Engineering Dependable Protection

Engineering Dependable Protection - Part III "Component Protection for Electrical Systems"

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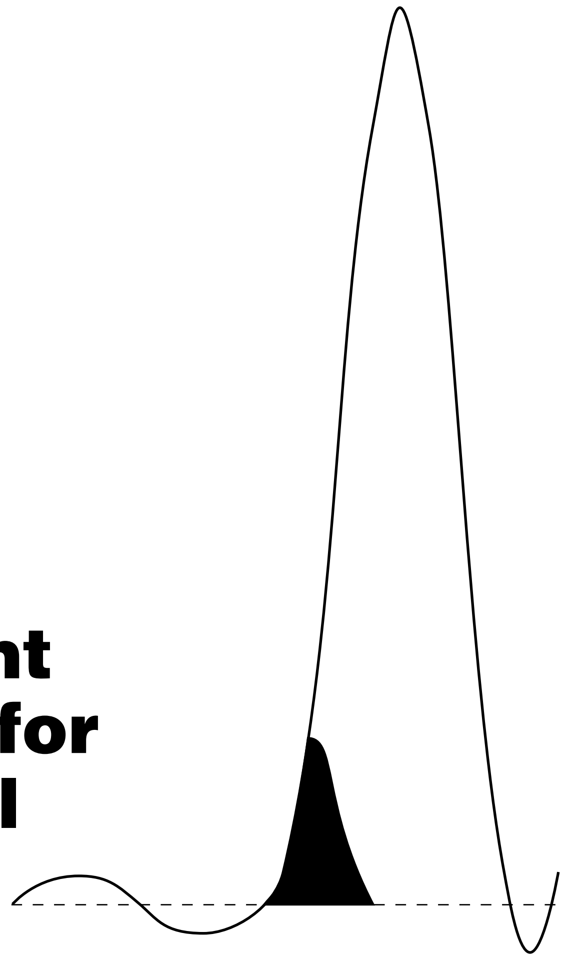
Part 3

Component Protection for Electrical Systems



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Basic Considerations of Component Protection

Engineering Dependable Protection

Part I provided the tools necessary to examine electrical distribution systems from the standpoint of reliability, to insure proper interrupting ratings of protective devices.

Part II dealt with selective coordination in order to prevent blackouts.

This handbook is Part III, "Component Short Circuit Protection". It will help the engineer understand the withstand rating of various system components, thus enabling him or her to explore the protection of the components that make up the system.

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.

Calculating Short-Circuit Currents

Before proceeding with a systems analysis of wire, cable and other component protection requirements, it will be necessary to establish the short-circuit current levels available at various points in the electrical system. This can be accomplished by using Engineering Dependable Protection - Part I (BUSS Bulletin EDP-I). After calculating the fault levels throughout the electrical system, the next step is to check the withstand rating of wire and cable, bus, circuit breakers, transfer switches, starters, etc., not only under overload conditions but also under short-circuit conditions.

Note: The let-thru 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 Figure 1, 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.

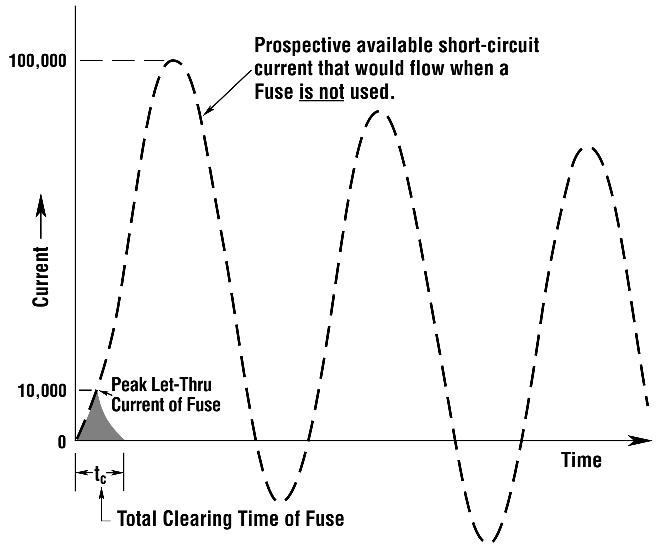


Figure 1. Current Limiting Effect of Fuses

Thus, the current-limiting fuse in this example would limit the let-thru 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.

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

Current-Limitation

Analysis of Current-Limiting Fuse Let-Thru 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-thru chart which, when applied from a practical point of view, is useful to determine the let-thru currents when a fuse opens.

Fuse let-thru charts are similar to the one shown in Figure 2 and 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-thru curves.

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

See charts and tables on pages 25 thru 31 for Bussmann fuse let-thru current data.

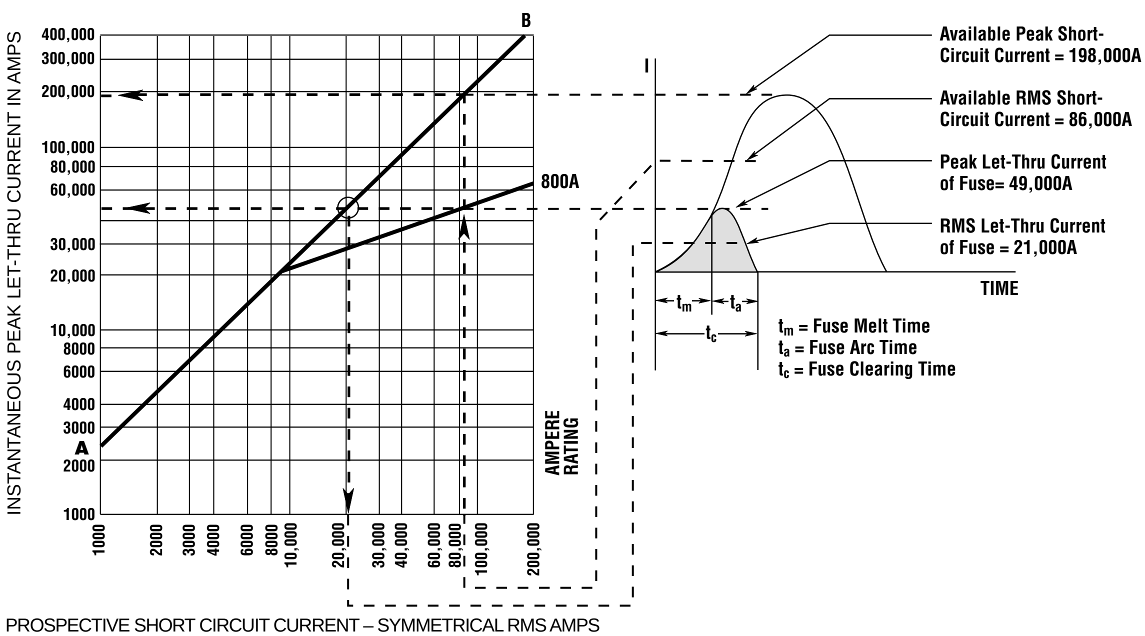


Figure 2. Analysis of a Current-LImiting Fuse

Let-Thru Data Pertinent to Equipment Withstand

Prior to using the Fuse Let-Thru Charts, it must be determined what let-thru 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-Thru Charts and their physical effects are the following:

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

Figure 3 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-thru data of interest.

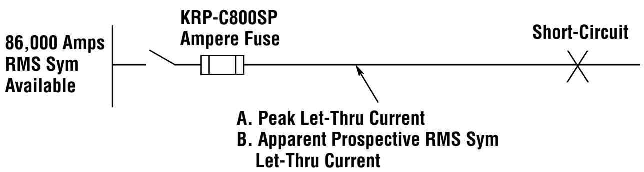


Figure 3. 800 Ampere LOW-PEAK® Current-Limiting Time-Delay Fuse and Associated Let-Thru Data

How to Use the Let-Thru Charts

Using the example given in Figure 3, one can determine the pertinent let-thru data for the KRP-C800SP ampere LOW-PEAK fuse. The Let-Thru Chart pertaining to the 800 ampere LOW-PEAK fuse is illustrated in Figure 4.

A. Determine the PEAK LET-THRU 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-Thru Current scale is intersected.

Step 3. Read the PEAK LET-THRU CURRENT as 49,000 amperes. (If a fuse had not been used, the peak current would have been 198,000 amperes.)

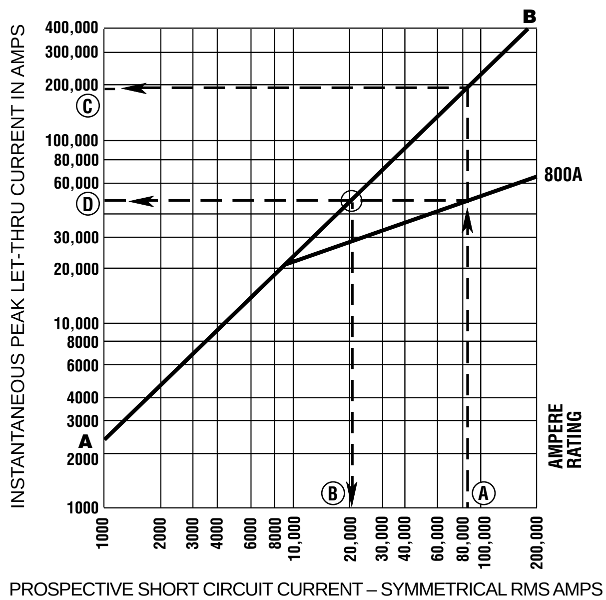
B. Determine the APPARENT PROSPECTIVE RMS SYMMETRICAL LET-THRU CURRENT.

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-THRU CURRENT as 21,000 amperes. (The RMS SYMMETRICAL LET-THRU CURRENT would be 86,000 amperes if there were no fuse in the circuit.)



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

Figure 4. Current-Limitation Curves – Bussmann LOW-PEAK® Time-Delay Fuse KRP-C800SP

A Practical Approach – Protecting System Components

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-Thru 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-thru 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:

A. Wire and Cable
B. Bus (Busway, Switchboards, Motor Control Centers and Panelboards)
C. Low-Voltage Motor Controllers
D. Circuit Breakers
E. Low-Voltage Transformers
F. Ballasts
G. Transfer Switches
H. HVAC Equipment

Protecting System Components

A. Wire and Cable

The circuit shown in Figure 5 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.

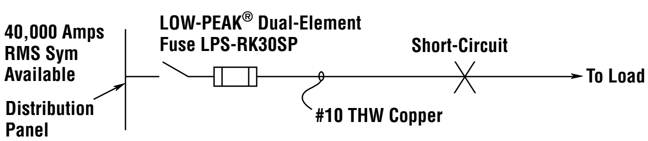


Figure 5. Example Showing Short-Circuit Protection of Wire and Cable.

Figures 6 thru 11 show the short-circuit withstand of copper and aluminum wire and cable based on Insulated Cable Engineers Association (ICEA) formulae.

The short-circuit withstand of the #10 THW copper conductor, from Figure 7 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-thru chart (page 27) 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 following charts show the currents which, after flowing for the times indicated, will produce these maximum temperatures for each conductor size. Figures 6, 7 and 8 give data for copper conductors, and Figures 9, 10 and 11 for aluminum conductors. 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 Figure 5 in order to prevent damaging temperature rise to the insulation. (Refer to Figure 6 for 1/0 withstand data.)

Using the formula shown on each 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 in Table 1.

Table 1. Copper, 75° Thermoplastic Insulated Cable Damage Table (Based on 60 HZ)

Copper Wire Size 75°C Thermoplastic	Maximum Short-Circuit Withstand Current in Amperes For 1/2 Cycle	For 1 Cycle	For 2 Cycles	For 3 Cycles
#14	2,400	1,700	1,200	1,000
#12	3,800	2,700	1,900	1,550
#10	6,020	4,300	3,000	2,450
*#8	9,600	6,800	4,800	3,900
#6	15,200	10,800	7,600	6,200
#4	24,200	17,100	12,100	9,900

Permission has been given by ICEA to reprint these charts. These charts have been reproduced on pages 8 thru 13.

A. Wire and Cable

Allowable Short-Circuit Currents for Insulated Copper Conductors*

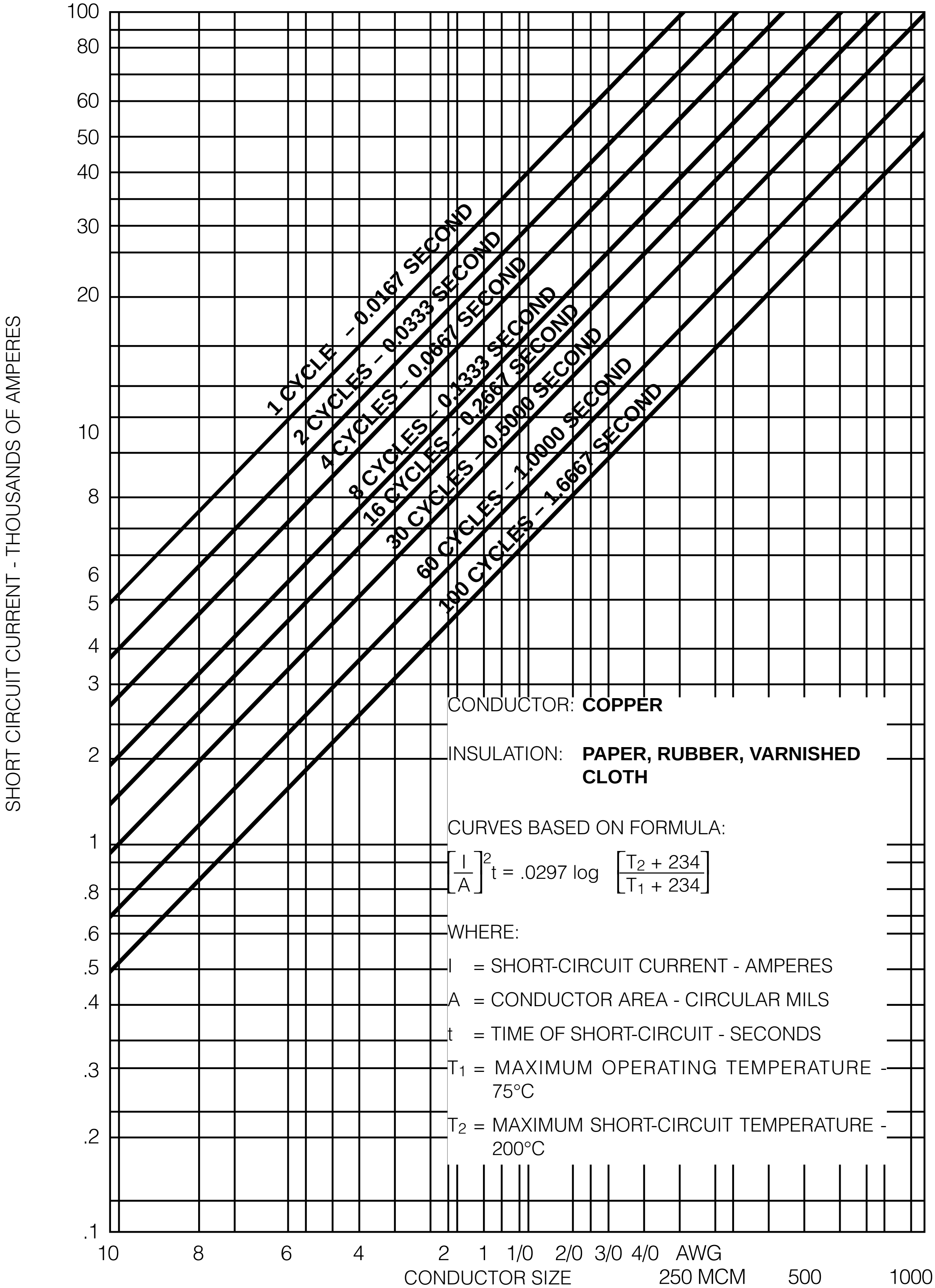


Figure 6. Short-Circuit Current Withstand Chart for Copper Cables with Paper, Rubber, or Varnished Cloth Insulation

A. Wire and Cable

Allowable Short-Circuit Currents for Insulated Copper Conductors*

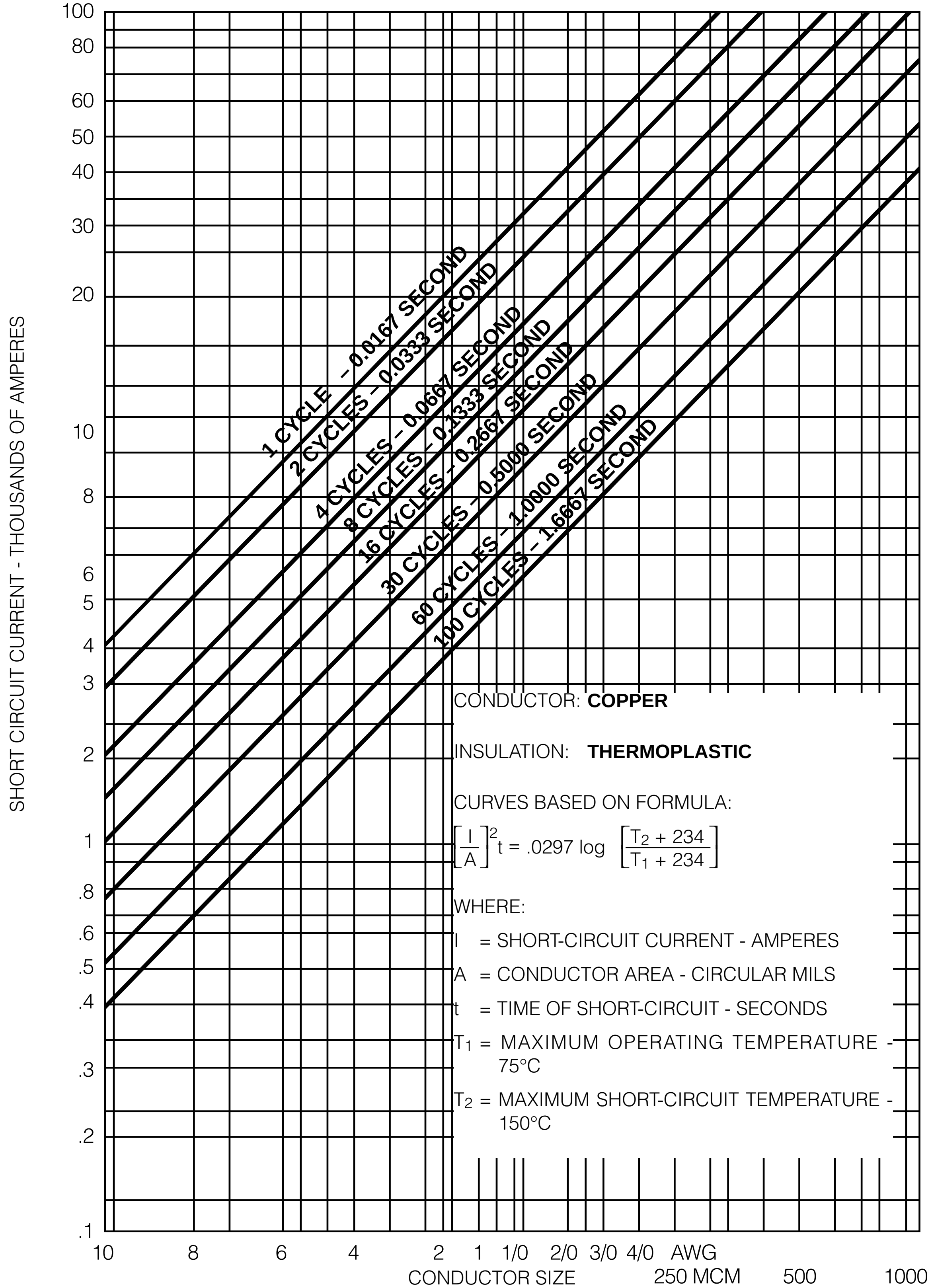


Figure 7. Short-Circuit Current Withstand Chart for Copper Cables with Thermoplastic Insulation

A. Wire and Cable

Allowable Short-Circuit Currents for Insulated Copper Conductors*

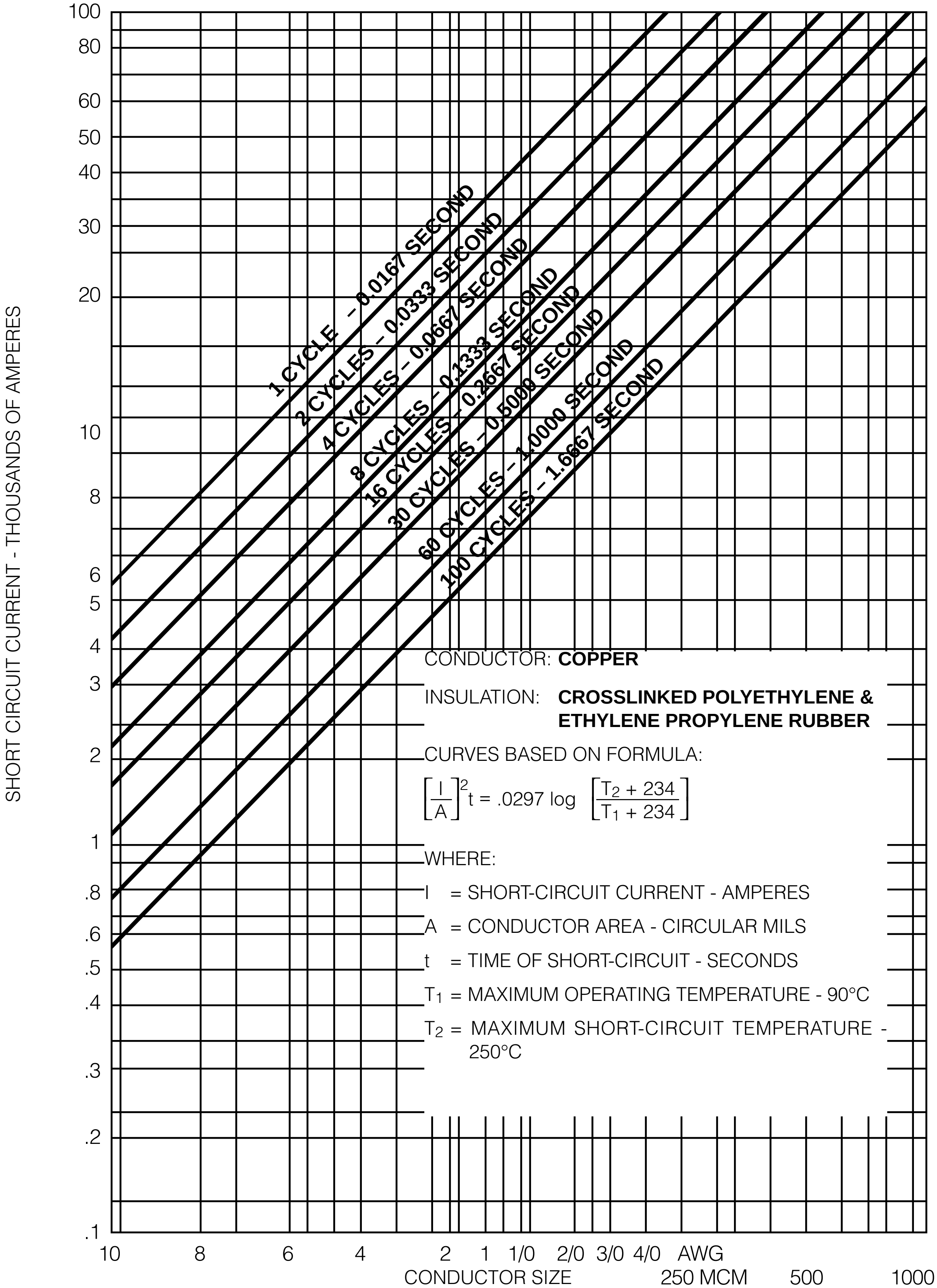


Figure 8. Short-Circuit Current Withstand Chart for Copper Cables with Crosslinked Polyethylene & Ethylene Propylene Rubber Insulation

A. Wire and Cable

Allowable Short-Circuit Currents for Insulated Aluminum Conductors*

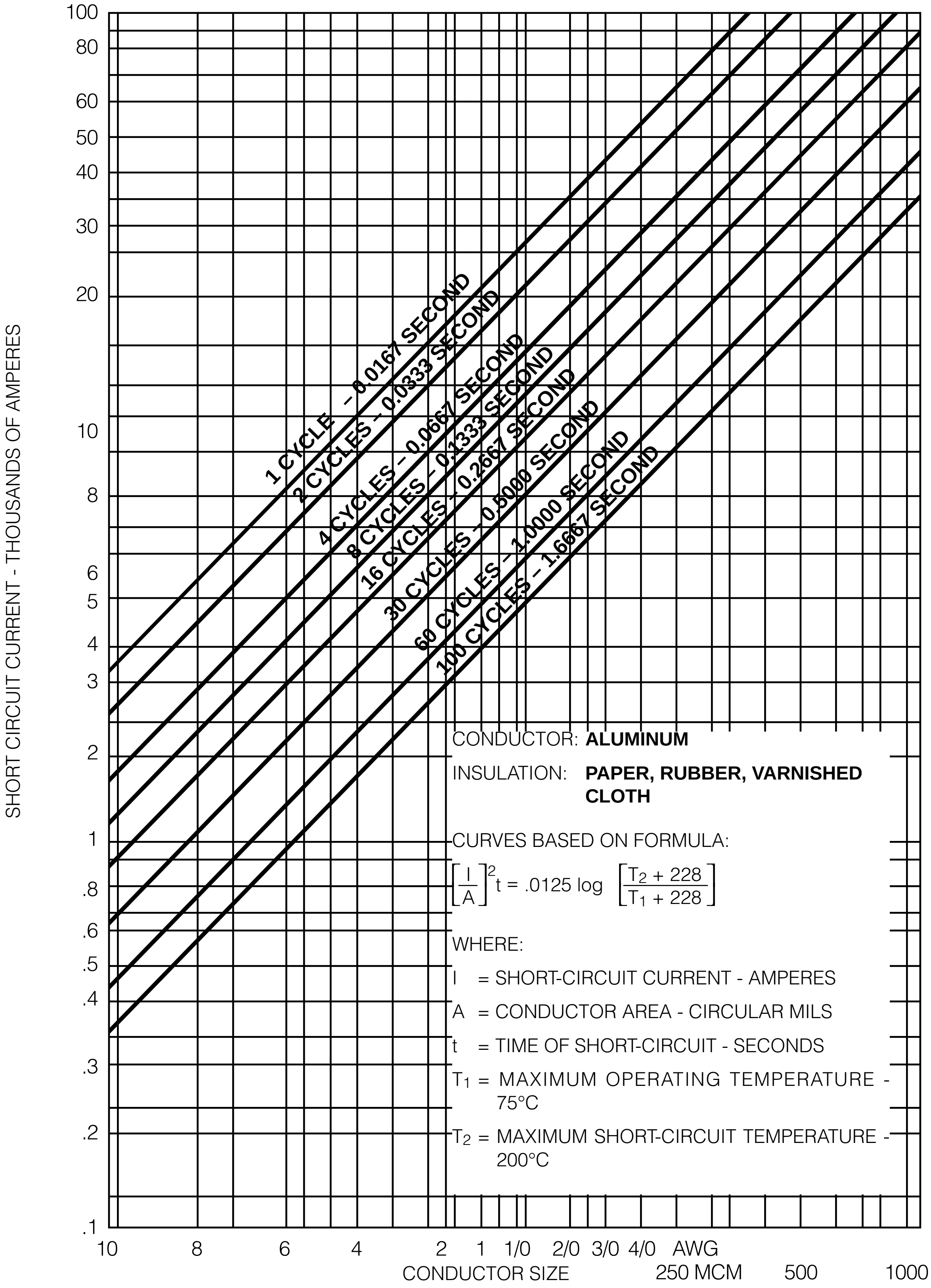


Figure 9. Short-Circuit Current Withstand Chart for Aluminum Cables with Paper, Rubber, or Varnished Cloth Insulation

A. Wire and Cable

Allowable Short-Circuit Currents for Insulated Aluminum Conductors*

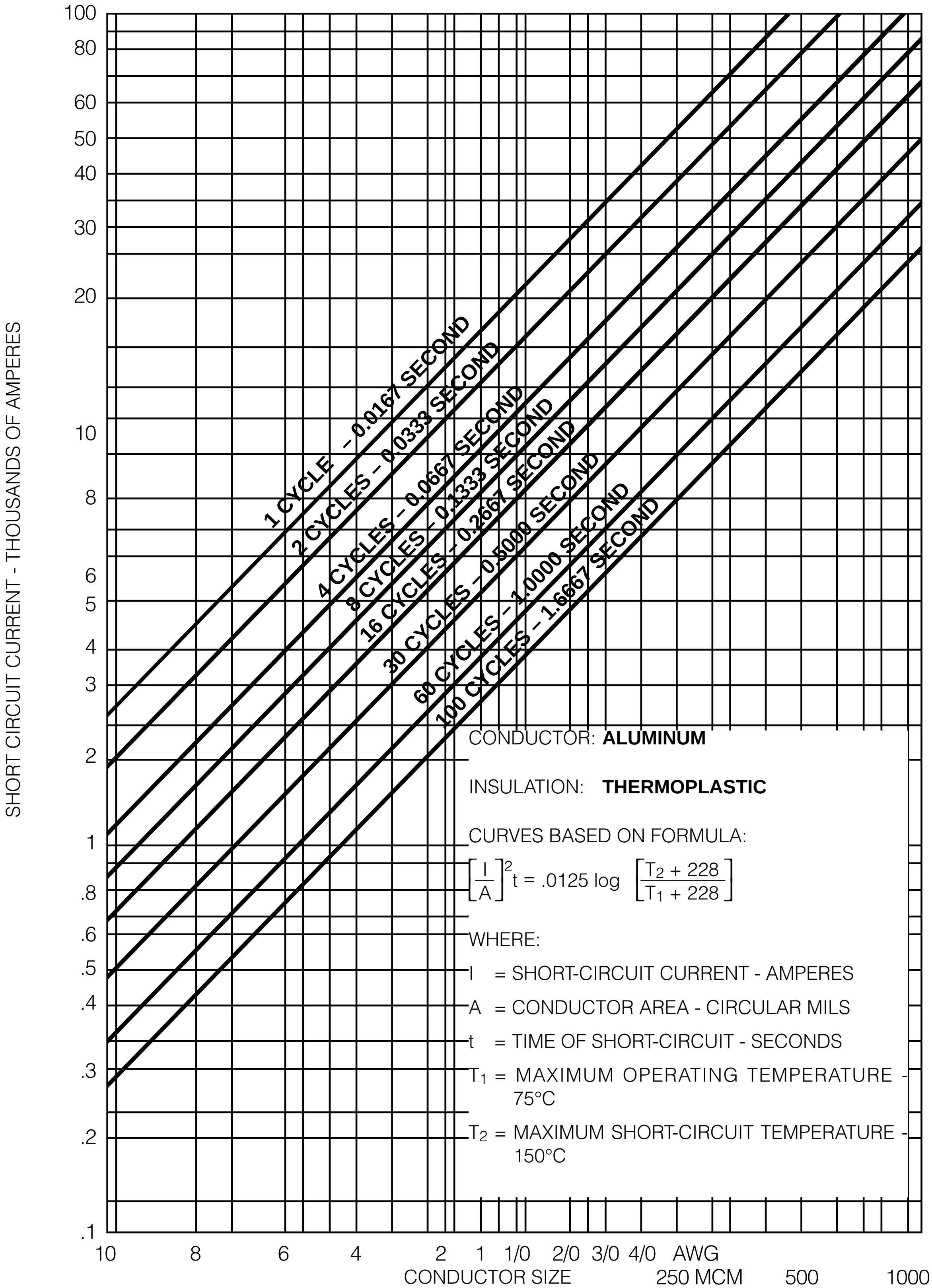


Figure 10. Short-Circuit Current Withstand Chart for Aluminum Cable with Thermoplastic Insulation

A. Wire and Cable

Allowable Short-Circuit Currents for Insulated Aluminum Conductors*

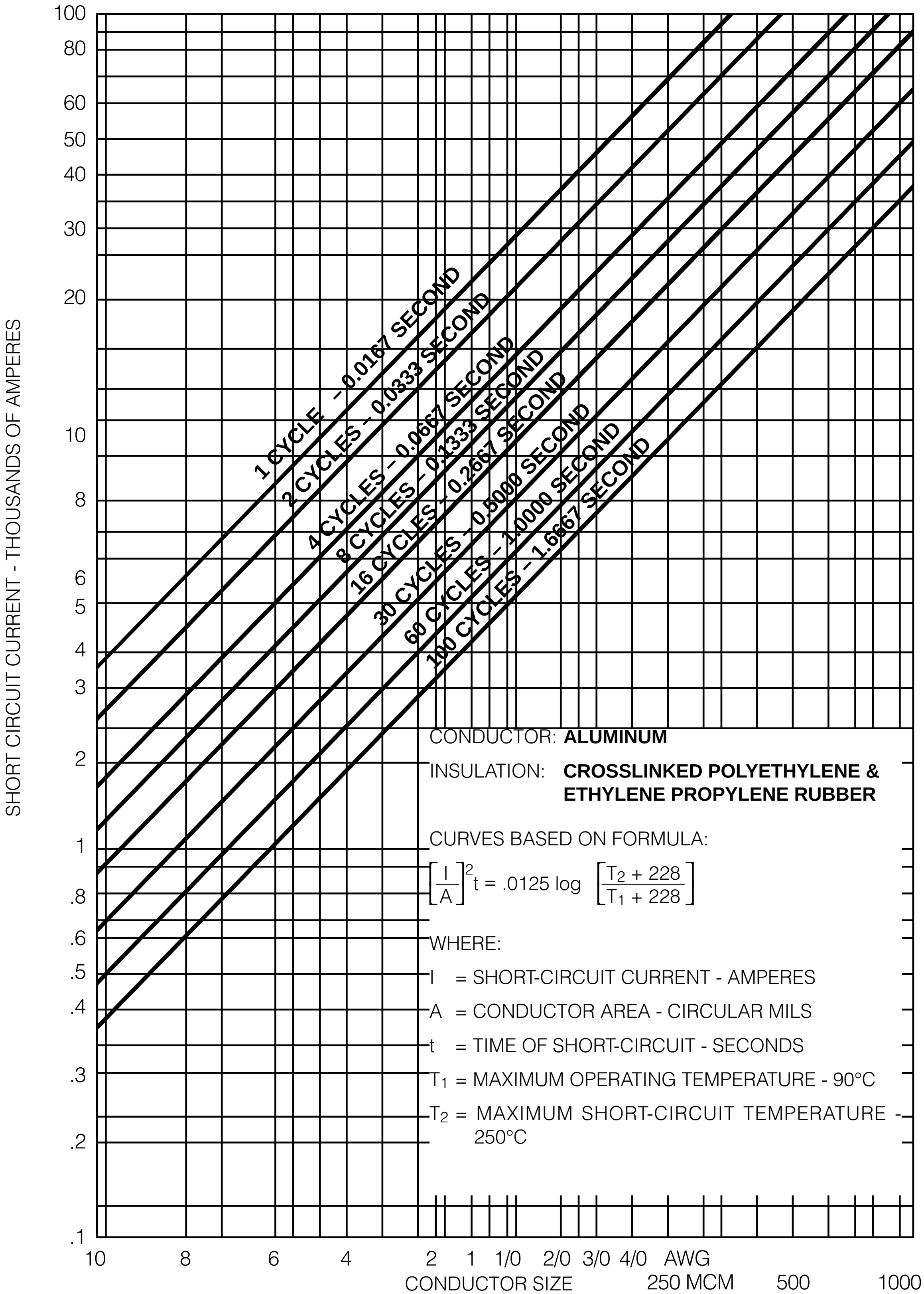


Figure 11. Short-Circuit Current Withstand Chart for Aluminum Cables with Crosslinked Polyethylene & Ethylene Propylene Rubber Insulation

A. Wire and Cable

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).

Table 2 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-thru energies for these devices should be compared with the short-circuit ratings of the equipment grounding conductors. Wherever let-thru energies exceed the “minimum” equipment grounding conductor withstand ratings, the equipment grounding conductor size must be increased until the withstand ratings are not exceeded.

Table 2. Comparison of Equipment Grounding Conductor Short-Circuit Withstand Ratings

	5 Sec. Rating (Amps)			I^2t Rating x10^6 (Ampere Squared Seconds)		
Conductor Size	ICEA P32-382 Insulation Damage 150°C	Soares 1 Amp/30 cm Validity 250°C	Onderdonk Melting Point 1,083°C	ICEA P32-382 Insulation Damage 150°C	Soares 1 Amp/30 cm Validity 250°C	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

B. 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 12 for an analysis of the short-circuit rating requirements for the 800 ampere plug-in bus.

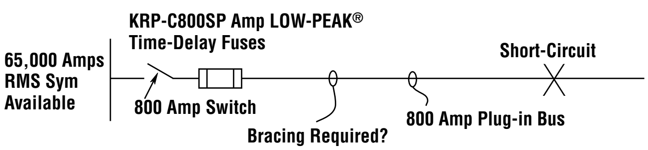


Figure 12. Determining the Short-Circuit Ratings of Busway

The 800 ampere plug-in bus in Figure 12 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. Upon checking the Data Section, page 25, 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.

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 (Figure 13) 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 given in Figure 14. 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 Pub. No. BU1-1988.

B. Bus Short-Circuit Rating and Bracing Requirements

Table 3.
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

Table 3 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.

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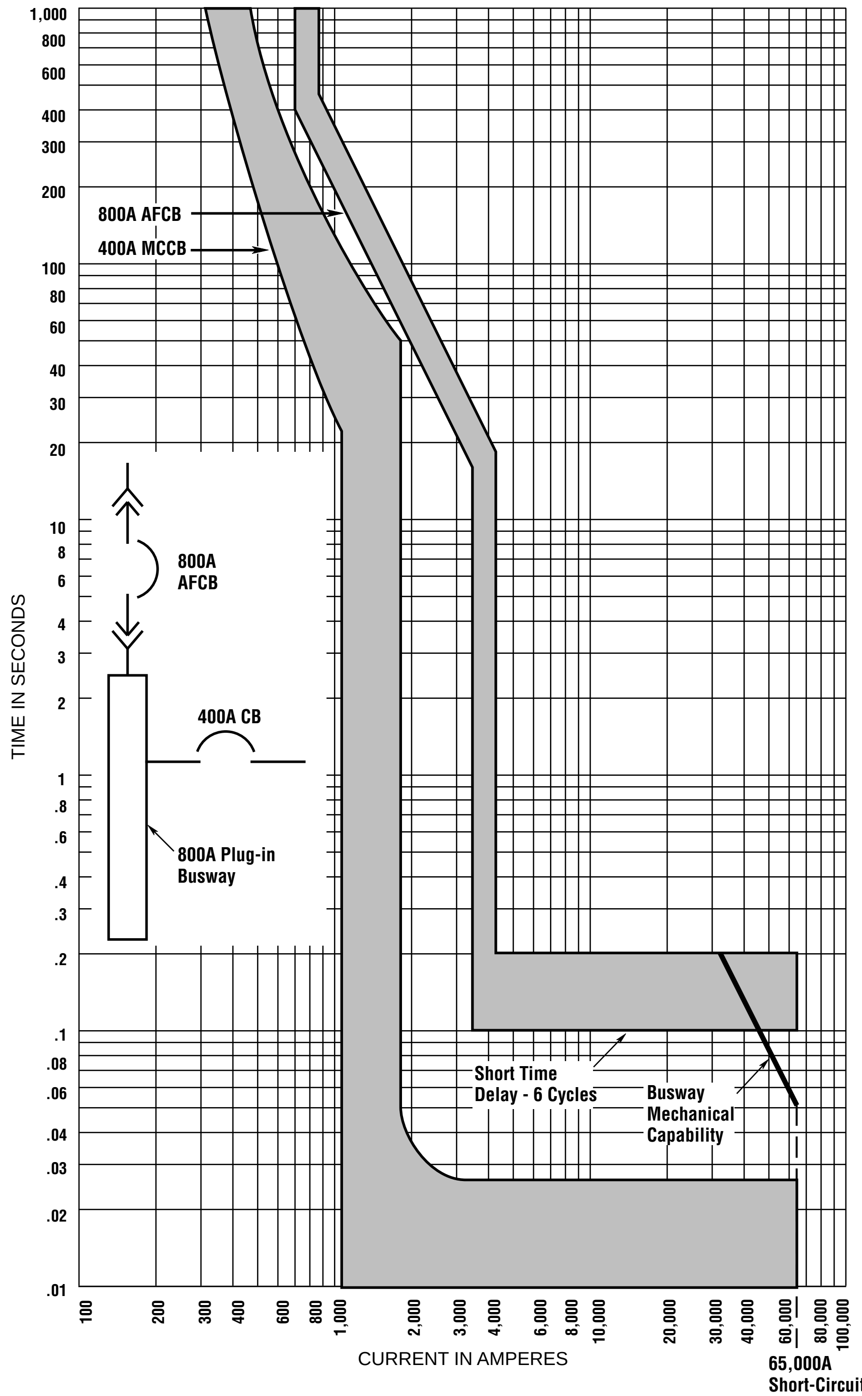


Figure 13.

B. Bus Short-Circuit Rating and Bracing Requirements

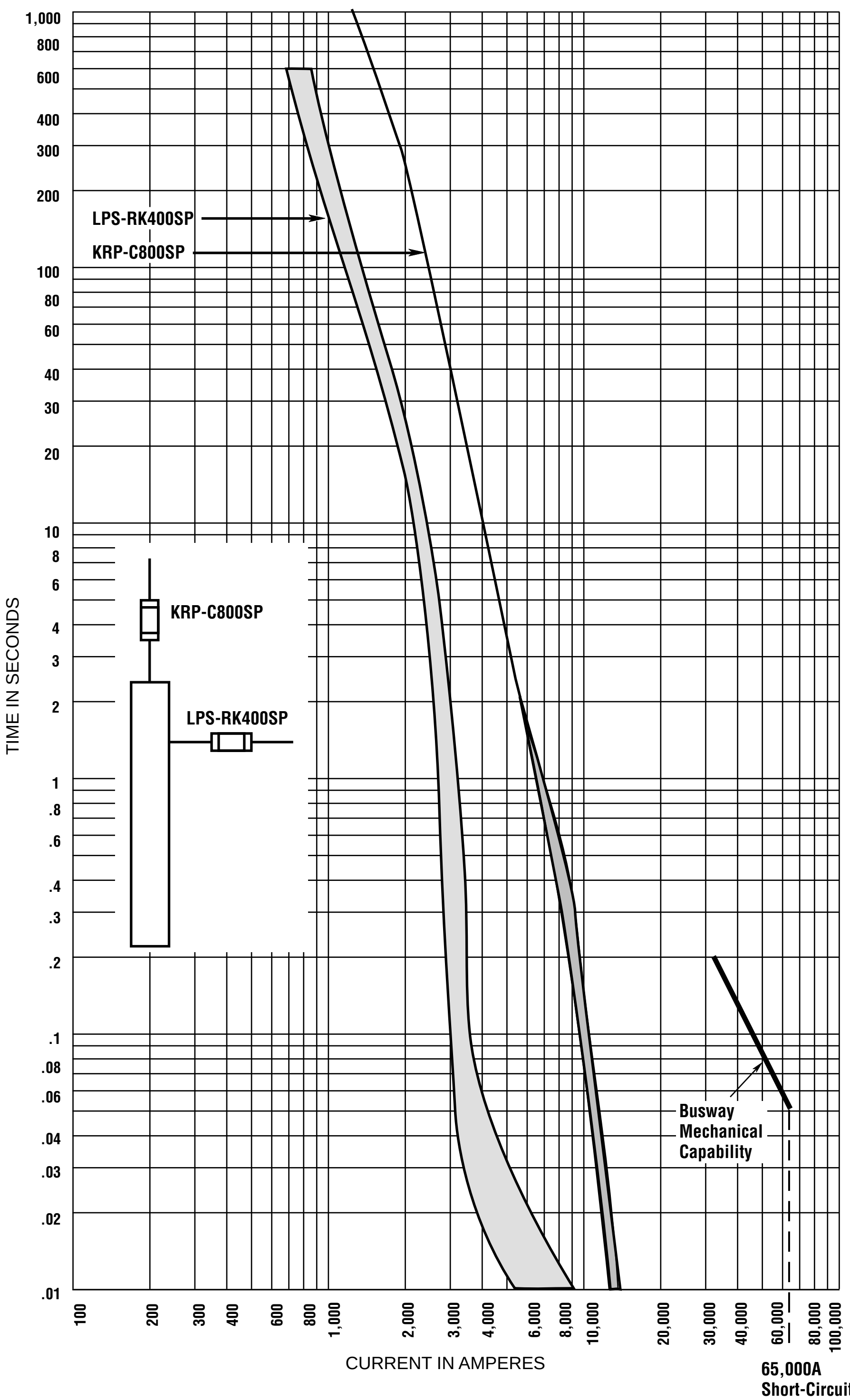


Figure 14.

C. Low Voltage Motor Controllers

The diagram in Figure 15 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.

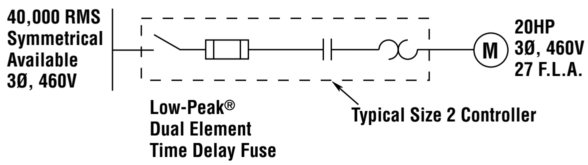


Figure 15. Short-Circuit Protection of Motor Controller

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 Table 4 for these values.*

Table 4.

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

UL 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 UL508, 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.

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: Contactors 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.

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

D. Molded Case Circuit Breakers

Until recently, molded case circuit breakers were protected the same way as other electrical equipment. Quicker acting circuit breakers, as well as test circuits that cause short-circuit test parameters to change, have required additional considerations in recommended protection procedures.

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-thru 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-thru 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. Figure 16 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. Figure 17 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 x RMS. The conservative approach would therefore assume a 1.414 multiplier also for three-pole breakers.

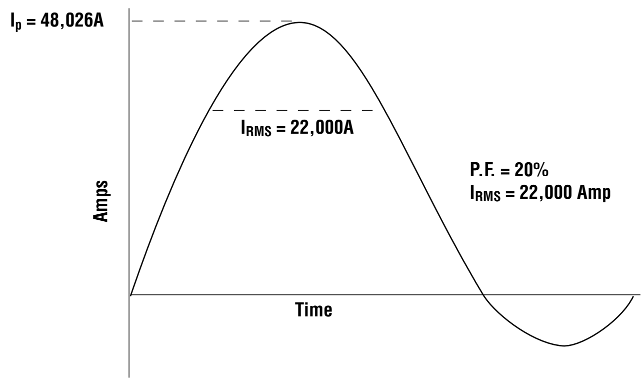


Figure 16

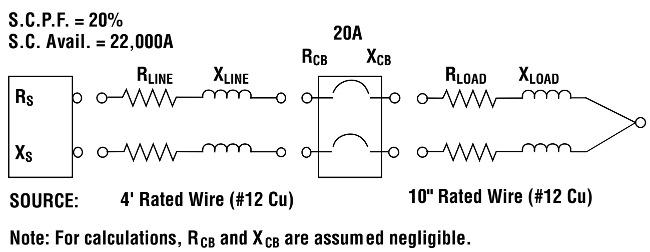


Figure 17

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 (Figure 18).

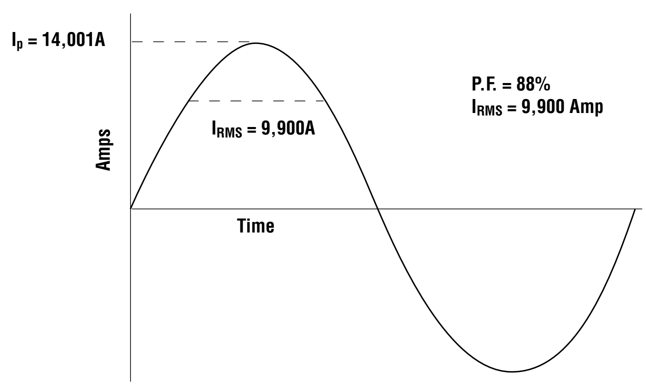


Figure 18

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.

D. Molded Case Circuit Breakers

Figure 19 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.)

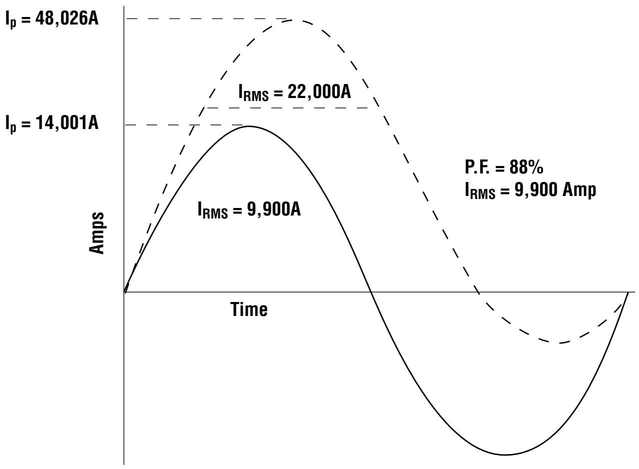


Figure 19

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.

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

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

Table 5. 240V - 2-Pole CB Interrupting Capacities (KA)

CB	10kA		14kA		18kA	
Rating	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 recently produced lighting and receptacle circuit breakers are utilized at values beyond their interrupting rating, the recommended alternative is to use listed systems which utilize tested and recognized combinations of main fuses and load side circuit breakers.

E. Transformers

1. Overload Protection

The National Electrical Code has developed separate sections and sizing recommendations for fuses with primary voltages above and below 600 volts, nominal. The following three paragraphs cover the basic requirements. See NEC Sections 450-3 and 430-72 for the most common exceptions.

Section 450-3a covers transformer protection when the primary voltage is greater than 600 volts. For low impedance transformers, fuse protection on the primary can be sized as high as 300% of primary current. Secondary protection must be offered at 250% or 125% for secondary voltages greater than 600 volts, or 600 volts or less, respectively. See Figures 20 and 21.

Table 6. 450-3(a)(1) Transformers Over 600 Volts

Maximum Rating or Setting for Overcurrent Device					
	Primary		Secondary		
	Over 600 Volts		Over 600 Volts		600 Volts or Below
Transformer Rated Impedance	Circuit Breaker Setting	Fuse Rating	Circuit Breaker Setting	Fuse Rating	Circuit Breaker Setting or Fuse Rating
Not more than 6%	600%	300%	300%	250%	125%
More than 6% and not more than 10%	400%	300%	250%	225%	125%

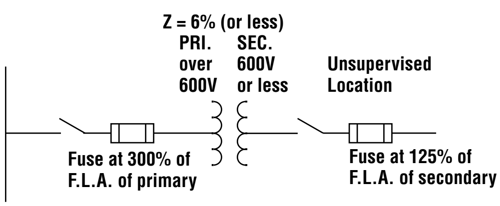


Figure 20

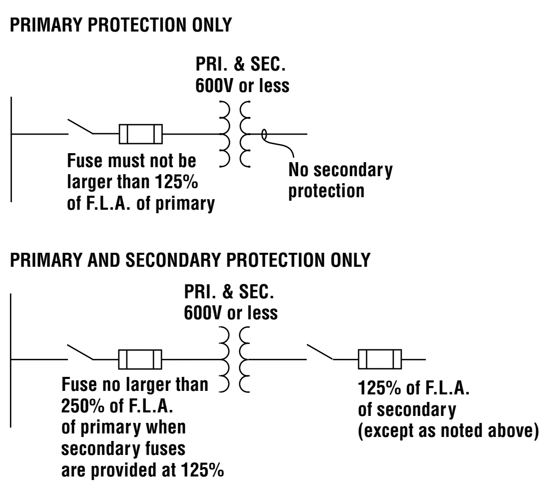


Figure 21

Section 450-3b covers transformer protection when the primary voltage is 600 volts or less. Primary fusing at 125% of primary current will not require secondary protection.

Note: Secondary conductor and panelboard protection are most often required by Articles 240 and 384 respectively.

Primary and secondary protection are required when the primary fuse is greater than 125%. The primary fuse may be sized no larger than 250% of primary current. The secondary fuse should then be sized no larger than 125% of the secondary current.

2. Magnetizing Inrush Currents

Primary fuses must be capable of handling the inrush currents associated with the transformer during start-up. A rule of thumb is that the fuse handle 12x full load current for 0.1 seconds, and 25x full load current for 0.01 seconds. Dual-element time-delay fuses are best suited to meet the sizing criteria of Article 450 and pass these initial surge characteristics.

Refer to Bussmann Bulletin EDP II for a discussion of these inrush points.

3. Short-Circuit Protection - Thermal and Magnetic

Withstand curves for distribution transformers define how much current a transformer can withstand, and for how long. As with any electrical component, if these curves are exceeded the transformer may be damaged or destroyed. These curves relate to both thermal and mechanical damage, and are defined by different fault conditions. Typically, three curves exist for a 3-phase transformer, defined by phase-phase, phase-phase-phase, and phase-ground fault conditions.

It is the designer's goal to find a fuse time-current curve that falls to the left of the damage curves and to the right of the transformer inrush points.

Refer to Bussmann Bulletin EDP II for a discussion of how to analyze these curves and protection levels.

F. 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 Figure 22 for a typical test for ballasts.

Most systems today will deliver more than 200 amperes of short-circuit current to a row of fixtures. (See Figure 23.) The fixtures should, therefore, be specified to incorporate individual ballast fusing within the fixture and external to the ballast.

Fusing each fixture, as shown in Figure 23, 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.

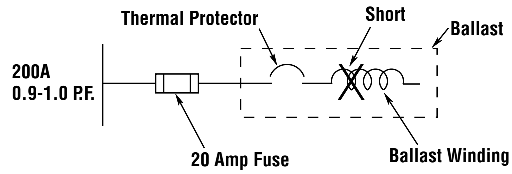


Figure 22. Underwriters’ Laboratories Short-Circuit Test for Ballast Protectors.

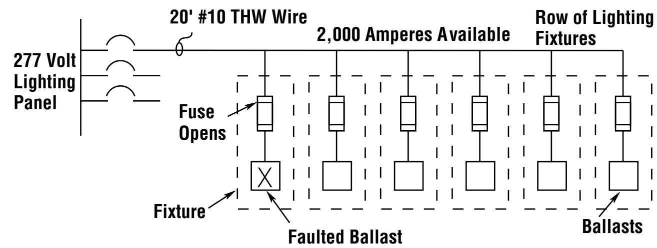


Figure 23. Fusing Fixture Ballasts to Provide Short-Circuit Protection and Isolation of Faulted Ballast. Good Ballasts Remain on the Line.

G. 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. See Table 7.

Table 7. 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.

H. 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 (Table 8 at right) 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.

Table 8. Short-Circuit Test Currents*

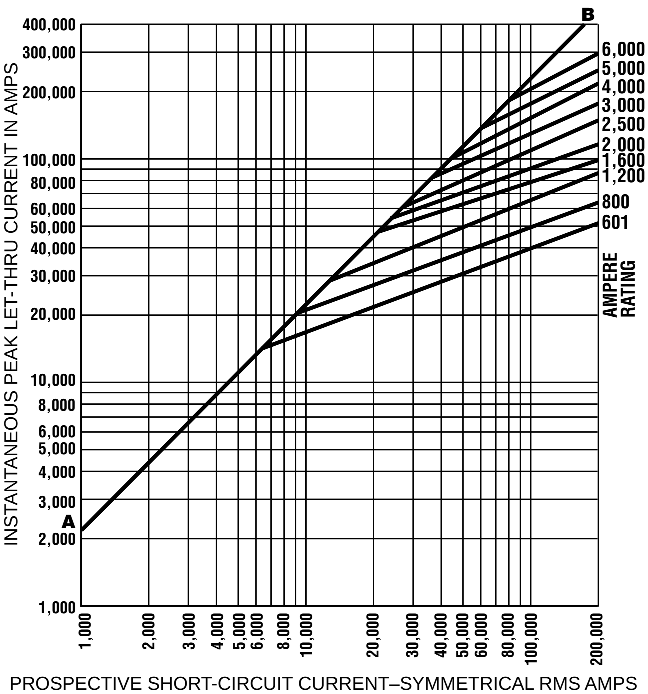
Product Ratings, A				
	Single-Phase			**Circuit Capacity,**
110-120V	**200-208V**	**220-240V**	**254-277V**	**A**
9.8 or less	5.4 or less	4.9 or less	–	200
9.9-16.0	5.5-8.8	5.0-8.0	6.65 or less	1000
16.1-34.0	8.9-18.6	8.1-17.0	–	2000
34.1-80.0	18.7-44.0	17.1-40.0	–	3500
Over 80.0	Over 44.0	Over 40.0	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.

Low-Peak Yellow™ KRP-C_SP Fuses

Data Section Index **Page**

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



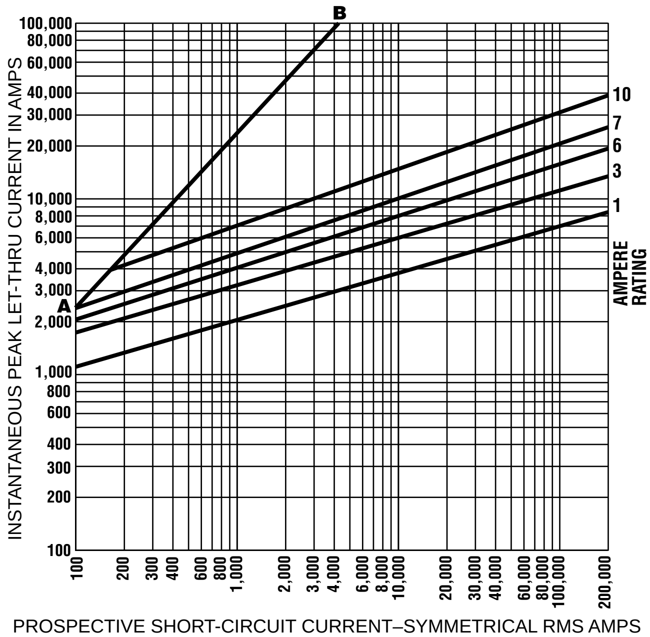
KRP-C_SP Fuse – RMS & Peak Let-Thru Currents (kA)

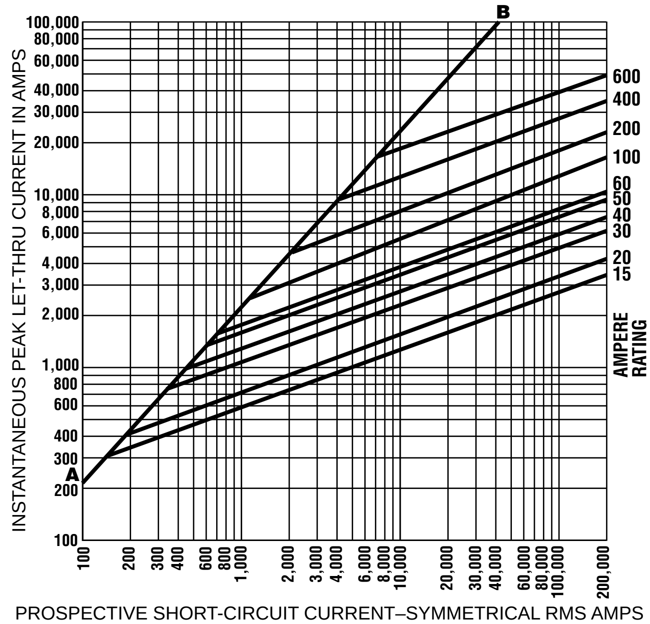
Prosp. Short C.C.	Fuse Size 601		800		1200		1600		2000		2500		3000		4000		5000		6000	
	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p
5,000	5	12	5	12	5	12	5	12	5	12	5	12	5	12	5	12	5	12	5	12
10,000	7	17	10	22	10	23	10	23	10	23	10	23	10	23	10	23	10	23	10	23
15,000	9	20	11	25	14	32	15	35	15	35	15	35	15	35	15	35	15	35	15	35
20,000	10	23	12	28	15	35	20	46	20	46	20	46	20	46	20	46	20	46	20	46
25,000	11	24	13	30	17	38	22	51	25	57	25	57	25	57	25	57	25	57	25	57
30,000	11	26	14	33	18	41	24	55	26	60	29	66	30	69	30	69	30	69	30	69
35,000	12	28	15	35	18	42	25	58	28	64	30	70	35	81	35	81	35	81	35	81
40,000	13	29	16	36	19	43	26	60	29	66	32	74	38	88	40	92	40	92	40	92
50,000	14	32	17	39	22	50	28	64	31	72	35	81	43	98	48	110	50	115	50	115
60,000	15	34	18	41	24	55	30	69	33	76	38	88	46	105	52	120	60	138	60	138
70,000	16	36	19	44	25	58	31	71	35	80	41	94	48	110	56	128	65	150	70	161
80,000	16	37	20	46	27	61	32	74	37	84	43	100	52	120	59	135	70	160	80	184
90,000	17	39	21	49	28	64	34	78	38	88	46	105	54	125	63	145	74	170	85	195
100,000	18	40	22	50	29	66	35	80	39	90	48	110	57	130	65	150	78	180	89	205
150,000	21	48	25	58	34	78	39	90	46	105	57	130	70	160	83	190	96	220	113	260
200,000	23	52	28	64	37	86	43	100	50	115	65	150	78	180	96	220	109	250	130	300

Note: For I_p and I_{RMS} values at 300,000 amperes, consult Factory.

Low-Peak Yellow™ LPJ_SP Fuses

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





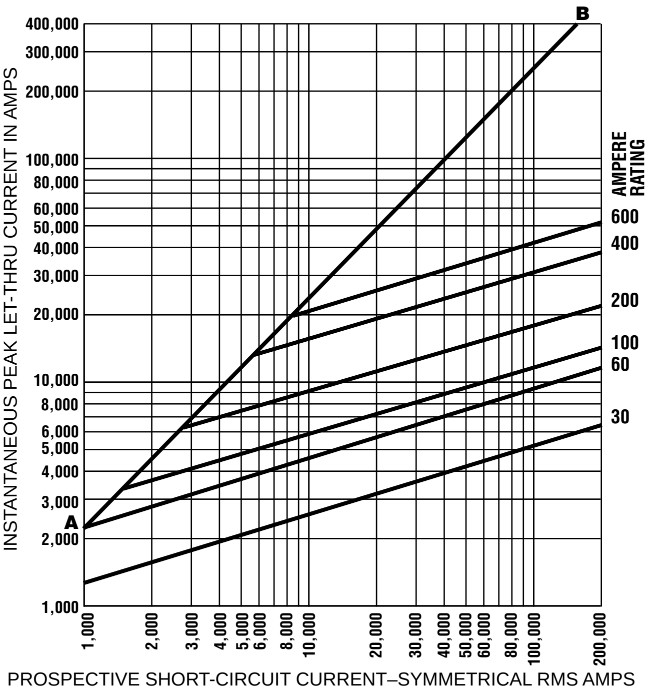
LPJ_SP – RMS & Peak Let-Thru Currents (kA)

Prosp. Short C.C.	Fuse Size 15		30		60		100		200		400		600	
	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p
1,000	0	1	0	1	1	2	1	2	1	2	1	2	1	2
3,000	0	1	1	2	1	3	2	4	2	5	3	7	3	7
5,000	0	1	1	2	1	3	2	4	3	6	4	10	5	12
10,000	1	1	1	2	2	4	2	6	4	8	6	13	8	18
15,000	1	1	1	3	2	4	3	7	4	9	6	15	9	21
20,000	1	2	1	3	2	5	3	7	4	10	7	16	10	23
25,000	1	2	1	3	2	5	3	8	5	12	8	17	11	26
30,000	1	2	2	4	2	5	4	8	5	12	8	18	12	27
35,000	1	2	2	4	3	6	4	9	5	12	8	19	13	29
40,000	1	2	2	4	3	6	4	9	6	13	9	21	13	31
50,000	1	2	2	4	3	6	4	10	6	14	9	22	14	32
60,000	1	2	2	4	3	7	5	11	6	15	10	23	15	35
80,000	1	3	2	5	3	7	5	12	7	17	11	26	16	37
100,000	1	3	2	5	4	8	5	12	8	18	12	28	17	40
150,000	1	3	2	6	4	9	6	14	9	21	14	33	19	44
200,000	2	4	3	6	4	10	7	16	10	23	16	36	21	47

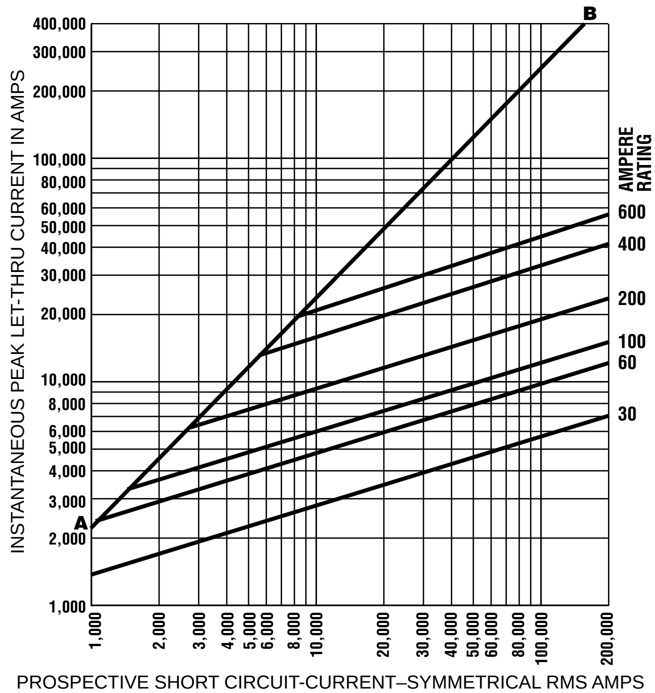
Note: For I_p and I_{RMS} values at 300,000 amperes, consult Factory.

Low-Peak Yellow™ LPN-RK_SP, LPS-RK_SP Fuses

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



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



LPN-RK_SP – RMS & Peak Let-Thru Currents (kA)

Prosp.	Fuse Size											
Short	30		60		100		200		400		600	
C.C.	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p
1,000	1	1	1	2	1	2	1	2	1	2	1	2
2,000	1	2	1	3	2	4	2	5	2	5	2	5
3,000	1	2	1	3	2	4	3	6	3	7	3	7
5,000	1	2	2	4	2	5	3	7	5	12	5	12
10,000	1	3	2	4	2	6	4	9	7	15	9	21
15,000	1	3	2	5	3	6	4	10	7	17	10	23
20,000	1	3	2	6	3	7	5	11	8	19	11	25
25,000	1	3	3	6	3	7	5	12	9	20	12	27
30,000	2	3	3	6	3	8	5	12	9	21	13	29
35,000	2	4	3	7	4	8	6	13	10	22	13	30
40,000	2	4	3	7	4	9	6	13	10	23	13	31
50,000	2	4	3	7	4	9	6	14	10	24	14	33
60,000	2	4	3	8	4	10	7	15	11	26	15	35
70,000	2	4	3	8	4	10	7	16	12	27	16	36
80,000	2	5	4	8	5	11	7	16	12	28	17	38
90,000	2	5	4	9	5	11	7	17	13	29	17	39
100,000	2	5	4	9	5	11	8	18	13	30	17	40
150,000	2	6	4	10	5	13	8	19	16	36	20	46
200,000	3	6	5	11	6	14	9	21	18	42	22	50

Note: For I_p and I_{RMS} values at 300,000 amperes, consult Factory.

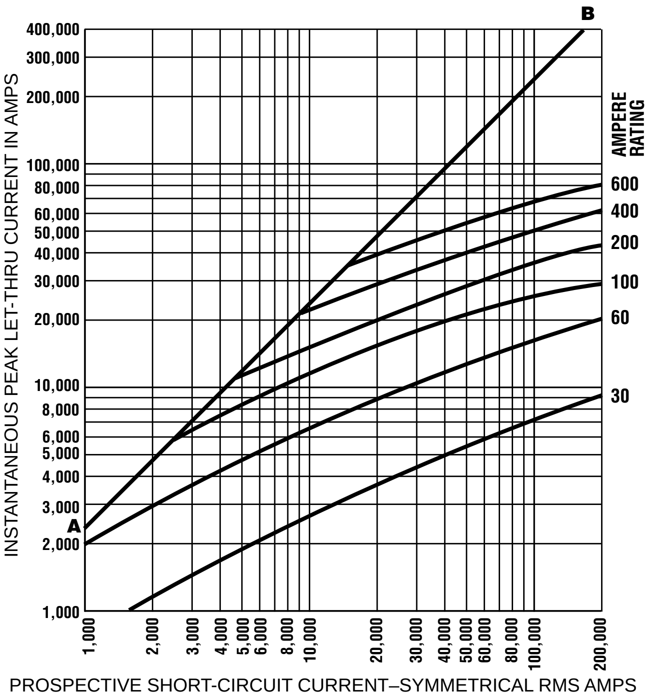
LPS-RK_SP – RMS & Peak Let-Thru Currents (kA)

Prosp.	Fuse Size											
Short	30		60		100		200		400		600	
C.C.	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p
1,000	1	1	1	2	1	2	1	2	1	2	1	2
2,000	1	2	1	3	2	4	2	4	2	4	2	4
3,000	1	2	1	3	2	4	3	6	3	7	3	7
5,000	1	2	2	4	2	5	3	7	5	12	5	12
10,000	1	3	2	5	3	6	4	9	7	16	9	21
15,000	1	3	2	5	3	7	5	11	8	18	10	24
20,000	1	3	3	6	3	7	5	12	8	19	11	26
25,000	2	4	3	6	3	8	5	12	9	21	12	28
30,000	2	4	3	6	4	8	6	13	10	22	13	30
35,000	2	4	3	7	4	9	6	14	10	23	13	31
40,000	2	4	3	7	4	9	6	14	10	24	14	32
50,000	2	5	3	8	4	10	7	15	11	26	15	35
60,000	2	5	3	8	4	10	7	16	12	28	16	37
70,000	2	5	4	8	5	11	7	17	13	29	17	39
80,000	2	5	4	9	5	11	8	18	13	30	17	40
90,000	2	5	4	9	5	12	8	18	13	31	18	42
100,000	2	6	4	9	5	12	8	19	14	32	19	44
150,000	3	6	5	11	6	14	9	21	16	36	22	50
200,000	3	7	5	12	7	15	10	23	17	40	23	54

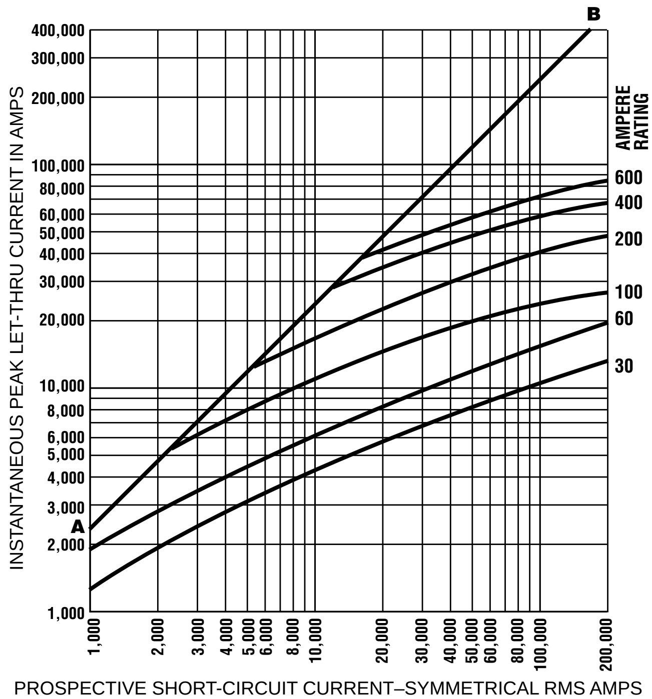
Note: For I_p and I_{RMS} values at 300,000 amperes, consult Factory.

Buss Fuse Let-Thru Charts – FRN-R, FRS-R

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



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



FRN-R – RMS & Peak Let-Thru Currents (kA)

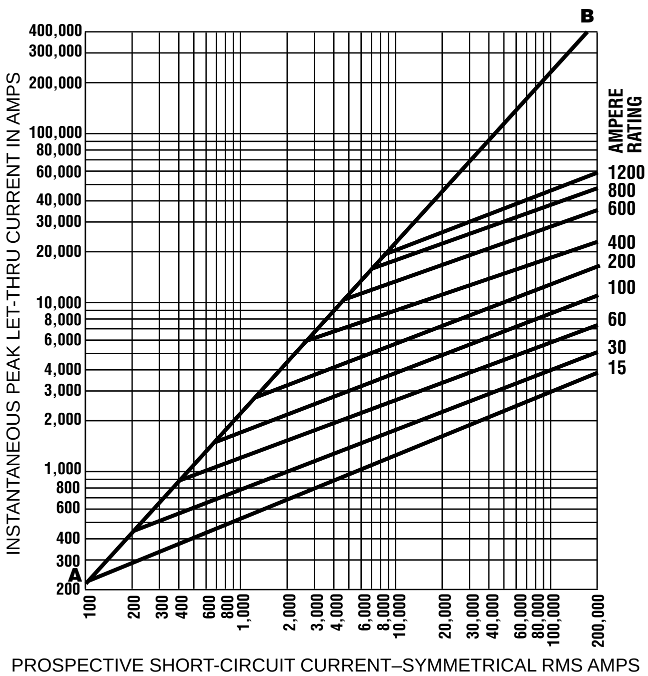
Prosp. Short C.C.	Fuse Size 30		60		100		200		400		600	
	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p
5,000	1	2	2	5	3	8	5	11	5	12	5	12
10,000	1	3	3	6	5	11	7	15	9	21	10	23
15,000	1	3	3	7	6	13	8	18	11	25	14	33
20,000	2	4	4	8	7	15	8	20	12	28	16	37
25,000	2	4	4	9	7	16	9	21	13	30	17	40
30,000	2	4	4	10	7	17	10	23	14	32	19	43
35,000	2	4	5	11	8	18	11	25	15	34	20	45
40,000	2	5	5	11	8	19	11	25	15	35	20	47
50,000	2	5	5	12	9	20	12	27	16	37	22	50
60,000	2	6	6	13	9	21	12	28	17	40	23	54
70,000	3	6	6	14	10	22	13	30	18	41	24	56
80,000	3	6	6	15	10	23	13	31	19	43	25	58
90,000	3	6	7	15	10	23	14	32	19	44	26	60
100,000	3	7	7	16	10	24	14	33	20	46	27	62
150,000	3	8	8	18	11	26	16	37	23	52	30	70
200,000	4	8	8	20	12	27	17	40	24	56	32	74

FRS-R – RMS & Peak Let-Thru Currents (kA)

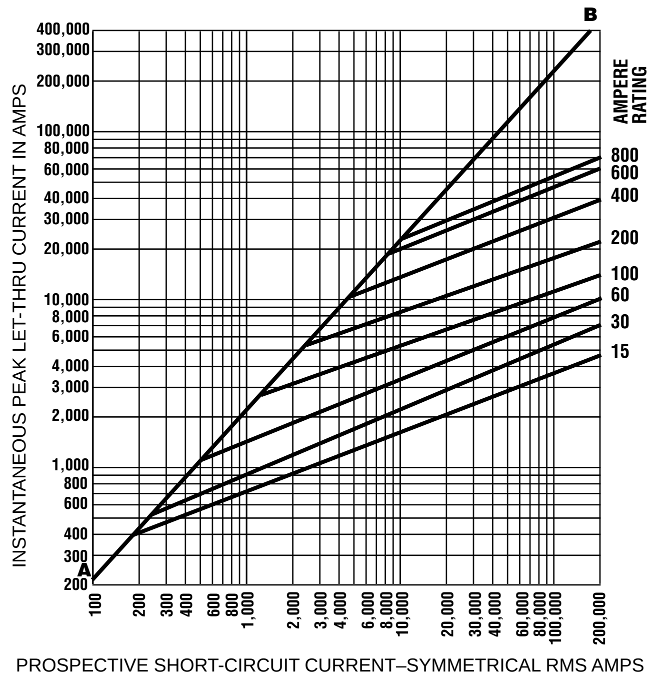
Prosp. Short C.C.	Fuse Size 30		60		100		200		400		600	
	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p
5,000	1	3	2	4	3	8	5	12	5	12	5	12
10,000	2	4	3	6	5	11	7	16	10	23	10	23
15,000	2	5	3	7	5	13	8	19	13	30	15	35
20,000	2	6	3	8	6	14	10	22	14	33	17	40
25,000	3	6	4	9	7	16	10	24	16	37	19	44
30,000	3	7	4	9	7	17	11	25	17	39	20	47
35,000	3	7	4	10	7	17	12	27	18	41	22	50
40,000	3	7	5	11	8	18	12	28	19	43	23	52
50,000	3	8	5	12	8	19	13	30	20	46	24	56
60,000	4	9	5	12	9	20	14	32	21	49	26	60
70,000	4	9	6	13	9	21	15	34	22	50	27	62
80,000	4	9	6	14	9	22	15	35	23	52	28	64
90,000	4	10	6	14	10	22	16	36	23	54	29	66
100,000	4	10	7	15	10	23	16	37	24	56	30	68
150,000	5	12	7	17	11	25	18	42	26	60	33	75
200,000	6	13	8	19	11	26	19	44	27	63	35	80

Buss Fuse Let-Thru Charts – JJN, JJS

TRON® Class T Fast-Acting Fuses JJN



TRON® Class T Fast-Acting Fuses JJS



JJN – RMS & Peak Let-Thru Current (kA)

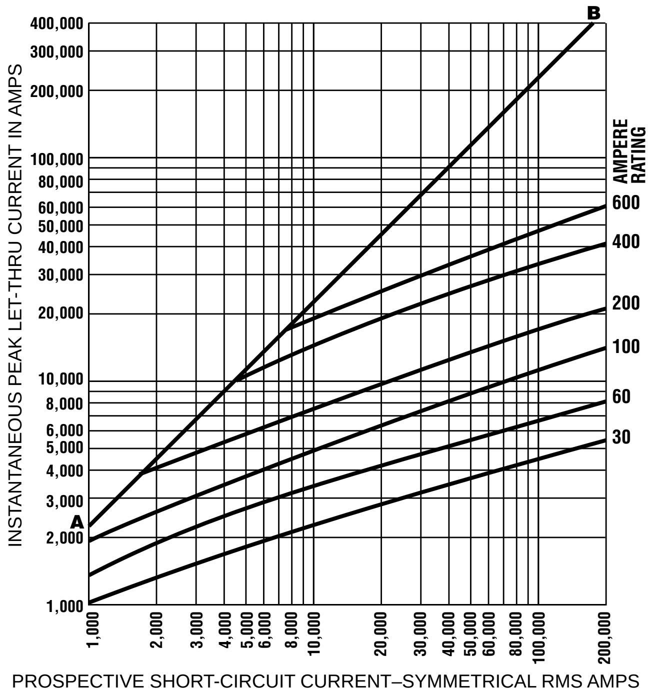
Prosp. Short C.C.	Fuse Size 15		30		60		100		200		400		600		800		1200	
	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p
500	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
1,000	0	1	0	1	1	1	1	2	1	2	1	2	1	2	1	2	1	2
5,000	0	1	1	1	1	2	1	3	2	4	3	7	5	11	5	12	5	12
10,000	1	1	1	2	1	3	2	4	2	6	4	9	6	13	7	17	9	20
15,000	1	1	1	2	1	3	2	4	3	6	4	10	6	15	9	20	10	23
20,000	1	2	1	2	1	3	2	5	3	7	5	11	7	16	10	22	11	25
25,000	1	2	1	2	2	4	2	5	3	8	5	12	7	17	10	23	12	27
30,000	1	2	1	3	2	4	2	5	3	8	5	12	8	18	11	25	13	29
35,000	1	2	1	3	2	4	3	6	4	9	5	13	8	19	11	25	13	30
40,000	1	2	1	3	2	4	3	6	4	9	6	14	9	20	11	26	13	31
50,000	1	2	1	3	2	4	3	6	4	10	6	14	9	22	12	28	15	34
60,000	1	2	1	3	2	5	3	7	4	10	7	15	10	23	13	30	16	36
70,000	1	3	1	3	2	5	3	7	5	11	7	16	10	24	14	32	17	38
80,000	1	3	2	4	2	5	3	8	5	13	7	17	11	25	15	34	17	40
90,000	1	3	2	4	2	5	3	8	6	13	8	18	11	26	15	35	18	42
100,000	1	3	2	4	2	6	4	8	6	14	8	19	12	27	16	36	19	44
150,000	1	3	2	4	3	6	4	9	6	14	9	20	13	30	17	40	22	50
200,000	2	4	2	5	3	7	4	10	7	15	9	21	15	34	19	44	23	54

JJS – RMS & Peak Let Thru Current (kA)

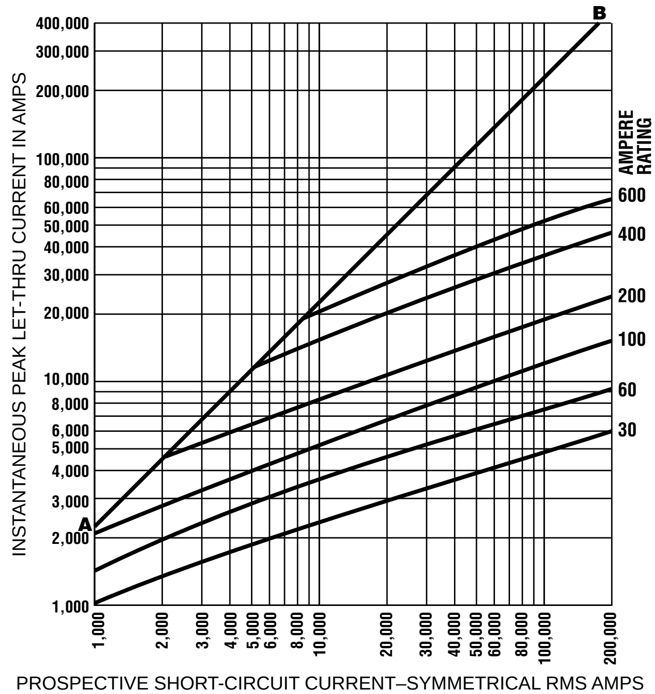
Prosp. Short C.C.	Fuse Size 15		30		60		100		200		400		600		800	
	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p
500	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1
1,000	0	1	0	1	1	1	1	2	1	2	1	2	1	2	1	2
5,000	1	1	1	2	1	3	2	4	3	7	4	10	5	12	5	12
10,000	1	2	1	2	1	3	2	5	3	8	6	13	8	19	9	21
15,000	1	2	1	3	2	4	3	6	4	9	7	15	10	22	11	25
20,000	1	2	1	3	2	4	3	6	4	10	7	17	10	24	12	27
25,000	1	2	1	3	2	4	3	7	5	11	7	17	11	26	13	30
30,000	1	2	1	3	2	5	3	7	5	12	8	19	12	28	14	32
35,000	1	2	1	3	2	5	3	8	5	12	9	20	13	30	15	34
40,000	1	3	2	4	2	5	3	8	5	13	9	21	13	31	15	35
50,000	1	3	2	4	2	6	4	9	6	13	10	22	14	33	17	38
60,000	1	3	2	4	3	6	4	9	6	14	10	24	16	36	18	41
70,000	1	3	2	5	3	6	4	9	7	15	11	25	17	39	19	44
80,000	1	3	2	5	3	7	4	10	7	16	11	26	17	40	20	46
90,000	1	3	2	5	3	7	4	10	7	17	12	27	18	42	21	48
100,000	2	4	2	5	3	7	5	11	7	17	12	28	19	44	22	50
150,000	2	4	3	6	4	8	6	13	8	18	14	32	22	50	25	58
200,000	2	4	3	7	4	9	6	14	9	20	16	36	24	56	28	64

Buss Fuse Let-Thru Charts – KTN-R, KTS-R

LIMITRON® Class RK1 Fast-Acting Fuses KTN-R



LIMITRON® Class RK1 Fast-Acting Fuses KTS-R



KTN-R – RMS & Peak Let-Thru Currents (kA)

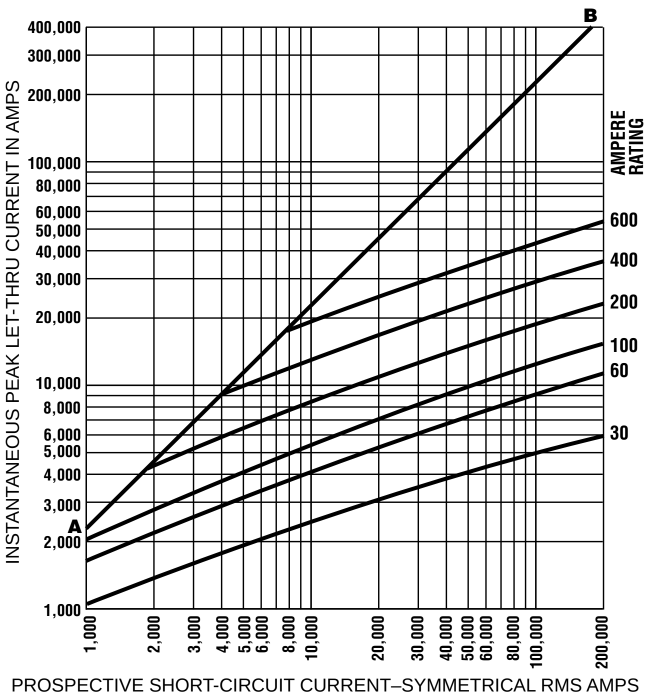
Prosp.	Fuse Size											
Short	30		60		100		200		400		600	
C.C.	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p
5,000	1	2	1	3	2	4	3	6	5	10	5	12
10,000	1	2	1	3	2	5	3	8	6	14	8	19
15,000	1	3	2	4	2	6	4	9	7	17	10	22
20,000	1	3	2	4	3	6	4	10	8	19	11	25
25,000	1	3	2	5	3	7	4	10	9	20	12	27
30,000	1	3	2	5	3	7	5	11	10	22	13	29
35,000	1	3	2	5	3	8	5	12	10	23	13	31
40,000	1	3	2	5	3	8	5	12	10	24	14	32
50,000	2	4	2	5	4	9	6	13	11	26	15	36
60,000	2	4	2	6	4	9	6	14	12	28	17	38
70,000	2	4	3	6	4	9	6	15	13	29	17	40
80,000	2	4	3	6	4	10	7	15	13	30	18	42
90,000	2	4	3	6	5	10	7	16	13	31	19	44
100,000	2	4	3	7	5	11	7	17	14	32	20	46
150,000	2	5	3	7	5	13	8	19	16	37	23	53
200,000	2	5	3	8	6	14	9	21	18	41	26	59

KTS-R – RMS & Peak Let-Thru Currents (kA)

Prosp.	Fuse Size											
Short	30		60		100		200		400		600	
C.C.	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p
5,000	1	2	1	3	2	4	3	6	5	12	5	12
10,000	1	2	2	4	2	5	4	8	7	15	9	20
15,000	1	3	2	4	3	6	4	10	8	18	11	24
20,000	1	3	2	5	3	7	5	11	9	20	12	28
25,000	1	3	2	5	3	7	5	12	10	22	13	31
30,000	1	3	2	5	3	8	5	13	10	24	14	33
35,000	2	4	2	5	4	8	6	13	11	25	15	35
40,000	2	4	2	6	4	9	6	14	11	26	16	37
50,000	2	4	3	6	4	9	6	14	12	28	17	40
60,000	2	4	3	6	4	10	7	15	13	30	19	43
70,000	2	4	3	7	5	10	7	16	14	32	20	45
80,000	2	4	3	7	5	11	7	17	14	33	21	48
90,000	2	5	3	7	5	12	8	18	15	35	22	50
100,000	2	5	3	7	5	12	8	19	16	36	23	52
150,000	2	5	4	8	6	14	9	21	18	41	26	60
200,000	3	6	4	9	7	15	10	23	20	46	29	66

Buss Fuse Let-Thru Charts – JKS

LIMITRON® Class J Fast Acting Fuses JKS



JKS – RMS & Peak Let-Thru Currents (kA)

Prosp.	Fuse Size											
Short	30		60		100		200		400		600	
C.C.	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}	I_p
5,000	1	2	1	3	2	4	3	7	4	10	5	12
10,000	1	3	2	4	3	6	4	9	6	13	9	19
15,000	1	3	2	4	3	6	4	10	7	15	10	22
20,000	1	3	2	5	3	7	5	12	8	18	11	25
25,000	2	4	3	6	3	8	6	13	9	19	12	28
30,000	2	4	3	6	3	8	6	13	9	20	13	30
35,000	2	4	3	7	4	9	6	14	9	21	13	30
40,000	2	4	3	7	4	9	7	15	10	22	14	32
50,000	2	5	3	8	4	10	7	16	10	23	15	35
60,000	2	5	3	8	5	11	7	17	11	25	16	37
70,000	2	5	3	8	5	12	8	18	11	25	17	39
80,000	2	5	3	8	5	12	8	18	12	28	17	39
90,000	2	5	4	9	6	13	9	19	13	29	18	41
100,000	2	5	4	9	6	13	9	19	13	30	18	42
150,000	2	5	5	11	6	14	9	21	14	33	22	50
200,000	3	6	5	12	7	15	10	22	16	37	24	55

Buss Fuse Selection Chart (600 Volts or Less).

Circuit	Load	Ampere	Fuse Rating	Symbol Type	Voltage Rating (AC)	Class	Interrupting Rating (KA)	Remarks
	Conventional Dimensions–Class RK1, RK5 (1/10-600A), L (601-6000A)							
Main, Feeder and Branch	All type loads–resistive or inductive (optimum overcurrent protection).	1/10 to 600A	LOW-PEAK YELLOW™ (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 YELLOW™ (time-delay)	**KRP-C_SP**	600V	L	300	
	Motors, welders, transformers, capacitor banks (circuits with heavy inrush currents).	1/10 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.
		601 to 4000A	LIMITRON® (time-delay)	**KLU**	600V	L	200	General purpose fuse. Time-delay passes surge-currents.
	Non-motor loads (circuits with no heavy inrush currents). LIMITRON fuses suited for circuit breaker protection.	1 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(1-600A), T(1-1200A), CC(1/10-30A), G(1/2-60A)							
	All type loads (optimum overcurrent protection).	1 to 600A	LOW-PEAK YELLOW™ (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.
		1 to 1200A	T-TRON™	**JJN** **JJS**	300V 600V	T	200	The space saver (1/3 the size of KTN-R/KTS-R).
Branch	Control transformer circuits and lighting ballasts, etc.	1/10 to 30A	LIMITRON® (fast-acting)	**KTK-R**	600V	CC	200	Very compact (13/32" x 1 1/2"); rejection feature. Excellent for control transformer protection .
		1/4 to 10A	CC-TRON™ (time-delay)	**FNQ-R**				
	All type loads - especially small HP motors	1/2 to 30A	LOW-PEAK YELLOW™ (time-delay)	**LP-CC**				
	General purpose, i.e., lighting panelboards.	1/2 to 60A	SC	**SC**	300V	G	100	Current-limiting; 13/32" dia. x varying lengths per ampere rating.
General Purpose (non-current-limiting fuses)	Miscellaneous.	1/8 to 600A	ONE-TIME	**NON** **NOS**	250V 600V	H or K5†	10	Forerunners of the modern cartridge fuse.
			SUPER-LAG® RENEWABLE	**REN** **RES**	250V 600V	H	10	
	Plug fuses can be used for branch circuits and small component protection.	1/4 to 30A	FUSTAT® (dual-element, time-delay)	**S**	125V	S	10	Base threads of Type S differ with ampere 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	

* LPN-RK_SP, 125VDC; LPS-RK_SP, 300VDC. FRN-R, 125VDC; FRS-R, 300VDC; LPJ_SP, 300VDC.
** Listed as Edison-Base Plug Fuse.
† Some ampere ratings are available as 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).

COOPER
Bussmann

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