Author: *Arnold L Augustoni*

ES&H STANDARD OPERATING PROCEDURE
Center 1100 SOP

Title: **ROUTINE TROUBLESHOOTING, CIRCUIT DIAGNOSTIC AND CIRCUIT MEASUREMENTS OF LABORATORY ELECTRONIC EQUIPMENT, LASERS, POWER SUPPLIES AND LABORATORY APPARATUS APPLICABLE TO ELECTRONIC CIRCUITS FROM 50 VOLTS TO 25 KILOVOLTS**

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SANDIA NATIONAL LABORATORIES

ROUTINE TROUBLESHOOTING, CIRCUIT DIAGNOSTIC AND CIRCUIT MEASUREMENTS OF LABORATORY ELECTRONIC EQUIPMENT, LASERS, POWER SUPPLIES AND LABORATORY APPARATUS APPLICABLE TO ELECTRONIC CIRCUITS FROM 50 VOLTS TO 25 KILOVOLTS

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1.0 PURPOSE, SCOPE, AND OWNERSHIP

Purpose

The purpose of this Standard Operating Procedure (SOP) is to implement the electrical safety requirements of the *ES&H Manual, Chapter 4B, Electrical Safety Manual* and the *Electrical Safety Program* on the performance of routine:

- Non-Energized replacement of electronic circuit components (circuit boards, flash lamps, etc.)
- Circuit troubleshooting
- Diagnostic and circuit voltage measurements

This SOP is applicable to "plug and cord" devices:

- Laboratory electronic equipment and devices
- Lasers and power supplies
- Laboratory apparatus

With device voltage ranges:

- 50 volts to 25 kilovolts.

With continuous power:

- Up to 1,000 watts.

And circuit fault current limited to:

- Instantaneous (short circuit) fault currents less than 10 kiloamps.

And stored energy limited to:

- Ten joules.

note *AC voltage limits presented are RMS values.*

Scope

This SOP describes the safe work strategies and procedures to be followed by laboratory and test personnel (*qualified workers*) when performing: routine electronic circuit component replacement, circuit troubleshooting, circuit diagnostic and circuit parameter measurements on standard laboratory electronic equipment, lasers, power supplies, and experimental laboratory apparatus, where there is a potential for personnel exposure to voltage levels of **50 volts to 25 kilovolts** in circuits with **continuous power to 1000 watts**. Such laboratory electronics, while presenting possible high voltages, are generally of low current capacity (less than 50 milliamps) due to circuit construction with various circuit components, such as transformers, rectifiers, potted power modules, fuses, etc., in series with the energizing ac power source and do not generally present an arc flash or arc blast hazard. These series circuit components act as current chokes which greatly limits fault currents caused by possible short circuits down stream during "live" or energized work. **Energized work within the scope of this SOP is restricted to: troubleshooting**, **circuit measurements and diagnostic measurements <u>only</u>**. Energized electrical work outside the scope of this SOP, such as the repair or replacement of circuit components in energized circuits or the reconfiguration of the circuit while the circuit is in the energized state, is **prohibited** unless it meets the ES&H Manual definition for appropriate energized electrical work. If such work is *appropriate energized electrical* work, then staff must gain approval for performing such work by completing: Energized Electrical Work Justification (SF 2004-EWJ) and Energized Electrical Work Permit (SF 2004-EWP). The Energized Electrical Work Permit is the tool workers shall use to plan the energized electrical work task.

Task Specific OP

A task specific Operating Procedure (OP) shall be developed for electrical work activities having hazards that are not addressed by the SOP.

Ownership

Center 1100 owns this procedure. Any suggestions for improvements should be directed to the author, *Arnold L Augustoni, MS1423.*

Location of This SOP

This SOP applies to laboratories and facilities associated with Center 1100, which use electronic equipment, lasers and experimental apparatus.

Exclusions

This SOP <u>does not apply</u> to electrical work performed on:

- Electrical Power Distribution Systems (Feed or Branch Circuits) and Electrical Power Distribution Equipment.
- Electronic equipment that is not "plug and cord", which might require formal Lock Out/Tag Out (LOTO) of the energizing source.

2.0 RESPONSIBILITIES

Department Manager

The Department Manager is responsible for:

- Ensuring that experimental and support activities are conducted in accordance with OSHA regulations, Sandia requirements and DOE Orders and directives.
- Authorizing new users, ensuring that personnel who perform work are qualified, have read this SOP, and have signed the Authorized Users List.

Authorized Electrical / Electronic Worker

Authorized Workers are responsible for:

- Conducting laboratory operations in accordance with this SOP, OSHA regulations, Sandia requirements, the SNL ES&H Manual, DOE Order 440.1A, NFPA 70E and DOE and SNL directives.
- Maintaining a safe, healthful, and clean work environment.
- Informing the department manager, during the planning stage, that they will be performing work covered by this SOP.
- Discussing with the department manager, as needed, the specifics of the type and scope of the work they plan to perform under this SOP.
- Activating the Notification roster in the event of emergency situations.

Safety Watch

- Maintain both visual and audible contact with personnel performing the work.
- Know the specific working procedures to be followed and the work to be performed.
- Monitor the work area for unsafe conditions or work practices and take necessary action to correct the unsafe condition or work practice.
- Know the locations of emergency shutdown buttons and power disconnects for the equipment involved in the work to be performed.

During any operation, anyone may question the safety of any aspect of any activity and at any time request and be granted an immediate cessation of the activity until the matter can be resolved. Such requests should be made to the responsible person in charge at the time of the operation. The responsible person shall be responsible and accountable to judge whether the activity can be continued or if immediate cessation of the activity is warranted. All activities that are stopped shall not resume until both project management and appropriate ES&H personnel resolve the matter.

3.0 TRAINING QUALIFICATIONS

Job Training/ Qualifications

The appropriate job training and qualifications for laboratory electronics workers (*Qualified Worker*) shall be reviewed and approved by their Department Manager.

Once approved they may perform, in accordance with this SOP, routine circuit component replacement, troubleshooting, diagnostic and circuit measurements on laboratory electronic equipment, lasers and laboratory apparatus, where there exits the potential to expose workers to voltage levels from 50 volts to 25 kilovolts.

All *Authorized Electronics Workers* must have completed the SNL mandatory ES&H training:

- ESH100 – ES&H Awareness (annually)
- ELC106 – R&D Electrical Safety (Greater Than 50 Volts)
- LAB100 – Laboratory Standard Information and Training (initially)

Electrical Safety Watch, also referred to as a "Second Person" for "live" or energized work over 50 volts (*ESM, Chapter 2, Section 2.1*) is to have:

- Completed MED 104 – Heart Saver CPR (*ESM, Chapter 1, Section 1.3*)
- Stated a willingness to perform CPR (as necessary) on the personnel involved prior to agreeing to be the **Electrical Safety Watch**.

All *Authorized Electronics Workers* must be knowledgeable, trained and experienced in the construction, the operation, the maintenance and the troubleshooting of the equipment to which they are assigned or tasked and be familiar with the operation and the design of the equipment they intend to perform routine parts replacement, diagnostic and circuit measurements on.

Authorized Electronic Workers should be trained in and familiar with:

- The abatement of the hazards associated with troubleshooting and repair of the equipment they are assigned or tasked.
- Safety related work practices regarding troubleshooting such equipment (practices to prevent exposure to electrical hazards associated with such equipment).
- Skills and techniques for distinguishing exposed energized circuit parts from the other parts of the circuit.
- Skills and techniques to determine voltage of exposed energized parts.
- The ability to anticipate and recognize electrical hazards of equipment addressed in this SOP.
- Work methods, PPE selection and use, tool selection and use.
- Determine and establish the approach boundaries specified in Table 1.

4.0 DEFINITIONS

Arcing Fault Current	A fault current flowing through electrical arc plasma, also called arc fault current or arc current.
Arc Flash Clothing	FR clothing that meets test requirements specified in *ASTM F 1959* regarding arc flash rating of FR clothing.
Arc Flash Rating	Failure mode rating derived by subjecting FR clothing to an instantaneous arc flash in order to determine clothing charring and "break open" threshold.
Authorized Worker	Trained personnel, who have the approval of their manager (a.k.a. *Qualified Worker*) to perform routine circuit component or parts replacement, electronic circuit troubleshooting, circuit diagnostic and circuit measurements on laboratory electronic equipment, lasers, power supplies and laboratory apparatus and have signed as an Authorized Worker of this SOP.
Available Fault Current	The electrical current that can be provided by the serving utility or facility owned electrical generating devices and the amount of impedance in the current path.
Bolted Fault Current	A short circuit or electrical contact between two conductors at different potentials in which the impedance or resistance between the conductors is essentially zero. Typical laboratory fault currents available are less than 10 kA..
CPR	Cardiopulmonary Resuscitation.
De-energized	Free from any electrical connection to a source of potential difference or free from electrical charge; **not having a potential difference to ground**.
Electrical Hazard	A dangerous condition such that contact with can result in electric shock, arc flash burn, thermal burn or blast.

Electrically Safe Work Condition	A state in which the electrical/electronic part to be worked on has been disconnected from the energizing source and has been tested to ensure the absence of voltage.
Electrical Shock	Physical stimulation that occurs when electrical current passes through the body.
Enclosed	Surrounded by a case, housing or walls that prevents personnel from accidental contact with "live" or energized parts.
Enclosure	The case or housing of apparatus to prevent accidental contact with "live" or energized parts.
Energized	Electrically connected to or having a source of voltage.
ESM	Electrical Safety Manual.
Exposed Electrical Part	Unguarded, accessible unprotected energized circuit parts that, are capable of being inadvertently touched and as a consequence allowing a current flow from the part to the contacting person.
Fault Current	A current that flows from one conductor to a ground or to another conductor due to an abnormal connection (including arc) between the two.
FR	Flame-Resistant property of a material whereby combustion is prevented, terminated, or inhibited.
Flash Hazard	A dangerous condition associated with the release of energy caused by an electric arc.
Flash Hazard Analysis	A method to determine the risk of personal injury and the selection of arc flash PPE as a result of exposure to incident energy from an electrical arc flash at the working distance.
Flash Protection Boundary	An approach limit at a distance from exposed live parts within which a person could receive a second degree burn if an electrical arc flash were to occur. Defines the distance from exposed energized parts within which FR PPE is required.

Ground	A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth or some conducting body that serves in place of the earth.
Grounded	Connected to earth or some conducting body that serves in place of the earth.
Grounded Conductor	A system or circuit conductor that is intentionally grounded.
Grounded, Effectively	Intentionally connected to earth through a ground connection or connections of sufficiently low impedance and having sufficient current-carrying capacity to prevent buildup of voltages that may result in undue hazards to connected equipment or personnel.
Grounding Conductor	A conductor used to connect equipment, part or the grounded circuit of a wiring system to a grounding electrode or electrodes.
Ground Fault	An unintentional, electrically conducting connection between an ungrounded conductor of an electrical circuit and the normally non-current-carrying conductors, metallic enclosures, metallic equipment or earth.
Ground Plane	An electrically conductive surface that may serve as reference ground such as the electronic circuit's physical enclosure.
Incident Energy Density (Fluence)	The amount of energy per unit area impressed on a surface, a certain distance from the source, generated during an electrical arc event.
Insulated	Separated from other conduction surfaces by a dielectric material offering a high resistance to the passage of electrical current.
Limited Approach Shock Boundary	An approach limit at a distance from an exposed live part within which a shock hazard exists. *Unqualified personnel* are not permitted closer than this boundary without specific PPE, awareness of the electrical hazard and being continuously escorted by a qualified worker.
Modified Restricted Approach Shock Boundary	That boundary defined by the ground plane (electrical enclosure) of the specific electronic equipment being serviced, or troubleshot. Personnel located outside the ground plane boundary, when the electrical enclosure or housing has been removed, may be considered to be outside this "modified restricted approach boundary" if an arc flash or arc blast hazard is known not to exits specific to the particular electronic equipment and the electrical hazards have been evaluated and approved by a level 2 manager.

LOTO	Lock Out / Tag Out
Over current	Any current in excess of the rated current of equipment or the capacity of a conductor. May result from overload, short circuit or ground fault.
PPE	Personal Protective Equipment.
Prohibited Approach Shock Boundary	An approach limit, at a distance from an exposed live or energized electrical or electronic part within which work is considered the same as making contact with that energized part.
Qualified Worker	One who has the skills and knowledge related to the construction and operation of the electrical / electronic equipment and has received the safety training on the hazards involved and has the approval of the responsible manager to perform the intended task.
Restricted Approach Shock Boundary	An approach limit, at a distance from an exposed live or energized 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. *Qualified Workers* are not permitted closer than this boundary without specific PPE. This is also the distance within which one is considered to be working "near" energized parts.
Safety Watch	Also known as a Second Worker, CPR trained, to respond in the event of an emergency situation with the qualified worker performing work on energized electronic circuits above 50 volts as specified by the SNL *Electrical Safety Manual, Chapter 2 - Section 2.1.*
Second Person	Also known as a Safety Watch, the second person is a person whose duties include maintaining contact with personnel performing hazardous operations in order to assist them in the case of an emergency. The second person should not be directly involved in the hazardous operation and should be familiar with the hazards involved and know how to respond to emergency situations. Reference: *ESM Chapter 1, section 1.3.*
Shock Hazard	A dangerous condition associated with the possible release of energy caused by contact with or approach to live or energized parts.
TWD	Technical Work Document.
Unqualified Worker / Personnel	Worker(s) who have not been trained in electrical safety, or who have not received training on the specific electrical hazards present or who does not have the approval of the responsible manager to cross inside the *limited approach boundary*.

Working Distance The dimension between the possible arc point and the head and body of the worker positioned in the place to perform the assigned tasked. The working distance is always based on the incident energy levels on the face and body, not the incident energy on the hands or arms.

5.0 HAZARDS IDENTIFICATION

5.1 Electrical Hazards

5.1.1

Electric Shock An electric shock can occur whenever an exposed body part comes close to or in contact with an electrically "live" or energized circuit part and a difference in potential (voltage) exists across the person to the electrical ground. There are varying degrees of shock depending on the level of the voltage, the amount of electric current passing through the body and the path through the body taken by the current. The effect of the shock can range from a slight tingle of the skin to its most severe effect of death.

5.1.2

Thermal Burns Thermal burns can occur when parts of the body come in contact with circuit parts that have become hot due to electrical activity (resistance heating, inductive heating, etc.) or as a result of an arc flash producing a volume of very hot gas or molten debris. Thermal burns can also occur as a result of electric shock due to electric current passing through a body part causing resistive heating of the effected body parts.

5.1.3

Arc Flash Arc flash can occur when a high current discharges through an air gap creating a visual flash of intense light which can have a high content of ultraviolet light and accompanied by expanding hot gas and an audible sound. An arc flash potential can exist for electronic circuits which have the capability of storing electrical energy of **10 joules** or greater or circuits capable of delivering continuous electrical power of **1000 watts** or greater.

5.1.4

Arc Blast Similar to an arc flash but with pressure waves driven by rapidly expanding gas and flying debris (shrapnel).

5.1.5

Fire Ignition A high current flow can cause circuit parts or surrounding flammable or combustible materials to reach temperatures sufficient to start a fire.

5.2 Hazard Abatement/Mitigation Strategies

Until proven otherwise, by voltage measurements, electronic circuits **containing energy storage/retaining components** are assumed to be energized and are treated accordantly.

Electronic circuits **known** (by technical manual or schematic diagrams) **not to contain** energy retaining circuit components may be considered de-energized by removing the electronic device from the source of electrical power, such as un-plugging the device from the ac power receptacle.

Electronic devices and equipment that contain integrated voltmeters, that is known to be functional and reliable, and actually indicate zero volts may be used as an indicator of the energized state or the non-energized state of its electronic circuits.

5.2.1

Abatement - Mitigation Strategies:

ELECTRIC SHOCK

1. Whenever possible work on electronic circuits should be performed in a de-energized condition.
    a. Turn "off" power to the device.
    b. Disconnect the device from the energizing source (place the plug so that it can be viewed by the qualified worker).
    c. Remove jewelry and electrically conductive objects.
    d. Determine the need for a *Safety Watch* or second person.
    e. Establish and post limited approach shock boundary.
    f. Don appropriate PPE as necessary (see section 6.1).
    g. Discharge circuit capacitors (use sufficient impedance to prevent arcing).
    h. Ground energy storage capacitors (lasers, power supplies, etc.).
    i. Verify *de-energized* condition with an appropriate voltmeter.

2. Prevent physical contact of the worker's exposed body parts with energized circuit parts (if the circuit must be energized to perform the task).
    a. Use insulated barrier between the worker and the energized circuit parts or components.
    b. Use insulated tools rated for the voltage of interest.
    c. Use measuring instruments rated for the circuit voltage/current and having insulated enclosures and test leads.
    d. Work with only one hand.

e. Use appropriate PPE for circuit conditions.
   1. 100% untreated natural cotton fiber clothing (section 6.1.2)
   2. Insulated gloves and footwear (see section 6.1.2)
   3. Special items as necessary (device's technical manual)

3. Prevent incidental personnel from contacting energized circuit parts.
   a. Establish and post limited approach boundaries (refer to Table 1, section 5.3).

4. Task a qualified *second person* as an *electrical Safety Watch,* when working on **energized** electronic circuits above 50 volts (greater than 5 ma) is anticipated (*ESM, Chapter 2- section 2.1*) unless the associated electrical hazards have been evaluated and it has been determined that a *Safety Watch* is not needed and the determination has also been approved by a level 2 managers as not requiring a *Safety Watch*. The primary duty of the electrical Safety Watch is to respond to emergency situations involving the qualified worker (refer to section 7.4.3 of this SOP).

5. Prevent incidental personnel from contacting circuit components.
   a. Establish and post *limited approach shock boundary* for *unqualified workers* (refer to Table 1, section 5.3).
   b. Establish *restricted approach* and *prohibited approach* shock boundaries for *qualified workers* (refer to Table 1, section 5.3)

5.2.2

Abatement / Mitigation Strategies:

THERMAL BURNS

1. Whenever possible work on electronic circuits should be performed in a de-energized condition.
   a. Disconnect the device from the energizing source (place the plug so that it can be viewed by the qualified worker).
   b. Remove jewelry and electrically conductive objects.
   c. Determine the need for *Safety Watch* or second person.
   d. Establish and post limited approach shock boundary.
   e. Don appropriate PPE, as necessary (see section 6.1.2).
   f. Discharge circuit capacitors (use sufficient impedance to prevent arcing).
   g. Ground energy storage capacitors (lasers, power supplies, etc.).
   h. Verify *de-energized* condition with an appropriate voltmeter.

2. Prevent physical contact of exposed body parts with circuit parts that may be thermally hot.
   a. Use of barriers.
      1. Insulating material between worker and the hazard.
      2. Establish the *prohibited approach shock boundary*.

b. Use of appropriate PPE
   1. Insulated gloves
   2. Long sleeve shirt
   3. Insulated shoes.

3. Prevent incidental personnel from contacting circuit components.
   a. Establish and post *limited approach shock boundary* for *unqualified workers* (refer to Table 1, section 5.3).
   b. Establish the *restricted approach* shock boundary or "modified restricted approach shock boundary" approved by a level 2 manager for *qualified workers* (refer to Table 1, section 5.3)

5.2.3

Abatement / Mitigation Strategies:

In general, laboratory electronic equipment, lasers, power supplies and laboratory apparatus may give rise to situations which could initiate an arc if these circuits have sufficient power (**1,000 watts** or greater) or have sufficient energy (greater than **10 joules**) necessary to initiate an arc flash or arc blast. See the Appendix to determine the Arc Flash Hazard and calculate associated distances (flash protection boundary and the working distance).

ARC FLASH and ARC BLAST

1. Whenever possible work on electronic circuits should be performed in a de-energized condition.
   a. Turn off power
   b. Disconnect the device from the energizing source (place the plug so that it can be viewed by the qualified worker).
   c. Remove jewelry and electrically conductive objects.
   d. Determine flash protection boundary and the working distance.
   e. Establish and post the Arc Flash Boundary, if required.
   f. Don appropriate PPE for arc flash/blast and shock, as needed.
   g. Establish and post limited approach shock boundary.
   h. Discharge circuit capacitors (use sufficient impedance to prevent arcing).
   i. Ground energy storage capacitors (lasers, power supplies, etc.).

2. Don't switch or "break" connections while under a current load, which might initiate an arc or an *arc flash*.

3. Take care with hand tools not to accidentally contact energized circuits components which might initiate an arc leading to an arc flash.

4. Use appropriate PPE.
   a. Prevent ocular injury and burns
      1. Use safety eyewear and face shields (minimum arc resistant rating 8 calories).
   b. Wear natural fiber (100% untreated cotton clothing)

1. Natural fiber shirts (see section 6.1.2).
2. Natural fiber pants.

c. Hand protection.
1. Use leather over gloves.
2. Use electrical safety insulating gloves (see section 6.1.2).

d. Hearing protection
1. Ear inserts

5. Prevent incidental personnel from contacting energized circuit parts.
   a. Establish and post *limited approach shock boundaries* (refer to Table 1, section 5.3).
   b. Use insulation barriers to separate personnel from the electrical hazard.

5.2.4

Abatement / Mitigation Strategies:

FIRE IGNITION

1. Work on the circuit in a de-energized condition.
   a. Turn off power and disconnect the device from the energizing source (place the plug so that it can be viewed by the qualified worker).
   b. Remove jewelry and electrically conductive objects.
   c. Determine the need for second person.
   d. Establish and post limited approach shock boundary.
   e. Don appropriate PPE for arc flash/blast and shock, as needed.
   f. Discharge circuit capacitors (use sufficient impedance to prevent arcing).
   g. Ground energy storage capacitors (lasers, power supplies, etc.).

2. Remove flammable and combustible materials from work or test area.

5.3 Shock Approach Boundaries

5.3.1

Limited Approach Shock Boundary

Unqualified workers **may not** approach any closer to *exposed* energized circuit parts than the *limited approach shock boundary*. The responsible *qualified* worker shall warn unqualified workers in the area of the electrical hazards present and shall prevent the unqualified worker from entering the limited approach boundary. Temporary barriers and postings are to be used.

5.3.2

Restricted

A **procedurally established boundary**, where a *qualified worker* **may not**

Approach Shock Boundary approach any closer to *exposed* energized circuit parts than the *restricted approach shock boundary* without appropriate PPE and appropriate voltage rated insulated tools.

5.3.3

Prohibited Approach Shock Boundary **A procedurally established boundary,** where **only** *qualified workers* wearing appropriate PPE and appropriate voltage rated insulated tools may enter the *prohibited approach shock boundary*. Work is considered the same as having contact with live circuit parts or components.

Table 1

Approach Shock Boundaries for Specific Voltage Ranges* Involved in Energized Work

Nominal Voltage Range	**Limited Approach** (Exposed Circuit Part)	**Restricted Approach** (Inadvertent Movement)	**Prohibited Approach**
< 50	Not Specified	Not Specified	Not Specified
50 to 300	3 feet 6 inches	Avoid Contact	Avoid Contact
301 to 750	3 feet 6 inches	1 foot	1 inch
751 to 15 kV	5 feet	2 feet 2 inches	7 inches
>15 kV to 36 kV	6 feet	2 feet 7 inches	10 inches

*From NFPA 70E Table 130.2(c) 2004 Edition

Arc Flash Boundary is **4 feet** from exposed energized conductors (inside which Arc Flash PPE is required). Applicable for exposed energized parts operated at: 50 to 300 volts, with 6 cycle or greater clearing time (100 ms @ 60 Hz) and a bolted fault current of 50 kA or greater.

Pylons, marking tape, or an individual may be used to establish the limited approach shock boundary. See appendix for examples of boundary postings.

5.3.4

Modified Restricted Approach Shock Boundary The restrictive approach boundaries presented in *Table 1* are default values that may be constricted or reduced to the ***modified restricted approach shock boundary***, which is defined as the boundary of the device's electrical enclosure (removed) and it must also have been the ground plane of the electronic device; **providing** that an **arc flash** and an **arc blast hazard is known not to exist** for the particular electronic device being worked on and that the electrical hazards associated with that particular electronic device has been evaluated and documented, the modified restricted approach boundary has been approved by a Level 2 manager indorsing the cover of this electrical hazard assessment or analysis.

Example: Personnel located outside the approved ***modified restricted approach shock boundary*** are considered to be located outside the restricted approach

boundary and may, as an example, perform voltage measurements inside this boundary with a voltmeter and probe (both rated for the expected device voltages) from a location or position outside the approved modified restricted approach boundary without the need for electrical safety gloves.

6.0 Materials

6.1 Equipment and Materials

The minimum required electrical PPE for energized electrical work as specified by the ES&H Manual, Chapter 4B, Electrical PPE – Requirements are:

- Safety glasses.
- Untreated, natural-fiber shirts (i.e., cotton).
  - 50—120 volts, short-sleeve.
  - 120—208 volts, long-sleeve.
- Long natural-fiber pants (i.e., regular-weight, untreated, denim cotton blue jeans).
- Gloves (Class O, and/or OO) rated for the voltage to which they will be exposed.
- Insulated tools rated for the voltage to which they will be exposed.
- Measurement instruments rated for circuit location and voltage to which they will be exposed.

6.1.1 Electronic Ground Rod & Hook

The Electronic ground hook is a special discharging device used to de-energize capacitors, transformers and other voltage or electrical energy retaining components before maintenance work is performed. The resistor eliminates the initial surge current and reduces the possibility of an arc event. Safety Line or like electronic ground hook should be used to discharge energy storage capacitors. Use certified equipment such as:

Safety Line®*

Cat #	
19250005	Electronic Ground Hook With Resistor, 23”
19250007	Electronic Ground Hook With Resistor, 5’

*Safety Line Inc, Oakland CA, (415) 562-4945

6.1.2

Personal Protective Equipment

Insulating Gloves:

Always inspect gloves for serviceability (check for breaks, tares, or pin holes and contamination such as oil, grease or flux) prior to use.

Electrical Safety Insulating Gloves

Class	Maximum Use Voltage AC / DC
00	500 / 750
0	1,000 / 1,500
1	7,500 / 11,250
2	17,000 / 25,500

From ASTM D120 & IEC 903 Standards

Gloves are to be certified at the time of order by the vendor. Glove are to be certified (certification date within the past 6 months) prior to being used. Gloves do not need to be recertified after each use, if they appear to be serviceable. Gloves should be replaced if there is a question of the glove's serviceability.

Gloves may be stored in their hermetically sealed plastic packaging bag for up to 12 months. They must be re-certified six months after the gloves are removed from the packaging bag and placed in service.

Qualified workers shall be issued (purchase) one pair of insulated gloves or have their insulated gloves exchanged every six months. The serviceable gloves exchanged shall be recertified just prior to the next exchange.

JIT Supplier:

Border State Electric
338-3118 (sales) or 344-1313 (reception)

Specify the glove class and glove size when ordering. Gloves are not assigned a JIT part number. Because of the glove certification expiration time they are **not stocked,** but are only ordered specifically upon request.

Center stock:

David Lang, 844-1404
Wayne Davis, 844-6734

If electrical gloves are needed immediately check with Center 1100 to see if an appropriate certified pair of electrical safety gloves are available for use.

Glove Re-Certification:
Border State Electric
338-3118 (sales) or 344-1313 (reception)

Clear Plastic Eyewear:

Eyewear shall be used and eyewear must meet *ANSI Std. Z87.1-2003* requirements (side shields) and should be worn when there is a possibility of eye injury from flying debris and ultraviolet light emitted during an arc event.

Face Shields:

Face shields must meet *ANSI Std. Z87.1-2003* requirements and be arc resistant and have arc resistance rating of 8 calories. A typical face shield used to protect against chemical splash may not provide adequate arc resistance protection. Face shields are worn to protect the face and eyes from the flying debris and the heat generally associated with an arc blast. When using face shields, be sure to wear protective eyewear as well for maximum protection.

Cotton Clothing:

100% untreated natural cotton fiber clothing (to include cotton under garments) shall be worn by electronic workers were there exists the potential for the qualified worker to receive an arc flash.

50-120 volts	Short sleeve shirt
120-208 volts	Long sleeve shirt

Long, 100% untreated natural cotton fiber pants, such as denim cotton blue jeans (no “shorts”) should be worn.

Non-Conductive Insulation Footwear (Live or Energized Work):

The use of non-conductive, insulation (no open-toed) footwear eliminates another current path to ground through the electronics worker and shall be worn by the qualified worker where “live” or energized tasks are planned that may subject the worker to electrical shock.

Example: Leather work shoes – Category 1 or higher.

6.1.3

Insulation Mats

Non-conductive electrically insulated mats can be used, **when working on energized electronic circuits**, to protect the *qualified worker* by providing an additional layer of electrical insulation preventing another current path to ground.

6.1.4

Insulated Tools

Hand tools, used when **working on energized electronic circuits**, shall have the hand contact areas coated with an electrical insulated material to prevent a current path to the hands, and be voltage rated for the operating voltages present. Screwdriver shanks should also be insulated to prevent shorts (a current path between circuit parts through the tool).

6.1.5

Measuring Instruments

Measuring instruments suitable for performing circuit voltage measurements shall be appropriate for the maximum voltage present and have insulated or grounded housing with test probes having insulated hand grips. Measuring instrument shall be used in accordance with the procedures prescribed in the manufacturer's technical instructions or owner's manual. Do not modify or perform measurements outside the voltage range the instrument was designed for or the intended use as specified by the manufacturer.

7.0 STANDARD OPERATING PROCEDURES

7.1 Prerequisites

1. Determine the circuit parameters such as voltage and current from the equipment or apparatus' technical information (owner's manual, circuit schematic drawing, etc.) that is expected to be encountered by the worker while performing the intended task (routine troubleshooting, diagnostic and circuit measurements).
2. Determine the electrical hazards (shock, arc flash or arc blast) associated with the particular electronic device that the worker may be exposed to during the performance of the intended task (see Appendix 11.1 Arc Flash Hazard Calculations).
3. Determine the hazard mitigations necessary to safely perform the intended tasks (see section 5.2).

4. Inform the department (Level 1) manager (as part of the planning where energized work is anticipated) the nature, scope, hazards and hazard mitigations of the work intended to be performed.
5. Determine if the measuring instrument (multimeter, voltmeter, high voltage static voltmeter, oscilloscope, etc.) leads can be properly placed while the equipment is de-energized.
6. Determine if the instrument probe or test leads are appropriate for the intended circuit parameter measurement.
7. Determine if the measuring instrument's voltage ratings is appropriate to safely measure the intended circuit parameter (voltage).
8. Acquire the appropriate instrument (multimeter, voltmeter, high voltage, static voltmeter, oscilloscope, etc.) and test leads to perform the measurement.
9. Determine need for and obtain necessary voltage rated tools.
10. Determine the "approach boundaries" (see section 5.3) as necessary to protect incidental personnel if exposed circuit parts could present an electrical hazard.
11. Establish the approach boundaries dimension as necessary (see Table 1).
12. Post the limited approach boundary, as necessary.
13. Determine the appropriate PPE necessary to safely perform the intended task.
14. Determine if an *electrical Safety Watch* is required (energized work over 50 volts, unless exempted by a Level 2 manager).
15. Task the *electrical Safety Watch* if necessary. Explain to the electrical Safety Watch the intended task and the risks and hazards associated with the task and his actions to be taken when required by an emergency.
16. Acquire and don appropriate PPE, as necessary.

7.2 Non-Energized Electronic Circuit Component Replacement.

7.2.1

Circuit Part Replacement (De-energized)

Circuit **component** (including laser flash lamps) **replacemen**t shall be performed **only** with the circuit **de-energized** and the device in an electrically safe condition. Applicable to laboratory equipment, lasers, power supplies, laboratory apparatus, etc.

1. Perform **prerequisite "determinations"** and "tasks" (refer to section 7.1).
2. Set the device power switch to "OFF".
3. Remove the source of electric power to the device. Disconnect the power plug from the electric power receptacle and maintain positive

control of the plug and power cord/cable (physical and visual).

4. Determine if there are energy storage components contained in the electronic device or apparatus.
5. Determine from the integrated voltmeter (if applicable) the energized state on the electronic device or apparatus.
6. Determine need for PPE and don PPE (shock / arc flash) as necessary.
7. Determine, establish, demarcate and post **limited approach boundary if** the device is still not known to be de-energized or known to be in an energized state.
8. Using insulated tools, if there is a possibility of energy retaining circuit components that may still be energized remove the access panels or the enclosure as prescribed by the manufacturer's maintenance procedure or technical information guide.
9. Discharge all energy retaining circuit components such as storage capacitors, using an electronic ground hook with a resistor (see section 6) following the manufacturer's procedures, schematic diagrams, technical order, etc.
10. Field check voltmeter (multimeter) to verify proper functioning.
11. Verify using a voltmeter, appropriate for the circuit voltages, that all electrical contacts and connections to the circuit component to be replaced are at "zero" volts to ground and "zero" volts between contacts or connections.
12. Field check voltmeter (multimeter) to verify proper functioning.
13. Using appropriate tools remove and replace the circuit component as prescribed by the manufacturer's maintenance procedure.
14. **Replace the access panels** or the **enclosure** as prescribed by the manufacturer's maintenance procedure or technical information upon completion of the work or **if the worker must leave the area** before the completion of the work.
15. Replace the device "plug" to the facility power receptacle.
16. Relax any approach boundaries established in step "7" (if applicable).
17. Remove and stow PPE (if applicable).

7.3 Diagnostic & Circuit Test Measurements

7.3.1

De-Energized Probe Placement / Energized Circuit Measurements

Whenever possible the placement or the attachment of a measuring instrument test leads/test probes shall be performed while the electronic circuit is in a **de-energized** condition. This approach can be used to measure circuit voltage at the contact point when the device is **energized only after the placement of the test leads**.

Until proven otherwise, by voltage measurements, electronic circuits **containing energy storage/retaining components** are assumed to be energized and are treated accordantly.

Electronic circuits **known** (by technical manual or schematic diagrams) **not to contain** energy retaining circuit components may be considered de-energized by removing the electronic device from the source of electrical power, such as turning the device "off" and un-plugging the device from the power receptacle.

Electronic devices and equipment that contain integrated voltmeters, that are known to be functional and reliable and actually indicate zero volts, may be used as an indicator of the energized state or non-energized state of its electronic circuits.

1. Perform **prerequisite "determinations"** and "tasks" (refer to section 7.1).
2. Set the device to "OFF"
3. Determine and don PPE (shock / arc flash).
4. Determine, establish, demarcate and post limited approach boundaries.
5. Using insulated tools, if there is a possibility energy retaining circuit components that may still be energized, remove the access panels or the enclosure as prescribed by the manufacturer's maintenance procedure or technical information guide.
6. Discharge all energy retaining circuit components, such as storage capacitors, where applicable and appropriate using an electronic ground hook with a resistor (see section 6) following manufacturer's procedures, schematic diagrams, technical order, etc.
7. Field check voltmeter (test instrument) to verify proper functioning.

8. Place the test instrument at a stable and safe location near the circuit test points or contacts to be measured close enough so that the test leads can easily reach the test points or contacts.
9. Using one hand, place and attach each of the appropriate test leads, one at a time, to the circuit test points or part contacts to be measured. Ensure that the test instrument in "on" and is set on the appropriate scale to perform the measurement.
10. Re-energize the circuit (i.e. set the device to "ON").
11. Read the value measured by the test instrument.
12. De-energize the circuit (i.e. set the device to "OFF"). Verify the test instrument reads "zero".
13. Using one hand relocate the test instrument leads to the next location or test point to be measured. Repeat steps 7 through 10 until the testing or measuring task is complete.
14. De-energize the circuit (i.e. set the device to "OFF"). Verify the test instrument reads "zero".
15. Using one hand remove the test instrument leads from the circuit.
16. Using insulated tools re-attach the access panels, protective housing or replace the enclosure.
17. Relax the approach boundaries and remove posting.

7.3.2

Energized Circuit Measurements

(Live / Energized Work)

Sometimes it is necessary to perform special diagnostic or circuit voltage measurements, which requires the placing of the measuring instrument test leads while the circuit is under energized conditions. Under these conditions a qualified *Safety Watch* or *second person* shall be present (unless exempted by a Level 2 manager) where exposed circuit voltages are expected to be 50 volts or greater. The Safety Watch shall wear the same PPE and have the same qualifications and complete the same task related training as the worker performing the "energized task" especially if the *Safety Watch* will or might be inside the limited approach or arc flash boundary.

1. Perform **prerequisite "determinations"** and "tasks" (refer to section 7.1).
2. Set the device power switch to "OFF".
3. Determine, establish, demarcate and post limited approach boundaries.
4. Select a measuring instrument appropriate for the measurement to be performed with insulated housing or enclosure.
5. Ensure the test leads are appropriately insulated to prevent shock to the qualified worker.

6. Field check voltmeter (test instrument) to verify proper functioning.
7. Place the measuring instrument on a stable surface, at a safe location near the circuit test point or contacts to be measure. Generally, this is within the *restricted approach boundary,* close enough so the qualified worker can easily reach and place the instrument leads or test probe to the circuit test point or contacts and can also be easily read by the qualified worker making the circuit measurement.
8. Don appropriate PPE as determined in step "1".
9. Using insulated tools remove the access panels, protective housing or the enclosure to gain access to the test point as prescribed by the manufacturer's maintenance procedure, technical information guide or owner's manual.
10. Attach the "ground" test lead securely to the device or system "ground".
11. Energize the circuit (i.e. set the device power switch to "ON").
12. Using one hand, hold the test probe insulated handle and place the test probe to the appropriate test point. If possible have a second qualified worker read the instrument. Care should be taken not to slip off the test point during the reading of the instrument.
13. Using one hand, remove the test probe from the circuit at the completion of the energized circuit testing. Place the test probe with the measuring instrument in a stable and safe location.
14. Once again field check voltmeter (test instrument) to verify that the instrument is still functioning properly.
15. De-energize the circuit (i.e. set the device to "OFF").
16. Using insulated tools re-attach the access panels, protective housing or replace the enclosure.
17. Relax the approach boundaries and remove posting.
18. Remove and stow PPE.

7.4 Work Near Energized Circuits

7.4.1

Work Near Energized Circuit

Sometimes it may be necessary to perform non-electrical work, such as the alignment of older model ion lasers, which require the adjustment of optical elements (mirrors, prisms and output couplers), while the laser is "on" and the protective housing is open or has been removed. While performing this work the worker might be "near" (at or within the

restricted approach shock boundary – typically one foot) **exposed** energized circuits or components operating at or above **300 volts**.

Note: that the manufacturers of later model commercial lasers have engineered these systems such that the high voltage components are encapsulated, enclosed or positioned such that the worker performing optical alignments are not exposed to these energized parts.

Although this work may be non-electrical in nature; if there exists a potential for the worker to come in contact with or to hold or to use a conductive object that might come in contact with, exposed energized electrical circuits operating at or above 50 volts, then this work is to be considered the same as electrical work "on or near" exposed energized electrical circuits operating at or above 50 volts.

Whenever possible an insulating barrier shall be employed to separate the worker from the electrical hazard. If an insulating barrier cannot be employed the same personnel protective equipment and mitigating strategies use for live or energized work shall be use.

Under these conditions a qualified *Safety Watch* shall be present unless exempted by a Level 2 manager. The *Safety Watch* shall wear the same PPE and have the same qualification and training as the worker performing the "energized task" especially if the *Safety Watch* will or might be inside the limited approach or arc flash boundary.

1. Perform **prerequisite "determinations"** and "tasks" (refer to section 7.1).
2. Determine collateral hazards, such as laser light.
3. Determine collateral hazard mitigations needed.
4. Determine, establish, demarcate and post limited approach boundaries as required unless a detailed hazard analysis has determined that a shock, arc flash or arc blast hazard does not apply and the requirement is exempted by a Level 2 manager.
5. Don appropriate PPE as determined in step "1", such as laser safety eyewear, electrical safety gloves, etc.
6. Remove the protective housing to expose the optics or optical elements to be adjusted.
7. Activate the device (laser).
8. Whenever possible only use one hand to perform adjustments near exposed energized circuits operating at or above 50 volts.
9. When the task is complete de-energize the circuit (i.e. set the device to "OFF").
10. Replace the protective housing or covers.
11. Relax the approach boundaries and remove posting.
12. Remove and stow PPE.

7.4 EMERGENCY AND FIRST AID PROCEDURES

7.4.1 Fire Fighting Measures

In the event of a fire, pull the fire alarm pull box and call 911.

7.4.2 Emergency Procedures

Step **Action**

1. Obtain/apply first-aid or medical assistance as necessary:

Emergency	Dial
Medical assistance	**911**
Assistance to free trapped personnel	**911**
Security	**911**

Stay on the phone until properly released by the 911 operator.

2. Notify the Department Manager.

If your Department Manager is not available, notify the Manager of another Department in the Center.

3. Notify the Center 1100 ES&H Coordinator:
M. Wayne Davis, 844-6734, pager 540-1798

4. In all occurrences of electric shock, the ***affected individuals*** must be escorted to Medical for evaluation.

7.4.3

Electrical *Safety Watch*

First Response / First Aid

In the event of electric shock, the qualified *electrical Safety Watch* shall:

- De-energize the electronic equipment.
- Safely remove or separate the effected person from the energizing source using non-conductive means.
- Call 911 immediately.
- Perform CPR (previously agreed to) as necessary or as directed by emergency response personnel.
- Escort affected individual to Medical for evaluation or as directed by emergency response personnel.
- Notify the Department Manager.
- Notify the Center ES&H Coordinator: Wayne Davis, (505) 844-6734, pager: (505) 540-1798.

7.4.4

General Post Incident Actions

- Stop activity.
- Secure the scene to prevent further injury or damage.
- Evacuate if necessary
- Do not disturb the scene.
- **Notify**:

  Department Manager

  Center 1100 ES&H Coordinator: **Wayne Davis, (505) 844-6734,** pager: (505) 540-1798

8.0 WASTE DISPOSAL and POLLUTION PREVENTION

8.1

Waste Minimization & Pollution Prevention

Waste minimization and pollution prevention will be incorporated in the planning and operation of the activity covered by this operating procedure. Waste minimization and pollution prevention includes but is not limited to:

- Ordering the minimum quantity of chemicals required to conduct an activity
- Designing waste minimization and pollution prevention into programs, processes and activities
- Substituting non-hazardous or less hazardous chemicals where applicable

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9.0 ES&H REPORTING AND DOCUMENTATION

Records

The following records are required for ES&H reporting:

- Authorized Users Signature Sheet signed by each new Authorized Worker before performing work.
- ES&H Training Records (maintained in TEDS).
- PHS or other ES&H-related records for each lab shall be maintained according to SNL guidelines.
- Report all shock events, even perceived shock events.

SOP Review

The following are procedures for SOP reviews:

- Reviews of this SOP will be performed every three years and Authorized Worker will read and sign-off on any changes or revisions. Interim reviews and revisions may be performed as necessary due to changing equipment, changes in procedures, or change in conditions.

10.0 REFERENCES

MN471001	ES&H Manual, Chapter 4B.
CPR400.1.1.28	Electrical Safety Manual.
DOE Order 440.1A	Worker Protection Management for DOE Federal and Contractor Employees.
NFPA 70E-2004	Standard for Electrical Safety in the Workplace
ANSI Std. Z87.1-2003	Practice for Occupational and Educational Eye and Face Protection.
IEEE Std. 1584-2002	IEEE Guide for Performing Arc-Flash Hazard Calculations.
IEEE Std. 1584a-2004	IEEE Guide for Performing Arc-Flash Hazard Calculations – Amendment 1.
IEEE Transactions on Industry Applications, VOL. 1A-18, NO.3, MAY/JUNE 1982.	*The Other Electrical Hazard: Electric Arc Blast Burns* by Ralph H. Lee.
	Appropriate Manufacturer's Technical Manuals (Owner's Manual, Manufacturer's Maintenance Manual, etc) of the equipment involved.

11.0 APPENDIX

11.1 **Arc Flash Hazard Calculations**

11.1.1 Background

The methods presented in *NFPA 70E*, Standard for Electrical Safety in the Workplace and *IEEE Standard 1584™-2002*, Guide for Performing Arc-Flash Hazard Calculations for the calculations of arc flash hazards are based on 3-phase AC power distribution systems. The *IEEE Std. 1584* states that where single phase (such as typical of laboratory equipment) sources are encountered the 3-phase model will produce conservative results.

11.1.2 Qualifications

"An arc-flash hazard study for the purposes of determining arc-flash PPE and protection boundaries should include Department 10861 electrical power Systems Engineers (SE), qualified Center 1100 Staff, and Electrical Safety Program Staff. Should one choose to not perform such arc-flash studies, then arc flash PPE must be selected by using the NFPA 70E table method. Note that the table method requires SE involvement relative to determining over current protection device trip time and bolted fault current (kA).

11.1.3 Procedures (Excerpted and Adopted from *IEEE Std.1584*)

Step 1: Collect supply circuit and electronic device data and document the system voltages.

Contact Department 10861 System Engineer (SE) and request available bolted fault current ($\mathbf{I}_{bf}$) and over current device trip (circuit breaker) time for relevant disconnect or circuit breaker panel. The 10861 System Engineers are assigned by building. Provide the 10861 SE with information regarding any dry type transformers between the relevant circuit breaker panel and equipment service disconnect.

Step 2: Determine the Arc Fault current (systems operating at < 1000 V).

Assume infinite buss between equipment and service-disconnect or circuit breaker panel and calculate arc fault current:

$$\lg(I_a) = K + (0.662)\lg(I_{bf}) + (0.0966)V + (0.000526)G + (0.5588)V\lg(I_{bf}) - (0.00304)G\lg(I_{bf})$$

Where:
lg = shortened notation for $\log_{10}$
I_a = arc fault current (kA)
I_{bf} = available bolted fault current (kA) obtained from Department 10861 SE
K = -0.097 for arcs-in-a-box
V = system voltage (kV)
G = conductor gap from Over Current protection Device (OCD) type table

The arc fault current depends on the bolted fault current. For systems with 1000 V or less the arc fault current will be less than the bolted fault current. A conservative approach sets both these currents equal.

Step 3: Calculate Incident Energy normalized for time (0.2 seconds) and distance (610 mm)

$$\lg(E_n) = K_1 + K_2 + 1.081 \cdot \lg(I_a) + 0.0011G$$ **(Joules/cm^2)(0.24) = calories/cm^2**

Where:
$\lg(E_n)$ = normalized Incident Arc Energy (Joules/cm^2)
K_1 = -0.555 for arc-in-a-box
K_2 = -0.113 for grounded systems
Lg(I_a)= value from Step 2

Step 4: Calculate Incident Energy

$$E = 4.184 \cdot C_f \cdot E_n \cdot \left(\frac{t}{0.2}\right) \cdot \left(\frac{610^x}{D^x}\right)$$

Where:
E = incident energy (joules/cm^2) covert to cal/cm^2 by multiplying the energy by 0.24
C_f = calculation factor 1.5 for systems operating at < 1 kV
E_n = incident energy normalized ($10^{\lg En}$)
t = OCD trip time (seconds) (1.5 cycles = 0.025 sec) [*IEEE 1854 (Table 1)*]
x = distance factor from OCD type [*IEEE 1584 (Table 4)*]
D = distance between worker and conductor (460 mm)

Note: For *t* use the protective device trip time determined based on calculated arcing fault current, if device trip time data is available.

Source of information include the manufacturer's fuse data, or [*IEEE 1584 (Table 1)*].

Step 5: Select the proper working distances.

The working distance (D_w) is always <u>based on the incident energy levels on the face and body</u>, not the incident energy on the hands or arms. For electronic devices with system voltages less than 1 kilovolts, this distance would be similar to that of low-voltage MCC and panelboards, which is given as 455 mm (~18 inches or 1.5 feet) [*IEEE Std. 1584-2002 (Table 3)*].

Step 6: Determine the flash-protection boundary for the electronic device.

$$D_B = \left[4.184 \cdot (C_f) \cdot (E_n) \cdot \left(\frac{t}{0.2} \right) \cdot \left(\frac{610^x}{E_B} \right) \right]^{\frac{1}{X}}$$

<u>Where</u>:
D_B = Arc Flash Distance
E_B = Incident Energy at Arc Flash Boundary Distance (≤ 5 J/cm^2 or 1.2 cal/cm^2)
Note: 5 J/cm^2 = 1.2 cal/cm^2

If the flash protection boundary (D_c) is greater than the working distance (D_w), selected in step 7; the worker must don appropriate PPE capable of withstanding the incident energy density at the working distance.

Always use safety glasses and cotton clothing when working on multiphase equipment regardless of whether the working distances is greater than the flash protection boundary distance.

An alternative to the above methods for calculating incident energy and arc flash hazard boundary distance is to use the [*IEEE 1584 (Table 5)*] equations as described below.

E and F_B of the form $C_f(I_{bf}) + C_{f2}$ *

<u>Where</u>:
E = Incident Arc Energy joules/cm^2
F_B = Arc Flash hazard distance (mm) where arc energy is ≤ 1.2 cal/cm^2
C_{f2} = Calculation Factor from calculation table [*IEEE 1584 (Table 5)*] based on OCD rating and operating voltage
I_{bf} = available bolted fault current (kA)

*Values for C_f and C_{f2} are given in *IEEE 1584 (Table 5)*.

Flash-protection boundary for RC circuit

$$D_c = \sqrt{(5.3 \times 10^{-6}) \cdot E_{sto}}$$

<u>Where</u>:
E_{sto} = Stored Energy (Joules) this provides for the time component

11.1.4 **Arc Flash/Blast Hazard Threshold at the Working Distance**

System Power at the Flash Protection Boundary Set to the Working Distance

The surface area of the radiant arc at the working distance (D_w), where the working distance is 45.5 cm [*IEEE Std. 1584-2002 (Table 3)*] is as follows:

$$A_{s-w} = 4\pi D_w^2 = 26 \times 10^3 cm$$

The arc energy (Q_{arc}) for an energy density of 5 J/cm^2 at this working distance is:

$$Q_{arc} = \left(5 \ J/cm^2\right) \cdot \left(26 \times 10^3 \ cm^2\right) = 130 \times 10^3 \ J$$

The arc power (P_{arc}) based on a 0.025 second exposure (time for the circuit protection device clearing) defaulted to the standard time for a circuit breaker [*IEEE Std. 1584-2002 (4.6) (Table 1)*].

$$P_{arc} = \frac{Q_{arc}}{t} = \frac{130 \times 10^3 \ J}{0.025 \ \text{sec}} = 5.2 \times 10^6 \ watts$$

The minimum system (faulted) power for maximum power transfer is:

$$P_{sys} = 2 \cdot P_{arc} = 10.4 \times 10^6 watts$$

Alternately; **System Bolted Fault Power Threshold at the Working Distance**

The bolted fault power for the condition where the flash protection boundary distance from the source arc is equaled to the working distance (~1.5 feet) requiring the worker to don PPE can be found as follows.

$$MVA_{bf} = \frac{D_c^2}{2.65 \cdot t} = \frac{(1.5)^2}{2.65 \cdot t} = \frac{0.849}{t}$$ From: NFPA 70E-2004 (D.3(d)

For a "worst case" exposure of 0.1 seconds, based on the typical circuit breaker clearance time [*NFPA 70E-2004 (Annex D)*], the bolted fault power for the working distance equaled to the flash protection distance:

$$VA_{bf} = \frac{0.849}{0.1} Mw = 8.49 \ Megawatts$$

Conservatively, the minimum system fault power for an arc flash/blast hazard threshold at the **working distance** is the smaller value derived from these two methods. Hence; for an electronic device with system **fault powers** of less than **8.49 megawatts** the **working distance is outside the Flash Protection Boundary** distance and an **Arc Flash/Blast hazard does not apply**. However, worker exposure control regarding the

molten projectile hazard must be addressed through the use of safety glasses and cotton clothing.

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11.2 Example of Approach Boundary Signage

Figure 1

Example of a warning sign for a Limited Approach Boundary posting.

Figure 2

Example of a warning sign for a Limited Approach Boundary posting

Figure 3

Example of a warning sign for an Arc Flash Boundary posting.

12.0 AUTHORIZED Worker LIST

Authorized Worker List Authorized workers must be approved by Department Manager.

By my signature below, I affirm that I have read and understand this SOP, and all references called out in procedural and informational steps, and I agree to operate within the stated constraints. The Department Manager's signature confirms approval and authorization for the individual to perform the work covered by the SOP.

Name (Printed)	Signature	Date	Department Manager Signature