Informative Annex A Referenced Publications

A.1 General. This informative annex is not part of the requirements of this document and is included for information only. To the extent the documents or portions thereof listed in this informative annex are referenced within this standard, those documents are to be considered part of the requirements of this document in the section and manner in which they are referenced.

A.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 70®, *National Electrical Code*®, 2014 edition.

A.3 Other Publications.

A.3.1 ANSI Publications. American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI/ASC A14.1, *American National Standard for Ladders — Wood — Safety Requirements,* 2007.

ANSI/ASC A14.3, *American National Standard for Ladders — Fixed — Safety Requirements,* 2008.

ANSI/ASC A14.4, *American National Standard Safety Requirements for Job-Made Ladders,* 2009.

ANSI/ASC A14.5, *American National Standard for Ladders — Portable Reinforced — Safety Requirements,* 2007.

ANSI Z87.1, *Practice for Occupational and Educational Eye and Face Protection,* 2010.

ANSI Z89.1, *Requirements for Protective Headwear for Industrial Workers,* 2009.

ANSI Z535, *Series of Standards for Safety Signs and Tags,* 2011.

A.3.2 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O Box C700, West Conshohocken, PA 19428-2959.

ASTM D120, *Standard Specification for Rubber Insulating Gloves*, 2009.

ASTM D1048, *Standard Specification for Rubber Insulating Blankets,* 2012.

ASTM D1049, *Standard Specification for Rubber Covers,* 1998 (R 2010).

ASTM D1050, *Standard Specification for Rubber Insulating Line Hoses,* 2005 (R 2011).

ASTM D1051, *Standard Specification for Rubber Insulating Sleeves*, 2008.

ASTM F478, *Standard Specification for In-Service Care of Insulating Line Hose and Covers*, 2009.

ASTM F479, *Standard Specification for In-Service Care of Insulating Blankets,* 2006 (R 2011).

ASTM F496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves*, 2008.

ASTM F696, *Standard Specification for Leather Protectors for Rubber Insulating Gloves and Mittens,* 2006 (R 2011).

ASTM F711, *Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used in Live Line Tools,* 2002 (R 2007).

ASTM F712, *Standard Test Methods and Specifications for Electrically Insulating Plastic Guard Equipment for Protection of Workers,* 2006 (R 2011).

ASTM F855, *Standard Specification for Temporary Protective Grounds to Be Used on De-energized Electric Power Lines and Equipment*, 2009.

ASTM F887, *Standard Specification for Personal Climbing Equipment*, 2011.

ASTM F1116, *Standard Test Method for Determining Dielectric Strength of Dielectric Footwear*, 2003 (R 2008).

ASTM F1117, *Standard Specification for Dielectric Footwear*, 2003 (R 2008).

ASTM F1236, *Standard Guide for Visual Inspection of Electrical Protective Rubber Products,* 1996 (R 2012).

ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, 2008.

ASTM F1449, *Standard Guide for Industrial Laundering of Flame, Thermal, and Arc Resistant Clothing*, 2008.

ASTM F1505, *Standard Specification for Insulated and Insulating Hand Tools,* 2010.

ASTM F1506, *Standard Performance Specification for Flame Resistant and Arc Rated Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards*, 2010a.

ASTM F1742, *Standard Specification for PVC Insulating Sheeting*, 2003 (R 2011).

ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear,* 2012.

ASTM F1959/F1959M, *Standard Test Method for Determining the Arc Rating of Materials for Clothing,* 2012.

ASTM F2178, *Standard Test Method for Determining the Arc Rating and Standard Specification for Eye or Face Protective Products*, 2012.

ASTM F2249, *Standard Specification for In-Service Test Methods for Temporary Grounding Jumper Assemblies Used on De-Energized Electric Power Lines and Equipment*, 2003 (R 2009).

ASTM F2412/F2320, *Standard Specification for Rubber Insulating Sheeting*, 2011.

ASTM F2412, *Standard Test Methods for Foot Protections*, 2011.

ASTM F2413, *Standard Specification for Performance Requirements for Protective (Safety) Toe Cap Footwear*, 2011.

ASTM F2522, *Standard Test Method for Determining the Protective Performance of a Shield Attached on Live Line Tools or on Racking Rods for Electric Arc Hazards*, 2012.

ASTM F2676, *Standard Test Method for Determining the Protective Performance of an Arc Protective Blanket for Electric Arc Hazards*, 2009.

ASTM F2677, *Standard Specification for Electrically Insulating Aprons*, 2008a.

ASTM F2757, *Standard Guide for Home Laundering Care and Maintenance of Flame, Thermal and Arc Resistant Clothing*, 2009.

A.3.3 ICRP Publications. International Commission on Radiological Protection, SE-171 16 Stockholm, Sweden.

ICRP Publication 33, *Protection Against Ionizing Radiation from External Sources Used in Medicine*, March 1981.

A.3.4 IEC Publications. International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

IEC 60479, *Effects of Current Passing Through the Body*.

60479-1 Part 1: General aspects, 2005.

60479-1-1 Chapter 1: Electrical impedance of the human body.

60479-1-2 Chapter 2: Effects of ac in the range of 15 Hz to 100 Hz.

60479-2 Part 2: Special aspects, 2007.

60479-2-4 Chapter 4: Effects of ac with frequencies above 100 Hz.

60479-2-5 Chapter 5: Effects of special waveforms of current.

60479-2-6 Chapter 6: Effects of unidirectional single impulse currents of short duration.

A.3.5 IEEE Publications. Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

IEEE C37.20.7, *Guide for Testing Metal-Enclosed Switchgear Rated up to 38 kV for Internal Arcing Faults*, 2007/Corrigendum 1, 2010.

A.4 References for Extracts in Mandatory Sections.

NFPA 70®, *National Electrical Code®*, 2014 edition.

Informative Annex B Informational References

B.1 Referenced Publications. The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not part of the requirements of this document unless also listed in Informative Annex A.

B.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 1, *Fire Code*, 2015 edition.

NFPA 70,® National Electrical Code®, 2014 edition.

NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance,* 2013 edition.

NFPA 79, *Electrical Standard for Industrial Machinery*, 2015 edition.

B.1.2 ANSI Publications. American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI/AIHA Z10, *American National Standard for Occupational Health and Safety Management Systems*, 2012.

ANSI/ASSE Z244.1, *Control of Hazardous Energy — Lockout/Tagout and Alternative Methods*, 2003 (R 2008).

ANSI C84.1, *Electric Power Systems and Equipment – Voltage Ratings (60 Hz)*, 2011.

ANSI/ISO 14001, *Environmental Management Systems — Requirements with Guidance for Use*, 2004/Corrigendum 1, 2009.

ANSI/NETA MTS, *Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems,* 2011.

ANSI Z535.4, *Product Safety Signs and Labels*, 2011.

B.1.3 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM F496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves*, 2008.

ASTM F711, *Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used in Live Line Tools*, 2002 (R 2007).

ASTM F1449, *Standard Guide for Industrial Laundering of Flame, Thermal, and Arc Resistant Clothing*, 2008.

ASTM F1506, *Standard Performance Specification for Flame Resistant and Arc Rated Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards,* 2010a.

ASTM F1959/F1959M, *Standard Test Method for Determining the Arc Rating of Materials for Clothing*, 2012.

ASTM F2249, *Standard Specification for In-Service Test Methods for Temporary Grounding Jumper Assemblies Used on De-Energized Electric Power Lines and Equipment*, 2003 (R 2009).

ASTM F2413, *Standard Specifications for Performance Requirements for Protective (Safety) Toe Cap Footwear,* 2011.

ASTM F2757, *Standard Guide for Home Laundering Care and Maintenance of Flame, Thermal and Arc Resistant Clothing*, 2009.

B.1.4 British Standards Institute, Occupational Health and Safety Assessment Series (OHSAS) Project Group Publications. British Standards Institute, American Headquarters, 12110 Sunset Hills Road, Suite 200, Reston VA 20190-5902.

BS OSHAS 18001, *Occupational Health and Safety Management Systems*, 2007.

B.1.5 CSA Publications. Canadian Standards Association, 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada.

CAN/CSA Z462, *Workplace Electrical Safety*, 2012.

CAN/CSA Z1000, *Occupational Health and Safety Management*, 2006 (R 2011).

B.1.6 IEC Publications. International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

IEC 60204-1 ed 5.1 Consol. with am 1, *Safety of Machinery — Electrical Equipment of Machines — Part 1: General Requirements,* 2009.

B.1.7 IEEE Publications. Institute of Electrical and Electronic Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

ANSI/IEEE C2, *National Electrical Safety Code,* 2012.

ANSI/IEEE C 37.20.6, *Standard for 4.76 kV to 38 kV-Rated Ground and Test Devices Used in Enclosures*, 2007.

IEEE 4, *Standard Techniques for High Voltage Testing,* 2013.

IEEE 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*, 2010.

IEEE 516, *Guide for Maintenance Methods on Energized Power Lines,* 2009.

IEEE 937, *Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic Systems,* 2007.

IEEE 946, *IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Systems*, 2004.

IEEE 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*, 2005 (R 2011).

IEEE 1184, *IEEE Guide for Batteries for Uninterruptible Power Supply Systems*, 2006.

IEEE 1187, *Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications,* 2002.

IEEE 1188, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*, 2005 (R 2010).

• IEEE 1491, *IEEE Guide for Selection and Use of Battery Monitoring Equipment in Stationary Applications*, 2012.

IEEE 1584™, *Guide for Performing Arc Flash Hazard Calculations,* 2002.

IEEE 1584a™, *Guide for Performing Arc Flash Hazard Calculations, Amendment 1*, 2004.

IEEE 1584b™, *Guide for Performing Arc Flash Hazard Calculations — Amendment 2: Changes to Clause 4*, 2011.

IEEE 1657, *Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries,* 2009.

IEEE 3007.1, *IEEE Recommended Practice for the Operation and Management of Industrial and Commercial Power Systems*, 2010.

IEEE 3007.2, *IEEE Recommended Practice for the Maintenance of Industrial and Commercial Power Systems*, 2010.

IEEE 3007.3, *IEEE Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems*, 2012.

Anderson, W. E., "Risk Analysis Methodology Applied to Industrial Machine Development," *IEEE Transactions on Industrial Applications,* Vol. 41, No. 1, January/February 2005, pp. 180–187.

Ammerman, R. F., Gammon, T., Sen, P. K., and Nelson, J. P., "DC-Arc Models and Incident-Energy Calculations," *IEEE Transactions on Industrial Applications*, Vol. 46, No. 5, 2010.

Doan, D. R, "Arc Flash Calculations for Exposures to DC Systems," *IEEE Transactions on Industrial Applications*, Vol 46, No. 6, 2010.

Doughty, R. L., T. E. Neal, and H. L. Floyd II, "Predicting Incident Energy to Better Manage the Electric Arc Hazard on 600 V Power Distribution Systems," *Record of Conference Papers IEEE IAS 45th Annual Petroleum and Chemical Industry Conference*, September 28–30, 1998.

Lee, R., "The Other Electrical Hazard: Electrical Arc Flash Burns," *IEEE Trans. Applications*, Vol. 1A-18, No. 3, May/June 1982.

B.1.8 ISA Publications. Instrumentation, Systems, and Automation Society, 67 Alexander Drive, Research Triangle Park, NC 27709.

ANSI/ISA 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements,* 2007.

B.1.9 ISEA Publications. International Safety Equipment Association, 1901 North Moore Street, Arlington, VA 22209-1762.

ANSI/ISEA Z358.1, *American National Standard for Emergency Eye Wash and Shower Equipment*, 2009.

B.1.10 ISO Publications. International Organization for Standardization, 1, Ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland.

ISO 14001, *Environmental Management Systems — Requirements with Guidance for Use*, 2004.

B.1.11 NIOSH Publications. National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, 1600 Clifton Road, Atlanta, GA 30333.

DHHS (NIOSH) Publication No. 94-110, *Applications Manual for the Revised NIOSH Lifting Equation*, 1994.

B.1.12 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

ANSI/UL 943, *Standard for Ground-Fault Circuit Interrupters*, 2006 (R 2012).

• **B.1.13 U.S. Government Publications.** U.S. Government Printing Office, Washington, DC 20402.

• Title 29, Code of Federal Regulations, Part 1910, Occupational Safety and Health Standards, Subpart S, Electrical, 1910.137, Personal Protective Equipment, and 1910.305(j)(7), Storage Batteries; and Part 1926, Safety and Health Regulations for Construction, Subpart K, Electrical, 1926.441, Batteries and Battery Charging.

B.1.14 Other Publications.

• "DC Arc Hazard Assessment Phase II," Copyright Material, Kinectrics Inc., Report No. K-012623-RA-0002-R00.

Informative Annex C Limits of Approach

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 Preparation for Approach. Observing a safe approach distance from exposed energized electrical conductors or circuit parts is an effective means of maintaining electrical safety. As the distance between a person and the exposed energized conductors or circuit parts decreases, the potential for electrical accident increases.

C.1.1 Unqualified Persons, Safe Approach Distance. Unqualified persons are safe when they maintain a distance from the exposed energized conductors or circuit parts, including the longest conductive object being handled, so that they cannot contact or enter a specified air insulation distance to the exposed energized electrical conductors or circuit parts. This safe approach distance is the limited approach boundary. Further, persons must not cross the arc flash boundary unless they are wearing appropriate personal protective clothing and are under the close supervision of a qualified person. Only when continuously escorted by a qualified person should an unqualified person cross the limited approach boundary. Under no circumstance should an unqualified person cross the restricted approach boundary, where special shock protection techniques and equipment are required.

C.1.2 Qualified Persons, Safe Approach Distance.

C.1.2.1 Determine the arc flash boundary and, if the boundary is to be crossed, appropriate arc-rated protective equipment must be utilized.

C.1.2.2 For a person to cross the limited approach boundary and enter the limited space, a person should meet the following criteria:

(1) Be qualified to perform the job/task
(2) Be able to identify the hazards and associated risks with the tasks to be performed

C.1.2.3 To cross the restricted approach boundary and enter the restricted space, qualified persons should meet the following criteria:

(1) Have an energized electrical work permit authorized by management
(2) Use personal protective equipment (PPE) that is rated for the voltage and energy level involved
(3) Minimize the likelihood of bodily contact with exposed energized conductors and circuit parts from inadvertent movement by keeping as much of the body out of the restricted space as possible and using only protected body parts in the space as necessary to accomplish the work
(4) Use insulated tools and equipment

(See Figure C.1.2.3.)

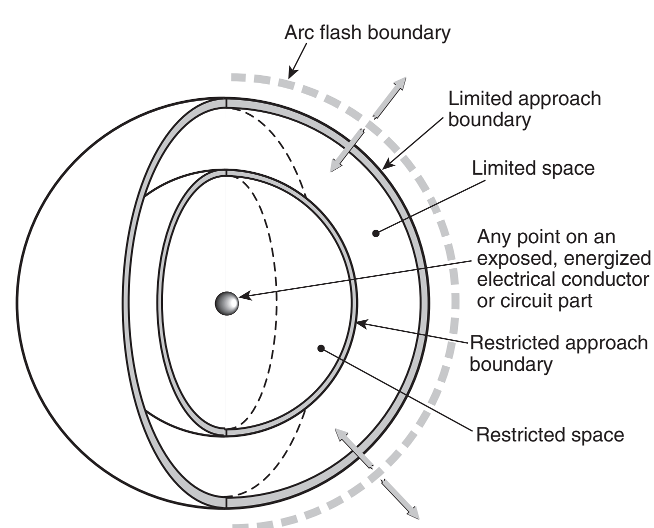

Figure C.1.2.3 Limits of Approach.

C.2 Basis for Distance Values in Tables 130.4(D)(a) and 130.4(D)(b).

C.2.1 General Statement. Columns 2 through 4 of Table 130.4(D)(a) and Table 130.4(D)(b) show various distances from the exposed energized electrical conductors or circuit parts. They include dimensions that are added to a basic minimum air insulation distance. Those basic minimum air insulation distances for voltages 72.5 kV and under are based on IEEE 4, *Standard Techniques for High Voltage Testing,* Appendix 2B; and voltages over 72.5 kV are based on IEEE 516, *Guide for Maintenance Methods on Energized Power Lines*. The minimum air insulation distances that are required to avoid flashover are as follows:

(1) ≤300 V: 1 mm (0 ft 0.03 in.)
(2) >300 V to ≤750 V: 2 mm (0 ft 0.07 in.)
(3) >750 V to ≤2 kV: 5 mm (0 ft 0.19 in.)
(4) >2 kV to ≤15 kV: 39 mm (0 ft 1.5 in.)
(5) >15 kV to ≤36 kV: 161 mm (0 ft 6.3 in.)
(6) >36 kV to ≤48.3 kV: 254 mm (0 ft 10.0 in.)
(7) >48.3 kV to ≤72.5 kV: 381 mm (1 ft 3.0 in.)
(8) >72.5 kV to ≤121 kV: 640 mm (2 ft 1.2 in.)
(9) >138 kV to ≤145 kV: 778 mm (2 ft 6.6 in.)

(10) >161 kV to ≤169 kV: 915 mm (3 ft 0.0 in.)
(11) >230 kV to ≤242 kV: 1.281 m (4 ft 2.4 in.)
(12) >345 kV to ≤362 kV: 2.282 m (7 ft 5.8 in.)
(13) >500 kV to ≤550 kV: 3.112 m (10 ft 2.5 in.)
(14) >765 kV to ≤800 kV: 4.225 m (13 ft 10.3 in.)

C.2.1.1 Column 1. The voltage ranges have been selected to group voltages that require similar approach distances based on the sum of the electrical withstand distance and an inadvertent movement factor. The value of the upper limit for a range is the maximum voltage for the highest nominal voltage in the range, based on ANSI C84.1, *Electric Power Systems and Equipment— Voltage Ratings (60 Hz).* For single-phase systems, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.

C.2.1.2 Column 2. The distances in column 2 are based on OSHA's rule for unqualified persons to maintain a 3.05 m (10 ft) clearance for all voltages up to 50 kV (voltage-to-ground), plus 100 mm (4.0 in.) for each 10 kV over 50 kV.

C.2.1.3 Column 3. The distances in column 3 are based on the following:

(1) ≤750 V: Use *NEC* Table 110.26(A)(1), Working Spaces, Condition 2, for the 151 V to 600 V range.
(2) >750 V to ≤145 kV: Use *NEC* Table 110.34(A), Working Space, Condition 2.
(3) >145 kV: Use OSHA's 3.05 m (10 ft) rules as used in Column 2.

C.2.1.4 Column 4. The distances in column 4 are based on adding to the flashover dimensions shown in C.2.1 the following inadvertent movement distance:

≤300 V: Avoid contact.

Based on experience and precautions for household 120/240-V systems:

>300 V to ≤750 V: Add 304.8 mm (1 ft 0 in.) for inadvertent movement.

These values have been found to be adequate over years of use in ANSI/IEEE C2, *National Electrical Safety Code,* in the approach distances for communication workers.

>72.5 kV: Add 304.8 mm (1 ft 0 in.) for inadvertent movement.

These values have been found to be adequate over years of use in ANSI/IEEE C2, *National Electrical Safety Code,* in the approach distances for supply workers.

Informative Annex D Incident Energy and Arc Flash Boundary Calculation Methods

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

D.1 Introduction. Informative Annex D summarizes calculation methods available for calculating arc flash boundary and incident energy. It is important to investigate the limitations of any methods to be used. The limitations of methods summarized in Informative Annex D are described in Table D.1.

D.2 Ralph Lee Calculation Method.

D.2.1 Basic Equations for Calculating Arc Flash Boundary Distances. The short-circuit symmetrical ampacity, I_{sc}, from a bolted three-phase fault at the transformer terminals is calculated with the following formula:

[D.2.1(a)]

$$I_{sc} = \{[MVA \text{ Base } \times 10^6] \div [1.732 \times V]\} \times \{100 \div \%Z\}$$

where I_{sc} is in amperes, V is in volts, and $\%Z$ is based on the transformer *MVA*.

A typical value for the maximum power, P (in MW) in a three-phase arc can be calculated using the following formula:

[D.2.1(b)]

$$P = [\text{maximum bolted fault, in } MVA_{bf}] \times 0.707^2$$

[D.2.1(c)]

$$P = 1.732 \times V \times I_{sc} \times 10^{-6} \times 0.707^2$$

The arc flash boundary distance is calculated in accordance with the following formulae:

[D.2.1(d)]

$$D_c = [2.65 \times MVA_{bf} \times t]^{1/2}$$

[D.2.1(e)]

$$D_c = [53 \times MVA \times t]^{1/2}$$

where:

D_c = distance in feet of person from arc source for a just curable burn (that is, skin temperature remains less than 80°C).

MVA_{bf} = bolted fault *MVA* at point involved.

MVA = *MVA* rating of transformer. For transformers with *MVA* ratings below 0.75 *MVA*, multiply the transformer *MVA* rating by 1.25.

t = time of arc exposure in seconds.

The clearing time for a current-limiting fuse is approximately ¼ cycle or 0.004 second if the arcing fault current is in the fuse's current-limiting range. The clearing time of a 5-kV and 15-kV circuit breaker is approximately 0.1 second or 6 cycles if the instantaneous function is installed and operating. This can be broken down as follows: actual breaker time (approximately 2 cycles), plus relay operating time of approximately 1.74 cycles, plus an additional safety margin of 2 cycles, giving a total time of approximately 6 cycles. Additional time must be added if a time delay function is installed and operating.

The formulas used in this explanation are from Ralph Lee, "The Other Electrical Hazard: Electrical Arc Flash Burns," in *IEEE Trans. Industrial Applications*. The calculations are based on the worst-case arc impedance. *(See Table D.2.1.)*

Table D.1 Limitation of Calculation Methods

Section	Source	Limitations/Parameters
D.2	Lee, "The Other Electrical Hazard: Electrical Arc Flash Burns"	Calculates incident energy and arc flash boundary for arc in open air; conservative over 600 V and becomes more conservative as voltage increases
D.3	Doughty, et al., "Predicting Incident Energy to Better Manage the Electrical Arc Hazard on 600 V Power Distribution Systems"	Calculates incident energy for three-phase arc on systems rated 600 V and below; applies to short-circuit currents between 16 kA and 50 kA
D.4	IEEE 1584, *Guide for Performing Arc Flash Calculations*	Calculates incident energy and arc flash boundary for: 208 V to 15 kV; three-phase; 50 Hz to 60 Hz; 700 A to 106,000 A short-circuit current; and 13 mm to 152 mm conductor gaps
D.5	Doan, "Arc Flash Calculations for Exposure to DC Systems"	Calculates incident energy for dc systems rated up to 1000 V dc

Table D.2.1 Flash Burn Hazard at Various Levels in a Large Petrochemical Plant

(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Bus Nominal Voltage Levels	System (MVA)	Transformer (MVA)	System or Transformer (% *Z*)	Short-Circuit Symmetrical (A)	Clearing Time of Fault (cycles)	Arc Flash Boundary Typical Distance*	
						SI	U.S.
230 kV	9000		1.11	23,000	6.0	15 m	49.2 ft
13.8 kV	750		9.4	31,300	6.0	1.16 m	3.8 ft
Load side of all 13.8-V fuses	750		9.4	31,300	1.0	184 mm	0.61 ft
4.16 kV		10.0	5.5	25,000	6.0	2.96 m	9.7 ft
4.16 kV		5.0	5.5	12,600	6.0	1.4 m	4.6 ft
Line side of incoming 600-V fuse		2.5	5.5	44,000	60.0–120.0	7 m–11 m	23 ft–36 ft
600-V bus		2.5	5.5	44,000	0.25	268 mm	0.9 ft
600-V bus		1.5	5.5	26,000	6.0	1.6 m	5.4 ft
600-V bus		1.0	5.57	17,000	6.0	1.2 m	4 ft

*Distance from an open arc to limit skin damage to a curable second degree skin burn [less than 80°C (176°F) on skin] in free air.

D.2.2 Single-Line Diagram of a Typical Petrochemical Complex. The single-line diagram *(see Figure D.2.2)* illustrates the complexity of a distribution system in a typical petrochemical plant.

D.2.3 Sample Calculation. Many of the electrical characteristics of the systems and equipment are provided in Table D.2.1. The sample calculation is made on the 4160-volt bus 4A or 4B. Table D.2.1 tabulates the results of calculating the arc flash boundary for each part of the system. For this calculation, based on Table D.2.1, the following results are obtained:

(1) Calculation is made on a 4160-volt bus.
(2) Transformer *MVA* (and base *MVA*) = 10 *MVA*.
(3) Transformer impedance on 10 *MVA* base = 5.5 percent.
(4) Circuit breaker clearing time = 6 cycles.

Using Equation D.2.1(a), calculate the short-circuit current:

$$\begin{aligned} I_{sc} &= \left\{\left[MVA \text{ Base } \times 10^6\right] \div \left[1.732 \times V\right]\right\} \times \{100 \div \%Z\} \\ &= \left\{\left[10 \times 10^6\right] \div \left[1.732 \times 4160\right]\right\} \times \{100 \div 5.5\} \\ &= 25{,}000 \text{ amperes} \end{aligned}$$

Using Equation D.2.1(b), calculate the power in the arc:

$$\begin{aligned} P &= 1.732 \times 4160 \times 25{,}000 \times 10^{-6} \times 0.707^2 \\ &= 91 \text{ MW} \end{aligned}$$

Using Equation D.2.1(d), calculate the second degree burn distance:

$$\begin{aligned} D_c &= \left\{2.65 \times \left[1.732 \times 25{,}000 \times 4160 \times 10^{-6}\right] \times 0.1\right\}^{1/2} \\ &= 6.9 \text{ or } 7.00 \text{ ft} \end{aligned}$$

Or, using Equation D.2.1(e), calculate the second degree burn distance using an alternative method:

$$\begin{aligned} D_c &= \left[53 \times 10 \times 0.1\right]^{1/2} \\ &= 7.28 \text{ ft} \end{aligned}$$

D.2.4 Calculation of Incident Energy Exposure Greater Than 600 V for an Arc Flash Hazard Analysis. The equation that follows can be used to predict the incident energy produced by a three-phase arc in open air on systems rated above 600 V. The parameters required to make the calculations follow.

(1) The maximum bolted fault, three-phase short-circuit current available at the equipment.
(2) The total protective device clearing time (upstream of the prospective arc location) at the maximum short-circuit current. If the total protective device clearing time is longer than 2 seconds, consider how long a person is likely to remain in the location of the arc flash. It is likely that a person exposed to an arc flash will move away quickly if it is physically possible, and 2 seconds is a reasonable maximum time for calculations. A person in a bucket truck or a person who has

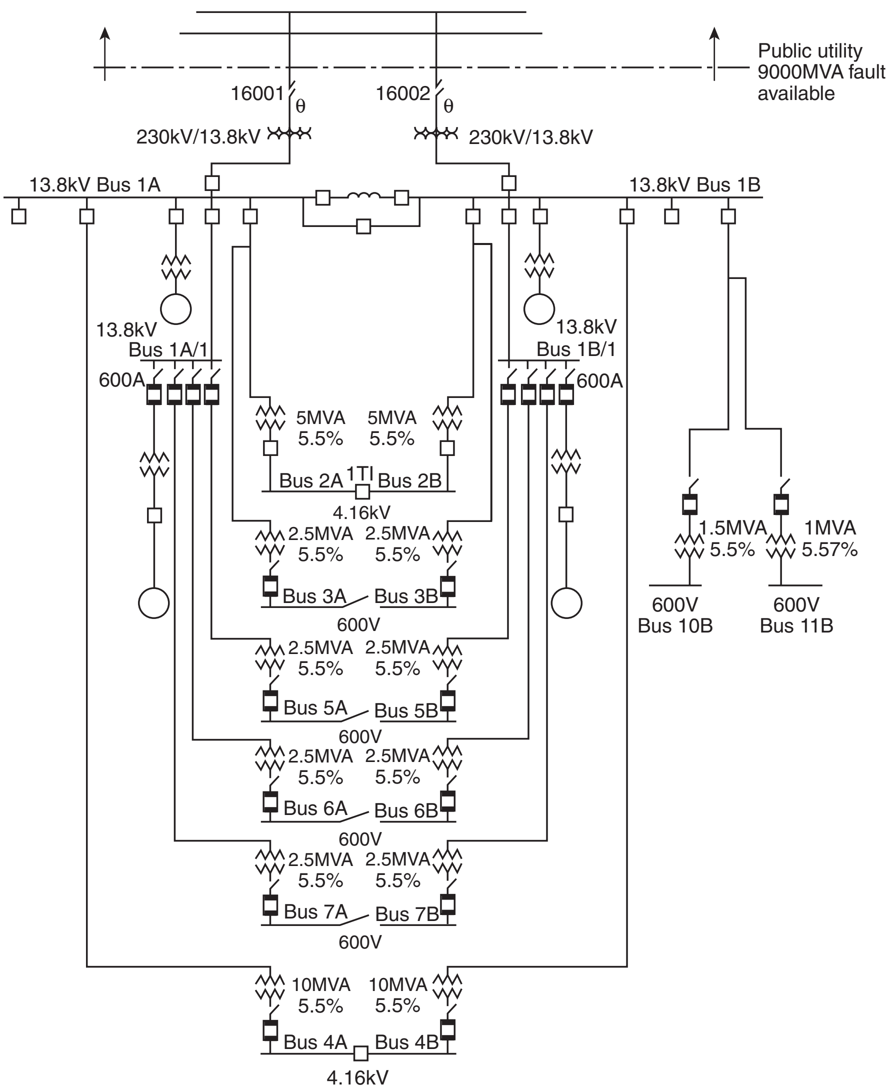

Figure D.2.2 Single-Line Diagram of a Typical Petrochemical Complex.

crawled into equipment will need more time to move away. Sound engineering judgment must be used in applying the 2-second maximum clearing time, since there could be circumstances where an employee's egress is inhibited.

(3) The distance from the arc source.

(4) Rated phase-to-phase voltage of the system.

$$E = \frac{793 \times F \times V \times t_A}{D^2} \quad \textbf{[D.2.4(4)]}$$

where:

E = incident energy, cal/cm^2

F = bolted fault short-circuit current, kA

V = system phase-to-phase voltage, kV

t_A = arc duration, sec

D = distance from the arc source, in.

D.3 Doughty Neal Paper.

D.3.1 Calculation of Incident Energy Exposure. The following equations can be used to predict the incident energy produced by a three-phase arc on systems rated 600 V and below. The results of these equations might not represent the worst case in all situations. It is essential that the equations be used only within the limitations indicated in the definitions of the variables shown under the equations. The equations must be used only under qualified engineering supervision.

Informational Note: Experimental testing continues to be performed to validate existing incident energy calculations and to determine new formulas.

The parameters required to make the calculations follow.

(1) The maximum bolted fault, three-phase short-circuit current available at the equipment and the minimum fault level at which the arc will self-sustain. (Calculations should be made using the maximum value, and then at lowest fault level at which the arc is self-sustaining. For 480-volt systems, the industry accepted minimum level for a sustaining arcing fault is 38 percent of the available bolted fault, three-phase short-circuit current. The highest incident energy exposure could occur at these lower levels where the overcurrent device could take seconds or minutes to open.)
(2) The total protective device clearing time (upstream of the prospective arc location) at the maximum short-circuit current, and at the minimum fault level at which the arc will sustain itself.
(3) The distance of the worker from the prospective arc for the task to be performed.

Typical working distances used for incident energy calculations are as follows:

(1) Low voltage (600 V and below) MCC and panelboards — 455 mm (18 in.)
(2) Low voltage (600 V and below) switchgear — 610 mm (24 in.)
(3) Medium voltage (above 600 V) switchgear — 910 mm (36 in.)

D.3.2 Arc in Open Air. The estimated incident energy for an arc in open air is as follows:

$$E_{MA} = 5271 D_A^{-1.9593} t_A \begin{bmatrix} 0.0016F^2 \\ -0.0076F \\ +0.8938 \end{bmatrix} \quad \textbf{[D.3.2(a)]}$$

where:
E_{MA} = maximum open arc incident energy, cal/cm^2
D_A = distance from arc electrodes, in. (for distances 18 in. and greater)
t_A = arc duration, sec
F = short-circuit current, kA (for the range of 16 kA to 50 kA)

Sample Calculation: Using Equation D.3.2(a), calculate the maximum open arc incident energy, cal/cm^2, where D_A = 18 in., t_A = 0.2 second, and F = 20 kA.

$$\begin{aligned} E_{MA} &= 5271\ D_A^{-1.9593} t_A \begin{bmatrix} 0.0016F^2 - 0.0076F \\ +0.8938 \end{bmatrix} \quad \textbf{[D.3.2(b)]} \\ &= 5271 \times .0035 \times 0.2 [0.0016 \times 400 - 0.0076 \times 20 + 0.8938] \\ &= 3.69 \times [1.381] \\ &= 21.33\ \text{J/cm}^2 (5.098\ \text{cal/cm}^2) \end{aligned}$$

D.3.3 Arc in a Cubic Box. The estimated incident energy for an arc in a cubic box (20 in. on each side, open on one end) is given in the equation that follows. This equation is applicable to arc flashes emanating from within switchgear, motor control centers, or other electrical equipment enclosures.

$$E_{MB} = 1038.7 D_B^{-1.4738} t_A \begin{bmatrix} 0.0093F^2 \\ -0.3453F \\ +5.9675 \end{bmatrix} \quad \textbf{[D.3.3(a)]}$$

where:
E_{MB} = maximum 20 in. cubic box incident energy, cal/cm^2
D_B = distance from arc electrodes, in. (for distances 18 in. and greater)
t_A = arc duration, sec
F = short-circuit current, kA (for the range of 16 kA to 50 kA)

Sample Calculation: Using Equation D.3.3(a), calculate the maximum 20 in. cubic box incident energy, cal/cm^2, using the following:

(1) D_B = 18 in.
(2) t_A = 0.2 sec
(3) F = 20 kA

$$\begin{aligned} E_{MB} &= 1038.7 D_B^{-1.4738} t_A \begin{bmatrix} 0.0093F^2 - 0.3453F \\ +5.9675 \end{bmatrix} \quad \textbf{[D.3.3(b)]} \\ &= 1038 \times 0.0141 \times 0.2 \begin{bmatrix} 0.0093 \times 400 - 0.3453 \times 20 \\ +5.9675 \end{bmatrix} \\ &= 2.928 \times [2.7815] \\ &= 34.1\ \text{J/cm}^2 (8.144\ \text{cal/cm}^2) \end{aligned}$$

D.3.4 Reference. The equations for this section were derived in the IEEE paper by R. L. Doughty, T. E. Neal, and H. L. Floyd, II, "Predicting Incident Energy to Better Manage the Electric Arc Hazard on 600 V Power Distribution Systems."

D.4 IEEE 1584 Calculation Method.

D.4.1 Basic Equations for Calculating Incident Energy and Arc Flash Boundary. This section provides excerpts from IEEE 1584, *IEEE Guide for Performing Arc Flash Hazard Calculations*, for estimating incident energy and arc flash boundaries based on statistical analysis and curve fitting of available test data. An IEEE working group produced the data from tests it performed to produce models of incident energy.

The complete data, including a spreadsheet calculator to solve the equations, can be found in the IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*. Users are encouraged to consult the latest version of the complete document to understand the basis, limitation, rationale, and other pertinent information for proper application of the standard. It can be ordered from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

D.4.1.1 System Limits. An equation for calculating incident energy can be empirically derived using statistical analysis of raw data along with a curve-fitting algorithm. It can be used for systems with the following limits:

(1) 0.208 kV to 15 kV, three-phase
(2) 50 Hz to 60 Hz
(3) 700 A to 106,000 A available short-circuit current
(4) 13 mm to 152 mm conductor gaps

For three-phase systems in open-air substations, open-air transmission systems, and distribution systems, a theoretically derived model is available. This theoretically derived model is intended for use with applications where faults escalate to three-phase faults. Where such an escalation is not possible or likely, or where single-phase systems are encountered, this equation will likely provide conservative results.

D.4.2 Arcing Current. To determine the operating time for protective devices, find the predicted three-phase arcing current.

For applications with a system voltage under 1 kV, solve Equation D.4.2(a) as follows:

$$\lg I_a = K + 0.662 \lg I_{bf} + 0.0966V + 0.000526G + 0.5588V\left(\lg I_{bf}\right) - 0.00304G\left(\lg I_{bf}\right) \quad \textbf{[D.4.2(a)]}$$

where:
lg = the $\log_{10}$
I_a = arcing current, kA
K = –0.153 for open air arcs; –0.097 for arcs-in-a-box
I_{bf} = bolted three-phase available short-circuit current (symmetrical rms), kA
V = system voltage, kV
G = conductor gap, mm *(see Table D.4.2)*

For systems greater than or equal to 1 kV, use Equation D.4.2(b):

$$\lg I_a = 0.00402 + 0.983 \lg I_{bf} \quad \textbf{[D.4.2(b)]}$$

This higher voltage formula is used for both open-air arcs and for arcs-in-a-box.

Convert from lg:

$$I_a = 10^{\lg I_a} \quad \textbf{[D.4.2(c)]}$$

Use 0.85 I_a to find a second arc duration. This second arc duration accounts for variations in the arcing current and the time for the overcurrent device to open. Calculate the incident energy using both arc durations (I_a and 0.85 I_a), and use the higher incident energy.

Table D.4.2 Factors for Equipment and Voltage Classes

System Voltage (kV)	Type of Equipment	Typical Conductor Gap (mm)	Distance Exponent Factor *x*
0.208–1	Open air	10–40	2.000
	Switchgear	32	1.473
	MCCs and panels	25	1.641
	Cables	13	2.000
>1–5	Open air	102	2.000
	Switchgear	13–102	0.973
	Cables	13	2.000
>5–15	Open air	13–153	2.000
	Switchgear	153	0.973
	Cables	13	2.000

D.4.3 Incident Energy at Working Distance — Empirically Derived Equation. To determine the incident energy using the empirically derived equation, determine the $\log_{10}$ of the normalized incident energy. The following equation is based on data normalized for an arc time of 0.2 second and a distance from the possible arc point to the person of 610 mm:

$$\lg E_n = k_1 + k_2 + 1.081 \lg I_a + 0.0011G \quad \textbf{[D.4.3(a)]}$$

where:
E_n = incident energy, normalized for time and distance, J/cm^2
k_1 = –0.792 for open air arcs
= –0.555 for arcs-in-a-box
k_2 = 0 for ungrounded and high-resistance grounded systems
= –0.113 for grounded systems
G = conductor gap, mm *(see Table D.4.2)*

Then,

$$E_n = 10^{\lg E_n} \quad \textbf{[D.4.3(b)]}$$

Converting from normalized:

$$E = 4.184 C_f \; E_n \left(\frac{t}{0.2}\right)\left(\frac{610^x}{D^x}\right) \qquad \textbf{[D.4.3(c)]}$$

where:
E = incident energy, J/cm^2.
C_f = calculation factor
= 1.0 for voltages above 1 kV.
= 1.5 for voltages at or below 1 kV.
E_n = incident energy normalized.
t = arcing time, sec.
x = distance exponent from Table D.4.2.
D = distance, mm, from the arc to the person (working distance). See Table D.4.3 for typical working distances.

If the arcing time, t, in Equation D.4.3(c) is longer than 2 seconds, consider how long a person is likely to remain in the location of the arc flash. It is likely that a person exposed to an arc flash will move away quickly if it is physically possible, and 2 seconds is a reasonable maximum time for calculations. Sound engineering judgment should be used in applying the 2-second maximum clearing time, because there could be circumstances where an employee's egress is inhibited. For example, a person in a bucket truck or a person who has crawled into equipment will need more time to move away.

Table D.4.3 Typical Working Distances

Classes of Equipment	Typical Working Distance* (mm)
15-kV switchgear	910
5-kV switchgear	910
Low-voltage switchgear	610
Low-voltage MCCs and panelboards	455
Cable	455
Other	To be determined in field

* Typical working distance is the sum of the distance between the worker and the front of the equipment and the distance from the front of the equipment to the potential arc source inside the equipment.

D.4.4 Incident Energy at Working Distance — Theoretical Equation. The following theoretically derived equation can be applied in cases where the voltage is over 15 kV or the gap is outside the range:

$$E = 2.142 \times 10^6 V I_{bf} \left(\frac{t}{D^2}\right) \qquad \textbf{[D.4.4]}$$

where:
E = incident energy, J/cm^2
V = system voltage, kV
I_{bf} = available three-phase bolted fault current
t = arcing time, sec
D = distance (mm) from the arc to the person (working distance)

For voltages over 15 kV, arcing fault current and bolted fault current are considered equal.

D.4.5 Arc Flash Boundary. The arc flash boundary is the distance at which a person is likely to receive a second degree burn. The onset of a second degree burn is assumed to be when the skin receives 5.0 J/cm^2 of incident energy.

For the empirically derived equation,

$$D_B = \left[4.184 C_f E_n \left(\frac{t}{0.2}\right)\left(\frac{610^x}{E_B}\right)\right]^{\frac{1}{x}} \qquad \textbf{[D.4.5(a)]}$$

For the theoretically derived equation,

$$D_B = \sqrt{2.142 \times 10^6 V I_{bf} \left(\frac{t}{E_B}\right)} \qquad \textbf{[D.4.5(b)]}$$

where:
D_B = distance (mm) of the arc flash boundary from the arcing point
C_f = calculation factor
= 1.0 for voltages above 1 kV
= 1.5 for voltages at or below 1 kV
E_n = incident energy normalized
t = time, sec
x = distance exponent from Table D.4.2
E_B = incident energy in J/cm^2 at the distance of the arc flash boundary
V = system voltage, kV
I_{bf} = bolted three-phase available short-circuit current

Informational Note: These equations could be used to determine whether selected personal protective equipment (PPE) is adequate to prevent thermal injury at a specified distance in the event of an arc flash.

D.4.6 Current-Limiting Fuses. The formulas in this section were developed for calculating arc flash energies for use with current-limiting Class L and Class RK1 fuses. The testing was done at 600 V and at a distance of 455 mm, using commercially available fuses from one manufacturer. The following variables are noted:

I_{bf} = available three-phase bolted fault current (symmetrical rms), kA

E = incident energy, J/cm^2

(A) Class L Fuses 1601 A through 2000 A. Where $I_{bf} < 22.6$ kA, calculate the arcing current using Equation

D.4.2(a), and use time-current curves to determine the incident energy using Equations D.4.3(a), D.4.3(b), and D.4.3(c).

Where 22.6 kA ≤ I_{bf} ≤ 65.9 kA,

$$E = 4.184\left(-0.1284 I_{bf} + 32.262\right) \quad \textbf{[D.4.6(a)]}$$

Where 65.9 kA < I_{bf} ≤106 kA,

$$E = 4.184\left(-0.5177 I_{bf} + 57.917\right) \quad \textbf{[D.4.6(b)]}$$

Where I_{bf} >106 kA, contact the manufacturer.

(B) Class L Fuses 1201 A through 1600 A. Where I_{bf} <15.7 kA, calculate the arcing current using Equation D.4.2(a), and use time-current curves to determine the incident energy using Equations D.4.3(a), D.4.3(b), and D.4.3(c).

Where 15.7 kA ≤ I_{bf} ≤ 31.8 kA,

$$E = 4.184\left(-0.1863 I_{bf} + 27.926\right) \quad \textbf{[D.4.6(c)]}$$

Where 44.1 kA ≤ I_{bf} ≤ 65.9 kA,

$$E = 12.3\,\text{J/cm}^2\left(2.94\ \text{cal/cm}^2\right) \quad \textbf{[D.4.6(e)]}$$

Where 65.9 kA <I_{bf} ≤106 kA,

$$E = 4.184\left(-0.0631 I_{bf} + 7.0878\right) \quad \textbf{[D.4.6(f)]}$$

Where I_{bf} >106 kA, contact the manufacturer.

(C) Class L Fuses 801 A through 1200 A. Where I_{bf} <15.7 kA, calculate the arcing current using Equation D.4.2(a), and use time-current curves to determine the incident energy per Equations D.4.3(a), D.4.3(b), and D.4.3(c).

Where 15.7 kA ≤ I_{bf} ≤ 22.6 kA,

$$E = 4.184\left(-0.1928 I_{bf} + 14.226\right) \quad \textbf{[D.4.6(g)]}$$

Where 22.6 kA < I_{bf} ≤ 44.1 kA,

$$E = 4.184\begin{pmatrix}0.0143 I_{bf}^{\,2} - 1.3919 I_{bf}\\ +34.045\end{pmatrix} \quad \textbf{[D.4.6(h)]}$$

Where 44.1 kA < I_{bf} ≤ 106 kA,

$$E = 1.63 \quad \textbf{[D.4.6(i)]}$$

Where I_{bf} >106 kA, contact the manufacturer.

(D) Class L Fuses 601 A through 800 A. Where I_{bf} <15.7 kA, calculate the arcing current using Equation D.4.2(a), and use time-current curves to determine the incident energy using Equations D.4.3(a), D.4.3(b), and D.4.3(c).

Where 15.7 kA ≤ I_{bf} ≤ 44.1 kA,

$$E = 4.184\left(-0.0601 I_{bf} + 2.8992\right) \quad \textbf{[D.4.6(j)]}$$

Where 44.1 kA < I_{bf} ≤106 kA,

$$E = 1.046 \quad \textbf{[D.4.6(k)]}$$

Where I_{bf} > 106 kA, contact the manufacturer.

(E) Class RK1 Fuses 401 A through 600 A. Where I_{bf} < 8.5 kA, calculate the arcing current using Equation D.4.2(a), and use time-current curves to determine the incident energy using Equations D.4.3(a), D.4.3(b), and D.4.3(c).

Where 8.5 kA ≤ I_{bf} ≤ 14 kA,

$$E = 4.184\left(-3.0545 I_{bf} + 43.364\right) \quad \textbf{[D.4.6(l)]}$$

Where 14 kA < I_{bf} ≤ 15.7 kA,

$$E = 2.510 \quad \textbf{[D.4.6(m)]}$$

Where 15.7 kA < I_{bf} ≤ 22.6 kA,

$$E = 4.184\left(-0.0507 I_{bf} + 1.3964\right) \quad \textbf{[D.4.6(n)]}$$

Where 22.6 kA < I_{bf} ≤ 106 kA,

$$E = 1.046 \quad \textbf{[D.4.6(o)]}$$

Where I_{bf} > 106 kA, contact the manufacturer.

(F) Class RK1 Fuses 201 A through 400 A. Where I_{bf} < 3.16 kA, calculate the arcing current using Equation D.4.2(a), and use time-current curves to determine the incident energy using Equations D.4.3(a), D.4.3(b), and D.4.3(c).

Where 3.16 kA ≤ I_{bf} ≤ 5.04 kA,

$$E = 4.184\left(-19.053 I_{bf} + 96.808\right) \quad \text{[D.4.6(p)]}$$

Where 5.04 kA < I_{bf} ≤ 22.6 kA,

$$E = 4.184\left(-0.0302 I_{bf} + 0.9321\right) \quad \text{[D.4.6(q)]}$$

Where 22.6 kA < I_{bf} ≤ 106 kA,

$$E = 1.046 \quad \text{[D.4.6(r)]}$$

Where I_{bf} >106 kA, contact the manufacturer.

(G) Class RK1 Fuses 101 A through 200 A. Where I_{bf} <1.16 kA, calculate the arcing current using Equation D.4.2(a), and use time-current curves to determine the incident energy using Equations D.4.3(a), D.4.3(b), and D.4.3(c).

Where 1.16 kA ≤ I_{bf} ≤1.6 kA,

$$E = 4.184\left(-18.409 I_{bf} + 36.355\right) \quad \textbf{[D.4.6(s)]}$$

Where 1.6 kA < I_{bf} ≤3.16 kA,

$$E = 4.184\left(-4.2628 I_{bf} + 13.721\right) \quad \textbf{[D.4.6(t)]}$$

Where 3.16 kA < I_{bf} ≤106 kA,

$$E = 1.046 \quad \textbf{[D.4.6(u)]}$$

Where I_{bf} > 106 kA, contact the manufacturer.

(H) Class RK1 Fuses 1 A through 100 A. Where I_{bf} < 0.65 kA, calculate the arcing current using Equation D.4.2(a), and use time-current curves to determine the incident energy using Equations D.4.3(a), D.4.3(b), and D.4.3(c).

Where 0.65 kA ≤ I_{bf} ≤ 1.16 kA,

$$E = 4.184\left(-11.176 I_{bf} + 13.565\right) \quad \textbf{[D.4.6(v)]}$$

Where 1.16 kA < I_{bf} ≤ 1.4 kA,

$$E = 4.184\left(-1.4583 I_{bf} + 2.2917\right) \quad \textbf{[D.4.6(w)]}$$

Where 1.4 kA < I_{bf} ≤ 106 kA,

$$E = 1.046 \quad \textbf{[D.4.6(x)]}$$

Where I_{bf} > 106 kA, contact the manufacturer.

D.4.7 Low-Voltage Circuit Breakers. The equations in Table D.4.7 can be used for systems with low-voltage circuit breakers. The results of the equations will determine the incident energy and arc flash boundary when I_{bf} is within the range as described. Time-current curves for the circuit breaker are not necessary within the appropriate range.

When the bolted fault current is below the range indicated, calculate the arcing current using Equation D.4.2(a), and use time-current curves to determine the incident energy using Equations D.4.3(a), D.4.3(b), and D.4.3(c).

Table D.4.7 Incident Energy and Arc Flash Protection Boundary by Circuit Breaker Type and Rating

			480 V and Lower		575 V–600 V	
Rating (A)	**Breaker Type**	**Trip Unit Type**	**Incident Energy (J/cm^2)[a]**	**Arc Flash Boundary (mm)[a]**	**Incident Energy (J/cm^2)[a]**	**Arc Flash Boundary (mm)[a]**
100–400	MCCB	TM or M	$0.189\ I_{bf} + 0.548$	$9.16\ I_{bf} + 194$	$0.271\ I_{bf} + 0.180$	$11.8\ I_{bf} + 196$
600–1200	MCCB	TM or M	$0.223\ I_{bf} + 1.590$	$8.45\ I_{bf} + 364$	$0.335\ I_{bf} + 0.380$	$11.4\ I_{bf} + 369$
600–1200	MCCB	E, LI	$0.377\ I_{bf} + 1.360$	$12.50\ I_{bf} + 428$	$0.468\ I_{bf} + 4.600$	$14.3\ I_{bf} + 568$
1600–6000	MCCB or ICCB	TM or E, LI	$0.448\ I_{bf} + 3.000$	$11.10\ I_{bf} + 696$	$0.686\ I_{bf} + 0.165$	$16.7\ I_{bf} + 606$
800–6300	LVPCB	E, LI	$0.636\ I_{bf} + 3.670$	$14.50\ I_{bf} + 786$	$0.958\ I_{bf} + 0.292$	$19.1\ I_{bf} + 864$
800–6300	LVPCB	E, LS[b]	$4.560\ I_{bf} + 27.230$	$47.20\ I_{bf} + 2660$	$6.860\ I_{bf} + 2.170$	$62.4\ I_{bf} + 2930$

MCCB: Molded-case circuit breaker.
TM: Thermal-magnetic trip units.
M: Magnetic (instantaneous only) trip units.
E: Electronic trip units have three characteristics that may be used separately or in combination: L: Long time, S: Short time, I: Instantaneous.
ICCB: Insulated-case circuit breaker.
LVPCB: Low-voltage power circuit breaker.
[a] I_{bf} is in kA; working distance is 455 mm (18 in.).
[b] Short-time delay is assumed to be set at maximum.

The range of available three-phase bolted fault currents is from 700 A to 106,000 A. Each equation is applicable for the following range:

$$I_1 < I_{bf} < I_2$$

where:
I_1 = minimum available three-phase, bolted, short-circuit current at which this method can be applied. I_1 is the lowest available three-phase, bolted, short-circuit current level that causes enough arcing current for instantaneous tripping to occur, or, for circuit breakers with no instantaneous trip, that causes short-time tripping to occur.
I_2 = interrupting rating of the circuit breaker at the voltage of interest.

To find I_1, the instantaneous trip (I_t) of the circuit breaker must be found. I_t can be determined from the time-current curve, or it can be assumed to be 10 times the rating of the circuit breaker for circuit breakers rated above 100 amperes. For circuit breakers rated 100 amperes and below, a value of I_t = 1300 A can be used. When short-time delay is utilized, I_t is the short-time pickup current.

The corresponding bolted fault current, I_{bf}, is found by solving the equation for arc current for box configurations by substituting I_t for arcing current. The 1.3 factor in Equation D.4.7(b) adjusts current to the top of the tripping band.

$$\lg(1.3I_t) = 0.084 + 0.096V + 0.586(\lg I_{bf}) + 0.559V(\lg I_{bf}) \quad \textbf{[D.4.7(a)]}$$

At 600 V,

$$\lg I_1 = 0.0281 + 1.091\lg(1.3I_t) \quad \textbf{[D.4.7(b)]}$$

At 480 V and lower,

$$\lg I_1 = 0.0407 + 1.17\lg(1.3I_t) \quad \textbf{[D.4.7(c)]}$$

$$I_{bf} = I_1 = 10^{\lg I_1} \quad \textbf{[D.4.7(d)]}$$

D.4.8 References. The complete data, including a spreadsheet calculator to solve the equations, can be found in IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*. IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

D.5 Direct-Current Incident Energy Calculations.

D.5.1 Maximum Power Method. The following method of estimating dc arc flash incident energy that follows was published in the *IEEE Transactions on Industry Applications (see reference 2, which follows)*. This method is based on the concept that the maximum power possible in a dc arc will occur when the arcing voltage is one-half the system voltage. Testing completed for Bruce Power *(see reference 3, which follows)* has shown that this calculation is conservatively high in estimating the arc flash value. This method applies to dc systems rated up to 1000 V.

$$I_{arc} = 0.5 \times I_{bf}$$
$$IE_m = 0.01 \times V_{sys} \times I_{arc} \times T_{arc} / D^2$$

where:
I_{arc} = arcing current amperes
I_{bf} = system bolted fault current amperes
IE_m = estimated dc arc flash incident energy at the maximum power point cal/cm^2
V_{sys} = system voltage volts
T_{arc} = arcing time sec
D = working distance cm

For exposures where the arc is in a box or enclosure, it would be prudent to use a multiplying factor of 3 for the resulting incident energy value.

D.5.2 Detailed Arcing Current and Energy Calculations Method. A thorough theoretical review of dc arcing current and energy was published in the *IEEE Transactions on Industry Applications*. Readers are advised to refer to that paper *(see reference 1)* for those detailed calculations.

References:

1. "DC-Arc Models and Incident-Energy Calculations," Ammerman, R.F.; et al.; *IEEE Transactions on Industry Applications*, Vol. 46, No. 5.

2. "Arc Flash Calculations for Exposures to DC Systems," Doan, D.R., *IEEE Transactions on Industry Applications*, Vol. 46, No. 6.

3. "DC Arc Hazard Assessment Phase II", Copyright Material, Kinectrics Inc., Report No. K-012623-RA-0002-R00.

D.5.3 Short Circuit Current. The determination of short circuit current is necessary in order to use Table 130.7(C)(15)(B). The arcing current is calculated at 50 percent of the dc short-circuit value. The current that a battery will deliver depends on the total impedance of the short-circuit path. A conservative approach in determining the short-circuit current that the battery will deliver at 25°C is to assume that the maximum available short-circuit current is 10 times the 1 minute ampere rating (to 1.75 volts per cell at 25°C and the specific gravity of 1.215) of the battery. A more accurate value for the short-circuit current for the specific application can be obtained from the battery manufacturer.

References:

1. IEEE 946, *Recommended Practice for the Design of DC Auxiliary Powers Systems for Generating Stations*.

Informative Annex E Electrical Safety Program

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

(See 110.1, Electrical Safety Program.)

E.1 Typical Electrical Safety Program Principles. Electrical safety program principles include, but are not limited to, the following:

(1) Inspecting and evaluating the electrical equipment
(2) Maintaining the electrical equipment's insulation and enclosure integrity
(3) Planning every job and document first-time procedures
(4) De-energizing, if possible *(see 120.1)*
(5) Anticipating unexpected events
(6) Identifying the electrical hazards and reduce the associated risk
(7) Protecting employees from shock, burn, blast, and other hazards due to the working environment
(8) Using the right tools for the job
(9) Assessing people's abilities
(10) Auditing the principles

E.2 Typical Electrical Safety Program Controls. Electrical safety program controls can include, but are not limited to, the following:

(1) The employer develops programs, including training, and the employees apply them.
(2) Employees are to be trained to be qualified for working in an environment influenced by the presence of electrical energy.
(3) Procedures are to be used to identify the electrical hazards and to develop plans to eliminate those hazards or to control the associated risk for those hazards that cannot be eliminated.
(4) Every electrical conductor or circuit part is considered energized until proved otherwise.
(5) De-energizing an electrical conductor or circuit part and making it safe to work on is, in itself, a potentially hazardous task.
(6) Tasks to be performed on or near exposed energized electrical conductors and circuit parts are to be identified and categorized.
(7) Precautions appropriate to the working environment are to be determined and taken.
(8) A logical approach is to be used to determine the associated risk of each task.

E.3 Typical Electrical Safety Program Procedures. Electrical safety program procedures can include, but are not limited to determination and assessment of the following:

(1) Purpose of task
(2) Qualifications and number of employees to be involved
(3) Identification of hazards and assessment of risks of the task
(4) Limits of approach
(5) Safe work practices to be used
(6) Personal protective equipment (PPE) involved
(7) Insulating materials and tools involved
(8) Special precautionary techniques
(9) Electrical single-line diagrams
(10) Equipment details
(11) Sketches or photographs of unique features
(12) Reference data

Informative Annex F Risk Assessment Procedure

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

F.1 Risk Assessment (General). This informative annex provides guidance regarding a qualitative approach for risk assessment, including risk estimation and risk evaluation, which can be helpful in determining the protective measures that are required to reduce the likelihood of injury or damage to health occurring in the circumstances under consideration. To receive the full benefit of completing the risk assessment process the relationships between the source or cause of risk and the effects of the hierarchy of controls on those causes must be understood. This informative annex is intended to provide guidance.

Risk assessment is an analytical process consisting of a number of discrete steps intended to ensure that hazards are properly identified and analyzed with regard to their severity and the likelihood of their occurrence. Once hazards have been identified and analyzed, the risk associated with those hazards can be estimated using the parameters outlined in F.2.1. Appropriate protective measures can then be implemented and evaluated in order to determine if adequate risk reduction has been achieved.

Risk assessment includes a comprehensive review of the hazards, the associated foreseeable tasks, and the protective measures that are required in order to maintain a tolerable level of risk, including the following:

(1) Identifying and analyzing electrical hazards
(2) Identifying tasks to be performed
(3) Documenting hazards associated with each task
(4) Estimating the risk for each hazard/task pair
(5) Determining the appropriate protective measures needed to adequately reduce the level of risk

Figure F.1(a) illustrates the steps to be taken and the decisions to be considered when performing an electrical work risk assessment. See 110.1 for a hazard and risk evaluation procedure. Figure F.1(b) illustrates in more detail the steps of the risk analysis, assessment, and evaluation process.

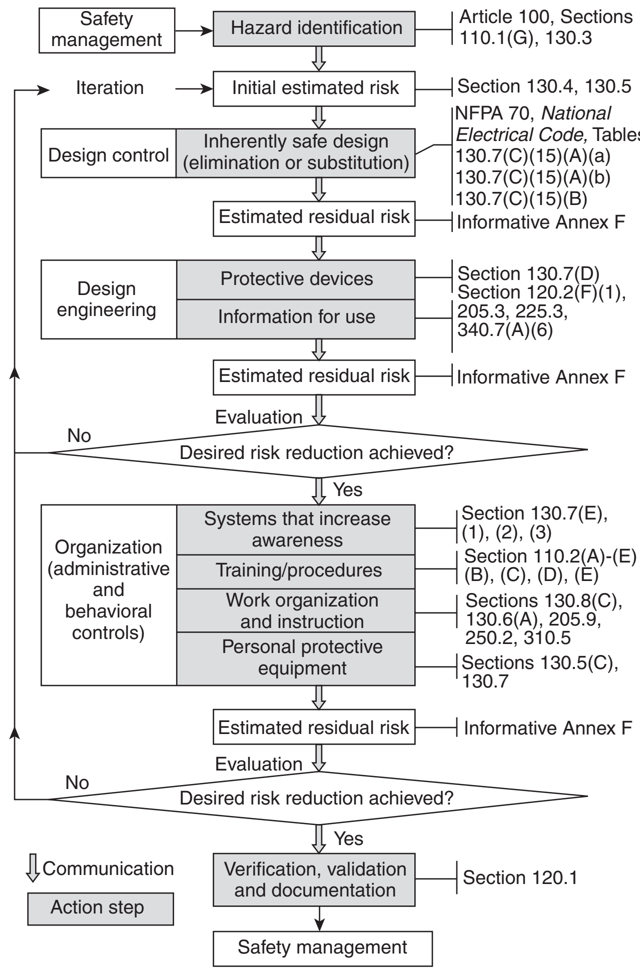

Figure F.1(a) Risk Assessment Process.

F.1.1 Responsibility. Electrical system designers, constructors, and users have responsibilities for defining and achieving tolerable risk. The supplier and the user either separately or jointly identify hazards, estimate risks, and reduce risks to a tolerable level within the scope of their respective work activities. Although the responsibilities of the supplier and the user differ over the life cycle of the electrical equipment, each entity should use the risk assessment process.

In general, the electrical system supplier is responsible for the design, construction, and information for operation and maintenance of the electrical system, while the user is responsible for the operation and maintenance of the electrical system.

Suppliers and users should involve qualified personnel in meeting their respective responsibilities. The supplier and the user should ensure compliance with the regulations and standards applicable to their work activity. This could include regulations and standards for a specific location, a specific application, or both.

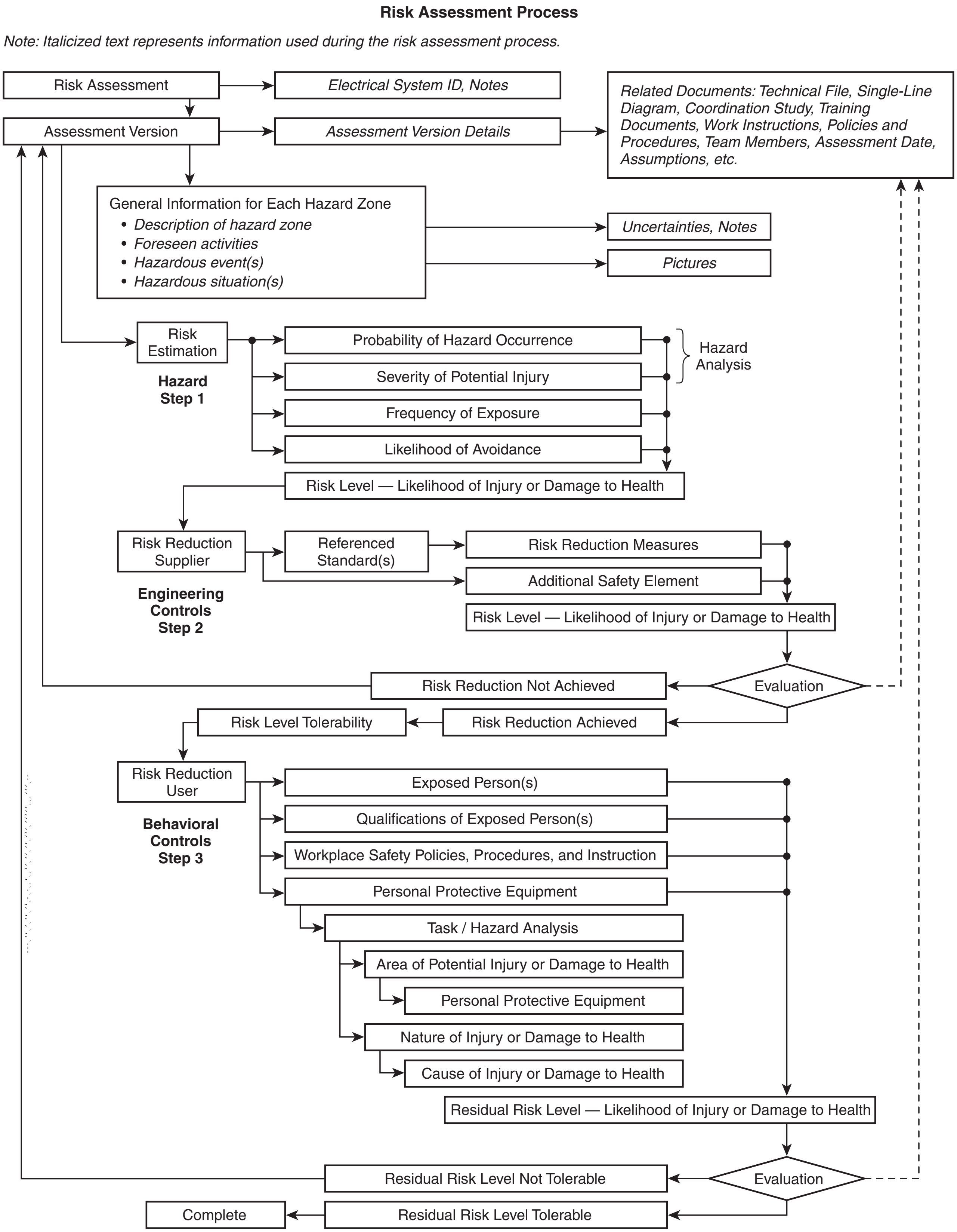

Figure F.1(b) Detailed Risk Assessment Process.

F.2 Risk Assessment.

F.2.1 Initial Risk Estimation. An initial estimation of risk should be carried out for each hazard. Risk related to the identified hazard should be derived by using the risk parameters that are shown in Figure F.2.1 including the following:

(1) Severity of injury or damage to health (Se)

(2) Likelihood of occurrence of that injury or damage to health, which is a function of all of the following:

 a. Frequency and duration of the exposure of persons to the hazard (Fr)

 b. Likelihood of occurrence of a hazardous event (Pr)

 c. Likelihood of avoiding or limiting the injury or damage to health (Av)

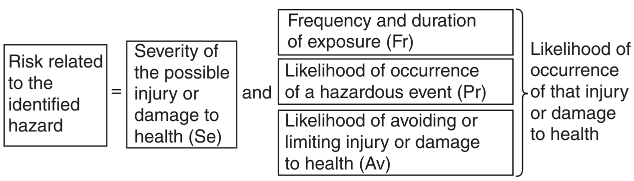

Figure F.2.1 Elements of Risk.

F.2.2 Parameters Used in Risk Estimation. In preparation for the risk assessment, parameters are estimated and can be entered into Table F.2.5. These parameters should be based on worst-case considerations for the electrical system. Different risk reduction strategies can be implemented for each hazard. The risk estimation stage is the only one at which hazards can be eliminated, thus avoiding the need for additional protective measures, such as safeguarding or complementary protective measures.

F.2.3 Severity of the Possible Injury or Damage to Health (Se). Severity of injuries or damage to health can be estimated by taking into account reversible injuries, irreversible injuries, and death. Typically, the types of hazards to be considered include, but are not limited to, shock and electrocution, burns, and impact. Choose the appropriate value of severity from Table F.2.3, based on the consequences of an injury, as follows:

(1) 8: a fatal or a significant irreversible injury, such that it will be very difficult to continue the same work after healing, if at all

(2) 6: a major or irreversible injury, in such a way that it can be possible to continue the same work after healing and can also include a severe major but reversible injury such as broken limbs

(3) 3: a reversible injury, including severe lacerations, stabbing, and severe bruises, that requires attention from a medical practitioner

(4) 1: a minor injury, including scratches and minor bruises that require attention by first aid.

Select the appropriate value for severity of the possible injury or damage to health (Se) from Table F.2.3 and insert in the Se column in Table F.2.5.

Table F.2.3 Severity of the Possible Injury or Damage to Health (Se) Classification

Severity of Injury or Damage to Health	Se Value
Irreversible — trauma, death	8
Permanent — skeletal damage, blindness, hearing loss, third degree burns	6
Reversible — minor impact, hearing damage, second degree burns	3
Reversible — minor laceration, bruises, first degree burns	1

F.2.4 Likelihood of Occurrence of Injury or Damage to Health. Each of the three parameters of likelihood of occurrence of injury or damage to health (that is, Fr, Pr, and Av) should be estimated independently of each other. A worst-case assumption needs to be used for each parameter to ensure that the protective measures, determined during risk evaluation, will provide adequate risk reduction. Generally, the use of a form of hazard/task–based evaluation is strongly recommended to ensure that proper consideration is given to the estimation of the likelihood of occurrence of injury or damage to health.

F.2.4.1 Frequency and Duration of Exposure (Fr). The following aspects should be considered to determine the level of exposure:

(1) Need for access to the hazard zone based on all modes of use; for example, normal operation and maintenance

(2) Nature of access, for example, examination, repair, and troubleshooting

It should then be possible to estimate the average interval between exposures and, thus, the average frequency of access.

This factor does not include consideration of the failure of the short-circuit interruption device(s) or the failure to use the appropriate PPE.

Select the appropriate row for frequency and duration of exposure (Fr) from Table F.2.4.1. Insert the appropriate number under the Fr column in Table F.2.5.

Table F.2.4.1 Frequency and Duration of Exposure (Fr) Classification

Frequency of Exposure	Fr Value (for Duration >10 min)
≤ 1 per hour	5
> 1 per hour to ≤ 1 per day	5
> 1 per day to ≤ 1 every 2 weeks	4
> 1 every 2 weeks to ≤ 1 per year	3
> 1 per year	2

F.2.4.2 Likelihood of Occurrence of a Hazardous Event (Pr). The occurrence of a hazardous event influences the likelihood of the occurrence of injury or damage to health. The possibility of the hazardous event occurring should describe the likelihood of the event materializing during the use or foreseeable misuse, or both, of the electrical system or process. Subjectivity may have a substantial impact on the result of the risk assessment. The use of subjective information should be minimized as far as reasonably practicable.

The likelihood of occurrence of the hazardous event should be estimated independently of other related parameters (Fr and Av) and will typically be based on the results of the completed study of the arc flash potential. The worst-case scenario should be used for this parameter to ensure that short-circuit interruption device(s) have, where practicable, been properly selected and installed and will provide adequate protection.

Elements of the electrical system that are intended to ensure an intrinsically safe design shall be taken into consideration in the determination of the likelihood of the hazardous event(s). These can include, but are not limited to, the mechanical structure, electrical devices, and electronic controls integral to the system, the process, or both at the time of the analysis. Types of components that could contribute to an inherently safe design include, but are not limited to, current-limiting devices and ground-fault circuit interrupters.

This parameter can be estimated by taking into account the following factors:

(1) The predictability of the performance of component parts of the electrical system relevant to the hazard in different modes of use (e.g., normal operation, maintenance, fault finding).

At this point in the risk assessment process, the protective effect of any personal protective equipment (PPE) and other protective measures should not be taken into account. This is necessary in order to estimate the amount of risk that will be present if the PPE and other protective measures are not in place at the time of the exposure. In general terms, it must be considered whether the electrical system being assessed has the propensity to act in an unexpected manner. The electrical system performance will vary from very predictable to not predictable. Unexpected events cannot be discounted until it can be clearly demonstrated that the electrical system will perform as expected.

Informational Note: Predictability is often linked to the complexity of the electrical system and the characteristics of the energy supply.

(2) The specified or foreseeable characteristics of human behavior with regard to interaction with the component parts of the machine relevant to the hazard, which can be characterized by one or both of the following:

a. Stress (e.g., due to time constraints, work task, perceived damage limitation)

b. Lack of awareness of information relevant to the hazard

Human behavior will be influenced by factors such as skills, training, experience, and complexity of the machine or the process.

These attributes are not usually directly under the influence of the electrical system designer, but a task analysis will reveal activities in which total awareness of all issues, including unexpected outcomes, cannot be reasonably assumed. "Very high" likelihood of occurrence of a hazardous event should be selected to reflect normal workplace constraints and worst-case considerations. Positive reasons (e.g., well-defined application and a high level of user competence) are required for any lower values to be used.

Any required or assumed skills, knowledge, and so forth, should be stated in the information for use.

Select the appropriate row for likelihood of occurrence of a hazardous event (Pr) from Table F.2.4.2.

Indicate the appropriate risk level under the Pr column in Table F.2.5.

Table F.2.4.2 Likelihood of a Hazardous Event (Pr) Classification

Likelihood of a Hazardous Event	Pr Value
Very high	5
Likely	4
Possible	3
Rare	2
Negligible	1

F.2.4.3 Likelihood of Avoiding or Limiting Injury or Damage to Health (Av). This parameter can be estimated by taking into account aspects of the electrical system design and its intended application that can help to avoid or limit the injury or damage to health from a hazard, including the following examples:

(1) Sudden or gradual appearance of the hazardous event; for example, an explosion caused by high fault values under short-circuit conditions.
(2) Spatial possibility to withdraw from the hazard.
(3) Nature of the component or system; for example, the use of touch-safe components, which reduce the likelihood of contact with energized parts. Working in close proximity to high voltage can increase the likelihood of personnel being exposed to hazards due to approach to live parts.
(4) Likelihood of recognition of a hazard; for example, as an electrical hazard, a copper bar does not change its appearance, whether it is under voltage or not. To recognize the presence of the hazard, an instrument is needed to establish whether or not electrical equipment is energized; thus, both inadvertent and intentional contact need to be considered.

Select the appropriate row for likelihood of avoiding or limiting injury or damage to health (Av) from Table F.2.4.3.

Insert the appropriate value for risk level in the Av column in Table F.2.5.

Table F.2.4.3 Likelihood of Avoiding or Limiting Injury or Damage to Health (Av) Classification

Likelihood of Avoiding or Limiting Injury or Damage to Health	Av Value
Impossible	5
Rare	3
Probable	1

F.2.5 Risk Level and Likelihood of Injury or Damage to Health. Once the parameters for each hazard under consideration have been entered in Table F.2.5, the information can be used in the first step of the risk assessment process as outlined in Figure F.1(a).

F.3 Risk Reduction.

F.3.1 Protective Measures. Once the risk prior to the application of protective measures has been estimated, all practicable efforts must be made to reduce the risk of injury or damage to health. Careful consideration of failure modes is an important part of risk reduction. Care should be taken to ensure that both technical and behavioral failures, which could result in ineffective risk reduction, are taken into account during the risk reduction stage of the risk assessment.

Table F.2.5 Parameters for Determining Risk Levels and Likelihood of Injury or Damage to Health (See Figure F.2.1)

Zone No.	Hazard	Se	Fr	Pr	Av

Situations in which hazard elimination cannot be attained typically require a balanced approach in order to reduce the likelihood of injury or damage to health. For example, the effective control of access to an electrical system requires the use of barriers, awareness placards, safe operating instructions, qualification and training, and PPE personnel protective equipment as required by this standard, as well as initial and refresher or periodic training for all affected personnel in the area. Engineering controls alone are not sufficient to reduce the remaining risk to a tolerable level. Typically, all five areas of risk reduction must be implemented to achieve the desired result.

Consideration of all five of the items in F.3.1.1 through F.3.1.5 is required to establish an adequate risk reduction strategy.

F.3.1.1 Engineering Controls. Engineering controls can have a substantial impact on risk. They should, where practicable, be considered and analyzed. Typically, engineering controls take the form of barriers and other safeguarding devices as described in *NFPA 70*, *National Electrical Code*; IEC 60204-1 ed 5.1 Consol. with am 1, *Safety of Machinery — Electrical Equipment of Machines — Part 1: General Requirements*; and NFPA 79, *Electrical Standard for Industrial Machinery*.

F.3.1.2 Awareness Devices. Awareness means can be used to complement the effects of engineering controls with regard to risk reduction. They should be chosen based on the design configuration for each specific application and their potential effectiveness during foreseen interaction. Each design and configuration can require unique awareness devices in order to have the desired impact on risk. Typically, awareness means take the form of signs, visual alarms, audible alarms, and so forth.

F.3.1.3 Procedures. Procedures and instructions that are required for individual(s) to safely interact with the electrical system should be identified. The procedures and instructions should include descriptions of the hazards, the possible hazardous events, hazardous situations, and the protective measures that need to be implemented. Procedures and instructions should also be used to communicate foreseeable misuse of the system that could contribute to an increased level of risk. Typically, formal procedures are provided in written form; however, in some cases, verbal instruction can be provided. Care should be taken in the latter case to ensure that the verbal instructions will have the desired impact on risk.

F.3.1.4 Training. Training, with regard to the proper interaction and for foreseeable inappropriate interaction with the electrical system, must be completed. The intent of the training is to ensure that all affected personnel are able to understand when and how hazardous situations can arise and how to best reduce the risk associated with those situations. Typically, training for individuals interacting with electrical systems will include technical information regarding hazards, hazardous situations, or both as well as information related to potential failure modes that could affect risk. This type of training generally will be provided by a trainer who has an in-depth understanding of electrical system design, as well as experience in the field of adult education. Less technical training content could be appropriate in situations in which only awareness of electrical hazards is needed to ensure that unqualified personnel do not interact with the electrical system.

F.3.1.5 Personal Protective Equipment (PPE). The electrical system must be analyzed in order to determine the appropriate PPE. Once the appropriate PPE has been determined, personnel must maintain and use it as required in order to ensure that residual risk remains at the desired level.

F.4 Risk Evaluation.

F.4.1 Risk Evaluation. Once the appropriate protective measures described in F.3.1 have been applied, the effect of those measures on the elements of risk *(see Figure F.2.1)* should be taken into account. Each type of protective measure could affect one or more of the elements that contribute to risk. The effects on risk or on the individual elements of risk, should be considered in the final risk estimation. The cumulative effect of the final combination of protective measures can then be used to estimate the residual risk. Paragraphs F.4.1.1 through F.4.1.5 provide a general, nonexhaustive outline that can be used as a guide to the final estimation of risk.

F.4.1.1 Design — Elimination or Substitution by Design.

(a) Elimination of the hazard — impacts both severity of injury or damage to health and likelihood of injury or damage to health

Failure mode(s) examples:

(1) Component(s) failure
(2) Application of an incorrect construction or manufacturing specification
(3) Incorrect calculation (that is, potential energy, toxicity, strength, durability)
(4) Inadequate procurement control
(5) Incorrect or insufficient maintenance, or both

(b) Substitution — can affect severity of injury or damage to health, frequency of exposure to the hazard under consideration, or the likelihood of avoiding or limiting injury or damage to health, depending on which method of substitution or combination thereof is applied.

Failure mode(s) examples:

(1) Unexpected or unanticipated interaction
(2) Excessive production pressure
(3) Inadequate procurement control

F.4.1.2 Design — Use of Engineering Controls.

(a) Greatest impact on the likelihood of a hazardous event(s) under certain circumstances

(b) No impact on severity of injury or damage to health

Failure mode(s) examples:

(1) Incorrect application of construction or manufacturing specification
(2) Unanticipated tasks
(3) Incentive to circumvent or reduce effectiveness
(4) Excessive production pressure
(5) Protective system failure

F.4.1.3 Use of Systems that Increase Awareness of Potential Hazards.

(a) Potential impact on avoiding or limiting injury or damage to health

(b) Potential impact on inadvertent exposure

(c) Minimal or no impact on severity of injury or damage to health

Failure mode(s) examples:

(1) Too many warning signs
(2) Depreciation of effect over time
(3) Lack of understanding

F.4.1.4 Organization and Application of a Safe System of Work.

F.4.1.4.1 Personnel training.

(a) Greatest impact on avoiding or limiting injury or damage to health

(b) Minimal, if any, impact on severity of injury or damage to health
(c) Possible impact on the likelihood of a hazardous event(s) under certain circumstances

Failure mode(s) examples:

(1) Training not understood
(2) Identified hazards not clearly communicated
(3) Depreciation of effect over time
(4) Training material not current
(5) Training not consistent with instructions
(6) Training material not inclusive of detail regarding how to perform work

F.4.1.4.2 Access restrictions.

(a) Greatest impact on exposure
(b) No impact on severity of injury or damage to health

Failure mode(s) examples:

(1) Work permit system does not exist
(2) Competency complacency
(3) Insufficient monitoring, control, or corrective actions, or combination thereof

F.4.1.4.3 Safe work procedures.

(a) Greatest impact on avoiding or limiting injury or damage to health
(b) Minimal, if any, impact on severity of injury or damage to health
(c) Possible impact on the likelihood of a hazardous event(s) under certain circumstances

Failure mode(s) examples:

(1) Inconsistent with the current culture
(2) Procedures not current or accessible
(3) Does not consider all tasks, hazards, hazardous situations, or combination thereof
(4) Insufficient monitoring, control, corrective actions, or combination thereof
(5) Instructions not consistent with training content
(6) Content too general (e.g., "Don't touch the live parts; Be careful.")

F.4.1.4.4 Policies and instructions.

(a) Greatest impact on exposure
(b) Possible impact on the likelihood of a hazardous event(s) under certain circumstances
(c) Minimal or no impact on severity of injury or damage to health

Failure mode(s) examples:

(1) Policies and instructions inconsistent
(2) Instructions not clearly communicated or accessible
(3) Insufficient monitoring, control, or corrective actions, or combination thereof
(4) Allows personnel to make the decision to work live without adequate justification

F.4.1.5 Personal Protective Equipment (PPE).

(a) Greatest impact on avoiding or limiting injury or damage to health
(b) Potential impact on inadvertent exposure
(c) Minimal impact on severity of injury or damage to health
(d) No impact on the likelihood of a hazardous event(s)

Failure mode(s) examples:

(1) Reason for use not understood
(2) Creates barriers to effective completion of the work
(3) PPE specification inappropriate for the considered hazards
(4) Production pressure does not afford time to use or maintain
(5) Worker forgets to use when needed
(6) Excessive discomfort
(7) Perceived invulnerability
(8) Insufficient monitoring, control, corrective actions, or combination thereof

F.5 Risk Reduction Verification.

F.5.1 Verification. Once the assessment has been completed and protective measures have been determined, it is imperative to ensure that the protective measures are implemented prior to initiating the electrical work. While this procedure might not result in a reduction of the PPE required, it could improve the understanding of the properties of the hazards associated with a task to a greater extent and thus allow for improvement in the implementation of the protective measures that have been selected.

F.5.2 Auditing. For each activity that has been assessed, it might be necessary to audit the risk reduction strategy that is applicable. If an audit is required, the auditing process should take place prior to commencement of work on electrical systems. An example of a nonexhaustive audit is shown in Figure F.5.2. Each audit process might need to be specific to the properties of the electrical system, to the task to be performed, or to both.

Hazard (situation)	Risk Reduction Strategy	Confirmation (in place) Yes / No
Human factors (mistakes)	Training and instructions include details regarding hazardous situations that could arise.	
Human factors (willful disregard)	Policies and supervision are in place in order to ensure that instructions are followed.	
Unqualified person performing electrical work	Work permit system is in place to control personnel activities.	
Inappropriate overcurrent protection	Instructions include details regarding the selection or replacement of fuses and/or circuit breakers.	
Short circuits between test leads	Training and instructions include details regarding care and inspection of testing equipment.	
Meter malfunctions	Training and instructions include details regarding care and inspection of testing equipment.	
Meter misapplication	Training and instructions include details regarding use of testing equipment.	
Qualified person performing electrical work that exceeds individual's qualification	Work permit system is in place to control personnel activities.	

Figure F.5.2 Sample Auditing Form.

Informative Annex G Sample Lockout/Tagout Procedure

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

Lockout is the preferred method of controlling personnel exposure to electrical energy hazards. Tagout is an alternative method that is available to employers. To assist employers in developing a procedure that meets the requirement of 120.2 of *NFPA 70E*, the sample procedure that follows is provided for use in lockout and tagout programs. This procedure can be used for a simple lockout/tagout, or as part of a complex lockout/tagout. A more comprehensive plan will need to be developed, documented, and used for the complex lockout/tagout.

LOCKOUT/TAGOUT PROCEDURE
FOR [COMPANY NAME]
OR
TAGOUT PROCEDURE FOR [COMPANY NAME]

1.0 Purpose. This procedure establishes the minimum requirements for lockout/tagout of electrical energy sources. It is to be used to ensure that conductors and circuit parts are disconnected from sources of electrical energy, locked (tagged), and tested before work begins where employees could be exposed to dangerous conditions. Sources of stored energy, such as capacitors or springs, shall be relieved of their energy, and a mechanism shall be engaged to prevent the reaccumulation of energy.

2.0 Responsibility. All employees shall be instructed in the safety significance of the lockout/tagout procedure. All new or transferred employees and all other persons whose work operations are or might be in the area shall be instructed in the purpose and use of this procedure. *[Name(s) of the person(s) or the job title(s) of the employee(s) with responsibility]* shall ensure that appropriate personnel receive instructions on their roles and responsibilities. All persons installing a lockout/tagout device shall sign their names and the date on the tag *[or state how the name of the individual or person in charge will be available]*.

3.0 Preparation for Lockout/Tagout.

3.1 Review current diagrammatic drawings (or their equivalent), tags, labels, and signs to identify and locate all disconnecting means to determine that power is interrupted by a physical break and not de-energized by a circuit interlock. Make a list of disconnecting means to be locked (tagged).

3.2 Review disconnecting means to determine adequacy of their interrupting ability. Determine if it will be possible to verify a visible open point, or if other precautions will be necessary.

3.3 Review other work activity to identify where and how other personnel might be exposed to electrical hazards. Review other energy sources in the physical area to determine employee exposure to those sources of other types of energy. Establish energy control methods for control of other hazardous energy sources in the area.

3.4 Provide an adequately rated test instrument to test each phase conductor or circuit part to verify that they are deenergized *(see Section 11.3)*. Provide a method to determine that the test instrument is operating satisfactorily.

3.5 Where the possibility of induced voltages or stored electrical energy exists, call for grounding the phase conductors or circuit parts before touching them. Where it could be reasonably anticipated that contact with other exposed energized conductors or circuit parts is possible, call for applying ground connecting devices.

4.0 Simple Lockout/Tagout. The simple lockout/tagout procedure will involve 1.0 through 3.0, 5.0 through 9.0, and 11.0 through 13.0.

5.0 Sequence of Lockout/Tagout System Procedures.

5.1 The employees shall be notified that a lockout/tagout system is going to be implemented and the reason for it. The qualified employee implementing the lockout/tagout shall know the disconnecting means location for all sources of electrical energy and the location of all sources of stored energy. The qualified person shall be knowledgeable of hazards associated with electrical energy.

5.2 If the electrical supply is energized, the qualified person shall de-energize and disconnect the electric supply and relieve all stored energy.

5.3 Wherever possible, the blades of disconnecting devices should be visually verified to be fully opened, or draw-out type circuit breakers should be verified to be completely withdrawn to the fully disconnected position.

5.4 Lockout/tagout all disconnecting means with lockout/tagout devices.

Informational Note: For tagout, one additional safety measure must be employed, such as opening, blocking, or removing an additional circuit element.

5.5 Attempt to operate the disconnecting means to determine that operation is prohibited.

5.6 A test instrument shall be used. *(See 11.3.)* Inspect the instrument for visible damage. Do not proceed if there is an indication of damage to the instrument until an undamaged device is available.

5.7 Verify proper instrument operation and then test for absence of voltage.

5.8 Verify proper instrument operation after testing for absence of voltage.

5.9 Where required, install a grounding equipment/conductor device on the phase conductors or circuit parts, to eliminate induced voltage or stored energy, before touching them. Where it has been determined that contact with other exposed energized conductors or circuit parts is possible, apply ground connecting devices rated for the available fault duty.

5.10 The equipment, electrical source, or both are now locked out (tagged out).

6.0 Restoring the Equipment, Electrical Supply, or Both to Normal Condition.

6.1 After the job or task is complete, visually verify that the job or task is complete.

6.2 Remove all tools, equipment, and unused materials and perform appropriate housekeeping.

6.3 Remove all grounding equipment/conductors/devices.

6.4 Notify all personnel involved with the job or task that the lockout/tagout is complete, that the electrical supply is being restored, and that they are to remain clear of the equipment and electrical supply.

6.5 Perform any quality control tests or checks on the repaired or replaced equipment, electrical supply, or both.

6.6 Remove lockout/tagout devices. The person who installed the devices is to remove them.

6.7 Notify the owner of the equipment, electrical supply, or both, that the equipment, electrical supply, or both are ready to be returned to normal operation.

6.8 Return the disconnecting means to their normal condition.

7.0 Procedure Involving More Than One Person. For a simple lockout/tagout and where more than one person is involved in the job or task, each person shall install his or her own personal lockout/tagout device.

8.0 Procedure Involving More Than One Shift. When the lockout/tagout extends for more than one day, it shall be verified that the lockout/tagout is still in place at the beginning of the next day. When the lockout/tagout is continued on successive shifts, the lockout/tagout is considered to be a complex lockout/tagout.

For a complex lockout/tagout, the person in charge shall identify the method for transfer of the lockout/tagout and of communication with all employees.

9.0 Complex Lockout/Tagout. A complex lockout/tagout plan is required where one or more of the following exist:

(1) Multiple energy sources (more than one)
(2) Multiple crews
(3) Multiple crafts
(4) Multiple locations
(5) Multiple employers
(6) Unique disconnecting means
(7) Complex or particular switching sequences
(8) Lockout/tagout for more than one shift; that is, new shift workers

9.1 All complex lockout/tagout procedures shall require a written plan of execution. The plan shall include the requirements in 1.0 through 3.0, 5.0, 6.0, and 8.0 through 12.0.

9.2 A person in charge shall be involved with a complex lockout/tagout procedure. The person in charge shall be at the procedure location.

9.3 The person in charge shall develop a written plan of execution and communicate that plan to all persons engaged in the job or task. The person in charge shall be held accountable for safe execution of the complex lockout/tagout plan. The complex lockout/tagout plan must address all the concerns of employees who might be exposed, and they must understand how electrical energy is controlled. The person in charge shall ensure that each person understands the electrical hazards to which they are exposed and the safety-related work practices they are to use.

9.4 All complex lockout/tagout plans identify the method to account for all persons who might be exposed to electrical hazards in the course of the lockout/tagout.

One of the following methods is to be used:

(1) Each individual shall install his or her own personal lockout or tagout device.

(2) The person in charge shall lock his/her key in a lock box.
(3) The person in charge shall maintain a sign-in/sign-out log for all personnel entering the area.
(4) Another equally effective methodology shall be used.

9.5 The person in charge can install locks/tags or direct their installation on behalf of other employees.

9.6 The person in charge can remove locks/tags or direct their removal on behalf of other employees, only after all personnel are accounted for and ensured to be clear of potential electrical hazards.

9.7 Where the complex lockout/tagout is continued on successive shifts, the person in charge shall identify the method for transfer of the lockout and the method of communication with all employees.

10.0 Discipline.

10.1 Knowingly violating this procedure will result in [*state disciplinary actions that will be taken*].

10.2 Knowingly operating a disconnecting means with an installed lockout device (tagout device) will result in [*state disciplinary actions to be taken*].

11.0 Equipment.

11.1 Locks shall be [*state type and model of selected locks*].

11.2 Tags shall be [*state type and model to be used*].

11.3 The test instrument(s) to be used shall be [*state type and model*].

12.0 Review. This procedure was last reviewed on [date] and is scheduled to be reviewed again on [date] (not more than 1 year from the last review).

13.0 Lockout/Tagout Training. Recommended training can include, but is not limited to, the following:

(1) Recognition of lockout/tagout devices
(2) Installation of lockout/tagout devices
(3) Duty of employer in writing procedures
(4) Duty of employee in executing procedures
(5) Duty of person in charge
(6) Authorized and unauthorized removal of locks/tags
(7) Enforcement of execution of lockout/tagout procedures
(8) Simple lockout/tagout
(9) Complex lockout/tagout
(10) Use of single-line and diagrammatic drawings to identify sources of energy
(11) Alerting techniques
(12) Release of stored energy
(13) Personnel accounting methods
(14) Temporary protective grounding equipment needs and requirements
(15) Safe use of test instruments

Informative Annex H Guidance on Selection of Protective Clothing and Other Personal Protective Equipment (PPE)

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

H.1 Arc-Rated Clothing and Other Personal Protective Equipment (PPE) for Use with Arc Flash PPE Categories. Table 130.7(C)(15)(A)(a), Table 130.7(C)(15)(A)(b), Table 130.7(C)(15)(B), and Table 130.7(C)(16) provide guidance for the selection and use of PPE when using arc flash PPE categories.

H.2 Simplified Two-Category Clothing Approach for Use with Table 130.7(C)(15)(A)(a), Table 130.7(C)(15)(A)(b), Table 130.7(C)(15)(B), and Table 130.7(C)(16). The use of Table H.2 is a simplified approach to provide minimum PPE for electrical workers within facilities with large and diverse electrical systems. The clothing listed in Table H.2 fulfills the minimum arc-rated clothing requirements of Table 130.7(C)(15)(A)(a), Table 130.7(C)(15)(A)(b), Table 130.7(C)(15)(B), and Table 130.7(C)(16). The clothing systems listed in this table should be used with the other PPE appropriate for the arc flash PPE category *[see Table 130.7(C)(16)]*. The notes to Table 130.7(C)(15)(A)(a), Table 130.7(C)(15)(A)(b), and Table 130.7(C)(15)(B), must apply as shown in those tables.

H.3 Arc-Rated Clothing and Other Personal Protective Equipment (PPE) for Use with Risk Assessment of Electrical Hazards. Table H.3(a) provides a summary of specific sections within the *NFPA 70E* standard describing PPE for electrical hazards. Table H.3(b) provides guidance on the selection of arc-rated and other PPE for users who determine the incident energy exposure (in cal/cm^2).

Table H.2 Simplified Two-Category, Arc-Rated Clothing System

Clothing[a]	Applicable Tasks
Everyday Work Clothing Arc-rated long-sleeve shirt with arc-rated pants (minimum arc rating of 8) *or* Arc-rated coveralls (minimum arc rating of 8)	All arc flash PPE category 1 and arc flash PPE category 2 tasks listed in Table 130.7(C)(15)(A)(a), Table 130.7(C)(15)(A)(b), and Table 130.7(C)(15)(B)[b]
Arc Flash Suit A total clothing system consisting of arc-rated shirt and pants and/or arc-rated coveralls and/or arc flash coat and pants (clothing system minimum arc rating of 40)	All arc flash PPE category 3 and arc flash PPE category 4 tasks listed in Table 130.7(C)(15)(A)(a), Table 130.7(C)(15)(A)(b), and Table 130.7(C)(15)(B)[b]

[a]Note that other PPE listed in Table 130.7(C)(16), which include arc-rated face shields or arc flash suit hoods, arc-rated hard hat liners, safety glasses or safety goggles, hard hats, hearing protection, heavy-duty leather gloves, rubber insulating gloves, and leather protectors, could be required. The arc rating for a garment is expressed in cal/cm^2.

[b]The estimated available short-circuit current capacities and fault clearing times or arcing durations are listed in the text of Table 130.7(C)(15)(A)(b) and Table 130.7(C)(15)(B). Various tasks are listed in Table 130.7(C)(15)(A)(a). For tasks not listed or for power systems with greater than the estimated available short-circuit capacity or with longer than the assumed fault clearing times or arcing durations, an arc flash risk assessment is required in accordance with 130.5.

Tables H.3(a) and (b) were revised by a tentative interim amendment (TIA). See page 1.

Table H.3(a) Summary of Specific Sections Describing PPE for Electrical Hazards

Shock Hazard PPE	Applicable Section(s)
Rubber insulating gloves and leather protectors (unless the requirements of ASTM F 496 are met)	130.7(C)(7)(a)
Rubber insulating sleeves (as needed)	130.7(C)(7)(a)
Class G or E hard hat (as needed)	130.7(C)(3)
Safety glasses or goggles (as needed)	130.7(C)(4)
Dielectric overshoes (as needed)	130.7(C)(8)

Table H.3(a) Summary of Specific Sections Describing PPE for Electrical Hazards

Arc Flash Hazard PPE	Applicable Section(s)
Incident energy exposures up to 1.2 cal/cm²	
Clothing: nonmelting or untreated natural fiber long-sleeve shirt and long pants or coverall	130.7(C)(1); 130.7(C)(9)(d)
Gloves: heavy-duty leather	130.7(C)(7)(b); 130.7(C)(10)(d)
Hard hat: class G or E	130.7(C)(3)
Face shield: covers the face, neck, and chin (as needed)	130.7(C)(3)
Safety glasses or goggles	130.7(C)(4); 130.7(C)(10)(c)
Hearing protection	130.7(C)(5)
Footwear: heavy-duty leather (as needed)	130.7(C)(10)(e)
Incident Energy Exposures ≥ 1.2 cal/cm²	
Clothing: arc-rated clothing system with an arc rating appropriate to the anticipated incident energy exposure	130.7(C)(1); 130.7(C)(2); 130.7(C)(6); 130.7(C)(9)(d)
Clothing underlayers (when used): arc-rated or nonmelting untreated natural fiber	130.7(C)(9)(c); 130.7(C)(11); 130.7(C)(12)
Gloves:	130.7(C)(7)(b); 130.7(C)(10)(d)
Exposures ≥ 1.2 cal/cm² and ≤ 8 cal/cm²: heavy-duty leather gloves	
Exposures > 8 cal/cm²: rubber insulating gloves with their leather protectors; or arc-rated gloves	
Hard hat: class G or E	130.7(C)(1); 130.7(C)(3)
Face shield:	130.7(C)(1); 130.7(C)(3); 130.7(C)(10)(a); 130.7(C)(10)(b); 130.7(C)(10)(c)
Exposures ≥1.2 cal/cm² and 12 cal/cm²: arc-rated face shield that covers the face, neck, and chin and an arc-rated balaclava or an arc-rated arc flash suit hood	
Exposures >12 cal/cm²: arc-rated arc flash suit hood	
Safety glasses or goggles	130.7(C)(4); 130.7(C)(10)(c)
Hearing protection	130.7(C)(5)
Footwear:	130.7(C)(10)(e)
Exposures ≤4 cal/cm²: heavy-duty leather footwear (as needed)	
Exposures > 4 cal/cm²: heavy-duty leather footwear	

Table H.3(b) Guidance on Selection of Arc-Rated Clothing and Other PPE for Use When Incident Energy Exposure Is Determined

Incident Energy Exposure	Protective Clothing and PPE
≤ 1.2 cal/cm²	
Protective clothing, nonmelting (in accordance with ASTM F 1506) or untreated natural fiber	Shirt (long sleeve) and pants (long) or coverall
Other PPE	Face shield for projectile protection (AN) Safety glasses or safety goggles (SR) Hearing protection Heavy-duty leather gloves or rubber insulating gloves with leather protectors (AN)
≥ 1.2 to 12 cal/cm² Arc-rated clothing and equipment with an arc rating equal to or greater than the determined incident energy *(See Note 3.)*	Arc-rated long-sleeve shirt and arc-rated pants or arc-rated coverall or arc flash suit (SR) *(See Note 3.)* Arc-rated face shield and arc-rated balaclava or arc flash suit hood (SR) *(See Note 1.)* Arc-rated jacket, parka, or rainwear (AN)
Other PPE	Hard hat Arc-rated hard hat liner (AN) Safety glasses or safety goggles (SR) Hearing protection Heavy-duty leather gloves or rubber insulating gloves with leather protectors (SR) *(See Note 4.)* Leather footwear
> 12 cal/cm²	
Arc-rated clothing and equipment with an arc rating equal to or greater than the determined incident energy *(See Note 3.)*	Arc-rated long-sleeve shirt and arc-rated pants or arc-rated coverall and/or arc flash suit (SR) Arc-rated arc flash suit hood Arc-rated gloves Arc-rated jacket, parka, or rainwear (AN)
Other PPE	Hard hat Arc-rated hard hat liner (AN) Safety glasses or safety goggles (SR) Hearing protection Arc-rated gloves or rubber insulating gloves with leather protectors (SR) *(See Note 4.)* Leather footwear

AN: As needed [in addition to the protective clothing and PPE required by 130.5(C)(1)].
SR: Selection of one in group is required by 130.5(C)(1).
Notes:
(1) Face shields with a wrap-around guarding to protect the face, chin, forehead, ears, and neck area are required by 130.7(C)(10)(c). For full head and neck protection, use a balaclava or an arc flash hood.
(2) All items not designated "AN" are required by 130.7(C).
(3) Arc ratings can be for a single layer, such as an arc-rated shirt and pants or a coverall, or for an arc flash suit or a multi-layer system consisting of a combination of arc-rated shirt and pants, coverall, and arc flash suit.
(4) Rubber insulating gloves with leather protectors provide arc flash protection in addition to shock protection. Higher class rubber insulating gloves with leather protectors, due to their increased material thickness, provide increased arc flash protection.

Informative Annex I Job Briefing and Planning Checklist

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

I.1 Job Briefing and Planning Checklist. Figure I.1 illustrates considerations for a job briefing and planning checklist.

Identify	
❏ Hazards	❏ Shock protection boundaries
❏ Voltage levels involved	❏ Available incident energy
❏ Skills required	❏ Potential for arc flash (Conduct an arc flash hazard analysis.)
❏ Any "foreign" (secondary source) voltage source	❏ Arc flash boundary
❏ Any unusual work conditions	
❏ Number of people needed to do the job	
Ask	
❏ Can the equipment be de-energized?	❏ Is a standby person required?
❏ Are backfeeds of the circuits to be worked on possible?	
Check	
❏ Job plans	❏ Safety procedures
❏ Single-line diagrams and vendor prints	❏ Vendor information
❏ Status board	❏ Individuals are familiar with the facility
❏ Information on plant and vendor resources is up to date	
Know	
❏ What the job is	❏ Who is in charge
❏ Who else needs to know — Communicate!	
Think	
❏ About the unexpected event . . . What if?	❏ Install and remove temporary protective grounding equipment
❏ Lock — Tag — Test — Try	❏ Install barriers and barricades
❏ Test for voltage — FIRST	❏ What else . . . ?
❏ Use the right tools and equipment, including PPE	
Prepare for an emergency	
❏ Is the standby person CPR trained?	❏ What is the exact work location?
❏ Is the required emergency equipment available? Where is it?	❏ How is the equipment shut off in an emergency?
❏ Where is the nearest telephone?	❏ Are the emergency telephone numbers known?
❏ Where is the fire alarm?	❏ Where is the fire extinguisher?
❏ Is confined space rescue available?	❏ Are radio communications available?

Figure I.1 Sample Job Briefing and Planning Checklist.

Informative Annex J Energized Electrical Work Permit

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

J.1 Energized Electrical Work Permit Sample. Figure J.1 illustrates considerations for an energized electrical work permit.

J.2 Energized Electrical Work Permit. Figure J.2 illustrates items to consider when determining the need for an energized electrical work permit.

ENERGIZED ELECTRICAL WORK PERMIT

PART I: TO BE COMPLETED BY THE REQUESTER:

Job/Work Order Number ______________

(1) Description of circuit/equipment/job location: ______________

(2) Description of work to be done: ______________

(3) Justification of why the circuit/equipment cannot be de-energized or the work deferred until the next scheduled outage: ______________

Requester/Title ______________ Date ______________

PART II: TO BE COMPLETED BY THE ELECTRICALLY QUALIFIED PERSONS *DOING* THE WORK:

Check when complete

(1) Detailed job description procedure to be used in performing the above detailed work: ☐

(2) Description of the safe work practices to be employed: ______________ ☐

(3) Results of the shock risk assessment: ______________

(a) Voltage to which personnel will be exposed ☐

(b) Limited approach boundary ☐

(c) Restricted approach boundary ☐

(d) Necessary shock, personal, and other protective equipment to safely perform assigned task ☐

(4) Results of the arc flash risk assessment: ______________

(a) Available incident energy at the working distance or arc flash PPE category ☐

(b) Necessary arc flash personal and other protective equipment to safely perform the assigned task ☐

(c) Arc flash boundary ☐

(5) Means employed to restrict the access of unqualified persons from the work area: ______________ ☐

(6) Evidence of completion of a job briefing, including discussion of any job-related hazards: ______________ ☐

(7) Do you agree the above-described work can be done safely? ❑ Yes ❑ No (If *no,* return to requester.)

Electrically Qualified Person(s) ______________ Date ______________

Electrically Qualified Person(s) ______________ Date ______________

PART III: APPROVAL(S) TO PERFORM THE WORK WHILE ELECTRICALLY ENERGIZED:

Manufacturing Manager ______________ Maintenance/Engineering Manager ______________

Safety Manager ______________ Electrically Knowledgeable Person ______________

General Manager ______________ Date ______________

Note: Once the work is complete, forward this form to the site Safety Department for review and retention.

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Figure J.1 Sample Permit for Energized Electrical Work.

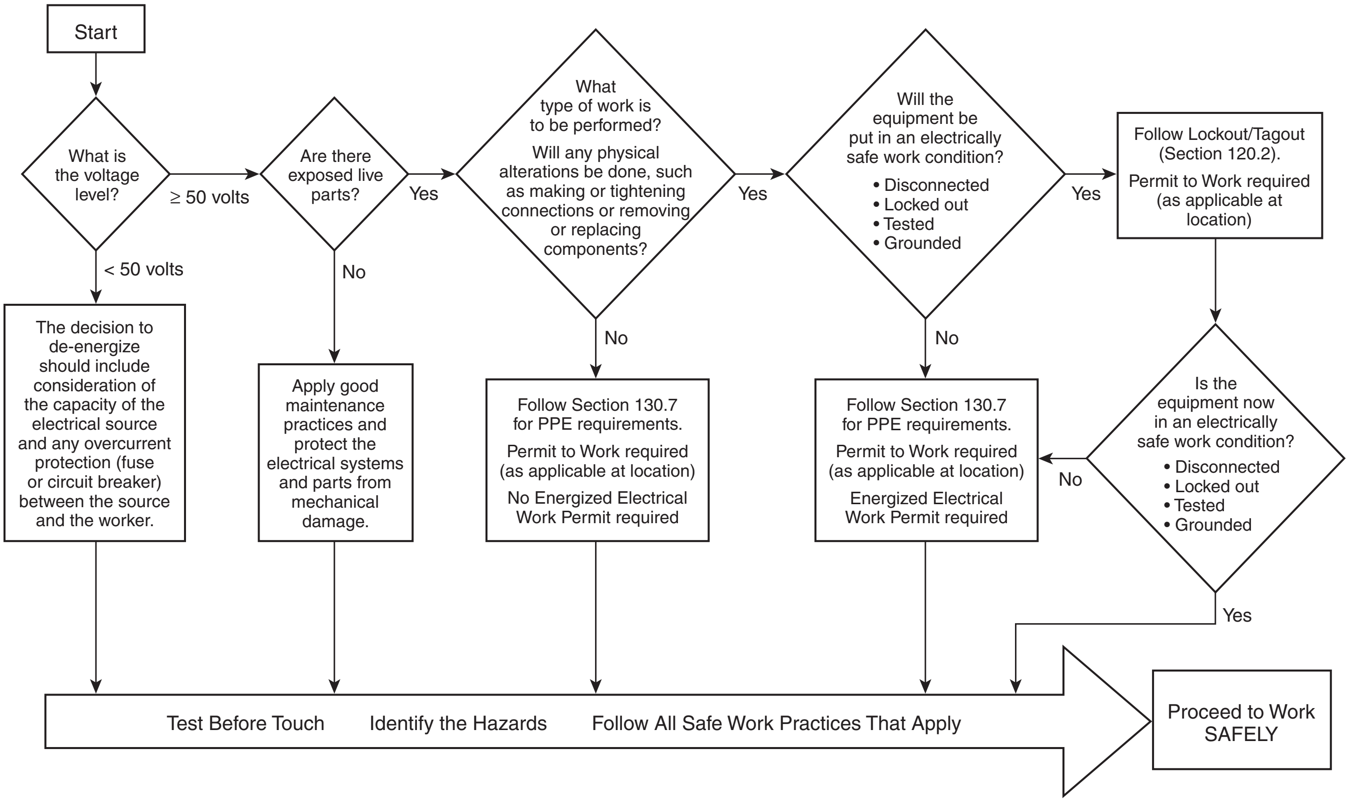

Figure J.2 Energized Electrical Work Permit Flow Chart.

Informative Annex K General Categories of Electrical Hazards

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

K.1 General Categories. There are three general categories of electrical hazards: electrical shock, arc flash, and arc blast.

K.2 Electric Shock. Approximately 30,000 nonfatal electrical shock accidents occur each year. The National Safety Council estimates that about 1000 fatalities each year are due to electrocution, more than half of them while servicing energized systems of less than 600 volts.

Electrocution is the fourth leading cause of industrial fatalities, after traffic, homicide, and construction accidents. The current required to light a 7½-watt, 120-volt lamp, if passed across the chest, is enough to cause a fatality. The most damaging paths through the body are through the lungs, heart, and brain.

K.3 Arc Flash. When an electric current passes through air between ungrounded conductors or between ungrounded conductors and grounded conductors, the temperatures can reach 35,000°F. Exposure to these extreme temperatures both burns the skin directly and causes ignition of clothing, which adds to the burn injury. The majority of hospital admissions due to electrical accidents are from arc flash burns, not from shocks. Each year more than 2000 people are admitted to burn centers with severe arc flash burns. Arc flashes can and do kill at distances of 3 m (10 ft).

K.4 Arc Blast. The tremendous temperatures of the arc cause the explosive expansion of both the surrounding air and the metal in the arc path. For example, copper expands by a factor of 67,000 times when it turns from a solid to a vapor. The danger associated with this expansion is one of high pressures, sound, and shrapnel. The high pressures can easily exceed hundreds or even thousands of pounds per square foot, knocking workers off ladders, rupturing eardrums, and collapsing lungs. The sounds associated with these pressures can exceed 160 dB. Finally, material and molten metal are expelled away from the arc at speeds exceeding 1120 km/hr (700 mph), fast enough for shrapnel to completely penetrate the human body.

Informative Annex L Typical Application of Safeguards in the Cell Line Working Zone

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

L.1 Application of Safeguards. This informative annex permits a typical application of safeguards in electrolytic areas where electrical hazards exist. Take, for example, an employee working on an energized cell. The employee uses manual contact to make adjustments and repairs. Consequently, the exposed energized cell and grounded metal floor could present an electrical hazard. Safeguards for this employee can be provided in the following ways:

(1) Protective boots can be worn that isolate the employee's feet from the floor and that provide a safeguard from the electrical hazard.
(2) Protective gloves can be worn that isolate the employee's hands from the energized cell and that provide a safeguard.
(3) If the work task causes severe deterioration, wear, or damage to personal protective equipment (PPE), the employee might have to wear both protective gloves and boots.
(4) A permanent or temporary insulating surface can be provided for the employee to stand on to provide a safeguard.
(5) The design of the installation can be modified to provide a conductive surface for the employee to stand on. If the conductive surface is bonded to the cell, a safeguard will be provided by voltage equalization.
(6) Safe work practices can provide safeguards. If protective boots are worn, the employee should not make long reaches over energized (or grounded) surfaces such that his or her elbow bypasses the safeguard. If such movements are required, protective sleeves, protective mats, or special tools should be used. Training on the nature of electrical hazards and proper use and condition of safeguards is, in itself, a safeguard.
(7) The energized cell can be temporarily bonded to ground.

L.2 Electrical Power Receptacles. Power supply circuits and receptacles in the cell line area for portable electric equipment should meet the requirements of 668.21 of *NFPA 70*, *National Electrical Code*. However, it is recommended that receptacles for portable electric equipment not be installed in electrolytic cell areas and that only pneumatic-powered portable tools and equipment be used.

Informative Annex M Layering of Protective Clothing and Total System Arc Rating

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

M.1 Layering of Protective Clothing.

M.1.1 Layering of arc-rated clothing is an effective approach to achieving the required arc rating. The use of all arc-rated clothing layers will result in achieving the required arc rating with the lowest number of layers and lowest clothing system weight. Garments that are not arc-rated should not be used to increase the arc rating of a garment or of a clothing system.

M.1.2 The total system of protective clothing can be selected to take credit for the protection provided by all the layers of clothing that are worn. For example, to achieve an arc rating of 40 cal/cm^2, an arc flash suit with an arc rating of 40 cal/cm^2 could be worn over a cotton shirt and cotton pants. Alternatively, an arc flash suit with a 25 cal/cm^2 arc rating could be worn over an arc-rated shirt and arc-rated pants with an arc rating of 8 cal/cm^2 to achieve a total system arc rating of 40 cal/cm^2. This latter approach provides the required arc rating at a lower weight and with fewer total layers of fabric and, consequently, would provide the required protection with a higher level of worker comfort.

M.2 Layering Using Arc-Rated Clothing over Natural Fiber Clothing Underlayers.

M.2.1 Under some exposure conditions, natural fiber underlayers can ignite even when they are worn under arc-rated clothing.

M.2.2 If the arc flash exposure is sufficient to break open all the arc-rated clothing outerlayer or underlayers, the natural fiber underlayer can ignite and cause more severe burn injuries to an expanded area of the body. This is due to the natural fiber underlayers burning onto areas of the worker's body that were not exposed by the arc flash event. This can occur when the natural fiber underlayer continues to burn underneath arc-rated clothing layers even in areas in which the arc-rated clothing layer or layers are not broken open due to a "chimney effect."

M.3 Total System Arc Rating.

M.3.1 The total system arc rating is the arc rating obtained when all clothing layers worn by a worker are tested as a multilayer test sample. An example of a clothing system is an arc-rated coverall worn over an arc-rated shirt and arc-rated pants in which all of the garments are constructed from the same arc-rated fabric. For this two-layer arc-rated clothing system, the arc rating would typically be more than three times higher than the arc ratings of the individual layers; that is, if the arc ratings of the arc-rated coverall, shirt, and pants were all in the range of 5 cal/cm^2 to 6 cal/cm^2, the total two-layer system arc rating would be over 20 cal/cm^2.

M.3.2 It is important to understand that the total system arc rating cannot be determined by adding the arc ratings of the individual layers. In a few cases, it has been observed that the total system arc rating actually decreased when another arc-rated layer of a specific type was added to the system as the outermost layer. The only way to determine the total system arc rating is to conduct a multilayer arc test on the combination of all of the layers assembled as they would be worn.

Informative Annex N Example Industrial Procedures and Policies for Working Near Overhead Electrical Lines and Equipment

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

N.1 Introduction. This informative annex is an example of an industrial procedure for working near overhead electrical systems. Areas covered include operations that could expose employees or equipment to contact with overhead electrical systems.

When working near electrical lines or equipment, avoid direct or indirect contact. Direct contact is contact with any part of the body. Indirect contact is when part of the body touches or is in dangerous proximity to any object in contact with energized electrical equipment. The following two assumptions should always be made:

(1) Lines are "live" (energized).
(2) Lines are operating at high voltage (over 1000 volts).

As the voltage increases, the minimum working clearances increase. Through arc-over, injuries or fatalities could occur, even if actual contact with high-voltage lines or equipment is not made. Potential for arc-over increases as the voltage increases.

N.2 Overhead Power Line Policy (OPP). This informative annex applies to all overhead conductors, regardless of voltage, and requires the following:

(1) That employees not place themselves in close proximity to overhead power lines. "Close proximity" is within a distance of 3 m (10 ft) for systems up to 50 kV, and should be increased 100 mm (4 in.) for every 10 kV above 50 kV.
(2) That employees be informed of the hazards and precautions when working near overhead lines.
(3) That warning decals be posted on cranes and similar equipment regarding the minimum clearance of 3 m (10 ft).
(4) That a "spotter" be designated when equipment is working near overhead lines. This person's responsibility is to observe safe working clearances around all overhead lines and to direct the operator accordingly.
(5) That warning cones be used as visible indicators of the 3 m (10 ft) safety zone when working near overhead power lines.

Informational Note: "Working near," for the purpose of this informative annex, is defined as working within a distance from any overhead power line that is less than the combined height or length of the lifting device plus the associated load length and the required minimum clearance distance [as stated in N.2(1)]. Required clearance is expressed as follows:
Required clearance = lift equipment height or length + load length + at least 3 m (10 ft)

(6) That the local responsible person be notified at least 24 hours before any work begins to allow time to identify voltages and clearances or to place the line in an electrically safe work condition.

N.3 Policy. All employees and contractors shall conform to the OPP. The first line of defense in preventing electrical contact accidents is to remain outside the limited approach boundary. Because most company and contractor employees are not qualified to determine the system voltage level, a qualified person shall be called to establish voltages and minimum clearances and take appropriate action to make the work zone safe.

N.4 Procedures.

N.4.1 General. Prior to the start of all operations where potential contact with overhead electrical systems is possible, the person in charge shall identify overhead lines or equipment, reference their location with respect to prominent physical features, or physically mark the area directly in front of the overhead lines with safety cones, survey tape, or other means. Electrical line location shall be discussed at a pre-work safety meeting of all employees on the job (through a job briefing). All company employees and contractors shall attend this meeting and require their employees to conform to electrical safety standards. New or transferred employees shall be informed of electrical hazards and proper procedures during orientations.

On construction projects, the contractor shall identify and reference all potential electrical hazards and document such actions with the on-site employers. The location of overhead electrical lines and equipment shall be conspicuously marked by the person in charge. New employees shall be informed of electrical hazards and of proper precautions and procedures.

Where there is potential for contact with overhead electrical systems, local area management shall be called to decide whether to place the line in an electrically safe work condition or to otherwise protect the line against accidental contact. Where there is a suspicion of lines with low clearance [height under 6 m (20 ft)], the local on-site electrical supervisor shall be notified to verify and take appropriate action.

All electrical contact incidents, including "near misses," shall be reported to the local area health and safety specialist.

N.4.2 Look Up and Live Flags. In order to prevent accidental contacts of overhead lines, all aerial lifts, cranes, boom trucks, service rigs, and similar equipment shall use look up and live flags. The flags are visual indicators that the equipment is currently being used or has been returned to its "stowed or cradled" position. The flags shall be yellow with black lettering and shall state in bold lettering "LOOK UP AND LIVE."

The procedure for the use of the flag follows.

(1) When the boom or lift is in its stowed or cradled position, the flag shall be located on the load hook or boom end.
(2) Prior to operation of the boom or lift, the operator of the equipment shall assess the work area to determine the location of all overhead lines and communicate this information to all crews on site. Once completed, the operator shall remove the flag from the load hook or boom and transfer the flag to the steering wheel of the vehicle. Once the flag is placed on the steering wheel, the operator can begin to operate the equipment.
(3) After successfully completing the work activity and returning the equipment to its stowed or cradled position, the operator shall return the flag to the load hook.
(4) The operator of the equipment is responsible for the placement of the look up and live flag.

N.4.3 High Risk Tasks.

N.4.3.1 Heavy Mobile Equipment. Prior to the start of each workday, a high-visibility marker (orange safety cones or other devices) shall be temporarily placed on the ground to mark the location of overhead wires. The supervisors shall discuss electrical safety with appropriate crew members at on-site tailgate safety talks. When working in the proximity of overhead lines, a spotter shall be positioned in a conspicuous location to direct movement and observe for contact with the overhead wires. The spotter, equipment operator, and all other employees working on the job location shall be alert for overhead wires and remain at least 3 m (10 ft) from the mobile equipment.

All mobile equipment shall display a warning decal regarding electrical contact. Independent truck drivers delivering materials to field locations shall be cautioned about overhead electrical lines before beginning work, and a properly trained on-site or contractor employee shall assist in the loading or off-loading operation. Trucks that have emptied their material shall not leave the work location until the boom, lift, or box is down and is safely secured.

N.4.3.2 Aerial Lifts, Cranes, and Boom Devices. Where there is potential for near operation or contact with overhead lines or equipment, work shall not begin until a safety meeting is conducted and appropriate steps are taken to identify, mark, and warn against accidental contact. The supervisor will review operations daily to ensure compliance.

Where the operator's visibility is impaired, a spotter shall guide the operator. Hand signals shall be used and clearly understood between the operator and spotter. When visual contact is impaired, the spotter and operator shall be in radio contact. Aerial lifts, cranes, and boom devices shall have appropriate warning decals and shall use warning cones or similar devices to indicate the location of overhead lines and identify the 3 m (10 ft) minimum safe working boundary.

N.4.3.3 Tree Work. Wires shall be treated as live and operating at high voltage until verified as otherwise by the local area on-site employer. The local maintenance organization or an approved electrical contractor shall remove branches touching wires before work begins. Limbs and branches shall not be dropped onto overhead wires. If limbs or branches fall across electrical wires, all work shall stop immediately and the local area maintenance organization is to be called. When climbing or working in trees, pruners shall try to position themselves so that the trunk or limbs are between their bodies and electrical wires. If possible, pruners shall not work with their backs toward electrical wires. An insulated bucket truck is the preferred method of pruning when climbing poses a greater threat of electrical contact. Personal protective equipment (PPE) shall be used while working on or near lines.

N.4.4 Underground Electrical Lines and Equipment. Before excavation starts and where there exists reasonable possibility of contacting electrical or utility lines or equipment, the local area supervision (or USA DIG organization, when appropriate) shall be called and a request is to be made for identifying/marking the line location(s).

When USA DIG is called, their representatives will need the following:

(1) Minimum of two working days' notice prior to start of work, name of county, name of city, name and number of street or highway marker, and nearest intersection
(2) Type of work
(3) Date and time work is to begin
(4) Caller's name, contractor/department name and address
(5) Telephone number for contact
(6) Special instructions

Utilities that do not belong to USA DIG must be contacted separately. USA DIG might not have a complete list of utility owners. Utilities that are discovered shall be marked before work begins. Supervisors shall periodically refer their location to all workers, including new employees, subject to exposure.

N.4.5 Vehicles with Loads in Excess of 4.25 m (14 ft) in Height. This policy requires that all vehicles with loads in excess of 4.25 m (14 ft) in height use specific procedures to maintain safe working clearances when in transit below overhead lines.

The specific procedures for moving loads in excess of 4.25 m (14 ft) in height or via routes with lower clearance heights are as follows:

(1) Prior to movement of any load in excess of 4.25 m (14 ft) in height, the local health and safety department, along with the local person in charge, shall be notified of the equipment move.
(2) An on-site electrician, electrical construction representative, or qualified electrical contractor should check the intended route to the next location before relocation.
(3) The new site is to be checked for overhead lines and clearances.
(4) Power lines and communication lines shall be noted, and extreme care used when traveling beneath the lines.
(5) The company moving the load or equipment will provide a driver responsible for measuring each load and ensuring each load is secured and transported in a safe manner.
(6) An on-site electrician, electrical construction representative, or qualified electrical contractor shall escort the first load to the new location, ensuring safe clearances, and a service company representative shall be responsible for subsequent loads to follow the same safe route.

If proper working clearances cannot be maintained, the job must be shut down until a safe route can be established or the necessary repairs or relocations have been completed to ensure that a safe working clearance has been achieved.

All work requiring movement of loads in excess of 4.25 m (14 ft) in height are required to begin only after a general work permit has been completed detailing all pertinent information about the move.

N.4.6 Emergency Response. If an overhead line falls or is contacted, the following precautions should be taken:

(1) Keep everyone at least 3 m (10 ft) away.
(2) Use flagging to protect motorists, spectators, and other individuals from fallen or low wires.
(3) Call the local area electrical department or electric utility immediately.
(4) Place barriers around the area.
(5) Do not attempt to move the wire(s).
(6) Do not touch anything that is touching the wire(s).
(7) Be alert to water or other conductors present.
(8) Crews shall have emergency numbers readily available. These numbers shall include local area electrical department, utility, police/fire, and medical assistance.
(9) If an individual becomes energized, DO NOT TOUCH the individual or anything in contact with the person. Call for emergency medical assistance and call the local utility immediately. If the individual is no longer in contact with the energized conductors, CPR, rescue breathing, or first aid should be administered immediately, but only by a trained person. It is safe to touch the victim once contact is broken or the source is known to be de-energized.
(10) Wires that contact vehicles or equipment will cause arcing, smoke, and possibly fire. Occupants should remain in the cab and wait for the local area electrical department or utility. If it becomes necessary to exit the vehicle, leap with both feet as far away from the vehicle as possible, without touching the equipment. Jumping free of the vehicle is the last resort.
(11) If operating the equipment and an overhead wire is contacted, stop the equipment immediately and, if safe to do so, jump free and clear of the equipment. Maintain your balance, keep your feet together and either shuffle or bunny hop away from the vehicle another 3 m (10 ft) or more. Do not return to the vehicle or allow anyone else for any reason to return to the vehicle until the local utility has removed the power line from the vehicle and has confirmed that the vehicle is no longer in contact with the overhead lines.

Informative Annex O Safety-Related Design Requirements

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

O.1 Introduction. This informative annex addresses the responsibilities of the facility owner or manager or the employer having responsibility for facility ownership or operations management to perform a risk assessment during the design of electrical systems and installations.

O.1.1 This informative annex covers employee safety-related design concepts for electrical equipment and installations in workplaces covered by the scope of this standard. This informative annex discusses design considerations that have impact on the application of the safety-related work practices only.

O.1.2 This informative annex does not discuss specific design requirements. The facility owner or manager or the employer should choose design options that eliminate hazards or reduce risk and enhance the effectiveness of safety-related work practices.

O.2 General Design Considerations.

O.2.1 Employers, facility owners, and managers who have responsibility for facilities and installations having electrical energy as a potential hazard to employees and other personnel should ensure that electrical hazards risk assessments are performed during the design of electrical systems and installations.

O.2.2 Design option decisions should facilitate the ability to eliminate hazards or reduce risk by doing the following:

(1) Reducing the likelihood of exposure
(2) Reducing the magnitude or severity of exposure
(3) Enabling achievement of an electrically safe work condition

O.2.3 Incident Energy Reduction Methods. The following methods have proved to be effective in reducing incident energy:

(1) Zone-selective interlocking. A method that allows two or more circuit breakers to communicate with each other so that a short circuit or ground fault will be cleared by the breaker closest to the fault with no intentional delay. Clearing the fault in the shortest time aids in reducing the incident energy.
(2) Differential relaying. The concept of this protection method is that current flowing into protected equipment must equal the current out of the equipment. If these two currents are not equal, a fault must exist within the equipment, and the relaying can be set to operate for a fast interruption. Differential relaying uses current transformers located on the line and load sides of the protected equipment and fast acting relay.
(3) Energy-reducing maintenance switching with a local status indicator. An energy-reducing maintenance switch allows a worker to set a circuit breaker trip unit to operate faster while the worker is working within an arc flash boundary, as defined in NFPA 70E, and then to set the circuit breaker back to a normal setting after the work is complete.

O.2.4 Other Methods.

(1) Energy-reducing active arc flash mitigation system. This system can reduce the arcing duration by creating a low impedance current path, located within a controlled compartment, to cause the arcing fault to transfer to the new current path, while the upstream breaker clears the circuit. The system works without compromising existing selective coordination in the electrical distribution system.
(2) Arc flash relay. An arc flash relay typically uses light sensors to detect the light produced by an arc flash event. Once a certain level of light is detected the relay will issue a trip signal to an upstream overcurrent device.
(3) High-resistance grounding. A great majority of electrical faults are of the phase-to-ground type. High-resistance grounding will insert an impedance in the ground return path and will typically limit the fault current to 10 amperes and below (at 5 kV nominal or below), leaving insufficient fault energy and thereby helping reduce the arc flash hazard level. High-resistance grounding will not affect arc flash energy for line-to-line or line-to-line-to-line arcs.
(4) Current-limiting devices. Current-limiting protective devices reduce incident energy by clearing the fault faster and by reducing the current seen at the arc source. The energy reduction becomes effective for current above the current-limiting threshold of the current-limiting fuse or current limiting circuit breaker.

Informative Annex P Aligning Implementation of This Standard with Occupational Health and Safety Management Standards

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

P.1 General. Injuries from electrical energy are a significant cause of occupational fatalities in the workplace in the United States. This standard specifies requirements unique to the hazards of electrical energy. By itself, however, this standard does not constitute a comprehensive and effective electrical safety program. The most effective application of the requirements of this standard can be achieved within the framework of a recognized health and safety management system standard. ANSI/AIHA Z10, *American National Standard for Occupational Health and Safety Management Systems*, provides comprehensive guidance on the elements of an effective health and safety management system and is one recognized standard. ANSI/AIHA Z10 is harmonized with other internationally recognized standards, including CAN/CSA Z1000, *Occupational Health and Safety Management*; ANSI/ISO 14001, *Environmental Management Systems - Requirements with Guidance for Use*; and BS OSHAS 18001, *Occupational Health and Safety Management Systems*. Some companies and other organizations have proprietary health and safety management systems that are aligned with the key elements of ANSI/AIHA Z10.

The most effective design and implementation of an electrical safety program can be achieved through a joint effort involving electrical subject matter experts and safety professionals knowledgeable about safety management systems.

Such collaboration can help ensure that proven safety management principles and practices applicable to any hazard in the workplace are appropriately incorporated into the electrical safety program.

This informative annex provides guidance on implementing this standard within the framework of ANSI/AIHA Z10 and other recognized or proprietary comprehensive occupational health and safety management system standards.

Index

Sequence of Events for the Standards Development Process

As soon as the current edition is published, a Standard is open for Public Input

Step 1: Input Stage

- Input accepted from the public or other committees for consideration to develop the First Draft
- Committee holds First Draft Meeting to revise Standard (23 weeks)
  Committee(s) with Correlating Committee (10 weeks)
- Committee ballots on First Draft (12 weeks)
  Committee(s) with Correlating Committee (11 weeks)
- Correlating Committee First Draft Meeting (9 weeks)
- Correlating Committee ballots on First Draft (5 weeks)
- First Draft Report posted

Step 2: Comment Stage

- Public Comments accepted on First Draft (10 weeks)
- If Standard does not receive Public Comments and the Committee does not wish to further revise the Standard, the Standard becomes a Consent Standard and is sent directly to the Standards Council for issuance
- Committee holds Second Draft Meeting (21 weeks)
  Committee(s) with Correlating Committee (7 weeks)
- Committee ballots on Second Draft (11 weeks)
  Committee(s) with Correlating Committee (10 weeks)
- Correlating Committee First Draft Meeting (9 weeks)
- Correlating Committee ballots on First Draft (8 weeks)
- Second Draft Report posted

Step 3: Association Technical Meeting

- Notice of Intent to Make a Motion (NITMAM) accepted (5 weeks)
- NITMAMs are reviewed and valid motions are certified for presentation at the Association Technical Meeting
- Consent Standard bypasses Association Technical Meeting and proceeds directly to the Standards Council for issuance
- NFPA membership meets each June at the Association Technical Meeting and acts on Standards with "Certified Amending Motions" (certified NITMAMs)
- Committee(s) and Panel(s) vote on any successful amendments to the Technical Committee Reports made by the NFPA membership at the Association Technical Meeting

Step 4: Council Appeals and Issuance of Standard

- Notification of intent to file an appeal to the Standards Council on Association action must be filed within 20 days of the Association Technical Meeting
- Standards Council decides, based on all evidence, whether or not to issue the Standards or to take other action

Committee Membership Classifications[1,2,3,4]

The following classifications apply to Committee members and represent their principal interest in the activity of the Committee.

1. M *Manufacturer:* A representative of a maker or marketer of a product, assembly, or system, or portion thereof, that is affected by the standard.
2. U *User:* A representative of an entity that is subject to the provisions of the standard or that voluntarily uses the standard.
3. IM *Installer/Maintainer:* A representative of an entity that is in the business of installing or maintaining a product, assembly, or system affected by the standard.
4. L *Labor:* A labor representative or employee concerned with safety in the workplace.
5. RT *Applied Research/Testing Laboratory:* A representative of an independent testing laboratory or independent applied research organization that promulgates and/or enforces standards.
6. E *Enforcing Authority:* A representative of an agency or an organization that promulgates and/or enforces standards.
7. I *Insurance:* A representative of an insurance company, broker, agent, bureau, or inspection agency.
8. C *Consumer:* A person who is or represents the ultimate purchaser of a product, system, or service affected by the standard, but who is not included in (2).
9. SE *Special Expert:* A person not representing (1) through (8) and who has special expertise in the scope of the standard or portion thereof.

NOTE 1: "Standard" connotes code, standard, recommended practice, or guide.

NOTE 2: A representative includes an employee.

NOTE 3: While these classifications will be used by the Standards Council to achieve a balance for Technical Committees, the Standards Council may determine that new classifications of member or unique interests need representation in order to foster the best possible Committee deliberations on any project. In this connection, the Standards Council may make such appointments as it deems appropriate in the public interest, such as the classification of "Utilities" in the National Electrical Code Committee.

NOTE 4: Representatives of subsidiaries of any group are generally considered to have the same classification as the parent organization.

Submitting Public Input / Public Comment through the Electronic Submission System (e-Submission):

As soon as the current edition is published, a Standard is open for Public Input.

Before accessing the e-Submission System, you must first sign-in at www.NFPA.org. *Note: You will be asked to sign-in or create a free online account with NFPA before using this system*:

a. Click in the gray Sign In box on the upper left side of the page. Once signed-in, you will see a red "Welcome" message in the top right corner.
b. Under the Codes and Standards heading, Click on the Document Information pages (List of Codes & Standards), and then select your document from the list or use one of the search features in the upper right gray box.

OR

a. Go directly to your specific document page by typing the convenient short link of www.nfpa.org/document#, (Example: NFPA 921 would be www.nfpa.org/921) Click in the gray Sign In box on the upper left side of the page. Once signed in, you will see a red "Welcome" message in the top right corner.

To begin your Public Input, select the link The next edition of this standard is now open for Public Input (formally "proposals") located on the Document Information tab, the Next Edition tab, or the right-hand Navigation bar. Alternatively, the Next Edition tab includes a link to Submit Public Input online

At this point, the NFPA Standards Development Site will open showing details for the document you have selected. This "Document Home" page site includes an explanatory introduction, information on the current document phase and closing date, a left-hand navigation panel that includes useful links, a document Table of Contents, and icons at the top you can click for Help when using the site. The Help icons and navigation panel will be visible except when you are actually in the process of creating a Public Input.

Once the First Draft Report becomes available there is a Public comment period during which anyone may submit a Public Comment on the First Draft. Any objections or further related changes to the content of the First Draft must be submitted at the Comment stage.

To submit a Public Comment you may access the e-Submission System utilizing the same steps as previous explained for the submission of Public Input.

For further information on submitting public input and public comments, go to: http://www.nfpa.org/publicinput

Other Resources available on the Doc Info Pages

Document information tab: Research current and previous edition information on a Standard

Next edition tab: Follow the committee's progress in the processing of a Standard in its next revision cycle.

Technical committee tab: View current committee member rosters or apply to a committee

Technical questions tab: For members and Public Sector Officials/AHJs to submit questions about codes and standards to NFPA staff. Our Technical Questions Service provides a convenient way to receive timely and consistent technical assistance when you need to know more about NFPA codes and standards relevant to your work. Responses are provided by NFPA staff on an informal basis.

Products/training tab: List of NFPA's publications and training available for purchase.

Community tab: Information and discussions about a Standard

Information on the NFPA Standards Development Process

I. Applicable Regulations. The primary rules governing the processing of NFPA standards (codes, standards, recommended practices, and guides) are the NFPA *Regulations Governing the Development of NFPA Standards (Regs)*. Other applicable rules include NFPA *Bylaws*, NFPA *Technical Meeting Convention Rules*, NFPA *Guide for the Conduct of Participants in the NFPA Standards Development Process*, and the NFPA *Regulations Governing Petitions to the Board of Directors from Decisions of the Standards Council*. Most of these rules and regulations are contained in the *NFPA Standards Directory*. For copies of the *Directory*, contact Codes and Standards Administration at NFPA Headquarters; all these documents are also available on the NFPA website at "www.nfpa.org."

The following is general information on the NFPA process. All participants, however, should refer to the actual rules and regulations for a full understanding of this process and for the criteria that govern participation.

II. Technical Committee Report. The Technical Committee Report is defined as "the Report of the responsible Committee(s), in accordance with the Regulations, in preparation of a new or revised NFPA Standard." The Technical Committee Report is in two parts and consists of the First Draft Report and the Second Draft Report. (See *Regs* at 1.4)

III. Step 1: First Draft Report. The First Draft Report is defined as "Part one of the Technical Committee Report, which documents the Input Stage." The First Draft Report consists of the First Draft, Public Input, Committee Input, Committee and Correlating Committee Statements, Correlating Input, Correlating Notes, and Ballot Statements. (See *Regs* at 4.2.5.2 and Section 4.3) Any objection to an action in the First Draft Report must be raised through the filing of an appropriate Comment for consideration in the Second Draft Report or the objection will be considered resolved. [See *Regs* at 4.3.1(b)]

IV. Step 2: Second Draft Report. The Second Draft Report is defined as "Part two of the Technical Committee Report, which documents the Comment Stage." The Second Draft Report consists of the Second Draft, Public Comments with corresponding Committee Actions and Committee Statements, Correlating Notes and their respective Committee Statements, Committee Comments, Correlating Revisions, and Ballot Statements. (See *Regs* at Section 4.2.5.2 and 4.4) The First Draft Report and the Second Draft Report together constitute the Technical Committee Report. Any outstanding objection following the Second Draft Report must be raised through an appropriate Amending Motion at the Association Technical Meeting or the objection will be considered resolved. [See *Regs* at 4.4.1(b)]

V. Step 3a: Action at Association Technical Meeting. Following the publication of the Second Draft Report, there is a period during which those wishing to make proper Amending Motions on the Technical Committee Reports must signal their intention by submitting a Notice of Intent to Make a Motion. (See *Regs* at 4.5.2) Standards that receive notice of proper Amending Motions (Certified Amending Motions) will be presented for action at the annual June Association Technical Meeting. At the meeting, the NFPA membership can consider and act on these Certified Amending Motions as well as Follow-up Amending Motions, that is, motions that become necessary as a result of a previous successful Amending Motion. (See 4.5.3.2 through 4.5.3.6 and Table1, Columns 1-3 of *Regs* for a summary of the available Amending Motions and who may make them.) Any outstanding objection following action at an Association Technical Meeting (and any further Technical Committee consideration following successful Amending Motions, see *Regs* at 4.5.3.7 through 4.6.5.3) must be raised through an appeal to the Standards Council or it will be considered to be resolved.

VI. Step 3b: Documents Forwarded Directly to the Council. Where no Notice of Intent to Make a Motion (NITMAM) is received and certified in accordance with the Technical Meeting Convention Rules, the standard is forwarded directly to the Standards Council for action on issuance. Objections are deemed to be resolved for these documents. (See *Regs* at 4.5.2.5)

VII. Step 4a: Council Appeals. Anyone can appeal to the Standards Council concerning procedural or substantive matters related to the development, content, or issuance of any document of the Association or on matters within the purview of the authority of the Council, as established by the *Bylaws* and as determined by the Board of Directors. Such appeals must be in written form and filed with the Secretary of the Standards Council (See *Regs* at 1.6). Time constraints for filing an appeal must be in accordance with 1.6.2 of the *Regs*. Objections are deemed to be resolved if not pursued at this level.

VIII. Step 4b: Document Issuance. The Standards Council is the issuer of all documents (see Article 8 of *Bylaws*). The Council acts on the issuance of a document presented for action at an Association Technical Meeting within 75 days from the date of the recommendation from the Association Technical Meeting, unless this period is extended by the Council (See *Regs at* 4.7.2). For documents forwarded directly to the Standards Council, the Council acts on the issuance of the document at its next scheduled meeting, or at such other meeting as the Council may determine (See *Regs* at 4.5.2.5 and 4.7.4).

IX. Petitions to the Board of Directors. The Standards Council has been delegated the responsibility for the administration of the codes and standards development process and the issuance of documents. However, where extraordinary circumstances requiring the intervention of the Board of Directors exist, the Board of Directors may take any action necessary to fulfill its obligations to preserve the integrity of the codes and standards development process and to protect the interests of the Association. The rules for petitioning the Board of Directors can be found in the *Regulations Governing Petitions to the Board of Directors from Decisions of the Standards Council* and in 1.7 of the *Regs*.

X. For More Information. The program for the Association Technical Meeting (as well as the NFPA website as information becomes available) should be consulted for the date on which each report scheduled for consideration at the meeting will be presented. For copies of the First Draft Report and Second Draft Report as well as more information on NFPA rules and for up-to-date information on schedules and deadlines for processing NFPA documents, check the NFPA website (www.nfpa.org/aboutthecodes) or contact NFPA Codes & Standards Administration at (617) 984-7246.

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- ❏ Loss Control, Risk Manager (L11)
- ❏ Inspector, Building Official, Fire Marshal (F03)
- ❏ Owner, President, Manager, Administrator (C10)
- ❏ Other (please specify): (G11)____________________

Type of Organization *(check one)*

- ❏ Architecture, Engineering, Contracting (A14)
- ❏ Commercial Firm (Office, Retail, Lodging, Restaurant) (G13)
- ❏ Electrical Services, Installation (J11)
- ❏ Fire Service, Public and Private (AA1)
- ❏ Government (C12)
- ❏ Industrial Firm (Factory, Warehouse) (C11)
- ❏ Institutional (Health Care, Education, Detention, Museums) (B11)
- ❏ Insurance, Risk Management (B12)
- ❏ Utilities (G12)
- ❏ Other (please specify): (G11)____________________

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