

## Amp Rating and Interrupting Rating

Slash voltage devices are limited in application to solidly grounded, wye systems due to the nature of the way that these devices are tested, listed and labeled. Any piece of equipment that utilizes a slash voltage rated overcurrent protective device is therefore, limited to installation only in a solidly grounded, wye system and should require marking that notes this limitation.

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

### Amp Rating

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

### Testing Knife-Blade Fuses

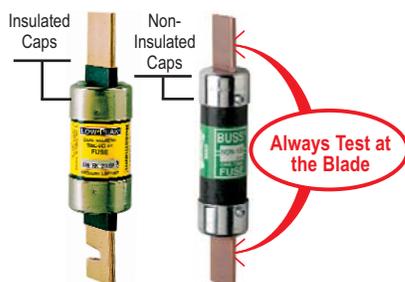
A common practice when electricians are testing fuses is to touch the end caps of the fuse with their probes. Contrary to popular belief, fuse manufacturers do not generally design their knife-blade fuses to have electrically energized fuse caps during normal fuse operation. Electrical inclusion of the caps into the circuit occurs as a result of the coincidental mechanical contact between the fuse cap and terminal extending through it. In most brands of knife-blade fuses, this mechanical contact is not guaranteed; therefore, electrical contact is not guaranteed. Thus, a resistance reading taken across the fuse caps is not indicative of whether or not the fuse is open. In a continuing effort to promote safer work environments, Cooper Bussmann has introduced newly designed versions of knife-blade Fusetron® fuses (Class RK5) and knife-blade Low-Peak fuses (Class RK1) for some of the amp ratings. The improvement is that the end caps are insulated to reduce the possibility of accidental contact with a live part. With these improved fuses, the informed electrician knows that the end caps are isolated. With older style non-insulated end caps, the electrician doesn't really know if the fuse is "hot" or not. A portion of all testing-related injuries could be avoided by proper testing procedures. Cooper Bussmann hopes to reduce such injuries by informing electricians of proper procedures.



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

### Interrupting Rating

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



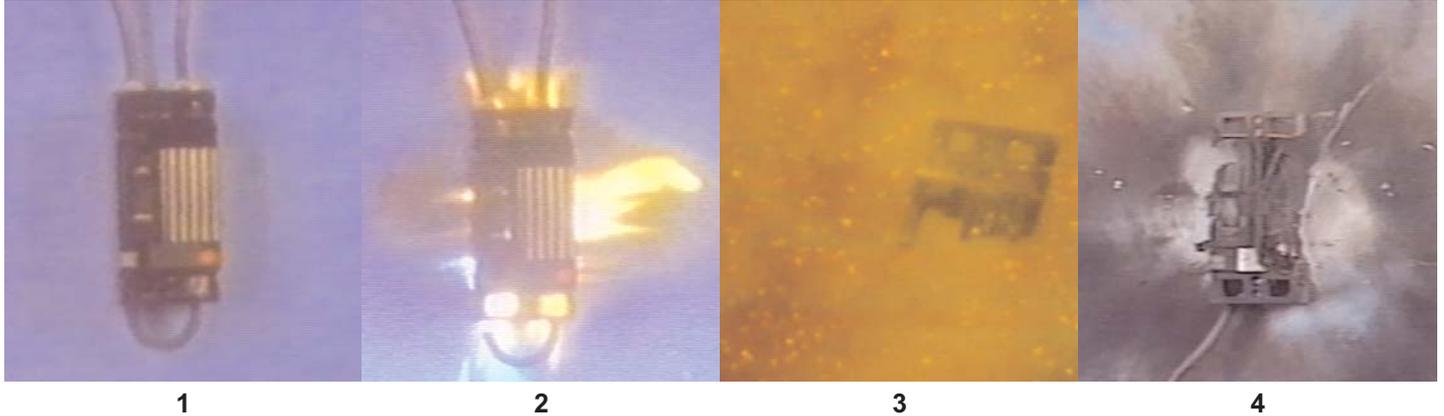
**A continuity test across any knife-blade fuse should be taken ONLY along the fuse blades. Do NOT test a knife-blade fuse with meter probes to the fuse caps.**

# Fuseology

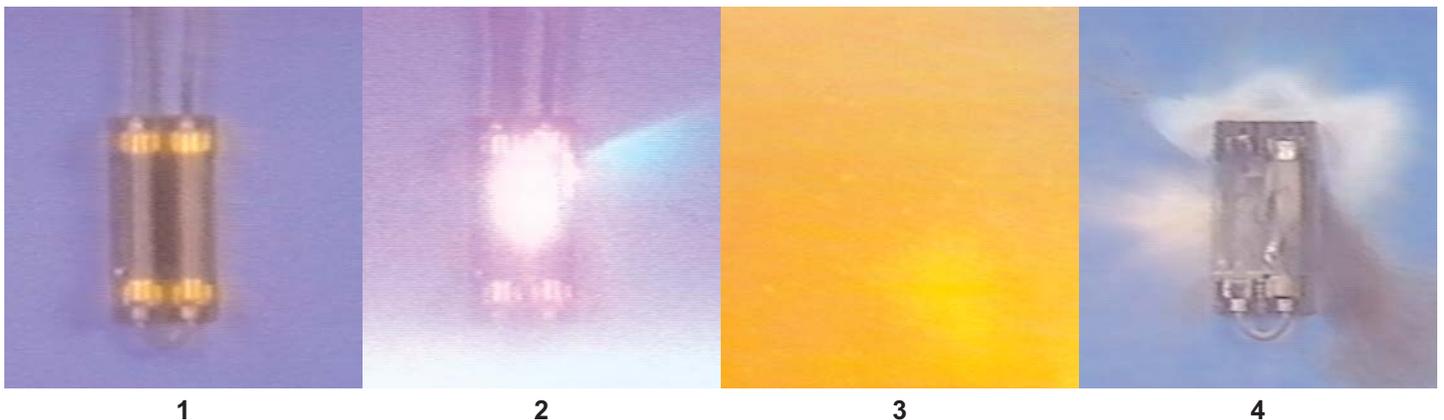
## Interrupting Rating

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

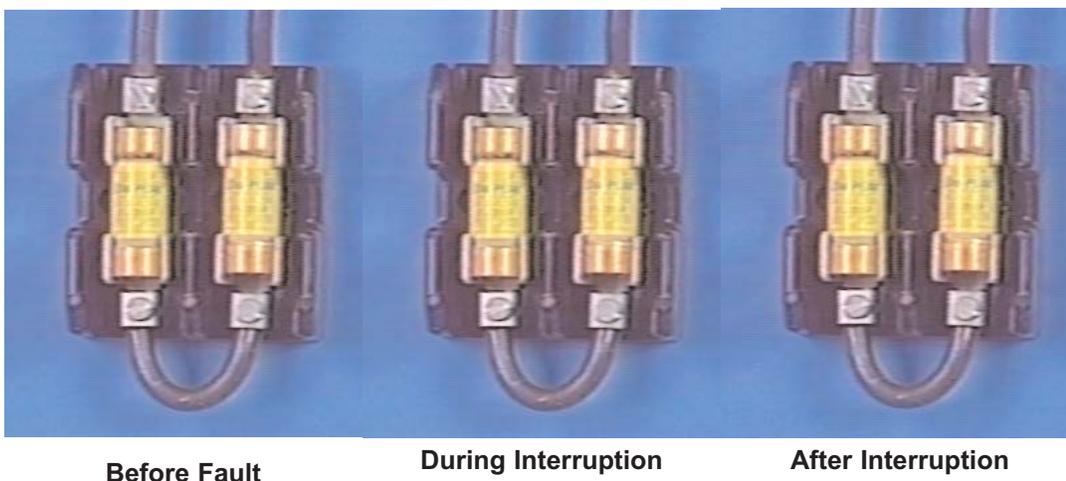
The first group of photos depicts a test conducted on a 480V circuit breaker. The breaker has an interrupting rating of 14,000A, however, the test circuit was capable of delivering 50,000A of short-circuit current at 480V. The results can be seen below.



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



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



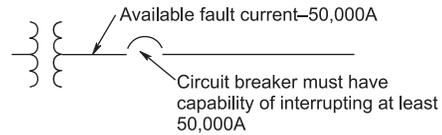
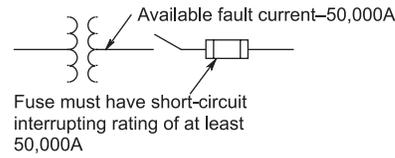
## Interrupting Rating

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

Circuit with Overcurrent Protective Device Current Rating = 100A and Interrupting Rating = 10,000A	Circuit Conditions	Application And Action of Protective Device
<p><b>OVERCURRENT PROTECTION DEVICE</b></p> <p>100 Amps AMMETER LOAD</p>	Normal	Proper
<p>200 AMMETER LOAD</p>	Overload Current Greater Than Device's Amp Rating	Proper-Safe Interruption of Current
<p>10,000 AMMETER LOAD</p>	Short-Circuit Current Within Device Interrupting Rating	Proper-Safe Interruption of Current
<p>50,000 AMMETER LOAD</p>	Short-Circuit Current Exceeds Device Interrupting Rating	Improper: Explosion or Rupture Could Result

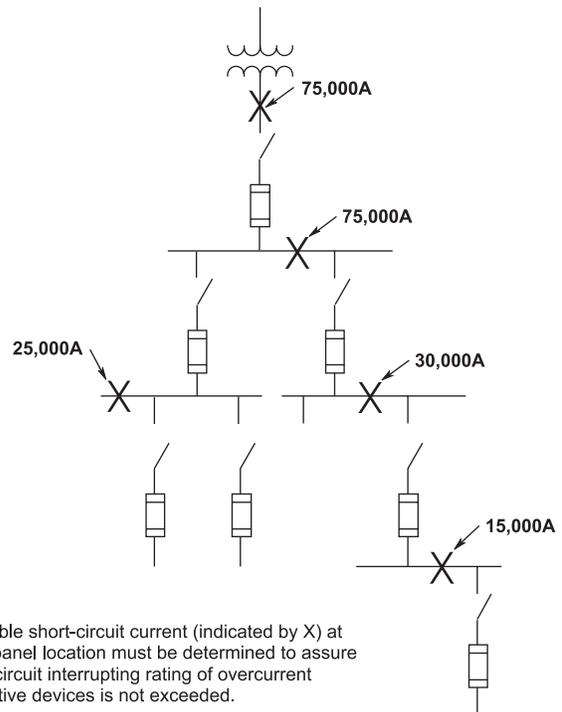
In the first three instances above, the circuit current condition is within the safe operating capabilities of the overcurrent protective device. However, the fourth case involves a misapplication of the overcurrent device. A short circuit on the load side of the device has resulted in a fault current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

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



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

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



## Interrupting Rating Vs. Interrupting Capacity

### General Fuse Application Data For Compliance With NEC® 110.9

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

### Interrupting Rating

It is the maximum short-circuit current that an overcurrent protective device can safely interrupt under standard test conditions. The phrase “under standard test conditions” means it is important to know how the overcurrent protective device is tested in order to assure it is properly applied. This can be very important when it comes to the application of circuit breakers, mainly ratings of 100A and less.

### Interrupting Capacity

The highest current at rated voltage that the device can interrupt. This definition is from the IEEE Standard Dictionary of Electrical and Electronic Terms.

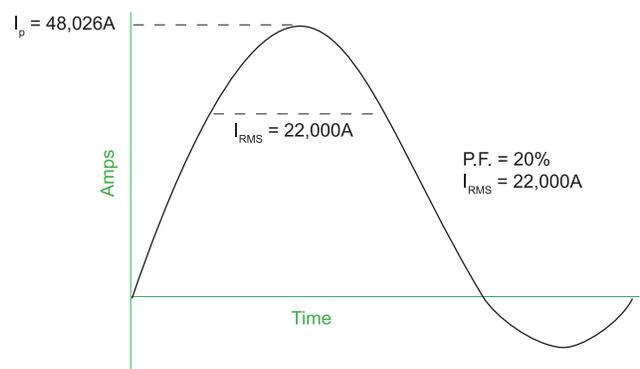
### Standard Test Conditions - Fuses

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

### “Standard” Test Conditions - Circuit Breakers

This is not the case with circuit breakers. Because of the way circuit breakers are short circuit tested (with additional conductor impedance), their interrupting capacity can be less than their interrupting rating. When the test circuit is calibrated for the circuit breaker interrupting rating tests, the circuit breaker is not in the circuit. After the test circuit has been verified to the proper level of short-circuit current, the circuit breaker is placed into the circuit. However, in addition to the circuit breaker, significant lengths of conductor are permitted to be added to the circuit after the calibration. This additional conductor impedance can result in a significantly lower short-circuit current. So a circuit breaker marked with an interrupting rating of 22,000A may in fact have an interrupting capacity of only 9,900A.

To better understand this, it is necessary to review the standard interrupting rating test procedures for circuit breakers: Molded Case Circuit Breakers - UL 489 and CSA 5 Test Procedures. UL 489 requires a unique test set-up for testing circuit breaker interrupting ratings. The diagram below illustrates a typical calibrated test circuit waveform for a 20A, 240V, 2-pole molded case circuit breaker, with a marked interrupting rating of 22,000A, RMS symmetrical.

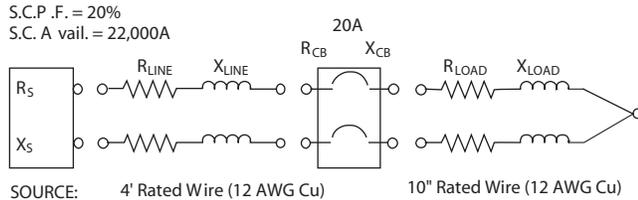


# Applying Interrupting Rating: Circuit Breakers

## Interrupting Rating Vs. Interrupting Capacity

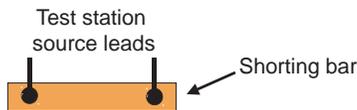
The diagram below illustrates the test circuit as allowed by UL 489.

Standard interrupting rating tests for a 22,000A sym. RMS interrupting rated circuit breaker will allow for a maximum 4 feet rated wire on the line side for each lead, and 10 inch rated wire on the load side for each lead of the circuit breaker. See the following diagrams and table, that provide a short circuit analysis of this test circuit as seen by the circuit breaker.



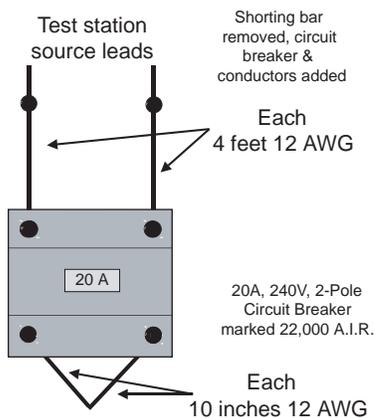
Note: For calculations,  $R_{CB}$  and  $X_{CB}$  are assumed negligible.

Test station source impedance is adjusted to achieve a calibrated 22,000 RMS symmetrical amps at 20% or less power factor. This circuit can achieve a peak current of 48,026 amps. For the calibration test, a bus bar (shorting bar) is inserted between the test station terminals.



After the circuit calibration is verified, the shorting bar is removed and the circuit breaker is inserted. In addition, lengths of rated conductor are permitted to be added as shown. This extra rated conductor has a high impedance and effectively restricts the current to 9900 RMS symmetrical amps. The power factor increases to 88% due to small conductor high resistance versus its reactance.

This circuit can now only achieve a peak current of 14,001 amps.

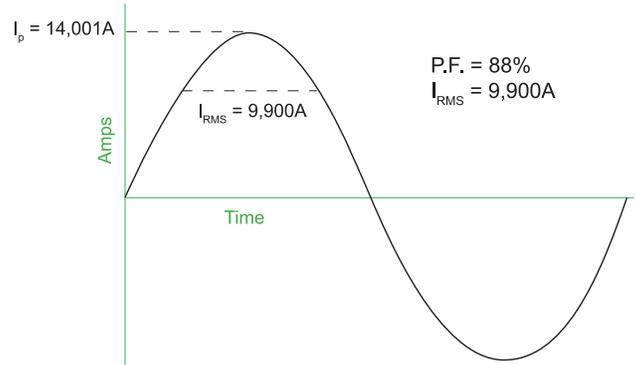


20A, 240V, 2-Pole Molded Case Circuit Breaker With 22,000A Interrupting Rating	RMS Symmetrical Amps	Maximum Instantaneous Peak	Power Factor
Calibrated Interrupting Rating Circuit	22,000	48,026	20%
Actual Circuit With Wire Impedance Added After Calibration	9900	14,001	88%

### Conclusion (refer to table above and graphs below)

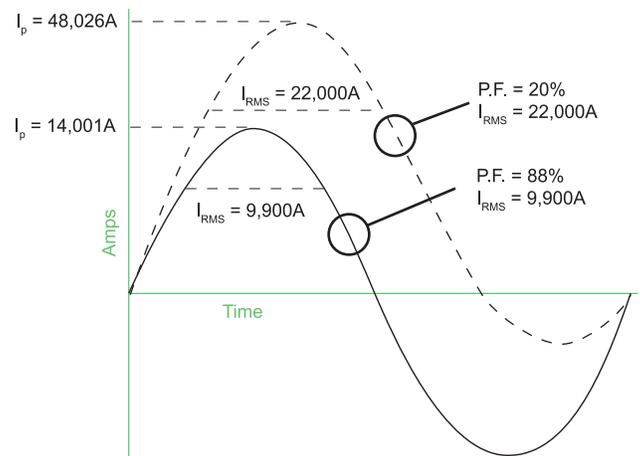
This 22,000A (with short circuit power factor of 20%) interrupting rated circuit breaker has an interrupting capacity of 9900A at a short circuit power factor of 88%. Unless there is a guarantee that no fault will ever occur at less than 4 feet 10 inches from the load terminals of the circuit breaker, this circuit breaker must only be applied where there are 9,900A or less available on its line side.

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 9900A at 88% power factor, not 22,000A 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.)



## Interrupting Rating Vs. Interrupting Capacity

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 an example of a partial table showing the actual  $I_p$  and  $I_{RMS}$  values to which circuit breakers are tested.

**240V - 2-Pole CB Interrupting Capacities (amps)**

CB AMP RATING	10,000 RMS Sym. Interrupting Rating		14,000 RMS Sym. Interrupting Rating		18,000 RMS Sym. Interrupting Rating	
	$I_p$	$I_{RMS}$	$I_p$	$I_{RMS}$	$I_p$	$I_{RMS}$
15A	7200	5100	8700	6100	9300	6600
20A	8900	6300	11,400	8100	12,600	8900
25A	10,700	7500	14,200	10,100	16,500	11,700
30A	10,700	7500	14,200	10,100	16,500	11,700
40A	11,700	8300	16,000	11,300	19,200	13,600
50A	11,700	8300	16,000	11,300	19,200	13,600
60A	12,500	8800	17,300	12,200	21,300	15,100
70A	13,000	9200	18,100	12,800	22,600	16,000
80A	13,000	9200	18,100	12,800	22,600	16,000
90A	13,200	9300	18,300	12,900	23,000	16,300
100A	13,200	9300	18,300	12,900	23,000	16,300

### “Bus Bar Conditions”- Circuit Breakers

Beginning October 31, 2000, UL 489 requires circuit breakers rated 100A and less to additionally be tested under “bus bar conditions.” However, this does not assure that the circuit breaker’s interrupting capacity equals its interrupting rating nor even that the circuit breaker is reusable. In this test, line and load terminals are connected to 10 inches of rated conductor. For single pole circuit breakers, these 10 inch leads are then connected to 4 feet of 1 AWG for connection to the test station. For multi-pole circuit breakers, the 10 inch line side leads are connected to the test station through 4 feet of 1 AWG. The load side is shorted by 10 inch leads of rated conductor per pole. These “bus bar condition” tests still do not fully address the situation where a fault can occur less than 4 feet 10 inches from the circuit breaker.

One point to be made is that acceptable bus shot test results per the product standard do not meet the NEC® definition for a circuit breaker. For example, 7.1.11.6.3.1 of UL 489 states “The inability to relatch, reclose, or otherwise reestablish continuity ... shall be considered acceptable for circuit breakers which are tested under bus bar conditions”. In practical terms, this means the circuit breaker doesn’t have to work after a fault near the circuit breaker occurs. This is in violation of the NEC® definition for a circuit breaker: “A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating.” In addition, under “bus bar condition” tests the circuit breaker is required to only interrupt one short-circuit current. For this one short circuit test shot, the circuit breaker is in its closed position and the short-circuit current is initiated by the test station switch closing randomly. The “bus bar conditions” test procedures do not evaluate the circuit breaker for “closing-on” the short circuit. “Closing-on” a short circuit is an important criteria for safety.