XI. Costs Associated with Safety

What are the costs associated with accidents, incidents, injuries, and implementing a good safety program?

In most cases, employer safety efforts are intended for two purposes:

- As an inherent benefit to employees
- To build a legal defense, just in case an injury occurs

Gathering and compiling information related to costs of incidents and injuries is very difficult. Employers and owners tend to avoid public access to that type of information. However, the National Safety Council has established some data associated with these costs in an attempt to identify a cost/benefit ratio. Some injury costs are in the public realm.

The most recent figures from the National Safety Council estimate that the total occupational death and injury cost in 1996 was $121 billion. This figure includes wage and productivity losses of $60.2 billion, medical costs of $19.0 billion, and administrative expenses of $25.6 billion. While this dollar figure is not specific to the electrical industry, it is staggering.

A paper presented at the IEEE Petroleum and Chemical Industry Conference in 1990 entitled *"Maintaining Safe Work Practices in a Competitive Environment"* contains information on costs. This paper, published in the IEEE Transactions in 1991, is available from the IEEE.

When an incident involving injury occurs, associated costs might be viewed as either direct costs or indirect costs. Direct costs include repair or replacement of the failed equipment and production loss due to the failure. Indirect costs include costs that are difficult to calculate.

Direct costs associated with an incident or injury might include:

- Equipment repair or replacement
- Lost production and employee down time

Indirect costs might include the following:

- Citation costs
- Incident investigation
- Creation and maintenance of documentation for legal purposes
- Insurance
- Ineffective work as employees talk about the incident and poor general morale
- Management reviews and reports
- Identification of procedural shortcomings and enacting "fixes"
- Litigation expenses
- Medical costs

Estimates of the ratio of direct to indirect costs are reported to vary from 1 to 4 on the low end to 1 to 8 on the upper end. Of course, legal expenses might be extreme should litigation result from the injury.

Employers are subject to inspection by field representatives from OSHA. Frequently, OSHA inspectors identify violations and assess fines. Most OSHA citations are small, in the hundreds of dollars. However, some are cited as serious violations. The Act (OSHA) does contain considerable "teeth". Section 666 provides that an employer can be issued a civil penalty of $7,000 for a serious violation and up to $70,000 for each willful or repeated violation of the Act. In addition, an employer can be liable under the Act for criminal sanctions, including monetary fines and imprisonment.

Lockout/tagout citations have declined in recent years, but every year the standard ranks as one of OSHA's most violated rules. Between October 1994 and June 1997, 10,272 violations of the standard were recorded. The total cost of these penalties: $15 million.

To this point, this document has discussed only costs. Spending money now to avoid safety incidents and injuries avoids future expenditures. An effective safety program is the best possible legal defense. It is also the best way to document the employer's efforts, should the employer experience an OSHA inspection.

Dollars expended in an effective safety program are reported to be an excellent investment. In fact, money invested in a safety program reportedly results in a 400 percent return on investment (ROI).

In one instance, an electrical contractor was near bankruptcy. After a review of where the money was going, the contractor established an effective safety program. Although criticized for that "soft" expenditure, the result was a significant improvement in profitability. As the contractor's safety experience improved, the contractor's business increased dramatically, and overhead costs were significantly lowered. Safety is good business. Another large electrical contractor found that each serious electrical incident typically costs $4 million.

XII. References

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OSHA Regulations 29 CFR 1926, Subpart K, "Electrical." Washington, DC: Occupational Safety and Health Administration, U. S. Department of Labor.

"Protecting Yourself When Working On High-Power Circuits," *EC&M Magazine*, June 1997

XIII. Glossary of Terms

Accessible. Capable of being removed or exposed without damaging the building structure or finish, or not permanently closed in by the structure or finish of the building.

Arc-blast. The release of concentrated energy associated with extreme pressure and rapid pressure buildup resulting from an arcing fault.

Arc-flash. The release of concentrated (thermal) energy that is the result of an arcing fault.

Arc-rating. The maximum incident energy resistance demonstrated by a material (or a layered system of materials) prior to breakopen or at the onset of a second-degree skin burn. Arc rating is normally expressed in cal/cm^2.

Branch Circuit. The circuit conductor between the final overcurrent protection device protecting the circuit and the outlet(s).

Controller. A device or group of devices that serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected.

Dead Front. Without live parts exposed to a person on the operating side of the equipment.

De-energized. Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.

Disconnecting Means. A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply.

Electrically Safe Work Condition. A state in which the conductor or circuit part to be worked on or near has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

Enclosure. The case or housing of apparatus, or the fence or walls surrounding an installation to prevent personnel from accidentally contacting energized parts, or to protect the equipment from physical damage.

Energized. Electrically connected to or having a source of voltage.

Equipment Grounding Conductor. The conductor used to connect the non-current-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor and/or the grounding electrode conductor of the circuit at the service equipment or at the source of a separately derived system.

Exposed (live parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to parts that are not suitably guarded, isolated, or insulated.

Feeder. All circuit conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device.

Flash Hazard. A dangerous condition associated with the release of energy caused by an electric arc.

Flash Hazard Analysis. A study investigating a worker's potential exposure to arc-flash energy, conducted for the purpose of injury prevention and the determination of safe work practices and the appropriate levels of PPE.

Flash Protection Boundary. An approach limit at a distance from exposed live parts within which a person could receive a second-degree burn if an electrical arc-flash were to occur.

Grounded Conductor. A system or circuit conductor that is intentionally grounded. Note that all neutrals are grounded conductors but not all grounded conductors are neutrals.

Grounding Conductor. A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes.

Guarded. Covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers, casings, barriers, rails, screens, mats, or platforms to remove the likelihood of approach or contact by persons or objects to a point of danger.

Isolated. Not readily accessible to persons unless special means for access are used.

Limited Approach Boundary (for shock). An approach limit at a distance from an exposed live part within which a shock hazard exists.

Overcurrent. Any current in excess of the rated current of equipment or the ampacity of a conductor. It might result from overload, short circuit, or ground fault.

Overload. Operation of equipment in excess of normal, full-load rating, or of a conductor in excess of rated ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload.

Prohibited Approach Boundary (for shock). An approach limit at a distance from an exposed live part within which work is considered the same as making contact with the live part.

Qualified Person. A person who has sufficient training and experience on a particular type of electrical equipment to demonstrate to supervision that he or she is competent to complete the work to be done and is fully aware of the hazards involved.

Readily Accessible. Capable of being reached quickly for operation, renewal, or inspection, without requiring those to whom ready access is required to climb over or remove obstacles or to resort to portable ladders, chairs, etc.

Restricted Approach Boundary (for shock). An approach limit at a distance from an exposed live part within which there is an increased risk of shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the live part.

Switches.

- **General-Use Switch.** A switch intended for use in general distribution and branch circuits. It is rated in amps, and it is capable of interrupting its rated current at its rated voltage.
- **Isolation Switch.** A switch intended for isolating an electric circuit from the source of power. It has no interrupting rating, and it is intended to be operated only after the circuit has been opened by some other means.
- **Motor-Circuit Switch.** A switch, rated in horsepower, capable of interrupting the maximum locked-rotor current of a motor of the same horsepower rating as the switch at the rated voltage.

