ground fault relay opening the feeder disconnect. But the analysis must also include the overcurrent device characteristics since these devices also respond to current.



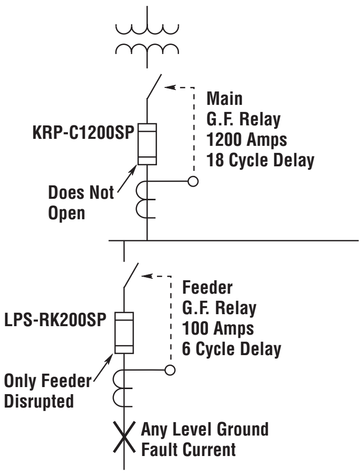
The two step ground fault relays give a false sense of security. The graph above illustrates that the ground fault relays are coordinated, but overcurrent devices are not coordinated for feeder or branch circuit ground faults above 11,000 amperes. This is indicated as the BLACKOUT AREA on the curve. In this case the main overcurrent device and the feeder overcurrent device both open on a feeder circuit fault. Thus the entire system is blacked out; even though two step ground fault relays are provided.

WARNING!

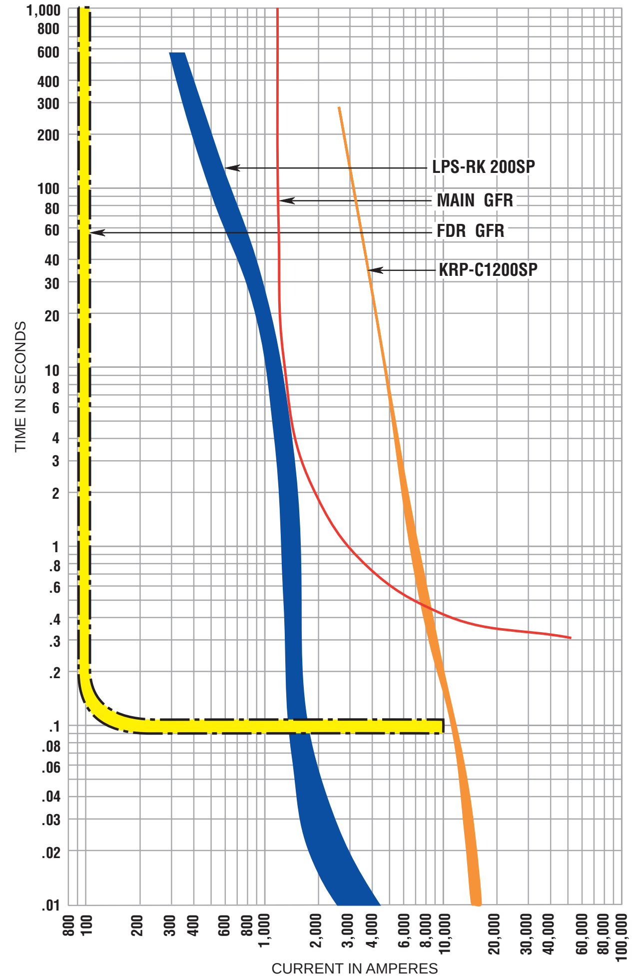
For Health Care Facilities - Section 517-17 requires the main and feeders to be 100% selectively coordinated for all magnitudes of ground fault current - including low, medium, and high ground fault currents.

Ground Fault Protection

In many cases two step relays do provide a higher degree of ground fault coordination. When properly selected, the main fuse can be selectively coordinated with the feeder fuses. Thus on all feeder ground faults or short-circuits the feeder fuse will always open before the main fuse. When selectively coordinated main and feeder fuses are combined with selectively coordinated main and feeder ground fault relays, ground fault coordination between the main and feeder is predictable.



The above figure illustrates a selectively coordinated main and feeder for all levels of ground faults, overloads and short-circuits. Any fault on the feeder will not disrupt the main service.



This system offers full selective coordination for all levels of ground faults or short-circuits.

1. The feeder ground fault relay is set at a lower time band than the main ground fault relay, therefore the relays are coordinated.

2. The feeder fuses are selectively coordinated with the main fuses for all ground faults, short-circuits, or overloads on the load side of the feeder. The feeder fuses would clear the fault before the main fuses open.

Conclusion: This system is completely selective for all levels of ground faults and short-circuits. This system meets the intent of NEC Section 517-17 for 100% selectivity.

Complete Ground Fault Selective Coordination Is Necessary To Prevent Blackouts!

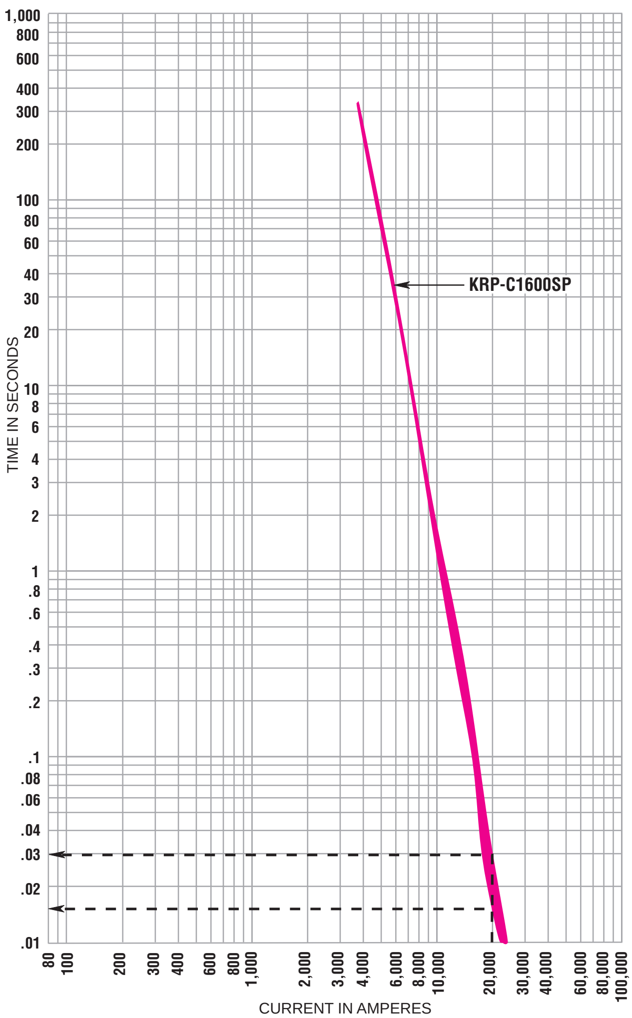
To assure complete selective coordination for all ground faults, it is essential that the conventional overcurrent protective devices be selectively coordinated as well as the ground fault relays requirement. The intent of Section 517-17 is to achieve “100 percent selectivity” for all magnitudes of ground fault current.

Ground Fault Protection

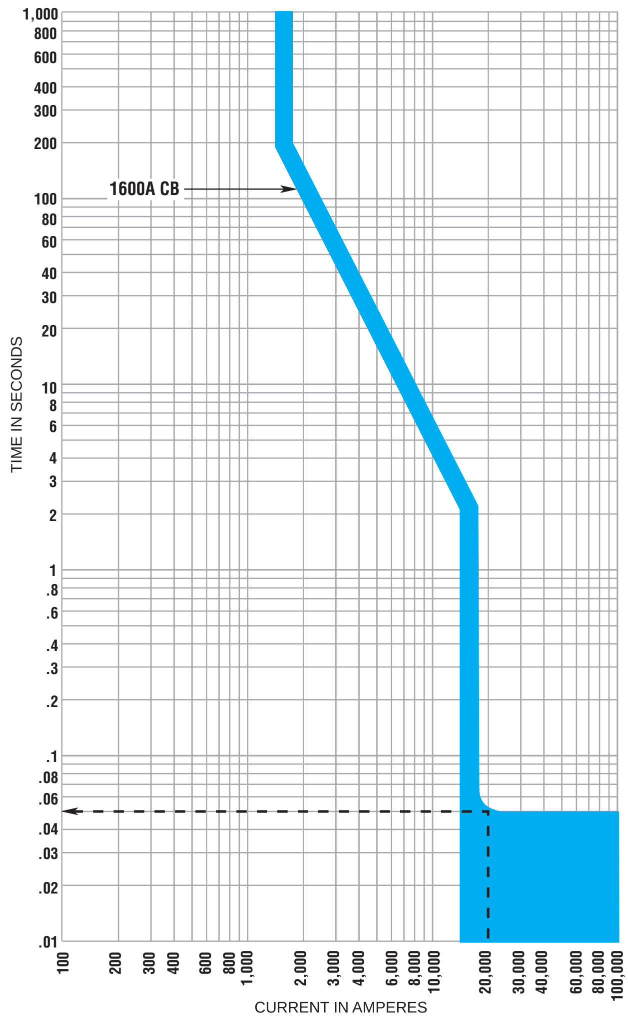
The Need for Current-Limitation

If ground fault protection is required, then the best protection is a switch equipped with a ground fault relay scheme, a shunt trip mechanism, and current-limiting fuses. The reason is that this system will offer protection for high magnitude ground faults as well as low magnitude ground faults. Ground fault relay schemes and shunt trip mechanisms on switches or circuit breakers can protect equipment against extensive damage from low magnitude ground faults - this is their intended purpose. However, burn downs still occur in switchboards, large motor control centers, and large distribution panels generally located in equipment rooms where high available ground fault currents are present.

The National Electrical Code requires ground fault protection for intermediate and high ground faults as well as low grade ground faults. For high magnitude ground faults, ground fault relay schemes operate too slowly to prevent extensive equipment damage. The main or feeder overcurrent devices, such as fuses or circuit breakers must clear the circuit. Current-limiting fuses substantially limit the energy let-through for higher magnitude ground faults and thereby offer a higher degree of protection. Conventional circuit breakers are not current-limiting protective devices and during higher magnitude ground faults can let-through large amounts of damaging energy.



Clearing characteristic for a 1600 ampere fuse. A 20,000 ampere fault is cleared by the KRP-C 1600SP fuse in .015 to .030 seconds (between one and two cycles). For currents greater than 25,000 amperes the fuse enters its current-limiting range. Then the clearing time is less than one half cycle.



Clearing characteristic for 1600 ampere circuit breaker. A 20,000 ampere fault is cleared by the 1600 ampere circuit breaker in .05 seconds. The circuit breaker has a fixed operating time for high values of current. This time is approximately .05 seconds (3 cycles). Therefore, high magnitude ground faults and short-circuits are permitted to flow for at least 3 cycles.

Ground Fault Protection

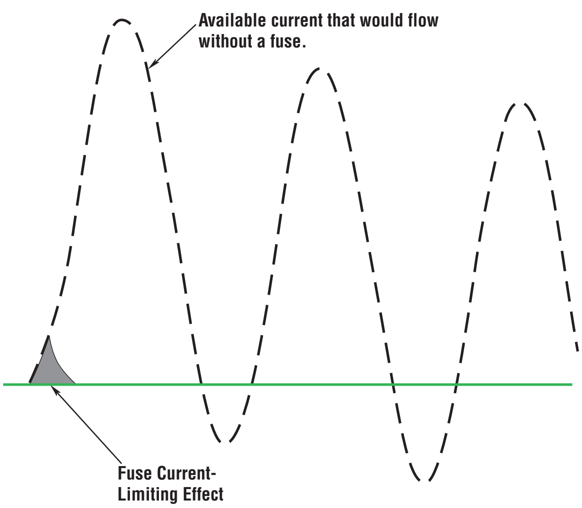
The previous two figures illustrate the time-current characteristics for a 1600 ampere current-limiting fuse and a 1600 ampere circuit breaker. The higher the fault current the faster the fuse operates. Notice, the mechanical overcurrent protective device reaches an irreducible operating time. For large conventional service entrance circuit breakers this fixed operating time varies from 1½ cycles to 5 cycles depending on the type and size. (If short-time-delay tripping units are used the operating time can be as long as 30 cycles.)

Of importance is the fact that modern, rejection type fuses are current-limiting protective devices. For faults above approximately 25,000 amperes, the 1600 ampere fuse operates in its current-limiting range; clearing the circuit in less than ½ cycle and limiting the peak current and energy let-through to the circuit components.

Current-Limitation

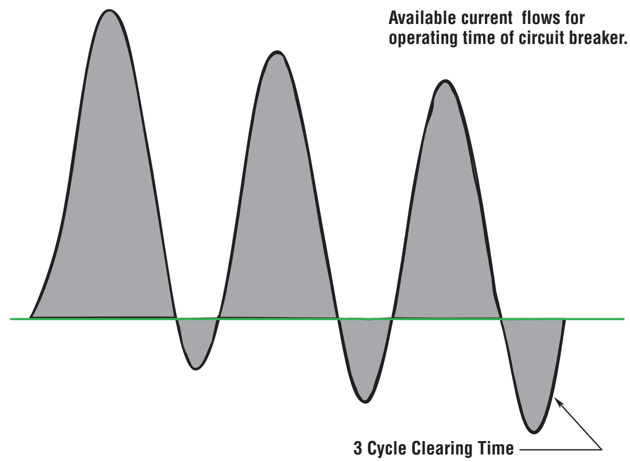
The effect of a fuse protecting the circuit is to limit the instantaneous peak current and thermal or heating effect current to a value less than that which would flow in the first half cycle had the fuse not been in the circuit. Current-limitation for high level ground faults can substantially reduce the damaging effect.

Current-Limitation



The large conventional mechanical overcurrent protective device reaches an irreducible minimum clearing time and therefore permits the full fault current flow for several cycles. The damaging peak current and thermal or heating effect current flow unrestricted without limitation for several cycles. At higher magnitude fault currents, large amounts of heating energy and magnetic forces are permitted to flow and the equipment must absorb the full available fault current energy.

No Current-Limitation



Motor Protection

OVERLOAD PROTECTION

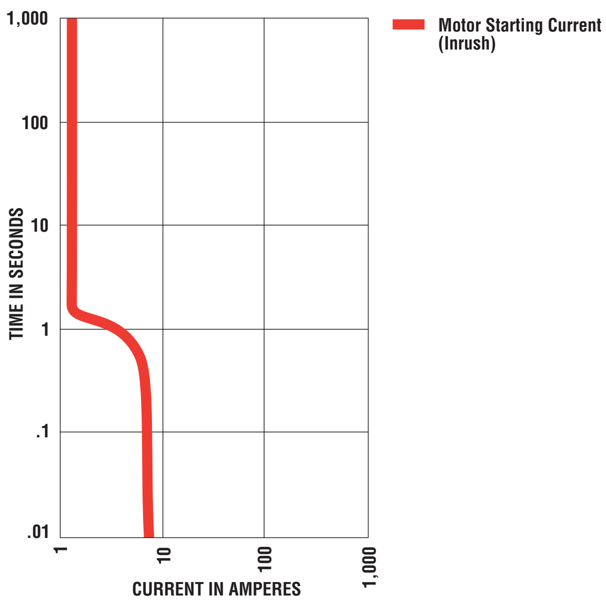
Overcurrents

An overcurrent exists when the normal load current for a circuit is exceeded. It can be in the form of an overload or short-circuit. When applied to motor circuits an overload is any current, flowing within the normal circuit path, that is higher than the motor's normal full load amperes (F.L.A.). A short-circuit is an overcurrent which greatly exceeds the normal full load current of the circuit. Also, as its name infers, a short-circuit leaves the normal current carrying path of the circuit and takes a "short cut" around the load and back to the power source. Motors can be damaged by both types of currents.

Single-phasing, overworking and locked rotor conditions are just a few of the situations that can be protected against with the careful choice of protective devices. If left unprotected, motors will continue to operate even under abnormal conditions. The excessive current causes the motor to overheat, which in turn causes the motor winding insulation to deteriorate and ultimately fail. Good motor overload protection can greatly extend the useful life of a motor. Because of a motor's characteristics, many common overcurrent devices actually offer limited or no protection.

Motor Starting Currents

When an AC motor is energized, a high inrush current occurs. Typically, during the initial half cycle, the inrush current is often higher than 20 times the normal full load current. After the first half-cycle the motor begins to rotate and the starting current subsides to 4 to 8 times the normal current for several seconds. As a motor reaches running speed, the current subsides to its normal running level. Typical motor starting characteristics are shown in Curve 1.

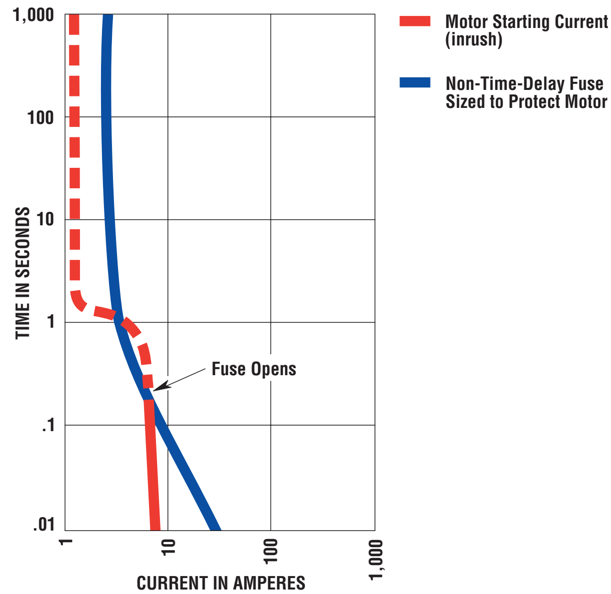


Curve 1

Because of this inrush, motors require special overload protective devices that can withstand the temporary overloads associated with starting currents and yet protect the motor from sustained overloads. There are four major types. Each offers varying degrees of protection.

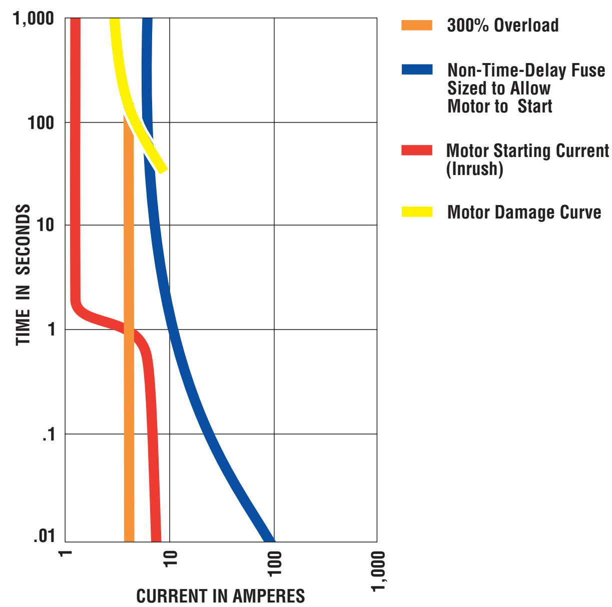
Fast Acting Fuses

To offer overload protection, a protective device, depending on its application and the motor's service factor, should be sized at 115% to 125% of the motors F.L.A. However, as shown in Curve 2, when fast-acting, non-time-delay fuses are sized to the recommended level the motors inrush will cause nuisance openings.



Curve 2

A fast-acting, non-time-delay fuse sized at 300% will allow the motor to start but sacrifices the overload protection of the motor. As shown by Curve 3 below, a sustained overload will damage the motor before the fuse can open.



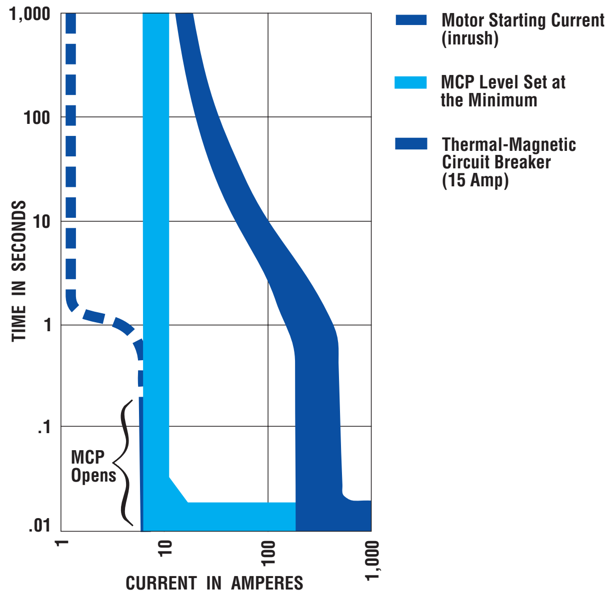
Curve 3

Motor Protection

MCP'S and Thermal Magnetic Breakers

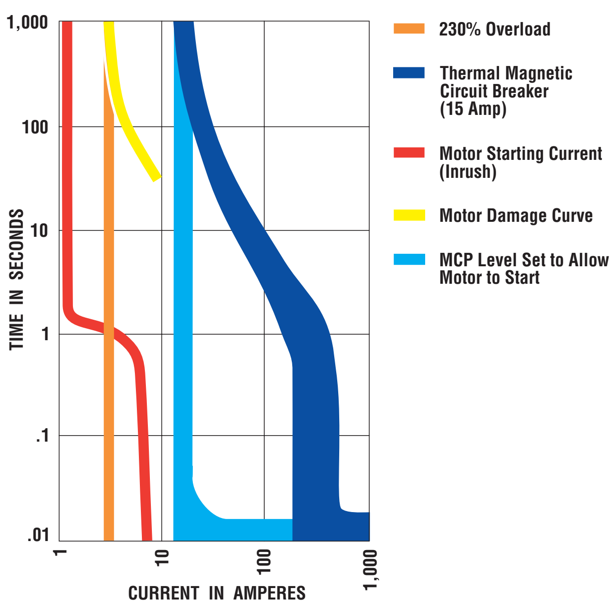
Magnetic only breakers (MCP's) and thermal magnetic breakers are also unsatisfactory for the protection of motors. Once again to properly safeguard motors from overloads, these devices should be sized at 115% to l25% of the motor's F.L.A. When sized this close to the F.L.A. the inrush causes these breakers to open needlessly.

Curve 4 shows an MCP opening from motor inrush and an unaffected 15 amp thermal magnetic circuit breaker (the minimum standard size).



Curve 4

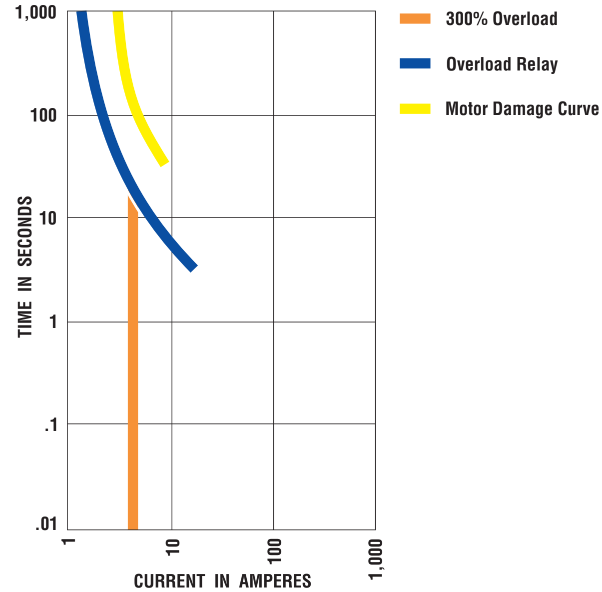
To allow the motor to start, the MCP must be sized at about 700-800% of the F.L.A. and the thermal magnetic breaker must be sized at about 250% of F.L.A. Curve 5 clearly shows that breakers sized to these levels are unable to protect motors against overloads.



Curve 5

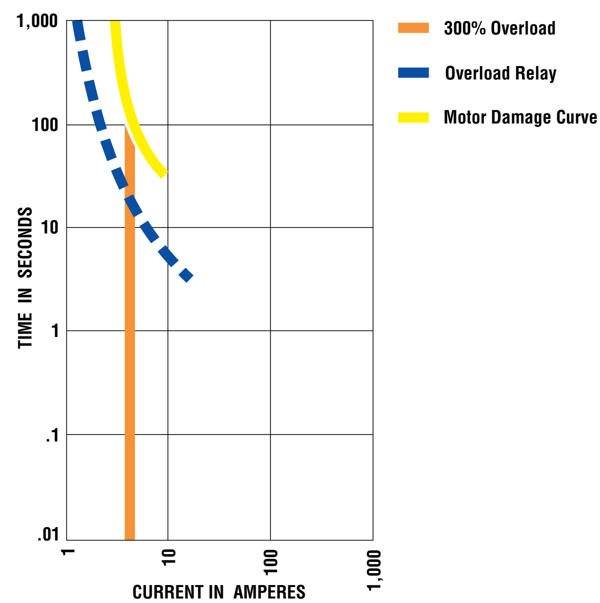
Overload Relays

Overload relays, or heaters, installed in motor starters are usually the melting alloy or bi-metallic type. When properly sized and maintained, the relay can offer good overload protection. When operating properly, overload relays allow the motor to start, but when a sustained overload occurs the overload relays cause the contacts to open (Curve 6).



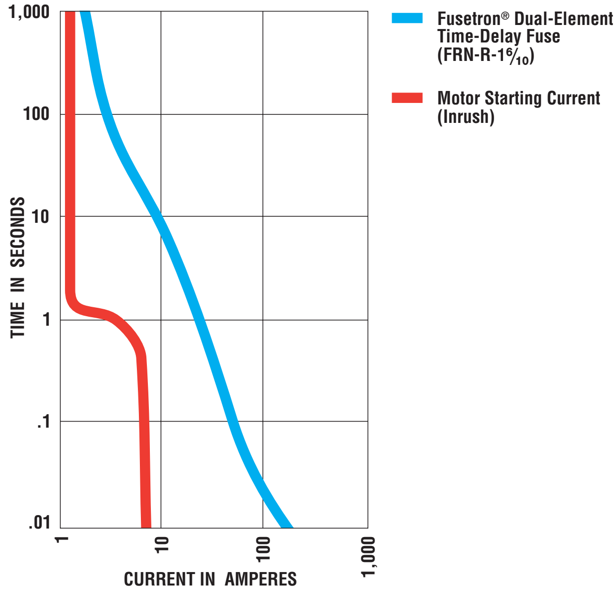
Curve 6

However, if the overload relays are oversized or if the contacts fail to open for any reason (i.e., welded contacts), the motor is left unprotected. Also, overload relays cannot offer any protection for short-circuits, and in fact must be protected by fuses or circuit breakers under short-circuit conditions Curve 7 .



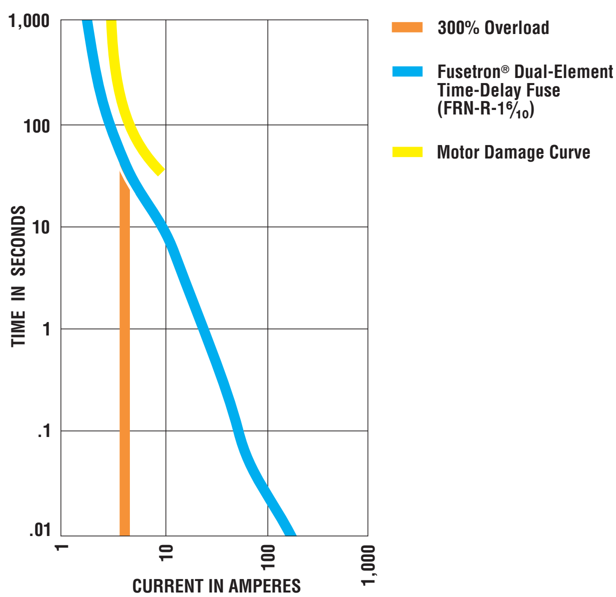
Curve 7

The dual-element fuse is unaffected by the motor inrush current (Curve 8), but opens before a sustained overload can reach the motor damage curve (Curve 9).



Curve 8

The NEC allows dual-element fuses to be used by themselves for both overload and short-circuit protection, (see NEC sections 430-36, 430-37, 430-55, 430-57, & 430-90). All other types of overcurrent protective devices must be used in combination. Curve 9 shows that the dual-element fuse offers excellent overload protection of motors.

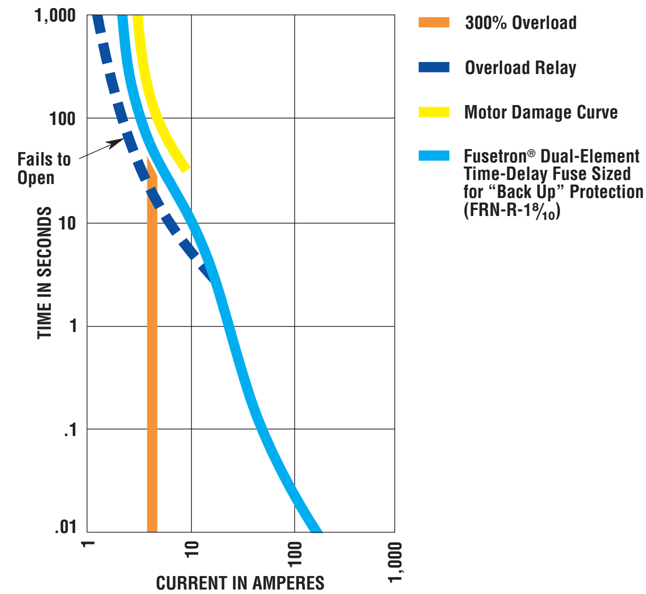


Curve 9

Given a motor with 1.15 service factor or greater, size the LPN-RK_SP, LPS-RK_SP, FRN-R, or FRS-R fuse at 125% of the motor full load current or the next smaller available fuse size. With a motor having a service factor of less than 1.15, size these same fuses at 115% of the motor's F.L.A. or the next smaller standard size.

By using the following "backup" method of fusing, it is possible to have two levels of overload protection. Begin by sizing the overload relays according to the manufacturers directions. Then, size the fuse at 125%-130% or the next larger size. With this combination you have the convenience of being able to quickly reset the overload relay after solving a minor problem, while the fuses remain unopened. However, if the overload relays are sized too large or if the contacts fail to open for any reason, the fuses will open before the motor damage curve is reached.

Curve 10 graph below shows the backup protection available with this method.



Curve 10

Motor Protection — Voltage Unbalance/Single-Phasing

Historically, the causes of motor failure can be attributed to:

Overloads	30%
Contaminants	19%
Single-phasing	14%
Bearing failure	13%
Old age	10%
Rotor failure	5%
Miscellaneous	9%
	100%

From the above data, it can be seen that 44% of motor failure problems are related to HEAT.

Allowing a motor to reach and operate at a temperature 10°C above its maximum temperature rating will reduce the motor's expected life by 50%. Operating at 10°C above this, the motor's life will be reduced again by 50%. This reduction of the expected life of the motor repeats itself for every 10°C. This is sometimes referred to as the "half life" rule.

Although there is no industry standard that defines the life of an electric motor, it is generally considered to be 20 years.

The term, temperature "rise", means that the heat produced in the motor windings (copper losses), friction of the bearings, rotor and stator losses (core losses), will continue to increase until the heat dissipation equals the heat being generated. For example, a continuous duty, 40°C rise motor will stabilize its temperature at 40°C above ambient (surrounding) temperature.

Standard motors are designed so the temperature rise produced within the motor, when delivering its rated horsepower, and added to the industry standard 40°C ambient temperature rating, will not exceed the safe winding insulation temperature limit.

The term, "Service Factor" for an electric motor, is defined as: "a multiplier which, when applied to the rated horsepower, indicates a permissible horsepower loading which may be carried under the conditions specified for the Service Factor of the motor."

"Conditions" include such things as operating the motor at rated voltage and rated frequency.

Example: A 10 H.P. motor with a 1.0 S.F. can produce 10 H.P. of work without exceeding its temperature rise requirements. A 10 H.P. motor with a 1.15 S.F. can produce 11.5 H.P. of work without exceeding its temperature rise requirements.

Overloads, with the resulting overcurrents, if allowed to continue, will cause heat build-up within the motor. The outcome will be the eventual early failure of the motor's insulation. As stated previously for all practical purposes, insulation life is cut in half for every 10°C increase over the motor's rated temperature.

Voltage Unbalance

When the voltage between all three phases is equal (balanced), current values will be the same in each phase winding.

The NEMA standard for electric motors and generators recommends that the maximum voltage unbalance be limited to 1%.

When the voltages between the three phases (AB, BC, CA) are not equal (unbalanced), the current increases dramatically in the motor windings, and if allowed to continue, the motor will be damaged.

It is possible, to a limited extent, to operate a motor when the voltage between phases is unbalanced. To do this, the load must be reduced.

Voltage Unbalance in Percent	Derate Motor to These Percentages of the Motor's Rating*
1%	98%
2%	95%
3%	88%
4%	82%
5%	75%

*This is a general "rule of thumb", for specific motors consult the motor manufacturer.

Some Causes of Unbalanced Voltage Conditions

- Unequal single-phase loads. This is why many consulting engineers specify that loading of panelboards be balanced to ± 10% between all three phases.
- Open delta connections.
- Transformer connections open - causing a single-phase condition.
- Tap settings on transformer(s) not proper.
- Transformer impedances (Z) of single-phase transformers connected into a "bank" not the same.
- Power factor correction capacitors not the same. . .or off the line.

Insulation Life

The effect of voltage unbalance on the insulation life of a typical T-frame motor having Class B insulation, running in a 40°C ambient, loaded to 100%, is as follows:

	Insulation Life	
Voltage Unbalance	Service Factor 1.0	Service Factor 1.15
0%	1.00	2.27
1%	0.90	2.10
2%	0.64	1.58
3%	—	0.98
4%	—	0.51

Note that motors with a service factor of 1.0 do not have as much heat withstand capability as does a motor that has a service factor of 1.15.

Older, larger U-frame motors, because of their ability to dissipate heat, could withstand overload conditions for longer periods of time than the newer, smaller T-frame motors.

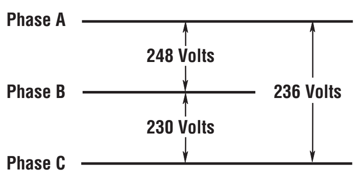
Motor Protection — Voltage Unbalance/Single-Phasing

Insulation Classes

The following shows the maximum operating temperatures for different classes of insulation.

Class A Insulation	105°C
Class B Insulation	130°C
Class F Insulation	155°C
Class H Insulation	180°C

How to Calculate Voltage Unbalance and the Expected Rise in Heat



Step 1: Add together the three voltage readings:

$248 + 236 + 230 = 714$ volts

Step 2: Find the "average" voltage.

$\frac{714}{3} = 238$ volts

Step 3: Subtract the "average" voltage from one of the voltages that will indicate the **greatest** voltage difference. In this example:

$248 - 238 = 10$ volts

Step 4:

$$100 \times \frac{\text{greatest voltage difference}}{\text{average voltage}}$$

$$= 100 \times \frac{10}{238} = 4.2 \text{ percent voltage unbalance}$$

Step 5: Find the expected temperature rise in the phase winding with the highest current by taking. . .

$2 \times (\text{percent voltage unbalance})^2$

In the above example:

$2 \times (4.2)^2 = 35.28$ percent temperature rise.

Therefore, for a motor rated with a 60°C rise, the unbalanced voltage condition in the above example will result in a temperature rise in the phase winding with the highest current of:

$60°C \times 135.28\% = 81.17°C$

The National Electrical Code

The National Electrical Code, in Table 430-37, requires three overload protective devices, one in each phase, for the protection of all three-phase motors.

Prior to the 1971 National Electrical Code, three-phase motors were considered to be protected from overload (overcurrent) by two overload protective devices. These devices could be in the form of properly sized time-delay, dual-element fuses, or overload heaters and relays (melting alloy type, bimetallic type, magnetic type, and solid-state type.)

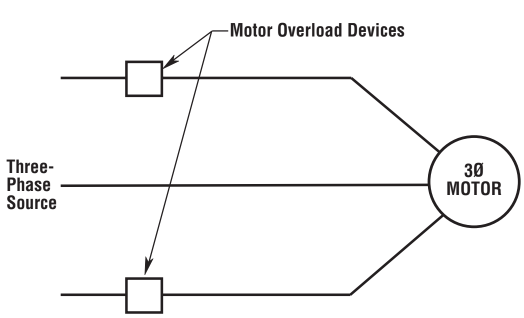


Diagram showing two overload devices protecting a three-phase motor. This was acceptable by the National Electrical Code prior to 1971.

Two motor overload protective devices provide adequate protection against balanced voltage overload conditions where the voltage between phases is equal. When a balanced voltage overload persists, the protective devices usually open simultaneously. In some cases, one device opens, and shortly thereafter, the second device opens. In either case, three-phase motors are protected against balanced voltage overload conditions.

Three-phase motors protected by two overload protective devices are not assured protection against the effect of single-phasing. For example, when the electrical system is WYE/DELTA or DELTA/WYE connected, all three phases on the secondary side of the transformer bank will continue to carry current when a single-phasing caused by an open phase on the primary side of the transformer bank occurs. As will be seen later, single-phasing can be considered to be the **worst case** of unbalanced voltage possible.

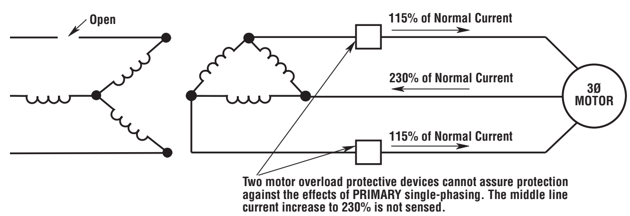
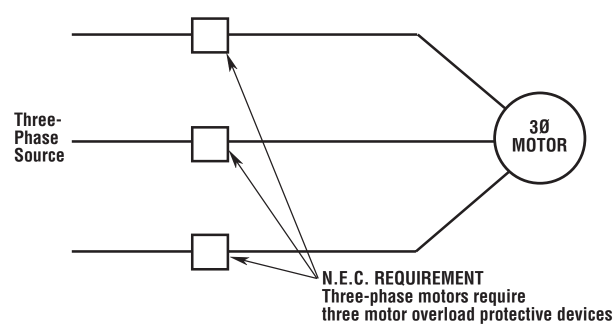


Diagram of a WYE/DELTA transformation with one primary phase open. The motor is protected by two overload devices. Note that one phase to the motor is carrying two times that of the other two phases. Without an overload device in the phase that is carrying two times the current in the other two phases, the motor will burn out.

The 1996 National Electrical Code, Section 430-36 requires that when fuses are used for motor overload protection, a fuse shall be inserted in each phase. Where thermal overload devices, heaters, etc. are used for motor overload protection, Table 430-37 requires one be inserted in each phase. With these requirements, the number of single-phasing motor burnouts are greatly reduced, and are no longer a serious hazard to motor installations. The following figure shows three overload protective devices protecting the three-phase motor.



Since 1971, The National Electrical Code has required three overload protective devices for the protection of three-phase motors, one in each phase.

Motor Protection — Voltage Unbalance/Single-Phasing

Motor Branch Circuit, Short-Circuit and Ground Fault Protection

When sized according to NEC Section 430-52, a 3-pole common trip circuit breaker or MCP can not protect against single-phasing damage.

It should be emphasized, the causes of single-phasing cannot be eliminated. However, motors can be protected from the damaging effects of single-phasing through the use of proper overcurrent protection.

Dual-element, time-delay fuses can be sized at or close to the motor's nameplate full-load ampere rating without opening on normal motor start-up. This would require sizing the fuses at 100-125% of the motors full-load current rating. Since all motors are not necessarily fully loaded, it is recommended that the actual current draw of the motor be used instead of the nameplate rating. This is possible for motors that have a fixed load, but not recommended where the motor load varies.*

Thus, when single-phasing occurs, FUSETRON® and LOW-PEAK® dual-element, time-delay fuses will sense the overcurrent situation and respond accordingly to take the motor off the line.

For motor branch-circuit protection only, the following sizing guidelines[†] per section 430-52 of the National Electrical Code are allowed.

	Normal	Maximum
• Dual-element, time-delay fuses	175%	225%
• Non-time-delay fuses and all Class CC fuses	300%	400%
• Inverse-time circuit breaker	250%	400% for motors 100 amperes or less. 300% for motors more than 100 amperes.
• Instantaneous only trip** circuit breakers (sometimes referred to as MCPs. These are motor circuit protectors, not motor protectors.)	800%[††]	1300%[†††]

† See NEC 430-52 for specifics and exceptions.
†† 1100% for design E motors
††† 1700% for design E motors

Note: When sized according to table 430-152, none of these overcurrent devices can provide single-phasing protection.

*When sizing to the actual running current of the motor is not practical, an economic analysis can determine if the addition of one of the electronic "black boxes" is financially justified. These electronic "black boxes" can sense voltage and current unbalance, phase reversal, single-phasing, etc.

**Instantaneous only trip breakers are now permitted to have time-delay. This could result in more damaging let-through current during short-circuits.

Single-Phasing

The term **single-phasing**, means one of the phases is open. A single-phasing condition subjects an electric motor to the **worst possible case** of voltage unbalance.

If a three-phase motor is running when the "single-phase" condition occurs, it will attempt to deliver its full horsepower …enough to drive the load. The motor will continue to try to drive the load…until the motor burns out. . . or until the properly sized overload elements and/or properly sized dual-element, time-delay fuses take the motor off the line.

For lightly loaded three-phase motors, say 70% of normal full-load amperes, the phase current will increase by the square root of three (√3) under secondary single-phase conditions. This will result in a current draw of approximately 20% more than the nameplate full load current. If the overloads are sized at 125% of the motor nameplate, circulating currents can still damage the motor. That is why it is recommended that motor overload protection be based upon the actual running current of the motor under its given loading, rather than the nameplate current rating.

Single-Phasing Causes Are Numerous

One fact is sure: Nothing can prevent or eliminate all types of single-phasing.

There are numerous causes of both primary and secondary single-phasing. A device must sense and respond to the resulting increase in current when the single-phasing condition occurs…and do this in the proper length of time to save the motor from damage.

The term "single-phasing" is the term used when one phase of a three-phase system opens. This can occur on either the primary side or secondary side of a distribution transformer. Three-phase motors, when not individually protected by three time-delay, dual-element fuses, or three overload devices, are subject to damaging overcurrents caused by **primary** single-phasing or **secondary** single-phasing.

Single-Phasing on Transformer Secondary – Typical Causes

1. Damaged motor starter contact–one pole open. The number of contact kits sold each year confirms the fact that worn motor starter contacts are the most common cause of single-phasing. Wear and tear of the starter contacts can cause contacts to burn open, or develop very high contact resistance, resulting in single-phasing. This is most likely to occur on automatically started equipment such as air conditioners, compressors, fans, etc.
2. Burned open overload relay (heater) from a line-to-ground fault on a 3 or 4 wire grounded system. This is more likely to occur on smaller size motor starters that are protected by non-current-limiting overcurrent protective devices.
3. Damaged switch or circuit breaker on the main, feeder, or motor branch circuit.
4. Open fuse or open pole in circuit breaker on main, feeder, or motor branch circuit.
5. Open cable or bus on secondary of transformer terminals.
6. Open cable caused by overheated lug on secondary side connection to service.
7. Open connection in wiring such as in motor junction box (caused by vibration) or any pull box. Poor connections, particularly when aluminum conductors are not properly spliced to copper conductors, or when aluminum conductors are inserted into terminals and lugs suitable for use with copper conductors or copper-clad conductors only.
8. Open winding in motor.
9. Open winding in one phase of transformer.
10. **ANY** open circuit in **ANY** phase **ANYWHERE** between the secondary of the transformer and the motor.

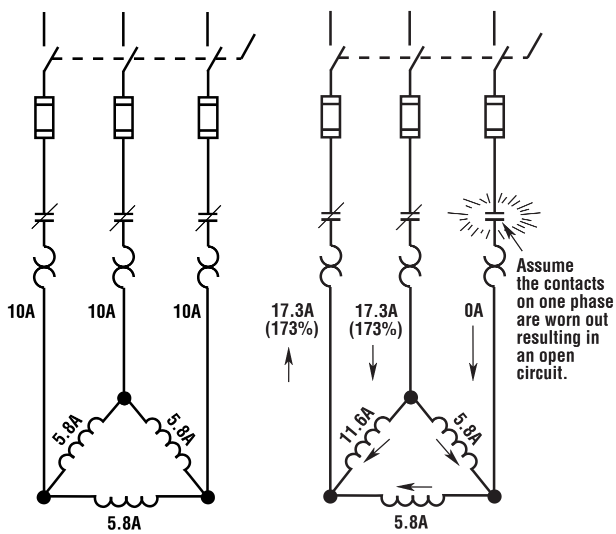
Motor Protection — Voltage Unbalance/Single-Phasing

Hazards of Secondary Single-Phasing for a Three-Phase Motor

When one phase of a secondary opens, the current to a motor in the two remaining phases theoretically increase to 1.73 (173%) times the normal current draw of the motor. The increase can be as much as 2 times (200%) because of power factor changes. Where the motor has a high inertia load, the current can approach locked rotor values under single-phased conditions. Three properly sized time-delay, dual-element fuses, and/or three properly sized overload devices will sense and respond to this overcurrent.

SINGLE-PHASING ON SECONDARY

NORMAL CONDITION **SINGLE-PHASING CONDITION**

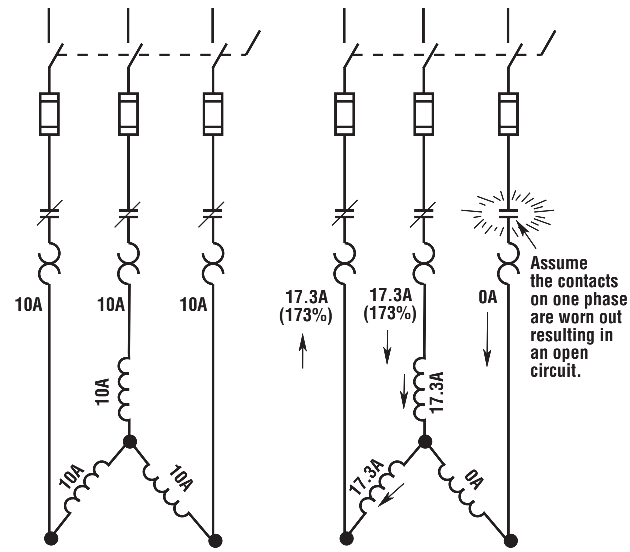


Delta-Connected Motor
FLA = 10 Amperes

(Delta-Connected Motor) Diagram showing the increase in current in the two remaining phases after a single-phasing occurs on the secondary of a transformer.

SINGLE-PHASING ON SECONDARY

NORMAL CONDITION **SINGLE-PHASING CONDITION**

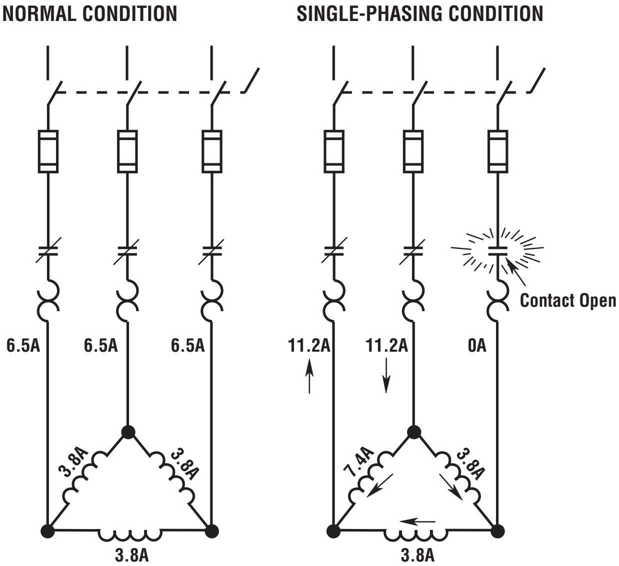


WYE-Connected Motor
FLA = 10 Amperes

(WYE-Connected Motor) Diagram showing the increase in current in the two remaining phases after a single-phasing occurs on the secondary of a transformer.

Motor Protection — Voltage Unbalance/Single-Phasing

SINGLE-PHASING ON SECONDARY



Delta-connected three-phase motor loaded to only 65% of its rated horsepower. Normal FLA = 10 amperes. Overload (overcurrent) protection should be based upon the motor's actual current draw for the underloaded situation for optimum protection. If load varies, overload protection is difficult to achieve. Temperature sensors, phase failure relays and current differential relays should be installed.

When a motor is single-phased, the current in the remaining two phases increases to 173% of normal current. Normally the overload relays will safely clear the motor from the power supply. However, should the overload relays or controller fail to do so, LOW-PEAK® or FUSETRON® time-delay, dual-element fuses properly sized to provide back-up overload protection will clear the motor from its power supply.

Single-Phasing on Transformer Primary – Typical Causes

1. Primary wire broken by:
    a. Storm – wind
    b. Ice – sleet – hail
    c. Lightning
    d. Vehicle or airplane striking pole or high-line
    e. Falling trees or tree limbs
    f. Construction mishaps
2. Primary wire burned off from short-circuit created by birds or animals.
3. Defective contacts on primary breaker or switch – failure to make up on all poles.
4. Failure of 3-shot automatic recloser to make up on all 3 poles.
5. Open pole on 3-phase automatic voltage tap changer.
6. Open winding in one phase of transformer.
7. Primary fuse open.

Hazards of Primary Single-Phasing for a Three-Phase Motor

Probably the most damaging single-phase condition is when one phase of the primary side of WYE/DELTA or DELTA/WYE transformer is open. Usually these causes are not within the control of the user who purchases electrical power. When primary single-phasing occurs, unbalanced voltages appear on the motor circuit, causing excessive unbalanced currents. This was covered earlier in this bulletin.

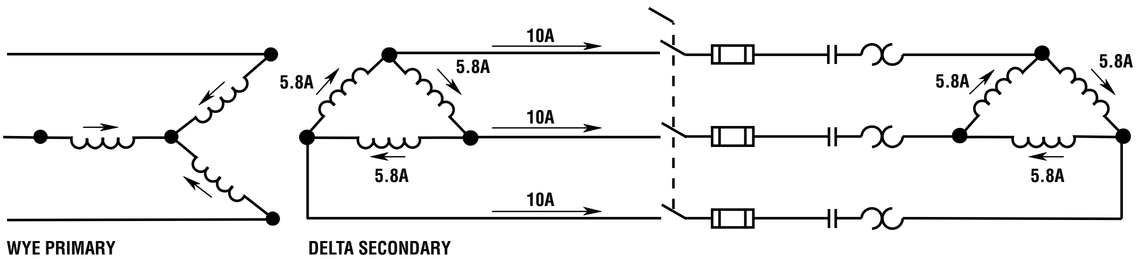
When primary single-phasing occurs, the motor current in one secondary phase increases to 230% of normal current. Normally, the overload relays will protect the motor. However, if for some reason the overload relays or controller fail to function, the LOW-PEAK® or FUSETRON® dual-element fuses properly sized to provide overload protection will clear the motor from the power supply.

Effect of Single-Phasing on Three-Phase Motors

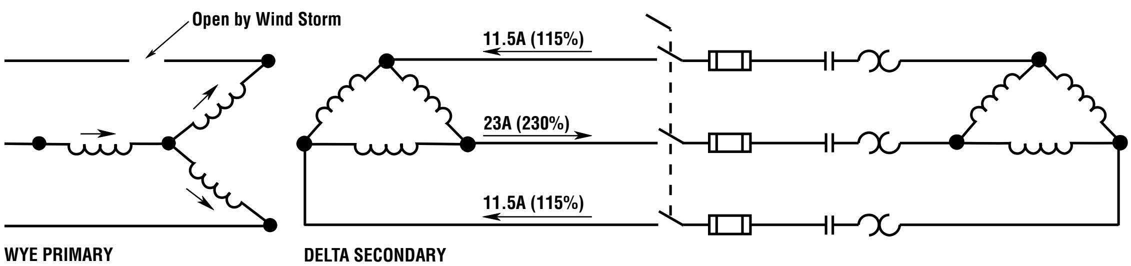
The effects of single-phasing on three-phase motors varies with service conditions and motor thermal capacities. When single-phased, the motor temperature rise may not vary directly with the motor current. When single-phased, the motor temperature rise may increase at a rate greater than the increase in current. In some cases, protective devices which sense only current may not provide complete single-phasing protection. However, PRACTICAL experience has demonstrated that motor running overload devices properly sized and maintained can greatly reduce the problems of single-phasing for the majority of motor installations. In some instances, additional protective means may be necessary when a higher degree of single-phasing protection is required. Generally, smaller horsepower rated motors have more thermal capacity than larger horsepower rated motors and are more likely to be protected by conventional motor running overload devices.

SINGLE-PHASING ON PRIMARY
Delta-Connected Motor; FLA = 10 Amperes

NORMAL CONDITION



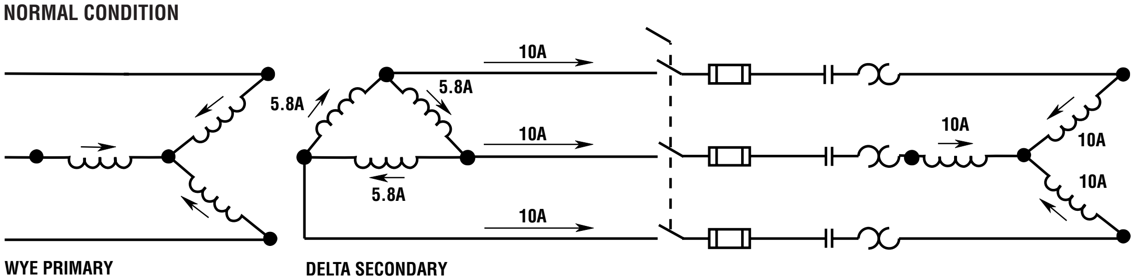
SINGLE-PHASING CONDITION



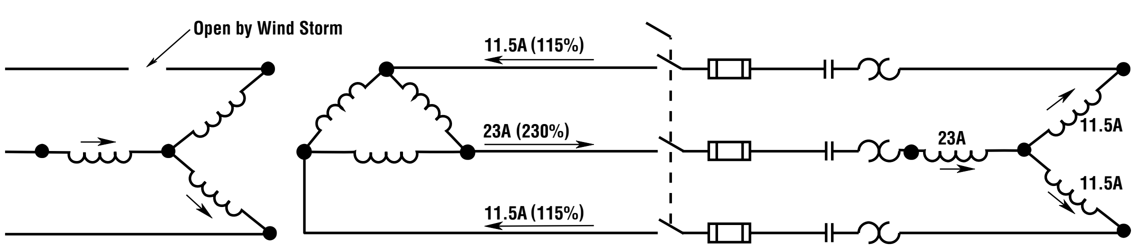
(Delta-Connected Motor) Diagram showing how the phase currents to a three-phase motor increase when a single-phasing occurs on the primary. For older installations where the motor is protected by two overload devices, the phase winding having the 230% current will burn up. However, properly sized overload relays or LOW-PEAK® or FUSETRON® dual-element, time-delay fuses will clear the motor from the power supply.

SINGLE-PHASING ON PRIMARY
Wye-Connected Motor; FLA = 10 Amperes

NORMAL CONDITION



SINGLE-PHASING CONDITION



(Wye-Connected Motor) Diagram showing how the phase currents to a three-phase motor increase when a single-phasing occurs on the primary. For older installations where the motor is protected by two overload devices, the phase winding having the 230% current will burn up. However, properly sized overload relays or LOW-PEAK® or FUSETRON® dual-element, time-delay fuses, will clear the motor from the power supply.

Motor Circuit Protection

MOTOR CIRCUIT PROTECTION TABLES FOR MOTORS COVERED IN NEC ARTICLE 430

Columns 1 & 2

Motor horsepower ratings are listed in Column 1. Full load amps from Tables 430-147 through 430-150 are provided in Column 2.

Column 3

Various fuse types are listed in Column 3. The LPJ_SP is a 600 volt AC, 0-600 ampere, time-delay, Class J, "LOW-PEAK® YELLOW™" fuse, with a 300,000 ampere interrupting rating. The LP-CC is a 600 volt AC, 0-30 ampere, time-delay, Class CC, "LOW-PEAK® YELLOW™" fuse with a 200,000 ampere interrupting rating. The LPS-RK_SP and LPN-RK_SP are 600 and 250 volt AC, 0-600 ampere, time-delay, Class RK1, "LOW-PEAK® YELLOW™" fuses with interrupting ratings of 300,000 amperes. FRS-R and FRN-R are 600 and 250 volt AC, 0-600 ampere, time-delay, Class RK5, FUSETRON® Dual-Element fuses with interrupting ratings of 200,000 amperes. The KRP-C_SP is a 600 volt AC, 601-6000 ampere, time-delay, Class L, "LOW-PEAK® YELLOW™" fuse, with a 300,000 ampere interrupting rating. The DC listed ratings for these fuses are:

LPJ	110 to 200SP	300 Vdc	LPN-RK	0 to 600SP	125 Vdc
LP-CC	0 to $2\frac{8}{10}$	300 Vdc	LPS-RK	0 to 10SP	300 Vdc
LP-CC	3 to 15	150 Vdc	LPS-RK	35 to 600SP	300 Vdc
LP-CC	20 to 30	300 Vdc	FRN-R	0 to 600	125 Vdc
			FRS-R	0 to 600	300 Vdc

Column 4

Fuses sized in accordance with Column 4 must be used in combination with properly sized overload relays (430-32). This sizing is normally large enough to allow the overload relay to operate on overloads without opening the fuse, but small enough to offer a maximum amount of "back-up" protection for the motor and motor circuit.

Sizing for LPJ_SP is based on 150% of Column 2 or the next larger Bussmann size if 150% does not correspond to a Bussmann fuse size.

Sizing for LP-CC is based on 200% of Column 2 or the next larger Bussmann size if 200% does not correspond to a Bussmann fuse size. (In DC circuits, this size is not larger than shown in column 5.)

Sizing for LPS-RK_SP and LPN-RK_SP is based on 130% of Column 2 or the next larger Bussmann size if 130% does not correspond to a Bussmann fuse size.

Sizing for FRS-R and FRN-R is based on 125% of Column 2 or the next Bussmann size if 125% does not correspond to a Bussmann fuse size.

Column 5

Fuses sized in accordance with Column 5 must be used in combination with properly sized overload relays (430-32). This sizing provides the maximum NEC® Table 430-152 sizes for general purpose applications. It takes into account 430-52(c)(1) Exception No. 1, which allows the next standard (240-6) size fuse to be used if the maximum percentage in Table 430-152 does not correspond to a standard fuse size.

Sizing for LPJ_SP, LPS-RK_SP, LPN-RK_SP, FRS-R, FRN-R, and KRP-C_SP is based on 175% (150% for DC motors) of Column 2 or the next larger standard (240-6) size if 175% (150% for DC motors) does not correspond to a standard fuse size.

Sizing for LP-CC is based on 300% (150% for DC motors) of Column 2 or the next larger standard (240-6) size if 300% (150% for DC motors) does not correspond to a standard fuse size.

Sizes shown for the LP-CC can also be used for non-time-delay fuses such as JKS, KTN-R, KTS-R, JJN, JJS, and KTK-R.

Column 6

When the sizes shown in Column 5 are not sufficient to start the motor, a larger size is often available by utilizing 430-52(c)(1) Exception No. 2. The sizes in Column 6 are the larger of the sizes allowed by 430-52(c)(1) Exception No. 1, or 430-52(c)(1) Exception No. 2. These sizes will often be required when acceleration times are greater than 5 seconds, when plugging or jogging applications exist, or where there are high inrush currents (such as Design E motors).

Sizing for LPJ_SP, LPS-RK_SP, LPN-RK_SP, FRS-R, and FRN-R is based on 225% of Column 2 or the next smaller Bussmann size if 225% does not correspond to a Bussmann fuse size. Sizing for LPCC is based on 400% of Column 2 or the next smaller Bussmann size if 400% does not correspond to a Bussmann fuse size. Sizing for KRP-C_SP is based on 300% of column 2, or the next smaller Bussmann size, if 300% does not correspond to a Bussmann size.

Sizes shown for the LP-CC can also be used for non-time-delay fuses such as JKS, KTN-R, KTS-R, JJN, JJS, AND KTK-R.

Column 7

Horsepower-rated switch sizes given in Column 7 are based on 115% (430-110) of Column 2. Switch sizes need to be increased when, because of starting requirements, the fuses are sized above the rating of the switch shown in this column.

A disconnect switch for a Design E motor above 2 HP must be marked for use with a Design E motor or it must have a HP rating not less than 1.4 times the rating of the motor for motors rated 3 through 100 HP or not less than 1.3 times the rating of the motor for motors rated over 100 HP.

Column 8

Sizes listed are for general-purpose magnetic controllers (single speed, full-voltage for limited plugging and jogging-duty) as shown in NEMA Standards Publication ICS-2-1993.

A motor controller for a Design E motor above 2 HP must be marked for use with a Design E motor or it must have a HP rating not less than 1.4 times the rating of the motor for motors rated 3 through 100 HP or not less than 1.3 times the rating of the motor for motors rated over 100 HP.

Column 9

Copper wire sizes are based upon 125% (430-22) of values shown in Column 2 and ampacities listed in Table 310-16 for 75°C terminals. Although the NEC allows 60°C terminations for equipment rated 100 ampere or less, most equipment terminations have been rated for 75°C conductors. If equipment terminations are rated for 60°C conductors only, the 60°C ampacities must be utilized and therefore larger conductor sizes may be required than those shown in this column.

Column 10

These rigid metallic conduit sizes are based upon copper conductors with THHN insulation, Table C8 of Appendix C, and 75°C equipment terminals.

Conduit sizes are for three conductors per circuit for three phase motors and two conductors per circuit for single phase and DC motors. Conduit sizes may need to be increased if equipment grounding conductors or neutrals are also installed in the conduit.

If equipment terminations are rated for 60°C conductors only, the 60˚C ampacities must be utilized and therefore larger conductor sizes and conduit sizes may be required.

Conductors operated in a high ambient temperature may need to be derated. (See correction factor table at the bottom of Table 310-16.)

Motor Circuit Protection

Single-Phase, 115 Volt Motors & Circuits (110-120V System)

1 Motor Size Table 430-148 HP	2 Motor FLA Table 430-148 AMPS	3 Fuse Type	 Class	4 Optimal Branch Ckt Protection AMPS[1]	5 Nec Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	6 Nec Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	7 Minimum Switch Size Sect. 430-110 AMPS	8 Minimum Nema Starter Nema ICS 2-1993 Size	9 Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	10 Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
⅙	4.4	LPJ_SP	J	8	10	10	30	00	14	½
		LP-CC	CC	9	15	17½				
		LPN-RK_SP	RK1	6	10	10				
		FRN-R	RK5	5 6/10	10	10				
¼	5.8	LPJ_SP	J	9	15	15	30	00	14	½
		LP-CC	CC	12	20	20				
		LPN-RK_SP	RK1	8	15	15				
		FRN-R	RK5	7½	15	15				
⅓	7.2	LPJ_SP	J	12	15	15	30	00	14	½
		LP-CC	CC	15	25	25				
		LPN-RK_SP	RK1	10	15	15				
		FRN-R	RK5	9	15	15				
½	9.8	LPJ_SP	J	15	20	20	30	0	14	½
		LP-CC	CC	20	30	–				
		LPN-RK_SP	RK1	15	20	20				
		FRN-R	RK5	15	20	20				
¾	13.8	LPJ_SP	J	25	25	30	30	0	14	½
		LP-CC	CC	30	–	–				
		LPN-RK_SP	RK1	20	25	30				
		FRN-R	RK5	17½	25	30				
1	16	LPJ_SP	J	25	30	35	30*	0	14	½
		LPN-RK_SP	RK1	25	30	35				
		FRN-R	RK5	20	30	35				
1½	20	LPJ_SP	J	30	35	45	30*	1	12	½
		LPN-RK_SP	RK1	30	35	45				
		FRN-R	RK5	25	35	45				
2	24	LPJ_SP	J	40	45	50	30*	1	10	½
		LPN-RK_SP	RK1	35	45	50				
		FRN-R	RK5	30	45	50				
3	34	LPJ_SP	J	60	60	70	60*	2	8**	½**
		LPN-RK_SP	RK1	45	60	70				
		FRN-R	RK5	45	60	70				
5	56	LPJ_SP	J	90	100	125	100*	3	4	¾**
		LPN-RK_SP	RK1	80	100	125				
		FRN-R	RK5	70	100	125				
7½	80	LPJ_SP	J	125	150	175	100*	3	3**	1**
		LPN-RK_SP	RK1	110	150	175				
		FRN-R	RK5	100	150	175				
10	100	LPJ_SP	J	150	175	225	200*	4[2]	1	1¼
		LPN-RK_SP	RK1	150	175	225				
		FRN-R	RK5	125	175	225				

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.

[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

[2]This size is typical. It is not shown in NEMA ICS 2-1993.

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Single-Phase, 230 Volt Motors & Circuits (220-240V System)

1	2	3		4	5	6	7	8	9	10
Motor Size Table 430-148 HP	Motor FLA Table 430-148 AMPS	Fuse		Optimal Branch Ckt Protection AMPS[1]	NEC Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	NEC Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	Minimum Switch Size Sect. 430-110 AMPS	Minimum NEMA Starter NEMA ICS 2-1993 Size	Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
		Type	Class							
⅙	2.2	LPJ_SP	J	3½	6	6	30	00	14	½
		LP-CC	CC	4½	10	10				
		LPN-RK_SP	RK1	3	6	6				
		FRN-R	RK5	2 8/10	6	6				
¼	2.9	LPJ_SP	J	4½	6	6	30	00	14	½
		LP-CC	CC	6	10	10				
		LPN-RK_SP	RK1	4	6	6¼				
		FRN-R	RK5	4	6	6¼				
⅓	3.6	LPJ_SP	J	5 6/10	10	10	30	00	14	½
		LP-CC	CC	7	15	15				
		LPN-RK_SP	RK1	5	10	10				
		FRN-R	RK5	4½	10	10				
½	4.9	LPJ_SP	J	8	10	10	30	00	14	½
		LP-CC	CC	10	15	17½				
		LPN-RK_SP	RK1	8	10	10				
		FRN-R	RK5	6¼	10	10				
¾	6.9	LPJ_SP	J	12	15	15	30	00	14	½
		LP-CC	CC	15	25	25				
		LPN-RK_SP	RK1	9	15	15				
		FRN-R	RK5	9	15	15				
1	8	LPJ_SP	J	12	15	17½	30	00	14	½
		LP-CC	CC	17½	25	30				
		LPN-RK_SP	RK1	12	15	17½				
		FRN-R	RK5	10	15	17½				
1½	10	LPJ_SP	J	15	20	20	30	0	14	½
		LPCC	CC	20	30	–				
		LPN-RK_SP	RK1	15	20	20				
		FRN-R	RK5	15	20	20				
2	12	LPJ_SP	J	20	25	25	30	0	14	½
		LPCC	CC	25	–	–				
		LPN-RK_SP	RK1	17½	25	25				
		FRN-R	RK5	15	25	25				
3	17	LPJ_SP	J	30	30	35	30*	1	12	½
		LPN-RK_SP	RK1	25	30	35				
		FRN-R	RK5	25	30	35				
5	28	LPJ_SP	J	45	50	60	60	2	10**	½
		LPN-RK_SP	RK1	40	50	60				
		FRN-R	RK5	35	50	60				
7½	40	LPJ_SP	J	60	70	90	60*	2	8**	½**
		LPN-RK_SP	RK1	60	70	90				
		FRN-R	RK5	50	70	90				
10	50	LPJ_SP	J	80	90	110	100*	3	6**	½**
		LPN-RK_SP	RK1	70	90	110				
		FRN-R	RK5	70	90	110				

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.

[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

Motor Circuit Protection

Three-Phase, 200 Volt Motors & Circuits

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC Max for Gen.Applic 430-52(C)(1) Exc. No. 1	NEC Max for Heavy Start 430-52(C)(1) Exc. No. 2	Minimum Switch Size Sect. 430-110	Minimum NEMA Starter NEMA ICS 2-1993	Minimum Copper Wire THHN AWG or KCMIL Table 310-16	Minimum Rigid Metallic Conduit Appendix C Table C8
HP	AMPS	Type	Class	AMPS[1]	AMPS[1]	AMPS[1]	AMPS	Size	Size	Inches
½	2.5	**LPJ_SP** **LP-CC** **LPN-RK_SP** **FRN-R**	**J** **CC** **RK1** **RK5**	4 5 3½ 3 2/10	6 10 6 6	6 10 6 6	30	00	14	½
¾	3.7	**LPJ_SP** **LP-CC** **LPN-RK_SP** **FRN-R**	**J** **CC** **RK1** **RK5**	5 6/10 7½ 5 5	10 15 10 10	10 15 10 10	30	00	14	½
1	4.8	**LPJ_SP** **LP-CC** **LPN-RK_SP** **FRN-R**	**J** **CC** **RK1** **RK5**	8 10 6¼ 6	10 15 10 10	10 15 10 10	30	00	14	½
1½	6.9	**LPJ_SP** **LP-CC** **LPN-RK_SP** **FRN-R**	**J** **CC** **RK1** **RK5**	12 15 9 9	15 25 15 15	15 25 15 15	30	00	14	½
2	7.8	**LPJ_SP** **LP-CC** **LPN-RK_SP** **FRN-R**	**J** **CC** **RK1** **RK5**	12 17½ 12 10	15 25 15 15	17½ 30 17½ 17½	30	0	14	½
3	11	**LPJ_SP** **LP-CC** **LPN-RK_SP** **FRN-R**	**J** **CC** **RK1** **RK5**	17½ 25 15 15	20 – 20 20	20 – 20 20	30	0	14	½
5	17.5	**LPJ_SP** **LPN-RK_SP** **FRN-R**	**J** **RK1** **RK5**	30 25 25	35 35 35	35 35 35	30*	1	12	½
7½	25.3	**LPJ_SP** **LPN-RK_SP** **FRN-R**	**J** **RK1** **RK5**	40 35 35	45 45 45	50 50 50	60	1	10**	½**
10	32.2	**LPJ_SP** **LPN-RK_SP** **FRN-R**	**J** **RK1** **RK5**	50 45 45	60 60 60	70 70 70	60*	2	8**	½**
15	48.3	**LPJ_SP** **LPN-RK_SP** **FRN-R**	**J** **RK1** **RK5**	80 70 70	90 90 90	100 100 100	100	3	6**	¾**
20	62.1	**LPJ_SP** **LPN-RK_SP** **FRN-R**	**J** **RK1** **RK5**	100 90 80	110 110 110	125 125 125	100*	3	4**	1
25	78.2	**LPJ_SP** **LPN-RK_SP** **FRN-R**	**J** **RK1** **RK5**	125 110 100	150 150 150	175 175 175	100*	3	3**	1**

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.

[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

Three-Phase, 200 Volt Motors & Circuits (Continued)

1	2	3		4	5	6	7	8	9	10
Motor Size Table 430-150 HP	Motor FLA Table 430-150 AMPS	Fuse		Optimal Branch Ckt Protection AMPS[1]	NEC Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	NEC Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	Minimum Switch Size Sect. 430-110 AMPS	Minimum NEMA Starter NEMA ICS 2-1993 Size	Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
		Type	Class							
30	92	LPJ_SP	J	150	175	200	200	4	2**	1**
		LPN-RK_SP	RK1	125	175	200				
		FRN-R	RK5	125	175	200				
40	120	LPJ_SP	J	200	225	250	200*	4	1/0	1¼
		LPN-RK_SP	RK1	175	225	250				
		FRN-R	RK5	150	225	250				
50	150	LPJ_SP	J	225	300	300	200*	5	3/0	1½
		LPN-RK_SP	RK1	200	300	300				
		FRN-R	RK5	200	300	300				
60	177	LPJ_SP	J	300	350	350	400	5	4/0	2
		LPN-RK_SP	RK1	250	350	350				
		FRN-R	RK5	225	350	350				
75	221	LPJ_SP	J	350	400	450	400*	5	300	2
		LPN-RK_SP	RK1	300	400	450				
		FRN-R	RK5	300	400	450				
		KRP-C_SP	L	–	–	650				
100	285	LPJ_SP	J	450	500	600	400*	6	500	3
		LPN-RK_SP	RK1	400	500	600				
		FRN-R	RK5	400	500	600				
		KRP-C_SP	L	–	–	800				
125	359	LPJ_SP	J	600	–	–	600*	6	4/0 2/PHASE	(2)2
		LPN-RK_SP	RK1	500	–	–				
		FRN-R	RK5	450	–	–				
		KRP-C_SP	L	–	700	1000				
150	414	LPN-RK_SP	RK1	600	–	–	600*	6	300 2/PHASE	(2)2
		FRN-R	RK5	600	–	–				
		KRP-C_SP	L	–	800	1200				
200	552	KRP-C_SP	L	–	1000	1600	1200	76	500 2/PHASE	(2)3

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.

[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

Motor Circuit Protection

Three-Phase, 208 Volt Motors & Circuits

1	2	3		4	5	6	7	8	9	10
Motor Size Table 430-150 HP	Motor FLA Table 430-150 AMPS	Fuse		Optimal Branch Ckt Protection AMPS[1]	Nec Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	Nec Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	Minimum Switch Size Sect. 430-110 AMPS	Minimum Nema Starter Nema ICS 2-1993 Size[2]	Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
		Type	Class							
½	2.4	LPJ_SP LP-CC LPN-RK_SP FRN-R	J CC RK1 RK5	4 5 3½ 3	6 10 6 6	6 10 6 6	30	00	14	½
¾	3.5	LPJ_SP LP-CC LPN-RK_SP FRN-R	J CC RK1 RK5	5 6/10 7 5 4½	10 15 10 10	10 15 10 10	30	00	14	½
1	4.6	LPJ_SP LP-CC LPN-RK_SP FRN-R	J CC RK1 RK5	7 10 6 6	10 15 10 10	10 15 10 10	30	00	14	½
1½	6.6	LPJ_SP LP-CC LPN-RK_SP FRN-R	J CC RK1 RK5	10 15 9 9	15 20 15 15	15 25 15 15	30	00	14	½
2	7.5	LPJ_SP LP-CC LPN-RK_SP FRN-R	J CC RK1 RK5	12 15 10 10	15 20 15 15	15 30 15 15	30	0	14	½
3	10.6	LPJ_SP LP-CC LPN-RK_SP FRN-R	J CC RK1 RK5	17½ 25 15 15	20 – 20 20	20 – 20 20	30	0	14	½
5	16.7	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	30 25 25	30 30 30	35 35 35	30*	1	12	½
7½	24.2	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	40 35 35	45 45 45	50 50 50	60	1	10**	½
10	30.8	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	50 45 40	60 60 60	60 60 60	60	2	8	½**
15	46.2	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	70 70 60	90 90 90	100 100 100	60*	3	6**	¾**
20	59.4	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	90 80 80	110 110 110	125 125 125	100*	3	4**	1
25	74.8	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	125 100 100	150 150 150	150 150 150	100*	3	3**	1**

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.

[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

[2]These sizes are typical. They are not shown in NEMA ICS 2-1993.

Motor Circuit Protection

Three-Phase, 208 Volt Motors & Circuits (Continued)

1	2	3		4	5	6	7	8	9	10
Motor Size Table 430-150 HP	Motor FLA Table 430-150 AMPS	Fuse		Optimal Branch Ckt Protection AMPS[1]	Nec Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	Nec Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	Minimum Switch Size Sect. 430-110 AMPS	Minimum Nema Starter Nema ICS 2-1993 Size[2]	Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
		Type	Class							
30	88	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	150 125 110	175 175 175	175 175 175	200	4	2**	1**
40	114	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	175 150 150	200 200 200	250 250 250	200*	4	1/0	1¼
50	143	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	225 200 200	300 300 300	300 300 300	200*	5	3/0	1½
60	169	LPJ_SP LPN-RK_SP FRN-R	J RK1 RK5	300 225 225	300 300 300	350 350 350	400	5	4/0	2
75	211	LPJ_SP LPN-RK_SP FRN-R KRP-C_SP	J RK1 RK5 L	350 300 300 –	400 400 400 –	450 450 450 601	400*	5	300	2
100	273	LPJ_SP LPN-RK_SP FRN-R KRP-C_SP	J RK1 RK5 L	450 400 350 –	500 500 500 –	600 600 600 800	400*	6	500	3
125	343	LPJ_SP LPN-RK_SP FRN-R KRP-C_SP	J RK1 RK5 L	600 450 450 –	– – – 601	– – – 1000	600*	6	4/0 2/PHASE	(2)2
150	396	LPJ_SP LPN-RK_SP FRN-R KRP-C_SP	J RK1 RK5 L	600 600 500 –	– – – 700	– – – 1100	600*	6	250 2/PHASE	(2)2
200	528	KRP-C_SP	L	–	1000	1500	1200	7	400 2/PHASE	(2)2-2½

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.
[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.
**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.
[2]These sizes are typical. They are not shown in NEMA ICS 2-1993.

Motor Circuit Protection

Three-Phase, 230 Volt Motors & Circuits (220 - 240V System)

1	2	3		4	5	6	7	8	9	10
Motor Size Table 430-150 HP	Motor FLA Table 430-150 AMPS	Fuse Type	Fuse Class	Optimal Branch Ckt Protection AMPS[1]	NEC Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	NEC Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	Minimum Switch Size Sect. 430-110 AMPS	Minimum NEMA Starter NEMA ICS 2-1993 Size	Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
½	2.2	LPJ_SP	J	3½	6	6	30	00	14	½
		LP-CC	CC	4½	10	10				
		LPN-RK_SP	RK1	3	6	6				
		FRN-R	RK5	2 8/10	6	6				
¾	3.2	LPJ_SP	J	5	6	7	30	00	14	½
		LP-CC	CC	7	10	12				
		LPN-RK_SP	RK1	4½	6	7				
		FRN-R	RK5	4	6	7				
1	4.2	LPJ_SP	J	7	10	10	30	00	14	½
		LP-CC	CC	9	15	15				
		LPN-RK_SP	RK1	5 6/10	10	10				
		FRN-R	RK5	5 6/10	10	10				
1½	6	LPJ_SP	J	9	15	15	30	00	14	½
		LP-CC	CC	12	20	20				
		LPN-RK_SP	RK1	8	15	15				
		FRN-R	RK5	7½	15	15				
2	6.8	LPJ_SP	J	12	15	15	30	0	14	½
		LP-CC	CC	15	25	25				
		LPN-RK_SP	RK1	9	15	15				
		FRN-R	RK5	9	15	15				
3	9.6	LPJ_SP	J	15	20	20	30	0	14	½
		LP-CC	CC	20	30	–				
		LPN-RK_SP	RK1	15	20	20				
		FRN-R	RK5	12	20	20				
5	15.2	LPJ_SP	J	25	30	30	30	1	14	½
		LPN-RK_SP	RK1	20	30	30				
		FRN-R	RK5	20	30	30				
7½	22	LPJ_SP	J	35	40	45	30*	1	10	½
		LPN-RK_SP	RK1	30	40	45				
		FRN-R	RK5	30	40	45				
10	28	LPJ_SP	J	45	50	60	60	2	10**	½
		LPN-RK_SP	RK1	40	50	60				
		FRN-R	RK5	35	50	60				
15	42	LPJ_SP	J	70	80	90	60*	2	6	¾
		LPN-RK_SP	RK1	60	80	90				
		FRN-R	RK5	60	80	90				
20	54	LPJ_SP	J	90	100	110	100*	3	4	1
		LPN-RK_SP	RK1	80	100	110				
		FRN-R	RK5	70	100	110				
25	68	LPJ_SP	J	110	125	150	100*	3	4**	1
		LPN-RK_SP	RK1	90	125	150				
		FRN-R	RK5	90	125	150				

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.

[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

Motor Circuit Protection

Three-Phase, 230 Volt Motors & Circuits (220 - 240V System) (Continued)

1 Motor Size Table 430-150 HP	2 Motor FLA Table 430-150 AMPS	3 Fuse Type	3 Fuse Class	4 Optimal Branch Ckt Protection AMPS[1]	5 NEC Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	6 NEC Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	7 Minimum Switch Size Sect. 430-110 AMPS	8 Minimum NEMA Starter NEMA ICS 2-1993 Size	9 Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	10 Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
30	80	**LPJ_SP** **LPN-RK_SP** **FRN-R**	**J** **RK1** **RK5**	125 110 100	150 150 150	175 175 175	100*	3	3**	1**
40	104	**LPJ_SP** **LPN-RK_SP** **FRN-R**	**J** **RK1** **RK5**	175 150 150	200 200 200	225 225 225	200*	4	1**	1¼**
50	130	**LPJ_SP** **LPN-RK_SP** **FRN-R**	**J** **RK1** **RK5**	200 175 175	250 250 250	250 250 250	200*	4	2/0	1½
60	154	**LPJ_SP** **LPN-RK_SP** **FRN-R**	**J** **RK1** **RK5**	250 225 200	300 300 300	300 300 300	200*	5	3/0	1½
75	192	**LPJ_SP** **LPN-RK_SP** **FRN-R**	**J** **RK1** **RK5**	300 250 250	350 350 350	400 400 400	400	5	250	2
100	248	**LPJ_SP** **LPN-RK_SP** **FRN-R** **KRP-C_SP**	**J** **RK1** **RK5** **L**	400 350 350 –	450 450 450 –	500 500 500 700	400*	5	350	2½
125	312	**LPJ_SP** **LPN-RK_SP** **FRN-R** **KRP-C_SP**	**J** **RK1** **RK5** **L**	500 450 400 –	600 600 600 –	– – – 900	400*	6	3/0 2/PHASE	(2)1½
150	360	**LPJ_SP** **LPN-RK_SP** **FRN-R** **KRP-C_SP**	**J** **RK1** **RK5** **L**	600 500 450 –	– – – 700	– – – 1000	600*	6	4/0 2/PHASE	(2)2
200	480	**FRN-R** **KRP-C_SP**	**RK5** **L**	600 –	– 1000	– 1400	600*	6	350 2/PHASE	(2)2½

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.
[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.
**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

Motor Circuit Protection

Three-Phase, 460 Volt Motors & Circuits (440 - 480V System)

1 Motor Size Table 430-150 HP	2 Motor FLA Table 430-150 AMPS	3 Fuse Type	3 Fuse Class	4 Optimal Branch Ckt Protection AMPS[1]	5 NEC Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	6 NEC Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	7 Minimum Switch Size Sect. 430-110 AMPS	8 Minimum NEMA Starter NEMA ICS 2-1993 Size	9 Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	10 Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
½	1.1	LPJ_SP LP-CC LPS-RK_SP FRS-R	J CC RK1 RK5	1 8/10 2¼ 1½ 1 4/10	3 6 3 3	3 6 3 3	30	00	14	½
¾	1.6	LPJ_SP LP-CC LPS-RK_SP FRS-R	J CC RK1 RK5	2½ 3 2/10 2¼ 2	3 6 3 3	3½ 6¼ 3½ 3½	30	00	14	½
1	2.1	LPJ_SP LP-CC LPS-RK_SP FRS-R	J CC RK1 RK5	3 2/10 4½ 2 8/10 2 8/10	6 10 6 6	6 10 6 6	30	00	14	½
1½	3	LPJ_SP LP-CC LPS-RK_SP FRS-R	J CC RK1 RK5	4½ 6 4 4	6 10 6 6	6 12 6¼ 6¼	30	00	14	½
2	3.4	LPJ_SP LP-CC LPS-RK_SP FRS-R	J CC RK1 RK5	5 6/10 7 4½ 4½	6 15 6 6	7 15 7 7½	30	00	14	½
3	4.8	LPJ_SP LP-CC LPS-RK_SP FRS-R	J CC RK1 RK5	8 10 6¼ 6	10 15 10 10	10 15 10 10	30	0	14	½
5	7.6	LPJ_SP LP-CC LPS-RK_SP FRS-R	J CC RK1 RK5	12 17½ 10 10	15 25 15 15	15 30 15 15	30	0	14	½
7½	11	LPJ_SP LP-CC LPS-RK_SP FRS-R	J CC RK1 RK5	17½ 25 15 15	20 – 20 20	20 – 20 20	30	1	14	½
10	14	LPJ_SP LP-CC LPS-RK_SP FRS-R	J CC RK1 RK5	25 30 20 17½	25 – 25 25	30 – 30 30	30	1	14	½
15	21	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	35 30 30	40 40 40	45 45 45	30*	2	10	½
20	27	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	45 40 35	50 50 50	60 60 60	60	2	10**	½
25	34	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	60 45 45	60 60 60	70 70 70	60*	2	8**	½**

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.

[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

Motor Circuit Protection

Three-Phase, 460 Volt Motors & Circuits (440 - 480V System) (Continued)

1 Motor Size Table 430-150 HP	2 Motor FLA Table 430-150 AMPS	3 Fuse Type	 Class	4 Optimal Branch Ckt Protection AMPS[1]	5 NEC Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	6 NEC Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	7 Minimum Switch Size Sect. 430-110 AMPS	8 Minimum NEMA Starter NEMA ICS 2-1993 Size	9 Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	10 Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
30	40	**LPJ_SP** **LPS-RK_SP** **FRS-R**	**J** **RK1** **RK5**	60 60 50	70 70 70	90 90 90	60*	3	8**	½**
40	52	**LPJ_SP** **LPS-RK_SP** **FRS-R**	**J** **RK1** **RK5**	80 70 70	100 100 100	110 110 110	100*	3	6**	¾**
50	65	**LPJ_SP** **LPS-RK_SP** **FRS-R**	**J** **RK1** **RK5**	100 90 90	125 125 125	125 125 125	100*	3	4**	1
60	77	**LPJ_SP** **LPS-RK_SP** **FRS-R**	**J** **RK1** **RK5**	125 110 100	150 150 150	150 150 150	100*	4	3**	1**
75	96	**LPJ_SP** **LPS-RK_SP** **FRS-R**	**J** **RK1** **RK5**	150 125 125	175 175 175	200 200 200	200	4	1**	1¼**
100	124	**LPJ_SP** **LPS-RK_SP** **FRS-R**	**J** **RK1** **RK5**	200 175 175	225 225 225	250 250 250	200*	4	2/0	1½
125	156	**LPJ_SP** **LPS-RK_SP** **FRS-R**	**J** **RK1** **RK5**	250 225 200	300 300 300	350 350 350	200*	5	3/0	1½
150	180	**LPJ_SP** **LPS-RK_SP** **FRS-R**	**J** **RK1** **RK5**	300 250 225	350 350 350	400 400 400	400	5	4/0	2
200	240	**LPJ_SP** **LPS-RK_SP** **FRS-R** **KRP-C_SP**	**J** **RK1** **RK5** **L**	400 350 300 –	450 450 450 –	500 500 500 700	400*	5	350	2½
250	302	**LPJ_SP** **LPS-RK_SP** **FRS-R** **KRP-C_SP**	**J** **RK1** **RK5** **L**	500 400 400 –	600 600 600 –	– – – 900	400*	6	3/0 2/PHASE	(2)1½
300	361	**LPJ_SP** **LPS-RK_SP** **FRS-R** **KRP-C_SP**	**J** **RK1** **RK5** **L**	600 500 500 –	– – – 700	– – – 1000	600*	6	4/0 2/PHASE	(2)2
350	414	**LPS-RK_SP** **FRS-R** **KRP-C_SP**	**RK1** **RK5** **L**	600 600 –	– – 800	– – 1200	600*	6	300 2/PHASE	(2)2
400	477	**KRP-C_SP** **FRS-R**	**L** **RK5**	–	1000 600	1400	1200 600	6	350 2/PHASE	(2)2½
450	515	**KRP-C_SP**	**L**	–	1000	1500	1200	7	400 2/PHASE	(2)2½
500	590	**KRP-C_SP**	**L**	–	1200	1600	1200	7	500 2/PHASE	(2)3

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.

[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

Three-Phase, 575 Volt Motors & Circuits (550 - 600V System)

1	2	3		4	5	6	7	8	9	10
Motor Size Table 430-150 HP	Motor FLA Table 430-150 AMPS	Fuse		Optimal Branch Ckt Protection AMPS[1]	NEC Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	NEC Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	Minimum Switch Size Sect. 430-110 AMPS	Minimum NEMA Starter NEMA ICS 2-1993 Size[2]	Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
		Type	Class							
½	0.9	LPJ_SP	J	1 4/10	3	3	30	0	14	½
		LP-CC	CC	1 8/10	3	3½				
		LPS-RK_SP	RK1	1¼	3	3				
		FRS-R	RK5	1⅛	3	3				
¾	1.3	LPJ_SP	J	2	3	3	30	0	14	½
		LP-CC	CC	2 8/10	6	6				
		LPS-RK_SP	RK1	1 8/10	3	3				
		FRS-R	RK5	1 8/10	3	3				
1	1.7	LPJ_SP	J	2 8/10	3	3½	30	0	14	½
		LP-CC	CC	3½	6	6¼				
		LPS-RK_SP	RK1	2¼	3	3½				
		FRS-R	RK5	2¼	3	3½				
1½	2.4	LPJ_SP	J	4	6	6	30	0	14	½
		LP-CC	CC	5	10	10				
		LPS-RK_SP	RK1	3 2/10	6	6				
		FRS-R	RK5	3	6	6				
2	2.7	LPJ_SP	J	4½	6	6	30	0	14	½
		LP-CC	CC	5 6/10	10	10				
		LPS-RK_SP	RK1	4	6	6				
		FRS-R	RK5	3½	6	6				
3	3.9	LPJ_SP	J	6	10	10	30	0	14	½
		LP-CC	CC	5	15	15				
		LPS-RK_SP	RK1	5 6/10	10	10				
		FRS-R	RK5	5	10	10				
5	6.1	LPJ_SP	J	10	15	15	30	0	14	½
		LP-CC	CC	15	20	20				
		LPS-RK_SP	RK1	8	15	15				
		FRS-R	RK5	8	15	15				
7½	9	LPJ_SP	J	15	20	20	30	1	14	½
		LP-CC	CC	20	30	–				
		LPS-RK_SP	RK1	12	20	20				
		FRS-R	RK5	12	20	20				
10	11	LPJ_SP	J	17½	20	20	30	1	14	½
		LP-CC	CC	25	–	–				
		LPS-RK_SP	RK1	15	20	20				
		FRS-R	RK5	15	20	20				
15	17	LPJ_SP	J	30	30	35	30*	2	12	½
		LPS-RK_SP	RK1	25	30	35				
		FRS-R	RK5	25	30	35				
20	22	LPJ_SP	J	35	40	45	30*	2	10	½
		LPS-RK_SP	RK1	30	40	45				
		FRS-R	RK5	30	40	45				
25	27	LPJ_SP	J	45	50	60	60	2	10**	½**
		LPS-RK_SP	RK1	40	50	60				
		FRS-R	RK5	35	50	60				

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.

[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

[2]These sizes are typical. They are not shown in NEMA ICS 2-1993.

Motor Circuit Protection

Three-Phase, 575 Volt Motors & Circuits (550 - 600V System) (Continued)

1	2	3		4	5	6	7	8	9	10
Motor Size Table 430-150 HP	Motor FLA Table 430-150 AMPS	Fuse Type	Fuse Class	Optimal Branch Ckt Protection AMPS[1]	NEC Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	NEC Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	Minimum Switch Size Sect. 430-110 AMPS	Minimum NEMA Starter NEMA ICS 2-1993 Size[2]	Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
30	32	LPJ_SP	J	50	60	70	60*	3	8	½
		LPS-RK_SP	RK1	45	60	70				
		FRS-R	RK5	40	60	70				
40	41	LPJ_SP	J	70	80	90	60*	3	6	¾
		LPS-RK_SP	RK1	60	80	90				
		FRS-R	RK5	60	80	90				
50	52	LPJ_SP	J	80	100	110	100*	3	6**	¾**
		LPS-RK_SP	RK1	70	100	110				
		FRS-R	RK5	70	100	110				
60	62	LPJ_SP	J	100	110	125	100*	4	4**	1
		LPS-RK_SP	RK1	90	110	125				
		FRS-R	RK5	80	110	125				
75	77	LPJ_SP	J	125	150	150	100*	4	3**	1**
		LPS-RK_SP	RK1	110	150	150				
		FRS-R	RK5	100	150	150				
100	99	LPJ_SP	J	150	175	200	200	4	1**	1¼**
		LPS-RK_SP	RK1	150	175	200				
		FRS-R	RK5	125	175	200				
125	125	LPJ_SP	J	200	225	250	200*	5	2/0	1½
		LPS-RK_SP	RK1	175	225	250				
		FRS-R	RK5	175	225	250				
150	144	LPJ_SP	J	225	300	300	200*	5	3/0	1½
		LPS-RK_SP	RK1	200	300	300				
		FRS-R	RK5	200	300	300				
200	192	LPJ_SP	J	300	350	400	400	5	250	2
		LPS-RK_SP	RK1	250	350	400				
		FRS-R	RK5	250	350	400				
250	242	LPJ_SP	J	400	450	500	400*	6	350	2½
		LPS-RK_SP	RK1	350	450	500				
		FRS-R	RK5	350	450	500				
		KRP-C_SP	L	–	–	700				
300	289	LPJ_SP	J	450	600	600	400*	6	500	3
		LPS-RK_SP	RK1	400	600	600				
		FRS-R	RK5	400	600	600				
		KRP-C_SP	L	–	–	800				
350	336	LPJ_SP	J	600	600	–	600*	6	4/0 2/PHASE	(2)2
		LPS-RK_SP	RK1	450	600	–				
		FRS-R	RK5	450	600	–				
		KRP-C_SP	L	–	601	1000				
400	382	LPJ_SP	J	600	–	–	600*	6	250 2/PHASE	(2)2
		LPS-RK_SP	RK1	500	–	–				
		FRS-R	RK5	500	–	–				
		KRP-C_SP	L	–	700	1100				
450	412	LPS-RK_SP	RK1	600	–	–	600*	7	300 2/PHASE	(2)2
		FRS-R	RK5	600	–	–				
		KRP-C_SP	L	–	800	1200				
500	472	FRS-R	RK5	600	–	–	600*	7	350 2/PHASE	(2)2½
		KRP-C_SP	L	–	1000	1400				

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.

[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

[2]These sizes are typical. They are not shown in NEMA ICS 2-1993.

Motor Circuit Protection

Direct-Current[3], 90 Volt Motors & Circuits

1	2	3		4	5	6	7	8	9	10
Motor Size Table 430-147 HP	Motor FLA Table 430-147 AMPS	Fuse		Optimal Branch Ckt Protection AMPS[1]	NEC Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	NEC Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	Minimum Switch Size Sect. 430-110 AMPS	Minimum NEMA Starter NEMA ICS 2-1993 Size[2]	Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
		Type	Class							
¼	4.0	LPC_CC LPN-RK_SP FRN-R	CC RK1 RK5	6 6 5	6 6 6	15 9 9	30	1	14	½
⅓	5.2	LP-CC LPN-RK_SP FRN-R	CC RK1 RK5	10 8 7	10 10 10	20 10 10	30	1	14	½
½	6.8	LP-CC LPN-RK_SP FRN-R	CC RK1 RK5	15 9 9	15 15 15	25 15 15	30	1	14	½
¾	9.6	LP-CC LPN-RK_SP FRN-R	CC RK1 RK5	15 15 12	15 15 15	30 20 20	30	1	14	½
1	12.2	LP-CC LPN-RK_SP FRN-R	CC RK1 RK5	20 17½ 17½	20 20 20	– 25 25	30	1	14	½

Direct-Current[3], 180 Volt Motors & Circuits

1	2	3		4	5	6	7	8	9	10
Motor Size Table 430-147 HP	Motor FLA Table 430-147 AMPS	Fuse		Optimal Branch Ckt Protection AMPS[1]	NEC Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	NEC Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	Minimum Switch Size Sect. 430-110 AMPS	Minimum NEMA Starter NEMA ICS 2-1993 Size[2]	Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
		Type	Class							
¼	2.0	LPS-RK_SP FRS-R	RK1 RK5	2⁸⁄₁₀ 2½	3 3	4½ 4½	30	1	14	½
⅓	2.6	LPS-RK_SP FRS-R	RK1 RK5	3½ 3½	6 6	6 6	30	1	14	½
½	3.4	LPS-RK_SP FRS-R	RK1 RK5	4½ 4½	6 6	6¼ 7½	30	1	14	½
¾	4.8	LP-CC LPS-RK_SP FRS-R	CC RK1 RK5	10 6¼ 6	10 10 10	17½ 10 10	30	1	14	½
1	6.1	LP-CC FRS-R	CC RK5	– 8	– 10	20 12	30	1	14	½
1½	8.3	LP-CC FRS-R	CC RK5	– 12	– 15	30 17½	30	1	14	½
2	10.8	LP-CC FRS-R	CC RK5	20 15	20 20	– 20	30	1	14	½
3	16	LP-CC FRS-R	CC RK5	25 20	25 25	– 35	30*	1	14	½
5	27	LPS-RK_SP FRS-R	RK1 RK5	40 35	45 45	60 60	60	2	10**	½

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.

[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.

**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.

[2]This size is typical. It is not shown in NEMA ICS 2-1993.

[3]All equipment manufacturers should be consulted about DC voltage ratings of their equipment.

Motor Circuit Protection

Direct-Current[3], 120 Volt Motors & Circuits

1	2	3		4	5	6	7	8	9	10
Motor Size	Motor FLA	Fuse		Optimal Branch Ckt Protection	NEC Max for Gen.Applic 430-52(C)(1) Exc. No. 1	NEC Max for Heavy Start 430-52(C)(1) Exc. No. 2	Minimum Switch Size Sect. 430-110	Minimum NEMA Starter NEMA ICS 2-1993	Minimum Copper Wire THHN AWG or KCMIL Table 310-16	Minimum Rigid Metallic Conduit Appendix C Table C8
Table 430-147 HP	Table 430-147 AMPS	Type	Class	AMPS[1]	AMPS[1]	AMPS[1]	AMPS	Size[2]	Size	Inches
¼	3.1	LP-CC	CC	6	6	12	30	1	14	½
		LPN-RK_SP	RK1	4½	6	6¼				
		FRN-R	RK5	4	6	6¼				
⅓	4.1	LP-CC	CC	9	10	15	30	1	14	½
		LPN-RK_SP	RK1	5 6/10	10	10				
		FRN-R	RK5	5 6/10	10	10				
½	5.4	LP-CC	CC	10	10	20	30	1	14	½
		LPN-RK_SP	RK1	7½	10	12				
		FRN-R	RK5	7	10	12				
¾	7.6	LP-CC	CC	15	15	30	30	1	14	½
		LPN-RK_SP	RK1	10	15	15				
		FRN-R	RK5	10	15	15				
1	9.5	LP-CC	CC	15	15	–	30	1	14	½
		LPN-RK_SP	RK1	15	15	20				
		FRN-R	RK5	12	15	20				
1½	13.2	LP-CC	CC	20	20	–	30	1	14	½
		LPN-RK_SP	RK1	17½	20	25				
		FRN-R	RK5	17½	20	25				
2	17	LP-CC	CC	30	30	35	30*	1	12	½
		LPN-RK_SP	RK1	25	30	–				
		FRN-R	RK5	25	30	35				
3	25	LPN-RK_SP	RK1	35	40	50	60	1	10**	½
		FRN-R	RK5	35	40	50				
5	40	LPN-RK_SP	RK1	60	60	90	60*	2	8**	½**
		FRN-R	RK5	50	60	90				
7½	58	LPJ_SP	J	–	–	125	100*	3	4**	¾**
		LPN-RK_SP	RK1	80	90	125				
		FRN-R	RK5	80	90	125				
10	76	LPJ_SP	J	125	125	150	100*	3	3**	1
		LPN-RK_SP	RK1	100	125	150				
		FRN-R	RK5	100	125	150				

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.
[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.
**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.
[2]Reduced voltage magnetic controller ratings.
[3]All equipment manufacturers should be consulted about DC voltage ratings of their equipment.

Motor Circuit Protection

Direct-Current[3], 240 Volt Motors & Circuits

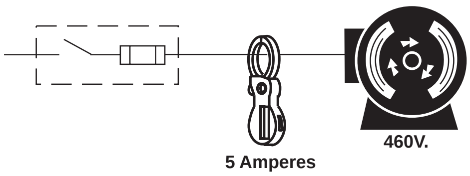
1	2	3		4	5	6	7	8	9	10
Motor Size Table 430-147 HP	Motor FLA Table 430-147 AMPS	Fuse		Optimal Branch Ckt Protection AMPS[1]	NEC Max for Gen.Applic 430-52(C)(1) Exc. No. 1 AMPS[1]	NEC Max for Heavy Start 430-52(C)(1) Exc. No. 2 AMPS[1]	Minimum Switch Size Sect. 430-110 AMPS	Minimum NEMA Starter NEMA ICS 2-1993 Size[2]	Minimum Copper Wire THHN AWG or KCMIL Table 310-16 Size	Minimum Rigid Metallic Conduit Appendix C Table C8 Inches
		Type	Class							
¼	1.6	LPS-RK_SP FRS-R	RK1 RK5	2¼ 2	3 3	3½ 3½	30	1	14	½
⅓	2.0	LPS-RK_SP FRS-R	RK1 RK5	2 8/10 2½	3 3	4½ 4½	30	1	14	½
½	2.7	LPS-RK_SP FRS-R	RK1 RK5	4 3½	6 6	6 6	30	1	14	½
¾	3.8	LP-CC LPS-RK_SP FRS-R	CC RK1 RK5	6 5 5	6 6 6	15 8 8	30	1	14	½
1	4.7	LPS-RK_SP FRS-R	RK1 RK5	6¼ 6	10 10	10 10	30	1	14	½
1½	6.6	LPS-RK_SP FRS-R	RK1 RK5	9 9	10 10	– 12	30	1	14	½
2	8.5	FRS-R	RK5	12	15	17½	30	1	14	½
3	12.2	LP-CC FRS-R	CC RK5	20 17½	20 20	– 25	30	1	14	½
5	20	LP-CC LPS-RK_SP FRS-R	CC RK1 RK5	30 30 25	30 30 30	– 45 45	30*	1	12	½
7½	29	LPS-RK_SP FRS-R	RK1 RK5	40 40	45 45	60 60	60	2	8	½
10	38	LPS-RK_SP FRS-R	RK1 RK5	50 50	60 60	80 80	60*	2	8**	½**
15	55	LPS-RK_SP FRS-R	RK1 RK5	80 70	90 90	110 110	100*	3	4	¾**
20	72	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	110 100 90	110 110 110	150 150 150	100*	3	3**	1
25	89	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	150 125 125	150 150 150	200 200 200	200	3	2**	1**
30	106	LPJ_SP LPS-RK_SP FRS-R	J RK1 RK5	175 150 150	175 175 175	– 225 225	200*	4	1/0**	1¼
40	140	LPS-RK_SP FRS-R	RK1 RK5	200 175	225 225	300 300	200*	4	2/0**	1¼**
50	173	LPS-RK_SP FRS-R	RK1 RK5	225 225	300 300	350 350	400	5	4/0**	1½**
60	206	LPS-RK_SP FRS-R	RK1 RK5	300 300	350 350	450 450	400*	5	300**	2**
75	255	LPS-RK_SP FRS-R	RK1 RK5	350 350	400 400	500 500	400*	5	400**	2**
100	341	LPS-RK_SP FRS-R	RK1 RK5	450 450	600 600	– –	600	6	4/0 2/PHASE	(2)1½**

*Switch size must be increased if the ampere rating of the fuse exceeds the ampere rating of the switch.
[1]Per 430-52(c)(2), if the motor controller manufacturer's overload relay tables state a maximum branch circuit protective device of a lower rating, that lower rating must be used in lieu of the sizes shown in Columns 4, 5, or 6.
**If equipment terminations are rated for 60°C conductors only, the 60°C conductor ampacities must be utilized and therefore larger conductor sizes or conduit sizes may be required.
[2]Reduced voltage magnetic DC controller ratings.
[3]All equipment manufacturers should be consulted about DC voltage ratings of their equipment.

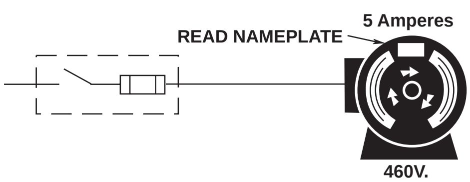
Main, Feeder, and Branch Circuit Protection

Recommendations for Electrician and Maintenance Crews

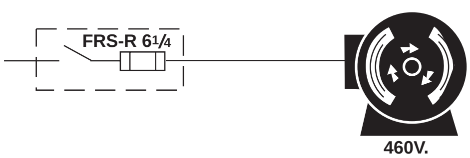
Often, for various reasons, motors are oversized for applications. For instance, a 5 HP motor is installed when the load demand is only 3 HP. In these cases a much higher degree of protection can be obtained by sizing the overload relay elements and/or FUSETRON® and LOW-PEAK® YELLOW™ dual-element, time-delay fuses based on the actual full-load current draw.



1. **Preferable –** With a clamp-on meter, determine running RMS current when the motor is at normal full-load. (Be sure this current does not exceed nameplate current rating.) The advantage of this method is realized when a lightly loaded motor (especially those over 50 HP) experiences a single-phase condition. Even though the relays and fuses may be sized correctly based on motor nameplate, circulating currents within the motor may cause damage.



Alternate – If unable to meter the motor current, then take the current rating off the nameplate.



2. Then size the overload relay elements and FUSETRON® or LOW-PEAK® YELLOW™ dual-element fuses based on this current. For optimum motor circuit protection offering a high degree of "back-up overload" protection, use the table that follows to assist in sizing dual-element fuses.
3. Use a labeling system to mark the type and ampere rating of the fuse that should be in the fuse clips, such as FRS-R6¼. This simple step makes it easy to run spot checks for proper fuse replacement.

When installing the proper fuses in the switch to give the desired level of protection, it often is advisable to leave spare fuses on top of the disconnect, the starter enclosure or in a cabinet adjacent to the motor control center. In this way, should the fuses open, the problem can be corrected and proper size fuses easily reinstalled.

*Abnormal installations may require FUSETRON® or LOW-PEAK® YELLOW™ dual-element fuses of a larger size than shown providing only short-circuit protection. These applications include:
(a) FUSETRON® or LOW-PEAK® YELLOW™ dual-element fuses in high ambient temperature environments.
(b) A motor started frequently or rapidly reversed.
(c) Motor is directly connected to a machine that cannot be brought up to full speed quickly (large fans, centrifugal machines such as extractors and pulverizes, machines having large fly wheels such as large punch presses.)
(d) Motor has a high Code Letter (or possibly no Code Letter) with full voltage start.
(e) Wye delta open transition start.
(f) Motor has a large inrush current, such as a Design B or E motor.

* Selection of FUSETRON® or LOW-PEAK® YELLOW™ Dual-Element Fuses based upon Motor FULL Load Amps for Optimum Motor Circuit Protection.

FUSETRON® or LOW-PEAK® YELLOW™ Dual-Element Fuse Size	Motor Current			
	FRN-R FRS-R Class RK5	LPN-RK_SP LPS-RK_SP Class RK1	LPJ_SP Class J	LP-CC Class CC
1/10	0-0.08	0.0000-0.0769	—	—
1/8	0.09-0.10	0.0770-0.0961	—	—
15/100	0.11-0.12	0.0962-0.1153	—	—
2/10	0.13-0.16	0.1154-0.1538	—	—
1/4	0.17-0.20	0.1539-0.1923	—	—
3/10	0.21-0.24	0.1924-0.2307	—	—
4/10	0.25-0.32	0.2308-0.3076	—	—
1/2	0.33-0.40	0.3077-0.3846	—	0.0000-0.2500
6/10	0.41-0.48	0.3847-0.4615	—	0.2501-0.3000
8/10	0.49-0.64	0.4616-0.6153	—	0.3001-0.4000
1	0.65-0.80	0.6154-0.7692	0.0-0.6666	0.4001-0.5000
1 1/8	0.81-0.90	0.7693-0.8653	0.6667-0.7500	0.5001-0.5625
1 1/4	0.91-1.00	0.8654-0.9615	0.7501-0.8333	0.5626-0.6250
1 4/10	1.01-1.12	0.9616-1.076	0.8334-0.9333	0.6251-0.7000
1 1/2	1.13-1.20	1.077-1.153	0.9334-1.000	0.7001-0.7500
1 6/10	1.21-1.28	1.154-1.230	1.001-1.066	0.7501-0.8000
1 8/10	1.29-1.44	1.231-1.384	1.067-1.200	0.8001-0.9000
2	1.45-1.60	1.385-1.538	1.201-1.333	0.9001-1.000
2 1/4	1.61-1.80	1.539-1.730	1.334-1.500	1.001-1.125
2 1/2	1.81-2.00	1.731-1.923	1.501-1.666	1.126-1.250
2 8/10	2.01-2.24	1.924-2.153	1.667-1.866	1.251-1.400
3	2.25-2.40	2.154-2.307	1.867-2.000	1.401-1.500
3 2/10	2.41-2.56	2.308-2.461	2.001-2.133	1.501-1.600
3 1/2	2.57-2.80	2.462-2.692	2.134-2.333	1.601-1.750
4	3.81-3.20	2.693-3.076	2.334-2.666	1.751-2.000
4 1/2	3.21-3.60	3.077-3.461	2.667-3.000	2.001-2.250
5	3.61-4.00	3.462-3.846	3.001-3.333	2.251-2.500
5 6/10	4.01-4.48	3.847-4.307	3.334-3.733	2.501-2.800
6	4.49-4.80	4.308-4.615	3.734-4.000	2.801-3.000
6 1/4	4.81-5.00	4.616-4.807	—	3.001-3.125
7	5.01-5.60	4.808-5.384	4.001-4.666	3.126-3.500
7 1/2	5.61-6.00	—	—	3.501-3.750
8	6.01-6.40	5.385-6.153	4.667-5.333	3.751-4.000
9	6.41-7.20	6.154-6.923	5.334-6.000	4.001-4.500
10	7.21-8.00	6.924-7.692	6.001-6.666	4.501-5.000
12	8.01-9.60	7.693-9.230	6.667-8.000	5.001-6.000
15	9.61-12.00	9.231-11.53	8.001-10.00	6.001-7.500
17 1/2	12.01-14.00	11.54-13.46	10.01-11.66	7.501-8.750
20	14.01-16.00	13.47-15.38	11.67-13.33	8.751-10.00
25	16.01-20.00	15.39-19.23	13.34-16.66	10.01-12.50
30	20.01-24.00	19.24-23.07	16.67-20.00	12.51-15.00
35	24.01-28.00	23.08-26.92	20.01-23.33	—
40	28.01-32.00	26.93-30.76	23.34-26.66	—
45	32.01-36.00	30.77-34.61	26.67-30.00	—
50	36.01-40.00	34.62-38.46	30.01-33.33	—
60	40.01-48.00	38.47-46.15	33.34-40.00	—
70	48.01-56.00	46.16-53.84	40.01-46.66	—
75	56.01-60.00	—	—	—
80	60.01-64.00	53.85-61.53	46.67-53.33	—
90	64.01-72.00	61.54-69.23	53.34-60.00	—
100	72.01-80.00	69.24-76.92	60.01-66.66	—
110	80.01-88.00	76.93-84.61	66.67-73.33	—
125	88.01-100.00	84.62-96.15	73.34-83.33	—
150	100.01-120.00	96.16-115.3	83.34-100.0	—
175	120.01-140.00	115.4-134.6	100.1-116.6	—
200	140.01-160.00	134.7-153.8	116.7-133.3	—
225	160.01-180.00	153.9-173.0	133.4-150.0	—
250	180.01-200.00	173.1-192.3	150.1-166.6	—
300	200.01-240.00	192.4-230.7	166.7-200.0	—
350	240.01-280.00	230.8-269.2	200.1-233.3	—
400	280.01-320.00	269.3-307.6	233.4-266.6	—
450	320.01-360.00	307.7-346.1	266.7-300.0	—
500	360.01-400.00	346.2-384.6	300.1-333.3	—
600	400.01-480.00	384.7-461.5	333.4-400.0	—

Protection of Motor Starters

Motor Starter Protection

Motor controllers are highly susceptible to damage due to short-circuits. Even for moderate or low-level faults, extensive damage may occur if the short-circuit protective device is not carefully selected. The most vulnerable parts are the starter contacts and heater elements. Fault currents can weld the contacts and cause the heater elements to vaporize or be critically damaged. The metallided vapors from such damage then can initiate further starter destruction in the enclosure.

Often, after a fault, no apparent damage is visible (i.e., the contacts are not welded and the heater elements are not burnt up). However, the heat energy from the fault may have caused too high of a heat excursion for the heater elements or overload relay sensing element to withstand, with the result being a permanently altered and degradated level of overload protection.

The question is, what can be done to obtain the highest degree of short-circuit protection for motor controllers? The solution is to use short-circuit protective devices that are current-limiting and size them as close as practical. A current-limiting fuse can cut off the short-circuit current before it reaches damaging levels. Even for potentially high short-circuit currents, the quick clearing of the fuse can limit the current passed through the starter to safe levels. Dual-element fuses are recommended since they can be sized at 125% of the motor full-load current, rather than 300% sizing for non-time-delay fuses.

The branch circuit protective device size cannot exceed the maximum rating shown on equipment labels or controller manufacturer's tables. Section 430-53 requires observance of the requirements of 430-52 plus, for circuits under 430-53(c) the motor running overload device and controller must be approved for group installation with a specified maximum rating protective device. Under 430-54 for multi-motor and combination-load equipment, the rating of the branch circuit protective device cannot exceed the rating marked on the equipment. Therefore, be sure to check labels, controller overload relay tables, equipment nameplates, etc. In no case can the manufacturer's specified rating be exceeded. This would constitute a violation NEC 110-3b. When the label, table, etc. is marked with a "Maximum Fuse Ampere Rating" rather than marked with a "Maximum Overcurrent Device" this then means only fuses can be used for the branch circuit protective device.

Achieving Short-Circuit Protection

In order to properly select an overcurrent device for a motor starter, four areas require particular attention:

1. Withstand rating of the contactor.
2. Wire Damage,
3. Cross-over point of the fuse and relay curve,
4. Motor Damage.

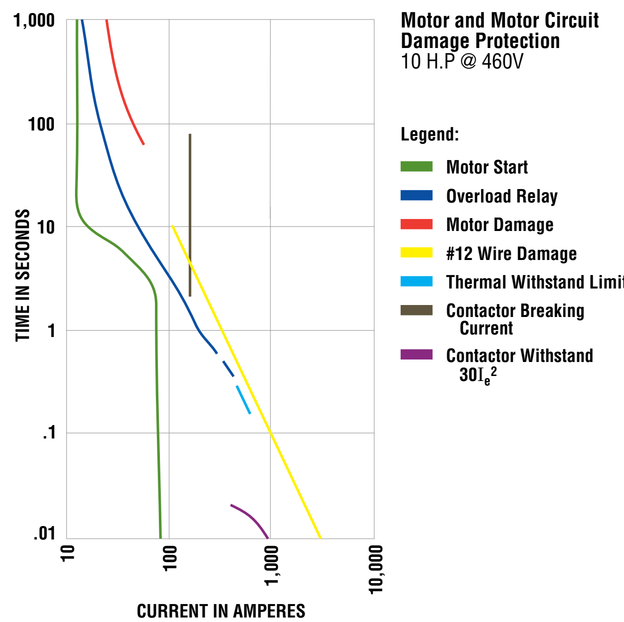
Please refer to the following graph.

Contactor Withstand Rating

The first area of concern is the withstand rating of the contactor. In order to prevent damage to the contactor, the maximum peak let-through current (I_p) and maximum clearing energy (I^2t) (amperes^2 seconds) of the fuse must be less than the equivalent ratings for the contactor. The clearing time and let-through characteristics of the fuse must be considered when verifying adequate protection of the contactor.

Wire Damage

Secondly, motor circuit conductors have a withstand rating that must not be exceeded. If the overcurrent protective device is not capable of limiting the short-circuit current to a value below the wire withstand, the wire may be damaged, or destroyed.



Cross Over Point

Thirdly, the cross-over point (I_c) is the point where the fuse curve intersects the overload relay curve. For current levels less than the cross-over point the overload relay opens the circuit. For current values greater than the cross-over point the fuses open the circuit and prevent thermal damage to the overload relay, contacts, and the motor circuit. This point of intersection should be approximately 7-10 times Ie. Ideally the fuse should allow the overload relay to function under overload conditions, and operate before the overcurrent reaches the contactor's breaking capacity.

Motor Damage

Finally, all motors have an associated motor damage curve. Single phasing, overworking, and locked rotor conditions are just a few of the situations that cause excessive currents in motor circuits. Excessive currents cause motors to overheat, which in turn causes the motor winding insulation to deteriorate and ultimately fail. Overload relays and dual-element, time-delay fuses, are designed to open the motor circuit before current levels reach the motor damage curve.

IEC and U.L. Standards for Allowable Damage

IEC 947-4-1 and U.L. 508E currently differentiate between two different types of coordination, or damage levels.

—Type "1" Considerable damage, requiring replacement. No external damage to the enclosure. Short-circuit protective devices interrupt intermediate to high short-circuit currents which exceed the withstand rating of the motor starter. A non-current-limiting device will interrupt these high currents, but this type of damage will typically result.

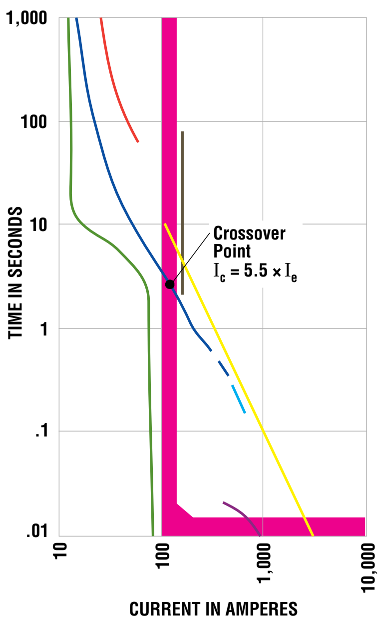
—Type "2" "No Damage" is allowed to either the contactor or overload relay. Light contact welding is allowed, but must be easily separable. (Note: If access is not possible and the contacts cannot be separated, Type "2" protection cannot be achieved.) This level of protection typically can only be provided by a current-limiting device, that is, one which limits the available short-circuit current to a significantly lower value.

Protection of Motor Starters

Five Choices—1 Solution
IEC Motor Starter Protection

Five methods of providing motor starter overcurrent protection are delineated in the five examples that follow. In noting the levels of protection provided by each method, it becomes apparent that the use of dual-element, time-delay fuses (Example 5) is the only one that gives protection at all levels whether it be "Type 2", "Back-up Overload", "Back-up Single-Phase", etc.

These examples are based on a typical motor circuit consisting of an IEC Starter, and a 10 HP, 460 volt motor (Service factor = 1.15). These "Level of Protection" examples reflect the branch circuit protective device operating in combination with the IEC starter overload relays sized at approximately 115% of motor FLA and contactor Ie = 18 amperes.



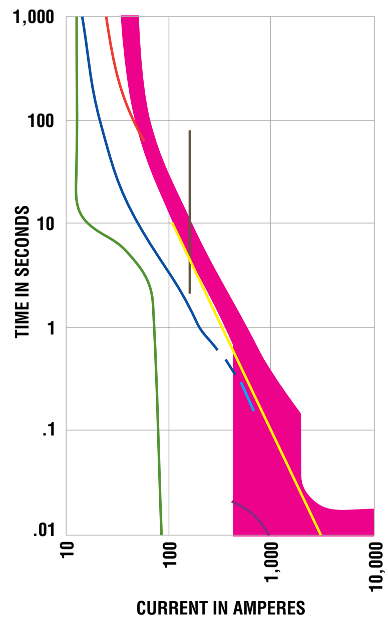
Motor Circuit Protector
(700% FLA)

Legend:
- Motor Start
- Overload Relay
- Motor Damage
- #12 Wire Damage
- Thermal Withstand Limit
- Contactor Breaking Current
- Contactor Withstand $30I_e^2$
- MCP (700%)

Level of Protection:

Type "2"	No
Single-Phase	Yes
Back-up Single-Phase	No
Overload	Yes
Back-up Overload	No
Meets 110-10	No
Meets 430-52	Yes

Example 1



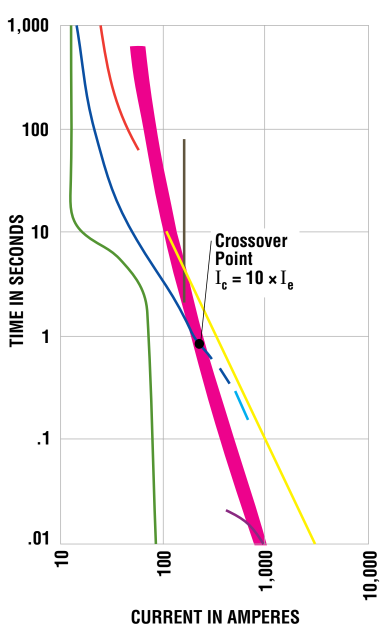
Molded Case Circuit Breaker
(250% FLA)

Legend:
- Motor Start
- Overload Relay
- Motor Damage
- #12 Wire Damage
- Thermal Withstand Limit
- Contactor Breaking Current
- Contactor Withstand $30I_e^2$
- MCCB 40A

Level of Protection:

Type "2"	No
Single-Phase	Yes
Back-up Single-Phase	No
Overload	Yes
Back-up Overload	No
Meets 110-10	No
Meets 430-52	Yes

Example 2



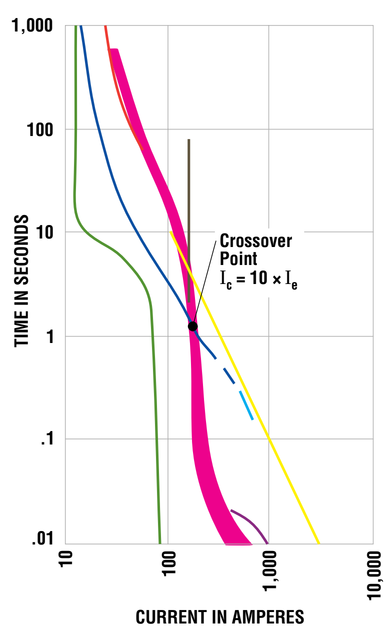
Fast-Acting Fuse
(IEC) (300% FLA)

Legend:
- Motor Start
- Overload Relay
- Motor Damage
- #12 Wire Damage
- Thermal Withstand Limit
- Contactor Breaking Current
- Contactor Withstand $30I_e^2$
- Fast-Acting Fuse 45A

Level of Protection:

Type "2"	Yes
Single-Phase	Yes
Back-up Single-Phase	No
Overload	Yes
Back-up Overload	No
Meets 110-10	Yes
Meets 430-52	Yes

Example 3



Dual-Element, Time-Delay Fuse
(175% FLA)

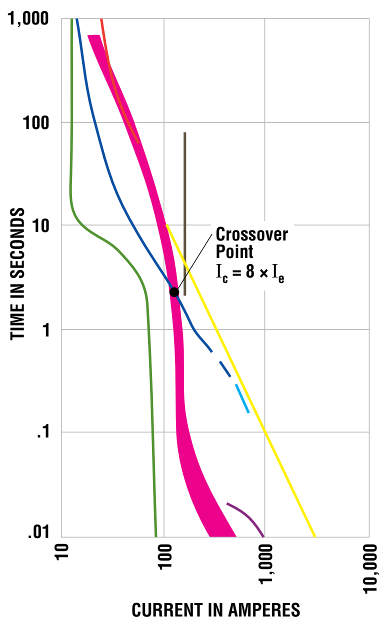
Legend:
- Motor Start
- Overload Relay
- Motor Damage
- #12 Wire Damage
- Thermal Withstand Limit
- Contactor Breaking Current
- Contactor Withstand $30I_e^2$
- LOW PEAK®, Dual-Element, Time-Delay 25A

Level of Protection:

Type "2"	Yes
Single-Phase	Yes
Back-up Single-Phase	No
Overload	Yes
Back-up Overload	No
Meets 110-10	Yes
Meets 430-52	Yes

Example 4

Protection of Motor Starters



Dual-Element, Time-Delay Fuse
(125%) - Class RK1 or J

Legend:

- **Motor Start**
- **Overload Relay**
- **Motor Damage**
- **#12 Wire Damage**
- **Thermal Withstand Limit**
- **Contactor Breaking Current**
- **Contactor Withstand $30I_e^2$**
- **LOW PEAK®, Dual-Element, Time-Delay 17½A**

Level of Protection:

Type "2"	Yes
Single-Phase	Yes
Back-up Single-Phase	Yes
Overload	Yes
Back-up Overload	Yes
Meets 110-10	Yes
Meets 430-52	Yes

Example 5

MEDIUM VOLTAGE CIRCUITS

R-Rated Fuses for Medium Voltage Motor Circuits

R-rated medium voltage fuses are back-up current-limiting fuses used in conjunction with medium voltage motors and motor controllers. These fuses are designed for short-circuit protection only and do not protect themselves or other components during extended overloads. Thus, this type of fuse does not have an ampere rating, but rather an R-rating. Current-limiting fuses may be designated as R-rated if they meet the following requirements:

1. The fuse will safely interrupt an currents between its minimum and maximum interrupting ratings,
2. The fuse will melt in a range of 15 to 35 seconds at a value of 100 times the "R" number (ANSIC37.46).

Bussmann R-rated current-limiting fuses are designed for use with medium voltage starters to provide short-circuit protection for the motor and motor-controller. These fuses offer a high level of fault current interruption in a self-contained, non-venting package which can be mounted indoors or in an enclosure. All of the R-rated product comes with blown fuse indication. Some of the product is available with a hookeye option. A hookstick can be used for non-loadbreak isolation.

Application

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

Guideline for Applying R-Rated Fuses

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

A preliminary choice is obtained through the following formula:

$$\frac{6.6 \times \text{Full Load Current}}{100} = \text{R rating of fuse}$$

This value is rounded up to the next R-rating fuse.

Example:

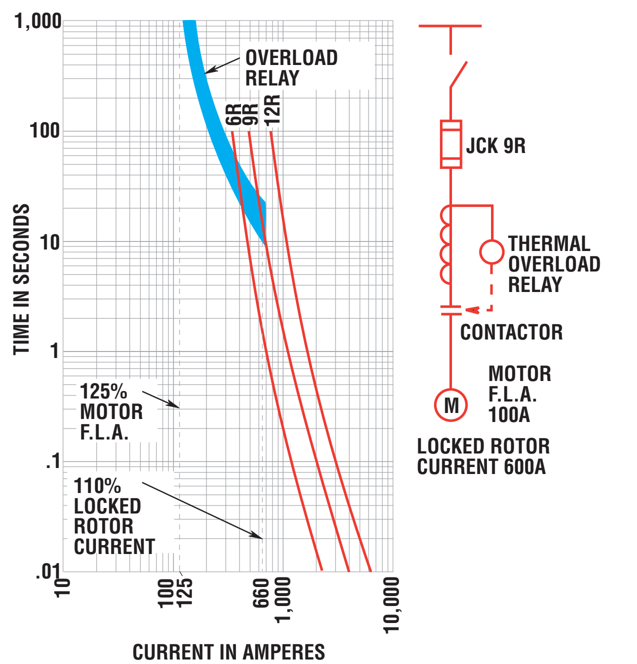
A 2300 volt motor has a 100 ampere full load current rating and a locked rotor current of 600 amperes.

The preliminary choice is

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

Thus one rounds up to the next standard R-rating, 9R. But this must be checked with the appropriate time-current characteristics curves.

The overload relay being used has the time-current characteristic as shown in the adjacent Figure. To choose the proper fuse one must plot 110% of the locked rotor current and the family of fuses on the same graph as the overload relay.



The fuse that should be selected is the smallest fuse whose minimum melting characteristic crosses the overload relay at a current greater than 110% of the locked rotor current. In this example, it would be a 2400 Volt 9R fuse. This agrees with the quick selection choice. Depending on the type of installation and starter being used, a JCK-9R, JCK-A-9R, or JCH-9R would be the correct choice.

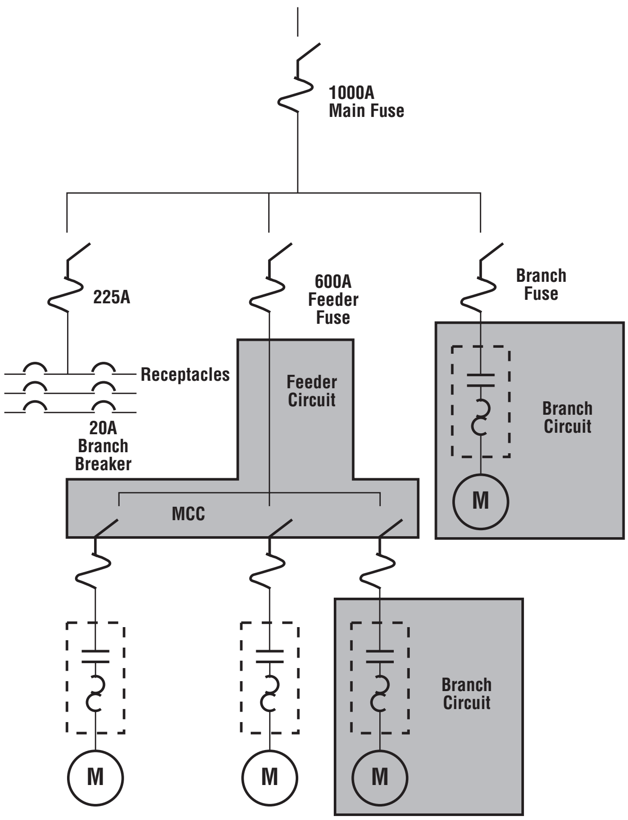
Motor Circuit Protection

Motor Circuit Protection

Motor circuit protection describes the short-circuit protection of conductors supplying power to the motor, the motor controller, and motor control circuits/conductors.

Section 430-52 provides the maximum sizes or settings for overcurrent devices protecting the motor branch circuit. A branch circuit is defined in Article 100 as “The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s).”

NEC Motor Circuit Protection Requirements



Note that the branch circuit extends from the last branch circuit overcurrent device to the load.

Table 430-152 lists the maximum sizes for Non-Time-Delay Fuses, Dual Element (Time-Delay) Fuses, Instantaneous Trip Circuit Breakers, and Inverse Time Circuit Breakers. Sizing is based on full load amp values shown in Table 430-147 through 430-150, not motor nameplate values.

For example, the maximum time-delay fuse for a 10 HP, 460 volt, 3 phase motor with a nameplate FLA of 13 amps would be based on 175% of 14 amperes, not 175% of 13 amps.

Table 430-152. Maximum Rating or Setting of Motor Branch Circuit, Short-Circuit and Ground Fault Protective Devices

	Percent of Full-Load Current			
Type of Motor	Non-Time-Delay Fuse**	Dual-Element (Time-Delay) Fuse**	Instantaneous Trip Breaker	Inverse Time Breaker*
Single-phase motors	300	175	800	250
AC polyphase motors other than wound-rotor				
Squirrel Cage:				
Other than Design E	300	175	800	250
Design E	300	175	1100	250
Synchronous†	300	175	800	250
Wound Rotor	150	150	800	150
Direct-current (constant voltage)	150	150	250	150

For certain exceptions to the values specified, see Sections 430-52 through 430-54.

* The values given in the last column also cover the ratings of non-adjustable inverse time types of circuit breakers that may be modified as in Section 430-52.

** The values in the Non-Time-Delay Fuse Column apply to Time-Delay Class CC fuses.

† Synchronous motors of the low-torque, low-speed type (usually 450 rpm or lower), such as are used to drive reciprocating compressors, pumps, etc., that start unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200 percent of full-load current.

The 1993 NEC required the user to round down if the percentages in Table 430-150 did not correspond to a standard ampere rating. For the example using the 1993 NEC, 1.75 × 14 = 24.5, with a round down to 20 amps. The 1996 NEC allows the user to round up for the same situation. Using the example with the 1996 NEC, 1.75 × 14 = 24.5, with a round up to 25 amps.

Standard sizes for fuses and fixed trip circuit breakers, per 240-6, are 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000 5000, and 6000 amperes. Additional standard fuse sizes are 1, 3, 6, 10, and 601 amperes.

The exceptions in 430-52 allow the user to increase the size of the overcurrent device if the motor is not able to start. All Class CC fuses can be increased to 400%, along with non-time-delay fuses not exceeding 600 amperes. Time-delay (dual-element) fuses can be increased to 225%. All Class L fuses can be increased to 300%. Inverse time (thermal-magnetic) circuit breakers can be increased to 400% (100 amp and less) or 300% (larger than 100 amps). Instant trip circuit breakers may be adjusted to 1300% for other than Design E motors and 1700% for Design E motors.

430-52(c)(2) reminds the user that the maximum device ratings which are shown in a manufacturer’s overload relay table must not be exceeded even if higher values are allowed by other parts of 430-52.

430-52(c)(3) details the requirements that instant-trip cb’s and motor short-circuit protectors can only be used if part of a listed combination motor controller.

Group Motor Protection

GROUP FUSING

Section 430-53 covers the requirements for group motor installations. Two or more motors or one or more motors and other loads may be protected by the same branch circuit overcurrent device if

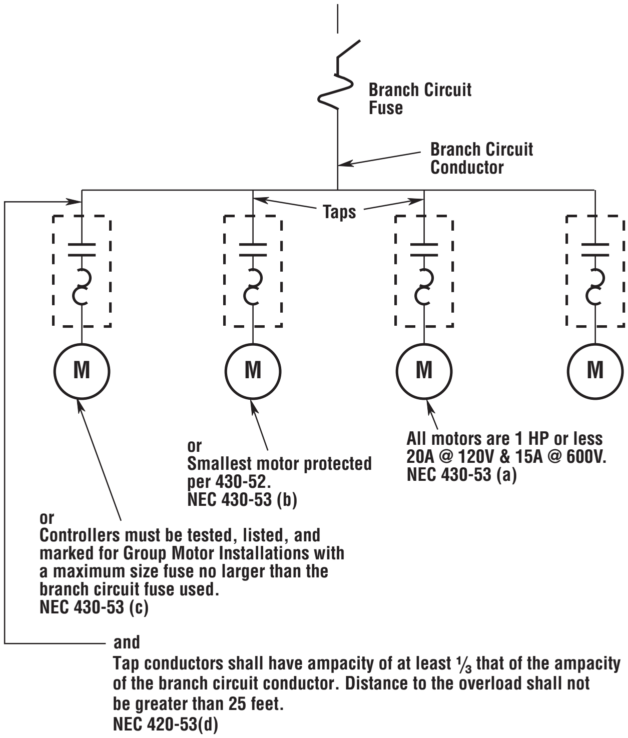
(a) all motors are 1 HP or less, protected at not over 20A at 120 volts or at 15A at 600 volts or less, the full load amp rating of each motor does not exceed 6 amperes, the device rating marked on the controller is not exceeded, and individual overload protection conforms to 430-32.

or (b) the smallest motor is protected per 430-52

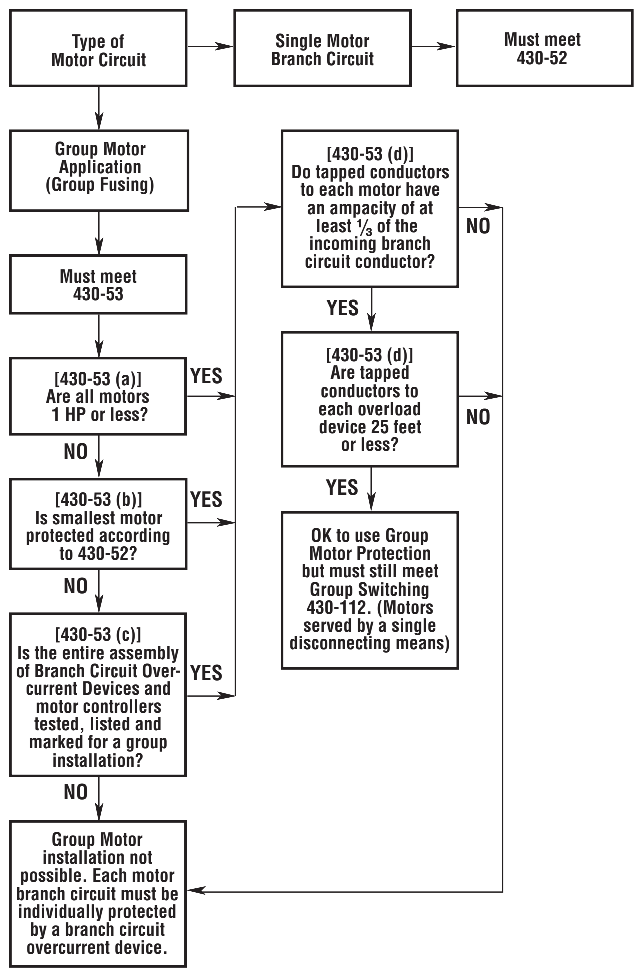
or (c) the complete assembly of overcurrent protective device, controller, and overload is tested, listed, and marked

and (d) (the ampacity of conductors to motors are no less than the ampacity of the branch circuit conductors) or (the conductors to motors have at least ⅓ the ampacity of the branch circuit conductors, are protected from physical damage and are not more than 25 feet long before being connected to the motor overload device.)

Group Motor Installation (Group Fusing) NEC 430-53



Group Motor Protection



Group Switching

Motors Served by a Single Disconnecting Means (Group Switching)

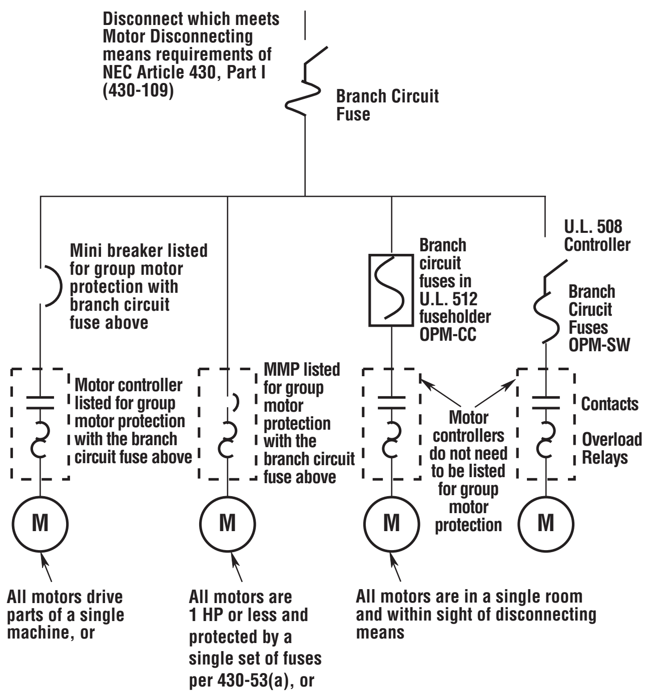
Section 430-112 covers the requirements for serving two or more motors with the same disconnecting means. Each motor must be provided with an individual disconnecting means unless:

(a) all motors drive parts of a single machine

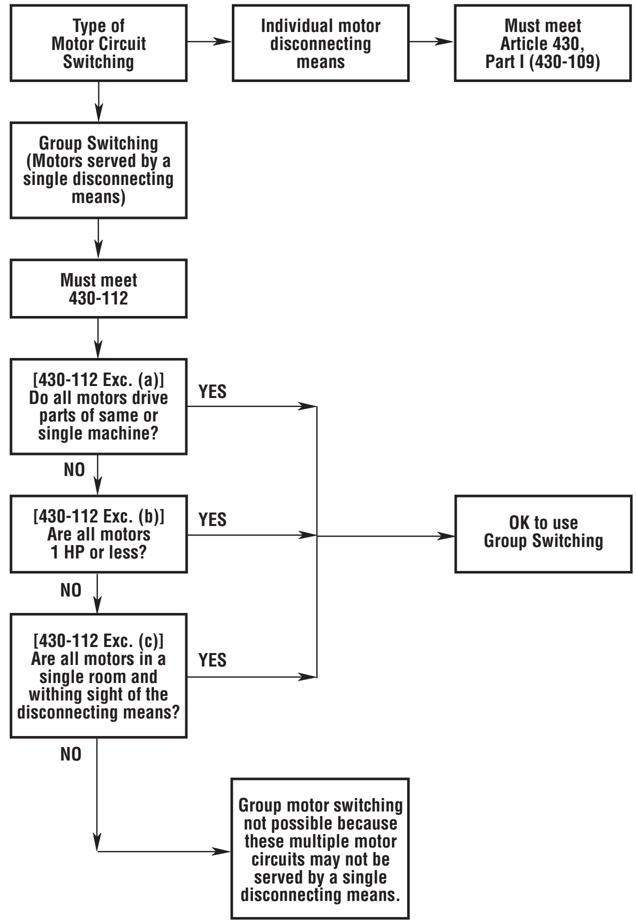
or (b) all motors are 1 HP or less as permitted by 430-53(a)

or (c) all motors are in a single room and within sight (visible and not more than 50 feet) of the disconnecting means.

Motors Served By a Single Disconnecting Means (Group Switching) NEC 430-112



Group Switching



OVERCURRENT DEVICES AND DISCONNECTING MEANS FOR MOTOR & MOTOR CIRCUIT PROTECTION

Branch Circuit Fuses
As listed to the U.L. 248 series of standards.

These are fuses which cannot be replaced with a fuse having a lower voltage rating. When installed in rejection style clips, current-limiting branch circuit fuses cannot be replaced with fuses which are not current-limiting. Examples of branch circuit fuses are Class L, RK1, RK5, T, J, K1, K5, G, H, CC, and plug fuses. Interrupting ratings range from 10,000 amperes to 300,000 amperes.

Supplemental Fuses
As listed to U.L. 248-14

These are fuses which can have many voltages and interrupting ratings within the same case size. Examples of supplemental fuses are ¼″ × 1¼″, 5 × 20mm, and 13⁄32″ × 1½″ fuses. Interrupting ratings range from 35 to 100,000 amperes.

Branch Circuit vs. Supplemental Fuses

Branch circuit fuses can be used everywhere fuses are used, from protection of motors and motor circuits and group motor circuits, to protection of distribution and utilization equipment.

Supplemental fuses can only be used where proper protection is already being provided by a branch circuit device, by exception (i.e., 430-72(a)), or if protection is not required. Supplemental fuses can often be used to protect motor control circuits but they cannot be used to protect motors or motor circuits.

Disconnect Switches
As listed to U.L. 98

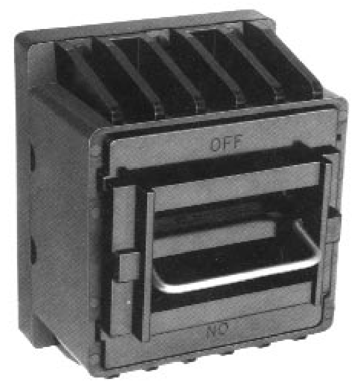
These are disconnect switches from 30 through 6000* amperes, which may be used on service equipment, panelboards, switchboards, industrial control equipment, motor control centers, motor branch circuits, etc. These switches may be used as a motor disconnecting means to meet NEC 430-109. They may also be used as a motor controller (on-off function) to meet NEC article 430, part G, and may be used as both a motor disconnecting means and a motor controller (NEC 430-111). When used with properly sized branch circuit fuses, disconnect switches may be used for motor, motor circuit, and group motor protection.

*U.L. listing through 4000 amperes.

BDCF-30J6 Disconnect Switch

Pullout Switches
As listed to U.L. 1429

These are switches from 30 through 200 amperes at 600 volts or less. Pullout switches with horsepower ratings are suitable for motor disconnecting means to meet NEC 430-109, as motor controllers to meet NEC Article 430 Part G (if rated 100 HP or less), and in general use for panelboards, switchboards, etc. They may be used as both a motor disconnecting means and a motor controller to meet 430-111. Pullout switches with ampere ratings only (no HP ratings) are suitable for general use only, not motor circuits. If they are marked “Motor circuit pullout switch” they may be used only in a motor circuit. When used with properly sized branch circuit fuses, pullout switches may be used for motor, motor circuit, and group motor protection.



15149 Class J Pullout

Molded Case Switches
As listed to U.L. 1087

These switches are very similar to molded case thermal magnetic circuit breakers except that they have no thermal overload protection. They may or may not be equipped with a “magnetic” instantaneous trip as a self protect mechanism. They may be used on service equipment, panelboards, switchboards, industrial control equipment, motor control centers, motor branch circuits, etc. They are suitable for use as a motor circuit disconnect per NEC 430-109. When used with properly sized branch circuit fuses, molded case switches may be used for motor, motor circuit, and group motor protection. They may be used as a motor controller (On-Off Function) to meet NEC Article 430 Part G, and as both a motor disconnecting means and motor controller to meet NEC 430-111. Molded case switches may contain a shunt trip with or without ground fault protection.

Disconnect Switches
As listed to U.L. 508

These switches may be used as a motor controller (On-Off Function) to meet NEC Article 430 Part G. As motor controllers, they have creepage and clearance distances which are less than those required by U.L. 98. As a result, they cannot be used as a motor disconnecting means to meet NEC 430-109. These switches require properly sized branch circuit fuses and a motor disconnecting means on their line side when used to provide motor, motor circuit, or group motor protection.

Overcurrent Devices for Motor Circuit Protection

Bussmann Optima - Overcurrent Protection Module with Disconnect Switch

Fuse Holders

As listed to U.L. 512

When used with a motor disconnecting means and properly sized branch circuit fuses, fuseholders may provide motor, motor circuit, and group motor protection. They cannot be used alone as a motor disconnecting means to meet NEC 430-109, nor can they be used alone as a motor controller (On-Off Function) to meet NEC Article 430, Part G.

Bussmann Optima - Overcurrent Protection Module Non-Switch Series

Thermal Magnetic (Inverse Time) Circuit Breakers

As listed to U.L. 489

These circuit breakers are intended to provide branch, feeder, and main protection, with interrupting ratings from 5,000 to 200,000 amperes. They are suitable for use as a motor disconnecting means per NEC 430-109, as a motor controller (On-Off Function) per NEC Article 430, Part G, and as both a motor disconnecting means and motor controller per NEC 430-111. Properly sized inverse time circuit breakers may provide motor circuit protection. They may be used for group motor protection only when the entire package is tested, listed and marked (430-53(c)).

Instantaneous Trip Circuit Breakers (MCP'S)

As recognized to U.L. 489

These are circuit breakers without overload (thermal) protection capability. They are intended to provide only short-circuit protection for individual motor branch circuits. They may not be used to provide main, motor feeder, motor overload or group motor protection.

Because they are recognized, not listed, they cannot be used with loose control. NEC 430-52 requires that they shall only be used as part of a listed combination controller. MCP's are short-circuit tested only in combination with a combination motor controller. They have no interrupting rating by themselves. Per NEC 430-109 exception 7, they may be used as a motor disconnecting means when part of a listed combination motor controller.

Supplementary Protectors (Mini-Breakers)

As recognized to U.L. 1077

With applications similar to supplemental fuses, these circuit breakers cannot be used as a branch circuit protective device. As such they cannot provide motor, motor circuit, or group motor protection. They can only be used for protecting an appliance or other electrical equipment where branch circuit overcurrent protection is already provided, or is not required. They have creepage and clearance distances which are less than those in U.L. 489, so they cannot be listed as a circuit breaker or used as a motor disconnecting means to meet the requirements of NEC 430-109. Interrupting ratings are quite low. Those devices that are short-circuit tested in series with a fuse must be applied with a fuse on their line side. Some mini-breakers have been tested in a group motor application (as the protected device, not the protective device) so that several of them may be able to be protected by one larger upstream fuse.

IEC Manual Motor Protectors

As listed to U.L. 508

These manual motor starters, often called MMP's, combine a magnetic short-circuit trip and adjustable motor overload protection. They provide motor protection per NEC 430-32 and controller function (On-Off) per NEC Article 430, Part G. Creepage and clearance distances are not as great as required in U.L. 489, and therefore they cannot be listed as a circuit breaker or used as a motor disconnecting means. MMP's cannot provide motor circuit (branch circuit) protection. They need a branch circuit overcurrent device and a motor disconnecting means on the line side for both single motor and group motor applications. MMP's do not meet requirements for a motor disconnecting means as required in NEC 430-109. Most IEC manual motor protectors have been tested and listed for group motor applications (as the protected device, not the protective device) so that several of them may be able to be protected by one larger upstream fuse.

Integrated Starters

As listed to U.L. 508

Integrated starters are an assembled combination of an IEC manual motor starter and an IEC contactor. They cannot be listed for motor circuit (branch circuit) protection or used as a motor disconnecting means. They do not provide motor circuit (branch circuit) protection. They do not meet the requirements for a motor disconnecting means as required in NEC 430-109. Integrated starters need a branch circuit overcurrent device and a motor disconnecting means on their line side, for both single motor and group motor applications. Most integrated starters have been tested and listed for group motor applications (as the protected device, not the protective device) so that several of them may be able to be protected by one larger upstream fuse.

Self-Protected Starters

As listed to U.L. 508

Self protected starters are often called "Coordinated protected starters" and "Type E" starters. They provide motor and motor circuit (branch circuit) protection by combining a magnetic short-circuit trip and adjustable motor overload in one package. A "Type E" starter is a listed combination starter suitable for use without additional branch circuit short-circuit protection.

Motor Circuit Notes

Disconnecting Means for Motor Circuits

Notes:

1. "In Sight From" means that the motor must be visible and not more than 50 feet distant. (Definitions in Article 100.)
2. "Controller" includes any switch or device normally used to start or stop a motor by making and breaking the motor circuit current (430-81).
3. A disconnecting means must be located in sight of the controller (430-102). For exceptions see 430-102.
4. A switch can serve both as a controller and disconnecting means if properly rated in accordance with 430-111 and 430-83.

Switches for Motor Circuits

The Code requirements for switches used as controllers and disconnect switches are as follows (430-81, 430-83, 430-109, 430-110, 430-111):

For 0 to 300 volt stationary motors:

2 HP or Less – Use horsepower rated switch, or general use switch having ampere rating at least twice the ampere rating of the motor, or general use AC (only) snap switch having ampere rating at least 125% of motor current rating.
Greater than 2 HP to 100 HP – Switch must have horsepower rating.
Larger than 100 HP – Disconnect purposes–switch must have an ampere rating at least 115% of the motor nameplate rating. Controller purposes–switch must have horsepower rating.

For 301 to 600 volt stationary motors:

Less than 100 HP – Switch must have horsepower rating.
Larger than 100 HP – Disconnect purposes–switch must have an ampere rating at least 115% of the motor nameplate rating. Controller purposes–switch must have horsepower rating.

For portable motors:

An attachment plug and receptacle may serve as disconnect on all sizes.
1/3 HP or Less – An attachment plug and receptacle may serve as controller.
Larger than 1/3 HP – Controller must meet requirements as outlined for stationary motors (shown above).

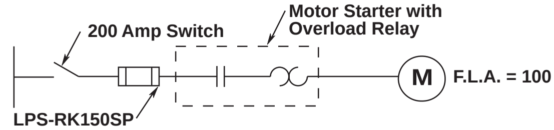
Size of HP Rated Switches (Switch Size Savings)

LOW-PEAK® YELLOW™ and FUSETRON® dual-element fuses rather than non-time-delay fuses are recommended for motor branch circuit protection because normally dual-element fuses permit the use of a smaller switch size, give better protection, reduce cost, and require less space.

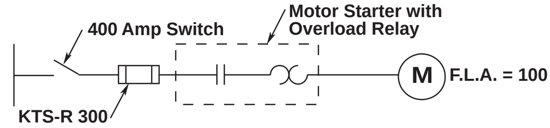
For motors, oversized switches must be used with non-time-delay fuses because this type of fuse has very little time-lag. Non-time-delay fuses are generally sized 300% of the motor rating to hold normal motor starting current. Consequently, the switch also has be be oversized to accommodate these fuses.

The dual-element fuse can be sized close to the motor full-load amperes and a smaller switch used, as shown in the following illustrations.

WHEN USING DUAL-ELEMENT, TIME-DELAY FUSES



WHEN USING NON-TIME-DELAY FUSES



Branch circuit (short-circuit) protection can be provided for the given motor by either a 150 ampere dual-element, time-delay fuse or a 300 ampere non-time-delay fuse. The dual-element fuse selection above provides these advantages: (1) Backup overload protection, (2) smaller switch size, resulting in lower cost, (3) smaller fuse ampere case size, resulting in lower cost, (4) short-circuit protection that is comparable or better than non-time-delay (fast-acting) fuse.

Most switches are listed with two HP ratings. The *Standard* horsepower rating is based on the largest non-time-delay (non-dual-element) fuse rating (1) which can be used in the switch, and (2) which will normally permit the motor to start. The *Maximum* horsepower rating is based on the largest rated time-delay LOW-PEAK® YELLOW™ or FUSETRON® dual-element fuse (1) which can be used in the switch, and (2) which will normally permit the motor to start. Thus when LOW-PEAK® YELLOW™ or FUSETRON® dual-element fuses are used smaller size switches can be used (430-57 Exception).

CONDUCTORS FOR MOTOR BRANCH AND FEEDER CIRCUITS

Motor Branch Circuit Conductors

The ampacity of branch circuit conductors supplying a single motor must be at least 125% of the motor full-load current rating (430-22a).

Exceptions: For conductors supplying motors used for short-time, intermittent, periodic, or varying duty refer to 430-22a.

Any motor application must be considered continuous duty unless the nature of the apparatus it drives is such that the motor will not operate continuously with load under any conditions of use.

FEEDER CIRCUITS FOR MOTORS

Feeder Conductor Ampacity

The ampacity of a conductor supplying two or more motors must be at least equal to the sum of (1) 125% of the largest motor (if there are two or more motors of the largest size, one of them is considered to be the largest), and (2) the total of the full-load ampere ratings for all other motors and other loads.

Where different voltages exist, the current determined per the above shall be multiplied by the ratio of output to input voltage.

Feeder Fuse Size

On normal installations, size FUSETRON® dual-element fuses or LOW-PEAK® YELLOW™ dual-element fuses equal to the combined ampere rating of (1) 150% to 175% F.L.A. of the largest AC motor (if there are two or more motors of the same size, one of them is considered to be the largest), and (2) the sum of all the F.L.A. for all other motors.

This dual-element fuse size should provide feeder protection without unnecessary fuse openings on heavy motor startings.

Motor Circuit Notes

Where conditions are severe, as where a high percentage of motors connected must be started at one time, a larger size may be necessary. In that event, use the maximum size permitted by the Code as follows.

The Maximum Motor Circuit Feeder Fuse (430-62)

1. *For the one motor in the group with the highest starting current* —Find the largest fuse permitted for branch circuit protection using the Tables (430-152) and [440-22(a)]. The fuse capacity permitted for the motor with the heaviest starting current may be considered for only one motor. If two or more motors can each have a fuse of the same maximum size, only one of them can be considered.

2. *The Ampere Rating of All other Motors on that feeder.*

Feeder Motor Schedule – Example

No. of Units	HP	Amps*	Multiplier†
1	3	4.8	1¾
1	5	7.6	1¾
1	15	21	1¾
1	40	52	1¾
1	75	96	1¾

*Per NEC Table 430-150.
†Per NEC Table 430-152.

Calculations:

Maximum.
1. Largest motor (96A × 175% = 168A) (Round up to 175A)
2. F.L.A. all other motors (85.4A)
3. Total (175A + 85.4A = 260.4A) (Round down to 250A)

Choose 250 ampere dual-element fuse.

Feeder Circuit-Combination Motor, Power and Lighting Loads

Where a feeder supplies motor load and power and/or lighting load, the permitted feeder fuse size calculation is the sum of that calculated for the motor load in accordance with Section 430-62, plus that calculated for the other loads in accordance with Articles 210 and 220 (430-63). The conductor ampacity supplying motors and other loads must be at least the sum of that calculated for the motor load in accordance with Sections 430-22 and 430-24, plus that calculated for the other loads in accordance with Article 220 (430-25). (For exceptions see 430-25.)

Example of Sizing of Dual-Element Fuses for Combination Load Feeder

Motor Load (Use "Motor Schedule" in preceding example).
Continuous Heating and Lighting Load 135A
Non-Continuous Loads 110A

Calculations:

1. Motor Load: (Use calculation in preceding example) ...260.4A
2. Continuous Non-Motor Load 135A × 125% 168.8A
3. Non-Continuous, Non-Motor Load 110.0A

Total 539.2A
(Round down to 500A)

Choose 500 ampere dual-element fuse.

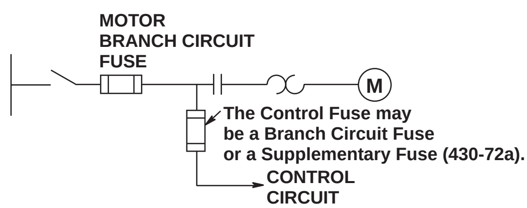
MOTOR CONTROL CIRCUIT PROTECTION

General

A motor control circuit is a circuit of a control apparatus or system that carries the electric signal directing the performance of the controller (430-71). It does not carry the main power current.

A control circuit tapped on the load-side of the motor branch circuit fuse which controls the motor on that branch circuit shall be protected against overcurrent as in Section 430-72 Such a circuit is not considered a branch circuit and may be protected by a supplementary fuse or a branch circuit fuse.

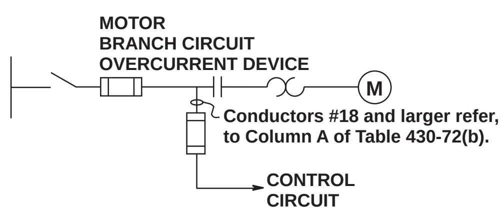
A new standards requirement pertinent to motor controllers listed for available fault currents greater than 10,000 amperes, states that the control circuit fuse must be a branch circuit fuse with a sufficient interrupting rating. (The use of Buss® KTK-R, FNQ-R, JJS, JJN, or LPJ_SP fuses is recommended—these fuses have branch circuit listing status, high interrupting rating, and small size.)



MOTOR CONTROL CIRCUIT CONDUCTORS

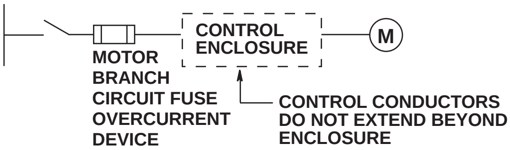
Control Circuits Tapped on Load-Side of Branch Circuit Fuse (430-72b)

1. Control circuit conductors #18 and larger shall be protected against overcurrent in accordance with Table 430-72b, Column A, as applicable.



Motor Control Circuit Protection

Exception No. 1
Control conductors not extending beyond the enclosure shall be considered protected by the branch circuit fuse if in accordance with Table 430-72(b), Column B.



Exception No. 2
For control conductors extending beyond the enclosure, the motor branch circuit overcurrent device shall be considered to protect the conductors if in accordance with Table 430-72(b), Column C.

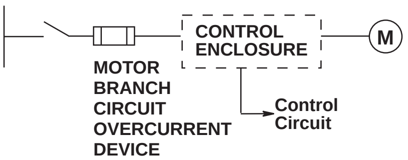


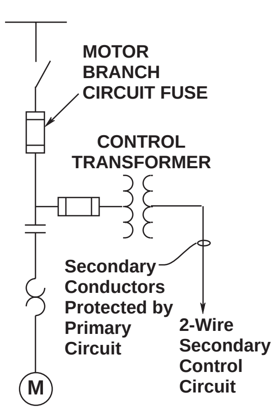
Table 430-72(b). Maximum Rating of Overcurrent Protective Device-Amperes

	Column A Basic Rule		Column B Exception No. 1		Column C Exception No. 2	
Control Circuit Conductor Size, AWG	Copper	Alum. or Copper-Clad Alum.	Copper	Alum. or Copper-Clad Alum.	Copper	Alum. or Copper-Clad Alum.
18	7	–	25	–	7	–
16	10	–	40	–	10	–
14	Note 1	–	100	–	45	–
12	Note 1	Note 1	120	100	60	45
10	Note 1	Note 1	160	140	90	75
larger than 10	Note 1	Note 1	Note 2	Note 2	Note 3	Note 3

Note 1: Value specified in Section 310-15, as applicable.
Note 2: 400 percent of value specified in Table 310-17 for 60°C conductors.
Note 3: 300 percent of value specified in Table 310-16 for 60°C conductors.

Exception No. 3
Secondary conductors of a single-phase transformer having only a 2-wire secondary are protected by the primary fuse (600 volts or less) if the primary fuse rating is:

1. Not larger than that determined in Table 430-72(b), multiplied by secondary-to-primary voltage ratio and,
2. not more than the following percent of transformer rated primary current:



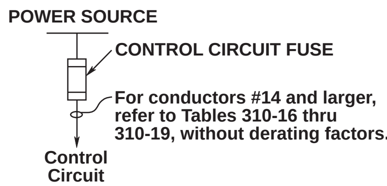
Transformer Primary Current	Primary Fuse Ampacity Must Not Exceed
Less than 2 amps	500%
2 to 9 amps	167%
9 amps or more	125%*

* If 125% of rated primary current does not correspond to a standard fuse rating, then the next higher standard fuse rating is permitted.

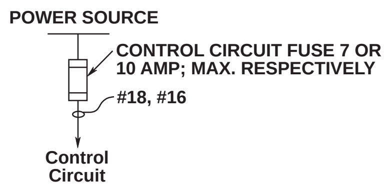
Exception No. 4
Control conductors are permitted to be protected by the motor branch circuit overcurrent device where the opening of the control circuit would create a hazard.

REMOTE MOTOR CONTROL CIRCUITS (Section 725-12) CLASS 1 CIRCUITS; Voltage Does Not Exceed 600 Volts (725-11b)

1. Control circuit conductors #14 and larger shall be protected from overcurrent in accordance with Section 310-15.



2. Control circuit conductors #18 and #16, shall be protected by a control circuit fuse not to exceed 7 and 10 amperes respectively.



Exception No. 2 Relative to Transformer Protection
Refer to Exception 3, (430-72b), covered in preceding paragraphs.

Motor Control Circuit Transformers [430-72(c)]
Control circuit transformers (600V or less) shall be protected as shown previously in Exception No. 3 under 430-72(b).

Exception No. 1
Control circuit transformers rated less than 50VA can be protected by a primary fuse, impedance limiting means, or other inherent means. The transformer must be an integral part of the motor controller, and be located within the controller.

Exception No. 2
Allows transformers with primary currents less than 2 amps to be protected with primary fuses at 500% or less of primary full-load amps.

Exception No. 3
Allows the control transformer to be protected by the motor branch circuit overcurrent device when the transformer supplies a Class 1 power-limited, circuit [see Section 725-11(a)] Class 2, or Class 3 remote control circuit conforming with the requirements of Article 725 (see Article 725, Part C).

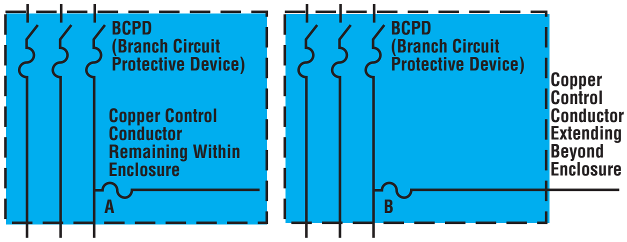
Exception No. 4
Allows the control transformer to be protected by the motor branch circuit overcurrent device where protection is provided by other approved means.

Exception No. 5
States that overcurrent protection shall be omitted where the opening of the control circuit would create a hazard, as for example, the control circuit of a fire pump motor and the like.

Motor Control Circuit Protection

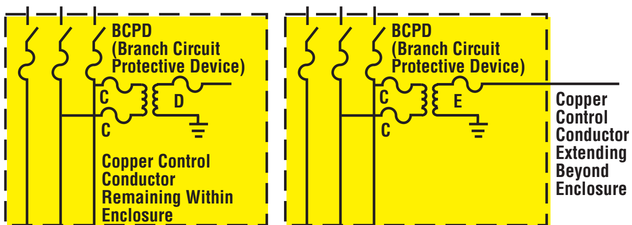
The following Selection Guide Tables simplify and permit easy application of fuses for the protection of the motor control circuits in accordance within the 1996 National Electrical Code. Apply fuses per Table 1 for control circuit without a control transformer (see Circuit Diagrams 1 and 2). Apply fuses per Table 2 for a control circuit with a control transformer (see Circuit Diagrams 3 and 4).

Control Circuit Without Control Transformer (See Table 1)



Circuit 1 Circuit 2

Control Circuit With Control Transformer (See Table 2)



Circuit 3 Circuit 4

Table 1. Fuse Selection Guide–Control Circuit Without Control Transformer (See Circuit Diagrams 1 & 2)

Ampere Rating of Branch Circuit Protective Device (BCPD)	Circuit 1 (Control Conductor Not Extending Beyond Enclosure) #18 Wire	#16 Wire	#14 Wire	#12 Wire	Circuit 2 (Control Conductor Extending Beyond Enclosure) #18 Wire	#16 Wire	#14 Wire	#12 Wire
Fuse Size	7A	10A	15A	20A	7A	10A	15A	20A
Requirements For Control Circuit Protection (See footnote data)								
1/10 – 7	■	■	■	■	■	■	■	■
7½ – 10	■	■	■	■	●	■	■	■
12 – 25	■	■	■	■	●	●	■	■
30 – 40	●	■	■	■	●	●	■	■
45	●	●	■	■	●	●	■	■
50 – 60	●	●	■	■	●	●	●	■
65 – 100	●	●	■	■	●	●	●	●
110	●	●	●	■	●	●	●	●
125 – up	●	●	●	●	●	●	●	●

● Control circuit fuse protection required.
■ Protection recommended but not mandatory when BCPD is a Class CC, G, J, R, or T fuse. Protection is mandatory when BCPD is a thermal magnetic or a magnetic-only circuit breaker (MCP), and available short-circuit current exceeds the values in the table below.

Control Circuit Conductor (AWG Copper)	Available Short-Circuit Current At Branch Circuit Protective Device (BCPD) 1 Cycle Clearing Time†	½ Cycle Clearing Time†
#18	660A	940A
#16	1050A	1500A
#14	1700A	2400A
#12	2700A	3800A

*Thermoplastic Insulation. †Based on ICEA Conductor Withstand Data.

Table 2. Fuse Selection Guide–Control Circuit With Control Transformer (See Circuit Diagrams 3 and 4)

Control Xfmr Rating	V_{pri}/V_{sec} (Volts)	Ipri (Amps)	I_{sec} (Amps)	[1]Fuse C [2]Req'd. If BCPD Exceeds These Amps Values	[4,5]Maximum Amps	Fuse D or E Required if BCPD and Fuse C (When Provided) Exceed These Amp Values #18 Wire	#16 Wire	#14 Wire	#12 Wire	Recommended Amps Time Delay[1]	Non-Time Delay[3]
25 VA	480/120	0.05	0.21	[6]See 430-72(c) Except. 1	0.25	0.25	0.25	0.25	0.25	0.25	0.60
	480/24	0.05	1.00		0.25	0.25	0.25	0.25	0.25	1.25	3.0
	240/120	0.10	0.21		0.50	0.50	0.50	0.50	0.50	0.25	0.60
	240/24	0.10	1.00		0.50	0.50	0.50	0.50	0.50	1.25	3.0
50 VA	480/120	0.10	0.42	0.5	0.50	0.50	0.50	0.50	0.50	0.50	1.0
	480/24	0.10	2.10	0.5	0.50	0.50	0.50	0.50	0.50	2.5	6.0
	240/120	0.21	0.42	1.0	1.0	1.0	1.0	1.0	1.0	0.50	1.0
	240/24	0.21	2.10	1.0	1.0	1.0	1.0	1.0	1.0	2.5	6.0
100 VA	480/120	0.21	0.83	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0
	480/24	0.21	4.20	1.0	1.0	1.0/.35[9]	1.0/.50[9]	1.0	1.0	5.0	12.0[7]
	240/120	0.42	0.83	2.0	2.0	2.0	2.0	2.0	2.0	1.0	2.0
	240/24	0.42	4.20	2.0	2.0	2.0/.70[9]	2.0/1.0[9]	2.0	2.0	5.0	12.0[7]
150 VA	480/120	0.31	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.50	3.50
	480/24	0.31	6.25	1.5	1.5	—	1.5/0.5[9]	1.5	1.5	7.50	15.0[7]
	240/120	0.62	1.25	3.0	3.0	3.0	3.0	3.0	3.0	1.50	3.50
	240/24	0.62	6.25	3.0	3.0	—	3.0/1.0[9]	3.0	3.0	7.50	15.0[7]
200 VA	480/120	0.42	1.67	2.0	2.0	2.0/1.75[9]	2.0	2.0	2.0	2.0	5.0
	480/24	0.42	8.33	2.0	2.0	—	—	2.0	2.0	10.0	20.0[8]
	240/120	0.84	1.67	4.0	4.0	4.0/3.5[9]	2.0	4.0	4.0	2.0	5.0
	240/24	0.84	8.33	4.0	4.0	—	—	4.0	4.0	10.0	20.0[8]

[1] Time-Delay Fuses: FNQ, FNW, FNM, FNA–Supplementary Type; FNQ-R, FRN-R, FRS-R, LPN-RK_SP, LPS-RK_SP, LPJ_SP, LP-CC, SC6 & above–Branch Circuit Fuses (Rejection Type).
[2] For exceptions, see 430-72(c), Exceptions 3, 4, & 5.
[3] Non-Time-Delay Fuses: KTK, BAN, BAF, MIN, MIC–Supplementary Fuses; KTK-R, JJN, JJS, SC½-5–Branch Circuit Fuses (Rejection Types).
[4] These are maximum values as allowed by 430-72(c), Exception 2. Closer sizing at 125%-300% may be possible for better overload protection using time-delay branch circuit fuses.
[5] Fuse shall be a rejection type branch circuit fuse when withstand rating of controller is greater than 10,000 amps RMS symmetrical
[6] These transformers less than 50VA still need protection–either primary overcurrent protection, inherent protection, or the equivalent. Note that the primary conductors may be protected as shown in Circuit 1 Table 1. [7] Minimum copper secondary control conductor for this application is #14. [8] Minimum copper secondary control conductor for this application is #12.
[9] Smaller value applied to Fuse "E".

Motor Control Circuit Protection

Supplementary Fuses (13/32″ × 1½″)

Dual-Element, Time-Delay		Time-Delay		Non-Time-Delay				
								
FNA 1/10-8/10A 250V† 1-15A 125V* 20-30A 32V**	**FNM** 1/10-10A 250V† 12-15A 125V* 20-30A 32V**	**FNQ** 1/10-30A 500V 10K AIR (FNQ1/10-3 2/10 Dual-Element)	**FNW** 12-30A 250V†	**BAF** ½-15A 250V† 20-30A 125V*	**BAN** 2/10-30A 250V†	**KTK** 1/10-30A 600V 100K AIR	**MIC** 1-15A 250V† 20-30A 32V**	**MIN** 1-15A 250V† 20-30A 32V**

Branch Circuit Fuses

Class R Dual-Element, Time-Delay				Class G	Class CC Fast-Acting, Time-Delay		
							
LPN-RK_SP 1/10-30A 250V 300K AIR	**FRN-R** 1/10-30A 250V 200K AIR	**FRS-R** 1/10-30A 600V 200K AIR	**LPS-RK_SP** 1/10-30A 600V 300K AIR	**SC** ½-20A§ 300V 100K AIR	**KTK-R** 1/10-30A 600V 200K AIR	**FNQ-R** ¼-30A 600V 200K AIR	**LP-CC** ½-30A 600V 200K AIR

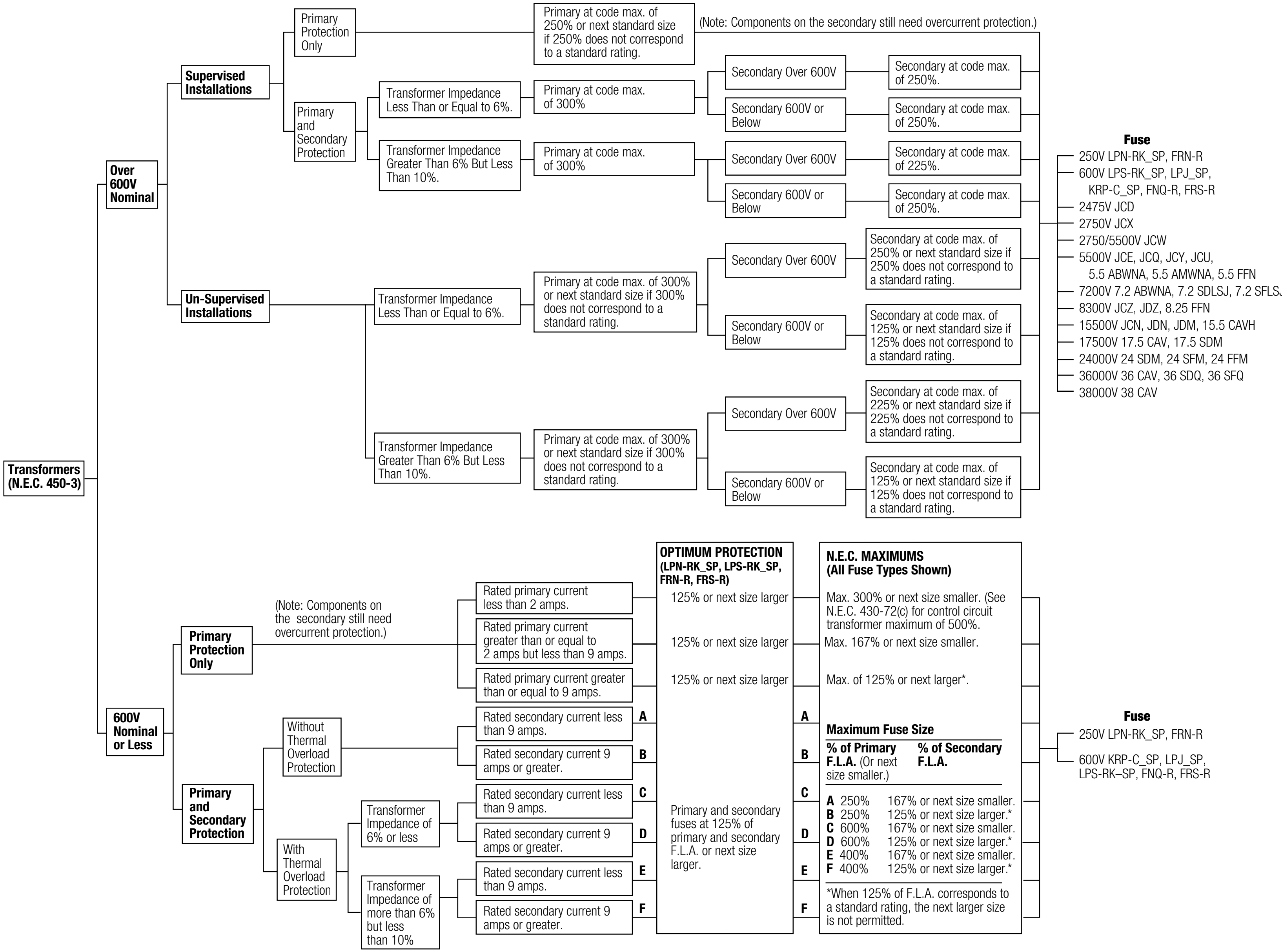
†0 to 1 amp–35 AIR; 1.1 to 3.5 amp–100 AIR; 3.6 to 10 amp–200 AIR; 10.1 to 15 amp–750 AIR; 15.1 to 30 amps–1500AIR *10K AIR. **1K AIR.
§½ thru 6 ampere fuses are Non-Time-Delay Type; 8 thru 60 ampere fuses are Time-Delay Type.

Catalog Number Designations for Fuseblocks.

Fuse		Ampere Rating	Single Pole Current*	Single Pole Old	Double Pole Current*	Double Pole Old
Supplementary	–	–	BM6031SQ	2807	BM6032SQ	2808
Branch Circuit	FRN-R	1/10-30A	R25030-1SR	1BR001	R25030-2SR	1BR002
	LPN-RK_SP	1/10-30A	R25030-1SR	1BR001	R25030-2SR	1BR002
	FRS-R	1/10-30A	R60030-1SR	1BR024	R60030-2SR	1BR025
	LPS-RK_SP	1/10-30A	R60030-1SR	1BR024	R60030-2SR	1BR025
	SC	20A	BG3011SQ	2961	BG3022SQ	2917
		½-15A	BG3021SQ	2962	BG3022SQ	2918
	KTK-R	1/10-30A	BC6031S	2078	BC6032S	2079
	FNQ-R	1/10-30A				
	LP-CC	½-30A				

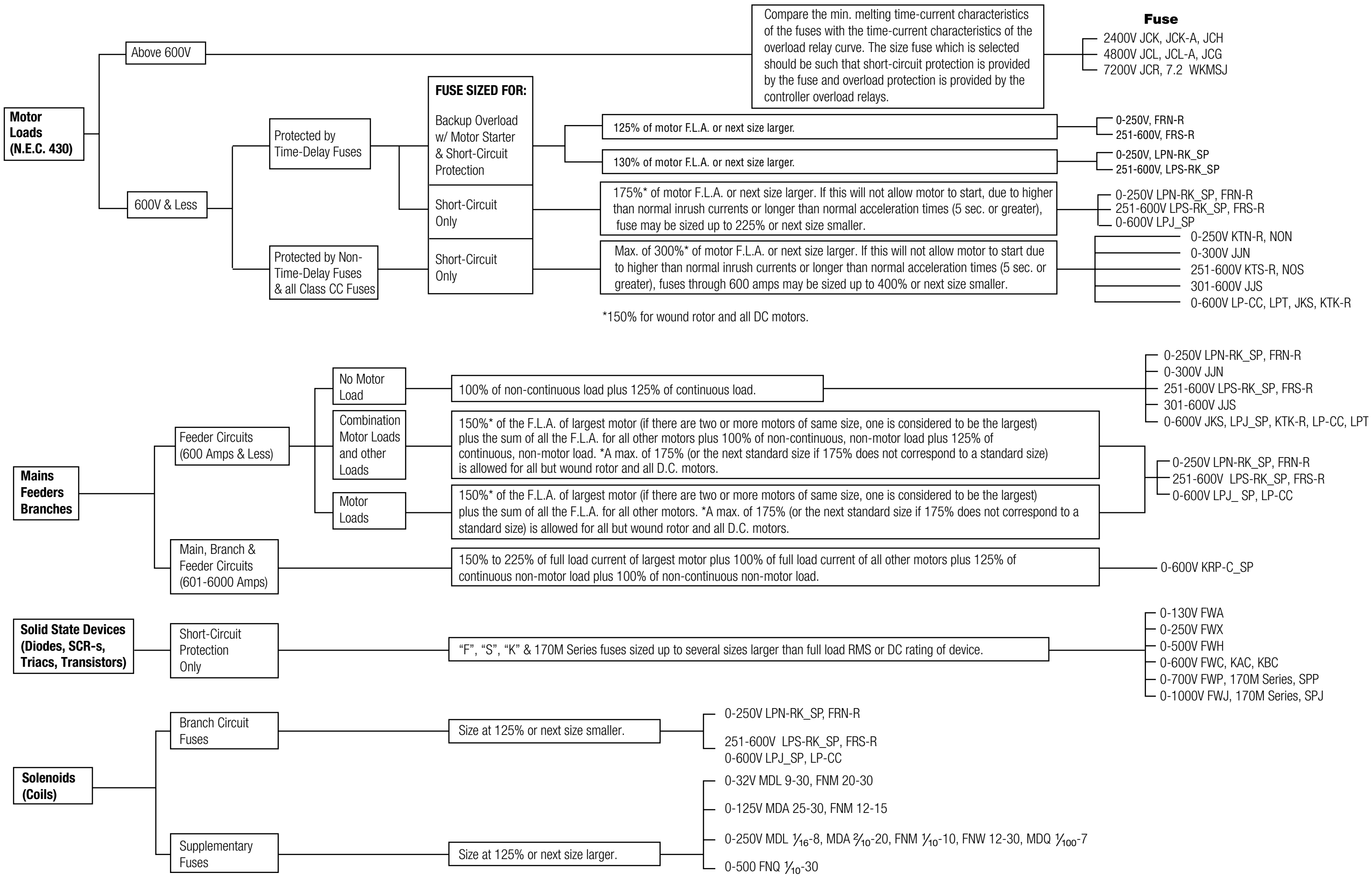
*Numbers reflect Catalog Number change only.

Fuse Diagnostic Chart



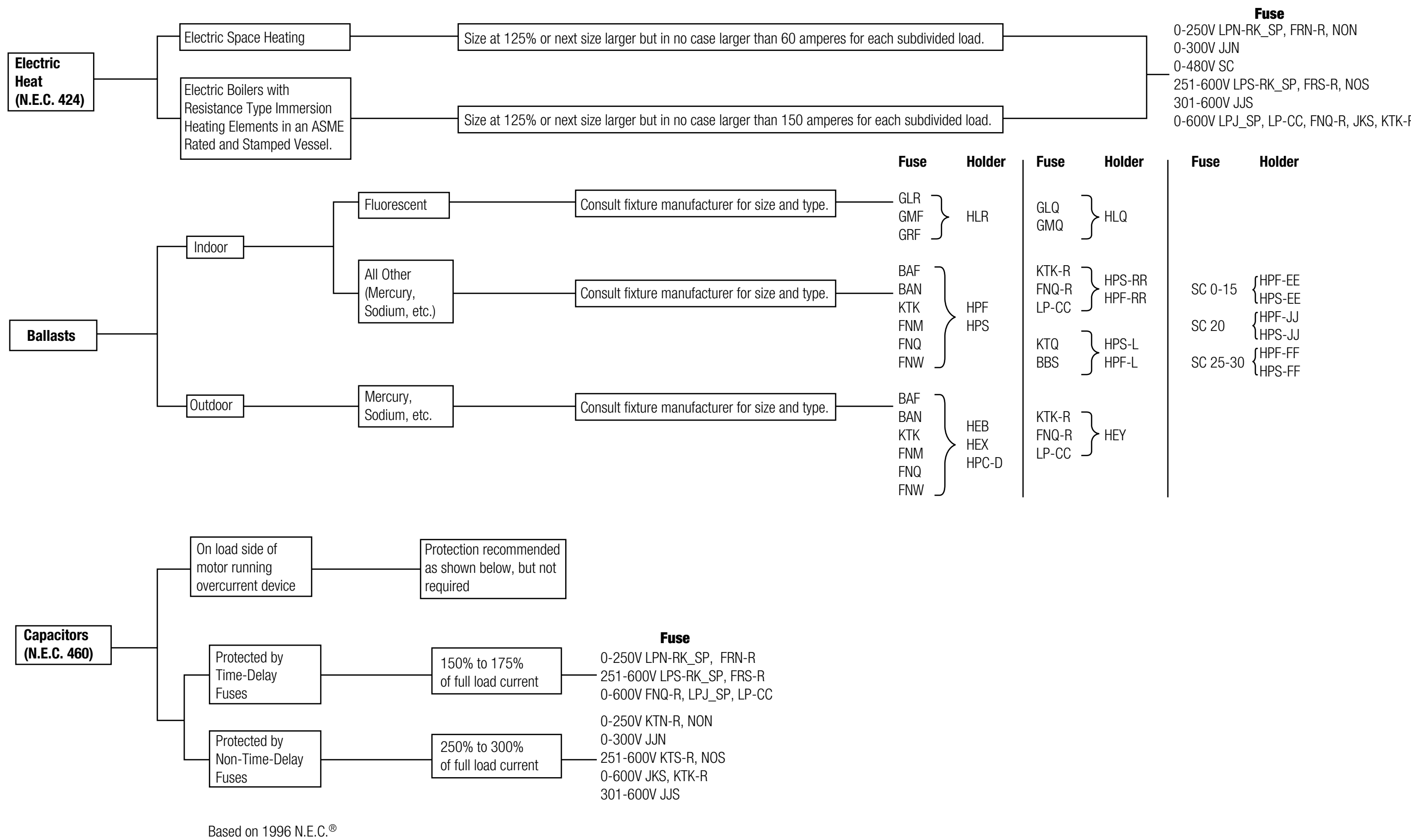
Based on 1996 N.E.C.®

Fuse Diagnostic Chart



Based on 1996 N.E.C.®

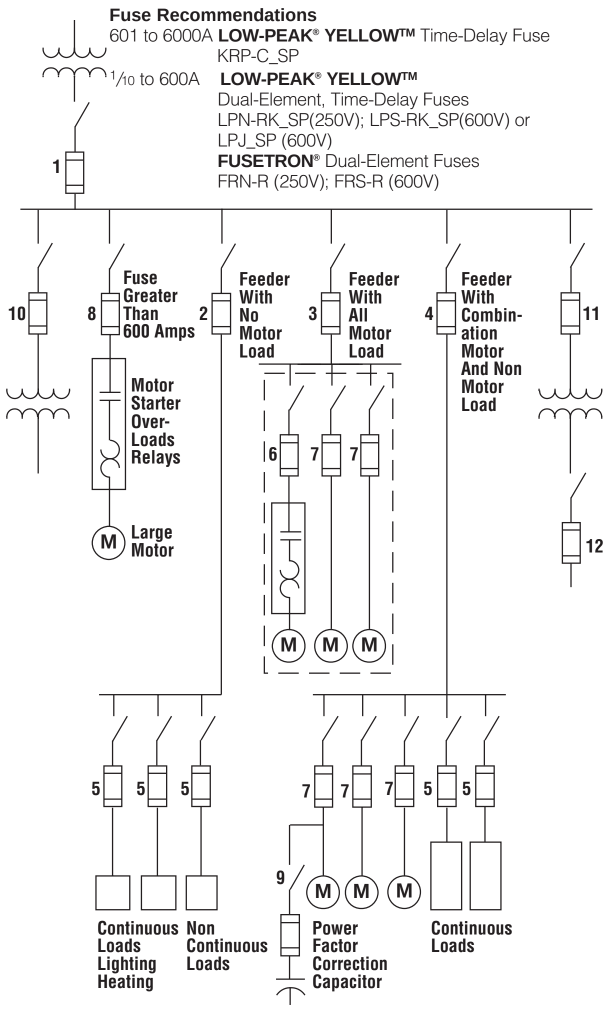
Fuse Diagnostic Chart



Main, Feeder, and Branch Circuit Fuse Sizing

Guide For Sizing Fuses

General guidelines are given for selecting fuse ampere ratings for most circuits. Some specific applications may warrant other fuse sizing; in these cases the load characteristics and appropriate NEC sections should be considered. The selections shown here are not, in all cases, the maximum or minimum ampere ratings permitted by the NEC. Demand factors as permitted per the NEC are not included in these guidelines.



DUAL-ELEMENT, TIME-DELAY FUSES (LPJ_SP, LPS-RK_SP, LPN-RK_SP, FRS-R, AND FRN-R)

1. Main Service. Size fuse according to method in **4**.

2. Feeder Circuit With No Motor Loads. The fuse size must be at least **125%** of the continuous load† plus **100%** of the non-continuous load. Do not size larger than ampacity of conductor*.

3. Feeder Circuit With All Motor Loads. Size the fuse at **150%**□ of the full load current of the largest motor plus the full-load current of all other motors∆.

4. Feeder Circuit With Mixed Loads∆. Size fuse at sum of:
- **a. 150%**□ of the full-load current of the largest motor plus
- **b. 100%** of the full-load current of all other motors plus
- **c. 125%** of the continuous, non-motor load† plus
- **d. 100%** of the non-continuous, non-motor load.

5. Branch Circuit With No Motor Load. The fuse size must be at least **125%** of the continuous load† plus **100%** of the non-continuous load. Do not size larger than ampacity of conductor*.

6. Motor Branch Circuit With Overload Relays. Where overload relays are sized for motor running overload protection, the following provide backup, ground fault, and short-circuit protection:
- **a.** Size RK5 & RK1 fuses at **125% & 130%** of motor full-load current respectively or next higher size.

7. Motor Branch Circuit With Fuse Protection Only. Where the fuse is the only motor protection, the following Class RK5 fuses provide motor running overload protection and short-circuit protection:
- **a. Motor 1.15 service factor or 40°C rise:** size the fuse at **110%** to **125%** of the motor full-load current.
- **b. Motor less than 1.15 service factor or over 40°C rise:** size fuse at **100%** to **115%** of motor full-load current.

8. Large Motor Branch Circuit. Fuse larger than 600 amps. For large motors, size KRP-C_SP LOW-PEAK® YELLOW™ time-delay fuse at **175%** to **225%** of the motor full-load current, depending on the starting method; i.e. part-winding starting, reduced voltage starting, etc.

9. Power Factor Correction Capacitors. Size dual-element fuses as low as practical, typically **150%** to **175%** of capacitor rated current.

10. Transformer Primary Fuse (without secondary fuse protection). When transformer primary current is equal to or greater than 9 amperes, the dual-element, time-delay fuse should be sized at **125%** of transformer primary current or the next size larger. **Note:** Secondary conductors must be protected from overcurrent damage.

11. Transformer Primary Fuse (with secondary fuse protection). May be sized at **250%** of transformer primary current if,

12. The secondary fuse is sized at no more than **125%** of secondary full-load current. **Note:** Secondary conductors must be protected at their ampacities.

NON-TIME-DELAY AND ALL CLASS CC FUSES (JKS, KTS-R, KTN-R, JJS, JJN, LP-CC, KTK-R, AND FRQ-R)

1. Main service. Size fuse according to method in **4**.

2. Feeder Circuit With No Motor Loads. The fuse size must be at least **125%** of the continuous load† plus **100%** of the non-continuous load. Do not size larger than the ampacity of the wire.

3. Feeder Circuit With All Motor Loads. Size the fuse at **300%** of the full-load current of the largest motor plus the full-load current of all other motors. Do not size fuse larger than the conductor capacity.

4. Feeder Circuit With Mixed Loads. Size fuse at sum of:
- **a. 300%** of the full-load current of the largest motor plus
- **b. 100%** of the full-load current of all other motors plus
- **c. 125%** of the continuous, non-motor load† plus
- **d. 100%** of the non-continuous, non-motor load.

5. Branch Circuit With No Motor Loads. The fuse size must be at least **125%** of the continuous load† plus **100%** of the non-continuous load. Do not size larger than the ampacity of conductor.*

6. Motor Branch Circuit With Overload Relays. Size the fuse as close to but not exceeding **300%** of the motor running full load current. Provides ground fault and short-circuit protection only.

7. Motor Branch Circuit With Fuse Protection Only. Non-time-delay fuses **cannot** be sized close enough to provide motor running overload protection. If sized for motor overload protection, non-time-delay fuses would open due to motor starting current. Use dual-element fuses.

CONDUCTOR AMPACITY SELECTION•

1. Feeder Circuit And Main Circuit With Mixed Loads.
Conductor ampacity at least sum of:
- **a. 125%** of continuous non-motor load plus
- **b. 100%** of non-continuous non-motor load plus
- **c. 125%** of the largest motor full-load current plus
- **d. 100%** of all other motors' full-load current.

2. Feeder Circuit With No Motor Load. Conductor ampacity at least **125%** of the continuous load plus **100%** of the non-continuous load.

3. Feeder Circuit With All Motor Loads. Conductor ampacity at least **125%** of the largest motor full-load amperes plus **100%** of all other motors' full-load amperes.

4. Feeder Circuit With Mixed Loads. Size according to method 1 above.

5. Branch Circuit With No Motor Load. Conductor ampacity at least **125%** of the continuous load plus **100%** of the non-continuous load.

6, 7, & 8. Motor Branch Circuits. Conductor ampacity at least **125%** of the motor full-load current.

9. Conductor ampacity at least 135% of capacitor rated current. The ampacity of conductors for a capacitor connected to a motor circuit must be ⅓ the ampacity of the motor circuit conductors.

10, 11. Conductor ampacity minimum 125% of transformer full-load current.

12. Conductor ampacity per 1 above.

† 100% of the continuous load can be used rather than 125% when the switch and fuse are listed for continuous operation. Most bolted pressure switches and high pressure contact switches 400A to 6000A with Class L fuses are listed for 100% continuous operation.

* Where conductor ampacity does not correspond to a standard fuse rating, next higher rating fuse is permitted when 800 amperes or less (240-3. Exc. 1).

∆ In many motor feeder applications dual-element fuses can be sized at ampacity of feeder conductors.

• Available short-circuit current and the clearing time of the overcurrent device must be considered so that the conductor's ICEA (P32-382) withstand rating is not exceeded.

□ NEC® allows a maximum of 175% or the next standard size if 175% does not correspond with a standard fuse size, for all but wound rotor and DC motors.

Suggested Fuse Specification

General
Fuses shall not be installed until equipment is ready to be energized. This measure prevents fuse damage during shipment of the equipment from the manufacturer to the job site, or from water that may contact the fuse before the equipment is installed. Final tests and inspections shall be made prior to energizing the equipment. This shall include a thorough cleaning, tightening, and review of all electrical connections and inspection of all grounding conductors. All fuses shall be furnished and installed by the electrical contractor. All fuses shall be of the same manufacturer. Fuses shall be as follows:

A. Main, Feeder, and Branch Circuit Fuses
1. Circuits 601 through 6000 amperes

Circuits 601 through 6000 amperes shall be protected by current-limiting **BUSSMANN LOW-PEAK® YELLOW™ Time-Delay Fuses KRP-C(amp)SP.** Fuses shall employ "O" rings as positive seals between the end bells and the glass melamine fuse barrel. Fuse links shall be pure silver (99.9% pure) in order to limit the short-circuit current let-through values to low levels and comply with NEC® Sections requiring component protection. Fuses shall be time-delay and shall hold 500% of rated current for a minimum of 4 seconds, clear 20 times rated current in .01 seconds or less, with an interrupting rating of 300,000 amperes RMS symmetrical, and be listed by a nationally recognized testing laboratory. Peak let-through currents and I^2t let-through energies shall not exceed the values established for Class L fuses. Larger HP motors shall be protected by these fuses, with ratings as shown on the drawings.

2. Circuits 0 through 600 amperes

Circuits 0 through 600 amperes shall be protected by current-limiting **BUSSMANN LOW-PEAK® YELLOW™ Dual-Element, Time-Delay Fuses LPN-RK(amp)SP/LPS-RK(amp)SP or LPJ(amp)SP.** All fuses shall have separate overload and short-circuit elements. Fuses shall incorporate a spring activated thermal overload element that has a 284 degrees Fahrenheit melting point alloy. The fuses shall hold 500% of rated current for a minimum of 10 seconds (30A, 250V Class RK1 case size may be a minimum of 8 seconds at 500% of rated current) with an interrupting rating of 300,000 amperes RMS symmetrical, and be listed by a nationally recognized testing laboratory. Peak let-through currents and I^2t let-through energies shall not exceed the values established for Class RK1 or J fuses.

Motor Circuits - All individual motor circuits with full-load ampere ratings (F.L.A.) of 461 (or 400) amperes or less shall be protected by **BUSSMANN LOW-PEAK® YELLOW™ Dual-Element, Time-Delay Fuses LPN-RK(amp)SP/LPS-RK(amp)SP or LPJ(amp)SP.** The following guidelines apply for motors protected by properly sized overload relays: LPN-RK(amp)SP/LPS-RK(amp)SP fuses shall be installed in ratings of 130% [or 150% for LPJ(amp)SP fuses] of motor full-load current (or next size larger if this does not correspond to a fuse size), except where high ambient temperatures prevail, or where the motor drives a heavy revolving part which cannot be brought up to full speed quickly, such as large fans. Under such conditions the fuse may be 175%* of the motor full-load current, or the next standard size larger if 175%* does not correspond to a standard fuse size. If this will not allow the motor to start due to higher than normal inrush currents or longer than normal acceleration times (5 seconds or greater), fuses may be sized up to 225% (or next size smaller).

Motor Controllers - NEMA and IEC Style motor controllers shall be protected from short-circuits by **BUSSMANN LOW-PEAK® YELLOW™ Dual-Element, Time-Delay Fuses** in order to provide testing agency-witnessed Type 2 coordination for the controller. This provides "no damage" protection for the controller, under low and high level fault conditions, as required by IEC Publication 947-4 and U.L. 508E.

*150% for wound rotor and all DC motors.

3. Switchboards, Panelboards, Load Centers

The manufacturer shall supply equipment utilizing fully rated and listed components. This equipment shall be tested, listed and labeled for the available short-circuit current.
(Where series-rated fuse/circuit breaker systems are acceptable, the systems shall utilize tested, recognized components. The manufacturer shall supply switchboards, panelboards and load centers which have been tested, listed, and labeled for the available short-circuit current, and those combinations specified on the drawings.)

4. Marking

Fuses shall be **"LOW-PEAK® YELLOW™"** in color. **"LOW-PEAK® YELLOW™" NOTICE** labels to alert the end user of the engineered level of protection of the electrical equipment shall be field installed by the electrical contractor. They shall be marked with the proper fuse rating, per the specifications, and placed in a conspicuous location on the enclosure. These labels are available upon request from Bussmann.

B. Supplementary - Light Fixture Protective Fuses
1. Fluorescent fixtures shall be protected by **BUSSMANN GLR or GMF Fuses in HLR Holders.** These fixtures shall have individual protection on the line side of the ballast. A fuse and holder shall be mounted within, or as part of, the fixture. Size and type of fuse to be recommended by the fixture manufacturer.

2. All other ballast-controlled light fixtures shall be protected by **BUSSMANN KTK or FNQ Fuses in HEB, HPF, or HPS Holders.** These fixtures shall have individual protection on the line side of the ballast. Fuse and holder shall be mounted in a location convenient for changing fuses. Holder shall be mounted in protected location or be an in-line waterproof holder **(HEB, HEX, or HEY).** Size and type of fuse to be recommended by the fixture manufacturer or as indicated on plans.

C. Spares
Upon completion of the building, the electrical contractor shall provide the owner with spare fuses as shown below:
1. 10% (minimum of 3) of each type and rating of installed fuses shall be supplied as spares.

2. BUSSMANN spare fuse cabinets - Catalog No. **SFC** - shall be provided to store the above spares. A supply of **"LOW-PEAK® YELLOW™" NOTICE** Labels shall be provided along with the spare fuses in the spare fuse cabinet.

D. Substitution Approvals

The electrical contractor's proposal shall be based upon the fuses specified, using the manufacturer's catalog numbers as called for in the specification or on the drawings. Coordination and current limitation requirements for protection of each part of the electrical system have been engineered on the basis of the type, class and manufacturer specified.

In the event that the electrical contractor wishes to furnish materials other than those specified, a written request, along with a complete short-circuit and selective coordination study, shall be submitted to the engineer for evaluation at least two weeks prior to bid date. If the engineer's evaluation indicates acceptance, a written addendum will be issued listing the other acceptable manufacturer.

Glossary of Terms

Ampere
The measurement of intensity of rate of flow of electrons in an electric circuit. An ampere is the amount of current that will flow through a resistance of one ohm under a pressure of one volt.

Ampere Rating
The current-carrying capacity of a fuse. When a fuse is subjected to a current above its ampere rating, it will open the circuit after a predetermined period of time.

Ampere Squared Seconds, I^2t
The measure of heat energy developed within a circuit during the fuse's clearing. It can be expressed as "Melting I^2t", "Arcing I^2t" or the sum of them as "Clearing I^2t". "I" stands for effective let-through current (RMS), which is squared, and "t" stands for time of opening, in seconds.

Arcing Time
The amount of time from the instant the fuse link has melted until the overcurrent is interrupted, or cleared.

Breaking Capacity
(See Interrupting Rating)

Cartridge Fuse
A fuse consisting of a current responsive element inside a fuse tube with terminals on both ends.

Class CC Fuses
600V, 200,000 ampere interrupting rating, branch circuit fuses with overall dimensions of 13⁄32″ × 1½″. 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″ × 1½″ fuses. They are available from 1⁄10 amp through 30 amps.

Class G Fuses
480V, 100,000 ampere interrupting rating branch circuit fuses that are size rejecting to eliminate overfusing. The fuse diameter is 13⁄32″ while the length varies from 15⁄16″ to 2¼″. These are available in ratings from 1 amp through 60 amps.

Class H Fuses
250V and 600V, 10,000 ampere interrupting rating branch circuit fuses that may be renewable or non-renewable. These are available in ampere ratings of 1 amp through 600 amps.

Class J Fuses
These fuses are rated to interrupt a minimum of 200,000 amperes AC. They are labelled as "Current-Limiting", are rated for 600 volts AC, and are not interchangeable with other classes.

Class K Fuses
These are fuses listed as K-1, K-5, or K-9 fuses. Each subclass has designated I^2t and Ip maximums. These are dimensionally the same as Class H fuses, and they can have interrupting ratings of 50,000, 100,000, or 200,000 amps. These fuses are current-limiting. However, they are not marked "current-limiting" on their label since they do not have a rejection feature.

Class L Fuses
These fuses are rated for 601 through 6000 amperes, and are rated to interrupt a minimum of 200,000 amperes AC. They are labelled "current-limiting" and are rated for 600 volts AC. They are intended to be bolted into their mountings and are not normally used in clips. Some Class L fuses have designed in time-delay features for all purpose use.

Class R Fuses
These are high performance fuses rated 1⁄10 - 600 amps in 250 volt and 600 volt ratings. All are marked "current-limiting" on their label and all have a minimum of 200,000 amp interrupting rating. They have identical outline dimensions with the Class H fuses but have a rejection feature which prevents the user from mounting a fuse of lesser capabilities (lower interrupting capacity) when used with special Class R Clips. Class R fuses will fit into either rejection or non-rejection clips.

Class T Fuses
An industry class of fuses in 300 volt and 600 volt ratings from 1 amp through 1200 amps. They are physically very small and can be applied where space is at a premium. They are fast-acting and time-lag fuses, with an interrupting rating of 200,000 amps RMS.

Classes of Fuses
The industry has developed basic physical specifications and electrical performance requirements for fuses with voltage ratings of 600 volts or less. These are known as standards. If a type of fuse meets the requirements of a standard, it can fall into that class. Typical classes are K, RK1, RK5, G, L, H, T, CC, and J.

Clearing Time
The total time between the beginning of the overcurrent and the final opening of the circuit at rated voltage by an overcurrent protective device. Clearing time is the total of the melting time and the arcing time.

Current-Limitation
A fuse operation relating to short-circuits only. When a fuse operates in its current-limiting range, it will clear a short-circuit in less than ½ cycle. Also, it will limit the instantaneous peak let-through current to a value substantially less than that obtainable in the same circuit if that fuse were replaced with a solid conductor of equal impedance.

Dual-Element Fuse
Fuse with a special design that utilizes two individual elements in series inside the fuse tube. One element, the spring actuated trigger assembly, operates on overloads up to 5-6 times the fuse current rating. The other element, the short-circuit section, operates on short-circuits up to their interrupting rating.

Electrical Load
That part of the electrical system which actually uses the energy or does the work required.

Fast Acting Fuse
A fuse which opens on overload and short circuits very quickly. This type of fuse is not designed to withstand temporary overload currents associated with some electrical loads.

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

High Speed Fuses
Fuses with no intentional time-delay in the overload range and designed to open as quickly as possible in the short-circuit range. These fuses are often used to protect solid-state devices.

Inductive Load
An electrical load which pulls a large amount of current – an inrush current – when first energized. After a few cycles or seconds the current "settles down" to the full-load running current.

Interrupting Capacity
See Interrupting Rating

Interrupting Rating
(Breaking Capacity)
The rating which defines a fuse's ability to safely interrupt and clear short-circuits. This rating is much greater than the ampere rating of a fuse. The NEC® defines Interrupting Rating as "The highest current at rated voltage that an overcurrent protective device is intended to interrupt under standard test conditions."

Melting Time
The amount of time required to melt the fuse link during a specified overcurrent. (See Arcing Time and Clearing Time.)

"NEC" Dimensions
These are dimensions once referenced in the National Electrical Code. They are common to Class H and K fuses and provide interchangeability between manufacturers for fuses and fusible equipment of given ampere and voltage ratings.

Glossary of Terms

Ohm
The unit of measure for electric resistance. An ohm is the amount of resistance that will allow one ampere 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 amperes, and R is the resistance in ohms.

One Time Fuses
Generic term used to describe a Class H nonrenewable cartridge fuse, with a single element.

Overcurrent
A condition which exists on an electrical circuit when the normal load current is exceeded. Overcurrents take on two separate characteristics – overloads and short-circuits.

Overload
Can be classified as an overcurrent which exceeds the normal full load current of a circuit. Also characteristic of this type of overcurrent is that it does not leave the normal current carrying path of the circuit – that is, it flows from the source, through the conductors, through the load, back through the conductors, to the source again.

Peak Let-Through Current, Ip
The instantaneous value of peak current let-through by a current-limiting fuse, when it operates in its current-limiting range.

Renewable Fuse (600V & below)
A fuse in which the element, typically a zinc link, may be replaced after the fuse has opened, and then reused. Renewable fuses are made to Class H standards.

Resistive Load
An electrical load which is characteristic of not having any significant inrush current. When a resistive load is energized, the current rises instantly to its steady-state value, without first rising to a higher value.

RMS Current
The RMS (root-mean-square) value of any periodic current is equal to the value of the direct current which, flowing through a resistance, produces the same heating effect in the resistance as the periodic current does.

Semiconductor Fuses
Fuses used to protect solid-state devices. See "High Speed Fuses".

Short-Circuit
Can be classified as an overcurrent which exceeds the normal full load current of a circuit by a factor many times (tens, hundreds or thousands greater). Also characteristic of this type of overcurrent is that it leaves the normal current carrying path of the circuit – it takes a "short cut" around the load and back to the source.

Short-Circuit Rating
The maximum short-circuit current an electrical component can sustain without the occurrence of excessive damage when protected with an overcurrent protective device.

Short-Circuit Withstand Rating
Same definition as Short-Circuit Rating.

Single-Phasing
That condition which occurs when one phase of a three-phase system opens, either in a low voltage (secondary) or high voltage (primary) distribution system. Primary or secondary single-phasing can be caused by any number of events. This condition results in unbalanced currents in polyphase motors and unless protective measures are taken, causes overheating and failure.

Threshold Current
The symmetrical RMS available current at the threshold of the current-limiting range, where the fuse becomes current-limiting when tested to the industry standard. This value can be read off of a peak let-through chart where the fuse curve intersects the A-B line. A threshold ratio is the relationship of the threshold current to the fuse's continuous current rating.

Time-Delay Fuse
A fuse with a built-in delay that allows temporary and harmless inrush currents to pass without opening, but is so designed to open on sustained overloads and short-circuits.

Voltage Rating
The maximum open circuit voltage in which a fuse can be used, yet safely interrupt an overcurrent. Exceeding the voltage rating of a fuse impairs its ability to clear an overload or short-circuit safely.

Withstand Rating
The maximum current that an unprotected electrical component can sustain for a specified period of time without the occurrence of extensive damage.

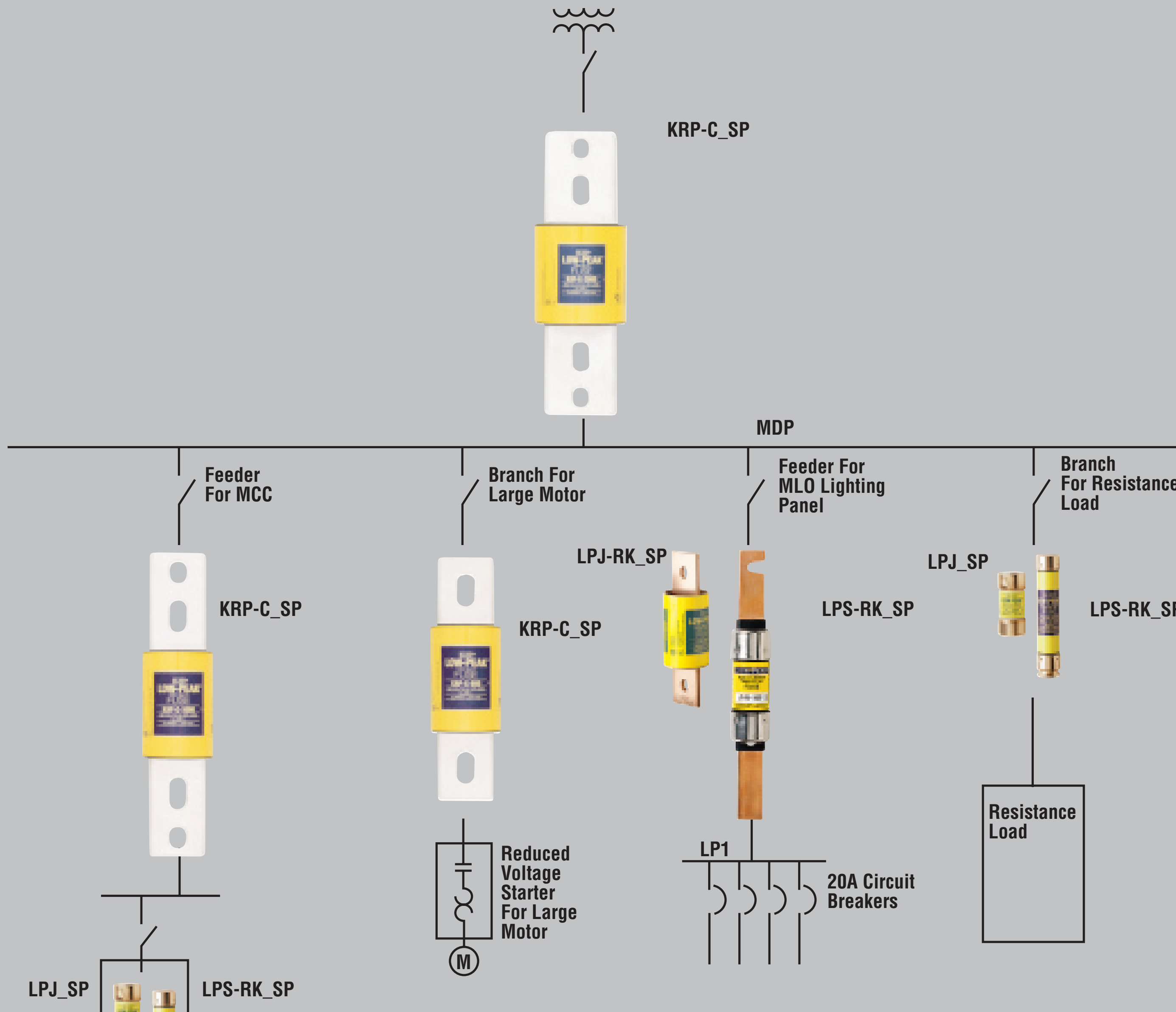
Useful Formulas

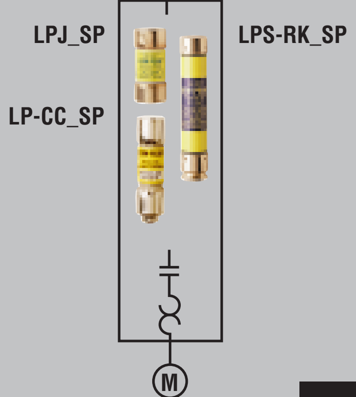
To Find	Single-Phase	Two-Phase	Three-Phase	Direct Current
Amperes when kVA is known	$\frac{kVA \times 1000}{E}$	$\frac{kVA \times 1000}{E \times 2}$	$\frac{kVA \times 1000}{E \times 1.73}$	Not Applicable
Amperes when horsepower is known	$\frac{HP \times 746}{E \times \%\,eff. \times pf}$	$\frac{HP \times 746}{E \times 2 \times \%\,eff. \times pf}$	$\frac{HP \times 746}{E \times 1.73 \times \%\,eff. \times pf}$	$\frac{HP \times 746}{E \times \%\,eff.}$
Amperes when kilowatts are known	$\frac{kW \times 1000}{E \times pf}$	$\frac{kW \times 1000}{E \times 2\,pf}$	$\frac{kW \times 1000}{E \times 1.73 \times pf}$	$\frac{kW \times 1000}{E}$
Kilowatts	$\frac{I \times E \times pf}{1000}$	$\frac{I \times E \times 2 \times pf}{1000}$	$\frac{I \times E \times 1.73 \times pf}{1000}$	$\frac{I \times E}{1000}$
Kilovolt-Amperes	$\frac{I \times E}{1000}$	$\frac{I \times E \times 2}{1000}$	$\frac{I \times E \times 1.73}{1000}$	Not Applicable
Horsepower	$\frac{I \times E\ \%\,eff. \times pf}{746}$	$\frac{I \times E \times 2 \times \%\,eff. \times pf}{746}$	$\frac{I \times E \times 1.73 \times \%\,eff. \times pf}{746}$	$\frac{I \times E \times \%\,eff.}{746}$
Watts	$E \times I \times pf$	$I \times E \times 2 \times pf$	$I \times E \times 1.73 \times pf$	$E \times I$

$$\text{Energy Efficiency} = \frac{\text{Load Horsepower} \times 746}{\text{Load Input kVA} \times 1000}$$

$$\text{Power Factor} = pf = \frac{\text{Power Consumed}}{\text{Apparent Power}} = \frac{W}{VA} \text{ or } \frac{kW}{kVA} = \cos\theta$$

I = Amperes; E = Volts; kW = Kilowatts; kVA = Kilovolt-Amperes
HP = Horsepower; % eff. = Percent Efficiency; pf = Power Factor





Specify the Buss LOW-PEAK® Yellow™ System

- Yellow = 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.
- 300,000 amperes interrupting rating.

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