Applying Interrupting Rating: Circuit Breakers

COOPER Bussmann

Interrupting Rating Vs. Interrupting Capacity

General Fuse Application Data For Compliance With NEC® 110.9

	Guideline	Features	Benefits	Commonly Used Cooper Bussmann Fuse Types
New Install-ations	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
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.	200,000A 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.

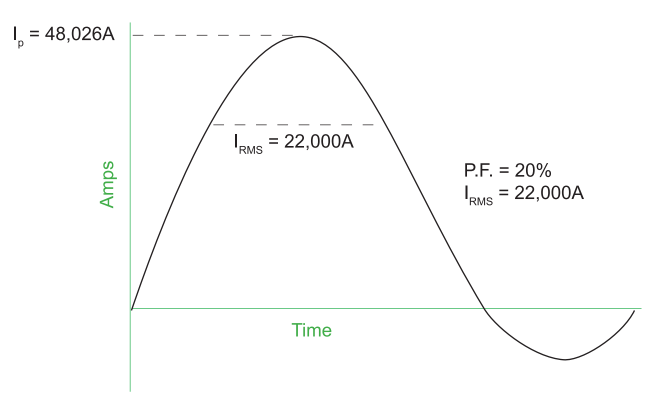
Standard Test Conditions - Fuses

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.

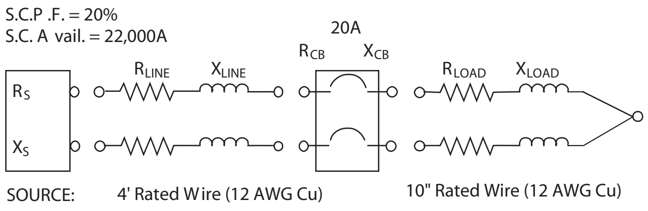
To better understand this, it is necessary to review the standard interrupting rating test procedures for circuit breakers: Molded Case Circuit Breakers - UL 489 and CSA 5 Test Procedures. UL 489 requires a unique test set-up for testing circuit breaker interrupting ratings. The diagram below illustrates 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.



Interrupting Rating Vs. Interrupting Capacity

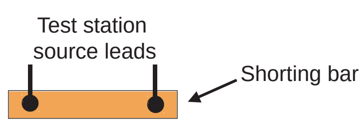
The diagram below illustrates the test circuit as allowed by UL 489.

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.



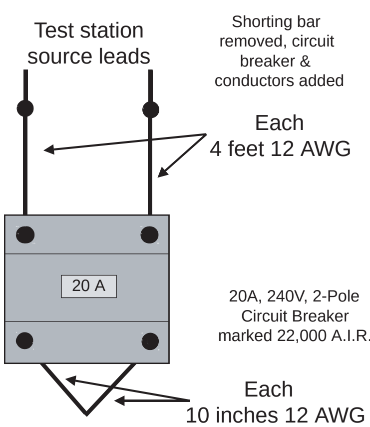
Note: For calculations, R_{CB} and X_{CB} are assumed negligible.

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.

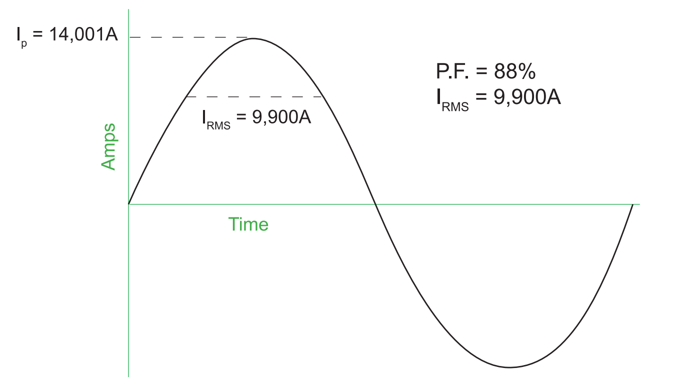


20A, 240V, 2-Pole Molded Case Circuit Breaker With 22,000A Interrupting Rating	RMS Symmetrical Amps	Maximum Instantaneous Peak	Power Factor
Calibrated Interrupting Rating Circuit	22,000	48,026	20%
Actual Circuit With Wire Impedance Added After Calibration	9900	14,001	88%

Conclusion (refer to table above and graphs below)

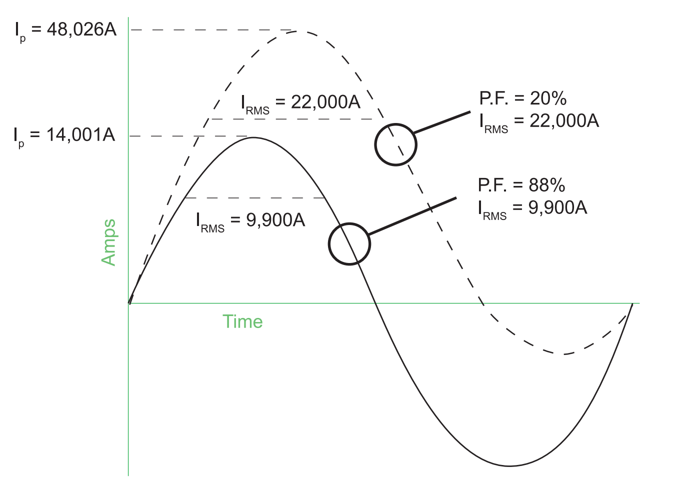
This 22,000A (with short circuit power factor of 20%) interrupting rated circuit breaker has an interrupting capacity of 9900A at a short circuit power factor of 88%. Unless there is a guarantee that no fault will ever occur at less than 4 feet 10 inches from the load terminals of the circuit breaker, 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.