Switching Device. A device designed to close and/or open one or more electric circuits. Switching devices include the following:

- **Circuit Breakers.** A switching device capable of making, carrying, and breaking currents under normal circuit conditions, and also making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions, such as those of short circuit.
- **Disconnecting (or Isolating) Switch (disconnector, isolator).** A mechanical switching device used for isolating a circuit or equipment from a source of power.
- **Disconnecting Means.** A device, group of devices, or other means whereby the conductors of a circuit can be disconnected from their source of supply.
- **Interrupter Switch.** A switch capable of making, carrying, and interrupting specified currents.

Unqualified Person. A person who is not qualified to perform a certain work task.

XIV. Annexes

Annex A: Checklist for victims of electrical incidents*

This list should be a part of a site's emergency response plan for electrical injuries. A completed copy should accompany the victim to the hospital or treatment center if at all possible. The information will ensure the best possible evaluation and treatment by initial medical caregivers.

Name of injured person ______________________________

1. When and where did the accident occur? ______________________________

2. What was the victim doing at the time of the accident? ______________________________

YES	NO	
☐	☐	3. Did the victim come in direct contact with electricity?
☐	☐	Was an arc the source of electrical current exposure? Explain. ______________
☐	☐	4. Could the victim have inhaled metal vapors or extremely hot air caused by arc-flash?
☐	☐	5. What was the duration of exposure to electricity?
☐	☐	6. Please identify the following as related to the incident: Voltage ______ Available short circuit current ______ Source of electrical hazard ______
☐	☐	7. Did the victim fall? If "yes," explain.
☐	☐	8. Was the victim wearing protective or insulated clothing, safety boots, or gloves? If "yes," what protective equipment? ______________
☐	☐	9. Were others involved in the accident? If "yes," explain. ______________
☐	☐	10. Before the accident, had the hazard been identified?
☐	☐	11. Did the victim seem dazed, confused, or lose consciousness at any point following the accident? If "yes," please elaborate. ______________
☐	☐	12. Did the victim require CPR?
☐	☐	13. Was the victim treated as if bones might be broken, especially in the neck?
☐	☐	14. Did the accident involve an explosion?
☐	☐	15. Did the accident occur in a closed space? If "yes," please elaborate. ______________
☐	☐	16. Did other hazards exist at the time of the accident, such as combustibles, heavy loads, moving or fixed machines, vehicles and equipment, or extreme ambient temperatures? If "yes," explain. ______________
☐	☐	17. Name and telephone number of person who can provide further information about the accident events. ______________

* This checklist has been adapted from one originally developed by the Electrical Trauma Research Program, University of Chicago, Section of Plastic and Reconstructive Surgery.

Annex B: Sources of information

Where to Obtain Standards Information

Name of SDO	Address	Telephone No.	Internet URL
National Fire Protection Association (NFPA)	1 Batterymarch Park Quincy MA 02269-9101	1-800-344-3555	www.nfpa.org
Institute of Electrical and Electronics Engineers (IEEE)	445 Hoes Lane PO Box 1331 Piscataway, NJ 08855-1331	1-800-678-IEEE	www.ieee.org
Occupational Safety and Health Administration (OSHA)[1]			www.osha.gov
International Electro-technical Commission[2]	11 W. 42nd Street New York, NY 10036	1-212-642-4900	www.iec.ch
National Electrical Manufacturers Association	Global 15 Inverness Way East Englewood, CO 80112-5776	1-800-854-7179	www.nema.org
American National Standards Institute	11 W. 42nd Street New York, NY 10036	1-212-642-8908	www.ansi.org
National Standards System Network[3]			www.nssn.org
Underwriters Laboratory	333 Pfingsten Rd Northbrook, IL 60062	1-847-272-8400	www.ul.com

1 OSHA maintains many offices throughout the United States. OSHA standards are available from many organizations and commercial outlets. All OSHA standards and OSHA-related information are available on the Worldwide Web. The OSHA Web site contains interpretive information in addition to all regulations.

2 IEC standards are available from several outlets in the United States. A visit to the IEC Worldwide Web home page will provide information on all available outlets.

3 The National Standards System Network is a service provided by ANSI that supplies information on all ANSI-related standards developing organizations. All American National Standards are available for purchase through this network.

Annex C: OSHA and other standards for protective equipment

Table XIV(C)(1). List of OSHA Standards for Protective Equipment

OSHA 1910.38	Employee Emergency Plans and Fire Prevention Plans
OSHA 1910.95	Hearing Protection
OSHA 1910.132	Personal Protective Equipment-General Requirements
OSHA 1910.133	Eye and Face Protection
OSHA 1910.134	Respiratory Protection
OSHA 1910.135	Head Protection
OSHA 1910.136	Foot Protection
OSHA 1910.138	Hand Protection
OSHA 1910.146	Permit-Required Confined Spaces
OSHA 1910.147	Lockout/Tagout
OSHA 1910.151	Medical Services and First Aid
OSHA 1910.212	Machine Guarding
OSHA 1910.331-335	Electrical Protection
• 1910.331	• Scope
• 1910.332	• Training
• 1910.333	• Selection and Use of Work Practices
• 1910.334	• Use of Equipment
• 1910.335	• Safeguards for Personnel Protection

Table XIV(C)(2). Standards on Protective Equipment (Table 130.7(C)(8) in *NFPA 70E*)

Subject	Number and Title
Head Protection	ANSI Z89.1, Requirements for Protective Headwear for Industrial Workers, 1997
Eye and Face Protection	ANSI Z87.1, Practice for Occupational and Educational Eye and Face Protection, 1998
Gloves	ASTM D120, Standard Specification for Rubber Insulating Gloves, 2002
Sleeves	ASTM D1051, Standard Specification for Rubber Insulating Sleeves, 2002
Gloves and Sleeves	ASTM F496, Standard Specification for In-Service Care of Insulating Gloves and Sleeves, 2002
Leather Protectors	ASTM F696, Standard Specification for Leather Protectors for Rubber Insulating Gloves and Mittens, 2002
Footwear	ASTM F1117, Standard Specification for Dielectric Overshoe Footwear, 1998
	ASTM Z41, Standard for Personnel Protection, Protective Footwear, 1991
Visual Inspection	ASTM F1236, Standard Guide for Visual Inspection of Electrical Protective Rubber Products, 1996
Apparel	ASTM F1506, Standard Specification for Protective Wearing Apparel for Use by Electrical Workers When Exposed to Momentary Electric Arc and Related Thermal Hazards, 2002
Face Protective Products	ASTM F2178, Standard Test Method for Determining the Arc-Flash Rating of Face Protective Products, 2002

ANSI—American National Standards Institute
ASTM—American Society for Testing and Materials

Table XIV(C)(3). Standards on Other Protective Equipment (Table 130.7(F) in *NFPA 70E*)

Subject Number and Title	
Safety Signs and Tags	ANSI Z535, Series of Standards for Safety Signs and Tags, 2002
Blankets	ASTM D1048 Standard Specification for Rubber Insulation Blankets, 1998
Covers	ASTM D1049, Standard Specification for Rubber Covers, 1998
Line Hoses	ASTM D1050, Standard Specification for Rubber-Insulating Line Hoses, 1990
Line Hoses and Covers	ASTM F478, Standard Specification for In-Service Care of Insulating Line Hoses and Covers, 1999
Blankets	ASTM F479, Standard Specification for In-Service Care of Insulating Blankets, 1995
Fiberglass Tools/Ladders	ASTM F711, Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used in Live Line Tools, 1997
Plastic Guards	ASTM F712, Test Methods for Electrically Insulating Plastic Guard Equipment for Protection of Workers, 1995
Temporary Grounding	ASTM F855, Standard Specification for Temporary Grounding Systems to Be Used on Deenergized Electric Power Lines and Equipment, 1997
Insulated Hand Tools	ASTM F1505, Specification for Insulated Hand Tools, 1994

ANSI—American National Standards Institute ASTM—American Society for Testing and Materials

Note: *The standards contained in Table XIV(C)(3) are the base standard used by OSHA to generate 29 CFR 1910.137-Personal Protective Equipment. The same information served as the basis for 29 CFR 1910.269 (generation, transmission, and distribution).*

Annex D: Listing of IEEE standards: color books

The Color Book Series by the Institute of Electrical and Electronic Engineers (IEEE) provides recommended practices and guidelines that go beyond the minimum requirements of the *NEC*®, NEMA, and UL standards. When designing electrical power systems for industrial and commercial facilities, consideration should be given to the design and safety requirements of the following IEEE color books:

Red Book	*IEEE Recommended Practice for Electrical Power Distribution for Industrial Plants*
Green Book	*IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems*
Gray Book	*IEEE Recommended Practice for Electrical Power Systems in Commercial Buildings*
Brown Book	*IEEE Recommended Practice for Power System Analysis*
Buff Book	*IEEE Recommended Practice Protection and Coordination of Industrial and Commercial Power Systems*
Orange Book	*IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications*
Gold Book	*IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power*
White Book	*IEEE Recommended Practice for Electrical Systems in Health Care Facilities*
Bronze Book	*IEEE Recommended Practice for Electrical Conservation and Cost-Effective Planning in Industrial Plants*
Emerald Book	*IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment*
Yellow Book	*IEEE Guide to Operation, Maintenance and Safety of Industrial and Commercial Power Systems*
Blue Book	*IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems*

Annex E: The Safety BASICs™ Safety Awareness Quiz

Date:________________________________

Name:________________________________

Title:________________________________

Company:________________________________

1. The American National Standards Institute writes its own standards.
   A. True B. False
2. The actions of people account for what percentage of incidents that result in injury?
   A. 25% B. 50% C. 75% D. 100%
3. Which of the following is the *National Electrical Code®*?
   A. *NFPA 70* B. *NFPA 70B* C. *NFPA 70E* D. *NFPA 73*
4. Compliance with the NEC® is all that is required to assure a safe and dependable system.
   A. True B. False
5. OSHA violations can result in jail time for employers.
   A. True B. False
6. *NFPA 70E* suggests the following:
   A. Electrical hazards include shock, arc-flash, and blast.
   B. The best way to avoid injury or incident is to establish an electrically safe work condition.
   C. Procedures and training are extremely important if injury is to be avoided.
   D. All of the above.
7. Which standard covers "electrical equipment maintenance"?
   A. NFPA 79 B. IEC 947-4-1 C. NESC D. NFPA 70B
8. Training records should be kept for legal reasons.
   A. True B. False
9. Every employee working with electricity must be able to provide CPR.
   A. True B. False
10. Of those people who were electrocuted on low-voltage systems (600V and below), approximately what percentage were working on energized equipment?
    A. 25% B. 50% C. 75% D. 100%
11. In an electrical incident, what happens when the skin is broken?
    A. The body's resistance goes down, exposing the body to greater current.
    B. The body's resistance goes down, exposing the body to less current.
    C. The body's resistance goes up, exposing the body to greater current.
    D. The body's resistance goes up, exposing the body to less current.
12. The "let-go" threshold refers to which of the following?
    A. The amount of current that causes the hand to let-go of an energized part
    B. The amount of voltage that causes the hand to let-go of an energized part
    C. The amount of current that causes the hand to be unable to let-go of an energized part
    D. The amount of voltage that causes the hand to be unable to let-go of an energized part
13. Tissue and organs can burn at currents of 1.5 amps.
    A. True B. False
14. The temperature at the terminal of an arc can reach which of the following?
    A. One-half the temperature of the surface of the sun
    B. The temperature of the surface of the sun
    C. Almost twice the temperature of the surface of the sun
    D. Almost four times the temperature of the surface of the sun
15. Skin exposed to a temperature of 200°F for one second will be unhurt.
    A. True B. False
16. When it vaporizes, copper expands by a factor of which of the following?
    A. 1,670 times C. 167,000 times
    B. 67,000 times D. None of the above
17. Facilities should know, before an electrical incident ever occurs, which medical facilities specialize in electrical trauma.
    A. True B. False
18. When coming to the aid of an electrical incident victim, which of the following is the first action of the rescuer should perform?
    A. Call OSHA.
    B. Apply first aid.
    C. Treat for shock.
    D. Make sure the power is off.
19. If the victim's pulse or breathing has stopped, in length of time can brain damage occur?
    A. One minute
    B. Two to three minutes
    C. Four to six minutes
    D. Eight to ten minutes
20. Who must provide a safe workplace?
    A. Employers
    B. Employees
    C. Both employers and employees
21. Who is responsible for implementing the safety program and procedures?
    A. Employers
    B. Employees
22. In which of the following was the concept of an electrically safe work condition introduced?
    A. NFPA 70 B. NFPA 70B C. *NFPA 70E* D. OSHA
23. After determining that the circuit is de-energized, it is never necessary to use grounding straps.
    A. True B. False
24. Any person within the prohibited approach boundary must be qualified.
    A. True
    B. False
25. What is the maximum allowable product of overcurrent protective device clearing time and available fault current to use the flash protection boundary of 4 feet from 70E-130.3(A)?
    A. 50kA B. 50kA cycles
    C. 300kA cycles D. 5000kA cycles

26. What is the maximum short-circuit current and overcurrent protective device clearing time that will allow the use of 70E-Table 130.7(C)(9)(a) to determine the hazard risk category for an MCC?
    A. 25kA short circuit current available, 0.03 second (2 cycle) fault clearing time
    B. 25kA short circuit current available, 0.33 second (20 cycle) fault clearing time
    C. 65kA short circuit current available, 0.03 second (2 cycle) fault clearing time
    D. 65kA short circuit current available, 0.33 second (20 cycle) fault clearing time
27. For arcing faults within their current-limiting range, current-limiting protective devices can:
    A. Limit the magnitude and duration of arcing faults
    B. Reduce the flash protection boundary
    C. Reduce the incident energy
    D. All of the above
28. If an arc could be initiated on the line side of a 30A switch with 10A fuses, the Flash Hazard Analysis should be based upon the device (and opening time) of the overcurrent device that feeds the disconnect.
    A. True B. False
29. For the circuit described in the previous question, the Flash Hazard Analysis could be based upon the 10A fuse if work were planned for a downstream controller ten feet away.
    A. True B. False
30. Flash protection boundary and incident energy needs only to be considered at the maximum available fault current.
    A. True B. False
31. Any part of a person's body within a flash protection boundary must be protected with appropriate personal protective equipment, such as flame resistant clothing.
    A. True B. False
32. Tagout must be used unless the employer can demonstrate that the use of a lockout system can provide full employee protection.
    A. True B. False
33. A circuit can shock you even if all external sources of power have been removed.
    A. True B. False
34. Which rating provides the greater protection against electrical shock?
    A. IP1X B. IP2X C. IP0X D. IP3X
35. Sizing an equipment grounding conductor according to Table 250.122 of the 2002 NEC® ensures an adequate, safe ground return path.
    A. True B. False
36. The use of a disconnecting means at every motor, even where not required,
    A. Is a waste of money
    B. Creates confusion during an electrical incident
    C. Provides a quick means of de-energizing
    D. Creates confusion and provides a quick means of de-energizing
37. An Energized Electrical Work Permit shall include the following:
    A. The available fault current
    B. The results of the Flash Hazard Analysis
    C. Signed approval from an authorized person
    D. A and B
    E. B and C
38. Which NEC® Section covers requirements for arc-flash warning labels?
    A. 110.9 B. 110.16 C. 240.85 D. 430.52
39. For overcurrent protective devices that require maintenance, failure to perform maintenance can lead to the following:
    A. Longer clearing times
    B. Increased flash protection boundaries
    C. Higher incident energies
    D. All of the above
40. All current-limiting overcurrent protective devices provide the same level of protection
    A. True B. False
41. Class RK1 fuses can replace Class H and Class RK5 fuses as a possible means to improve electrical safety.
    A. True B. False
42. Short-time delay settings on circuit breakers should be used to reduce the arc-flash hazard.
    A. True B. False
43. Arc resistant switchgear can be used to prevent arcing faults.
    A. True B. False
44. What kind of costs are litigation expenses?
    A. Direct costs B. Indirect costs
45. It is a violation of OSHA 1910.334(b)(2) for a machine operator to reset a circuit breaker without knowing if it was a short circuit or an overload that caused the breaker to trip.
    A. True B. False

Annex F: 3Ø Short-Circuit Calculation Method

General Comments on Short-Circuit Calculations

Normally, short-circuit studies involve calculating a bolted 3-phase fault condition. This can be characterized as all 3-phases "bolted" together to create a zero impedance connection. This establishes a "worst case" (highest current) condition that results in maximum three phase thermal and mechanical stress in the system. This "worst case" condition should be used for interrupting rating, component protection and selective coordination. However, in doing an arc-flash hazard analysis it is recommended to do the arc-flash hazard analysis at the highest bolted 3 phase short-circuit condition and at the "minimum" bolted three-phase short-circuit condition. There are several variables in a distribution system that affect calculated bolted 3-phase short-circuit currents. It is important to select the variable values applicable for the specific application analysis. The variables are utility source short-circuit capabilities, motor contribution, transformer percent impedance tolerance, and voltage variance; see notes and footnotes.

Procedures and Methods

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

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

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

This method can assume unlimited primary short-circuit current (infinite bus) or it can be used with limited primary available current.

Basic Point-to-Point Calculation Procedure

Step 1. Determine the transformer full load amperes (F.L.A.) from either the nameplate, the following formula or Table 3:

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

Step 2. Find the transformer multiplier. See Notes 1 and 2

$$\text{Multiplier} = \frac{100}{\%Z_{transformer}}$$

Note 1. Get %Z from nameplate or Table 3. Transformer impedance (Z) helps to determine what the short circuit current will be at the transformer secondary.
Note 2. In addition, UL (Std. 1561) listed transformers 25KVA and larger have a ± 10% impedance tolerance. Short circuit amperes can be affected by this tolerance. Therefore, for high end worst case, multiply %Z by 0.9. For low end of worst case, multiply %Z by 1.1. Transformers constructed to ANSI standards have a ±7.5% impedance tolerance (two-winding construction).

Step 3. Determine by formula below or Table 3 the transformer let-through short-circuit current. See Notes 3 and 4.

$$I_{S.C.} = \text{Transformer}_{F.L.A.} \times \text{Multiplier}$$

Note 3. Utility voltages may vary ±10% for power, therefore, for highest short-circuit conditions, multiply values as calculated in step 3 by 1.1. To find the lower end worst case, multiply results in step 3 by 0.9.
Note 4. Motor short-circuit contribution, if significant, may be added at all fault locations throughout the system. A practical estimate of motor short-circuit contribution is to multiply the total motor current in amperes by 4. Values of 4 to 6 are commonly accepted.

Step 4. Calculate the "f" factor for 3Ø Faults.

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

Where:

L = length (feet) of conductor to the fault.
C = constant from Table 2 of "C" values for conductors and Table 1 of "C" values for busway.
n = number of conductors per phase (adjusts C value for parallel runs)
I = available short-circuit current in amperes at beginning of circuit.

Step 5. Calculate "M" (multiplier). $M = \frac{1}{1+f}$

Step 6. Calculate the available short-circuit symmetrical RMS current at the point of fault. Add motor contribution, if applicable.

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

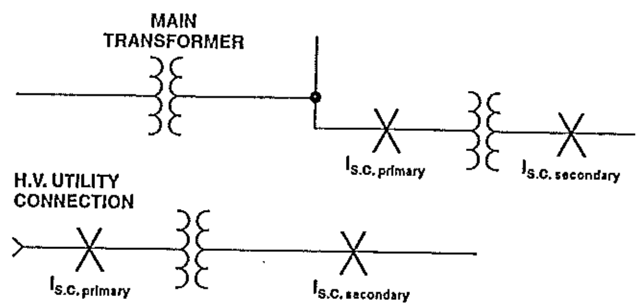
Step 6A. Motor short-circuit contribution, if significant, may be added at all fault locations throughout the system. A practical estimate of motor short-circuit contribution is to multiply the total motor current in amperes by 4. Values of 4 to 6 are commonly accepted.

Calculation of Short-Circuit Currents at Second Transformer in System

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

Procedure for Second Transformer in System

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



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

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

Step B. Calculate "M" (multiplier). $M = \frac{1}{1+f}$

Step C. Calculate the short-circuit current at the secondary of the transformer. (See Note under Step 3.)

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

Table 1. "C" Values for Busway

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

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

Table 2. "C" Values for Conductors

Copper

AWG or kcmil	Three Single Conductors, Conduit: Steel 600V	Steel 5kV	Steel 15kV	Nonmagnetic 600V	Nonmagnetic 5kV	Nonmagnetic 15kV
14	389	-	-	389	-	-
12	617	-	-	617	-	-
10	981	-	-	982	-	-
8	1557	1551	-	1559	1555	-
6	2425	2406	2389	2430	2418	2407
4	3806	3751	3696	3826	3789	3753
3	4774	4674	4577	4811	4745	4679
2	5907	5736	5574	6044	5926	5809
1	7293	7029	6759	7493	7307	7109
1/0	8925	8544	7973	9317	9034	8590
2/0	10755	10062	9390	11424	10878	10319
3/0	12844	11804	11022	13923	13048	12360
4/0	15082	13606	12543	16673	15351	14347
250	16483	14925	13644	18594	17121	15866
300	18177	16293	14769	20868	18975	17409
350	19704	17385	15678	22737	20526	18672
400	20566	18235	16366	24297	21786	19731
500	22185	19172	17492	26706	23277	21330
600	22965	20567	17962	28033	25204	22097
750	24137	21387	18889	29735	26453	23408
1,000	25278	22539	19923	31491	28083	24887

Aluminum

AWG or kcmil	Three Single Conductors, Conduit: Steel 600V	Steel 5kV	Steel 15kV	Nonmagnetic 600V	Nonmagnetic 5kV	Nonmagnetic 15kV
14	237	-	-	237	-	-
12	376	-	-	376	-	-
10	599	-	-	599	-	-
8	951	950	-	952	951	-
6	1481	1476	1472	1482	1479	1476
4	2346	2333	2319	2350	2342	2333
3	2952	2928	2904	2961	2945	2929
2	3713	3670	3626	3730	3702	3673
1	4645	4575	4498	4678	4632	4580
1/0	5777	5670	5493	5838	5766	5646
2/0	7187	6968	6733	7301	7153	6986
3/0	8826	8467	8163	9110	8851	8627
4/0	10741	10167	9700	11174	10749	10387
250	12122	11460	10849	12862	12343	11847
300	13910	13009	12193	14923	14183	13492
350	15484	14280	13288	16813	15858	14955
400	16671	15355	14188	18506	17321	16234
500	18756	16828	15657	21391	19503	18315
600	20093	18428	16484	23451	21718	19635
750	21766	19685	17686	25976	23702	21437
1,000	23478	21235	19006	28779	26109	23482

Note: These values are equal to one over the impedance per foot and based upon resistance and reactance values found in IEEE Std 241-1990 (Gray Book), IEEE Recommended Practice for Electric Power Systems in Commerical Buildings & IEEE Std 242-1986 (Buff Book), IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems. Where resistance and reactance values differ or are not available, the Buff Book values have been used. The values for reactance in determining the C Value at 5 KV & 15 KV are from the Gray Book only (Values for 14-10 AWG at 5 kV and 14-8 AWG at 15 kV are not available and values for 3 AWG have been approximated).

TRANSFORMERS

Table 3. Short-Circuit Currents Available from Various Size Transformers

(Based upon actual field nameplate data or from utility transformer worst case impedance)

Voltage and Phase	KVA	Full Load Amps	% Impedance†† (Nameplate)	Short Circuit Amps†
120/208 3 ph.**	45	125	1.0	13879
	75	208	1.0	23132
	112.5	312	1.11	31259
	150	416	1.07	43237
	225	625	1.12	61960
	300	833	1.11	83357
	500	1388	1.24	124364
	750	2082	3.50	66091
	1000	2776	3.50	88121
	1500	4164	3.50	132181
	2000	5552	4.00	154211
	2500	6940	4.00	192764
277/480 3 ph.**	75	90	1.00	10035
	112.5	135	1.00	15053
	150	181	1.20	16726
	225	271	1.20	25088
	300	361	1.20	33451
	500	602	1.30	51463
	750	903	3.50	28672
	1000	1204	3.50	38230
	1500	1806	3.50	57345
	2000	2408	4.00	66902
	2500	3011	4.00	83628

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

††UL listed transformers 25 KVA or greater have a ±10% impedance tolerance. Short-circuit amps shown in Table 1 reflect –10% condition. Transformers constructed to ANSI standards have a ±7.5% impedance tolerance (two-winding construction).

†Fluctuations in system voltage will affect the available short-circuit current. For example, a 10% increase in system voltage will result in a 10% greater available short-circuit currents than as shown in Table 1.

Example

Available Utility Infinite Assumption

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

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

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

2000A Switch KRP-C-2000SP Fuse

Fault X1

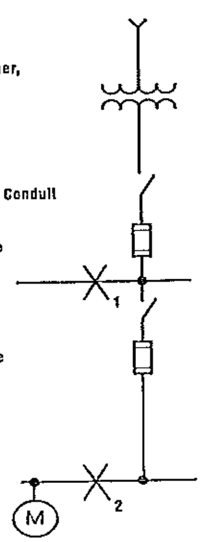
400A Switch

LPS-RK-400SP Fuse

50' - 500 kcmil Feeder Cable in Steel Conduit

Fault X2

Motor Contribution



Fault X_1

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

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

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

$I_{s.c.\ motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

$I_{total\ s.c.\ sym\ RMS} = 51{,}504 + 7{,}216 = 58{,}720A$

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

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

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

$I_{s.c.motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

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

Fault X_2

Step 4. Use $I_{s.c.sym\ RMS}$ @ Fault X1 to calculate "f"

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

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

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

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

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

*Assumes 100% motor load. If 50% of this load was from motors, $I_{s.c.\ motor\ contrib.} = 4 \times 1{,}804 \times .5 = 3608A$

Annex G Arc-Flash Calculator

Steps necessary to conduct a Flash Hazard Analysis.

1. Determine the available bolted fault current on the line side terminals of the equipment that will be worked upon.
2. Identify the amperage of the upstream LOW-PEAK® fuse or circuit breaker that is protecting the equipment where work is to be performed.
3. Consult the table to determine the incident energy exposure and the flash protection boundary.
4. Identify the minimum requirements for PPE when work is to be performed inside of the FPB by consulting the requirements found in *NFPA 70E*.

Notes for Arc-Flash Calculation Tables:

Note 1: First and foremost, this information is not to be used as a recommendation to work on energized equipment. This information is to help assist in determining the proper PPE to help safeguard a worker from the burns that can be sustained from an arc-flash incident. This information does not take into account the effects of pressure, shrapnel, molten metal spray, or the toxic copper vapor resulting from an arc-fault.

Note 2: This data is based upon IEEE Guide for Arc-flash Hazard Analysis, 1584. These methods were created so that the PPE selected from the calculated incident energy would be adequate for 98% of arc-flash incidents. In up to 2% of incidents, incurable burns to the body and torso could result. This was based upon PPE with standard arc ratings of 1.2, 8, 25, 40 and 100cal/cm². PPE with intermediate ATPV values can be utilized, but at the next lower standard ATPV rating.

Note 3: PPE must be utilized any time that work is to be performed on or near energized electrical equipment or equipment that could become energized. Voltage testing, while completing the lockout/tagout procedure (putting the equipment in an electrically safe work condition), is considered as working on energized parts per OSHA 1910.333(b).

Note 4: The data is based on 32mm (1¼") electrode spacing, 600V 3Ø ungrounded system, and 20" by 20" by 20" box. The incident energy is based on a working distance of 18 inches, and the flash protection boundary is based on 1.2cal/cm².

Note 5: The LOW-PEAK® fuse information is based upon tests that were conducted at various fault currents for each Bussmann® KRP-C_SP and LPS-RK_SP fuse indicated in the charts. Actual results from incidents could be different for a number of reasons, including different (1) system voltage, (2) short-circuit power factor, (3) distance from the arc, (4) arc gap, (5) enclosure size, (6) fuse manufacturer, (7) fuse class, (8) orientation of the worker and (9) grounding scheme. 100A LPS-RK_SP fuses were the smallest fuses tested. Data for the fuses smaller than that is based upon the 100A data. Arc-flash values for actual 30 and 60A fuses would be considerably less than 100A fuses, however, it does not matter since the values for the 100A fuses are already so low.

Note 6: The fuse incident energy values were chosen not to go below 0.25cal/cm² even though many actual values were below 0.25cal/cm². This was chosen to keep from encouraging work on energized equipment without PPE because of a low FPB.

Note 7: This slide rule can also be used for LPJ_SP, JJS, and LP-CC fuses to determine the incident energy available and flash protection boundary.

Note 8: These values from fuse tests and calculations for circuit breakers take into account the translation from available 3-phase bolted fault current to the arcing fault current.

Note 9: To determine the flash protection boundary and incident energy for applications with other fuses, use the equations in IEEE 1584 or *NFPA 70E*.

Note 10: The circuit breaker information comes from equations in IEEE 1584 that are based upon how circuit breakers operate.

Note 11: Where the arcing current is less than the instantaneous trip setting (IEEE 1584 calculation methods), the value for incident energy is given as >100cal/cm².

Note 12: The data for circuit breakers up to 400A is based on Molded Case Circuit Breakers (MCCB) with instantaneous trip, for 401-600A it is based on MCCBs with electronic trip units, and the data for circuit breakers from 601 up to 2000A is based on Low Voltage Power Circuit Breakers (LVPCB) with a short time delay. Per IEEE 1584 the short time delay is assumed to be set at maximum.

Note 13: The data for circuit breakers is based upon devices being properly maintained in accordance with manufacturer's instructions and industry standards. Devices that are not properly maintained and tested may have longer clearing times resulting in higher incident energies.

For further explanation please consult the SPD Electrical Protection Handbook available at www.bussmann.com.

Arc-Flash Incident Energy Calculator

Fuses: Cooper Bussmann LOW-PEAK® LPS-RK_SP (0-600A), Circuit Breakers: Molded Case Circuit Breakers

Incident Energy (I.E.) values are expressed in cal/cm². Flash Protection Boundary (FPB) values are expressed in inches.

Bolted Fault Current (kA)	1-100A				101-200A				201-400A				401-600A			
	Fuse		MCCB		Fuse		MCCB		Fuse		MCCB		Fuse		MCCB	
	I.E.	FPB	I.E.	FPB	I.E.	FPB	I.E.	FPB	I.E.	FPB	I.E.	FPB	I.E.	FPB	I.E.	FPB
1	2.39	29	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
2	0.25	6	0.25	6	5.20	49	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
3	0.25	6	0.27	7	0.93	15	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
4	0.25	6	0.35	8	0.25	6	0.35	8	20.60	124	>100	>120	>100	>120	>100	>120
5	0.25	6	0.43	9	0.25	6	0.43	9	1.54	21	>100	>120	>100	>120	>100	>120
6	0.25	6	0.50	10	0.25	6	0.50	10	0.75	13	>100	>120	>100	>120	>100	>120
8	0.25	6	0.65	12	0.25	6	0.65	12	0.69	12	0.65	12	36.85	184	>100	>120
10	0.25	6	0.81	14	0.25	6	0.81	14	0.63	12	0.81	14	12.82	90	>100	>120
12	0.25	6	0.96	15	0.25	6	0.96	15	0.57	11	0.96	15	6.71	58	1.70	23
14	0.25	6	1.11	17	0.25	6	1.11	17	0.51	10	1.11	17	0.60	11	1.96	25
16	0.25	6	1.26	19	0.25	6	1.26	19	0.45	9	1.26	19	0.59	11	2.22	27
18	0.25	6	1.41	20	0.25	6	1.41	20	0.39	8	1.41	20	0.48	10	2.48	29
20	0.25	6	1.56	22	0.25	6	1.56	22	0.33	7	1.56	22	0.38	8	2.74	32
22	0.25	6	1.72	23	0.25	6	1.72	23	0.27	7	1.72	23	0.28	7	3.00	34
24	0.25	6	1.87	24	0.25	6	1.87	24	0.25	6	1.87	24	0.25	6	3.26	36
26	0.25	6	2.02	26	0.25	6	2.02	26	0.25	6	2.02	26	0.25	6	3.53	37
28	0.25	6	2.17	27	0.25	6	2.17	27	0.25	6	2.17	27	0.25	6	3.79	39
30	0.25	6	2.32	28	0.25	6	2.32	28	0.25	6	2.32	28	0.25	6	4.05	41
32	0.25	6	2.47	29	0.25	6	2.47	29	0.25	6	2.47	29	0.25	6	4.31	43
34	0.25	6	2.63	31	0.25	6	2.63	31	0.25	6	2.63	31	0.25	6	4.57	45
36	0.25	6	2.78	32	0.25	6	2.78	32	0.25	6	2.78	32	0.25	6	4.83	46
38	0.25	6	2.93	33	0.25	6	2.93	33	0.25	6	2.93	33	0.25	6	5.09	48
40	0.25	6	3.08	34	0.25	6	3.08	34	0.25	6	3.08	34	0.25	6	5.36	50
42	0.25	6	3.23	35	0.25	6	3.23	35	0.25	6	3.23	35	0.25	6	5.62	51
44	0.25	6	3.38	36	0.25	6	3.38	36	0.25	6	3.38	36	0.25	6	5.88	53
46	0.25	6	3.54	37	0.25	6	3.54	37	0.25	6	3.54	37	0.25	6	6.14	55
48	0.25	6	3.69	39	0.25	6	3.69	39	0.25	6	3.69	39	0.25	6	6.40	56
50	0.25	6	3.84	40	0.25	6	3.84	40	0.25	6	3.84	40	0.25	6	6.66	58
52	0.25	6	3.99	41	0.25	6	3.99	41	0.25	6	3.99	41	0.25	6	6.92	59
54	0.25	6	4.14	42	0.25	6	4.14	42	0.25	6	4.14	42	0.25	6	7.18	61
56	0.25	6	4.29	43	0.25	6	4.29	43	0.25	6	4.29	43	0.25	6	7.45	62
58	0.25	6	4.45	44	0.25	6	4.45	44	0.25	6	4.45	44	0.25	6	7.71	64
60	0.25	6	4.60	45	0.25	6	4.60	45	0.25	6	4.60	45	0.25	6	7.97	65
62	0.25	6	4.75	46	0.25	6	4.75	46	0.25	6	4.75	46	0.25	6	8.23	67
64	0.25	6	4.90	47	0.25	6	4.90	47	0.25	6	4.90	47	0.25	6	8.49	68
66	0.25	6	5.05	48	0.25	6	5.05	48	0.25	6	5.05	48	0.25	6	8.75	69
68	0.25	6	5.20	49	0.25	6	5.20	49	0.25	6	5.20	49	0.25	6	9.01	71
70	0.25	6	5.36	50	0.25	6	5.36	50	0.25	6	5.36	50	0.25	6	9.28	72
72	0.25	6	5.51	51	0.25	6	5.51	51	0.25	6	5.51	51	0.25	6	9.54	74
74	0.25	6	5.66	52	0.25	6	5.66	52	0.25	6	5.66	52	0.25	6	9.80	75
76	0.25	6	5.81	53	0.25	6	5.81	53	0.25	6	5.81	53	0.25	6	10.06	76
78	0.25	6	5.96	53	0.25	6	5.96	53	0.25	6	5.96	53	0.25	6	10.32	78
80	0.25	6	6.11	54	0.25	6	6.11	54	0.25	6	6.11	54	0.25	6	10.58	79
82	0.25	6	6.27	55	0.25	6	6.27	55	0.25	6	6.27	55	0.25	6	10.84	80
84	0.25	6	6.42	56	0.25	6	6.42	56	0.25	6	6.42	56	0.25	6	11.10	82
86	0.25	6	6.57	57	0.25	6	6.57	57	0.25	6	6.57	57	0.25	6	11.37	83
88	0.25	6	6.72	58	0.25	6	6.72	58	0.25	6	6.72	58	0.25	6	11.63	84
90	0.25	6	6.87	59	0.25	6	6.87	59	0.25	6	6.87	59	0.25	6	11.89	85
92	0.25	6	7.02	60	0.25	6	7.02	60	0.25	6	7.02	60	0.25	6	12.15	87
94	0.25	6	7.18	61	0.25	6	7.18	61	0.25	6	7.18	61	0.25	6	12.41	88
96	0.25	6	7.33	61	0.25	6	7.33	61	0.25	6	7.33	61	0.25	6	12.67	89
98	0.25	6	7.48	62	0.25	6	7.48	62	0.25	6	7.48	62	0.25	6	12.93	90
100	0.25	6	7.63	63	0.25	6	7.63	63	0.25	6	7.63	63	0.25	6	13.20	92
102	0.25	6	7.78	64	0.25	6	7.78	64	0.25	6	7.78	64	0.25	6	13.46	93
104	0.25	6	7.93	65	0.25	6	7.93	65	0.25	6	7.93	65	0.25	6	13.72	94
106	0.25	6	8.09	66	0.25	6	8.09	66	0.25	6	8.09	66	0.25	6	13.98	95

Read attached notes. Fuse results are based on actual test data.
Circuit breaker results are based upon IEEE 1584 calculations; if circuit breakers are not properly maintained values can be considerably greater.

Arc-Flash Incident Energy Calculator

Fuses: Cooper Bussmann LOW-PEAK® KRP-C_SP (601-2000A), Circuit Breakers: Low Voltage Power Circuit Breakers (w/STD)
Incident Energy (I.E.) values are expressed in cal/cm². Flash Protection Boundary (FPB) values are expressed in inches.

Bolted Fault Current (kA)	601-800A				801-1200A				1201-1600A				1601-2000A			
	Fuse		LVPCB		Fuse		LVPCB		Fuse		LVPCB		Fuse		LVPCB	
	I.E.	FPB	I.E.	FPB	I.E.	FPB	I.E.	FPB	I.E.	FPB	I.E.	FPB	I.E.	FPB	I.E.	FPB
1	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
2	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
3	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
4	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
5	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
6	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
8	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
10	75.44	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
12	49.66	>120	>100	>120	73.59	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
14	23.87	>120	>100	>120	39.87	>120	>100	>120	>100	>120	>100	>120	>100	>120	>100	>120
16	1.94	25	31.22	>120	11.14	82	>100	>120	24.95	>120	>100	>120	>100	>120	>100	>120
18	1.82	24	35.05	>120	10.76	80	>100	>120	24.57	>120	>100	>120	>100	>120	>100	>120
20	1.70	23	38.87	>120	10.37	78	>100	>120	24.20	>120	>100	>120	>100	>120	>100	>120
22	1.58	22	42.70	>120	9.98	76	>100	>120	23.83	>120	>100	>120	>100	>120	>100	>120
24	1.46	21	46.53	>120	8.88	70	46.53	>120	23.45	>120	>100	>120	29.18	>120	>100	>120
26	1.34	19	50.35	>120	7.52	63	50.35	>120	23.08	>120	>100	>120	28.92	>120	>100	>120
28	1.22	18	54.18	>120	6.28	55	54.18	>120	22.71	>120	>100	>120	28.67	>120	>100	>120
30	1.10	17	58.01	>120	5.16	48	58.01	>120	22.34	>120	>100	>120	28.41	>120	>100	>120
32	0.98	16	61.83	>120	4.15	42	61.83	>120	21.69	>120	61.83	>120	28.15	>120	>100	>120
34	0.86	14	65.66	>120	3.25	35	65.66	>120	18.59	116	65.66	>120	27.90	>120	>100	>120
36	0.74	13	69.49	>120	2.47	29	69.49	>120	15.49	102	69.49	>120	27.64	>120	>100	>120
38	0.62	11	73.31	>120	1.80	24	73.31	>120	12.39	88	73.31	>120	27.38	>120	>100	>120
40	0.50	10	77.14	>120	1.25	18	77.14	>120	9.29	72	77.14	>120	27.13	>120	77.14	>120
42	0.38	8	80.97	>120	0.81	14	80.97	>120	6.19	55	80.97	>120	26.87	>120	80.97	>120
44	0.25	6	84.79	>120	0.49	10	84.79	>120	3.09	34	84.79	>120	26.61	>120	84.79	>120
46	0.25	6	88.62	>120	0.39	8	88.62	>120	2.93	33	88.62	>120	26.36	>120	88.62	>120
48	0.25	6	92.45	>120	0.39	8	92.45	>120	2.93	33	92.45	>120	26.10	>120	92.45	>120
50	0.25	6	96.27	>120	0.39	8	96.27	>120	2.93	33	96.27	>120	25.84	>120	96.27	>120
52	0.25	6	>100	>120	0.39	8	>100	>120	2.93	33	>100	>120	25.59	>120	>100	>120
54	0.25	6	>100	>120	0.39	8	>100	>120	2.93	33	>100	>120	25.33	>120	>100	>120
56	0.25	6	>100	>120	0.39	8	>100	>120	2.93	33	>100	>120	25.07	>120	>100	>120
58	0.25	6	>100	>120	0.39	8	>100	>120	2.93	33	>100	>120	24.81	>120	>100	>120
60	0.25	6	>100	>120	0.39	8	>100	>120	2.93	33	>100	>120	24.56	>120	>100	>120
62	0.25	6	>100	>120	0.39	8	>100	>120	2.93	33	>100	>120	24.30	>120	>100	>120
64	0.25	6	>100	>120	0.39	8	>100	>120	2.93	33	>100	>120	24.04	>120	>100	>120
66	0.25	6	>100	>120	0.39	8	>100	>120	2.92	33	>100	>120	23.75	>120	>100	>120
68	0.25	6	>100	>120	0.39	8	>100	>120	2.80	32	>100	>120	22.71	>120	>100	>120
70	0.25	6	>100	>120	0.39	8	>100	>120	2.67	31	>100	>120	21.68	>120	>100	>120
72	0.25	6	>100	>120	0.39	8	>100	>120	2.54	30	>100	>120	20.64	>120	>100	>120
74	0.25	6	>100	>120	0.39	8	>100	>120	2.42	29	>100	>120	19.61	120	>100	>120
76	0.25	6	>100	>120	0.39	8	>100	>120	2.29	28	>100	>120	18.57	116	>100	>120
78	0.25	6	>100	>120	0.39	8	>100	>120	2.17	27	>100	>120	17.54	111	>100	>120
80	0.25	6	>100	>120	0.39	8	>100	>120	2.04	26	>100	>120	16.50	107	>100	>120
82	0.25	6	>100	>120	0.39	8	>100	>120	1.91	25	>100	>120	15.47	102	>100	>120
84	0.25	6	>100	>120	0.39	8	>100	>120	1.79	24	>100	>120	14.43	97	>100	>120
86	0.25	6	>100	>120	0.39	8	>100	>120	1.66	22	>100	>120	13.39	93	>100	>120
88	0.25	6	>100	>120	0.39	8	>100	>120	1.54	21	>100	>120	12.36	88	>100	>120
90	0.25	6	>100	>120	0.39	8	>100	>120	1.41	20	>100	>120	11.32	83	>100	>120
92	0.25	6	>100	>120	0.39	8	>100	>120	1.28	19	>100	>120	10.29	77	>100	>120
94	0.25	6	>100	>120	0.39	8	>100	>120	1.16	18	>100	>120	9.25	72	>100	>120
96	0.25	6	>100	>120	0.39	8	>100	>120	1.03	16	>100	>120	8.22	66	>100	>120
98	0.25	6	>100	>120	0.39	8	>100	>120	0.90	15	>100	>120	7.18	61	>100	>120
100	0.25	6	>100	>120	0.39	8	>100	>120	0.78	13	>100	>120	6.15	55	>100	>120
102	0.25	6	>100	>120	0.39	8	>100	>120	0.65	12	>100	>120	5.11	48	>100	>120
104	0.25	6	>100	>120	0.39	8	>100	>120	0.53	10	>100	>120	4.08	41	>100	>120
106	0.25	6	>100	>120	0.39	8	>100	>120	0.40	9	>100	>120	3.04	34	>100	>120

Read attached notes. Fuse results are based on actual test data.
Circuit breaker results are based upon IEEE 1584 calculations; if circuit breakers are not properly maintained values can be considerably greater.

www.busmann.com
For more on Electrical Safety.

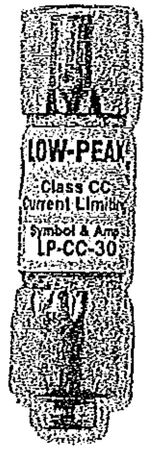
Notes

Cooper Bussmann LOW-PEAK® Upgrade

The left column represents Cooper Bussmann and competitors' part numbers. The right column represents the Cooper Bussmann LOW-PEAK® upgrades.

CLASS CC and MIDGET

Existing Fuse	LOW-PEAK® UPGRADE
A6Y type 2B	LP-CC
ABU	
AGU	
ATDR	
ATM	
ATMR	
ATQ	
BAF	
BAN	
BLF	
BLN	
CCMR	
CM	
CMF	
CNM	
CNQ	
CTK	
CTK-R	
FLM	
FLM	
FLQ	
FNM	
FNQ	
FNW	
GGU	
HCLR	
KLK	
KLK-R	
KTK	
KTK-R	
MCL	
MEN	
MEQ	
MOF	
MOL	
OTM	
TRM	
6JX	LP-CC



ATQR	FNQ-R
FNQ-R	FNQ-R
KLDR	FNQ-R

FNQ-R suggested on primary of control transformers

CLASS J

Existing Fuse	LOW-PEAK® UPGRADE
A4J	LPJ_SP
AJT	
CJ	
CJS	
GF8B	
HRCXXJ	
J	
JA	
JCL	
JDL	
JFL	
JHC	
JKS	
JLS	
JTD	LPJ_SP

The Cooper Bussmann LOW-PEAK® Upgrade offers superior performance while reducing the number of SKU's that need to be in stock. LOW-PEAK® fuses feature a high degree of current limitation, which will provide the best component protection and may reduce the arc-flash hazard. Listings are numerical-alpha by fuse class and fuse catalog symbol. Do you have a part that does not appear in the list? This list is only a consolidated cross-reference to some of our most common products. For a much more extensive database please consult the competitor cross-reference on

www.bussmann.com

or contact Customer Satisfaction at (636) 527-3877

CLASS R 250V

Existing Fuse	LOW-PEAK® UPGRADE
A2D	LPN-RK_SP
A2D-R	
A2K	
A2K-R	
A2Y type 1	
AT-DE	
CHG	
CRN-R type 3	
CTN-R	
DEN	
DLN	
DLN-R	
ECN	
ECN-R	
ERN	
FLN	
FLN-R	
FRN	
FRN-R	
FTN-R	
GDN	
HAC-R	
HB	
KLN-R	
KON	
KTN-R	
LENRK	
LKN	
LLN-RK	
LON-RK	
NCLR	
NLN	
NON	
NRN	
OTN	
OTN	
REN	
RFN	
RFN	
RHN	
RLN	
TR	
655	
660	
10KOTN	
50KOTN	LPN-RK_SP

CLASS R 600V

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

CLASS L

Existing Fuses	LOW-PEAK® UPGRADE
A4BQ	KRP-C_SP
A4BT	
A4BY	
A4BY type 55	
CLASS L	
CLF	
CLL	
CLU	
HRC-L	
KLLU	
KLPC	
KLU	
KTU	
L	
LCL	
LCU	KRP-C_SP

The comparative catalog numbers shown were derived from the latest available published information from various manufacturers. Because competitors' products may differ from Bussmann® products, it is recommended that each application be checked for required electrical and mechanical characteristics before substitutions are made. Bussmann® is not responsible for misapplications of our products. Overcurrent protection is application dependent. Consult latest catalogs and application literature, or contact our Application Engineering Department at (636) 527-1270.

Cooper Bussmann Products And Technical Support Delivered Worldwide

Customer Assistance

Customer Satisfaction Team

The Cooper Bussmann Customer Satisfaction Team is available to answers questions regarding Cooper Bussmann products and services. Calls should be made between 8:00 a.m. – 4:30 p.m. Central Time for all US time zones.

The Customer Satisfaction Team can be reached via:
- Phone: 636-527-3877
- Toll-free fax: 800-544-2570
- E-mail: fusebox@buss.com

Emergency and After-Hours Orders

To accommodate time-critical needs, Cooper Bussmann offers emergency and after-hours service for next flight out or will call. Customers pay only standard price for the circuit protection device, rush freight charges and a modest emergency fee for this service. Emergency and after-hours orders should be placed through the Customer Satisfaction Team. Call:
- 8:00 a.m.-4:30 p.m. Central Time 636-527-3877
- After hours 314-995-1342

Application Engineering

Application Engineering assistance is available to all customers. The Application Engineering team is staffed by degreed electrical engineers and available by phone with technical and application support Monday – Friday, 8:00 a.m. – 5:00 p.m. Central Time.

Application Engineering can be reached via phone, fax or email:
- Phone: 636-527-1270
- E-mail: fusetech@buss.com

Web Services

www.bussmann.com

The Cooper Bussmann web site makes available free information and other resources that include:

- Product Data Sheets for complete technical information on Bussmann products
- Online catalogs for the latest United States and European products
- Safety BASICs™ for the essentials of electrical safety
- Training Modules for increasing skill levels of customers and end users
- Fuse Cross Reference to find the correct Bussmann replacement for a competitive fuse
- Arc-Flash Calculator to determine the incident energy level and flash protection boundary along with the recommends the level of Personal Protective Equipment (PPE)

Your Authorized Cooper Bussmann Distributor is: