VCU Electrical Safety Program

I. Introduction/Purpose

a. This program provides information about electrical hazards, guides University safe-work policy and electrical safety procedures. This program has been developed to reduce exposures related to energized electrical work and to assure the safety of personnel who face a risk of electrical shock, arc flash events, or related injuries as part of their job duties.

II. Applicability/Scope

a. This program applies to all VCU staff, faculty, students, visitors and contractors working at VCU facilities who work on electrically energized equipment, circuits, or building systems ≥ 50 volts. This program:
   i. Defines safe work practices and use requirements for all people who work with electrically energized equipment as part of their normal job duties.
   ii. Establishes training requirements for qualifying and authorizing persons who work on or near energized electrical circuits and components.
   iii. Establishes a process for evaluating the hazards of potentially energized work tasks and determining appropriate controls.
   iv. Establishes a formal process for controlling energized electrical work through a documented Energized Work Permit approval process.

b. Energized parts that operate at > 50 volts and < 1000 watts are not required to be de-energized if there will be no exposure to electrical burns or to explosion blast due to electric arcs.

III. Definitions

a. <u>Arc-Flash Boundary</u> - The Arc Flash Boundary (AFB) is the distance from exposed, energized electrical components within which a person could receive a second degree burn if an electrical arc flash were to occur. All personnel must wear appropriate arc-rated protective equipment before crossing this boundary.

b. <u>Arc-Rating/ATPV</u> - Arc-thermal performance value (ATPV) refers to the arc rating of flame-resistant clothing, expressed in calories per square centimeter (cal/cm2).

c. <u>Authorized Employee</u> - An employee who works on electrically energized equipment, circuits, or building systems ≥ 50 volts. The Authorized Employee is both:
   i. <u>Qualified</u>, through appropriate training and experience, **and**

ii. Authorized to perform electrical work by the Superintendent/Supervisor or Principal Investigator having operational control of the area where the work is to occur, either through Job Description, task assignment, contract, or written communication.

d. De-energized - A state in which the conductor or circuit part to be worked on or near has been disconnected from energized parts, locked / tagged in accordance with the VCU Energy Isolation / LOTO Program, tested to ensure the absence of voltage, and grounded if determined necessary.

e. Diagnostic - see Troubleshooting / Diagnostic Work.

f. Energized Work – Physically working on or nearby electrically energized equipment and parts without barriers, guards or physical safe-guards in place.

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

h. FR (flame-resistant) clothing - The property of a material whereby combustion is prevented, terminated, or inhibited following the application of a flaming or non-flaming source of ignition, with or without subsequent removal of the ignition source.

i. Grounded - Connected to earth or to some conducting body that serves in place of the earth.

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

k. Insulated - Separated from other conducting surfaces by a dielectric material (including air space) offering a high resistance to the passage of electric current.

l. Isolated Equipment - Equipment that has been de-energized and locked-out according to the VCU Lockout/Tagout Energy Isolation Program.

m. Limited Approach Boundary (LAB) - A distance from an exposed live part within which an electrical shock hazard exists. The Limited Approach Boundary determines the minimum safe distance for the placement of barricades for shock protection. An unqualified worker may not enter the limited approach boundary without escort by a qualified worker. Working within the LAB is only acceptable if an Energized Electrical Work Assessment has been completed and approved, or if the work is specifically exempt as defined under "Troubleshooting / Diagnostic Work".

n. <u>LOTO</u> - Lockout / Tagout. The requirements for LOTO are documented in the VCU Lockout/Tagout Energy Isolation Program.
o. <u>NRTL</u> - Nationally Recognized Testing Laboratory. An organization which is recognized by OSHA for testing and certifying products to safety standards.
p. <u>Owner Department</u> - The Owner Department is a VCU School or Department that owns and/or has operational control of equipment/systems that by its nature/design must have this Electrical Safety program applied to the equipment for personnel to safely conduct inspection, modification, repair, adjustment, development, or maintenance work on the equipment.
q. <u>Restricted Approach Boundary</u> - The Restricted Approach Boundary (RAB) is closest to live parts. Inside this boundary is the highest likelihood of electric shock. *Under no circumstances should an unqualified worker ever be permitted to cross the restricted boundary.* A qualified person required to cross the RAB must be protected from unexpected contact with exposed energized conductors or circuit parts. Working within the RAB is only acceptable if an Energized Electrical Work Assessment has been completed and approved, or if the work is specifically exempt as defined under "Troubleshooting / Diagnostic Work".
r. <u>Qualified Person</u> - A person as defined in NFPA 70E-2024 110.4(A)(1) has skills and knowledge in the construction, installation, maintenance and operation of electrical equipment and installations appropriate to the hazard level of intended work, and has received safety training on the hazard controls and PPE required to conduct assigned job tasks.
    i. A Qualified Person is familiar with the proper use of:
        1. Special precautionary techniques
        2. Applicable policies and procedures
        3. PPE
        4. Insulating and shielding material
        5. Insulated tools
        6. Test equipment
    ii. A Qualified Person is permitted to work within the Limited Approach Boundary and shall, at a minimum, be trained in the following:
        1. Skills and techniques necessary to distinguish exposed energized electrical conductors and circuit parts from other parts of electrical equipment.

2. Skills and techniques necessary to determine the nominal voltage of exposed energized electrical conductors and circuit parts.
3. Approach distances specified in NFAP-2024 Table 130.4(E)(a) and Table 130.4(E)(b) and the corresponding voltages to which the Qualified Person will be exposed.
4. Decision-making process necessary to be able to do the following:
    a. Perform the job safety planning
    b. Identify electrical hazards
    c. Assess the associated risk
    d. Select the appropriate risk control methods from the hierarchy of controls identified in NFPA 70E-2024 110.3(H)(3), including PPE

A person can be qualified with respect to certain equipment, but still be unqualified for others.

s. Supervisor - A general term used throughout this program that is defined as a person who has operational control of an area or equipment where electrical work is performed and/or supervises persons doing electrical work, and who have the primary responsibility of ensuring a safe working environment. At VCU, supervisors may include Superintendents, Principal Investigators (PIs), Researchers, Staff, Project Managers and / or Contractors.
t. Shock Hazard - A dangerous condition associated with the possible release of energy caused by contact or approach to live parts.
u. Troubleshooting / Diagnostic Work - Electrical work shall be permitted without an energized electrical work permit if a qualified person is provided with and uses appropriate safe work practices and PPE in accordance with NFPA 70E Chapter 1 under any of the following conditions (NFPA 70E-2024 130.2(C)):
    i. Testing, troubleshooting, or voltage measuring
    ii. Thermography, ultrasound, or visual inspections if the restricted approach boundary is **not** crossed
    iii. Access to an egress from an area with energized electrical equipment if electrical work is performed and the restricted approach boundary is not crossed
    iv. General housekeeping and miscellaneous non-electrical tasks if the restricted approach boundary is not crossed.

v. Unqualified worker - An employee who has not been trained to perform electrical work.
w. Voltage (of a circuit) - This is the greatest root-mean-square (rms) difference of electrical potential between any two conductors of a circuit.

IV. Roles/Responsibilities

a. All Employees have the authority to pause work to address an unsafe condition or behavior.
b. Owner Department:
    i. The Owner Department ensures all employees performing work on electrically energized circuits, equipment or building systems are trained commensurate with their assigned job tasks.
    ii. Owner Departments must provide Personal Protective Equipment (PPE) appropriate for the specific job tasks.
    iii. Owner Departments must ensure that all employees performing electrical work have attended:
        1. Electrical Safety training (70E or equivalent) and
        2. Lockout/Tagout training
    iv. Owner Departments must ensure that electrical systems, related equipment and monitoring tools and equipment are maintained in a safe manner in order to protect employees, students, and the public from hazardous conditions.
c. Occupational Health & Safety (OHS):
    i. Interprets and updates this written program as needed.
    ii. Performs inspection of the Electrical Safety program and its implementation.
    iii. Investigates injuries and near misses.
    iv. Maintains training records.
    v. Provides safety consultation upon request.
    vi. Reviews this written program periodically.
d. Supervisor
    i. Ensures the implementation of all applicable requirements of this program for people/projects within their operational control.
    ii. Ensures employees working in their operational area are trained to the level necessary to safely conduct their assigned work tasks.

iii. Ensures coordination and cooperation between employees and external contractors.
iv. Approves energized work by documenting the information required in Appendix G - Energized Work Permit (or equivalent) that clearly states all of the following criteria:
   1. Description of the circuit and equipment.
   2. Description of the work.
   3. Description of the safe work practices to be employed.
   4. Justification of why the equipment cannot be de-energized or the work deferred until the next scheduled outage.
   5. Risk Assessment (electric shock and arc flash).
   6. Approach Boundaries.
   7. PPE Selection.
   8. Means employed to restrict access.
   9. Evidence of completion of a job briefing.
   10. Approval.
   11. A sample Energized Work Permit is available in Appendix G.

e. Qualified Persons:
   i. Do **not** perform non-exempt work on energized equipment / systems without written approval prior to the start of work.
   ii. Follow the requirements of this program.
   iii. Maintain required qualification(s) through required training and/or work experience.
   iv. Use and wear PPE as designed. Report any flaws, breaks or malfunctions or PPE to the Area Supervisor so it may be repaired or replaced.

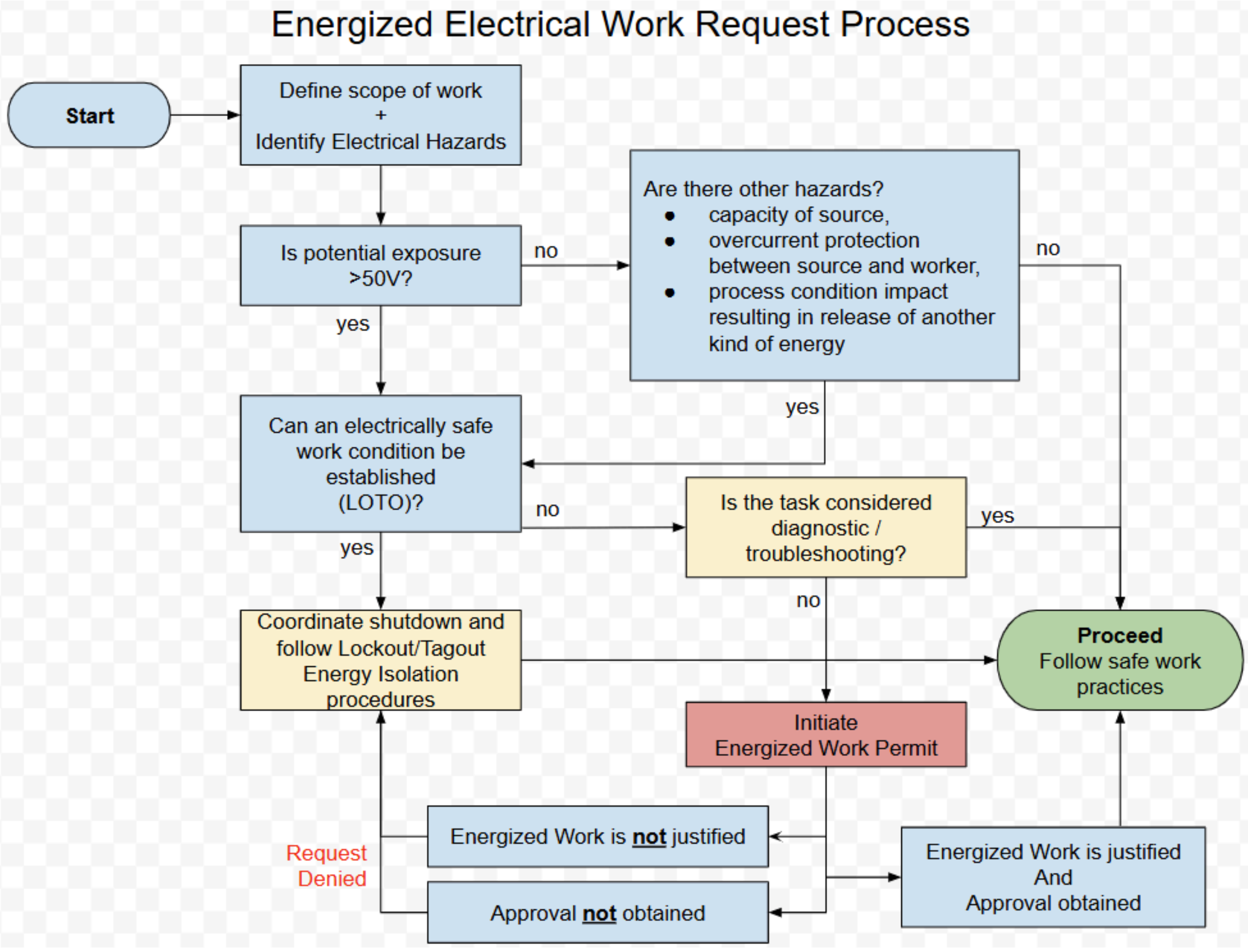
f. Unqualified Persons:
   i. Shall be notified of hazardous conditions & restricted work areas by the Qualified Person(s) through:
      1. Barricades or other effective means of pedestrian control and
      2. Where Unqualified Persons have access to the general area, signage indicating the presence of electrical hazard(s).

V. General Guidelines

a. Only qualified and authorized persons are allowed to work on wiring, conduits or related systems and equipment.

b. Always consider electrical equipment energized until positively proven otherwise.
c. Whenever possible de-energize the equipment before testing.
d. Apply LOTO principles and procedures as outlined in the VCU Lockout/Tagout Energy Isolation program.
e. Work on or near equipment operating within the electrical hazard conditions identified in this document is performed in an electrically safe state (verified de-energized) or is formally approved and documented through an Energized Work Permit process.
f. Be aware of hidden raceways and other utilities that may be concealed behind walls and/or concealed below or in concrete walls and slabs.
g. Use suitably rated electrical tools and devices only as intended.
h. Maintain the protection of covers, barriers and shielding of all electrical equipment.
i. Never penetrate premises wiring conduit or enclosed wire ways.

VI. General Sequence of Procedures



a. Identify the planned work tasks:
   i. Is the work <50V?
   ii. Can the equipment / system be de-energized?
   iii. Is the planned work considered to be diagnostic / troubleshooting as defined in this program?
b. If the answer is **Yes** to *any* of the above, follow safe work practices and proceed.
c. If the answer is **No** to *all* of the above, submit an Energized Work Permit to the area Supervisor including:
   i. Description of the circuit and equipment.
   ii. Description of the work.
   iii. Description of the safe work practices to be employed.

iv. Justification of why the equipment cannot be de-energized or the work deferred until the next scheduled outage.
v. Risk Assessment (electric shock and arc flash).
vi. Approach Boundaries.
vii. PPE Selection.
viii. Means employed to restrict access.
ix. Evidence of completion of a job briefing.
x. Approval.
xi. A sample Energized Work Permit is available in Appendix G

VII. Risk Assessment & PPE Selection

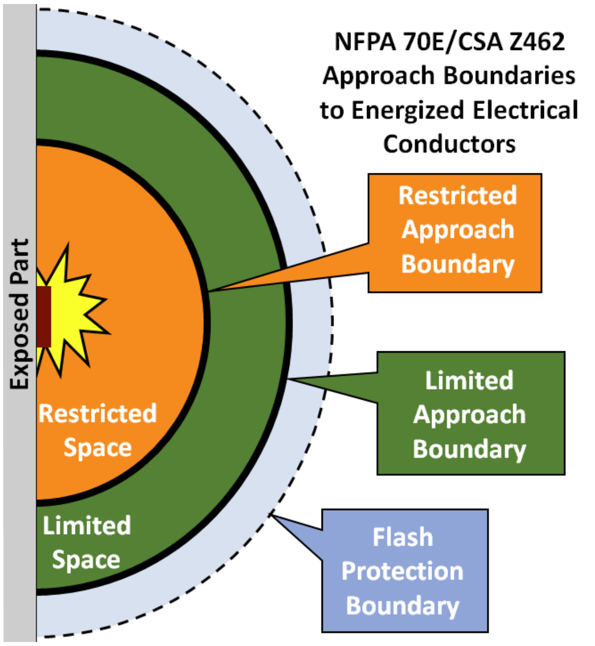
a. Electric Shock Risk Assessment

i. An electric shock risk assessment shall be performed to:
1. Identify electrical shock hazards,
2. Estimate the likelihood of electric shock,
3. Determine the
    a. **Restricted Approach Boundary** and
    b. **Limited Approach Boundary**
4. Determine if additional protective measures are required

b. Arc Flash Risk Assessment

i. An arc flash risk assessment shall be performed to:
1. Identify arc flash hazards
2. Estimate the likelihood (NFPA 70E-2024 Table 130.5(C)) of occurrence of an arc flash event.
3. To determine the **Arc Flash Protection Boundary**
4. To determine if additional protective measures are required, including the use of PPE

c. Determine Approach Boundaries



i. Restricted Approach Boundary
   1. Only Qualified Persons with proper PPE may work within the Restricted Approach Boundary.
   2. *Under no circumstance shall Unqualified Person(s) or conductive materials be permitted to cross the restricted approach boundary.*
   3. The Restricted Approach Boundary is determined by referencing:
      a. **Appendix A**: NFPA 70E-2024 Table 130.4(E)(a) for alternating current and **Appendix B**: NFPA 70E-2024 Table 130.4(E)(b) for direct current.
      b. Select the voltage range and exposed conductor/circuit condition consistent with the planned work.
   4. If you are unsure of the Restricted Approach Boundary and the voltage is <600V, the default Restricted Approach Boundary is 4ft.

ii. Limited Approach Boundary
   1. All persons working within the Limited Approach Boundary must wear PPE and be escorted by a Qualified Person.
   2. The Limited Approach Boundary determines the minimum safe distance for the placement of barricades for shock protection.
   3. The Limited Approach Boundary is determined by referencing:

a. **Appendix A** - NFPA 70E-2024 Table 130.4(E)(a) for alternating current or
b. **Appendix B** - NFPA 70E-2024 Table 130.4(E)(b) for direct current, then
c. Select the voltage range and exposed conductor/circuit condition consistent with the planned work.

iii. Arc Flash Protection Boundary
1. All persons working within the arc flash protection boundary must wear appropriate PPE.
2. Determine the *likelihood* of a task to have an arc flash event by referencing **Appendix C** - NFPA 70E-2024 Table 130.5(C). If there is a risk of an arc flash,
3. Determine the Arc Flash Protection Boundary by referencing:
   a. **Appendix D** - NFPA 70E-2024 Table 130.5(C)(15)(a) for alternating current or
   b. **Appendix E** - NFPA 70E-2024 Table 130.7(C)(15)(b) for direct current.

d. Keep unauthorized, unqualified people outside of the arc flash protection boundary, using locked doors, temporary barricades, guardrails or warning tape.

e. PPE Selection

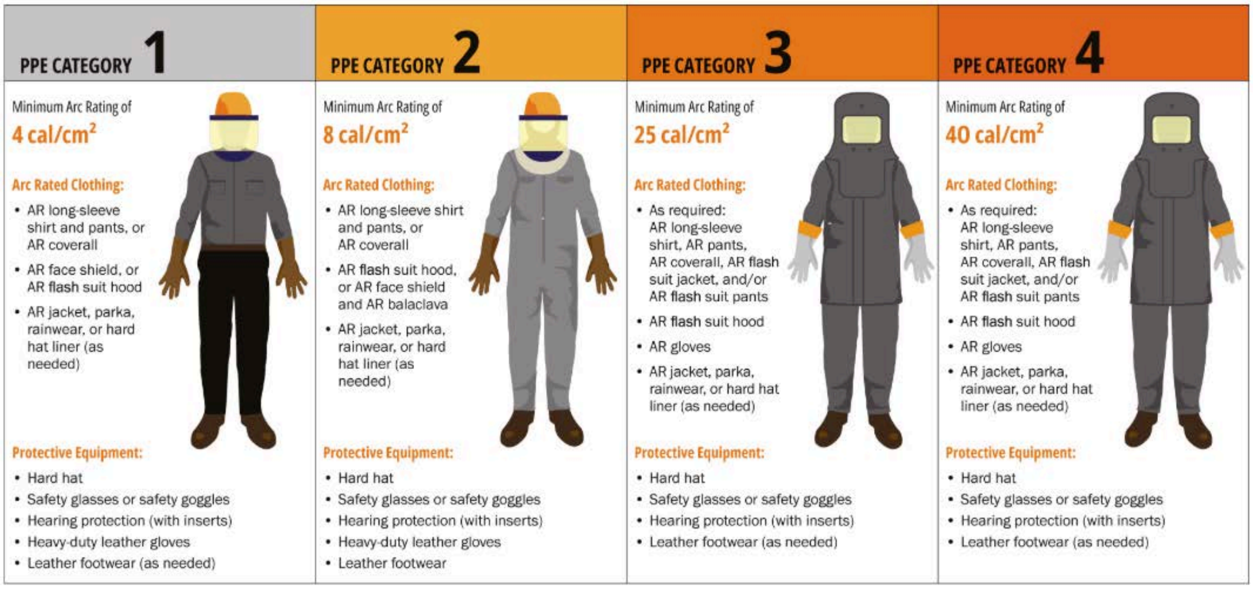
i. Employees working in areas where there are potential electrical hazards shall be provided and shall use, electrical protective equipment that is appropriate for the specific parts of the body to be protected and for the work to be performed.

ii. PPE selection is performed by the following:
1. <u>PPE Category Method (Tables Method) by task:</u>
   a. Using this method has limitations. If the equipment is not listed on the table or if even one parameter is exceeded, it cannot be used. Any variations (e.g. working distance) also negate its use. Additionally, this method requires accurate knowledge of the equipment, including bolted fault current supplied, impedance, and clearing time. If these are not known with certainty, this approach cannot be used.
   b. STEPS:

i. Locate TASK. Using **Appendix C** - NFPA 70E-2024 Table 130.5(C), locate the task to determine if there is a likelihood of an arc hazard occurrence (indicated by the Yes/No column). If the answer is "Yes," move to step ii.

ii. Locate EQUIPMENT. Use **Appendix D** - NFPA 70E-2024 Table 130.7(C)(15)(a) for alternating current equipment or **Appendix E** - NFPA 70E-2024 Table 130.7(C)(15)(b) for direct current equipment. Locate the equipment commensurate with the equipment involved in the job task and note the PPE category number. The equipment described in the table must be commensurate with the equipment involved in the job task. If the specifications/ parameters are exceeded or there are any variations, do not proceed further with this method.

iii. Locate PPE CATEGORY. Using **Appendix F** - NFPA 70E-2024 Table 130.7(C)(15)(c), locate the appropriate PPE category. The table contains a detailed list of PPE required and performance criteria for each category.



iv. If this method is used, the category determined must be recorded on the equipment's arc flash hazard label.

2. <u>PPE Selection by Incident Energy Analysis / Calculation Method:</u>
    a. An incident energy analysis shall be required in accordance with NFPA 70E 130.5(g) for the following:
        i. Tasks not listed in the tables
        ii. Power systems with greater than estimated maximum available short circuit current
        iii. Power systems with longer than the maximum fault clearing times
        iv. Tasks with less than the minimum working distance
    b. The Incident Energy Analysis Method for selecting appropriate PPE requires a detailed electrical analysis of the equipment. A series of calculations determines the incident energy at the prescribed working distance that a worker would be exposed to in the event of an arc flash. Employers are required to perform these analyses if an arc hazard is likely to exist and if the PPE Category Method (Tables Method) cannot be used.

c. The selected PPE ensemble must have an Arc Thermal Protection Value (ATPV) that is rated equal to or greater than the incident energy (calculated in cal/cm2).

3. Note that the two above methods are not interchangeable.

VIII. PPE Care & Inspection

a. Protective equipment shall be maintained in a safe, clean and reliable condition in accordance with manufacturer's recommendations.

b. The PPE shall be visually inspected before each use.

c. PPE shall be stored in a manner to prevent damage from moisture, dust, or other deteriorating agents.

d. Electrical personal protective equipment shall be subjected to periodic electrical tests as required by OSHA in 29 CFR 1910.137(c)(2)(viii):

e.

Table I-5	
Type of Equipment	When to Test
Rubber insulating line hose	Upon indication that insulating value is suspect and after repair.
Rubber insulating covers	Upon indication that insulating value is suspect and after repair.
Rubber insulating blankets	Before first issue and every 12 months thereafter; [1]upon indication that insulating value is suspect; and after repair
Rubber insulating gloves	Before first issue and every 6 months thereafter; [1]upon indication that insulating value is suspect; after repair; and after use without protectors.
Rubber insulating sleeves	Before first issue and every 12 months thereafter; [1]upon indication that insulating value is suspect; and after repair
[1]If the insulating equipment has been electrically tested but not issued for service, the insulating equipment may not be placed into service unless it has been electrically tested within the previous 12 months.	

IX. Restoring Equipment to Service

After the work is completed and the equipment is ready to be returned to normal operation, this procedure must be followed:

a. Clear the machine or equipment of tools and materials;
b. Inspect the equipment to ensure components are operationally intact, including reinstalling guards and safety devices.
c. Repair or replace defective guards before re-energizing.
d. If LOTO was employed, remove each lockout device using the correct removal sequence. Each lock is removed by the qualified person that applied it, or under their direct supervision.
e. Visually check the area before restoring energy to ensure that everyone is physically clear of the equipment.
f. Notify any affected persons that equipment has been restored to its operational state.

X. Extension Cords and Power Strips

a. Prior to use, extension cords and power strips must be visually inspected for external defects (such as loose parts, deformed and missing pins, or damage to outer jacket or insulation) and for evidence of possible internal damage (such as pinched or crushed outer jacket).
b. Any equipment that is found to have a defect shall be immediately removed from service and appropriately tagged. If equipment has a ground pin, it must not be removed and the equipment should be repaired or replaced before use.
c. Extension cords and power strips must be UL-listed, or approved by another NRTL, and used in accordance with manufacturer guidelines. Laboratory, machining, and other industrial equipment cannot be powered by extension cord or power strip unless they are specifically rated for use.
d. Extension cords and power strips must be plugged into an electrical outlet and may not be plugged into another extension cord or power strip. This practice is commonly referred to as “daisy-chaining” or interconnecting and is not permitted.
e. Extension cords may never be used in place of permanent wiring and may only be used for a temporary period of up to 90 days.

f. The following work practices shall be followed when using extension cords:
    i. Extension cords shall never be used to lift or hoist other objects or tools.
    ii. Do not run extension cords through windows or doorways, holes in floors, ceilings, or walls, or other openings.
    iii. When temporary cords are used, they should be located so as to not cause a tripping hazard. If they must be in a pathway or other work area, they should be covered to mitigate the trip hazard.
    iv. Cords should be appropriately rated for the work performed and the environment they are used in (ex. outdoor use requires cords rated for outdoor use).
    v. Never plug or unplug an extension cord or power strip while standing in water or with wet hands.

XI. Training Requirements

a. Qualified Persons shall be trained in accordance with the definition of "Qualified Person" as defined in this program.
b. All persons working within the Arc Flash Protection Boundary must be trained to the level consistent with their planned work.

XII. Recordkeeping

a. Each department is responsible for verifying that their staff's training is current and documented. OHS maintains general safety training records and are stored on the OHS learning management system.
b. The following are considered an acceptable means for making work procedures accessible:
    i. Electronic means;
    ii. Posting procedures on the equipment; or
    iii. Providing a binder in the mechanical room or working space.

XIII. References

a. NFPA 70E - Standard for Electrical Safety in the Workplace
b. 29 CFR 1910.137 - Electrical Protective Equipment
c. 29 CFR 1910 Subpart S - Electrical
d. Virginia Tech - Electrical Safety Program
e. UC Berkeley - Electrical Safety Program

XIV. Appendices

a. Appendix A - NFPA 70E-2024 Table 130.4(E)(a) - Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Part for Alternating-Current Systems
b. Appendix B - NFPA 70E-2024 Table 130.4(E)(b) - Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Part for Direct-Current Systems
c. Appendix C - NFPA 70E-2024 Table 130.5(C) - Risk Assessment for an Arc Flash event (Table Method)
d. Appendix D - NFPA 70E-2024 Table 130.7(C)(15)(a) - Equipment lists and associated arc flash PPE categories for alternating current
e. Appendix E - NFPA 70E-2024 Table 130.7(C)(15)(b) - Equipment lists and associated arc flash PPE categories for direct current
f. Appendix F - NFPA 70E-2024 Table 130.7(C)(15)(c) - Personal Protective Equipment arc flash category performance requirements
g. Appendix G - Energized Work Permit

Appendix A: **NFPA 70E: Table 130.4(E)(a) Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Alternating-Current Systems**			
	Limited Approach Boundary	**Limited Approach Boundary**	
Nominal System Voltage Range, Phase to Phase	**Exposed Movable Conductor**	**Exposed Fixed Circuit Part**	**Restricted Approach Boundary; Includes Inadvertent Movement Adder Less than 50 V**
Less than 50 V	Not specified	Not specified	Not specified
50 V-150 V	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact
151 V-750 V	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.31 m (1 ft 0 in.)
751 V-5 kV	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.63 m (2 ft 1 in.)
5.1 kV-15 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.65 m (2 ft 2 in.)
15.1 kV-36 kV	3.1 m (10 ft 0 in.)	1.8 m (6 ft 0 in.)	0.77 m (2 ft 7 in.)
36.1 kV-46 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.84 m (2 ft 10 in.)
46.1 kV-72.5 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 4 in.)
72.6 kV-121 kV	3.3 m (10 ft 8 in.)	2.5 m (8 ft 0 in.)	1.2 m (3 ft 9 in.)
121.1 kV-145 kV	3.4 m (11 ft 0 in.)	3.1 m (10 ft 0 in.)	1.3 m (4 ft 4 in.)
145.1 kV-169 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.5 m (4 ft 10 in.)
169.1 kV-242 kV	4.0 m (13 ft 0 in.)	4.0 m (13 ft 0 in.)	2.1 m (6 ft 10 in.)
242.1 kV-362 kV	4.7 m (15 ft 4 in.)	4.7 m (15 ft 4 in.)	3.5 m (11 ft 2 in.)
362.1 kV-420 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	4.3 m (14 ft 0 in.)
420.1 kV-550 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	5.1 m (16 ft 6 in.)
550.1 kV-800 kV	7.2 m (23 ft 9 in.)	7.2 m (23 ft 9 in.)	6.9 m (22 ft 7 in.)

Appendix B: NFPA 70E: Table 130.4(E)(b) Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Direct-Current Voltage Systems			
	Limited Approach Boundary	**Limited Approach Boundary**	
Nominal System Voltage Range, Phase to Phase	**Exposed Movable Conductor**	**Exposed Fixed Circuit Part**	**Restricted Approach Boundary; Includes Inadvertent Movement Adder Less than 50 V Not specified Not specified Not specified**
Less than 50 V	Not specified	Not specified	Not specified
50 V-300 V	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact
301 V - 1 kV	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)
1.1 kV - 5 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.5 m (1 ft 5 in.)
5.1 kV - 15 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.7 m (2 ft 2 in.)
15.1 kV - 45 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.8 m (2 ft 9 in.)
45.1 kV - 75 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)
75.1 kV - 150 kV	3.3 m (10 ft 8 in.)	3.1 m (10 ft 0 in.)	1.2 m (3 ft 10 in.)
150.1 kV - 250 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.6 m (5 ft 3 in.)
250.1 kV - 500 kV	6.0 m (20 ft 0 in.)	6.0 m (20 ft 0 in.)	3.5 m (11 ft 6 in.)
500.1 kV - 800 kV	8.0 m (26 ft 0 in.)	8.0 m (26 ft 0 in.)	5.0 m (16 ft 5 in.)

Appendix C NFPA 70E: Table 130.5(C) Estimate of the Likelihood of Occurrence of an Arc Flash Incident for AC and DC Systems		
Task	**Equipment Condition**	**Likelihood of Occurrence***
Reading a panel meter while operating a meter switch.	Any	No
Performing infrared thermography and other non-contact inspections outside the restricted approach boundary. This activity does not include opening of doors or covers.	Any	No
Working on control circuits with exposed energized electrical conductors and circuit parts, nominal 125 volts ac or dc, or below without any other exposed energized equipment over nominal 125 volts ac or dc, including opening of hinged covers to gain access.	Any	No
Examination of insulated cable with no manipulation of cable.	Any	No
For dc systems, maintenance on a single cell of a battery system or multi-cell units in an open rack.	Any	No
For ac systems, work on energized electrical conductors and circuit parts, including voltage testing.	Any	Yes
Operation of a CB or switch the first time after installation or completion of maintenance in the equipment.	Any	Yes
For dc systems, working on energized electrical conductors and circuit parts of series-connected battery cells, including voltage testing.	Any	Yes
Removal or installation of CBs or switches.	Any	Yes
Opening hinged door(s) or cover(s) or removal of bolted covers (to expose bare, energized electrical conductors and circuit parts). For dc systems, this includes bolted covers, such as battery terminal covers.	Any	Yes
Application of temporary protective grounding equipment, after voltage test.	Any	Yes
Working on control circuits with exposed energized electrical conductors and circuit parts, greater than 120 volts.	Any	Yes
Insertion or removal of individual starter buckets from motor control center (MCC).	Any	Yes
Insertion or removal (racking) of circuit breakers (CBs) or starters from cubicles, doors open or closed.	Any	Yes
Insertion or removal of plug-in devices into or from busways.	Any	Yes

Examination of insulated cable with manipulation of cable.	Any	Yes
Working on exposed energized electrical conductors and circuit parts of equipment directly supplied by a panelboard or motor control center.	Any	Yes
Insertion or removal of revenue meters (kW-hour, at primary voltage and current).	Any	Yes
Insertion or removal of battery conductive intercell connector covers.	Any	Yes
For dc systems, working on exposed energized electrical conductors and circuit parts of utilization equipment directly supplied by a dc source.	Any	Yes
Opening voltage transformer or control power transformer compartments.	Any	Yes
Operation of outdoor disconnect switch (hookstick operated) at 1 kV through 15 kV.	Any	Yes
Operation of outdoor disconnect switch (gang-operated, from grade) at 1 kV through 15 kV.	Any	Yes
Operation of a CB, switch, contactor, or starter.	Normal	No
Voltage testing on individual battery cells or individual multi-cell units.	Abnormal	No
Removal or installation of covers for equipment such as wireways, junction boxes, and cable trays that do not expose bare, energized electrical conductors and circuit parts.	Abnormal	No
Opening a panelboard hinged door or cover to access dead front overcurrent devices.	Abnormal	No
Removal of battery nonconductive intercell connector covers.	Abnormal	No
Maintenance and testing on individual battery cells or individual multi-cell units in an open rack.	Abnormal	Yes
Insertion or removal of individual cells or multi-cell units of a battery system in an open rack.	Abnormal	Yes
Arc-resistant equipment with the DOORS CLOSED and SECURED, and where the available fault current and fault clearing time does not exceed that of the arc-resistant rating of the equipment in one of the following conditions:	Abnormal	Yes
1) Insertion or removal of individual starter buckets		
2) Insertion or removal (racking) of CBs from cubicles		
3) Insertion or removal (racking) of ground and test device		
4) Insertion or removal (racking) of voltage transformers on or off the bus		

Equipment condition is considered to be “normal” if all of the following circumstances apply:		
● The equipment is properly installed in accordance with the manufacturer’s recommendations and applicable industry codes and standards.		
● The equipment is properly maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards.		
● The equipment is used in accordance with instructions included in the listing and labeling and in accordance with manufacturer’s instructions.		
● Equipment doors are closed and secured.		
● Equipment covers are in place and secured.		
*As defined in this standard, the two components of risk are the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a hazard. Risk assessment is an overall process that involves estimating both the likelihood of occurrence and severity to determine if additional protective measures are required. The estimate of the likelihood of occurrence contained in this table does not cover every possible condition or situation, nor does it address severity of injury or damage to health. Where this table identifies “No” as an estimate of likelihood of occurrence, it means that an arc flash incident is not likely to occur. Where this table identifies “Yes” as an estimate of likelihood of occurrence, it means that additional protective measures are required to be selected and implemented according to the hierarchy of risk control identified in NFPA 70E 110.3(H).		

Appendix D: NFPA 70E: Table 130.7(C)(15)(a) Arc-Flash PPE Categories for Alternating Current (ac) Systems			
Equipment	**Parameters**	**Arc Flash PPE Category**	**Arc-Flash Boundary**
Panelboards or other equipment rated 240 volts and below	Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in)	1	485 mm / 19 inch
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in)	2	900 mm / 3 ft
600-volt class motor control centers (MCCs)	Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in)	2	1.5 m / 5 ft
600-volt class motor control centers (MCCs)	Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in)	4	4.3 m / 14 ft
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	Maximum of 35 kA available fault current; maximum of 0.50 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18in)	4	6 m / 20 ft
Other 600-volt class (277 volts through 600 volts, nominal) equipment	Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in)	2	1.5 m / 5 ft
NEMA E2 (fused contractor) motor starters, 2.3 kV through 7.2 kV	Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 610 mm (36 in)	4	12 m / 40 ft
Metal-clad switchgear, 1 kV through 15 kV.	Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 36 in.	4	12 m / 40 ft
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV	Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 36 in.	4	12 m / 40 ft
Other equipment 1 kV through 15 kV.	Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 36 in.	4	12 m / 40 ft

Arc-resistant equipment up to 600-volt class	DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc resistant rating of the equipment	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV.	DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc resistant rating of the equipment	N/A	N/A

Appendix E: NFPA 70E: Table 130.7(C)(15)(b) Arc-Flash PPE Categories for Direct Current (dc) Systems		
Equipment	**Appendix E:Arc-Flash PPE Category**	**Arc-Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources. Parameters: Greater than 150 V. Maximum arc duration and minimum working distance: 2 sec @ 18 in.		
Available fault current less than 1.5 kA.	2	3 ft
Available fault current greater than or equal to 1.5 kA and less than 3 kA.	2	4 ft
Available fault current greater than or equal to 3 kA and less than 7 kA.	3	6 ft
Available fault current greater than or equal to 7 kA and less than 10 kA.	4	8 ft

Appendix F: NFPA 70E: Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)	
Arc-Flash PPE Category	**PPE**
Cat 1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm2 (16.75 J/cm2)** [a] Arc-rated long-sleeve shirt and pants OR arc-rated coverall Arc-rated face shield[b] OR arc flash suit hood Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f] **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[C] Heavy-duty leather gloves, ar-rated gloves, or rubber insulating gloves with protectors (SR)[d] Leather footwear[e] (AN)
Cat 2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm2 (33.5 J/cm2)** [a] Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f] **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[C] Heavy-duty leather gloves[d] Leather footwear[e]
Cat 3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm2 (104.7 J/cm2)** [a] Arc-rated long-sleeve shirt (AR) Arc-rated pants (AR) Arc-rated coverall (AR) Arc-rated arc flash suit jacket (AR) Arc-rated arc flash suit pants (AR) Arc-rated arc flash suit hood Arc-rated gloves or rubber insulating gloves with protectors (SR)[d] Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f] **Protective Equipment** Hard hat Safety glasses or safety goggles (SR)

	Hearing protection (ear canal inserts)[C] Leather footwear[e]
Cat 4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm2 (167.5 J/cm2)** [a] Arc-rated long-sleeve shirt (AR) Arc-rated pants (AR) Arc-rated coverall (AR) Arc-rated arc flash suit jacket (AR) Arc-rated arc flash suit pants (AR) Arc-rated arc flash suit hood Arc-rated gloves or rubber insulating gloves with protectors (SR)[d] Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f] **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[C] Leather footwear[e]
Notes	AN: As needed (optional). AR: As required. SR: Selection required. [a]*Arc rating* is defined in Article 100. [b]Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn. [c]Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood. [d]Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection. [e]Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category. [f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Appendix G - Energized Electrical Work Permit

I. Work Request (To be completed by the **person requesting the review.)**			
Work site location: (building & room number)		Work order/project no.:	
Planned **start** date/time:		Planned **end** date/time:	
Description of the work to be performed:			
Equipment requested to be shut down: (specify how long)	☐Until work is complete	☐Temporarily, while barriers are being placed	
Requested by:	Signature:	Title:	Date:

II. Hazard Analysis (To be completed by the **electrically qualified persons doing the work**.)					
Shock Analysis/Approach Boundaries: Limited approach boundary- Restricted approach boundary- Prohibited approach boundary-	 _____ft _____in _____ft _____in ☐Work will be conducted within this boundary. _____ft _____in ☐Work will be conducted within this boundary.				
Results of the flash hazard analysis -	☐The flash protection boundary is **4 ft 0 in** for systems that are 600 volts or less based on the product of clearing times of 6 cycles (0.1 second) and the available bolted fault current of 50 kA or any combination not exceeding 300 kA cycles (500 ampere seconds). ☐Calculation results: _____ft _____in				
Hazard/risk category for the task: ATPV rating (in cal/cm^2) for FR clothing:	■ 0 ☐N/A (Cat 0)	☐1 ☐4 (Cat 1)	☐2 ☐8 (Cat 2)	☐3 ☐25 (Cat 3)	☐4 ☐40 (Cat 4)
☐Voltage-rated tools ☐Voltage-rated gloves ☐Safety glasses ☐Hearing protection ☐Leather gloves ☐Leather work shoes ☐Hard hat ☐Hard hat FR liner (ATPV)	☐Short-sleeve shirt (nat fiber) ☐Long-sleeve shirt (nat fiber) ☐Long pants (natural fiber) ☐Long-sleeve FR shirt (ATPV) ☐Long FR pants (ATPV) ☐FR coveralls (ATPV) ☐FR jacket/rainwear (ATPV)	☐Multi-layer FR flash suit jacket (ATPV) ☐Multi-layer FR flash suit pants (ATPV) ☐Arc-rated face shield (ATPV) ☐Flash suit hood (ATPV)			
Means employed to restrict the access of unqualified persons from the work area:	☐Signs/tags ☐Barricades ☐Attendants				
Has a documented job briefing with detailed procedures been conducted?	■Yes, see attached ☐No				
Do you agree that the work described above can be done safely?	Electrically Qualified Person(s)	Date			
Justification for the live work request:	☐Shut down creates an increased/additional hazard (specify): ______________________ ☐Shut down is infeasible due to design or operational limitations (specify): ______________________				
The next available date for shutdown is:					
Request for energized electrical work:	Electrical qualified person:	Date:			

III. Proposed Energized Electrical Work Review (To be completed by **Departmental Management**.)		
Proposed energized electrical work has been reviewed by:	Supervisor:	Date:
	Safety Representative:	Date:
	Departmental Management:	Date: