Management System: Worker Safety and Health

Subject Area: Electrical Safety

VIEW/PRINT ALL (No Exhibits and Forms)

Effective Date: **Feb 29, 2016** (Rev 9.0) Periodic Review Due: **Feb 29, 2020**	Subject Matter Expert: Richard Biscardi	Management System Executive: Ed Nowak	Management System Steward: Gail Mattson

Introduction

The Electrical Safety Subject Area has been developed to promote an electrically safe workplace free from electrical hazards and to provide directions for the implementation of electrical requirements in compliance with 10 CFR 851 DOE Worker Safety and Health Program. This subject area describes the procedures to be used by employees of Brookhaven National Laboratory (BNL) and BNL contractors; employees of a subcontractor; individuals who visit to perform work for or in conjunction with BNL, and use BNL facilities.

The hierarchy of controls of the Electrical Safety Program are:

- Elimination or substitution of the hazard;
- Engineering controls;
- Administrative controls - lockout/tagout or unplug the equipment;
- Energized Work Permits with appropriate PPE.

It is Brookhaven National Laboratory policy that no one works on or near energized components above 50 volts, unless Qualified, Authorized and with an electrical work permit. This permit ensures that the energized work is necessary, the procedures and PPE are in place to protect the worker, and the training is current to perform the work. Live parts that operate at less than 50 volts to ground need not be deenergized if there will be no increased exposure to electrical burns or to explosion due to electric arcs. The hierarchy requires consideration for elimination/substitution of the hazard, engineering controls and Lockout/Tagout or unplugging of equipment before deciding to work energized. For information on Lockout/Tagout see the Lockout/Tagout (LOTO) for Installation, Demolition, or Service and Maintenance Subject Area.

Contents

Section	Overview of Content (see section for full process)

1. Implementing Electrical Safety	• Conduct periodic walkthroughs or field checks. • Follow electrical safety practices. • Design equipment and facilities incorporating safety for operation and maintenance. • Perform periodic inspections of electrical work. • Do not operate vehicles or mechanical equipment near overhead lines.
2. Operating Electrical Equipment	• Ensure personnel operating the equipment are trained. • Wear required PPE as specified for Hazard/Risk Category rating or follow exhibit if no category rating is posted. • Operators of Category 4 equipment must follow two-person rule. • Operators of circuit breaker, fused switches, and MCC starters or meters must wear PPE.
3. Energized Work	• Plan all electrical work using the electrical work permit. • Evaluate which type of electrical work permit is required. • Use Energized Electrical Work Permit for working on or near energized electrical conductors or circuit parts. • Issue Electrical Work Permit and list all authorized personnel. • Evaluate the proper energized electrical work permit. • Provide feedback following all electrical work.

4. Personal Protective Equipment (PPE) for Electrical Work	• Protect all personnel from electrical hazards by applying both of the following subprocesses: o PPE for Shock Hazard; o PPE for Arc-flash Hazard.
5. Design and Installation of Electrical Equipment	• Ensure electrical equipment includes energy isolating devices. • Ensure electrical equipment and installations conform to applicable Codes and Standards. • Document all electrical additions and changes on system or facility drawings. • Ensure arc-flash calculations are performed per NFPA 70E. • Ensure sufficient access and working space is provided. • When required, ensure ground detection is installed.
6. Implementing the Authority Having Jurisdiction (AHJ) Program	• Implement the Authority Having Jurisdiction (AHJ) Program by applying one of the following subprocesses: o Electrical Equipment Inspection; o Electrical Materials and Equipment Installation Inspection.

Definitions

Exhibits

Approved Equivalent Electrical Training
Authority Having Jurisdiction - Electrical Inspection Program
BNL Electrical Inspection Guidelines
Certification of Personal Protective Equipment (PPE) for Electrical Energized Work
Certification of Personal Protective Equipment (PPE) for Operating Electrical Equipment
Design Guide
Electrical Equipment Labels
Electrical Panel/Disconnect Labeling Program

Electrical Safe Work Practices
Reputable Manufacturer Requirements
Review and Approval of Electrical Equipment and Installations
Selection and Use of Rubber Gloves and Insulating Blankets
Task-based Electrical Safety Training Requirements
Topics to be Covered During Departmental Job-Specific Training
Work Distance Table (Control Zones)

Forms

BNL Checklist for Review and Approval of Electrical Equipment
Electrical Work Permits with Instructions

Training Requirements and Reporting Obligations

This subject area contains the following training requirements (see the BNL Training and Qualifications website):

- Current, documented safety training is required for all electrical work on or near energized conductors and consists of the following: Electrical Safety 1 (TQ-ELECSAF1); Lockout/Tagout Authorized Worker (HP-OSH-151B-W); and Cardiopulmonary Resuscitation (Adult CPR/AED). Departments/Divisions must maintain a list of these authorized workers.
- For approved equivalent training see the exhibit Approved Equivalent Electrical Training. For other task-based training requirements, see the exhibit Task-Based Training Requirements.
- Organizational-specific and on-the-job training must be conducted at least annually by each Department/Division for all personnel that the organization wishes to define as Authorized Workers.
- Organizational-specific training includes
    - Review of required personal protective equipment and tools appropriate for equipment voltage and current range;
    - Review of the Energized Electrical Work Permit;
    - Emergency actions that may be required.

This subject area does not contain reporting obligations.

External/Internal Requirements

Requirement Number	Requirement Title
10 CFR 830, Subpart A	Energy, Nuclear Safety Management, Quality Assurance Requirements

10 CFR 851	Worker Safety and Health Program
29 CFR 1910	Labor/Occupational Safety and Health Standards
29 CFR 1926	Labor/Safety and Health Regulations for Construction
ANSI Z 87.1; ANSI/ISEA Z 87.1	Occupational and Educational Personal Eye and Face Protection Devices [1968:IBR 29 CFR 1926.102; 1968, 1989 & 2003: IBR 1910.113, 133, 252]
BSA Contract No. DE-SC0012704 - Clause C.4	Statement Of Work
BSA Contract No. DE-SC0012704 - Clause H.27 (ACT)	Non-Federal Agreements for Commercializing Technology (Pilot) (ACT)
BSA Contract No. DE-SC0012704 - Clause I.131 (DEAR 970.5223-1)	INTEGRATION OF ENVIRONMENT, SAFETY, AND HEALTH INTO WORK PLANNING AND EXECUTION (DEC 2000)
DOE-STD-1066-99	Fire Protection Design Criteria
NEMA EW 1 (1962)	Requirements for Electric Arc Welding Apparatus [IBRI 29 CFR 1910.254]
NFPA 497	Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
NFPA 70	National Electrical Code

NFPA 70B	Electrical Equipment Maintenance
NFPA 70E (2009)	Electrical Safety Requirements for Employee Workplaces
NFPA 73	Standard for Electrical Inspections for Existing Dwellings
NFPA 79	Electrical Standard for Industrial Machinery
NFPA 790	Standard for Competency of Third-Party Field Evaluation Bodies
NFPA 791	Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation
NFPA Codes	National Fire Protection Association Codes
O 414.1D Admin Chg 1 (May 8, 2013)	Quality Assurance

References

10 CFR 851, DOE Worker Safety and Health Program

BNL Training and Qualifications website

DOE Electrical Safety Handbook, DOE-HDBK-1092-2004

Electrical Equipment Inspection Management System (EEIMS) (*Limited Access), Electrical Equipment Inspection Program, ESH Guide: Electrical Safety, Safety and Health Services website

Engineering Design Subject Area

Environment, Safety, Health and Quality (Tier I) Inspections Subject Area

Fire Safety Subject Area

Facility Hazard Analysis and Risk Assessment Subject Area

Integrated Safety Management Program Description

Laser Safety Subject Area

List of LESC Approved Inspectors, Laboratory Electrical Safety Committee website

Lockout/Tagout (LOTO) for Installation, Demolition, or Service and Maintenance Subject Area

Static Magnetic Fields Subject Area

Noise and Hearing Conservation Subject Area

Non-Ionizing Radiation Safety Subject Area

Occurrence Reporting and Processing System (ORPS) Subject Area

Organizations Currently Recognized by OSHA as NRTLs Web page

Radiological Control Manual

Radiation-Generating Devices Subject Area

Reputable Manufacturers Models, ESH Guide: Electrical Safety, Safety and Health Services website

Safety and Health Services Division website

Work Planning and Control for Experiments and Operations Subject Area

*Access limited - contact EEIMS Admin for assistance

Standards of Performance

Managers shall manage work to control risks and hazards, detect wrongdoing, ensure customer satisfaction, and provide a benefit to BNL.

Managers shall perform "field walkthroughs" as a standard practice for assessing performance and identifying areas for improvement.

All staff and guests shall share information based on experience (e.g., lessons learned) to promote continuous improvement in business and work practices.

All staff and users shall ensure that they are trained and qualified to carry out their assigned responsibilities, and shall inform their supervisor if they are assigned to perform work for which they are not properly trained or qualified.

All staff and users shall identify, evaluate, and control hazards in order to ensure that work is conducted safely and in a manner that protects the environment and the public.

All staff and guests shall promptly report accidents, injuries, ES&H deficiencies, emergencies, and off-normal events in accordance with procedures.

Management System: Worker Safety and Health		
Subject Area: Electrical Safety		
1. Implementing Electrical Safety		
Effective Date: **Feb 29, 2016**	Subject Matter Expert: Richard Biscardi	Management System Executive: Ed Nowak

Applicability

This information applies to any person at BNL, or in places under BNL jurisdiction.

Required Procedure

This section, used in conjunction with 29 CFR 1910 OSHA Subpart S, NFPA 70 National Electrical Code, and NFPA 70E Standard for Electrical Safety in the Workplace, addresses those electrical safety requirements for the practical safeguarding of employees in the workplace.

Step 1	Line Management must conduct periodic walkthroughs or field checks of electrical work to • Ensure workers performing lockout/tagout (LOTO) or working on or near live parts are Qualified and Authorized; • Verify procedure compliance; • Verify personal protective equipment (PPE) use.

Step 2	Staff must follow the electrical safety practices below:
	
	• Make sure hands are dry when plugging/unplugging energized equipment including extension cords;
	• Do not use any electrical device that is defective or shows evidence of damage;
	• Inspect portable cord and plug equipment and cord sets (extension cords) for
	  o External defects (loose parts, deformed or missing pins (especially ground pin), or damage to outer jacket or insulation;
	  o Evidence of internal damage (such as pinched or crushed outer jacket);
	  o Tears or dry rot in outer jacket.
	• Insert plugs fully into receptacle. Do not touch the blades of the plug while inserting and do not force, locking connectors must be properly secured after connection;
	• When a plug is to be connected to a receptacle (including cord sets), check contacts to ensure they are of correct mating configuration for voltage and current;
	• Adapters which interrupt continuity of equipment grounding connections may not be used;
	• Only Qualified Workers may perform testing work on electric circuits or equipment that may expose them to shock or arc-flash hazard;
	• Do not reset a circuit breaker that has tripped unless it has been determined that the equipment and circuit can be safely energized (i.e., cause of tripping is known), and then only if trained and approved by the Department/Division. Otherwise contact the F&O Facility Project Manager (FPM);
	• Do not use extension cords in place of permanent building wiring, they are for temporary use only;
	• Relocatable Power Taps (e.g., six-outlet power strips) cannot be used with extension cords or daisy-chained together;
	• Do not remove covers from electrical equipment that could expose energized uninsulated parts, unless authorized by Department/Division and with an energized work permit (see the exhibit Electrical Work Permits with Instructions);
	• Keep working space around electrical equipment clear to provide for safe operation and ensure that nothing is stored in this working space (see the section Design and Installation of Electrical Equipment). Marking the floor to indicate the following dimensions is encouraged:
	  o 3 feet for 150 volts to ground or less;

	o 3 feet 6 inches for 151 volts to 600 volts; o width of 30 inches or width of equipment, whichever is greater. • Do not use power cords to raise or lower equipment; • Report to F&O Facility Project Manager any hazards or damage of equipment or facilities that exposes electrical wiring; • If flammable materials are used only occasionally (i.e., flammable gases, vapors, or liquids; combustible dusts; and ignitable fibers or filings), do not use electrical equipment capable of igniting them (i.e., non-explosion proof motors); • Do not defeat or bypass any interlocks, unless approved by Department/Division; • Cords and extension cords must not be fastened with staples or hung in such a way to damage outer jacket; • Test GFCI receptacles prior to use, or if used continuously, follow manufacturer's requirements; • Report all electrical shocks from energized equipment or system to the supervisor and go to the clinic for an evaluation. Minor static shocks are not considered electrical shock.
Step 3	Prior to performing work, the electrical worker is responsible for • Inspection/evaluation of the work site; • Assembling proper tools for the job; • Using procedures as tools to assist in planning the job; • De-energizing the equipment and verifying a zero energy condition; • Identifying and minimizing hazards; • Using PPE consistent with the shock and arc-flash hazard (this is the last chance to avoid injury).

Step 4	The electrical worker is responsible for • Never leaving the work site in an unsafe condition; • Ensuring the work site is compliant with National Electrical Code (NEC) when the job is complete; • Ensuring the work site is compliant with NEC and NFPA 70E throughout the duration of the work.
Step 5	Electrical engineers and designers must purchase equipment, and design equipment and facilities to conform to current Codes and Standards. They are encouraged to incorporate the latest technologies, which enhance safety during operation and maintenance (e.g., specify arc-resistant switchgear). (See the section Design and Installation of Electrical Equipment). **Note:** Facilities in compliance with the National Electrical Code at the time of construction (Code of Record) are acceptable. A subsequent major renovation requires compliance with current codes and standards.
Step 6	Line management in organizations responsible for ungrounded electrical systems must have written procedures documenting • Monitoring ground detectors either remotely or by periodic inspections not to exceed monthly. • The response if a ground is detected, including: o The required notifications (both who and time frame) plus affected users and employees; o Management/designee notification who determine actions to be taken which may include: 1. shutdown; 2. limiting conditions of operations; 3. changes in PPE to perform operations or work; 4. additional inspections, and testing required for continued operations.
Step 7	Safety Engineers and ES&H Coordinators must perform periodic inspections of electrical work in their facilities. During TIER I inspections, use the checklist (see the Environment, Safety, Health and Quality (Tier I) Inspections Subject Area) and the safety practices in step 2 above, as an aid for inspecting equipment.

Step 8	All personnel working near overhead lines must not approach, nor bring objects closer than 10 feet (see the exhibit Work Distance Table [Control Zones]). • Do not operate vehicles or mechanical equipment near overhead lines closer than 10 feet. However, clearances are permitted to be reduced if: o The vehicle is in transit with its structure lowered, the allowed distance by 4 feet. o Aerial lifts insulated for the voltage and operated by an authorized worker are permitted to approach up to the Restricted Approach Boundary. • Employees standing on the ground must not contact the vehicle or any attachments, unless o The employee is using PPE; o The equipment is located so that no uninsulated part is closer than the requirement above.

References

Environment, Safety, Health and Quality (Tier I) Inspections Subject Area

Organizations Currently Recognized by OSHA as NRTLs Web page

Management System: Worker Safety and Health

Subject Area: Electrical Safety

2. Operating Electrical Equipment

Effective Date: **Aug 1, 2016**	Subject Matter Expert: **Richard Biscardi**	Management System Executive: **Ed Nowak**

Applicability

This information applies to any person at BNL, or in places under BNL jurisdiction, who operates circuit breakers (CB), fused switches, motor control center (MCC) starters, and meter switches with enclosure covers on of 50 volts or greater.

Note: These requirements do not apply to 120-volt utilization equipment switches (such as office light switches).

Required Procedure

Equipment with a calculated Hazard Risk Category of Dangerous (greater than 4 [40 cal/cm^2]) or with a DANGER – DO NOT OPERATE label (see the exhibit **Electrical Equipment Labels**) are not to be operated while energized without formal work planning through an approved work planning process and approval of the Authority Having Jurisdiction.

Racking a circuit breaker or inserting/removing an MCC starter bucket when the main bus remains energized requires an energized work permit (see the exhibit **Electrical Work Permits with Instructions**) and is not allowed if the Hazard/Risk Category is Dangerous.

All electrical work must be planned to reduce hazards and to protect the worker and others.

Step 1	Supervisors must ensure that personnel operating the equipment are trained in Electrical Circuit Breaker and Switch Operation Safety (TQ-ELECTBSOP) or Electrical Safety I (TQ-ELECSAF1). (See the **BNL Training and Development** website).
Step 2	Personnel who operate equipment with no Hazard Risk Category rating posted (otherwise go to step 3) must wear PPE as listed in the **Certification of Personal Protective Equipment (PPE) For Operating Electrical Equipment**.
Step 3	Operators of electrical equipment posted as Hazard/Risk Category rating 4 must follow the two-person rule (see the **Definitions** section for two-person rule).
Step 4	Personnel who operate circuit breakers (CB), fused switches, and MCC starters or MCC meter switches with enclosure covers on/closed, may wear personal protective equipment (PPE) of one less than the Hazard Risk Category posted (minus one rule) on the equipment, if the conditions below are met. Minus One Rule - The required PPE may be reduced as per the table below at the discretion of the work planning team based on a risk assessment. All the following conditions must be satisfied: 1. An arc flash calculation has been done and posted on the switch. 2. It is less than a Hazard/Risk Category 4. 3. Its covers are fully closed and all fasteners are present and properly installed. 4. The equipment is properly installed. 5. The equipment is properly maintained. 6. There is no evidence of impeding failure.

Posted Hazard/Risk Category	Hazard/Risk Category with Covers Closed
0+	Insignificant Arc-Flash Hazard (No Category) - Eye protection and ear protection (canal inserts) still required
1	0+
2, 2*	1
3	2
4	4 (Category not reduced)
Dangerous	Dangerous (not allowed to operate energized)

Guidelines

When possible, personnel operating a circuit breaker or switch should

- Not stand in front of the equipment;
- Turn their face away from the equipment, unless wearing a faceshield.

References

BNL Training and Development website

| SBMS Home Page | Top of Subject Area | Instructions | Changes |
Questions/Comments Disclaimer

Management System: Worker Safety and Health		
Subject Area: Electrical Safety		
3. Energized Work		
Effective Date: **Feb 29, 2016**	Subject Matter Expert: Richard Biscardi	Management System Executive: Ed Nowak

Applicability

This information applies to any person at BNL, or in places under BNL jurisdiction, who enter or plan work within a Limited Approach Boundary or an Arc Flash Boundary when there are exposed electrical hazards from electrical conductors or circuit parts that are or can become energized. This does not apply to 50 volts or less if there is no increased exposure to electric burns or explosion due to an arc flash.

Required Procedure

Energized parts to which personnel might be exposed must be put into an electrically safe work condition and lockout/tagout (LOTO) unless:

- De-energizing the equipment introduces additional or increased hazards;
- The component is an integral part of a continuous process and would require that the entire process be shut down in order to work on the piece of equipment; or
- Shutdown is infeasible due to equipment design or operational limitations, including the need to perform diagnostics and testing (e.g., start-up or troubleshooting) of electric circuits that can only be performed with the circuit energized.

Note: LOTO is not required for cord and plug equipment when the worker has exclusive control of the plug.

All electrical work must be planned to reduce hazards and to protect the worker and others.

Equipment with a Hazard Risk Category of Dangerous (greater than 4 [40 cal/cm2]), or with a "DANGER - DO NOT OPERATE" or "DANGER – DO NOT REMOVE COVER WHILE ENERGIZED" label (see the exhibit Electrical Equipment Labels) cannot be operated, serviced, maintained, or other work performed while energized, including operation of a circuit breaker or switch without formal work planning through an approved work planning process and approval of the Authority Having Jurisdiction.

Anyone working on or near energized electrical conductors or circuit parts greater than 50 volts must have the following:

1. Training – Electrical Safety 1 (TQ-ELECSAF1), CPR (TQ-ADULTCPR), LOTO Authorized (HP-OSH-151B-W) [or approved equivalent training, see the exhibit Approved Equivalent Electrical Training. For other task based training requirements see the exhibit Task-Based Training Requirements--add link];
2. Authorization – By the Department/Division they work for, in the case of a non-BNL employee it must be the sponsoring Department/Division;
3. Permits – A BNL energized work permit or approved equivalent procedure. See the exhibit Electrical Work Permits with Instructions.

Step 1	The Supervisor/designee plans all energized electrical work using the electrical work permit (refer to the exhibit Electrical Work Permits with Instructions). The planning may be as simple as a discussion among the electrical workers reviewing the job, or as complex as a specific procedure with multiple engineering reviews. Planning must include: • Information about the equipment and the installation; • Voltage levels, power availability which might be delivered into an arc flash; • The Flash Hazard/Risk Category for arc-flash rating of the PPE (cal/cm^2); • Any additional requirements necessary to perform the work, including, if required, additional training and non-electrical Work Permit for non-electrical hazards (see the Work Permit Form in the Work Planning and Control for Experiments and Operations Subject Area); • Applicability of the two-person rule or safety watch (see the Definitions section for two-person rule and safety watch).

Step 2	The supervisor/designee must evaluate which type of electrical work permit is required for the task. There are two types of working on or near electrical work permits: • Testing, Troubleshooting and Voltage Measuring (TTVM) Electrical Work Permit; • Specific Energized Electrical Work Permit. The Testing, Troubleshooting, and Voltage Measuring (TTVM) Electrical Work Permit (see the exhibit Electrical Work Permits with Instructions) is for work performed near or on energized electrical conductors or circuit parts for tasks such as testing, troubleshooting, voltage measuring, diagnostics, etc., for 600 volts or less. The permit may be issued for reasonable periods of time, not to exceed one year. Use the Energized Electrical Work Permit (see the exhibit Electrical Work Permits with Instructions) for working on or near energized electrical conductors or circuit parts when they cannot be placed in an electrically safe working condition, for racking LVCB or inserting MCC buckets, and for any testing, troubleshooting, and voltage measuring above 600 volts (this can be a standing permit for a specific task not exceeding a year). A meeting must be held for all personnel involved in the work during which all involved must reach consensus on safety concerns. As a further safeguard against unnecessary exposure to electrical hazards, the electrical range above 600 volts must also be approved by an independent reviewer (see the Definitions section). **Note:** An electrical work permit is not required for tasks below 50 volts. **Note:** A detailed switching procedure, which addresses the requirements of the Energized Electrical Work Permit, may be used in lieu of the permit.
Step 3	The Department Chair/Division Manager/designee reviews the permit and ensures that all personnel working under the permit: • Are qualified for the type and energy levels on the permit; • Have signed the permit; • Maintain currency of training as required by this procedure for the length of the permit; • Receive a pre-job briefing and understand the hazards associated with this task by discussing the following: o Limits of the permit, especially limits of only testing with TTVM permit; o PPE for various tasks;

	○ Any job specific or general work practices to be observed. The designee must be a person, either BNL or non-BNL, who understands all the requirements and hazards of working on or near live parts and is responsible for ensuring that personnel working under the permit are knowledgeable about the safety requirements.
Step 4	The Department Chair/Division Manager/designee issues the work permit for BNL and non-BNL employees by signing the permit and ensures that: • A log is kept for auditing purposes. • Periodic walkthroughs or field checks are conducted to verify the following: ○ Workers are qualified; ○ Compliance with procedure or permit; ○ Proper PPE (refer to the Certification of Personal Protective Equipment (PPE) for Operating Electrical Equipment).
Step 5	The person who performs the energized work must do the following: • **Prior to starting work:** ○ Review the work plan/permit and inform those involved with the work and those nearby who could be impacted that work will begin. ○ Establish safety barriers to keep unprotected personnel out of the arc flash control zone (see step 1 in the section PPE for Arc-flash Hazard) and shock hazard control zones (see the exhibit Work Distance Table [Control Zones]). • **While performing the work:** ○ Perform the work in accordance with conditions on the permit and with procedures; ○ Perform any necessary testing. • **After completing the work:** ○ Replace any physical barriers which were removed in order to do the work; ○ Inform those involved and those nearby who could have been impacted that the work has been completed and conditions are safe; ○ Remove the safety barriers and all tools, equipment, and scrap; ○ Provide feedback to confirm that the work was performed by the plan without incident or to improve future work. Follow the Core

		Functions and Guiding Principles of Integrated Safety Management (see the Integrated Safety Management Program Description).

References

Integrated Safety Management Program Description

Work Planning and Control for Experiments and Operations Subject Area

Management System: Worker Safety and Health		
Subject Area: Electrical Safety		
4. Personal Protective Equipment (PPE) for Electrical Work		
Effective Date: **Feb 29, 2016**	Subject Matter Expert: Richard Biscardi	Management System Executive: Ed Nowak

Applicability

This information applies to any person doing work at BNL, or in places under BNL jurisdiction.

Required Procedure

All personnel must be protected from the hazards associated with electricity. For non-qualified personnel they must be protected by enclosures, insulation, barricades and safety signs, or attendants.

Equipment with a Hazard Risk Category of Dangerous (greater than 4 [40 cal/cm2]), or with a "DANGER - DO NOT OPERATE" or "DANGER – DO NOT REMOVE COVER WHILE ENERGIZED" label (see the exhibit Electrical Equipment Labels) cannot be operated, serviced, maintained, or other work performed while energized, including operation of a circuit breaker or switch without formal work planning through an approved work planning process and approval of the Authority Having Jurisdiction.

Qualified personnel must be protected from the two hazards of working with electricity:

- **Shock hazard** - by distance, insulation, barricades, and PPE (rubber gloves, insulated tools, etc.);
- **Arc-flash (blast) hazard** - by distance, barricades, and PPE (fire-resistant clothes, eye protection, face shield, etc.).

Personal Protective Equipment (PPE) for Electrical Safety contains two subsections:

4.1 PPE for Shock Hazard

Step 1	Supervisors must ensure that Qualified Workers are protected from exposure to shock hazard in the three boundaries (see the exhibit Work Distance Table [Control Zone]): • **Limited Approach** - Employees must use insulated tools and/or handling equipment inside the Limited Approach Boundary if tools might make accidental contact to live parts. Unqualified workers may not cross the Limited Approach Boundary unless escorted by a qualified worker. • **Restricted Approach Boundary** - No Qualified Worker can approach or take conductive objects closer to exposed live parts, unless o The person is insulated (refer to the Certification of Personal Protective Equipment (PPE) for Electrical Energized Work) or guarded from the live parts and no uninsulated parts of the body crosses the Prohibited Approach Boundary; o The live part is insulated from the worker and from other conductive objects at a different potential; o The person is insulated from any other conductive object as during live-line bare-hand work. o Under no circumstances may an unqualified person cross the Restricted Approach Boundary. • **Prohibited Approach Boundary** - An approach limit from an energized live part, which is considered the same as making contact with the live part and varies from direct contact to several feet depending on the voltage (the gap is not sufficient to prevent a flashover to a grounded part).
Step 2	Supervisors must ensure that Qualified Workers do not wear conductive articles of clothing (e.g., watchbands, rings, metal-rimmed glasses, necklaces), nor bring metal rulers or other uninsulated tools near energized conductors. Tools must not be covered with electrical tape or otherwise modified to provide insulation. Voltage rated rubber gloves are required for all work on energized parts (refer to the Certification of Personal Protective Equipment (PPE) for Electrical Energized Work). Leather glove protectors are required over rubber gloves, except as follows: • Protector gloves are not required with Class 0 or 00 gloves if high finger dexterity is needed. While the exception is necessary to allow work to be performed on small energized parts, extra care is needed in the visual examination of the glove and in avoiding handling sharp objects. • The other exception to the requirement for protector gloves is when the possibility for damage is low and the gloves are one class higher than

	required for the voltage. Example, if a Class 2 glove is used at 7500 volts or less (the maximum use voltage for Class 1 equipment). This exception does not apply when the possibility of damage is significant.
Step 3	Supervisors must ensure that Qualified Workers use and maintain rubber gloves and insulating blankets per the requirements in the exhibit Selection and Use of Rubber Gloves and Insulating Blankets.

4.2 PPE for Arc-flash Hazard

Step 1

Qualified Workers must not allow unqualified personnel to enter the flash protection boundary (as listed in the following table, unless posted otherwise on the equipment) when equipment is being operated or live parts are exposed.

Hazard/Risk Category	Nominal Flash Protection Boundary (unless posted otherwise)
0	4'
1	5'
2	6'
3	10'
4	16'
Dangerous	Work Planning required to calculate boundary

Note: The calculated arc-flash boundary is the distance within which a person could receive a maximum of a second degree burn if an arc flash were to occur. In most cases the calculated distance will be smaller than listed in the table. The calculated values of distance and Hazard/Risk Category are the minimum required.

Step 2

Prior to operating equipment, the Qualified Worker must warn personnel of the arc-flash hazard. All personnel must wear the proper PPE within the Flash Protection Boundary

- If an arc-flash analysis was performed, based on the minus one rule (see the section Operating Electrical Equipment), the minimum required PPE to

	operate the equipment is one level less than listed on the warning sticker, but as a minimum, safety glasses and ear protection (canal inserts must be worn). • If no analysis is performed, use the PPE in the tables (refer to the Certification of Personal Protective Equipment (PPE) for Operating Electrical Equipment). • Operating equipment is NOT allowed if incident energy exceeds 40 cal/cm^2.
Step 3	Prior to working on or near live parts, the Qualified Worker must warn personnel of the arc-flash hazard. All personnel within the arc-flash boundary must wear the required PPE. • If an arc-flash analysis was performed, the proper PPE is listed on the warning sticker. • If no analysis has been performed use the PPE in the tables (see the exhibit Certification of Personal Protective Equipment (PPE) for Electrical Energized Work). • No working on or near is allowed if incident energy exceeds 40 cal/cm^2.
Step 4	As a minimum, Qualified Workers must wear eye protection while operating or working on equipment which has been identified as having no arc-flash hazard. If using the Minus One Rule, the minimum PPE is eye protection and ear protection (canal inserts). For example, if the warning sticker indicates Hazard/Risk Category 0+, then based on the minus one rule (see the section Operating Electrical Equipment), eye protection and ear protection (canal inserts) must be worn.
Step 5	Personnel who are required to wear long-sleeve shirts must ensure the wrists and neck are buttoned. Outer layer clothing must cover as much exposed area as possible.
Step 6	Supervisors must ensure that personnel inspect flame-resistant apparel before each use. Personnel must not use work clothing or flash suits that are contaminated, or damaged to the extent their protective qualities are impaired. Do not use protective items that become contaminated with grease, oil, or flammable liquids or combustible materials. Do not apply DEET insect repellent (K70766) to Flame Resistant Clothing. Use Permethrin Clothing Spray (K70764) if needed.
Step 7	Personnel must verify that the insulating capability of the following equipment is retained by appropriate tests and visual inspection: • Grounding equipment;

	• Hot sticks; • Rubber gloves, sleeves, and leather protectors; • Voltage test indicators; • Blanket and similar insulating equipment; • Protective barriers; • External circuit breaker rack-out devices; • Portable lighting units; • Safety grounding equipment; • Dielectric footwear; • Protective clothing; • Insulated tools. These tests or inspections must be performed prior to use or, as a minimum, at intervals as required by the manufacturer, but in no case greater three years. Qualified Workers must inspect protective ground cable sets for cuts in the protective sheath and damage to the conductors and check clamps and connector strain relief devices for tightness. These inspections must be made at intervals as required by service conditions, but the interval must not exceed one year. Contact the LESO for requirements for testing safety grounds that have been repaired or modified.

Management System: Worker Safety and Health		
Subject Area: Electrical Safety		
5. Design and Installation of Electrical Equipment		
Effective Date: **Feb 29, 2016**	Subject Matter Expert: Richard Biscardi	Management System Executive: Ed Nowak

Applicability

This information applies to any person at BNL, or in places under BNL jurisdiction, who designs and installs electrical equipment and systems.

Required Procedure

All electrical designs and construction, whether it be for facilities or experiments, must have the safety of workers as the highest priority. When still in the design or development stage, eliminating hazards from the design and substituting devices with lower hazards may be inexpensive and simple to implement. Safety and Code compliance must be paramount at every stage of a project, from the initial concept to the final construction and use. Use this subject area in conjunction with the National Electrical Code NFPA 70 and the Engineering Design Subject Area for all electrical designs and installations.

This subject area is not meant to take the place of knowledge of Codes and Standards. The Guidelines section discusses equipment commonly used in R&D and recommendations for design, construction, and operation.

Equipment and installations undergoing major repair, renovation, or modification must be in compliance with current codes and standards. The design basis must be supported by calculations including available short-circuit current and arc-flash incident energy. Results must be documented in project files and equipment properly labeled (contact the Facilities and Operations Electrical Project Engineer of the Energy and Utilities Division for standards for equipment labels and Hazard/Risk Category Labels).

Step 1	Ensure that the electrical equipment has energy isolating devices (disconnect switches or circuit breakers) that accept a lockout device. A lockout device is not required for cord and plug connected electrical equipment provided that the plug has the ability to be under the exclusive control of the person

	performing any maintenance or service. Each disconnecting means must be legibly marked to indicate its purpose unless located and arranged so the purpose is evident.
Step 2	Ensure that electrical equipment and installations are acceptable to the Authority Having Jurisdiction (AHJ), Laboratory Electrical Safety Officer (LESO), an Electrical Equipment Inspector (EEI), and/or a National Electrical Code Inspector (NECI). Refer to the section Implementing the Authority Having Jurisdiction (AHJ) Program for more detailed information. **Note:** OSHA requires that NRTL-labeled equipment (see Organizations Currently Recognized by OSHA as NRTLs) must be acquired whenever available, even if similar unlabeled equipment can be used. Contact the LESO or an EEI for review of non-NRTL equipment prior to acquisition. **Note:** For installation around flammable liquids and gases, the electrical classification of the equipment must be established. Contact Fire Protection Engineering and see subsection 5.1 When a Fire Hazards Analysis (FHA) is Needed in the Fire Safety Subject Area.
Step 3	Ensure drawings and diagrams are kept up-to-date (see the section Preparing and Revising Specifications and Drawings in the Engineering Design Subject Area). Ensure that panel schedules of all new or re-worked distribution panels are updated and current to maintain good configuration management. Any errors or omissions discovered in existing installations must be brought to the attention of the appropriate supervisor for correction.
Step 4	Ensure that the arc-flash calculations are performed as per NFPA 70E and the equipment is labeled appropriately (contact Facilities and Operations Electrical Project Engineer of the Energy and Utilities Division if assistance is required). For new projects or equipment replacement other than like-in-kind, the short circuit analysis, protective device coordination study, and arc flash analysis must be performed during design phase. Refer to the Electrical Facilities Design Criteria (MPO-100l).
Step 5	Ensure all electrical panels and disconnects are labeled with a unique ID number, device fed from, voltage and amperage rating (if used for lower voltage utilization voltage must be indicated). Refer to the Electrical Panel/Disconnect Labeling Program exhibit.
Step 6	Ensure that sufficient access and working space is provided around all electrical equipment to allow safe operation and maintenance. The width of the working space for 600 volts or less must be 30 inches minimum (measurement may start from either

	side with equipment centered), or the width of the equipment, whichever is greater, and the door must be able to open 90 degrees. For equipment with a nominal voltage to ground of 150 volts or less, the depth must be 3 ft, and for greater than 150 volts, with a grounded surface opposite, 42-inch depth is required. The height of the dedicated working space must extend from the grade to 6½ ft above grade. Only equipment associated with this installation that is located above or below, may extend not more than 6 in. beyond the front of the above equipment. It is recommended the exclusion zone be marked or otherwise noted to protect against other trades or users violating zone boundaries. **Note:** These measurements are illustrated in the NFPA 70 National Electrical Code Handbook, Article 110.26. For other electrical equipment, necessary access and working space requirements must conform to NFPA 70 Article 110.
Step 7	All switchboards, panelboards, distribution boards, and motor control centers are to be located in dedicated spaces and protected from damage.
Step 8	Ensure that ground detection is installed for ungrounded or high resistance alternating-current systems.

Guidelines

Recommendations for Design and Installation of Equipment

Consider contacting the Authority Having Jurisdiction (AHJ) or local Electrical Equipment Inspector (EEI) early in the design for review of the equipment and the installation. This step will be accomplished most effectively through a working relationship with the AHJ or EEI during the design and installation phases.

Guidance for Use of Components

Designers and engineers should review the general guidance for use of electrical and electronic components, as per the DOE Electrical Safety Handbook, and the special hazards associated with the equipment (see the exhibit Design Guide).

- Capacitors and Capacitor Banks;
- Electrical Conductors and Connectors;
- Enclosures for Electrical Equipment;
- Inductors, Electromagnets, and Coils;

- Instrumentation and Control Systems;
- Power Supplies;
- Resistors and Resistor Banks;
- Electrical Switches;
- Storage Batteries and Battery Banks;
- Chemical, Biological, Fire, and Other Hazards Associated with Electrical Equipment
    - Ozone;
    - Hydrogen;
    - Superconducting Devices;
    - Chlorinated Oils;
    - Batteries;
    - Noise;
    - Coolants;
    - Environmental Effects;
    - Fire Hazards;
    - Thermal Sources;
    - Moving Mechanical Devices;
    - Light Sources;
    - Magnetic Fields;
    - Electromagnetic Radiation;
    - Bio-Electric Implants;
    - X-rays;
    - Nuclear Radiation;
    - Stored Energy Equipment.

References

DOE Electrical Safety Handbook, DOE-HDBK-1092-2004

Engineering Design Subject Area

Fire Safety Subject Area

National Electrical Safety Code, ANSI C-2

Organizations Currently Recognized by OSHA as NRTLs Web page

Management System: Worker Safety and Health
Subject Area: Electrical Safety

6. Implementing the Authority Having Jurisdiction (AHJ) Program

Effective Date: **Feb 29, 2016**	Subject Matter Expert: Richard Biscardi	Management System Executive: Ed Nowak

Applicability

This information applies to any owners/stewards of electrical equipment, electrical installations, or electrical modifications at BNL, and to Electrical Inspectors.

Required Procedure

Materials and equipment required or permitted by the National Electrical Code must be approved by the Authority Having Jurisdiction. The Authority Having Jurisdiction for approval of electrical installations and equipment at BNL is the Laboratory Electrical Safety Committee (LESC) represented in the field by LESC approved Electrical Inspectors. This approval must be received prior to applying power to the equipment. "Cord and Plug" equipment must not be plugged in prior to receiving approval.

All personnel who are owners/stewards of electrical equipment, new electrical installations or modifications to electrical systems must ensure that the equipment, installation or modification is accepted by an LESC approved Inspector. Inspectors must ensure that assigned inspections are completed according to this procedure.

- The first group, Electrical Equipment Inspectors (EEI) have the authority to accept for use at BNL all newly acquired, purchased, constructed, modified and repaired equipment operating above 50 volts.
- The second group, National Electrical Code Inspectors (NECI) have the authority to accept all electrical distribution installations and facility hard wired electrical utilization equipment; including repairs and modifications to the electrical systems and facility utilization equipment.

Implementing the Authority Having Jurisdiction (AHJ) Program contains two subsections:

6.1 Electrical Equipment Inspection

<table>
<tr><td>Step 1</td><td>For new purchases, NRTL certified equipment must be acquired whenever available, even if similar uncertified equipment can be used. A list of OSHA-approved NRTLs is available (see the Organizations Currently Recognized by OSHA as NRTLs Web page). Some types of equipment which are non-NRTL have been pre-approved at BNL (see the Reputable Manufacturers Models on the ESH Guide: Electrical Safety).</td></tr>
<tr><td>Step 2</td><td>If no NRTL equipment can be found for the required application, or the equipment is custom built, modified NRTL, or BNL built the owner/steward or designee must arrange for a BNL-certified Electrical Equipment Inspector (EEI) to review the equipment for approval. For a list of BNL-certified EEIs, see the List of LESC Approved Inspectors. EEIs must not approve equipment if similar equipment that performs the same function as the non-NRTL equipment can be procured.</td></tr>
<tr><td>Step 3</td><td>The owner/steward initiates the inspection process by assuring that the equipment is input into the Electrical Equipment Inspection Management System (EEIMS) (*Limited Access) or an Electrical Equipment Inspector is contacted. The review process must be complete before use of the equipment.
Note: The equipment approval by an EEI applies to a finished, enclosed, grounded, item or installation with appropriate overcurrent protection; ready for its intended use. For approval of materials or electrical distribution installations, see section 6.2 Electrical Materials and Equipment Installation Inspection.</td></tr>
<tr><td>Step 4</td><td>The EEI applies a bar coded reference number to the equipment and a colored sticker that indicates its approval status. The sticker indicates the following status:
<table>
<tr><td>Green</td><td>Approved</td></tr>
<tr><td>Yellow</td><td>Conditional Approval (as documented on the review form)</td></tr>
<tr><td>Blue</td><td>NRTL (for items which have been approved by an NRTL and the NRTL marking is not readily visible in installed location)</td></tr>
<tr><td>Blue</td><td>DNA/NIS (does not apply/not in system)</td></tr>
<tr><td>Red</td><td>Rejected</td></tr>
</table>
Note: Equipment with a red (rejected) sticker must not be plugged-in, energized or used prior to re-inspection and approval.</td></tr>
</table>

Step 5	For multiple units purchased by manufacturers not on the "Reputable Manufacturers" list one item may be inspected and the remaining database entries will reference the initial item. For multiple units built at BNL that are identical, one item may be inspected and the remaining database entries will reference the initial item. Some items, i.e., those constructed in-house by a variety of technicians over an extended time period, will be individually inspected.
Step 6	The EEI must record the result of the inspection in the EEIMS. It is expected that general safety rules are followed for all equipment use. The EEI may list specific restrictions on use or operational limitations of the equipment on the inspection form. Deficiencies that support conditional use or rejection of the equipment must be recorded. The EEI must not be the owner of the equipment and is not responsible when equipment is disassembled for maintenance or troubleshooting, or when equipment is relocated or used for another purpose.
Step 7	The owner/steward is responsible for reviewing the results of the inspection and conducting any follow-up action required prior to equipment being used: a. For Approved, NRTL, or DNA/NIS items, no additional action required. b. Items with Conditional Approval must follow the restrictions on the use of the equipment and fulfill the required corrections in a timely manner. c. Items Rejected must not be energized prior to the correction of conditions for rejection and approval after re-inspection. **Note:** Modifications to equipment approved by an EEI Inspector will invalidate the approval and a re-inspection of the equipment is required. It is the responsibility of the equipment owner/steward to arrange for such an inspection.
Step 8	For repairs to electrical equipment in the EEI program, the owner/steward or designee must arrange for a BNL-certified Electrical Equipment Inspector (EEI) to re-inspect the equipment before use (EEIs must not inspect their own work). **Exception:** For "like-in-kind" repair of equipment that is completed under a LESC-approved process, no additional review or paperwork is required. The LESC currently approves two "like-in-kind" repair processes: • Like-in-kind repair that is completed under a work order by an F&O worker authorized to repair that equipment; and • Like-in-kind repair that is completed by workers approved by a Department Chair/Division Manager or designee authorizing those workers to repair that

	equipment.
Step 9	If records are kept in addition to the EEIMS, the organization files must be continually accessible to the Laboratory Electrical Safety Officer for purposes of review, and also for use in satisfying reporting requirements.

6.2 Electrical Materials and Equipment Installation Inspection

Step 1	Organizations ensure that they have an LESC-approved program (see the exhibit Authority Having Jurisdiction - Electrical Inspection Program) for documenting the acceptance of materials, electrical designs, repairs, installations and/or modifications. The program must include a list of Local Electrical Inspectors approved by the Chief Inspector and the LESC and a list of **Qualified Workers**. Local Inspectors and the Chief Inspector must also be Authorized as EEI inspectors under the EEI Program. This enables them to accept distribution equipment as necessary under the EEI program.
Step 2	Organizations ensure that all electrical designs, repairs, installations or modifications are • Designed and installed to Code of Record (the latest edition of the National Electrical Code); • Accepted by a NEC Inspector for the basis of approval by the LESC (see the exhibit Authority Having Jurisdiction - Electrical Inspection Program).
Step 3	A Qualified Worker repairs and installs electrical equipment and components falling under the jurisdiction of BNL's Electrical Materials and Equipment Installation Inspection Program.
Step 4	The **Qualified Worker** (as defined in the Definitions section of this subject area) is responsible for the installation of their work in a Code compliant and in a workman like manner. Installations of Like-In-Kind replacements or NRTL listed repair and replacement performed by a qualified worker provides the basis for approval and acceptance of the work.
Step 5	Using the BNL Electrical Inspection Guidelines, an LESC-approved Local Inspector must approve materials, modifications to electrical distribution equipment, new electrical distribution installations, and electrical designs that fall under the jurisdiction of the NEC. A Local Inspector

	• Reviews drawings and designs, and accepts modifications, materials, new installations, and mechanical execution of work for the basis of approval by the LESC; • Approves Self-Inspectors in concurrence with the LESC; and • Approves work performed on electrical distribution equipment and installations by non-inspectors.
Step 6	The LESC manages the BNL Electrical Materials and Equipment Installation program and the LESC-approved Chief Electrical Inspector coordinates the program. The Chief Electrical Inspector will: • Perform quality checks to ensure consistency in interpretation of the Codes and Standards; • Provide oversight of the program; • Coordinate supplemental training; • Update BNL inspection guideline documents; • Support Local Inspectors; • Request interpretations or equivalent means to meet the intent of the Codes and Standards from the LESC; and • Be an ex-officio member of the LESC. **Note:** The NEC Inspectors are not authorized to approve equivalencies or variances to the Codes or Standards.

Guidelines

For further guidelines on EEI inspections, see the BNL Checklist for Review and Approval of Electrical Equipment and Installations.

For further guidelines on NEC Inspection Program, see the exhibits Authority Having Jurisdiction - Electrical Inspection Program and BNL Electrical Inspection Guidelines.

References

Electrical Equipment Inspection Management System (EEIMS) (*Limited Access), Electrical Equipment Inspection Program, ESH Guide: Electrical Safety, Safety and Health Services website

List of LESC Approved Inspectors, Laboratory Electrical Safety Committee website

Organizations Currently Recognized by OSHA as NRTLs webpage

Reputable Manufacturers Models, ESH Guide: Electrical Safety, Safety and Health Services website

*Access limited - contact EEIMS Admin for assistance

Definition: Electrical Safety

Term	Definition
approved line-organization electrical procedures	Procedures written by Department/Division staff and approved by the Department Chair/Division Manager of that organization.
Authority Having Jurisdiction (AHJ)	Over electrical safety matters is the Laboratory Electrical Safety Committee composed of members having experience and knowledge of electrical codes and standards to make sound judgments with respect to Laboratory electrical safety policy as defined in NFPA 70, National Electrical Code, Section 90-4. The Laboratory Electrical Safety Officer (LESC) acts for the LESC as the AHJ in the field. The LESC has established two groups of Electrical Inspectors whose acceptance supplies the basis for approval by the Committee: • The first group, Electrical Equipment Inspectors (EEI), has the authority to accept for use at BNL all newly acquired, purchased, constructed, modified, and repaired equipment operating above 50 volts. • The second group, National Electrical Code Inspectors (NECI), has the authority to accept all electrical distribution installations and facility hard wired electrical utilization equipment, including repairs and modifications to the electrical systems and facility utilization equipment.
Authorized Worker	A Qualified Worker who is formally identified (listed) by the operating organization as authorized to perform a lockout/tagout and authorized to work on or near energized conductors with an Energized Work Permit. For this Standard, authorized workers equate to NFPA and OSHA's qualified workers with respect to approach distances.
backfed or "sneak" circuits	A condition, inadvertently built into a system, which causes an unwanted function to occur or inhibits a desired function, without regard to component failure. Backfed circuits may also increase the probability of personnel shock.

control zone	A generic term applied to the working space surrounding exposed live parts. It is the greater of the arc-flash or limited approach boundary.
Dangerous (when used in context of Hazard/Risk Category)	Hazard/Risk Category for equipment calculated greater than H/R Cat 4 (energy level greater than 40 Cal/cm2).
de-energized	Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.
electrical hazard	A dangerous condition such that contact or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.
electrically safe work condition	A state in which the energized live part to be worked on or near has been disconnected from energized parts, and controlled by lockout/tagout or administrative means (e.g., a person) in accordance with established standards; tested to ensure the absence of voltage; and grounded, if determined necessary.
Energized Electrical Work Permit	This permit is to be used when live parts can not be placed in an electrically safe working condition and for any testing, troubleshooting and voltage measuring above 600 volts. A “two-person rule” must be implemented for work above 250 volts, and a “safety watch” is required for work above 600 volts. Instructions for completing the electrical work permit, and a copy of the permit, may be found in the exhibit Electrical Work Permits with Instructions.
exposed (as applied to live parts)	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, or insulated.
flame-resistant (FR)	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.
flash hazards	A dangerous condition associated with the release of energy caused by an electric arc, often with high current flow, through an unintentional low impedance path. Hazardous characteristics associated with an arc flash are heat, light, noise, and thrown molten metal.

Hierarchy of Controls	A prioritized list of hazard control. They are 1) Elimination or substitution of the hazard; 2) Engineering controls; 3) Lockout/tagout or unplug the equipment; 4) Energized Work Permits with appropriate PPE. Representative examples for elimination and substitution are given below: • Elimination - a) removing hazardous voltages from a system design; b) removing a damaged piece of equipment from service. • Substitution - replacing a component that uses a hazardous voltage with one that uses a less hazardous voltage in a system.
independent reviewer	A person knowledgeable in electrical safety and not part of the work group covered under the Energized Electrical Work Permit.
Job Safety Analysis (JSA)	A hazard analysis technique which breaks down a job into functional steps, identifies the hazards with each step, and defines controls for each identified hazard.
labeled	Equipment or materials to which has been attached a label, symbol, or otherwise identifying mark of a Nationally Recognized Testing Laboratory (NRTL).
Laboratory Electrical Safety Officer (LESO)	The employee designated by Safety and Health Services Division as the Laboratory-level Authority Having Jurisdiction in the field. The LESO is a defacto member of the LESC.
like-in-kind	**Application:** Like-in-Kind can only be applied if the component to be replaced is already installed in a code-compliant manner. **Definition:** Used for maintenance and repair, Like-in-Kind pertains to two or more electrical components that can be used interchangeably and have the following characteristics: • Share similar physical, electrical, and operational characteristics, such as: o Voltage requirement, o Current draw, o Circuit overcurrent, and o Short circuit/arc flash characteristics. • Serves the same function within a given system.

	• Are mounted or located in the same physical location; and • Includes any electrical component that is authorized and NRTL-listed by the original equipment manufacturer as being a suitable replacement part. **Note:** • All new installations downstream of transformers that directly supply buildings (e.g., disconnects, panel boards, switchgear, motor control centers, and branch circuits) must be inspected by a Local Electrical Inspector (LEI). • All new equipment or replacement of complete equipment that have hard-wired utilization and skid-mounted equipment must be inspected by an LEI, with certain exceptions, such as, for example, the following equipment: o Spot replacement of existing light fixtures, o Existing fixture ballast, o Existing light control switches, o Existing receptacles, and o The replacement of components in existing in place or skid-mounted equipment. • The local LEI should be contacted for those situations that are unclear, as to equipment inspection, requirement, or responsibility.
limited approach boundary	A shock protection boundary to be crossed only by qualified persons which is not to be crossed by unqualified persons unless escorted by a qualified person.
listed	Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

live parts	Electric conductors, buses, terminals, or components that are uninsulated or exposed and a shock hazard exists.
lockout and tagout (LOTO)	The physical isolation of an energized system from the source of energy, verification of isolation, the application of a barrier for each person or group working on the system (padlock: BNL dedicated Stock #I65064), and identification for accountability at each barrier/red tag.
low-hazard operations	Tasks which present no immediate hazard of electrocution. These operations are not classified as working on or near energized conductors; but may contain other electrically-related dangers such as flash hazards and secondary injury from falls.
prohibited approach boundary	A shock protection boundary to be crossed only by qualified persons which, when crossed by a body part or object, requires the same protection as if direct contact is made with a live part.
qualified worker	Personnel, both employees and contractors, who have relevant electrical education and experience; who are familiar with the construction, operation, and hazards of the equipment involved; and who have current electrical safety training. Only Qualified Workers are eligible to be designated by their operating organization as Authorized Workers for the equipment involved.
restricted approach boundary	A shock protection boundary to be crossed only by authorized persons, which due to its proximity to a shock hazard, requires the use of shock protection techniques and equipment when crossed.
Safety Watch	A second qualified person, knowledgeable in rescue techniques to the level taught in Electrical Safety I (TQ-ELECSAF1) and Cardiopulmonary Resuscitation (Adult CPR/AED). The Safety Watch must • Have personal protective equipment (PPE) to be able to enter the area, if needed, for safety actions; stay out of area while observing; • Have knowledge of breakers and switches that need to be operated in an emergency; • Know where the phone is located or have a radio to summon help; • Be in visual and audible range of the person doing the work, but not in the control zone;

	• Check for unsafe acts or error traps while observing work and warn the worker of potential problems; • Have no other duties. The Safety Watch may operate breakers and switches without a second person if an emergency should arise.
Testing, Troubleshooting, and Voltage Measuring Electrical Work Permit	A permit for testing, diagnostics and voltage measuring (including Zero Energy Checks when performing LOTO) for 600 V or less. This permit is used for similar hazards (e.g., troubleshooting power supplies) and is approved for defined classes or types of work. The permit may be issued for reasonable periods of time, not to exceed one year. Instructions for completing the Testing, Troubleshooting, and Voltage Measuring Electrical Work Permit, and a sample of the permit, may be found in exhibit Electrical Work Permits with Instructions. An electrical work permit is not required for tasks below 50 volts.
tower line workers	Utility workers tasked with installing and maintaining electrical power generation, transmission and distribution systems, specifically substations and all work more than 600 Vac. All work associated with this electrical range is considered to have a high hazard potential; therefore, these workers must be trained to a level commensurate with that risk category. This group must work in compliance with 29 CFR 1910.269.
troubleshooting	Troubleshooting is the process of investigating, identifying, and locating problems in machinery, circuits, or systems. Given an approved Testing, Troubleshooting, and Voltage Measurement (TTVM) or other Energized Work Permit, activities may include taking voltage, current, or impedance measurements; testing and replacing fuses or motor overload heaters; and removing enclosure covers for investigation. The following troubleshooting-related activities are specifically allowed for an authorized electrical worker when performed under an approved TTVM Permit: • Manipulating energized control circuit components up to 150 volts (such as lifting of control circuit wires and

	tightening of control circuit terminals or connectors) • Removing wire nuts on branch circuits, provided the wire size is #10 AWG or smaller (e.g., #12) and voltage is no greater than 300 volts phase-to-ground, in order to measure voltage, or to trace or tone a circuit for the purpose of identifying the appropriate LOTO location (such as a specific circuit breaker or switch) • Verifying zero energy as part of the multi-step Lockout/Tagout process to make the circuit electrically safe. The TTVM Permit requires the authorized electrical worker to • Keep all uninsulated body parts outside of the prohibited approach boundary • Use required shock and arc-flash personal protective equipment (PPE), per the permit Line management is responsible for evaluating the experience and qualification of the workers involved prior to planning the scope of work authorized.
two-person rule	A second qualified person, knowledgeable in rescue techniques to the level taught in Electrical Safety I and CPR qualified, is required when ANY of the following criteria exists: -Performing work within the Arc-Flash Boundary of exposed live parts that has an arc-flash Hazard/Risk Category of 3 or 4; -Operating switches or breakers with an arc-flash Hazard/Risk Category of 4; -Any time there are exposed live parts with >250V but <600V **and** when either of the following exists: • A barricade is not established; • When performing tasks where there are multiple sources of exposed live parts with voltage >50V (e.g., multiple terminal strips, including some control panels and power supplies). **Examples:**

	- Two persons NOT required: Hazard Risk Category is less than 3 AND a single source of exposed voltage, such as a manually operated disconnect switch. (One set of 3 phase connections is considered a single source.) - Two persons required: Multiple sources of exposed voltage, such as a control panel with 480V exposed terminal lugs and 120V control terminals, regardless of which one is being worked on. -Any time work planning, including worker-planned work, determines the need for two-persons to perform a given task. The second person must wear the appropriate PPE if assisting the primary worker in the same control zone. **Note:** The second person may operate breakers and switches without an additional second person if an emergency should arise.
voltage (of a circuit)	The greatest root-mean-square (rms) (effective) difference of potential between any two conductors of the circuit concerned. Nominal Voltage is a value assigned to a circuit or system for the purpose of conveniently designating its voltage class (as 120/240 volts, 480Y/277 volts, 600 volts).
work	Any task performed on equipment such as operating, testing, troubleshooting, repairing, modifying, etc.
working near (live parts)	Any activity inside a limited approach boundary.
working on (live parts)	Coming in contact with live parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment a person is wearing.

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Approved Equivalent Electrical Training

Effective Date:**Feb 29, 2016**

The BNL Laboratory Electrical Safety Committee must review and approve all electrical training for workers who may enter the Limited Approach Boundary or the Arc-Flash boundary. This review may consist of reviewing the class syllabus to members of the committee auditing the training classes. The Training and Qualifications Program Office approves all non-electrical training required for this subject area. For all workers with approved equivalent training they must receive a copy of the Addenda to NFPA 70E for Contractors and a tool-box talk from an electrically knowledgeable supervisor or the Electrical Safety Subject Matter Expert to answer any questions. The approved equivalent training courses are the following:

Electrical Training

- Long Island Joint Apprenticeship & Training Committee (must have a card showing 70E training).

CPR Training

- Red Cross
- American Heart Association

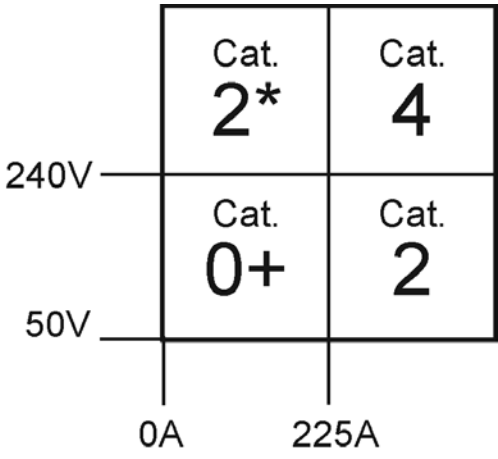
Addenda to NFPA 70E for Contractors
Brookhaven National Laboratory Electrical Safety Program

Brookhaven does not allow working on or near live parts greater than 50 volts unless it can be shown that de-energizing introduces additional or increased hazards or is infeasible because of equipment design or operational limitations.

- Brookhaven defines electrical workers as either "Qualified" or "Authorized" to perform electrical work.
  - **Qualified Worker**
    - A Qualified worker is someone who has relevant electrical education or experience to do their assigned tasks. This includes being familiar with construction and operation of electrical equipment, the hazards involved, and methods of dealing with these hazards.
  - **Authorized Worker**
    - An Authorized worker is a Qualified worker who has been formally identified (listed) by their sponsoring Brookhaven organization as authorized to perform Lockout/Tagout and permitted to work on energized equipment with the appropriate permit, but ONLY on the equipment for which they are authorized.
- Brookhaven has different requirements for operating electrical disconnect switches and for working on or near energized conductors and parts based on the hazard Risk Categories.

Hazard/Risk Categories for Operating Equipment

- Each piece of electrical equipment has a Hazard/Risk Category based on the potential incident-energy present when operating its switches and disconnects. These Hazard/Risk Categories are specified in order of increasing energy as:
  - N/A
  - 0+ (an upgrade from NFPA category 0; see below)
  - 2, 2*
  - 4
- Which category your work falls into is based on the voltage and amperage of the equipment, as the diagram shows.
- The voltage is nominal operating voltage of the equipment.
- The amperage is the rated amps of the panelboard or switchboard -- not from the individual switch.
- The minimum Personal Protective Equipment for operation of



circuit breakers and disconnect switches in panels rated 225 amps or less and 240 volts and less with covers on is:

- Safety glasses
- Long-sleeve shirt and pants made of non-melting natural fiber clothing such as untreated cotton, wool, rayon, or silk
- Gloves - Cotton/leather or full leather gloves

All buttons, including collar and sleeves, must be fastened and shirt tails tucked in.

Personnel Protective Equipment for Operating Equipment: Minus 1 Rule

- After Brookhaven does a Flash Hazard Analysis and has labeled the panel with the calculated hazard/risk category and minimum protective equipment, the hazard/risk category may be lowered by a factor of 1 to operate the equipment provided:
  - The cover (enclosure) of the equipment is in good shape
  - All fasteners for the cover are attached and tight
  - The cover has not been modified to weaken its resistance to an arc-blast

Posted Category	PPE level required to operate with covers on
0+	Insignificant arc-flash hazard (no category) eye protection required
1	0+
2	1
3	2
4	4 (Category not reduced)

- The Minus 1 rule applies only to operating equipment that has had its specific arc-flash hazard calculated and has been affixed with a specific arc-flash hazard label.
- **The Minus 1 rule does NOT apply to Category 4 equipment and tasks.**
- The Minus 1 Rule for circuit breakers and switches labeled as Hazard/Risk Category 0+ is considered no hazard to operate. Therefore, the only Personal Protective Equipment required to operate these items are safety glasses.

For performing energized diagnostic work or zero energy checks on Equipment

- You must have Authorization with a permit and Personal Protective Equipment required for working energized.

Brookhaven Electrical Work Permits

- All work on or near energized parts require a permit. There are two types of electrical permits at Brookhaven:
  - Testing, Troubleshooting, and Voltage Measuring - Electrical Work Permit
    - This permit is for diagnostic work and may be issued for up to one year.
  - Specific Energized Electrical Work Permit

- When placing live parts in an electrically safe work condition is infeasible, or will increase or create additional hazard, the work is considered energized electrical work and shall be performed within the limitations of this permit.

- Speak to your Point of Contact to have the appropriate Electrical Work Permit issued for your work.

Personnel Protective Equipment for working energized

The Brookhaven Electrical Safety Subject Area establishes three shock-protection approach distances, or boundaries that only qualified personnel are allowed to cross. Current boundary distances are available on-line at the exhibit Work Distance Table (Control Zones) or from your Point of Contact.

- Brookhaven cannot confirm the clearing time and bolted fault currents because of high power substations on-site and age of equipment. Therefore, the limiting conditions at Brookhaven are different than the tables in NFPA 70E.
- One difference that Brookhaven requires is that gloves are to be used as part of Hazard/Risk Category 0. Since this is beyond the NFPA's Hazard/Risk Category 0 requirements, we refer to this as "Category 0+."
- Another difference is the arc flash boundary distances for Hazard/Risk Categories; see table at right.
- The Electrical Safety Subject Area also establishes an arc flash-protection approach distance, or boundary, that only qualified personnel are allowed to cross.
- If a piece of equipment's arc flash hazard has been calculated, then the generic label is replaced with a specific warning label listing specific personal protective equipment requirements and approach boundary distances. See sample at right.

Hazard/Risk Category	Minimum Arc Flash Protection Boundary (unless posted)
0+	4'
1	5'
2, 2*	6'
3	10'
4	16'

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Authority Having Jurisdiction - Electrical Inspection Program

Effective Date:**Feb 29, 2016**

The Authority Having Jurisdiction - Electrical Inspection Program is provided as a PDF.

Authority Having Jurisdiction - Electrical Inspection Program Description

Scope

The Laboratory Electrical Safety Committee (LESC) has been vested as the Authority Having Jurisdiction (AHJ) for electrical safety at Brookhaven National Laboratory (BNL) by DOE through the Laboratory Director, the Deputy Director of Operations (DDO), and the Assistant Laboratory Director for ESH. The AHJ for electrical matters is responsible for interpreting the requirements of Electrical Codes and Standards and for approving electrical equipment, materials, installations, and procedures at BNL. To fulfill the requirements as AHJ, the LESC has established two programs: 1) the Electrical Equipment Inspection Program (EEI) and, 2) the Electrical Materials and Installation Inspection (EMII) Program.

Definitions

Approved. Acceptable to the authority having jurisdiction.
Authority Having Jurisdiction (AHJ). The organization responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure. For electrical issues, this is the LESC.
Basis for Approval. The acceptance of equipment, materials, and workmanship for compliance to the Codes and Standards by persons approved by the LESC to perform field inspections. Note: The LESC is not delegating the authority to approve equivalent means to meet the intent of the Codes and Standards; nor is it delegating the authority to provide formal Interpretation, Equivalency, or Variance to the Codes and Standards.

Programs

Electrical Equipment Inspection Program (EEI) – The scope of this program covers the review and approval of all electrical equipment at BNL operating above 50 volts, whether it is part of or connected to the facility electrical system, or a piece of stand-alone equipment. The qualifications for an Electrical Equipment Inspector are a minimum of ten years combined schooling/experience with electrical/electronic system design and/or electrical system construction/installation/inspection/safety. In addition, proposed EEIs attend classroom training and are evaluated in the field by approved EEIs during inspections. The EEI's qualifications, and completion of necessary training and

field evaluations are reviewed by the LESC for final approval. The EEI program is the subject of Section 7.1: Electrical Equipment Inspection of the Electrical Safety Subject Area.

Electric Materials and Equipment Installation Inspection Program (EMII) – The scope of this program covers the review and approval of the materials and installation of the electrical distribution for facilities and hard-wired equipment. There are two levels of inspectors: Chief Electrical Inspector (CEI) and the Local Electrical Inspector (LEI) as described below:

1) Chief Electrical Inspector (CEI), after being approved by the LESC, shall be responsible for the overall coordination of the EMII program. Qualifications for this position are ten years of experience with industrial/commercial facility electrical systems as a Master or journeyman electrician, electrical supervisor, or electrical engineer; and an LESC approved external Electrical Inspector Certification. Acting independently of line responsibility for electrical installations within Organizations, the CEI shall:

a. Perform quality checks by re-inspection of a sampling of work previously inspected by Local Electrical Inspectors (LEI) and installed by the qualified worker (TQW) to ensure consistency in the interpretation of Code requirements;

b. Provide oversight of the LEIs

c. Coordinate supplemental training (over and above required training indicated in the Job Training Assessment) to address specific issues as they arise, based on any perceived deficiencies resulting from the above inspections or from lessons-learned from other DOE facilities or industry;

d. Support LEIs by assisting as requested, including in their absence;

e. Assist the Laboratory Electrical Safety Officer (LESO) in electrical matters when requested, including in his absence;

f. Is an ex-officio voting member of the LESC.

2) Local Electrical Inspector (LEI) –The LEI is a qualified electrical worker, recommended by the cognizant Organization Head and reviewed by the ALD of ESH&Q for approval by the LESC and CEI. The LEI is the delegate of the CEI in the field and can provide the basis for approval of modifications and new installations. The Organization Head shall retain the primary responsibility for the compliance with Codes and Standards in their Organization and authorize the LEI to provide the basis for approval for the electrical work for the LESC.

Qualifications include five years of work experience in the areas they will be responsible for approving, formal NEC training, and passing a BNL test or receiving a LESC waiver for the test. The formal NEC training is by an LESC-approved NEC course, by an LESC-recognized electrical training program, or by an LESC-approved external Electrical Inspector certification.

The Qualified Worker (as defined in the Electrical Safety Subject Area) is responsible for the installation of their work in a Code compliant and in a workman like manner. Installations of Like-In-Kind replacements or NRTL listed repair and replacement performed by a qualified worker provides the basis for approval and acceptance of the work. The qualified worker must have relevant experience in the areas they work. The qualified worker must have LESC approved training that demonstrates the worker is knowledgeable to perform the work in compliance with applicable Codes and Standards. The qualified worker can provide the basis for approval of Like-in-Kind only during service and maintenance. All parts must be OEM or NRTL listed.

Local Inspectors and the Chief Electrical Inspector shall meet the qualifications to be EEI inspectors under the EEI Program.

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

BNL Electrical Inspection Guidelines

Effective Date:**Feb 29, 2016**

The BNL Electrical Inspection Guidelines is provided as a Word file.

This checklist is intended to be used by an LESC approved Inspector
It is not to be construed as all-inclusive; it is only to be used as a guideline

Construction Sites and Temporary Services Inspection	
Panel grounded and bonded	**2008 NEC 250.28 250.52 250.53**
Breaker/outlet requirements-sizing for outlets used	**2008 NEC 210.19**
Wire sizes and insulation	**2008 NEC 310.16**
No open holes/to remain water tight	**2008 NEC 314.17**
Unused breaker openings filled	**2008 NEC 408.7**
Clearances: 18' above traffic for overhead drop.	**2008 NEC 225.18**
Raceway used and installed	**2008 NEC 230.50 230.54**
Weather resistant receptacles 115-250 volt	**2008 NEC 406.8**
GFCI protection/in use covers for exposed outlets	**2008 NEC 406.8**
Listed Equipment shall be installed and used in accordance with the manufacturers instructions	**2008 NEC 110.3(B)**
All materials and equipment must be THIRD PARTY LISTED & LABLED or EEI approved	**2008 110.2 110.3**
Underground Services Inspection	
Over current Protection for Underground Wiring	**2008 NEC 240.3**
Type SE, USE and UF cables and uses permitted for underground installation	**2008 EC 338 340**
Conduit types permitted for underground installation (Intermediate metal conduit, liquid-tight flexible metal conduit, rigid metal conduit, rigid non-metallic conduit)	**2008 NEC 342 344 352 354**
Minimum trench depth or cover requirements	**2008 NEC 300.5(a)**
Minimum size and insulation of underground service - lateral conductors	**2008 NEC 230.30 230.41**
Backfill and bedding requirements (no large rocks, debris, paving material, sharply angular substance, corrosive materials, etc.)	**2008 NEC 300.5(f)**
All materials and equipment must be THIRD PARTY LISTED & LABLED or EEI approved	**2008 110.2 110.3**
Rough Inspection	
Proper conduit size and number of conductors for conduit	**2008 NEC Ch 9 Annex "C"**
Proper strapping of conduits	**2008 NEC 358.30 300.18**
Reaming of cut ends of conduits	**2008 NEC 358.28**

Installation of connectors and couplings	**2008 NEC 358.30**
Size for electrical service	**2008 NEC 230.31(a)(b)**
Type MC cable shall be supported, every 6'; 12" from box	**2008 NEC 330.30**
Boxes must be supported	**2008 NEC 314.23**
Number of bends in a run of conduit	**2008 NEC 358.26**
Unused openings protected other than those openings intended for the operation of the equipment	**2008 NEC 110.12**
Flexible metallic tubing as grounding	**2008 NEC 348.60**
Length limitation of flex Metal Conduit	**2008 NEC 348.20**
GFCI protection in commercial kitchens, *roof tops, bathrooms and outdoor receptacles*	**2008 NEC 210.8(A)(B)&(C)**
All materials and equipment must be THIRD PARTY LISTED & LABLED or EEI approved	**2008 110.2 110.3**
Working Space around Electrical Equipment	**2008 NEC 110.26 110.32**
<u>Service Inspection</u>	
Feeders and/or phase conductors shall be sized by 2008 NEC 310.16	**2008 NEC 310.16**
System grounding electrode conductor shall be sized by 2008 NEC 250.66	**2008 NEC 250.66**
Where phase conductors larger than 1100 kcmil copper or 1750 kcmil aluminum are installed, the equipment bonding jumper shall not be less than 12 ½ percent	**2008 NEC 250.102**
Main bonding jumper and system bonding jumper shall be installed by 2008 NEC 250.28 250.30A 250.66	**2008 NEC 250.28 250.30(A) 250.66**
The grounding electrode system shall include all grounding electrodes that are present as described in 250.52(A)(1) through (A)(6) 2008 NEC 250.50 250.52	**2008 NEC 250.50 250.52**
Switchboards and panel boards clearances	**2008 NEC 110.26 408.18**
Equipment containing over-current devices shall not be located over steps	**2008 NEC 240.24(F)**
Conductors and cables used above grade must be suitable for wet locations	**2008 NEC 300.9**
All materials and equipment must be THIRD PARTY LISTED & LABLED or EEI approved	**2008 110.2 110.3**
Working Space around Electrical Equipment	**2008 NEC 110.26 110.32**

Ceiling Inspection

Clearance of lighting fixtures from combustible materials	**2008 NEC 410.2 410.12 410.16**
Luminaire Support	**2008 NEC 410.36**
No exposed energized conductors	**2008 NEC 110.3**
Exposed, non current carrying metal parts of lighting fixtures shall be grounded	**2008 NEC 250.112**
Methods of grounding fixtures	**2008 NEC 250.118 410.40**
Type MC Cable shall be supported, every 6'	**2008 NEC 330.30**
EMT (conduit) must be supported every 10' and within 3' of each box	**2008 NEC 358.30**
Boxes must be supported	**2008 NEC 300.11 314.23**
Number of bends in a run of conduit	**2008 NEC 358.26**
Pull and junction boxes accessible	**2008 NEC 314.29**
Wiring in ducts, plenums and other air handling spaces	**2008 NEC 300.22**
Unused openings protected	**2008 NEC 110.12**
Flexible metallic tubing as grounding means and its limitations for use	**2008 NEC 348.60**
Length limitation of flex	**2008 NEC 348.20**
Accessibility of duct heater	**2008 NEC 424.65 424.66**
Luminaries multi-wires disconnects and locations	**2008 NEC 410.130.(G) 2 & 3**
All materials and equipment must be THIRD PARTY LISTED & LABLED or EEI approved	**2008 110.2 110.3**

Final Inspection

Service Feeder Size	**2008 NEC 230.42(B)**
Proper breaker Sizing	**2008 NEC 240.4**
Circuits labeled & identified	**2008 NEC 408.4**
Unused openings protected	**2008 NEC 110.12**
Proper over current protection at panels	**2008 NEC 210.20**
Grounding electrode system	**2008 NEC 250**
GFI locations & installation requirements	**2008 NEC 210.8(B) & (C) 422.49 426.28 427.22 511.12 517.20 547.5 551.71 620.85 680.22 680.51 680.62 680.71**
Installation of all devices required	**2008 NEC 110.3 110.13 110.7 110.21 210.50**
A/C & Heating disconnects	**2008 NEC 440.4 440.12 440.22**
Lighting & electrical outlet requirements	**2008 NEC 210.70**
Disconnect identification	**2008 NEC 110.22**

All bonding requirements for transformers	**2008 NEC 250.30**
Multi-wire Branch Circuits	**2008 NEC 210.4**
Identification of ungrounded phase system, when more than one voltage system	**2008 NEC 210.5**
Receptacles and switches complete with plate	**2008 NEC 406.4 406.5**
Marking of service disconnect	**2008 NEC 230.70(b) 230.72(a)**
Cables installed under roof deck	**2008 NEC 300.4(E)**
Insulated Fittings regarding ambient temperature locations	**2008 NEC 300.4(G)**
Conduit exposed to sunlight (temperature considerations)	**2008 NEC 310.15 (C)**
Drinking fountains must be protected by GFCI	**2008 NEC 422.52**
Vending machines protected by GFCI	**2008 NEC 422.51**
Arc Flash Protection Markings	**2008 NEC 110.16**
Working Space around Electrical Equipment	**2008 NEC 110.26 110.32**
All materials and equipment must be THIRD PARTY LISTED & LABLED or EEI approved	**2008 110.2 110.3**

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Certification of Personal Protective Equipment (PPE) for Electrical Energized Work

Effective Date:**Feb 29, 2016**

The exhibit Certification of Personal Protective Equipment (PPE) for Electrical Energized Work is provided as a PDF.

Laboratory Electrical Safety Committee
Certification of Personal Protective Equipment (PPE) for Electrical Energized Work

Date: April 4, 2014

This exhibit is the personal protective equipment (PPE) required for electrical energized work on electrical equipment rated 50 volts and above.

In all cases, personal protective equipment (PPE) from analysis or arc flash calculations must be used as a minimum. In the absence of calculations, PPE from the table Hazard Risk Category Classifications (below) is required.

If the arc-flash incident energy is above 40 cal/cm^2, the task must not be performed until an electrically safe work condition exists (equipment is de-energized and Locked out/Tagged out).

Clothing Material Characteristics

Flame-resistant (FR) material, such as flame-retardant treated cotton, meta-aramid, para-aramid, and poly-benzimidazole (PBI) fibers provide thermal protection. These materials can ignite, but will not continue to burn after the ignition source is removed. FR fabrics can reduce burn injuries (but not eliminate them) during an arc flash exposure by providing a thermal barrier.

Synthetic materials, such as polyester, nylon, and synthetic-cotton blends will melt into the skin when exposed to high temperatures and aggravate the burn injury. Clothing made from synthetic materials such as acetate, nylon, polyester, either alone or in blends with cotton, should not be worn.

Clothing made from non-melting flammable natural materials, such as cotton and polyester-cotton, silk, wool, rayon, and nylon fabrics are flammable and will burn but will not melt on the skin causing further injury.

Hazard Risk Category Classifications			
Task (Assumes Equipment Is Energized, and Work Is Done Within the Flash Protection Boundary)	**Hazard/ Risk Category**	**V-rated Gloves**	**V-rated Tools**
Panelboards rated 240 V and below	—	—	—
CB or fused switch operation with covers off	2	N	N

Remove/install CBs or fused switches	2	Y	Y
Removal of bolted covers (to expose bare, energized parts)	2	N	N
Opening hinged covers (to expose bare, energized parts)	2	N	N
Panelboards or Switchboards rated >240 V and up to 600 V (with molded case or insulated case circuit breakers)	—	—	—
CB or fused switch operation with covers off - less than or equal to 225 Amp	2	N	N
CB or fused switch operation with covers off - greater than 225 Amp	4	N	N
Work on energized parts, including voltage testing - less than or equal to 225 Amp	2*	Y	Y
Work on energized parts, including voltage testing - greater than 225 Amp	4	Y	Y
600-V Class Motor Control Centers (MCCs)	—	—	—
Reading a panel meter while operating a meter switch	2	N	N
CB or fused switch or starter operation with enclosure doors open	4	N	N
Work on energized parts, including voltage testing	4	Y	Y
Work on control circuits with energized parts 120 V or below, exposed	2	Y	Y
Work on control circuits with energized parts >120 V exposed	4	Y	Y
Insertion or removal of individual starter “buckets” from MCC — Note 4	4	Y	N
Application of safety grounds, after voltage test	2*	Y	N
Removal of bolted covers (to expose bare, energized parts)	4	N	N
Opening hinged covers (to expose bare, energized parts)	4	N	N
600 V Class Switchgear (with power circuit breakers or fused switches) - Notes 5 and 6	—	—	—
Reading a panel meter while operating a meter switch	2	N	N
CB or fused switch operation with enclosure doors open	4	N	N
Work on energized parts, including voltage testing	4	Y	Y
Work on control circuits with energized parts 120 V or below, exposed	2	Y	Y
Work on control circuits with energized parts >120 V exposed	4	Y	Y
Insertion or removal (racking) of CBs from cubicles,	4	N	N

Insertion or removal (racking) of CBs from cubicles, doors closed – if within arc flash boundary	4	N	N
Application of safety grounds, after voltage test	4	Y	N
Removal of bolted covers (to expose bare, energized parts)	4	N	N
Opening hinged covers (to expose bare, energized parts)	4	N	N
Other 600 V Class Equipment (277 V through 600 V, nominal)	—	—	—
Lighting or small power transformers (600 V, less than or equal to 225 A)	—	—	—
Removal of bolted covers (to expose bare, energized parts)	2*	N	N
Opening hinged covers (to expose bare, energized parts)	2	N	N
Work on energized parts, including voltage testing	2*	Y	Y
Application of safety grounds, after voltage test	2*	Y	N
Revenue meters (kW-hour, at primary voltage and current)	—	—	—
Insertion or removal	2*	Y	N
Cable trough or tray cover removal or installation	2	N	N
Miscellaneous equipment cover removal or installation	2	N	N
Work on energized parts, including voltage testing	2*	Y	Y
Application of safety grounds, after voltage test	2*	Y	N
NEMA E2 (fused contactor) Motor Starters, 2.3 kV through 7.2 kV	—	—	—
Reading a panel meter while operating a meter switch	2	N	N
Contactor operation with enclosure doors open	4	N	N
Work on energized parts, including voltage testing	4	Y	Y
Work on control circuits with energized parts 120 V or below, exposed	2	Y	Y
Work on control circuits with energized parts >120 V, exposed	4	Y	Y
Insertion or removal (racking) of starters from cubicles, doors open	4	N	N
Insertion or removal (racking) of starters from cubicles, doors closed	4	N	N
Application of safety grounds, after voltage test	4	Y	N
Removal of bolted covers (to expose bare, energized parts)	4	N	N
Opening hinged covers (to expose bare, energized parts)	4	N	N
Metal Clad Switchgear, 1 kV and above	—	—	—

Reading a panel meter while operating a meter switch	2	N	N
CB or fused switch operation with enclosure doors open	4	N	N
Work on energized parts, including voltage testing	4	Y	Y
Work on control circuits with energized parts 120 V or below, exposed	2	Y	Y
Work on control circuits with energized parts >120 V, exposed	4	Y	Y
Insertion or removal (racking) of CBs from cubicles, doors open	4	N	N
Insertion or removal (racking) of CBs from cubicles, doors closed	4	N	N
Application of safety grounds, after voltage test	4	Y	N
Removal of bolted covers (to expose bare, energized parts)	4	N	N
Opening hinged covers (to expose bare, energized parts)	4	N	N
Opening voltage transformer or control power transformer compartments	4	N	N
Other Equipment 1 kV and above	—	—	—
Metal clad load interrupter switches, fused or unfused	—	—	—
Switch operation, doors closed	2	N	N
Work on energized parts, including voltage testing	4	Y	Y
Removal of bolted covers (to expose bare, energized parts)	4	N	N
Opening hinged covers (to expose bare, energized parts)	4	N	N
Outdoor disconnect switch operation (gang-operated, from grade)	2	N	N
Insulated cable examination, in manhole or other confined space Is this true?	4	Y	N
Insulated cable examination, in open area	2	Y	N

Legend:
V-rated Gloves are gloves rated and tested for the maximum line-to-line voltage upon which work will be done.
V-rated Tools are tools rated and tested for the maximum line-to-line voltage upon which work will be done.
2* means that a double-layer switching hood or Salisbury Model AS1000FS Hard Hat with face shield and chin cup used with 10 cal/cm^2 AFHOOD 10 Nomex-Lenzing Balaclava/Racing hood and hearing protection are required for this task in addition to the other Hazard/Risk Category 2 requirements of the table below.
Y = yes (required)
N = no (not required)
Notes:
5. 35 kA short circuit current available, up to 0.5 second (30 cycle) fault clearing time.
6. For < 25 kA short circuit current available, the Hazard/Risk Category required may be reduced by

Protective Clothing and Personal Protective Equipment (PPE) Matrix	
Hazard / Risk Category	**Protective Clothing and PPE**
Hazard / Risk Category 0 Protective Clothing, Nonmelting or untreated natural fiber Minimum Arc Rating of N/A FR Protective equipment	Shirt (long sleeve) Pants (long) Safety glasses or safety goggles (SR) Hearing Protection (ear canal inserts) Leather gloves
Hazard / Risk Category 1 FR Clothing, Minimum Arc Rating of 4 FR Protective equipment	Arc-Rated long sleeve shirt Arc-Rated pants Arc-Rated coverall (Note 2) Arc-Rated face shield or arc flash suit hood Arc-rated jacket, parka, or rainwear (AN) Hard hat Safety glasses or Safety goggles (SR) Hearing protection (ear canal inserts) Leather gloves (Note 1) Leather work shoes (AN)
Hazard / Risk Category 2 FR Clothing, Minimum Arc Rating of 8 FR Protective equipment	Arc-Rated long sleeve shirt Arc-Rated pants Arc-Rated coverall (Note 2) Arc-Rated face shield or arc flash suit hood Arc-rated jacket, parka, or rainwear (AN) Hard hat Safety glasses or Safety goggles (SR) Hearing protection (ear canal inserts) Leather gloves (Note 1) Leather work shoes (AN)
Hazard / Risk Category 2* FR Clothing, Minimum Arc Rating of 8 FR Protective equipment	Arc-Rated long sleeve shirt Arc-Rated pants Arc-Rated coverall (Note 2) Arc-Rated face shield and balaclava (sock hood) or arc flash suit hood Arc-rated jacket, parka, or rainwear (AN)

	Hard hat Safety glasses or Safety goggles (SR) Hearing protection (ear canal inserts) Leather gloves (Note 1) Leather work shoes (AN)
Hazard/Risk Category 3 FR Clothing, Minimum Arc Rating of 25	Arc-Rated long sleeve shirt (AR) (Note 3) Arc-Rated pants (AR) (Note 3) Arc-Rated coverall (AR) (Note 3) Arc-Rated arc flash suit jacket (Note 3) Arc-Rated arc flash suit pants (Note 3) Arc-Rated arc flash suit hood (Note 3) Arc-rated jacket, parka, or rainwear (AN)
FR Protective equipment	Hard hat FR hard hat liner (AR) Safety glasses or Safety goggles (SR) Hearing protection (ear canal inserts) Arc-rated gloves (Note 1) Leather work shoes (AN)
Hazard/Risk Category 4 FR Clothing, Minimum Arc Rating of 40	Arc-Rated long sleeve shirt (AR) (Note 4) Arc-Rated pants (AR) (Note 4) Arc-Rated coverall (AR) (Note 4) Arc-Rated arc flash suit jacket (Note 4) Arc-Rated arc flash suit pants (Note 4) Arc-Rated arc flash suit hood (Note 4) Arc-rated jacket, parka, or rainwear (AN) (Note 4)
FR Protective equipment	Hard hat FR hard hat liner (AR) Safety glasses or Safety goggles (SR) Hearing protection (ear canal inserts) Arc-rated gloves (Note 1) Leather work shoes (AN)

AN = As needed
AR = As required
SR = Selection required

Notes:

1. If rubber insulating gloves with leather protectors are required additional leather or arc-rated gloves are not required.
2. Alternate is to use FR coveralls instead of FR shirt and FR pants.
3. An alternate is to use a total FR clothing system and hood, which shall have a minimum arc rating of 25.

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Certification of Personal Protective Equipment (PPE) for Operating Electrical Equipment

Effective Date:**Feb 29, 2016**

The exhibit Certification of Personal Protective Equipment (PPE) for Operating Electrical Equipment is provided as a PDF.

Laboratory Electrical Safety Committee Certification of Personal Protective Equipment (PPE) for Operating Electrical Equipment

Date: June 26, 2014

This exhibit is the BNL Personal Protective Equipment (PPE) requirements for operating circuit breakers and disconnect switches (not utilization equipment switches such as light switches or on-off switches) that are rated 50 volts to 600 volts. If flame-resistant (FR) clothing is required, it must cover associated parts of the body, as well as all flammable apparel while allowing movement and visibility. PPE equipment will normally be used in conjunction with one another as a system to provide the appropriate level of protection. Clothing must cover potentially exposed areas as completely as possible. Shirt sleeves must be fastened at the wrists, shirts must be tucked in and closed at the neck and jackets must be closed at the neck. (See Table 2 below for required PPE.)

WARNING: Equipment with a DANGER label that says

Arc Flash Hazard Hazard/Risk Category Dangerous Energized Work Prohibited	Or	**Equipment Overdutied Do Not Remove Cover or Operate Breakers/Switches While Energized**

must not be operated while energized. See the Required Procedure in the section Operating Electrical Equipment for further information.

The following table is only to be used if the equipment has a Generic Arc Flash label that does not list PPE or no label defining required PPE.

Table 1. Hazard Risk Category Classifications

If there is a label on the equipment that lists required PPE, you must use that PPE and hearing protection (ear canal inserts).

Light and Power panels fed from 30-KVA transformers that do not list PPE only require safety glasses and hearing protection (ear canal inserts).

Equipment	**Voltage**	**Ampere [Notes 3 and 4]**	**BNL PPE Rating**	
Circuit Breaker Panels or Disconnect Switches operating at less than or equal to 240 V and rated less than or equal to 225 A	Less than or equal 240 V	Less than or equal 225 A	NFPA 70E Cat. 0	
Circuit Breaker Panels or Disconnect Switches (excluding 277 V wall light switches) operating at more than 240V and rated less than or equal to 225 A	More than 240 V	Less than or equal 225 A	NFPA 70E Cat. 2 (8 Cal/cm^2)	
Circuit Breaker Panels or Disconnect Switches operating at less than or equal to 240 V and equipment rated greater than 225 A	Less than or equal 240 V	Greater than 225 A	NFPA 70E Cat. 2 (8 Cal/cm^2)	
Operating controls on 480V individual motor starters	Less than 600 V	Any Starter Motor Size	Arc Flash Hazard Analysis completed	PPE as listed on Panel and hearing protection (ear canal inserts).
			Work Planning performs arc flash analysis	PPE as listed on Permit
		Starter Size <4 (50 HP or less)	No Arc Flash Hazard Analysis	NFPA 70E Cat. 2 (8 Cal/cm^2)
		Starter Size 4+ (51 HP or more)	No Arc Flash Hazard Analysis	NFPA 70E Cat. 4 (40 Cal/cm^2
Circuit Breaker Panels, Motor Control Centers, or Disconnect Switches operating at greater than 240V and rated greater than 225A	More than 240 V	Greater than 225 A	Arc Flash Hazard Analysis completed	PPE as listed on Panel and hearing protection (ear canal inserts).
			Work Planning performs arc flash analysis	PPE as listed on Permit
			No Arc Flash Hazard Analysis	NFPA 70E Cat. 4 (40 Cal/cm^2

These new PPE requirements are based on arc-flash calculations or voltage and ampere rating of the equipment rather than only voltage. Do not wear "meltable" fiber clothing (acetate, nylon, polyester, polypropylene, or spandex) underneath any required PPE clothing (exception is incidental amount of elastic on underwear or socks). The BNL required PPE differs from the NFPA 70E tables to provide an enhanced margin of safety.

Table 2. Protective Clothing Characteristics for Operating Switches or Disconnects

NFPA Cat.	PPE Required
	PPE as listed on the cover of the panel (you may use the minus 1 rule if equipment meets the requirements of Section 2). An analysis of the available arc flash energy has been performed and PPE required is specific to this device, but in all circumstances you will require safety glasses with side shields and hearing protection (ear canal inserts).
0	Long-sleeve shirt and long pants made of non-melting, flammable natural materials (untreated 100% cotton, wool, rayon[2], or silk, or blends of these materials with a fabric weight of at least 4.5 oz/yd^2) leather gloves (minimum leather palm with cotton back: BNL # K62980), and safety glasses with side shields. (Cal/cm^2 N/A), hearing protection (ear canal inserts).
1	FR long-sleeve shirts and FR long pants with an Arc Rating of 4, safety glasses, all leather gloves: BNL # K62902, leather work shoes, hearing protection (ear canal inserts).
2	FR long-sleeve shirts and FR long pants with an Arc Rating of 8, hardhat with arc rated face Shield, hearing protection (ear canal inserts),: BNL # K64942 (protective storage bag for face shield and hat: K64793), safety glasses, all leather gloves: BNL # K62902, leather work shoes.
4	FR shirt and FR pants plus multilayer flash suit, hardhat, safety glasses, Flash Suit hood, hearing protection (ear canal inserts), leather gloves, and leather work shoes. (Cal/cm^2 40),

Note 1: These requirements are for operating switches and disconnects
Note 2: Rayon, a natural fiber made from cellulose, is allowed in NFPA 70E.

Note 3: The equipment Ampere rating is always the nameplate rating of the panel that the switch or circuit breaker is installed in and the Voltage is the line-to-line operating Voltage of the equipment.

Note 4: In the C-AD complex, switches and breakers tapped from "Royal Switches" must use the Royal Switch Rating (greater than 225 A).

Protective Clothing Characteristics

Typical Protective Clothing Systems

Hazard Risk Category	Clothing Description (Typical Number of clothing layers is given in parentheses)	Total Weight oz/yd²	Required Minimum Arc Rating of PPE cal/cm²
0	Non-melting, flammable materials (i.e., untreated cotton, wool, rayon, or silk, or blends of these materials) with a fabric weight of at lest 4.5 oz/yd² (1)	4.5 – 7	N/A
1	FR shirt and FR pants, or FR coverall (1)	4.5 – 8	4
2	FR shirt and FR pants (1 or 2)	9 – 12	8
3	FR shirt and FR pants plus FR coverall (2 or 3)	16 – 20	25
4	FR shirt and FR pants plus double layer switching coat and pants (3 or more)	24 – 30	40

***ATPV is defined in the ASTM P S58 standard arc test method for flame resistant (FR) fabrics as the incident energy that would just cause the onset of a second degree burn (1.2 cal/cm²). EBT is reported according to ASTM P S58 and is defined as the highest incident energy which did not cause FR fabric breakopen and did not exceed the second-degree burn criteria. EBT is reported when ATPV cannot be measured due to FR fabric breakopen.**

Portions reprinted from NFPA 70E Standard for Electrical Safety Requirements for Employee Workplaces

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Design Guide

Effective Date:**Feb 29, 2016**

The exhibit Design Guide is provided as a Word file.

Design Guide

A. Capacitors and Capacitor Banks

1. Description

This section deals with capacitors and capacitor banks with stored energy in excess of 10 J and voltage to ground exceeding 300 V. It is particularly directed to the application of capacitors which are used as a source of pulsed power, for blocking and filtering, and in oscillator and resonant circuits.

2. Hazards, Design, and Operating Criteria

a. General

Capacitor banks shall be isolated by elevation, NEC barriers, or enclosures to preclude accidental contact with charged terminals, conductors, or support structures. Enclosures and barriers shall be used to protect personnel from projectiles that might be expelled from the capacitors during a fault: for capacitor banks capable of storing more than 50 kJ of energy, special enclosure requirements may be required to provide protection.

Oil filled capacitors should be avoided in radiation environments. Experience has shown that the radiation breaks down the oil and causes a potential over pressure hazard.
Access to capacitor areas shall be restricted until all capacitors have been discharged, shorted, and grounded.

All capacitors in storage shall be short-circuited with a conductor securely fastened to the terminals and left in place until the capacitors are used again or scrapped. Ventilation to keep the temperature of ambient air at capacitor installations at recommended levels shall be provided.
Capacitor cases, unless obviously connected to a recognized grounding conductor or grounded structure, shall be considered "charged", and shall be grounded in the same manner as capacitor terminals. The capacitor cases should be properly labeled, with their operating voltages identified in accordance with OSHA regulations.

b. Stored Energy

Capacitors or capacitor banks with stored energy of 10 J or more constitute a LETHAL SHOCK HAZARD. Although they have been disconnected and discharged, capacitors may accumulate a charge without benefit of connection to an external power source. This charge is caused by the slow release of electric charges from within the dielectric material, because of the phenomenon known

as “dielectric absorption”. It also is possible for capacitors to acquire a charge from local atmospheric electrical disturbances and by corona from a nearby high-voltage terminal, such as on an adjacent capacitor.

During transient conditions, capacitors could acquire a charge hazardous to personnel, or an over-voltage harmful to the capacitor itself because of inductance in the circuit. This inductance can be in the form of coils or magnets, or in wiring and leakage.

c. Discharging

Discharging a capacitor by a grounding hook can cause an electric arc at the point of contact. Such release of energy can also cause burns from thermal radiation or flying molten metal. Any residual charge shall be removed from capacitors by grounding the terminals with a low-impedance grounding hook before beginning to work with them. Automatic discharge and grounding devices shall not be relied upon for personnel safety; grounding hooks must be used to ensure safe operations. Grounding hooks shall be inspected prior to use to ensure that all connections are secure, and that the grounding conductor is in good condition. Grounding the output typically will not discharge internal capacitor banks.

Short circuit all capacitors in storage with a conductor not smaller than 14 AWG, securely fastened to the terminals and left in place until the capacitors are to be used again.

d. Connecting

A dangerously high voltage can exist across the impedance of a few feet of grounding cable at the moment of contact with a charged capacitor. Operating personnel shall stand clear of cables attached to grounding hooks at the moment of application to a capacitor terminal.

e. Safety Devices

Safety devices, such as shorting switches and grounding switches, and their associated cables and cable connectors, shall be designed to withstand the mechanical forces from the large currents which result from their operation.

Protective devices, such as automatic shorting switches and grounding hooks, shall be tested after installation, and at a minimum of every 3 years thereafter to verify their operation.

f. Faults

Internal faults may rupture capacitor containers, particularly when

many capacitors are connected in parallel. This rupture is normally caused by the boiling of the insulating liquid in the capacitor and may even occur where the peak fault current is not high. Metal case capacitors will usually swell and vent before large amounts of overpressure occur. Cast or phenolic cased units present a more serious hazard: the force of the explosion may cause serious injury.

Capacitors should be provided with current-limiting devices, such as fuses and resistors, which are capable of interrupting available fault current or limiting it to safe and manageable values. When this is not possible, alternate means to ensure personnel protection should be incorporated (i.e., enclosure). Rupture of a container by an internal fault can create a fire hazard because combustible dielectric could be ignited.

g. PCBs

For capacitors with any quantity of poly-chlorinated biphenyls (PCBs), refer to the PCB Management Subject Area.

h. Fuses

Fuses may be used to interrupt the discharge of energy from a power source or a capacitor bank into a faulted individual capacitor. If fuses and the capacitors are not adequate for this application, they could explode, expelling dangerous projectiles. Fuses designed for AC operation depend on the current passing through zero on the next reversal of the line voltage to guarantee that the fuse will clear. Even if the correct DC-rated fuses are used, a complete capacitor bank may discharge through a fault at very high currents before the fuse clears. The fuse in this type of application usually does not allow a shorted capacitor to permanently load a power source that is feeding it, such as in factor correcting service on power transmission lines.

i. Bleeder Resistors

It is essential that bleeder resistors be used on each capacitor that is fused to ensure that the capacitor discharges when it becomes isolated. If bleeder resistors are not used to discharge the capacitors, the capacitors must be automatically discharged (See National Electric Code [NEC] 460-6). The residual voltage on capacitors must be reduced to 50 V or less, within one minute.

B. Electrical Conductors and Connectors

1. Description

The conductors and connectors covered in this section are those used in special

R&D activities and include pulsed or continuous high-current, high-voltage, high-frequency, liquid-cooled, and other special conductor and connector applications.

2. Hazards, Design, and Operating Criteria

a. Conductor Overheating

Dense packing of electrical cables in cable trays or raceways can cause overheating and insulation deterioration, leading to electrical arcing and fire. Conductor current capacities shall be de-rated commensurate with density of packing. Conductors shall also have capacity ratings sufficient for the capability of the energy supply system.

b. Insulation

Conductor insulation must be appropriate for the operating and environmental conditions. Insulation shall be selected based on thermal ratings, voltage ratings, mechanical strength, and resistance to moisture, chemical, and radiation environments. Cable exposed outdoors should be identified as being sunlight-resistant. Cable used in air-handling plenums must be specifically rated for this application. The general use of flame-retardant insulation/jacketing systems rated to pass the IEEE-383 vertical tray flame test shall be used where commercially available. Examples are XLP/Hypalon, Hypalon, or a combined insulation/jacket of Hypalon for all cable.

c. Shielded Cable

Shielding confines the electric field of the inner conductor to the conductor insulation system. Insulated cables constructed with metallic sheath armor or with a discharge resistant jacket should be shielded if operated at or about 5 kV. For insulated cables constructed without armor or discharge resistant jacket, shielding should be used when operated at 2 kV or above.

d. Physical Installation

High fault currents, or pulsed operation of cables, can produce large electromagnetic forces, resulting in physical movement of components. Bracing and conductor supports shall be provided that can physically and electrically withstand expected mechanical forces and voltages. Physical barriers shall be provided to separate high-voltage conductors from low-voltage conductors, and they shall be designed to withstand fault conditions. Spacing or loops between high-current supply and return conductors should be avoided to prevent inducing current in adjacent circuits or structural members. Suitable routing and additional protection shall be provided for coaxial cables used in pulsed-power applications,

where the braid of the coaxial cable may have significant voltage with respect to nearby structures. Single conductors installed in cable tray shall be AWG l/O or larger.

e. Metal Pipes
Metal pipes that are used as electrical conductors present shock hazards because they may not be readily recognizable as electrical conductors. Accordingly, labeling, insulation, or other protection shall be provided for metal piping used as conductors.

f. Liquid-Cooled Conductors
Where liquid-cooled pipes or cables are used, sensing devices for coolant flow or overheating shall be provided for equipment shutdown if the cooling system malfunctions.

g. Cable Care
Cables and their insulation systems shall be physically protected. Walking or climbing on cable trays shall not be permitted. Individual or bundled cables shall not be run unprotected across floors for experimental work: suitable protection and suitable cables shall be provided where electrical systems must be run across floors. Cables used in recurring experimental activities shall be carefully handled and stored between uses.

h. Terminations
Improper selection, application, or installation of connectors can cause overheating, arcing, and shock hazards. Connectors shall have adequate current-carrying capacity and voltage rating for their application. Adequate separation shall be provided between adjacent high- and low-voltage cable terminations. Appropriate connectors shall be provided for use with aluminum conductors, and they shall be assembled in accordance with approved techniques. Connectors wired to sources of power should be female. Cable connectors shall be checked periodically and adjusted for tightness in accordance with normal maintenance procedures. Plug-in cable connectors, particularly those for high voltages or high currents, shall be mechanically fastened in place, and the power source shall be energized before inserting or removing these connectors. Cable splices are not permitted in conduit runs or where inaccessible, but may be used in cable trays provided they remain accessible and do not project outside the side rails. Cable splices must be adequately insulated.

i. Wiring Methods:
Flexible cords and cables are not permitted to be used as a

substitute for fixed wiring of a structure, unless permitted by the National Electrical Code. In accordance with the National Electrical Code, wires and cables must be physically protected by being run in cable tray (considered below) or in raceway, a general term denoting enclosed channels (rigid and flexible conduit, wiring trough, etc.) designed expressly for holding wires, cables, or busbars. Just as ac power systems are afforded superior protection by installation in raceway, related or similar important systems should also be installed in raceway. Cables that share raceway or cable tray shall all have insulation ratings adequate for the voltage expected on any conductor in the raceway or cabletray.

ii. Use of CABLE TRAY is limited:
The National Electrical Code (Article 392) requires that only qualified persons may install and maintain cable tray systems. Cable trays shall be installed as complete systems, shall be exposed and accessible, and shall be electrically continuous and grounded. Single conductors installed in cable tray shall not be smaller than # l/O AWG. Power and control cables supported by cable tray should be rated for use in cable tray. Power cables should be installed in cable trays separate from control, signal, and instrumentation cables. Listed fire stops should be provided when tray penetrates floors or other fire cutoffs. Wires may not be spliced where hidden in conduit, although splices are permitted in trough or in cable tray (splices may not project outside the tray rails). Note that screwed and bolted connections and poorly soldered lugs tend to loosen and overheat; crimped connections are more uniform in application and are recommended. Cable tray is generally provided to support cables: the integrity of cable tray systems should not be compromised by any items added to the cable tray cross-section, outside rails, or supports. Other restrictions apply to raceway or cable tray installations; appropriate knowledgeable professionals should be consulted when such installations are considered. They will consider the maximum allowable percentage of cable cross-section allowed to be filled with cable, the flammability rating and flame propagation characteristics of items within the tray, the cable tray support system and weight restrictions placed on the cable tray installation, and other items.

C. Enclosures for Electrical Equipment

1. Description

This section covers all enclosures for equipment and also includes equipment where RF radiation or stored energy electrical components are contained.

2. Hazards, Design, and Operating Criteria

a. General

All cabinets and enclosures shall be of appropriate materials and finish for the environment in which they will be placed. Enclosures structurally adequate for their intended use shall be provided. Adequate material shall be used in viewing windows to protect personnel from flying parts that may result from electrical faults. Enclosures shall be designed so that no contact with live electrical parts can be made from outside, and so that adequate interior working space is provided. Enclosures shall be grounded.

b. Eddy Current, RF, or Microwave Heating

Signs and/or warning lights shall be provided to indicate these hazards. Properly shielded enclosures shall be provided for RF power equipment, and particular attention shall be paid to all openings, such as doors, access ports, and viewing windows as inadequate shielding can result in burns. Compliance with the Radiofrequency/Microwave Radiation Subject Area shall be provided by the use of proper equipment at the operating frequency to perform initial and routine measurements of radiation leakage and taking special measurements after equipment modifications or changes in radiation levels.

c. Interlocks

Electrical interlocks shall be provided as appropriate on doors, easily removable panels, and swinging panels that interrupt the circuit whenever open. Door locks should limit access to authorized personnel only. When a temporary enclosure is necessary, it should be electrically interlocked, if possible, and should meet the same requirements as a permanent enclosure where hazardous conditions exist, before energizing equipment. Interlocks provide additional protection to systems and should be used as appropriate.

d. Compartmentalization

Separate high- and low-voltage and/or instrumentation and control compartments shall be provided in all enclosures, especially large, high power systems.

D. Inductors, Electromagnets, and Coils

1. Description

This section covers inductors, electromagnets, and coils with stored energy of more than 10 joules, which are used in the following applications:

- Energy storage systems.
- Inductors used in a pulsed system with capacitors, to provide oscillatory wave-shaping or resonant conditions.
- Electromagnets and coils which produce magnetic fields to guide or confine charged particles.
- Inductors used in DC power supplies.

2. Hazards, Design, and Operating Criteria

a. Inductor Damage

Overheating from overloads, insufficient cooling, or failure of the cooling system could cause damage to the inductor and possible rupture of the cooling system. Sensing devices (temperature, coolant-flow) shall be provided for water or air-cooled inductor and magnet coils, interlocked with the power source. These devices are for safe shutdown if temperatures are abnormally high or the cooling system fails.

b. Fringe Fields

Large electromagnets may produce external fields which can affect the calibration and operation of protective instrumentation and controls. Refer to the Static Magnetic Fields Subject Area for guidance.

c. Eddy Currents

Whenever a magnet is suddenly de-energized, production of large eddy currents in adjacent conductive material can cause excessive heat. A fast rate-of-change of field strength produces high turn and terminal voltage and also can induce voltages in adjacent conductors, which can be hazardous. Equipment supports and bracing to withstand forces produced during normal operation and fault conditions shall be provided.

d. Leads

Loose and broken inductor or magnet connections can produce excessive heat and arcing. Extreme caution shall be exercised when disconnecting the leads of any large inductor. First, the power source should be locked out, as per the Lockout/Tagout (LOTO) Subject Area and then, when the current has decayed to zero, the leads can be disconnected.

e. Quench

Large amounts of energy stored in the field of an energized inductor can damage equipment and injure personnel if the energy is suddenly discharged in an inappropriate manner. A means shall be provided for safely dissipating stored energy when excitation is interrupted or when a fault occurs. The relatively long-time constants in large inductive

circuits can cause the continuous release of energy into a fault, producing severe equipment damage and possible fire. An appropriate emergency off system shall be provided to dissipate stored energy and to disconnect it from the source. All terminals must be covered to protect from accident shorting.

f. Grounding
Electrical supply circuits and magnetic cores shall be grounded wherever feasible and fault protection shall be provided. Ground-fault detection shall be provided for grounded and ungrounded electrical circuits (floating systems), for alarm purposes or for equipment shutdown.

g. Warnings
Signs and/or warning lights shall be provided to indicate equipment hazards.

E. Instrumentation and Control Systems

1. Description
Instrumentation and control systems covered in this section are those used in R&D applications.

2. Hazards, Design, and Operating Criteria

a. Process Isolation
Instrumentation and control (I&C) systems may be connected to circuits operating at hazardous voltage levels or with the capability of delivering high currents. Failure of insulating or isolating devices could extend such dangerous conditions to personnel, or could alter the components in such a way that control of the process is lost, or information about the process is distorted. To prevent this from occurring, isolation must be provided for all such systems, between the I&C components and the process or equipment that is being monitored and controlled. Isolation shall include physical separation between power and signal circuitry and equipment, and the use of surge protectors and isolation devices such as transformers, high impedances, optical coupling, and telemetering. Both normal and fault conditions shall be considered during the design of such systems. Signal wiring shall not be bundled with power wiring. Consistent grounding methods shall be used in each facility for shields in instrumentation cables.

b. Hazardous Systems
Failure or malfunction of a system can produce erroneous readings which can prevent recognition of hazardous conditions, can cause

unintentional operation of hazardous equipment, or can inhibit the operation of safety devices such as enclosure interlocks, warning devices, or overload protection. Redundant controls and instrumentation shall be provided on sections of a system where a single failure could otherwise result in hazardous conditions or operation. Redundant instrumentation should monitor actual conditions and provide independent verification of process conditions by monitoring required system attributes, i.e., flow derived from a flow monitor and not simply from operation of a solenoid valve. Control circuits shall be designed to be fail-safe, so that loss of power or a similar equipment failure does not result in a hazardous operating condition. A clear indication shall be provided of the status of hazardous remotely-controlled equipment, and each specific command shall be verified by definite feedback to the operator. Control circuits shall be designed to preclude the existence of "sneak" circuits (undesired circuits through series-parallel configurations), and shall be arranged so that accidental grounding of one conductor cannot cause safety devices to become inoperative.

c. Electrical Ratings

Electrical ratings of equipment and conductors shall be consistent with requirements of the National Electrical Code. Relay and interlock contacts on instrumentation and protective circuits shall be rated at least as high as the voltage of the circuit, and current ratings shall be as high as the normal disconnect rating of the protective fuse or circuit breaker used. Circuit inductance shall be considered in the application of relays and interlocks. Terminals in instrumentation and control compartments shall be covered and conspicuously labeled.

d. Computers/Programmable Controllers

Systems controlled by computers or programmable controllers shall be integrated to be fail-safe, so that failure of the stored-program device will result in a safe condition. The failure monitor shall be arranged in the form of a "heartbeat" circuit or equivalent, such that, a failure will not cause an unsafe condition in which must be continually refreshed by the computer/programmable controller. Manual overrides shall be provided so that a process connected to a computer or programmable controller can be interrupted by an operator regardless of the state of the stored-program device.

e. Manual Restart

Protective interlock circuits and process equipment controls shall be designed so that restoration of control or interlock circuits, or

resetting of equipment that caused a process trip, will not automatically restart the process, without operator reset.

f. Safety

Immediate attention shall be given to malfunctions or failures of I&C systems adversely affecting safety, and corrective action should be taken in accordance with the Occurrence Reporting and Processing System (ORPS) Subject Area. All new or modified instrumentation and control systems shall be carefully inspected and tested to assure that they perform in accordance with operating and safety requirements. Interlocks provided for personnel safety shall be tested and documented initially and at least annually to assure operability. Written checklists, including simulation of failures, operation of upper- or lower-limit control features, safety interlocks, and interlock systems should be incorporated into the procedures. Safety interlocks shall not be used in lieu of lockout/tagout.

g. Graphic Display Panels

Graphic control displays should be provided for large or complex systems. Consistent labeling types and nomenclature shall be used for control panels.

F. Power Supplies

1. Description

This section covers power supplies that are used in R&D activities. The power source can be either AC or DC, and from a protection point of view, the circuit extends to the connected load.

2. Hazards, Design, and Operating Criteria

a. General

Before initial operation and at least annually thereafter, the power supply shall be carefully inspected, calibrated, and the inspection documented, and all protective devices shall be checked.

b. Covers

Personnel could unknowingly come in contact with energized equipment. All terminal strips and live components shall be covered or protected by barriers; where visibility of the components is necessary (e.g., relays, contactors) the covers shall be made of transparent material. To the extent possible, access to incoming power to a power supply shall be limited, preferably through use of a separate compartment, or barriers.

c. Power Sources

Multiple input sources shall be avoided. A power supply in a remote location could be energized and personnel could unknowingly come into contact with the energized equipment (connected load). Where other sources are connected to a power supply, either externally or coupled into the power supply from the load itself, the power supply shall be clearly labeled with the source name and its location. Equipment shall be labeled to identify input power sources, which shall be labeled to identify their connected power-supply loads. Induced or back emf sources shall also be identified. Equipment which is remotely controlled or unattended while energized shall be labeled with emergency shutdown instructions, and the identity of the personnel who are responsible for the equipment shall be on the power supply, or prominently displayed in the building or area location.

When power supplies serve more than one load, switching errors can result in energizing the wrong equipment (load) creating hazards to nearby personnel.

d. Faults

Electrical faults or switching transients can cause voltage surges in excess of the normal terminal voltage rating of the power supply. Electrical faults can cause conductors to melt, and other components such as insulating materials could melt, burn, or explode. Protection from AC and DC instantaneous and continuous overcurrent, overheating, shall be provided, as applicable. Load protection and ground protection shall be coordinated with the above, including cables (insulation, rating, and size).

e. Wiring

Power supply power, control wiring, and load cable insulation shall be high temperature rated wherever possible, shall be selected for low oxygen content, and shall have passed IEEE or UL flame tests.

f. Component Failure/Overload

Overload or improper cooling can cause excessive rise in temperature, resulting in possible damage to equipment and associated hazards. Internal component failure can cause excessive voltages on external metering circuits and low-voltage rated components of the power supply. Provide overcurrent, undervoltage, or other protection for both power supply and load as appropriate.

g. Shutdown

The design of the power supply shall include a positive means of interlocking (preferably mechanically) its cabinet so that accidental access to energized components is prevented. The main input circuit breaker or disconnect switch shall be clearly identified, located as near as possible to the power supply, and equipped with lockout provisions coordinated with interlocks of the power supply. Control power should be generally derived from the AC input power so that the disconnect de-energizes both. In addition, a second means of shutdown shall be installed at the power supply, when the power supply is not in sight of the main disconnect device. Before entering power-supply or associated equipment enclosures the following precautions shall be taken:

(1) Open and lockout the main input power circuit breaker and verify that the input voltage is off (see the Lockout/Tagout [LOTO] Subject Area).
(2) Check for auxiliary power circuits which could still be energized.
(3) Inspect automatic shorting devices if installed, to verify proper operation.
(4) Short power from each terminal-to-ground and terminal-to-terminal, with grounding hooks.

An automatic switch or a bleeder resistor shall be provided in the power supply to discharge all stored energy when the power supply is turned off. This feature shall be interlocked with the other power supply safety systems, especially where large capacitive filters or capacitor banks are used. The residual voltage on capacitors must be reduced to 50 V or less within one minute. In the control systems of the power supply, remote/local mode switches are desirable. Remote shutdown or means for emergency stop shall also be provided.

h. Discharge

Output circuits and components can remain energized while input power is interrupted, because of parallel power sources or stored energy in reactive components (e.g., capacitors). For inductive loads, discharge paths for the stored energy, including, but not limited to, thyrites, MOVs, and reverse connected diodes, shall be provided.

i. Indicators

Auxiliary and control power circuits can remain energized when the main power circuit is interrupted. Alarms, signs, or lamps shall

be provided to indicate that a power supply is energized. If the local switch is remote from the power supply, there should also be a lamp to indicate a load.

G. Resistors and Resistor Banks

1. Description

Resistors and resistor banks used in R&D are typically used to connect instruments to a high-voltage circuit (as in a voltage divider and filter damping resisters), and to absorb the discharge of stored energy, where they may carry pulsed current exceeding their steady-state rating. Resistors and resistor banks may also be used in safety-related functions, such as resistive grounding.

2. Hazards, Design, and Operating Criteria

a. Resistor Ratings

Each resistor should be operated within its rating or capability. Large currents from faults or abnormal circuit operation may produce forces capable of destroying resistors. Resistors used where large pulse or fault currents may be expected shall be robust enough to withstand the resulting magnetic forces.

b. Physical Installation

Improperly installed resistors may injure personnel or damage adjacent equipment, because resistors may operate at temperatures high enough to cause severe burns or to ignite combustible materials. They may also be used in applications involving high voltages or currents. Resistors used in hazardous applications should be installed in an enclosure to prevent injury and minimize damage if a failure should occur. The enclosure should be well-ventilated, constructed of non-combustible material, grounded, and interlocked to prevent entry while the resistors are energized. Signs should be posted to warn personnel of the hazards present in resistor installations; warning lights and barriers may also be required.

Resistors should be installed in a manner to preclude damage to adjacent components from heat. The insulation of conductors used to connect resistors should be able to withstand the temperatures and voltages encountered. Resistors used in high-voltage circuits should be protected from surface contamination caused by adverse environmental conditions.

c. Transient Conditions

Resistors should be capable of withstanding any transient overvoltage to which they may be subjected. Resistors used in

pulsed circuits or discharge circuits can be physically damaged when operated at high-current or high-voltage levels, or when subjected to overvoltages, which might cause electrical arcs. Resistors applied in pulsed circuits should be sized to accommodate any possible succession of pulses. Resistors in grounding circuits may develop hazardous voltages during the flow of fault or discharge currents.

d. Hazards Introduced by Resistor Failures

When failure of a resistor could expose personnel to hazardous voltages, the installation of two or more resistors in parallel should be considered, each rated for maximum operating conditions. For example, failure of a resistor used in the low-voltage section of a voltage divider will result in applying the high voltage to the divider output terminal. Also, failure of a capacitor bleeder resistor could expose personnel to hazardous voltages.

Failure of an inductor discharge resistor, such as that used for a motor field winding, can result in hazardous and destructive voltages in the motor circuit. Failure of a resistor used as a discharge device for an energy storage system may create a hazardous condition when the discharge circuit does not function as intended.

e. Water-cooled and Forced-Air Cooled Resistors

Temperature-sensing or flow-sensing devices should be installed in resistor installations which require liquid cooling or air cooling. Water-cooled resistors may explode if insufficiently cooled; electrolytic resistors may simply open if the fluid level gets low. Resistors can operate at temperatures that are high enough to cause burns to personnel or ignite combustible material.

f. Inspections

The resistor installations including enclosure interlocks should be inspected periodically.

H. Electrical Switches

1. Description

This section covers special non signal electrical switches used in R&D where safety requirements are not specifically covered by existing codes.

2. Hazards, Design, and Operating Criteria

a. Electrical Shock

Electrical shock from contact with live exposed switch parts is a common hazard. Lockable and grounded switch enclosures shall

control access to the switches. Protective covers and/or barriers shall be provided when practical to prevent personnel from coming in contact with live parts.

b. Location
Switches shall be located as close as practical to equipment they are servicing (within line of sight). Switches shall be labeled as to where they are fed from. Switches, contactors and relays shall be mounted so that gravity tends to open the contacts or switch blades with loss of power or poor mechanical connection.

c. Phase Arrangement
Both line and load conductors shall be phased A-B-C from left to right on all three-phase switches, circuit breakers and contactors.

d. Operation
There must be assurance that switches not designed to disconnect under load conditions cannot be opened when the circuit is energized. Switches not intended to be opened under load conditions can create severe arcing.

e. Maintenance
A system of interlocks which interrupts the normal operating control power to remotely-controlled switches during testing or maintenance shall be provided. Locking features on switches to prevent operation when personnel are working shall accommodate the requirements of the Lockout/Tagout (LOTO) Subject Area.

Periodic (at least annual) inspections of switch and switch operating tests shall be performed and documented for critical or high value equipment.

f. Fault Conditions
Sufficient energy may be developed under fault conditions to cause a switch to explode. Arcing at switch terminals under transient fault conditions can subject the isolated section of a circuit to hazardous voltages and power levels. Switches used above their voltage and current ratings can cause shocks or other electrical hazards. Switches shall be selected so that under fully loaded and fault conditions their voltage, current, and interrupting ratings are not exceeded.

g. Unintentional Operation
Electrically controlled switches operated unintentionally, because of malfunction of the control circuits, present a shock hazard. All switches shall have a positive indication of switch position and

function; unlabelled or improperly switches also present a shock hazard. Operating procedures for checking that no one is working on the load and that all protective grounds have been removed before restoring power shall be established and implemented.

h. Switch Locking

Suitable means shall be provided for locking secondary isolating and/or transfer-type switches in the desired position. Wherever possible, however, disconnect switches should not be locked in the ON position, preventing circuits from being readily de-energized.

I. Storage Batteries and Battery Banks

1. Description

This section covers rechargeable-type batteries used for storage of electrical energy. These criteria are not limited to batteries of a particular voltage and energy rating, because the nature of the associated electrical hazards is similar for any battery size, except that the severity of the hazard increases with increased battery rating. This section is not intended to cover small batteries, i.e., watches, calculators, computer backup or hearing aids.

2. Hazards, Design, and Operation Criteria

a. General

All storage battery installations, including handling and storage areas, require special attention to ensure that batteries have a safe operating and storage environment.

b. Access

Access to station storage battery areas should be limited to authorized personnel only, through the use of locked doors and/or locked gate enclosures. Warning signs shall be posted prohibiting smoking.

c. Location

Batteries shall be located in a dedicated clean, dry room where there is sufficient ventilation to prevent an accumulation of explosive mixture of gases from the batteries. Unrestricted natural air movement in the vicinity of the batteries, together with normal air changes for occupied spaces or heat removal, may be sufficient. Mechanical ventilation in the vicinity of the batteries will be required for confined spaces. Ventilation can consist of a fan, roof ridge vent, louvered areas, or combinations of these. The ventilation system must be Class I Division I, as per NEC 500 and approved by the Safety and Health Services Division (SHSD).

d. Vapors
The vapors given off by storage batteries are very corrosive; therefore, wiring and its insulation is required to be of a type that will withstand corrosive action. Metal battery racks and metal raceways shall be constructed of treated material to make them resistant to corrosion.

The floor of storage battery areas should be of an acid-resistive material, or be painted with resistive paint, or otherwise protected.

e. Physical Installation
Choice of battery type, charging circuitry, and construction of storage area shall be consistent with the intended application of the installation. Protection devices installed shall be as required by applicable codes and/or specified by manufacturer of packaged battery/charger system. Large battery banks, used for uninterruptible power supply service (UPS) should have fused disconnects installed as per NEC Article 480.

Battery racks shall be firmly anchored to either the floor or to the wall. Metal battery racks shall meet the requirements of NEC 480.8.

f. Maintenance
Procedures for regularly scheduled maintenance, testing, and inspection shall be developed and implemented. These procedures should include testing and recording voltages and specific gravity of batteries, and the routine cleaning and torquing of connections. Maintenance, testing, and inspection of package battery/charging systems should follow the manufacturer's recommendations. Use NFPA 70B as guidance when no specific manufacturer's information can be found.

g. Spills
Provisions for neutralizing acid spills (bicarbonate of soda and water solution) should be provided. Equipment shall be provided to prevent spills from entering the facilities drainage systems, (i.e., secondary containment).

h. Personnel Protection Equipment
Personal protective equipment for personnel working in the battery areas are goggles and face shields, acid resistant gloves, and protective aprons. An eye wash station and an emergency shower in close proximity to the storage area shall be installed, and shall be easily accessible.

J. Chemical, Biological, Fire, and Other Hazards Associated with Electrical Equipment

1. Description

Electrical apparatus may contain hazards, which, while not electrical in nature, are intimately associated with the equipment. These hazards may involve physiological effects, toxicity, fire, explosion, corrosives, failure of safety systems from non-electrical causes, and many others. This section is not intended to present a detailed description of the hazards, with a full set of design and operation criteria for each. Rather, it is a list of some of the more probable dangers which may be encountered and which need to be considered during the safety review.

For most of the items listed, detailed codes, references, and standards exist. These explain the safety aspects of each area in great detail and may be consulted for more information.
This list can never be complete since new equipment, materials, applications, and designs continue to provide further sources of unusual and hazardous situations. Therefore, it is essential that all new systems are reviewed commensurate with the hazards involved.

2. Hazards, Design, and Operating Criteria

a. General

Warning signs shall be displayed indicating the presence of any potential hazard such as gas, fumes, laser light, UV, noise, toxic chemicals, nuclear radiation, fire hazards, magnetic fields, electromagnetic radiation, hydrogen, or other explosive gases. Operating permits flashing lights and audible alarms may be necessary in some cases. Warning signs should conform to OSHA guidelines.

Provide sufficient access and illumination around electrical equipment.

Areas where any toxic fumes may be present should be adequately ventilated. Permits may be required for air emissions (see the Environmental Monitoring Subject Area).
Grounded protective covers or barriers shall be provided for high voltage terminals and for low voltage terminals that have high currents available, to protect from inadvertent contact with energized parts.

Eye wash and safety showers near battery banks or other acid-containing equipment shall be provided, maintained, and kept assessable. Protective devices, equipment, and/or systems shall be

designed to be FAIL-SAFE, wherever practical.

Intercoms and telephone should be near hazardous equipment for use in emergencies. Their locations should be reported to Fire/Rescue and be properly posted, well-marked so that proper instructions can be given to responding emergency personnel.

A distinctive orange color-code and/or label shall identify any component which in its common use is non-hazardous, but in its actual use may be hazardous (e.g., a metallic cooling-water pipe also used as an electrical conductor, carrying high voltage or high current).

Warning or pilot lights shall be installed on the equipment and clearly indicate when equipment is energized.

b. Grounding

Metal cabinets, enclosures, and structural components and equipment shall be grounded with easily recognizable external grounding conductors sized for the maximum available fault currents.

Safety grounding hooks for hazardous electrical equipment for R&D shall have the following features:
(1) A visible, extra-flexible copper conductor of adequate size.
(2) Connectors crimped and/or soldered, and
(3) A bare conductor clearly visible through its insulating sheath.
(4) A bolted on connection from the conductor to the building ground. Spring connectors should be avoided.

Grounding hooks shall have a clearly visible metal-to-metal bolted connection to equipment ground, shall be of sufficient number to satisfy the equipment grounding requirements, and shall be located in a visible and accessible location.
Where it is necessary for safety in equipment grounding, a discharge point should be provided, with impedance capable of limiting the current to 50 A or less. A direct grounding point shall also be provided and the discharge and grounding point shall be clearly labeled.

c. Specific Hazards

- **Ozone**
  Many electrical devices generate significant quantities of ozone from sparking, corona, or ultraviolet light. Ozone, in concentrations as low as 0.1 ppm, can result in observable

physiological effects. In areas where ozone may be produced, ventilation shall be provided (see the Indoor Air Quality Subject Area).

- **Hydrogen**
  Hydrogen is used often in R&D for accelerator targets and cryogenic magnets and is also a by-product of battery charging or other electrolytic type of operations. It is a highly flammable, highly explosive gas with a lower explosive limit of about 4% in air. There are usually pieces of electrical equipment used in conjunction with the hydrogen device, and any one of these may act as an ignition source during a hydrogen release. All sources of ignition should be removed from the area or explosion proof equipment used as per National Electric Code Article 500. (See the Fire Safety and Cryogenics Safety Subject Areas.) All Hydrogen use must be reviewed by SHSD.

- **Superconducting Devices**
  The increasing use of superconducting magnets and other devices presents several different hazards. If hydrogen is the cryogenic fluid, it is a potential fire and explosion hazard. Cryogenic temperatures may cause severe "burns". When a cryogenic magnet "quenches", it may cause a sudden pressure buildup as the liquid turns to gas. This pressure buildup can rupture the containment vessel and create an explosion-type hazard. (See the Cryogenics Safety Subject Area.)

- **Chlorinated Oils**
  Oils, with trade names such as Chlorinal, Arochlor, Inerteen and Askarel, which have been modified to be fire-resistant, are not to be used on-site. (See the PCB Management Subject Area.)

- **Batteries**
  In addition to the electrical hazards associated with high current storage batteries, there are other problems. The most commonly used batteries have a sulfuric acid electrolyte which requires careful handling. During charging, hydrogen is generated in the cells and an inadvertent spark can cause the battery to explode. Other toxic gases may also be generated (See section I. Storage Batteries and Battery Banks).

- **Noise**
  Continued exposure to very high noise levels such as may

be present in the vicinity of some electrical equipment causes hearing to deteriorate. Sudden loud noises, such as a spark gap firing or capacitor bank discharging, can create a safety hazard by startling individuals who might be working on hazardous equipment such as machine tools or electrical equipment. (See the Noise and Hearing Conservation Subject Area.)

- **Coolants**
  The coolants used in electrical equipment are most commonly water, oil, and antifreeze, such as solutions of ethylene glycol. Release of the coolant near energized components can be a hazard. Water may create a leakage path for voltage, initiate short circuits, interfere with interlock systems, and create ground paths. Oil and glycol, when released, may cause a slippery surface as well as accidental electrical shock, and could become an environmental issue. Appropriate floor drainage shall be provided wherever electrical equipment is located, to minimize electrical shock hazards from accumulated moisture.

- **Environmental Effects**
  Any device which is used as part of a safety system is subject to malfunction as a result of environmental conditions. A relay may fail to release in the presence of a large stray magnetic field. Dirt or dust may make a contact inoperative and such failures may make a safety system inoperative. The environmental factors which have to be considered include temperature, dirt and dust, moisture, ice, dc magnetic fields, and electromagnetic fields.

- **Fire Hazards**
  Many of the materials used to construct electrical equipment are flammable. Inherent ignition sources are present in most electrical equipment and a fire is always a potential danger. Wire-insulating materials and capacitor oils that are commonly used can generate large amounts of smoke with toxic fumes arising from the chlorine used in many insulating materials.

- **Thermal Sources**
  Electrical equipment contains devices operating at temperatures which can cause thermal burns or initiate fires.

- **Moving Mechanical Devices**
  Unprotected actuators, fans, blowers, gears, and pulleys present a safety hazard. Guarding should be in conformance with OSHA. Automatic starting equipment also poses a hazard, and shall be as such.

- **Light Sources**
  Lasers, ultraviolet and infrared light sources, spark gaps, and other devices can constitute severe eye hazards. The ultraviolet light can cause conjunctivitis, which may lead to permanent eye damage during very short exposures. Laser beams can cause retinal damage and severe burns to exposed body areas. (See the Laser Safety Subject Area.)

- **Magnetic Fields**
  There is concern that there may be effects to biological organisms from exposure to dc magnetic fields. Carrying magnetic tools or equipment near magnets with large stray fields can lead to physical injuries (See the Static Magnetic Fields Subject Area.)
  Electromagnetic Radiation High-power pulses electromagnetic radiation can cause secondary effects near the source, such as sparking between any conducting materials in the area, heating of nearby objects, and biological effects such as tissue burning. (See Radiofrequency/Microwave Radiation Subject Area.)

- **Bio-electronic Implants**
  Many people have implants, such as pacemakers, which may be sensitive to electromagnetic fields. Exposure to electromagnetic fields should be avoided.

- **X-rays**
  Many high voltage devices (greater than 10 kV in vacuum such as klystrons, high voltage rectifiers, and high voltage tubes generate x-rays as an unwanted by-product. Proper attention to personnel protection shall be considered. Shielding for x-ray sources as well as high voltage devices producing x-rays as a by-product shall be provided. (see the Radiation-Generating Devices Subject Area)

- **Nuclear Radiation**
  Electrical and electronic equipment, which has been subjected to nuclear radiation may become activated and present a radiation exposure hazard to personnel.

- **Stored Energy Equipment**
  In addition to the electrical hazard, energy storage devices are capable of creating severe arcs and fireballs involving the vaporization and scattering of copper, steel, or other materials in the arc vicinity. Severe skin and eye damage can result from such an arc. An exploding capacitor can project busing and other material a considerable distance. In structural failures strong magnetic forces in coil and magnets can in some cases, produce hazards.

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Electrical Equipment Labels

Effective Date:**Feb 29, 2016**

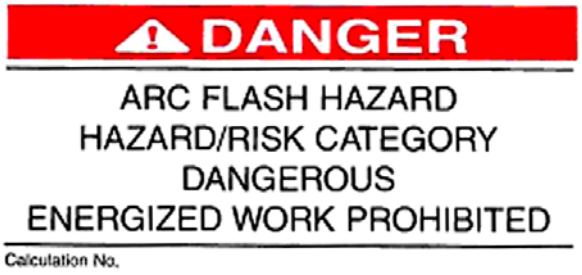
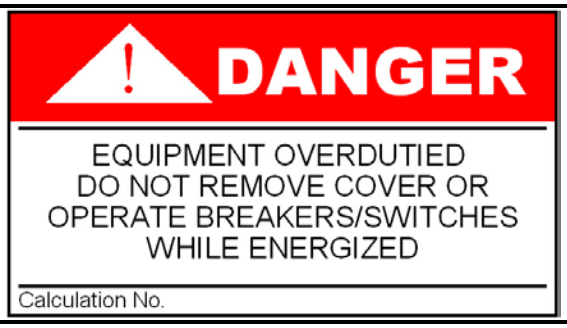
The exhibit Electrical Equipment Labels is provided as a Word file.

Exhibit Electrical Equipment Labels

	If the calculated Hazard/Risk Category of the equipment is greater than 4, BNL is defining this as "Hazard/Risk Category DANGEROUS". This equipment shall not be operated or work performed on while energized. The equipment has to be de-energized at an upstream disconnect to operate or remove covers.
	If the electrical equipment does not meet the Working Space requirements of National Electrical Code Section 110.26 or 110.34, BNL is not allowing removal of covers while energized. This label may be on equipment that also has the calculated hazard/risk category WARNING label below, but the haz/risk category can only be used for operating the equipment while energized not for removal of covers.
	After BNL completes the arc flash hazard analysis calculations this label will be installed on the equipment with the calculated Hazard/Risk Category. Also listed are the arc flash boundary and the minimum PPE to work on the equipment energized. If the cover is in good shape with all the mounting hardware installed, the circuit breakers or switches may be operated using the "minus 1" rule for PPE only if the equipment is less than haz/risk cat 4.

Archived Labels That Are Acceptable

	This label (or similar) was installed by the manufacturer or by BNL on legacy equipment. This is a generic label that does not tell workers the magnitude of the arc flash nor does it list the protective equipment required to operate or work on the equipment. If this is the only label on equipment that is rated greater than 208 volts/225 Amps you must contact F&O or your electrical supervisor for the calculated Haz/Risk Cat.

	This label was used to tell operators and electricians that the maximum energy in the equipment will not sustain an arc flash. There is still a hazard of burning your hands and receiving a shock, but an arc flash that might cause a second-degree burn to the body or face can not happen. The last line is missing and should say "Hazard/Risk Category 1."
	If the calculated Hazard/Risk Category is greater than 4, BNL is defining this as "Hazard/Risk Category DANGEROUS". This equipment shall not be operated or work performed on while energized. This label and the one below will be replaced by the Danger label in the above table.
	This label is used to prohibit operation of the circuit breakers or switches while the equipment is energized. This label may be used with WARNING labels or used with the above DANGER label.
	Equipment discovered during the arc flash analysis not rated for the calculated short circuit current will have this label attached. This label will be replaced by the Danger label in the above table.

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

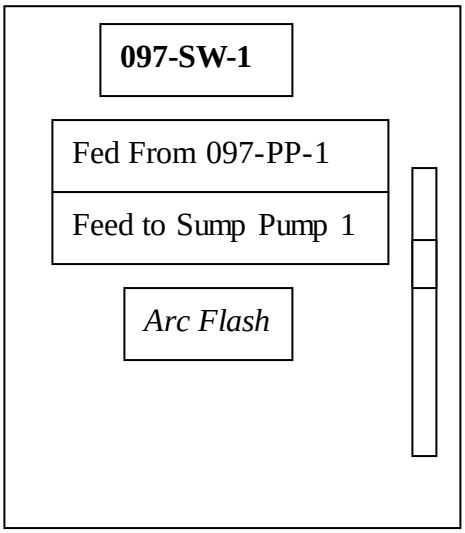
Electrical Panel/Disconnect Labeling Program

Effective Date:**Feb 29, 2016**

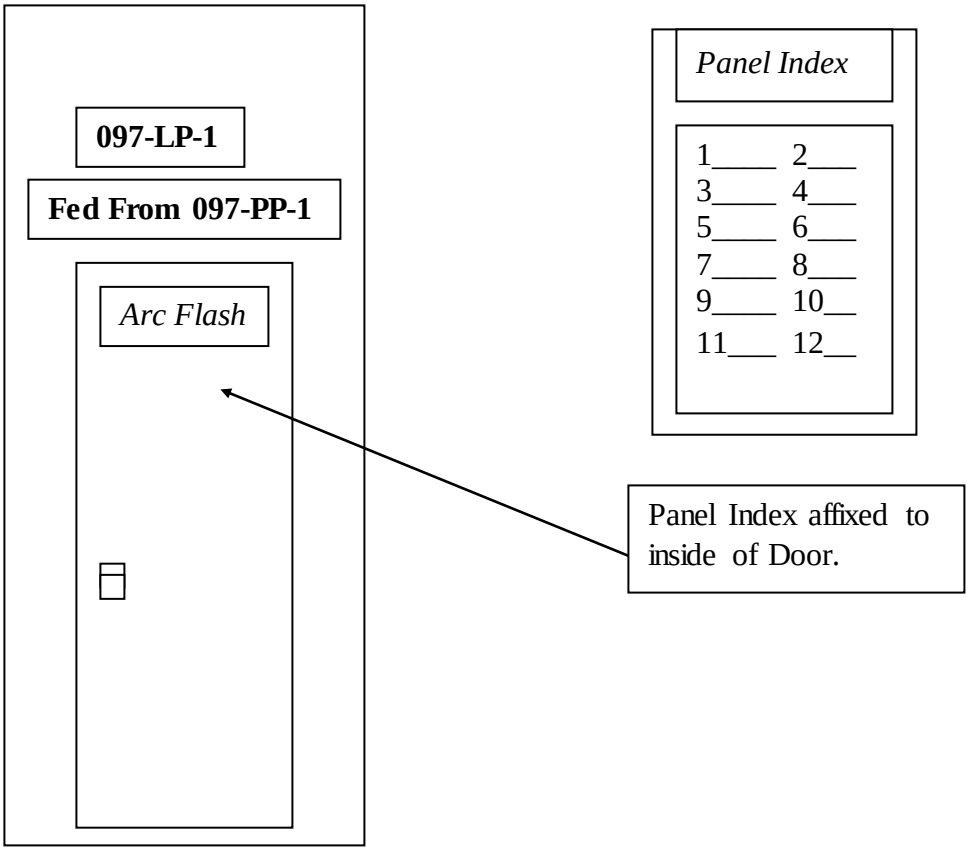
The Electrical Panel/Disconnect Labeling Program is provided as a Word file.

Electrical Panel/Disconnect Labeling Program
Typical Field Layout Drawing

Typical-Disconnect



Typical- Electrical Panel



Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Electrical Safe Work Practices

Effective Date:**Feb 29, 2016**

The exhibit Electrical Safe Work Practices is provided as a Word file.

Electrical Safe Work Practices

Electricity is inherently dangerous and must be treated with respect:

- Always anticipate failure and protect yourself by
  - Unplugging equipment before working on it;
  - Never using flammable materials near electrical equipment that is capable of igniting them;
  - Always turning your face away when operating circuit breakers or disconnect switches;
  - Always being alert when working with electrical equipment, especially in work situations where unexpected electrical hazards might exist.
- Never plug or unplug electrical connectors with wet hands.
- Keep fingers away from terminals when plugging or unplugging connectors (there have been problems with the new telephone chargers that the contacts move).
- Cord and plug equipment must be visually inspected prior to use for external defects, such as
  - Loose parts;
  - Deformed or missing pins (especially ground pin);
  - Evidence of possible internal damage (such as pinched or crushed outer jacket);
  - Tears or dry rot in outer jacket.

(**Exception:** Equipment and extension cords that remain connected and are not subject to damage are not required to be re-inspected until they are relocated).

- Cords and extension cords shall not be fastened with staples or hung in such a fashion to damage outer jacket.
- Flexible cords shall not be used to raise or lower equipment.
- GFCIs shall be used outside or in wet or damp locations.
- GFCIs must be tested per manufacturer's requirements (usually monthly).
- Prior to performing work, always de-energize electrical equipment.
- Never put conductive material near live parts (knife in a toaster).

Light and power panel circuit breakers (20 A) are allowed to be reset only once after tripping if you know why the breaker tripped (used toaster while microwave on and breaker tripped). Otherwise, call Plant Engineering to evaluate. You can only operate circuit breakers and disconnect switches if you are trained.

Per the NEC, **all** electrical equipment (including equipment designed for plug-in operation, cable tray and associated components, electrical distribution equipment, etc.) shall **not** be installed, modified, or put into service without first being accepted by the Authority Having Jurisdiction.

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Reputable Manufacturer Requirements

Effective Date:**Feb 29, 2016**

A reputable manufacturer must meet the following criteria:

- The manufacturer has a North American office/distributor (e.g., Thomas Register®)
- The manufacturer services their products and can provide technical support.
- The manufacturer provides adequate documentation. (acceptable to the approving EQUIPMENT INSPECTOR).
- One piece of unlisted electrical equipment from the manufacturer has been examined and approved by an EQUIPMENT INSPECTOR. Field Evaluation should be done according to the requirements for in-house built/modified equipment.

Note: Manufacturers meeting these criteria are not considered reputable when the manufacturer no longer exists. The age of equipment should be considered when determining the level of field examination with equipment made by a reputable manufacturer.

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Review and Approval of Electrical Equipment and Installations

Effective Date:**Feb 29, 2016**

The exhibit Review and Approval of Electrical Equipment and Installations is provided as a Word file.

Review and Approval of Electrical Equipment and Installations

The goal of the program for review and approval of electrical equipment and installations is to ensure that approved equipment is free from reasonably foreseeable risk due to electrical hazards. This program applies to all equipment built, acquired, or brought onto the Brookhaven National Laboratory (BNL) site by workers, guests and contractors, when the equipment will be connected to a source of electrical power.

Introduction

Electrical equipment and installations are acceptable at BNL only if approved, that is, acceptable to the Authority Having Jurisdiction (AHJ). The AHJ for electrical matters at BNL is the Laboratory Electrical Safety Committee (LESC), represented in the field by the Laboratory Electrical Safety Officer (LESO). The LESC has designated a group of Electrical Equipment Inspectors (EEIs), and given them the authority to review and approve electrical equipment and installations within the Laboratory on their behalf. While electrical equipment includes any physical device connected to a source of electrical power, devices connected to electrical sources below 50 volts are generally exempt from detailed review.

Approval is straightforward for equipment bearing the seal of a Nationally Recognized Testing Laboratory (NRTL), such as Underwriters Laboratories, Inc. (UL) or the Canadian Standards Association (CSA). Go to the Nationally Recognized Testing Laboratory (NRTL) Web site for a list of acceptable NRTLs. Please note that the generic CE mark is a European self-certification applied to a product by a manufacturer or vendor who declares that their product complies with European standards. The CE mark does not represent a third-party product evaluation and is not comparable with the NRTL listing.

OSHA requires that NRTL-labeled equipment must be acquired whenever labeled equipment is available, even if similar unlabeled equipment can be used. OSHA allows for approval of custom-made equipment or related installations, if equipment is determined to be safe for its intended use by its manufacturer, on the basis of test data, which the employer [BNL] keeps and makes available for inspection.

There are cases where the above pathway cannot be followed. These include cases where BNL manufactures equipment or causes the equipment to be manufactured in accordance with a specification, non-listed or foreign equipment is acquired to perform a unique experimental function in support of the Laboratory's scientific mission, and continued use of legacy equipment - some from vendors long out of business. The LESC deals with such issues through NEC Article 90.4, which allows the authority having jurisdiction (AHJ) to waive specific requirements in this Code or permit alternate methods that ensure equivalent objectives can be achieved by establishing and maintaining effective safety. The alternate method lies in a graded approach to approval of all electrical equipment and

installations by the EEIs who devote increased attention to review of non-NRTL equipment.

Electrical Equipment Inspector Qualifications

The process to become an EEI is straightforward. The qualification for becoming an EEI is a minimum of ten years combined schooling/experience with electrical/electronic system design and/or electrical system construction/ installation/inspection/safety. In addition, proposed EEI's attend an overview training presentation and are evaluated in the field while being accompanied by approved EEI's during inspections. The EEI's qualifications and completion of necessary training is reviewed by the Laboratory Electrical Safety Committee (LESC) and if appropriate, final approval is given by the LESC for the EEI to begin inspections without being accompanied by another approved EEI. Another path to be qualified to become an EEI is to become an LESC approved Local Inspectors or Chief Electrical Inspector working under the Electrical Materials and Equipment Installation Inspection program.

Review by Electrical Equipment Inspectors

The desired result of an AHJ electrical equipment inspection is that the approved equipment is free from reasonably foreseeable risks due to electrical hazards. The EEI process has inherent limitations since inspections are limited in scope, they are relatively brief, and there is no significant device testing – certainly not to destruction. EEI review concentrates on determining that equipment is appropriately enclosed so personnel are not exposed to energized parts, that metal parts of the enclosure are bonded and grounded, and that the equipment is afforded adequate overcurrent protection. EEI approval does not indicate total conformance with all applicable standards, nor does it indicate quality, reliability or functionality. EEI approval indicates that the equipment appears to meet minimum safety criteria; the equipment should not cause a shock, burn, or fire if used properly; the equipment is examined to the extent indicated on the inspection form; and the equipment is permitted to be connected to the BNL electrical system. Note that the equipment review by the EEI applies to a final configuration, and does not apply when personnel gain access to the equipment for maintenance or troubleshooting, or when equipment is relocated or modified. EEIs are allowed to approve modifications to NRTL equipment if the modification has been approved by the Department Manager/designee and, in their opinion, the modification does not diminish the safety of the equipment.

Under the BNL electrical equipment approval program, trained and qualified EEIs use a checklist (see the BNL Checklist for Review and Approval of Electrical Equipment) to guide and document their review. The checklist used during the review process is an outline. The actual scope of the EEI review may be more extensive, at the discretion of the EEI. Such expansion of activity, while providing minimum documentation, is recognized in electrical codes, as in NEC Article 90-1(c) which states, "This Code is not intended as a design specification nor an instruction manual for untrained persons." An EEI must apply professional judgment to performing a standards-based inspection or

hazard-based inspection, as appropriate. In a standards-based inspection, usually applied to new equipment, there is verification that

- The product conforms to an applicable standard;
- There is enforced consistency among all products; and
- The inspection criteria are determined by the standard.

A hazard-based inspection

- Allows making judgments about the safety of a product even though it may not totally conform to a standard;
- Allows for a realistic analysis within the confines of a given location or equipment situation;
- Follows criteria determined and documented by the EEI, and can be applied to existing in-service equipment.

EEI review must be independent, like that of an NRTL, and credible when viewed by a third party. Any appearance of conflict of interest must be avoided. There is no requirement that an EEI provide a design solution; the burden of conformity with accepted standards is on the equipment owner, not the EEI. Regarding standards, there is no need to justify the content of the NEC or any other standard, just a requirement to follow the provisions of the standard. Issues involving any dispute can be referred to the LESO for resolution. Also, EEIs must be aware that even though an item is a recognized component, it does not mean that it is automatically acceptable for any use, and relatively standard items are used in unique ways in research projects. Technical assistance is available to any EEI having questions regarding equipment approval. The EEI should include as much subject matter expert input as deemed necessary, and certain equipment approvals may require guidance by members of the Laboratory's scientific community.

Following the Process

Equipment Reference Number. Apply permanent individually numbered bar code stickers to all electrical items used within the Laboratory. The labels include the two-letter designation of the organization performing the review and a unique identification number.

Equipment Name. Electrical equipment may be items of commercial or industrial equipment, and may be contained in a chassis, rack, panel, console, cage, room, or building. Identify the equipment by name and use. The equipment may be a commercial product used on a benchtop or in a rack, or the equipment may consist of a rack or room full of power supplies, capacitors, or triggered-discharge electronics that can be reviewed and approved as an entity.

Equipment Origin. Identify the origin of the equipment. The inspected item(s) may be commercial off-the-shelf (COTS), commercial catalog items constructed when ordered, items constructed according to BNL specification, equipment built in-house by BNL

workers, or devices brought to the Laboratory by scientists or others. The equipment may be of domestic or foreign origin.

Equipment ID Number. All equipment must bear an identification label. Commercial equipment must have an identifying product and/or serial number.

Cognizant Group. There is some person or group that is responsible for each item of equipment at BNL. This cognizant group "owns" the equipment, is responsible for obtaining equipment approval from the EEI before operating new equipment, and is responsible for informing the EEI upon any changed equipment configuration.

Equipment Inspection Checklist. The written EEI checklist is relatively brief. Items to be considered by the EEI performing the inspection are explained, in part, in notes attached to the review form. Electrical equipment that is energized at BNL 50 volts ranges B and above

- Must be enclosed to protect workers from the hazards of electrical shock and arc flash, and to contain fire or pieces that could be violently expelled;
- Must have exposed metal parts of the enclosure bonded and grounded; and
- Must have overcurrent protection as appropriate.

Other equipment inspection guidance may be used at the discretion of the EEI.

Actions Following Equipment Review. Following the equipment review, the EEI enters a summary of the inspection results in the "comments" section of the review form, briefly describing the installation and noting any restrictions on use or operational limitations of the equipment. The EEI should especially note deficiencies that support rejecting the equipment. (Note that equipment approval by an EEI applies to a finished, enclosed, grounded, item or installation with appropriate overcurrent protection, ready for its intended use. The EEI is not the owner of the equipment, is not responsible when equipment is disassembled for maintenance or troubleshooting, and is not responsible when equipment is relocated or used for another purpose.)

The EEI next applies a colored sticker in addition to the equipment reference number to indicate equipment approval status. The stickers are initialed by the EEI and indicate the following status:

Green	Approved
Yellow	Conditional Approval (as documented on the review form)
Blue	NRTL (for items which have been approved by an NRTL
Blue	DNA/NIS (does not apply/not in system)
Red	Rejected

A copy of the checklist should be provided to the user of the equipment. The user should

be informed that unauthorized modifications to the equipment after the approval are not permitted and that the colored sticker on approved equipment, which is no longer used for its intended purpose, should be removed.

Reports of the equipment and installation review by an EEI is entered into a computer database that is permanently filed and managed within the EEI's organization. A copy of the approval checklist is forwarded to the LESO for review and possible challenge. The organization files must be continually accessible to the LESO for purposes of review and possible use in satisfying reporting requirements.

Additional Comments on Areas for EEI Review

General Instructions

1. All equipment at BNL must be approved, that is, acceptable to the AHJ. Approval is straightforward for equipment bearing the seal of an NRTL. OSHA requires that equipment listed or labeled by a Nationally-Recognized Testing Laboratory (NRTL) be acquired whenever labeled equipment is available, even if similar unlabeled equipment can be used. NRTLs include Underwriters Laboratories (UL), Canadian Standards Association (CSA), and Factory Mutual (FM). A list of NRTLs may be found at the Nationally Recognized Testing Laboratory (NRTL) Web site.

2. Section 1910.303, General Requirements, allows for approval of custom-made equipment, if equipment is determined to be safe for its intended use by its manufacturer on the basis of test data that the employer [BNL] keeps and makes available for inspection by the Assistant Secretary of Labor and his authorized representatives.

3. Other equipment may be determined to be acceptable for use at BNL through the process of review and approval by Electrical Equipment Inspectors (EEI). It is suggested that equipment approvals involving complex issues be reviewed by the Laboratory Electrical Safety Officer (LESO).

4. For multiple units by a reputable vendor, one item will be inspected and the remaining database entries will reference the initial items. Some items, i.e., those constructed in-house by a variety of technicians over an extended time period, will be individually inspected

The additional comments below are a partial list meant to assist a qualified EEI in the equipment approval process.

Equipment Must Be Enclosed

Equipment enclosure is the first barrier to personnel contact with energized parts, or to the effect of an internal failure. The enclosure can be a small box, a chassis, a rack, or a room. The enclosure must be complete and not damaged, of appropriate design and construction, made with appropriate material, have no open knockouts, and it should not be possible to insert the UL 508 “finger” and come into contact with energized parts. Covers must remain in place during normal use and during routine maintenance, and be removable only through use by a tool or removing a lock. The equipment should have an electrically "dead" front panel with no parts accessible energized over 50 volts and with 5 mA or 10 J (instantaneous) available. Enclosures that are accessible without using tools must have interlocks that remove power to accessible parts.

Additional items for EEI consideration include

- Equipment design that includes consideration of the available short circuit and ground fault current.
- Intended use of the enclosure: indoors or outdoors, dry or wet environment, etc.
- Enclosure of parts to contain the effects of arcing, heating, and explosion.
- Separation is provided between wiring and components operating at different voltages.
- Conductors (and insulation) are protected from damage by inadequate bending radius, over crowding, and location near moving parts within equipment and at termination points.
- Workmanship, integrity of electrical equipment and connections.
- Any condition that would adversely affect the safe operation or mechanical strength of the equipment, such as damaged, corroded, or overheated parts.

Exposed Metal Parts Must Be Bonded and Grounded

All noncurrent-carrying metal must be properly bonded, with bonding wires securely terminated. Bonding and grounding wires must be properly sized in accordance with Article 250 of the National Electrical Code. The equipment grounding conductor must be run with the circuit conductors.

Overcurrent Protection Must Be Appropriate for Intended Use

Properly sized and installed overcurrent protection, appropriate for the configuration of the circuit and equipment.

Additional Considerations

1. NRTL equipment that has been modified may no longer be acceptable. The user should consult with the EEI prior to the modification to determine whether additional examination is required. Modifications that "void the listing" are those that may have safety consequences, for example, alterations to the enclosure, the addition of special wiring or custom-made accessories, or substitution of original parts during equipment repair.

2. The equipment or the installation must provide means for implementing lockout/tagout. For equipment containing components capable of storing energy, consider devices arranged to automatically remove the stored energy upon equipment shutdown. Consider adding front-panel indication of the presence of input voltage above 50 volts ac, to allow simplification of zero-voltage verification during lockout/tagout. Also associated with lockout/tagout, consider possible effects from other sources of power (pneumatic, etc.) upon loss of electrical energy to the equipment.

3. Nameplates applied to electrical equipment can be helpful in identifying the equipment name, manufacturer, voltage, and current (or power) ratings. The information might also include drawing number references for non-commercial equipment, operational restrictions and limitations, and identification of any significant hazards.

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Selection and Use of Rubber Gloves and Insulating Blankets

Effective Date:**Feb 29, 2016**

The exhibit Selection and Use of Rubber Gloves and Insulating Blankets is provided as a Word file.

Selection and Use of Rubber Gloves and Insulating Blankets

Selection and Care of Rubber Gloves and Insulating Blankets

Rubber gloves are marked on the cuff area with their service class as follows:

Rubber Glove Marking		
Class of Equipment	**Proof-Test Voltage (rms)**	**Maximum Use Voltage (rms)**
00		500
0	5,000	1,000
1	10,000	7,500
2	20,000	17,000
3	30,000	26,000
4	40,000	36,000
Type I Type II	non-ozone-resistant ozone-resistant	

Rubber insulating gloves are particularly sensitive to physical damage. Insulating equipment must be inspected for damage before each day's use and immediately following any incident that might be suspected of having caused damage. Insulating gloves must be given an air test, along with the inspection. Insulating equipment with any of the following defects may not be used:

- A hole, tear, puncture, or cut;
- Ozone cutting or ozone checking (the cutting action produced by ozone on rubber under mechanical stress into a series of interlacing cracks);
- An embedded foreign object;
- Any of the following texture changes: swelling, softening, hardening, or becoming sticky or inelastic.
- Any other defect that damages the insulating properties.

Rubber gloves and other rubber insulating materials must be used within the manufacturer’s time recommendations. Rubber insulating gloves must be electrically tested before they are first issued, and every 6 months thereafter. If the gloves were tested but not issued for service, they must have been tested within the previous 12 months.

Rubber gloves and insulating material must be maintained and stored as per the manufacturer’s requirements.

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Task-based Electrical Safety Training Requirements

Effective Date:**Feb 29, 2016**

Task-based Electrical Safety Training Requirements is provided as a Word file.

Task-based Electrical Safety Training Requirements

Task	Electrical Safety Training Course	CPR (ADULT CPR/AED)	LOTO with Electrical JPM
Electrical energized work at or above 50 volts that requires a specific electrical energized work permit	Electrical Safety I (TQ-ELECSAF1)	Needed	LOTO Authorized per JTA: GE-68B LOTO Authorized Employee
Testing, Troubleshooting and Voltage Measuring on circuits at or above 50 volts	Electrical Safety I (TQ-ELECSAF1)	Needed	LOTO Authorized per JTA: GE-68B LOTO Authorized Employee
Tasks in vicinity of electrical utilities where it has been determined through work planning that the task does not require an Electrical Energized Work Permit[1,2]	Not Needed	Not needed	Not needed[3]
Electrical work on cord and plug benchtop equipment 50 volts to 120 volts with cord unplugged and plug in exclusive control of worker	Electrical Safety for Benchtop Workers (TQ-ELECT-BENCHTOP) or Electrical Safety I (TQ-ELECSAF1)	Not needed	Not needed[3]
Electrical work on cord and plug benchtop equipment 50 volts to 120 volts using TTVM or specific Electrical Energized Work permit	Electrical Safety for Benchtop Workers (TQ-ELECT-BENCHTOP) or Electrical Safety I (TQ-ELECSAF1)	Needed	LOTO Authorized per JTA: GE-68B LOTO Authorized Employee
Electrical Circuit Breaker/Switch operation less than or equal to 250 Volts and rated less than or equal to 225 A	Electrical Circuit Breaker/Switch Operation Safety (TQ-ELECT-BSOP) or Electrical Safety I (TQ-ELECSAF1)	Not needed	Not needed[3]
Electrical Circuit Breaker/Switch operation greater than 250 volts	Electrical Safety I (TQ-ELECSAF1)	Not needed	Not needed[3]
Aggressive Penetration of Concrete and Masonry	Electrical Safety for Shock Hazard (TQ-ESHOCK) or Electrical Safety I (TQ-ELECSAF1)	Not needed provided a second person who has unobstructed sight of the worker, is within 50 feet of the worker and; trained in CPR, methods of release and the use of an AED and emergency first aid procedures.	LOTO Authorized per JTA: GE-68B LOTO Authorized Employee
Electrical Welding with welding Open Circuit Voltages (OCV) at or above 50 volts	Electrical Safety for Welders (TQ-EWELD) or Electrical Safety I (TQ-ELECSAF1)	Needed	Not needed[3]

1. Extra care must be taken in work planning briefings and oversight to keep unqualified workers safe.
2. An Electrical Energized work permit is either a TTVM or specific permit.
3. Lockout/Tagout (LOTO) training is needed if LOTO is being implemented as required by the Lockout/Tagout (LOTO) for Installation, Demolition, or Service and Maintenance Subject Area.

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Topics to be Covered During Departmental Job-Specific Training

Effective Date:**Feb 29, 2016**

The exhibit Topics to be Covered During Departmental Job-Specific Training is provided as a Word file.

Topics to be Covered During Departmental Job-Specific Training

Authorizations and Limitations
1. Describe equipment authorized to work on;
2. Describe tasks permitted without consulting supervision;
3. Describe actions and/or equipment to be avoided.

Equipment
1. General hazards associated with this equipment;
2. Specific and unique hazards of this equipment;
3. Location of documentation for equipment;
4. Location of lockout/tagout devices;
5. Specific approach distances and personal protective equipment (PPE) for this equipment;
6. Acceptable parts replacement without need to re-evaluate safety and performance.

Work Tools and Techniques
1. Review safe and proper use of standard test equipment;
2. Review safe and proper use of special and unique test equipment;
3. ISM requirement to provide feedback on work with equipment;
4. Desirability of suggestions to modify equipment for improved worker safety.

Before Each Job
1. How to conduct an effective pre-job review;
2. Extent of pre-job review required depending on work tasks and hazards;
3. Common work factors to be included in each pre-job review;
4. Review errors that may have occurred on group equipment, and lessons learned.

Personal Protective Equipment (PPE)
1. Discuss proper testing and use of PPE;
2. Explain limitations of PPE.

Energized Electrical Work Permit
1. Review generic permits, purpose, and limitations;
2. Review requirements for specific permits;
3. Discuss PPE required for each permit.

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Work Distance Table (Control Zones)

Effective Date:**Feb 29, 2016**

The exhibit Work Distance Table (Control Zones) is provided as a Word file.

Work Distance Table (Control Zones)

Training Requirements	Qualified level training required		Authorized Personnel ONLY	
Nominal System Voltage Range Phase-to-Phase – greater than 10 joules	Limited Approach Boundary		Restricted Approach Boundary	Prohibited Approach Boundary
	Exposed Movable Conductor(s) (Overhead lines)	Exposed Fixed Circuit Part(s)		
Less than 50 V	Not specified	Not specified	Not specified	Not specified
50 V to 300 V	10'-0"	3'-6"	Avoid contact	Avoid contact
301 V to 750 V	10'-0"	3'-6"	1'-0"	0'-1"
751 V to 15 kV	10'-0"	5'-0"	2'-2"	0'-7"
15.1 kV to 36 kV	10'-0"	6'-0"	2'-7"	0'-10"
36.1 kV to 46 kV	10'-0"	8'-0"	2'-9"	1'-5"
46.1 kV to 72.5 kV	10'-0"	8'-0"	3'-2	2'-1"

Clearances required by OSHA for construction projects may be greater than stated above, as per 29 CFR 1926.416(g)(2)(i, ii). Consult the Laboratory Electrical Safety Officer for required clearances for construction activities in areas containing high voltages, or for voltages greater than those listed above.

Clearances as stated above are required for work on or adjacent to live sources capable of either fault currents greater than 10 mA or instantaneous release greater than 10 J.

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

BNL Checklist for Review and Approval of Electrical Equipment

Effective Date:**Feb 29, 2016**

The BNL Checklist for Review and Approval of Electrical Equipment is provided as a Word file.

BNL Checklist for Review and Approval of Electrical Equipment

BNL EQUIPMENT REFERENCE NUMBER	

EQUIPMENT NAME	
EQUIPMENT ORIGIN	
EQUIPMENT ID NUMBER	
COGNIZANT GROUP	

Electrical equipment and installations must be acceptable at BNL only if approved. BNL Electrical Equipment Inspectors are designated by their organizations and the Laboratory Electrical Safety Committee (the electrical Authority Having Jurisdiction) to review and approve equipment for use within the Laboratory.

In judging equipment, considerations such as those found in the following table must be evaluated. (See instructions that accompany this form.) Actual scope of EEI review and approval is more extensive, based on Art. 90-1(c), which states "This Code is not intended as a design specification nor an instruction manual for untrained persons."

		Inspected: (Check Box)
1	Equipment sufficiently enclosed to prevent accidental contact with energized parts.	
2	Exposed metal parts bonded and grounded.	
3	Overcurrent protection appropriate for intended use.	
4	Visually inspect field installed cord and plug wire connections	
5		
6		
7		
8		

NOTE: APPROVED EQUIPMENT MUST BE INSTALLED AND USED IN ACCORDANCE WITH THE INSTRUCTIONS PROVIDED BY THE DESIGNER/BUILDER AND EEI.

Comments: (Include all designer/builder instructions, restrictions on use, drawings or information that is relevant to the safe installation and use of this equipment. Attach additional sheets as necessary.)

Equipment status following EEI review (indicate status):

- ☐ Approved
- ☐ DNA/NIS (does not apply/not in system)
- ☐ Conditional Approval (as documented above)
- ☐ NRTL (for items approved by an NRTL)
- ☐ Rejected

If approved for use, then if this equipment is modified, relocated, damaged, repaired or utilized for other than the intended use stated above, this approval is void pending re-examination.

Date:	EEI:	EEI: Signature:
	Print Name	Signature

Management System: ***Worker Safety and Health***

Subject Area: ***Electrical Safety***

Electrical Work Permits with Instructions

Effective Date:**Feb 29, 2016**

Electrical Work Permits with Instructions

Energized Electrical Work Permit

Testing, Troubleshooting, and Voltage Measuring (TTVM) Electrical Work Permit

A. Description and Use of Permits

1. Description of Permits

There are two permits used to demonstrate that deenergizing the equipment introduces additional hazards or is infeasible due to design or operational limitations. Both permits describe the circuit and equipment to be worked on, justification for energized work, safe work practices, shock hazard analysis and protection boundary, flash hazard analysis and protection boundary, personal protective equipment (PPE) required, means employed to restrict access to unqualified persons, evidence of pre-job briefing and any post job feedback, and approving signatures. The Energized Electrical Work Permit is to be used when live parts cannot be placed in an electrically safe condition to perform the work. The Testing, Troubleshooting, and Voltage Measuring (TTVM) Electrical Work Permit, or approved equivalent procedure, is to be used for testing, troubleshooting, voltage measuring, and related tasks that are exempt from an electrical work permit in NFPA 70E, but require safe work practices and PPE. The TTVM may only be used for work under 600 V.

2. Use of Permits

All work on or near energized conductors requires a permit, which must include the following information:

Part I - to be filled out by the requestor for the electrical work permit

1. Description of the Location and Circuit.
2. Description of the task.
3. Justification of why the task must be done working on or near live parts.
4. The Start Date and Time and the Estimated Finish Date and Time for the job. On TTVM electrical work permits, it may be for a reasonable time span up to a maximum of a year.

Part II - to be filled out by the worker or supervisor/designee

1. Detailed job description. On the Energized Electrical Work Permit, the hazards of the job are to be identified, such as:
    i. Electrical conditions: massive ground(s) adjacent to the work, live input or output terminals;
    ii. Mechanical conditions: rotating equipment, pinch points or shear hazards of the equipment or adjacent equipment that may need to be locked out.
    iii. Environmental Conditions: flammable vapors, combustible, toxic vapors, or other physical or biological hazards.
    iv. Working space constraints: spaces in front of electrical boxes not meeting standards, energized circuits or parts behind the employee, or irregular working surface.
    v. Obstructions in the area: obstructions that make emergency escape difficult and obstructions to the work.
    vi. Other energized circuits or parts: other energized circuits close by that may have different voltage, different phase, or require different lockout locations to de-energize.
2. Procedures of the task are to be reviewed to ensure that proper precautions have been included, such as:

. Warnings specified: before a step involving a particular hazard, define it in unique clear type.
    i. Caution notes: are used to warn employee of actions that may damage equipment.
    ii. Warning notes: are used to warn employee of actions that may cause severe injury or death.
3. The shock and arc-flash hazard and boundaries.
4. Personal Protective Equipment required.
5. Clearance Zone and means to restrict unqualified personnel if required.
6. The Authorized Worker signs and includes their life number in the space provided only on the Energized Electrical Work Permit.

Part III

1. The supervisor is to verify that the employee has current generic and also task-specific training. Those not trained are not to be allowed to under take the work.
2. Signature of supervisor of the employee: the supervisor must review the job before dispatching the employee, according to departmental procedures. The supervisor is responsible for the job being performed safely.

For voltages above 600 Vac or 6000 Vdc, the following must be performed:

a. Independent Review of High-Hazard tasks ensures that the hazards have not been overlooked. The person who conducted the review signs in the space provided.

b. Job Safety Analysis completed or equivalent review is required for periodic high-hazard tasks. The hazards and the necessary controls are to be identified for each step of the task.
c. Employee briefing before the task: specific instructions or training may be required to clarify particular hazards for the workers. Warnings are to be pointed out and clarified when questions arise during briefing.
d. Approval to proceed: signature of the Department Chair/Division Manager or designee is required.

Part IV

Include evidence of completion of the Job Briefing, which may be the signature of the person performing the briefing, or the initials of the Authorized Worker verifying he reviewed for any job-related hazards.

Part V

For the Energized Electrical Work Permit, provide post-work feedback, if required. The worker initials the permit at job completion, and notes any feedback.

For the TTVM Electrical Work Permit, provide the signatures and life numbers of all the Authorized Workers allowed to perform the tasks associated with this specific permit.

A copy of the permit is to be kept by workers at the work site. A copy is to be sent to the facility's ES&H Coordinator and another copy to the Safety and Health Services Division Representative.

B. Review and Issuance of Permit

1. The supervisor obtains the permit and reviews the background information of the job or task, the hazards and the precautions to be taken, and the distance for the clearance zone(s).
2. The supervisor verifies that the employee has the necessary current training for this type of task.
3. After discussing the procedure and job with the worker, the supervisor and the worker sign the permit.
4. The signature of the Department Chair/Division Manager or formal designee is required to assure that the energized circuit work is appropriate.
5. For voltages above 600 Vac, or 6000 Vdc, an independent review must be conducted. The independent review must include the following:

i. The itemized procedural steps for the job or task.
ii. A Job Safety Analysis or equivalent review to identify the hazards and their controls for each job step.
iii. Signature of the independent reviewer(s) indicating that the controls for the job or task are adequate to protect the employee.

6. Copies should be sent to the facility ES&H Coordinator, or retained in accordance with the policy of the organization.

Department Code __ **ENERGIZED ELECTRICAL WORK PERMIT** Permit # Procedure #
Job/Work Order Number _____

PART I: TO BE COMPLETED BY THE REQUESTER:

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

(2) Description of work to be done: _____

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

Start Date:_____ Expire Date: _____

_____
Requester/Title Date

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

(1) Detailed job description procedure to be used in performing the above detailed work including hazards, conditions, mechanical, environmental, space obstructions, other voltages:_____
_____

(2) Description of the Safe Work Practices: ☐ LOTO ☐ Two Workers ☐ Safety Watch ☐ Notify affected workers ☐ _____
Reason not to LOTO _____

Restart Checks Required: _____

(3)

Flash Hazard (-1 to 4)		Shock Hazard (max V)		Working Distance	
Flash Boundary		Limited Approach		Glove Class, minimum	
Incident Energy (cal/cm^2)		Restricted Approach			
		Prohibited Approach			

(4) Protective Equipment

☐ Natural Fiber Clothing	☐ Safety Glasses/Goggles	☐ Ear Plugs	☐ Leather Shoes
☐ FR Clothing	☐ Face Shield	☐ Leather Gloves	☐ Voltage-rated Shoes
☐ Voltage-rated Tools	☐ Balaclava Hood	☐ Voltage-rated Gloves	☐ Hard Hat
☐ Category III Meter	☐ 2 Layer Switching Hood	☐ Flashsuit	☐ Other

Other _____

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

(6)

Authorized Workers	**Life #**	**Authorized Workers**	**Life #**
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

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

_____ _____
Department Chair/Division Manager/Designee Date Electrically Knowledgeable Person/ Engineer Date

_____
Independent Reviewer (Range D only) Date

PART IV: WORK

Evidence of completion of Job Briefing including discussion of any job-related hazards:
_____

PART V: POST WORK-FEEDBACK_____ (Worker Initials)
_____

_____ _____
Safety Manager/Representative Close-out Date

Return to: ES&H Coordinator,

TESTING, TROUBLESHOOTING, AND VOLTAGE MEASURING ELECTRICAL WORK PERMIT

Department Code: **Permit #**

PART I: TO BE COMPLETED BY THE REQUESTER:

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

_____

(2) Description of work to be done: _____

_____

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

_____

_____

_____ _____

Requester/Title Date

PART II: HAZARD ANALYSIS:

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

_____

_____

(2) Description of the Safe Work Practices to be employed: ☐ LOTO ☐ Reason not to LOTO _____

_____

(3)

Flash Boundary		Flash Hazard		Working Distance	
Shock Hazard		Limited Approach Restricted Approach Prohibited Approach		Glove Class	

(4) Protective Equipment

☐ None	☐ Earplugs	☐ Leather Gloves	☐ Leather Shoes
☐ Cotton Clothing	☐ Face shield	☐ Voltage-rated Gloves	☐ Voltage-rated Shoes
☐ Fr Clothing	☐ Flash suit	☐ Hard Hat	☐ Safety Glasses/Goggles

_____

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

_____

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

_____ _____

Group Leader/Supervisor Date

_____ _____

Electrically Knowledgeable Person/Lead Engineer Date

_____ _____

Department Chair/Division Manager/Designee Date

PART IV: WORK

Evidence of completion of Job Briefing including discussion of any job-related hazards:
Daily pre-work briefing
Post work feedback, if required

PART V: AUTHORIZED WORKERS:

Name	**Life #**	**Name**	**Life #**
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

_____ _____

Authorizing Supervisor Date

Supervisor acknowledges the above personnel are properly trained, knowledgeable and experienced to work under the permit.
Forward a copy to group's safety department.