ARC FLASH

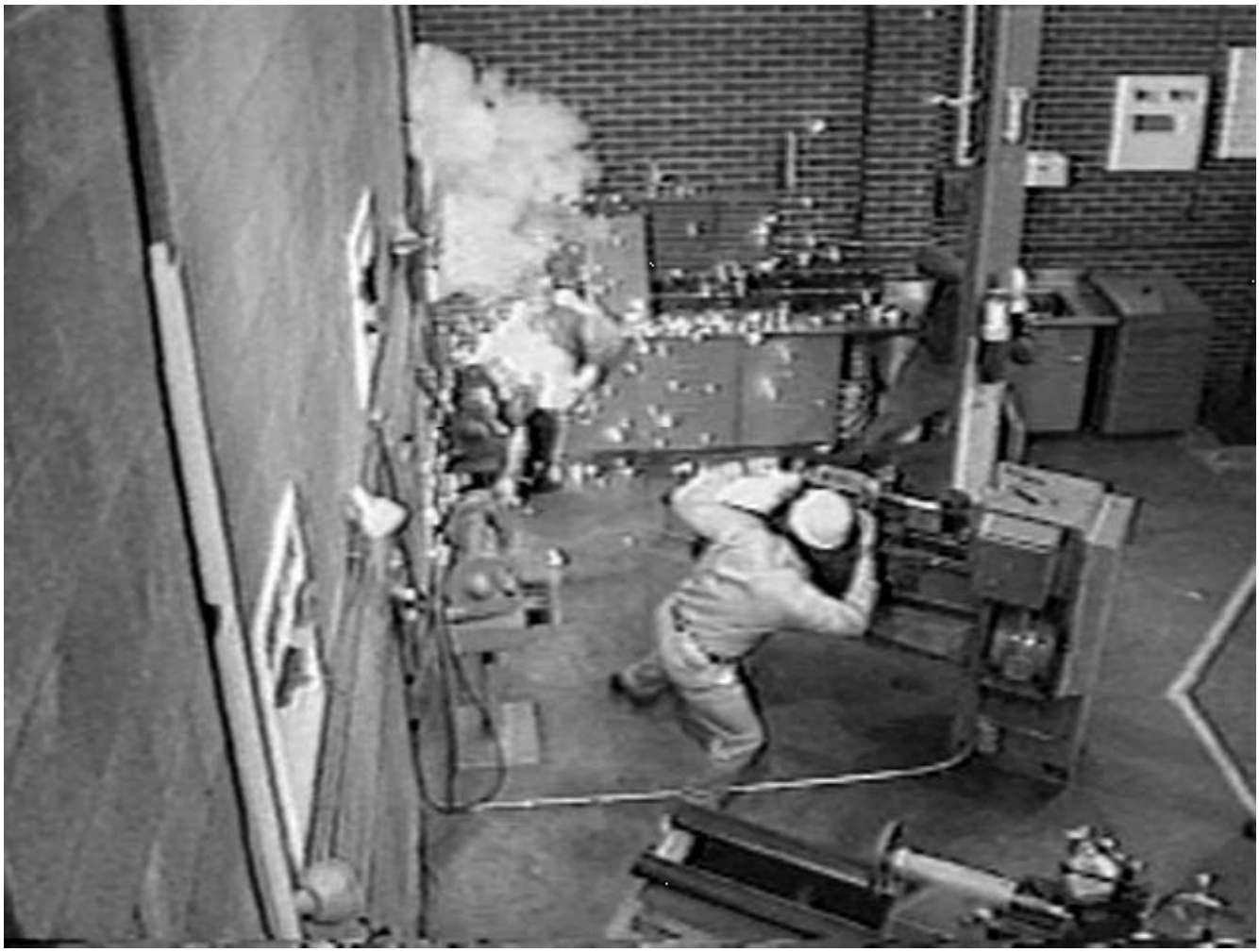


Table of Contents

Table of Contents(Continued)

Tables:

Introduction

Employees working in areas where there are potential electrical hazards must be provided with, and must use, electrical protective equipment appropriate for the parts of the body to be protected and the work performed. The following contains sections taken from NFPA 70E *"Standard for Electrical Safety in the Workplace".* The sections on Arc Flash have been compiled into one document in order to make reading easier.

130.1 Justification for Work

Live parts to which an employee might be exposed must be put into an electrically safe work condition before an employee works on or near them, unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. Energized parts that operate at less than 50 volts to ground must not be not required to be deenergized if there will be no increased exposure to electrical burns or to explosion due to electric arcs.

FPN No. 1: Examples of increased or additional hazards include, but are not limited to, interruption of life support equipment, deactivation of emergency alarm systems, and shutdown of hazardous location ventilation equipment.

FPN No. 2: Examples of work that might be performed on or near exposed energized electrical conductors or circuit parts because of infeasibility due to equipment design or operational limitations include performing diagnostics and testing (e.g., start-up or troubleshooting) of electric circuits that can only be performed with the circuit energized and work on circuits that form an integral part of a continuous process that would otherwise need to be completely shut down in order to permit work on one circuit or piece of equipment.

FPN No. 3: For voltages of less than 50 volts, the decision to deenergize should include consideration of the capacity of the source and any overcurrent protection between the energy source and the worker.

(A) Energized Electrical Work Permit

(1) Where Required.

If live parts are not placed in an electrically safe work condition (i.e., for the reasons of increased or additional hazards or infeasibility per 130.1), work to be performed must be considered energized electrical work and must be performed by written permit only.

(2) Elements of Work Permit.

The energized electrical work permit must include, but not be limited to, the following items:

1. A description of the circuit and equipment to be worked on and their location
2. Justification for why the work must be performed in an energized condition (130.1)
3. A description of the safe work practices to be employed
4. Results of the shock hazard analysis
5. Determination of shock protection boundaries [130.2(B) and Table 130.2(C)]
6. Results of the flash hazard analysis (130.3)
7. The Flash Protection Boundary [130.3(A)]
8. The necessary personal protective equipment to safely perform the assigned task [130.3(B), 130.7(C)(9), and Table 130.7(C)(9)(a)]
9. Means employed to restrict the access of unqualified persons from the work area Evidence of completion of a job briefing, including a discussion of any job-specific hazards
10. Energized work approval (authorizing or responsible management, safety officer, or owner, etc.) signature(s)

(3) Exemptions to Work Permit.

Work performed on or near live parts by qualified persons related to tasks such as testing, troubleshooting, voltage measuring, etc., must be permitted to be performed without an energized electrical work permit, provided appropriate safe work practices and personal protective equipment in accordance with *"NFPA 70E Chapter 1 Safety Related Work Practices"* are provided and used.

FPN: For an example of an acceptable energized electrical work permit, see page 17.

130.2 Approach Boundaries to Live Parts

(A) Shock Hazard Analysis

A shock hazard analysis must determine the voltage to which personnel will be exposed, boundary requirements, and the personal protective equipment necessary in order to minimize the possibility of electric shock to personnel.

(B) Shock Protection Boundaries

The shock protection boundaries identified as Limited, Restricted, and Prohibited Approach Boundaries are applicable to the situation in which approaching personnel are exposed to live parts. See Table 130.2(C) for the distances associated with various system voltages.

FPN: In certain instances, the Flash Protection Boundary might be a greater distance from the exposed live parts than the Limited Approach Boundary.

(C) Approach to Exposed Live Parts Operating at 50 Volts or More

No qualified person must approach or take any conductive object closer to exposed live parts operating at 50 volts or more than the Restricted Approach Boundary set forth in Table 130.2(C), unless any of the following apply:

1. The qualified person is insulated or guarded from the live parts operating at 50 volts or more (insulating gloves or insulating gloves and sleeves are considered insulation only with regard to the energized parts upon which work is being performed), and no uninsulated part of the qualified person's body crosses the Prohibited Approach Boundary set forth in Table 130.2(e).
2. The live part operating at 50 volts or more is insulated from the qualified person and from any other conductive object at a different potential.
3. The qualified person is insulated from any other conductive object as during live-line bare-hand work.

(D) Approach by Unqualified Persons

Unqualified persons must not be permitted to enter spaces that are required under 400.16(A) to be accessible to qualified employees only, unless the electric conductors and equipment involved are in an electrically safe work condition.

(1) Working At or Close to the Limited Approach Boundary

Where one or more unqualified persons are working at or close to the Limited Approach Boundary the designated person in charge of the work space where the electrical hazard exists must cooperate with the designated person in charge of the unqualified person(s) to ensure that all work can be done safely. This must include advising the unqualified person(s) of the electrical hazard and warning him or her to stay outside of the Limited Approach Boundary.

(2) Entering the Limited Approach Boundary

Where there is a need for an unqualified person(s) to cross the Limited Approach Boundary, a qualified person must advise him or her of the possible hazards and continuously escort the unqualified person(s) while inside the Limited Approach Boundary. Under no circumstance must the escorted unqualified person(s) be permitted to cross the Restricted Approach Boundary.

Table 130.2(C) Approach Boundaries to Live Parts for Shock Protection. (All dimensions are distance from live part to employee.)

1	2	3	4	5
	Limited Approach Boundary[1]		**Restricted Approach Boundary[1]; Includes Inadvertent Movement Adder**	
Nominal System Voltage Range, Phase to Phase	**Exposed Movable Conductor**	**Exposed Fixed Circuit Part**		**Prohibited Approach Bounday[1]**
Less than 50	Not specified	Not specified	Not specified	Not specified
50 to 300	3.05 m (10 ft 0 in.)	1.07 m (3 ft 6 in.)	Avoid contact	Avoid contact
301 to 750	3.05 m (10 ft 0 in.)	1.07 m (3 ft 6 in.)	304.8 mm (1 ft 0 in.)	25.4 mm (0 ft 1 in.)
751 to 15 kV	3.05 m (10 ft 0 in.)	1.53 m (5 ft 0 in.)	660.4 mm (2 ft 2 in.)	177.8 mm (0 ft 7 in.)
15.1 kV to 36 kV	3.05 m (10 ft 0 in.)	1.83 m (6 ft 0 in.)	787.4 mm (2 ft 7 in.)	254 mm (0 ft 10 in.)
36.1 kV to 46 kV	3.05 m (10 ft 0 in.)	2.44 m (8 ft 0 in.)	838.2 mm (2 ft 9 in.)	431.8 mm (1 ft 5 in.)
46.1 kV to 72.5 kV	3.05 m (10 ft 0 in.)	2.44 m (8 ft 0 in.)	965.2 mm (3 ft 2 in.)	635 mm (2 ft 1 in.)
72.6 kV to 121 kV	3.25 m (10 ft 8 in.)	2.44 m (8 ft 0 in.)	991 mm (3 ft 3 in.)	812.8 mm (2 ft 8 in.)
138 kV to 145 kV	3.36 m (11 ft 0 in.)	3.05 m (10 ft 0 in.)	1.093 m (3 ft 7 in.)	939.8 mm (3 ft 1 in.)
161 kV to 169 kV	3.56 m (11 ft 8 in.)	3.56 m (11 ft 8 in.)	1.22 m 4 ft 0 in.)	1.07 m (3 ft 6 in.)
230 kV to 242 kV	3.97 m (13 ft 0 in.)	3.97 m (13 ft 0 in.)	1.6 m (5 ft 3 in.)	1.45 m (4 ft 9 in.)
345 kV to 362 kV	4.68 m (15 ft 4 in.)	4.68 m (15 ft 4 in.)	2.59 m (8 ft 6 in.)	2.44 m (8 ft 0 in.)
500 kV to 550 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	3.43 m (11 ft 3 in.)	3.28 m (10 ft 9 in.)
765 kV to 800 kV	7.24 m (23 ft 9 in.)	7.24 m (23 ft 9 in.)	4.55 m (14 ft 11 in.)	4.4 m (14 ft 5 in.)

Note: For Flash Protection Boundary, see 130.3(A).

130.3 Flash Hazard Analysis

A flash hazard analysis must be done in order to protect personnel from the possibility of being injured by an arc flash. The analysis must determine the Flash Protection Boundary and the personal protective equipment that people within the Flash Protection Boundary must use.

[1]**Limited Approach Boundary** – An approach limit at a distance from an exposed live part within which a shock hazard exists.

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

[1]**Prohibited Approach Boundary** - An approach limit at a distance from an exposed live part within which work is considered the same as making contact with the live part.

Note: See Annex C for elaboration.

(A) Flash Protection Boundary

For systems that are 600 volts or less, the Flash Protection Boundary must be 4.0 ft, based on the product of clearing times of 6 cycles (0.1 second) and the available bolted fault current of 50 kA or any combination not exceeding 300 kA cycles (5000 ampere seconds). For clearing times and bolted fault currents other than 300 kA cycles, or under engineering supervision, the Flash Protection Boundary must alternatively be permitted to be calculated in accordance with the following general formula:

$$D_c = [2{,}65 \times MVA_{bf} \times t\ ]^{1/2}$$

or

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

where :

D_c = distance in feet from an arc source for a second-degree burn

MVA_{bf} = bolted fault capacity available at point involved (in mega volt-amps)

MVA = capacity rating of transformer (mega volt-amps). For transformers with *MVA* ratings below 0.75 MVA, multiply the transformer *MVA* rating by 1.25

t = time of arc exposure (in seconds)

(B) Protective Clothing and Personal Protective Equipment for Application with a Flash Hazard Analysis

Where it has been determined that work will be performed within the Flash Protection Boundary by 130.3(A), the flash hazard analysis must determine, and the employer must document, the incident energy exposure of the worker (in calories per square centimeter). The incident energy exposure level must be based on the working distance of the employee's face and chest areas from a prospective arc source for the specific task to be performed. Flame-resistant (FR) clothing and personal protective equipment (PPE) must be used by the employee base on the incident energy exposure associated with the specific task. Recognizing that incident energy increases as the distance form the arc flash decreases, additional PPE must be used for any parts of the body that are closer than the distance at which the incident energy was determined. As and alternative, the PPE requirements of 130.7 (C) (9) must be permitted to be used in lieu of the detailed flash hazard analysis approach described in 130.3 (A).

130.4 Test Instruments and Equipment Use

Only qualified persons must perform testing work on or near live parts operating at 50 volts or more.

130.7(C) (9) Selection of Personal Protective Equipment

(a) When Required for Various Tasks.

When selected in lieu of the flash hazard analysis of l30.3(A), Table 130.7(C)(9) (a) must be used to determine the hazard/risk category for a task. The assumed short-circuit current capacities and fault clearing times for various tasks are listed in the text and notes to Table 130.7(C)(9)(a). For tasks not listed, or for power systems with greater than the assumed short-circuit current capacity or with longer than the assumed fault clearing times, a flash hazard analysis must be required in accordance with 130.3.

FPN No. 1: Both larger and smaller available short-circuit currents could result in higher available arc-flash energies. If the available short-circuit current increases without a decrease in the opening time of the overcurrent protective device, the arc-flash energy will increase. If the available short-circuit current decreases, resulting in a longer opening time for the overcurrent protective device, arc-flash energies could also increase.

FPN No. 2: Energized parts that operate at less than 50 volts are not required to be de-energized to satisfy an "electrically safe work condition." Consideration should be given to the capacity of the source, any overcurrent protection between the energy source and the worker, and whether the work task related to the source operating at less than 50 volts increases exposure to electrical bums or to explosion from an electric arc.

Table 130.7(C)(9)(a) Hazard Risk Category Classifications

Task (Assumes Equipment Is Energized, and Work Is Done Within the Flash Protection Boundary	Hazard/Risk Category	V-rated Gloves	V-rated Tools
Panelboards Rated 240 V and Below –Notes 1 and 3			
Circuit breaker (CB) or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	0	N	N
Work on energized parts, including voltage testing	1	Y	Y
Remove/install CBs or fused switches	1	Y	Y
Removal of bolted covers (to expose bare, energized parts)	1	N	N
Opening hinged covers (to expose bare, energized parts)	0	N	N
Panelboards or Switchboards Rated >240 V and up to 600 V (with molded case or insulated case circuit breakers) – Notes 1 and 3			
CB or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	1	N	N
Work on energized parts, including voltage testing	2*	Y	Y
600 V Class Motor Control Centers (MCCs) – Notes 2 (except as indicated) and 3			
CB or fused switch or starter operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch	0	N	N
CB or fused switch or starter operation with enclosure doors open	1	N	N
Work on energized parts, including voltage testing	2*	Y	Y
Work on control circuits with energized parts 120 V or below, exposed	0	Y	Y
Work on control circuits with energized parts >120 V, exposed	2*	Y	Y
Insertion or removal of individual starter "buckets" from MCC – Note 4	3	Y	N
Application of safety grounds, after voltage test	2*	Y	N
Removal of bolted covers (to expose bare, energized parts)	2*	N	N
Opening of hinged covers (to expose bare, energized parts)	1	N	N
600 V Class Switchgear (with power circuit breakers or fused switches) – Notes 5 and 6	0	N	N
CB or fused switch operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch CB Or fused switch operation with enclosure doors open	1	N	N
Work on energized parts, including voltage testing	2*	Y	Y
Work on control circuits with energized parts 120 V or below, exposed	0	Y	Y
Work on control circuits with energized parts >120 V, exposed	2*	Y	Y
Insertion or removal (racking) of CBs from cubicles, doors open	3	N	N
Insertion or removal (racking) of CBs from cubicles, doors closed	2	N	N
Application of safety grounds, after voltage test	2*	Y	N
Removal of bolted covers (to expose bare, energized parts)	3	N	N
Opening hinged covers (to expose bare, energized parts)	2	N	N

Task (Assumes Equipment Is Energized, and Work Is Done Within the Flash Protection Boundary	Hazard/Risk Category	V-rated Gloves	V-rated Tools
Other 600 V Class (277 V – 600 V, nominal) Equipment – Note 3			
Lighting or small power transformers (600 V max.)	-	-	-
Removal of bolted covers (to expose bare, energized parts)	2*	N	N
Opening hinged covers (to expose bare, energized parts)	1	N	N
Work on energized parts, including voltage testing	2*	Y	Y
Application of safety grounds, after voltage test	2*	Y	N
Revenue meters (kW-hour, at primary voltage and current	-	-	-
Insertion or removal	2*	N	N
Cable trough or tray cover removal or installation	1	N	N
NEMA E2 (fused contactor) Motor Starters, 2.3 kV – 7.2 kV			
Contactor operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch	0	N	N
Contactor operation with enclosure doors open	2*	N	N
Work on energized parts, including voltage testing	3	Y	Y
Work on control circuits with energized parts 120 V or below, exposed	0	Y	Y
Work on control circuits with energized parts >120 V, exposed	3	Y	Y
Insertion or removal (racking) of starters from cubicles, doors open	3	N	N
Insertion or removal (racking) of starters from cubicles, doors closed	2	N	N
Application of safety grounds, after voltage test	3	Y	N
Removal of bolted covers (to expose bare, energized parts)	4	N	N
Opening hinged covers (to expose bare, energized parts)	3	N	N
Metal Clad Switchgear, 1 kV and Above			
CB or fused switch operation with enclosure doors closed	2	N	N
Reading a panel meter while operating a meter switch	0	N	N
CB or fused switch operation with enclosure doors open	4	N	N
Work on energized parts, including voltage testing	4	Y	Y
Work on control circuits with energized parts 120 V or below, exposed	2	Y	Y
Work on control circuits with energized parts >120 V, exposed	4	Y	Y
Insertion or removal (racking) of CBs from cubicles, doors open	4	N	N
Insertion or removal (racking) of CBs from cubicles, doors closed	2	N	N
Application of safety grounds, after voltage test	4	Y	N
Removal of bolted covers (to expose bare, energized parts)	4	N	N
Opening hinged covers (to expose bare, energized parts)	3	N	N
Opening voltage transformer or control power transformer components	4	N	N
Other Equipment 1 kV and Above			
Metal clad interrupter switches, fused or unfused	-	-	-
Switch operation, doors closed	2	N	N
Work on energized parts, including voltage testing	4	Y	Y
Removal of bolted covers (to expose bare, energized parts)	4	N	N
Opening hinged covers (to expose bare, energized parts)	3	N	N
Outdoor disconnect switch operation (hookstick operated)	3	Y	Y
Outdoor disconnect switch operation (gang operated from grade)	2	N	N
Insulated cable examination, in manhole or other confined space	4	Y	N
Insulated cable examination, in open area	2	Y	N

Note:
V-rated Gloves are gloves rated and tested for the maximum line-to-line voltage upon which work will be done.
V-rated Tools are tools rated and tested for the maximum line-to-line voltage upon which work will be done.
2* means that a double-layer switching hood and hearing protection are required for this task in addition to the other Hazard/Risk Category 2 requirements of Table 130.7(C)(10).
Y = Yes (required)
N = No (not required)
Notes:
1. 25 kA short circuit current available, 0.03 second (2 cycle) fault clearing time.
2. 65 kA short circuit current available, 0.03 second (2 cycle) fault clearing time.
3. For < 10 kA short circuit current available, the hazard/risk category required may be reduced by one number.
4. 65 kA short circuit current available, 0.33 second (20 cycle) fault clearing time.
5. 65 kA short circuit current available, up to 1.0 second (60 cycle) fault clearing time.
6. For < 25 kA short circuit current available, the hazard/risk category required may be reduced by one number.

130.7(C) (10) Protective Clothing and Personal Protective Equipment Matrix

Once the Hazard/Risk Category has been identified, Table 130.7(C)(1O) must be used to determine the required personal protective equipment (PPE) for the task. Table 130.7(C)(1O) lists the requirements for protective clothing and other protective equipment based on Hazard/Risk Category numbers 0 through 4. This clothing and equipment must be used when working on or near energized equipment within the Flash Protection Boundary.

FPN No.1: See Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

FPN No.2: The PPE requirements of this section are intended to protect a person from arc-flash and shock hazards.

While some situations could result in burns to the skin, even with the protection described in Table 130.7(C)(10),burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur.

The PPE requirements of this section do not provide protection against physical trauma other than exposure to the thermal effects of an arc flash.

130.7(C) (11) Protective Clothing Characteristics

Table 130.7(C)(11) lists examples of protective clothing systems and typical characteristics including the degree of protection for various clothing.

The protective clothing selected for the corresponding hazard/risk category number must have an arc rating of at least the value listed in the last column of Table 130.7(C)(11).

FPN: The arc rating for a particular clothing system can be obtained from the FR clothing manufacturer.

130.7(C) (12) Factors in Selection of Protective Clothing

Clothing and equipment that provide worker protection from shock and arc flash hazards must be utilized. Clothing and equipment required for the degree of exposure must be permitted to be worn alone or integrated with flammable, non-melting apparel.

If FR clothing is required, it must cover associated parts of the body as well as all flammable apparel while allowing movement and visibility. All personal protective equipment must be maintained in a sanitary and functionally effective condition.

Personal protective equipment items will normally be used in conjunction with one another as a system to provide the appropriate level of protection.

FPN: Protective clothing includes shirts, pants, coveralls, jackets, and parkas worn routinely by workers who, under normal working conditions, are exposed to momentary electric arc and related thermal hazards. Flame-resistant rainwear worn in inclement weather is included in this category of clothing.

(a) Layering

Non-melting, flammable fiber garments must be permitted to be used as underlayers in conjunction with FR garments in a layered system for added protection.

If non-melting, flammable fiber garments are used as underlayers, the system arc rating must be sufficient to prevent breakopen of the innermost FR layer at the expected arc exposure incident energy level to prevent ignition of flammable underlayers.

FPN: A typical layering system might include cotton underwear, a cotton shirt and trouser, and a FR coverall. Specific tasks might call for additional FR layers to achieve the required protection level.

(b) Outer Layers

Garments worn as outer layers over FR clothing, such as jackets or rainwear, must also be made from FR material.

(c) Underlayers

Meltable fibers such as acetate, nylon, polyester, polypropylene, and spandex must not be permitted in fabric underlayers (underwear) next to the skin.

Exception: *An incidental amount of elastic used on non melting fabric underwear or socks must be permitted.*

FPN No. 1: FR garments (e.g., shirts, trousers, and coveralls) worn as underlayers that neither ignite nor melt and drip in the course of an exposure to electric arc and related thermal hazards generally provide a higher system arc rating than non-melting, flammable fiber underlayers.

FPN No. 2: FR underwear or undergarments used as underlayers generally provide a higher system arc rating than non-melting, flammable fiber underwear or undergarments used as underlayers.

(d) Coverage

Clothing must cover potentially exposed areas as completely as possible. Shirt sleeves must be fastened at the wrists, and shirts and jackets must be closed the neck.

(e) Fit

Tight-fitting clothing must be avoided. Loose-fitting clothing provides additional thermal insulation because of air spaces. FR apparel must fit properly such that it does not interfere with the work task.

(f) Interference

The garment selected must result in the least interference with the task but still provide the necessary protection. The work method, location, and task could influence the protective equipment selected.

130.7(C) (13) Arc Flash Protective Equipment

(a) Flash Suits

Flash suit design must permit easy and rapid removal by the wearer. The entire flash suit, including the hood's face shield, must have an arc rating that is suitable for the arc flash exposure. When exterior air is supplied into the hood, the air hoses and pump housing must be either covered by FR materials or constructed of non-melting and nonflammable materials.

(b) Face Protection

Face shields must have an arc rating suitable for the arc flash exposure. Face shields without an arc rating must not be used. Eye protection (safety glasses or goggles) must always be worn under face shields or hoods.

FPN: Face shields made with energy-absorbing formulations that can provide higher levels of protection from the radiant energy of an arc flash are available, but these shields are tinted and can reduce visual acuity. Additional illumination of the task area might be necessary when these types of arc protective face shields are used.

Table 130.7(C)(10) Protective Clothing and Personal Protective Equipment (PPE) Matrix

Protective Clothing and Equipment	Protective Systems for Hazard / Risk Category					
Hazard / Risk Category Number	**-1** (Note 3)	**0**	**1**	**2**	**3**	**4**
Non-melting (according to ASTM F 1506-00) OR Untreated Natural Fiber						
a. T-shirt (short sleeve)	X			X	X	X
b. Shirt (long-sleeve)		X				
c. Pants (long)	X	X	X (Note 4)	X (Note 6)	X	X
FR Clothing (Note 1)						
a. Long-sleeve shirt			X	X	X	X
b. Pants			X	X	(Note 9) X	X
c. Coverall			(Note 4) (Note 5)	(Note 6) (Note 7)	(Note 9) X	(Note 5) AN
d. Jacket, parka, or rainwear			AN	AN	(Note 9) AN	
FR Protective Equipment						
a. Flash suit jacket (multilayer)						X
b. Flash suit pants (multilayer)						X
c. Head protection						
1. Hard hat			X	X	X	X
2. FR hard hat liner					AR	AR
d. Eye protection						
1. Safety glasses	X	X	X	AL	AL	AL
2. Safety goggles				AL	AL	AL
e. Face and Head area protection						
1. Arc-rated face shield, or flash suit hood				X (Note 8)		
2. Flash suit hood					X	X
3. Hearing protection (ear canal inserts)					X	X
f. Hand protection			AN			
Leather gloves (Note 2)					X	X
g. Foot protection			AN	X		
Leather work shoes					X	X
				X		

AN = As needed

AL = Select one in group

AR = As required

X = Minimum required

Notes:

1. See Table 130.7(C)(11). Arc rating for a garment is expressed in cal/cm^2.
2. If voltage-rated gloves are required, the leather protectors worn external to the rubber gloves satisfy this requirement.
3. Hazard/Risk Category Number "-1" is only defined if determined by Notes 3 or 6 of Table 130.7(C)(9)(a).
4. Regular weight (minimum 12 oz/yd^2 fabric weight), untreated, denim cotton blue jeans are acceptable in lieu of FR pants. The FR pants used for Hazard Risk Category 1 must have a minimum arc rating of 4.

5. Alternate is to use FR coveralls (minimum arc rating of 4) instead of FR shirt and FR pants.
6. If the FR pants have a minimum arc rating of 8, long pants of non-melting or untreated natural fiber are not required beneath the FR pants.
7. Alternate is to use FR coveralls (minimum arc rating of 4) over non-melting or untreated natural fiber pants and T-shirt.
8. A faceshield with a minimum arc rating of 8, with wrap-around guarding to protect not only the face, but also the forehead, ears, and neck (or, alternatively, a flash suit hood), is required.
9. Alternate is to use two sets of FR coveralls (the inner with a minimum arc rating of 4 and outer coverall with a minimum arc rating of 5) over non-melting or untreated natural fiber clothing, instead of FR coveralls over FR shirt and FR pants over non-melting or untreated natural fiber clothing.

Table 130.7(C)(11) Protective Clothing Characteristics

Typical Protective Clothing Systems		
Hazard/Risk Category	**Clothing Description** (Typical number of clothing layers is given in parentheses)	**Required Minimum Are Rating of PPE [J/cm^2(cal/cm^2)]**
0	Non-melting, flammable materials (i.e., untreated cotton, wool, rayon, or silk, or blends of these materials) with fabric weight at least 4.5 oz/yd^2 (1)	N/A
1	FR shire and FR pants or FR coverall (1)	16.74 (4)
2	Cotton underwear – conventional short sleeve and brief/shorts, plus FR shirt and pants (1 or 2)	33.47 (8)
3	Cotton underwear plus FR shirt and FR pants plus FR coverall, or cotton underwear plus two FR coveralls (2 or 3)	104.6 (25)
4	Cotton underwear plus FR shirt and FR pants plus multilayer flash suit (3 or more)	167.36 (40)

Note:
Arc rating is defined in Article 100 and can be either ATPV or E_{BT}. ATPV is defined in ASTM F 1959-99 as the incident energy on a fabric or material that results in sufficient heat transfer through the fabric or material to cause the onset of a second-degree burn based on the Stoll curve.
E_{BT} is defined in ASTM F 1959-99 as the average of the five highest incident energy exposure values below the Stoll curve where the specimens do not exhibit breakopen. E_{BT} is reported when ATPV cannot be measured due to FR fabric breakopen.

(c) Hand Protection

Leather or FR gloves must be worn where required for arc flash protection. Where insulating rubber gloves are used for shock protection, leather protectors must be worn over the rubber gloves.

FPN: Insulating rubber gloves and gloves made from layers of flame-resistant material provide hand protection against the arc flash hazard. Heavy-duty leather (e.g., greater than 12 oz/yd^2) gloves provide protection suitable up to Hazard/Risk Category 2. The leather protectors worn over insulating rubber gloves provide additional arc flash protection for the hands. During high arc flash exposures leather can shrink and cause a decrease in protection.

(d) Foot Protection

Heavy-duty leather work shoes provide some arc flash protection to the feet and must be used in all tasks in Hazard\Risk Category 2 and higher.

130.7(C) (14) Clothing Material Characteristics

FR clothing must meet the requirements described in 130.7(C)(14)(a) through 130.7(C)(15).

FPN: FR materials, such as flame-retardant treated cotton, meta-aramid, para-aramid, and poly-benzimidazole (PBI) fibers, provide thermal protection. These materials can ignite but will not continue to bum after the ignition source is removed. FR fabrics can reduce bum injuries during an arc flash exposure by providing a thermal barrier between the arc flash and the wearer. In aramid and PBI blends, para-aramid adds strength to a fabric to prevent the fabric from breaking open due to the blast shock wave and high thermal energy of the arc.

(a) Melting

Clothing made from flammable synthetic materials that melt at temperatures below 315°C (600°F), such as acetate, nylon, polyester, polypropylene, and spandex, either alone or in blends, must not be used.

2004 Edition

FPN: These materials melt as a result of arc flash exposure conditions, form intimate contact with the skin, and aggravate the bum injury.

Exception: Fiber blends that contain materials that melt, such as acetate, nylon, polyester, polypropylene, and spandex:, must be permitted if such blends in fabrics meet the requirements of ASTM F 1506, Standard Performance Specification for Textile Material for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards, and if such blends in fabrics do not exhibit evidence of a melting and sticking hazard during arc testing according to ASTM F 1959 [see also 130.7(C)(15)].

(b) Flammability

Clothing made from non-melting flammable natural materials, such as cotton, wool, rayon, silk, must be permitted for Hazard/Risk Categories 0 and -1 considered acceptable if it is determined by flash hazard analysis that the exposure level is 8.36 J/cm^2 (2.0 cal/cm^2 or less, and that the fabric will not ignite and continue to burn under the arc exposure hazard conditions to which it will be exposed (using data from tests done in accordance with ASTM F 1958.) See also 130.7(C)(12)(a) for layering requirements.

FPN No.1: Non-FR cotton, polyester-cotton blends, nylon, nylon-cotton blends, silk, rayon, and wool fabrics are flammable. These fabrics could ignite and continue to burn on the body, resulting in serious burn injuries.

FPN No.2: Rayon is a cellulose-based (wood pulp) synthetic fiber that is a flammable but non-melting material.

130.7(C) (15) Clothing Not Permitted

Clothing made from materials that do not meet the requirements of 130.7(C)(14)(a) regarding melting, or made from materials that do not meet the flammability requirements of 130.7(C)(14)(b), must not be permitted to be worn.

FPN: Some flame-resistant fabrics, such as non-FR modacrylic and nondurable flame-retardant treatments of cotton, are not recommended for industrial electrical or utility applications.

Exception: Non-melting, flammable (non-FR) materials must be permitted to be used as underlayers to FR clothing, as described in 130.7(C)(14)(a) and also must be permitted to be used for Hazard/Risk Category 0 and -1 as described in Table 130.7(C)(10).

130.7(C) (16) Care and Maintenance of FR Clothing and FR Flash Suits

(a) Inspection

FR apparel must be inspected before each use. Work clothing or flash suits that are contaminated, or damaged to the extent their protective qualities are impaired, must not be used. Protective items that become contaminated with grease, oil, or flammable liquids or combustible materials must not be used.

(b) Manufacturer's Instructions

The garment manufacturer's instructions for care and maintenance of FR apparel must be followed.

(D) Other Protective Equipment

(1) Insulated Tools and Equipment. Employees must use insulated tools and/or handling equipment when working inside the Limited Approach Boundary of exposed live parts where tools or handling equipment might make accidental contact. Insulated tools must be protected from damage to the insulating material.

FPN: See 130.2(B) for working on exposed live parts.

(a) Requirements for Insulated Tools

The following requirements must apply to insulated tools:

(1) Insulated tools must be rated for the voltages on which they are used.

(2) Insulated tools must be designed and constructed for the environment to which they are exposed and the manner in which they are used.

(b) Fuse or Fuse Holding Equipment

Fuse or fuse holder handling equipment, insulated for the circuit voltage, must be used to remove or install a fuse if the fuse terminals are energized.

(c) Ropes and Handlines

Ropes and handlines used near exposed live parts operating at 50 volts or more, or used where an electrical hazard exists, must be nonconductive.

(d) Fiberglass-Reinforced Plastic Rods

Fiberglass reinforced plastic rod and tube used for live line tools must meet the requirements of ASTM F 711, Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used; in Live Line Tools, 1989 (R 1997).

(e) Portable Ladders

Portable ladders must have nonconductive side rails if they are used where the employee or ladder could contact exposed live parts operating at 50 volts or more or where an electrical hazard exists. Nonconductive ladders must meet the requirements of ANSI standards for ladders listed in Table 130.7(F).

(f) Protective Shields

Protective shields, protective barriers, or insulating materials must be used to protect each employee from shock, burns, or other electrically related injuries while that employee is working near live parts that might be accidentally contacted or where dangerous electric heating or arcing might occur. When normally enclosed live parts are exposed for maintenance or repair, they must be guarded to protect unqualified persons from contact with the live parts.

(g) Rubber Insulating Equipment

Rubber insulating equipment used for protection from accidental contact with live parts must meet the requirements of the ASTM standards listed in Table 130.7(F).

(h) Voltage Rated Plastic Guard Equipment

Plastic guard equipment for protection of employees from accidental contact with live parts, or for protection of employees or energized equipment or material from contact with ground, must meet the requirements of the ASTM standards listed in Table 130.7(F).

(i) Physical or Mechanical Barriers

Physical or mechanical (field fabricated) barriers must be installed no closer than the restricted approach distance given in Table 130.2(C). While the barrier is being installed, the restrictive approach distance specified in Table 130.2(C) must be maintained, or the live parts must be placed in an electrically safe work condition.

(E) Alerting Techniques

(1) Safety Signs and Tags

Safety signs, safety symbols, or accident prevention tags must be used where necessary to warn employees about electrical hazards that might endanger them. Such signs and tags must meet the requirements of ANSI Standard Z535 given in Table 130.7(F).

(2) Barricades

Barricades must be used in conjunction with safety signs where it is necessary to prevent or limit employee access to work areas containing live parts. Conductive barricades must not be used where it might cause an electrical hazard. Barricades must be placed no closer than the Limited Approach Boundary given in Table 130.2(C).

(3) Attendants

If signs and barricades do not provide sufficient warning and protection from electrical hazards, an attendant must be stationed to warn and protect employees.

The primary duty and responsibility of an attendant providing manual signaling and alerting must be to keep unqualified employees outside a work area where the unqualified employee might be exposed to electrical hazards. An attendant must remain in the area as long as there is a potential for employees to be exposed to the electrical hazards.

(F) Standards for Other Protective Equipment

Other protective equipment required in 130.7(D) must conform to the standards given in Table 130.7(F).

Table 130.7(F) Standards on Other Protective Equipment

Subject	Number and Title
Ladders	ANSI AI4.1, Safety Requirements for Portable Wood Ladders, 1994 ANSI AI4.3, Safety Requirements for Fixed Ladders, 2002 ANSI AI4.4, Safety Requirements for Job-Made Ladders, 1992 ANSI A14.5, Safety Requirement for Portable Reinforced Plastic Ladders, 2000
Safety signs and tags	ANSI Z535, Series of Standards for Safety Signs and Tags, 1998
Blankets	ASTM D 1048, Standard Specification for Rubber Insulating Blankets, 1999
Covers	ASTM D 1049, Standard Specification for Rubber Covers, 1998
Line hoses	ASTM D 1050, Standard Specification for Rubber Insulating Line Hoses, 1990
Line hoses and covers	ASTM F 478, Standard Specification for In-Service Care of Insulating Line Hose and Covers, 1999
Blankets	ASTM F 479, Standard Specification for In-Service Care of Insulating Blankets, 1995
Fiberglass tools/ ladders	ASTM F 711, Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used; in Line Tools, 1989 (R 1997)
Plastic guards	ASTM F 712, Standard Test Methods for Electrically Insulating Plastic Guard Equipment for Protection of Workers, 1995
Temporary grounding	ASTM F 855, Standard Specification for Temporary Protective Grounds to Be Used on De-energized Electric Power Lines and Equipment, 1997
Insulated hand tools	ASTM F 1505, Standard Specification for Insulated and Insulating Hand Tools, 2001

Annex C Limits of Approach

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 Flash Protection 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 may an unqualified person cross the Limited Approach Boundary. Under no circumstance may 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 Flash Protection Boundary and, if the boundary is to be crossed, appropriate flash-flame protection equipment must be utilized.

C.1.2.2 For a person to cross the Limited Approach Boundary and enter the limited space, he or she must be qualified to perform the job/task.

C.1.2.3 To cross the Restricted Approach Boundary and enter the restricted space, qualified persons must do the following:

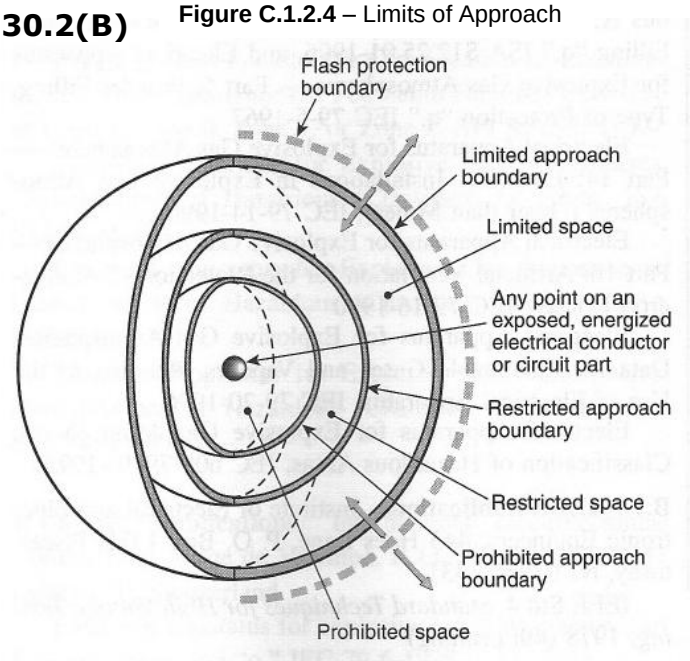
1. Have a plan that is documented and approved by authorized management
2. Use personal protective equipment that is appropriate for working near exposed energized conductors or circuit parts and is rated for the voltage and energy level involved
3. Be certain that no part of the body enters the prohibited space
4. Minimize the risk from inadvertent movement by keeping as much of the body out of the restricted space as possible, using only protected body parts in the space as necessary to accomplish the work

C.I.2.4 Crossing the Prohibited Approach Boundary and entering the prohibited space is considered the same as making contact with exposed energized conductors or circuit parts. See Figure C.1.2.4

Therefore, qualified persons must do the following:

1. Have specified training to work on energized conductors or circuit parts
2. Have a documented plan justifying the need to work that close
3. Perform a risk analysis
4. Have (2) and (3) approved by authorized management
5. Use personal protective equipment that is appropriate for working on exposed energized conductors or circuit parts and is rated for the voltage and energy level involved

Figure C.1.2.4 – Limits of Approach



C.2 Basis for Distance Values in Table 130.2(B)

C.2.1 General Statement

Columns 1 through 5 of Table 130.2(e) 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 ANSI/IEEE 4-1978 4th Printing, Standard Techniques for High- Voltage Testing, Appendix 2B; and voltages over 72.5 kV are based on ANSI/IEEE 516-2003, 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 ≤750 V: 2 mm (0 ft 0.07 in.)
3. >750 V ≤2 kV: 5 mm (0 ft 0.19 in.)
4. >2 kV ≤15 kV: 39 mm (0 ft 1.5 in.)
5. >15 kV ≤36 kV: 161 mm (0 ft 6.3 in.)
6. >36 kV ≤48.3 kV: 254 mm (0 ft 10.0 in.)
7. >48.3 kV ≤72.5 kV: 381 mm (1 ft 3.0 in.)
8. >72.5 kV ≤121 kV: 640 mm (2 ft 1.2 in.)
9. >138 kV ≤145 kV: 778 mm (2 ft 6.6 in.)
10. >161 kV ≤169 kV: 915 mm (3 ft 0.0 in.)
11. >230 kV ≤242 kV: 1.281 m (4 ft 2.4 in.)
12. >345 kV ≤362 kV: 2.282 m (7 ft 5.8 in.)
13. >500 kV ≤550 kV: 3.112 m (10 ft 2.5 in.)
14. >765 kV ≤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 highest nominal voltage in the range, base on ANSI C84.1-1995, *Electric Power Systems and Equipment (60 Hz)*. For single-phase systems, select the range that is equal to the system's maximum phase-to-ground voltage times 1.732.

C.2.1.2 Column 2

The distances in this column are base on OSHA's rule fo unqualified persons to maintain a 3.05-m (10 ft) clearance for all voltages up to 50 kV (voltage-to-ground), plus 102 mm (4.0 in.) for each 1 kV over 50 kV.

C.2.1.3 Column 3

The distances are based on the following:

1. >750 V: Use NEC Table 110.26(A)(1), Working Spaces, Condition 2 for 151 V-600 V range.
2. >750 V ≤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 are based on adding to the flashover dimensions shown above the following inadvertent movement distance:

≤300 V: Avoid contact.

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

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

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

C.2.1.5 Column 5

The distances are based on the following:

1. ≤300 V: Avoid contact.
2. ≤300 V ≤750 V: Use NEC Table 230.51(C), Clearances.

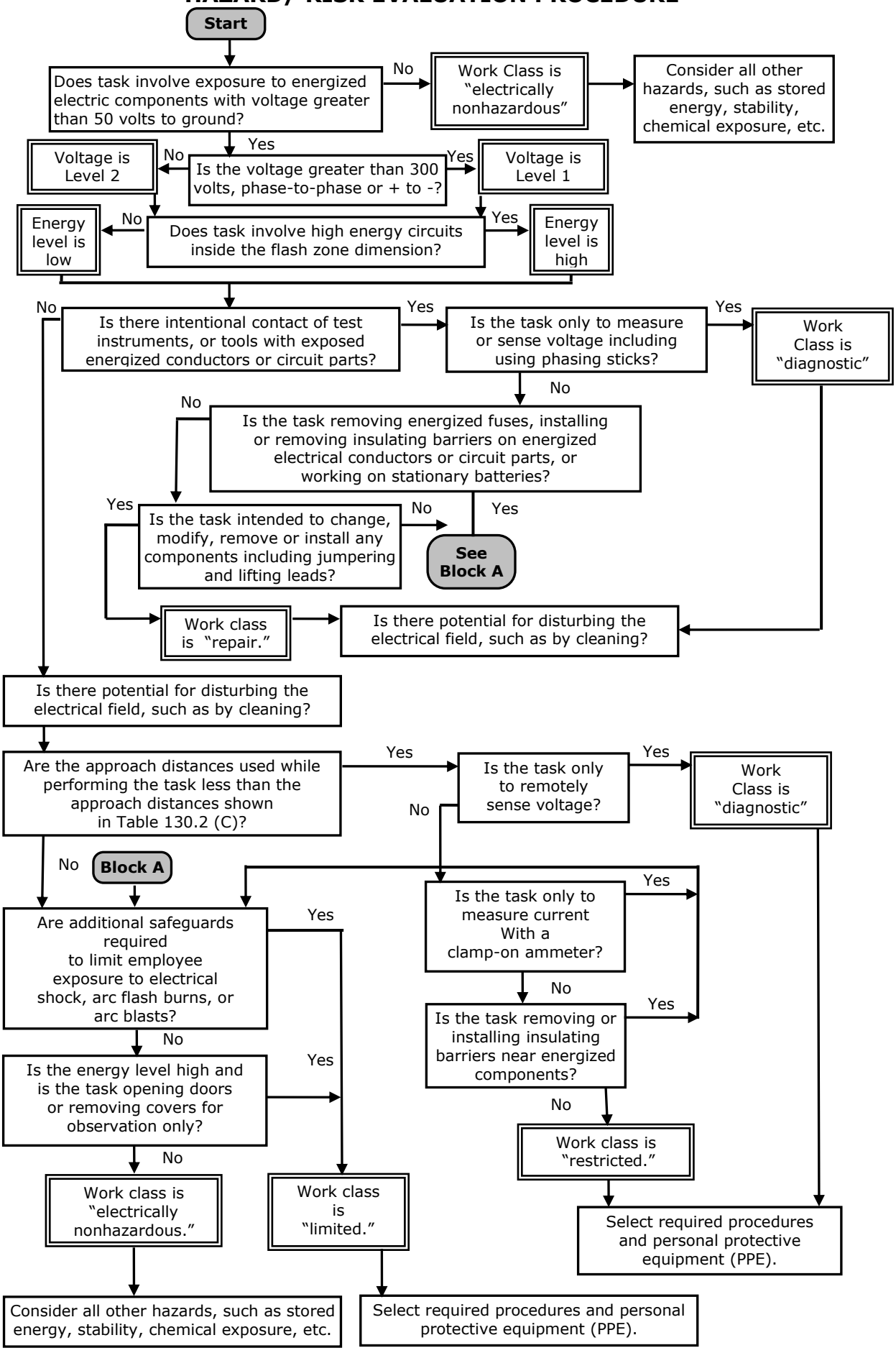
Between open conductors and surfaces, 600 V not exposed to weather.

1. >750 V ≤2.0 kV: Select value that fits in with adjacent values.
2. >2 kV ≤72.5 kV: Use NEC Table 490.24, Minimum Clearance of Live Parts, outdoor phase-to-ground values.
3. >72.5 kV: Add 152.4 mm (0 ft 6 in.) for inadvertent movement.

These values have been found to be adequate over years of use where there has been a hazard/risk analysis, either formal or informal, of a special work procedure that allows a closer approach than that permitted by the Restricted Approach Boundary distance.

Note: The following Hazard/Risk Evaluation Procedure, although not part of NFPA requirements, is included for informational purposes.

HAZARD/ RISK EVALUATION PROCEDURE



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 Hazard Analysis: _____ ☐

_____

_____

4. Determination of Shock Protection Boundaries: _____ ☐

_____

_____

5. Results of Flash Hazard Analysis: _____ ☐

_____

_____

6. Determination of the Flash Protection Boundary: _____ ☐

_____

_____

7. Necessary personal protective equipment to safely perform the assigned task: _____ ☐

_____

_____

8. Means employed to restrict the access of unqualified persons from the work area:_____ ☐

_____

_____

9. Evidence of completion of a Job Briefing including discussion of any job-related hazards: _____ ☐

_____

_____

10. 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 ELECTRICITY ENERGIZED:

Manufacturing Manager	***Maintenance/Engineering Manager***
Safety Manager	***Electrically Knowledgeable Person***
General Manager	***Date***

Notes: