Arc flash occurs when electricity arcs and results in radiation and shrapnel being created. It occurs when electrical insulation or isolation between conductors is broken or can no longer withstand the applied voltage. Arc flash explosions can be due to inserting a tool in the wrong place or dropping a tool into a circuit breaker or service area. In fact, an explosion can occur under any of the following conditions:

- If an employee is working on or near energized conductors or circuits
- Moves near or contact the equipment
- A failure of the equipment occurs

Any of these conditions may cause a phase-to-ground and/or a phase-to-phase electrical fault.

INTRODUCTION

Arc flash accidents are a serious problem in the workplace, as working on energized equipment has become commonplace in many industries. The Electrical Safety Foundation International estimates that every 30 minutes during the work day, a worker suffers an electrically induced injury that requires time off the job for recovery.

Injuries

The thermal temperature of an explosion can reach more than 5000 degrees. This energy is in the form of a blinding flash of light and a deafening noise. In this explosion, a giant amount of concentrated energy is forced outward from the electrical equipment toward the electrical worker, spreading hot gases and molten metal.

Injuries that can result from an arc flash:

- Burns
- Respiratory system damage
- Hearing damage
- Skin penetration from flying debris
- Eye and face injuries

In addition to burns, an arc flash can cause inhalation injuries. More than a hundred known toxic substances are present in fire smoke. When inhalation injuries are combined with external burns the chance of death can increase significantly.

Aside from personal injury, an arc flash can result in serious damage to electrical equipment causing disruption to electrical systems in manufacturing and process industry environments, office buildings, or institutions such as hospitals, airports, and schools.

Hazards

Arc flash incidents typically occur in applications above 120V and can occur when electrical equipment is being serviced or inspected. In fact, some incidents occur when a worker is removing a cover or trim from a piece equipment.

Data from the National Fire Protection Association (NFPA) shows:

- 5 to 10 arc flash accidents occur every day in North America
- More than 2,000 people are treated annually in burn centers with arc flash injuries
- 1-2 deaths occur per day from an arc flash incident
- $1.5M average cost of medical treatment
- 8-12 months away from work and possibility of permanent disability
- $10-15M average litigation cost for general industry incident
- Two-thirds of all electrical injuries result from inappropriate action of a worker
- Arc Flash temperatures at the source can reach of 30,000ºF (hotter than the surface of the Sun)
- Arc Blasts can produce a pressure wave greater than 2,000 lbs./sq.ft.
- 480 volts often times has a greater Arc Flash potential than medium voltage gear (4,160V and above)

A comprehensive electrical safety program will help protect employees from arc flash accidents. Often, energized work is being performed without ensuring that an electrically safe work condition exists or that exposed employees or contractors are using the right personnel protective equipment (PPE) for the hazards.

Employees working in areas where there are potential electrical hazards must be provided with, and must use, electrical PPE appropriate for the parts of the body that need to be protected depending on the work performed.

REGULATIONS

In an effort to protect workers, regulations have been established defining the requirements and procedures to be followed to prevent arc flash accidents. The standards that apply to arc flash hazards are:

- NFPA 70E, (created under the direction of the U.S. OHSA)
- CSA Z462 (considered to be the Canadian adoption of NFPA 70E)
- IEEE Standard 1584

These regulations identify a number requirements and procedures employers need to follow to ensure a safe working environment.

- Whenever possible, work should be performed when the equipment is de-energized
- Lockout and tagout procedures must be used
- Only qualified persons can work on conductors or circuits that are not in an electrically safe work condition
- An arc flash hazard (AFH) analysis must be performed by a competent person to determine the risk of personnel being injured by an arc flash
- Employees must be provided with all necessary PPE in order to perform their work safely

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 de-energizing introduces additional or increased hazards or is unfeasible due to equipment design or operational limitations. Examples of these conditions include:

- 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.
- Work on or near exposed energized electrical conductors or circuit parts because of 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.
- For voltages of less than 50 volts, the decision to de-energize should include consideration of the capacity of the source and any overcurrent protection between the energy source and the worker. Energized parts that operate at less than 50 volts to ground are not required to be de-energized if there will be no increased exposure to electrical burns or to explosion due to electric arcs.

ENERGIZED ELECTRICAL WORK PERMIT

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

Elements of Work Permit

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

- Circuit, equipment and location
- Why working while energized.
- Shock and arc flash hazard analysis
- Safe work practices
- Approach boundaries
- Required PPE and tools
- Access control
- Proof of job briefing

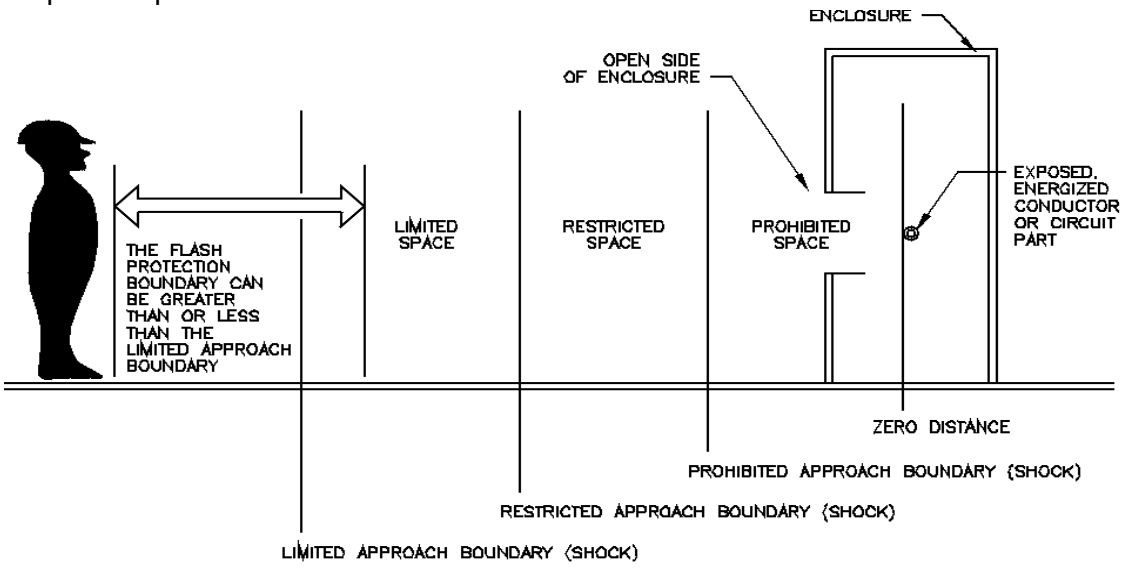
Exemptions to Work Permit

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 PPE are provided and used.

ARC FLASH HAZARD ANALYSIS

Section 4 of the IEEE 1584-2002, Guide for Arc Flash Hazard Calculations, states that the results of the arc flash hazard (AFH) analysis are used to "identify the flash-protection boundary and the incident energy at assigned working distances throughout any position or level in the overall electrical system." The analysis must determine the voltage personnel will be exposed to, the boundary requirements, and the PPE necessary in order to minimize the possibility of electric shock.

A Flash Protection Boundary is defined as: The distance from live parts, operating at 50 V or more that are un-insulated or exposed, within which a person could receive a second degree burn. The flash protection boundary is the closest approach allowed by qualified or unqualified persons without the use of arc flash PPE.



The table below provides general distances associated with various system voltages. This information is not intended to replace information defined by an AFH analysis.

General Boundary Distances

Nominal System Voltage Range, Phase to Phase	Limited Approach Boundary		Restricted Approach Boundary; Includes Inadvertent Movement Adder	Prohibited Approach Boundary
	Exposed Movable Conductor	Exposed Fixed Circuit Part		
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.)

Shock Protection Boundaries are classified as Limited, Restricted, and Prohibited. These apply when personnel are approaching exposed to live parts.

Limited Approach Boundary: An approach limit at a distance from an exposed live part within which a shock hazard exists

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

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

Conducting an AFH analysis involves performing the following steps and must be done by a competent person knowledgeable in the measurement and calculation procedures.

- Collect system and installation data
- Determine system modes of operation
- Determine bolted fault currents
- Determine arc fault currents
- Find protective device characteristics and duration of arcs
- Document system voltages and classes of equipment
- Select working distances
- Determine incident energy for all equipment
- Determine flash-protection boundary for all equipment

NOTE: For information about calculating short circuit currents and performing an overcurrent protective device coordination study, refer to NFPA 70E-2009 Annex D or the IEEE standard 1584.

APPROACH TO EXPOSED LIVE PARTS

No qualified person may approach or take any conductive object closer than the Restricted Approach Boundary to exposed live parts operating at 50 volts or more, unless any of the following apply:

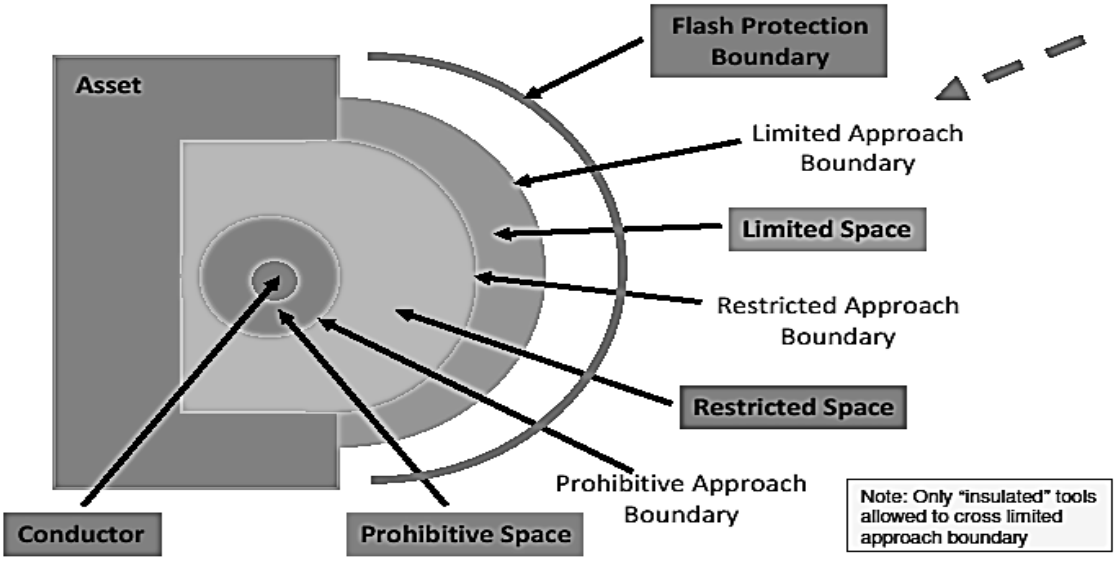
- The qualified person is insulated or guarded from the live parts operating (insulating gloves or insulating gloves and sleeves are considered insulation only with regard to the energized parts upon which work is being performed), and no uninsulated part of the qualified person's body crosses the Prohibited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

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.

Qualified Persons, Safe Approach Distance

- Determine the Flash Protection Boundary and, if the boundary is to be crossed, appropriate flash-flame protection equipment must be utilized.
- 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.
- To cross the Restricted Approach Boundary and enter the restricted space, qualified persons must do the following:
    - Have a plan that is documented and approved by authorized management
    - 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
    - Be certain that no part of the body enters the prohibited space
    - 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
- Crossing the Prohibitive Approach Boundary and entering the prohibited space is considered the same as making contact with exposed energized conductors or circuit parts. Therefore, qualified persons must do the following:
    - Have specified training to work on energized conductors or circuit parts
    - Have a documented plan justifying the need to work that close
    - Perform a risk analysis
    - Have plan and analysis approved by authorized management
    - Use PPE that is appropriate for working on exposed energized conductors or circuit parts and is rated for the voltage and energy level involved



Approach by Unqualified Persons

Unqualified persons are not be permitted to enter spaces identified as accessible to qualified employees only, unless the electric conductors and equipment involved are in an electrically safe work condition.

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

Entering the Limited Approach Boundary

If it necessary 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.

FLASH HAZARD ANALYSIS & PPE

When it has been determined that work must be performed within the Flash Protection Boundary, the flash hazard analysis must determine, and the employer must document, the thermal 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 PPE must be used by the employee based on the incident energy exposure associated with the specific task.

Thermal Incident Energy is measured in Calories/cm2. Arc flash protection is intended to limit the injury to no more than the "just curable" 2nd degree burn. PPE is selected based on this Calculated Value.

Note: 1.2 Calories/cm2 is the threshold of a second degree burn and is equal to holding your finger in the blue part of a match flame for one second.

Arc flash hazards are divided into five categories (0 through 4) based on the thermal incident levels that can be created. Different levels of PPE are required for each category.

Recognizing that incident energy increases as the distance from 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 an alternative, the PPE requirements listed below must be permitted when a detailed flash hazard analysis is not available.

NFPA 70E 2012 PPE REQUIREMENTS		
CATEGORY	ENERGY LEVEL	TYPICAL PPE REQUIRED
0	<2 Cal/cm^2	Non-melting flammable materials
1	4 Cal/cm2	Fire resistant (FR) shirt, FR pants (or FR coveralls), hard hat, safety glasses or goggles, leather protective gloves, leather shoes
2	8 Cal/cm2	Fire resistant (FR) shirt, FR pants (or FR coveralls), cotton underwear, safety glasses or goggles, arc rated face shield or flash hood, leather protective gloves, leather shoes
3	25 Cal/cm2	2 layers of FR clothing (shirt, pants, and coveralls), cotton underwear, safety glasses or goggles arc flash hood, leather protective gloves, leather shoes
4	40 Cal/cm2	Safety glasses or goggles, hearing protection, hard hat, cotton underwear, FR shirt and pants, FR coveralls (in addition to FR shirt and pants), full flash suit with hood, leather gloves, and leather shoes

SELECTING ARC FLASH PPE

Should it be necessary to select PPE without an arc flash hazard analysis having been completed, the following table may be used to determine the hazard/risk category for the task to be performed.

Note: This table from NFPA 70E is a valuable tool. However, like every other standard in industry, compromises were made in order to cover a broad spectrum of circumstances found in industry. It is not intended for use as a stand-alone answer sheet for PPE levels, but rather as a reference used in conjunction with an AFH study. Using only this table to determine settings can compromise worker safety. For tasks not listed, a flash hazard analysis must be performed.

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.

Energized parts operating at less than 50 volts are not required to be de-energized to satisfy an "electrically safe work condition." The capacity of the source, any overcurrent protection between the energy source and the worker, and whether the work increases exposure to electrical bums or to explosion from an electric arc should be considered.

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 circuit breakers or fuses) – Notes 5 and 6			
CB or fused switch operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch CB	0	N	N
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

Task (Assumes Equipment Is Energized, and Work Is Done Within the Flash Protection Boundary	Hazard/Risk Category	V-rated Gloves	V-rated Tools
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.
- 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.

PPE MATRIX

Once the Hazard/Risk Category has been identified, the PPE matrix table must be used to determine the required PPE for the task. The matrix table lists the requirements for protective clothing and other 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.

While some situations could result in burns to the skin, even with the protection described in the table, the 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.

PROTECTIVE CLOTHING CHARACTERISTICS

The matrix table lists examples of protective clothing systems and typical characteristics including the degree of protection for various clothing. The arc rating for a particular clothing system can be obtained from the FR clothing manufacturer.

The protective clothing selected for the corresponding hazard/risk category number must have an arc rating of at least the value defined by NFPA 70E.

PROTECTIVE CLOTHING FACTORS

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 potentially exposed areas as completely as possible. Shirt sleeves must be fastened at the wrists, and shirts and jackets must be closed the neck. It must also cover all flammable apparel while allowing movement and visibility. All personal protective equipment must be maintained in a sanitary and good condition.

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

Note: 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.

Layering

Non-melting, flammable fibre garments should 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 to prevent ignition of flammable underlayers.

Note: 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.

Outer Layers

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

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 is permitted.

- FR clothing (e.g., shirts, trousers, and coveralls) worn as underlayers generally provide a higher system arc rating than non-melting, flammable fibre underlayers.
- 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.

Fit

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

CLOTHING MATERIAL CHARACTERISTICS

FR clothing must meet the requirements described in NFPA 70E. FR materials 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. Some FR blends, add strength to a fabric to prevent it from breaking open from the blast shock wave and high thermal energy of the arc.

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. 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, are permitted if they 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 these blends do not exhibit a melting and sticking hazard during arc testing according to ASTM F 1959.

Flammability

Using clothing made from non-melting flammable natural materials, such as cotton, wool, rayon, silk, for Hazard/Risk Categories 0 and -1 is considered acceptable if it is determined by flash hazard analysis that the exposure level is 2.0 cal/cm2 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.

Prohibited Clothing

Clothing made from materials that do not meet the melting requirements, or made from materials that do not meet the flammability requirements, must not be permitted to be worn.

Note: 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.

FR CLOTHING & FR FLASH SUITS MAINTENANCE

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.

Manufacturer's Instructions

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

ARC FLASH SPECIFIC PPE

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 non-flammable materials.

Face Protection

Face shields must have an arc rating equal to the arc flash exposure risk. 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.

Energy-absorbing face shields that provide higher levels of protection from the radiant energy of an arc flash are available, but these shields are tinted and can reduce visibility. Additional lighting of the work area might be necessary.

Protective Clothing and 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 Fibre						
a. T-shirt (short sleeve)	X	X		X	X	X
b. Shirt (long-sleeve)	X	X	X (Note 4)	X (Note 6)	X	X
c. Pants (long)						
FR Clothing (Note 1)						
a. Long-sleeve shirt			X	X	X (Note 9)	X
b. Pants			X (Note 4)	X (Note 6)	X (Note 9)	X
c. Coverall			(Note 5)	(Note 7)	X (Note 9)	(Note 5)
d. Jacket, parka, or rainwear			AN	AN	AN	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)			AN		X	X
f. Hand protection				X	X	X
Leather gloves (Note 2)			AN			
g. Foot protection				X	X	X
Leather work shoes						

AN = As needed
AL = Select one in group
AR = As required
X = Minimum required

Notes:

- See the characteristics table below for the arc rating of a garment, expressed in cal/cm^2.
- If voltage-rated gloves are required, the leather protectors worn external to the rubber gloves satisfy this requirement.
- Hazard/Risk Category Number "-1" is only valid if determined by Notes 3 or 6 of the Hazard risk table listed earlier.
- 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.
- Alternate is to use FR coveralls (minimum arc rating of 4) instead of FR shirt and FR pants.
- If the FR pants have a minimum arc rating of 8, long pants of non-melting or untreated natural fibre are not required beneath the FR pants.
- Alternate is to use FR coveralls (minimum arc rating of 4) over non-melting or untreated natural fibre pants and T-shirt.
- 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.
- 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 fibre clothing, instead of FR coveralls over FR shirt and FR pants over non-melting or untreated natural fibre clothing.

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 can be either ATPV or E_{BT}. ATPV is defined 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 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.

HAND PROTECTION

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

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.

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.

OTHER PROTECTIVE EQUIPMENT

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.

Requirements for Insulated Tools

The following requirements apply to insulated tools:

- Insulated tools must be rated for the voltages on which they are used.
- Insulated tools must be designed and constructed for the environment to which they are exposed and the manner in which they are used.

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.

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.

Fibreglass-Reinforced Plastic Rods

Fibreglass reinforced plastic rods and tubes used for live line tools must meet the requirements of ASTM F 711.

Portable Ladders

Portable ladders must have nonconductive side rails if they are used where the employee or ladder could contact exposed live parts or where an electrical hazard exists. Nonconductive ladders must meet the requirements of ANSI standards for ladders.

Protective Shields

Protective shields, protective barriers, or insulating materials must be used to protect each employee from shock, bums, 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.

Rubber Insulating Equipment

Rubber insulating equipment used for protection from accidental contact with live parts must meet the requirements of the ASTM standards.

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.

Physical or Mechanical Barriers

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

ALERTING TECHNIQUES

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 and Canadian Electrical Code rule 2-306

Note: The posting of approved arc flash warning signs is intended to warn qualified personnel of potential arc flash hazards. They DO NOT provide authority to work on energized equipment based on complying with the PPE requirements listed.

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.

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 signalling and alerting is to keep unqualified employees outside a work area where they 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.

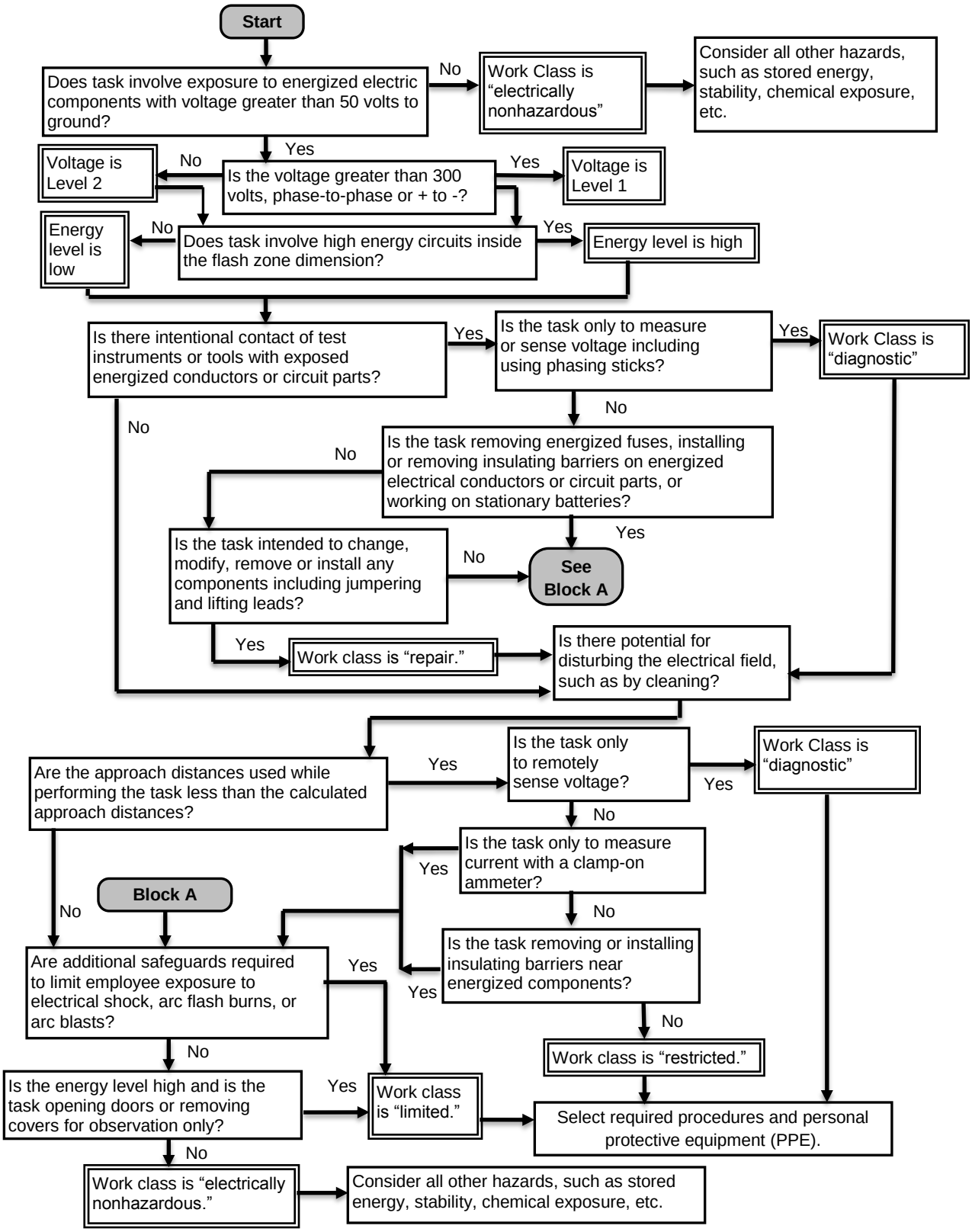
Standards on Other Protective Equipment

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, CEC 2-306
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
Fibreglass tools/ ladders	ASTM F 711, Standard Specification for Fibreglass-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

TEST EQUIPMENT USE

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

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: