

ELECTRICAL SAFETY in RESEARCH LABORATORIES and SUPPORT SHOPS

This excerpt (Section 11) from Penn's Electrical Safety Program defines practices and procedures to be implemented for electrical equipment that is not listed or labeled by a nationally-recognized testing laboratory (NRTL). Typically, this will include research related equipment that is custom built in-house or NRTL-listed or labeled equipment that has been modified which invalidates the listing or labeling.

An important concept to understand is that NRTL listed/labeled electrical equipment has undergone rigorous testing to help ensure that it is safe for use. If electrical equipment is modified or custom built in-house, the laboratory/group responsible for modifying or building the equipment is responsible to complete a field evaluation of the equipment to ensure that it is safe for use. EHRS is available to provide guidance and identify resources to aid in completion of the field evaluation, however, EHRS cannot perform the field evaluation.

A) General

- 1) Equipment and installations that bear the seal of a NRTL are considered approved if they are installed and used in accordance with any instructions included in the listing or labeling.
- 2) NRTL listed or labeled equipment must be acquired/used whenever it is available, even if similar unlisted or labeled equipment can be used. OSHA allows for approval of custom-made equipment or related installations if the equipment is determined to be safe for its intended use by its manufacturer based on test data which the employer keeps and makes available for inspection.
- 3) EHRS or the laboratory Competent Person shall act as the Electrical Safety Authority (ESA) for Penn. In this role, EHRS shall help guide the laboratory through the requirements of this section and if needed, assist with identifying the appropriate subject matter experts that may be needed to help the lab/group complete the field evaluation. EHRS shall not be responsible for field evaluation of equipment. The field evaluation must be completed by the Competent Person designated by the laboratory that modifies or builds the equipment. In some cases, the Competent Person may need to collaborate with the appropriate subject matter experts to assist with the field evaluation, but ultimately, the Competent Person must take responsibility for the equipment and ensure that it is safe for use.
- 4) Electrical equipment fabrication, modification or installation shall be completed by or under the direct supervision of a Competent Person.
- 5) A Competent Person is a person who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved. The Competent Person is responsible for all work activities or safety procedures related to custom or special equipment and has detailed knowledge regarding the exposure to electrical hazards, the appropriate control methods to reduce the risk associated with those hazards, and the implementation of those methods.
 - a) The Competent Person shall understand the following concepts:
 - (i) Skills and techniques necessary to distinguish exposed energized electrical conductors and circuit parts from other parts of electrical equipment.
 - (ii) Skills and techniques necessary to determine the nominal voltage of exposed energized electrical conductors and circuit parts.
 - (iii) Approach distances specified in Appendix 2 and the corresponding voltages to which the individual will be exposed.

(iv) Decision-making process necessary to be able to do the following:

- (a) Perform the job safety planning.
- (b) Identify electrical hazards.
- (c) Assess the associated risk.
- (d) Select the appropriate risk control methods from the hierarchy of controls including selection of appropriate personal protective equipment.

6) Where electrical equipment must be custom fabricated because NRTL listed or labeled equipment is not available or there is a case where foreign equipment is acquired to perform a unique experimental function in support of the laboratory's scientific mission or there is a need for continued use of legacy equipment, the equipment shall be free from recognized hazards that are likely to cause death or serious physical harm to employees. The equipment must be field evaluated and approved by a Competent Person and documented on the Custom Electrical Equipment Field Evaluation Form included in Appendix 12. The completed form shall be submitted to EHRS for attachment to the laboratory's BioRAFT record.

B) Energy Thresholds – Energy exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented as approved by the Competent Person:

- 1) AC: 50-volts and 5 milliamperes.
- 2) DC: 100-volts and 40 milliamperes.
- 3) Capacitive Systems:
 - a) 100-volts and 100 Joules of stored energy
 - b) 400-volts and 1.0 Joules of stored energy
 - c) 0.25 Joules of stored energy

C) Equipment Examination - In judging equipment, considerations such as the following shall be evaluated:

- 1) Suitability of equipment for an identified purpose may be evidenced by NRTL listing or labeling for that identified purpose.
- 2) Electrical equipment must be enclosed to protect personnel from the hazards of electrical shock and arc flash and to contain fire or pieces that could be violently expelled.
- 3) Exposed metal parts of the enclosure are bonded and grounded.
- 4) Appropriate overcurrent protection is installed.
- 5) Mechanical strength and durability, including for parts designed to enclose and protect other equipment, the adequacy of the protection thus provided.
- 6) Wire-bending and connection space.
- 7) Electrical insulation.
- 8) Heating effects under normal conditions of use and also under abnormal conditions likely to arise in service.

- 9) Arcing effects.
- 10) Classification by type, size, voltage, current capacity, and specific use.
- 11) Openings through which conductors enter shall be adequately closed and strain relief provided.
- 12) Other factors that contribute to the practical safeguarding of persons using or likely to come in contact with the equipment.

D) Equipment Marking and Documentation:

- 1) Marking - Marking of equipment shall be required for, but not limited to, equipment fabricated, designed, or developed for research testing and evaluation of electrical systems. Marking shall sufficiently list all voltage entering or leaving control cabinets, enclosures, and equipment. Caution, Warning, or Danger labels shall be affixed to the exterior describing specific hazards and safety concerns. Refer to ANSI Z535, Series of Standards of Safety Signs and Tags for more information.
- 2) Documentation - Sufficient documentation shall be provided and readily available to personnel that install, operate, and maintain equipment that describes operation, shutdown, safety concerns and nonstandard installations. Schematics, drawings, and bill of materials describing power feeds, voltage, currents, and parts used for construction, maintenance and operation of the equipment shall be provided.
- 3) Shutdown Procedures - Safety requirements and emergency shutdown procedures of equipment shall include control of hazardous energy (lockout/tagout) requirements.
- 4) Approvals - Drawings, standard operating procedures and equipment shall be approved by the Competent Person. Assembly of equipment shall comply with national standards where applicable unless research application requires exceptions. Equipment that does carry a listing or label from a NRTL shall be Field Evaluated. Proper safety shutdown procedures and PPE requirements shall be considered in the absence of grounding and/or bonding.

E) Field Evaluation Process

- 1) The laboratory or entity responsible for modification or custom fabrication of electrical equipment must complete or arrange for field evaluation of the equipment. The equipment must be inspected and approved by a Competent Person and documented on the Custom Electrical Equipment Field Evaluation Form (Appendix 12). The completed form must be submitted to the ESA and/or (EHRS) for review prior to start-up. The ESA will review the form and contact the lab if concerns are identified or upload the form to the lab's BioRAFT record. After review and approval, an "Electrical Safety Approved" barcode label will be supplied by EHRS to the Competent Person to install on the equipment. Once the completed form is uploaded to BioRAFT and the approval label is installed on the equipment, it may be considered approved for use.
- 2) **Documentation:** The following documents must be maintained by the laboratory that modified or fabricated the electrical equipment. This information is used by Field Evaluation Body for the equipment evaluation:
 - a) Justification for in-house modifications of NRTL listed or labeled equipment or need for in-house fabrication of equipment.

- b) Layout drawing showing all equipment with designators that match the schematic and actual marks on, or adjacent to the equipment.
 - c) Electrical schematic drawings for all power, control, and safety circuits.
 - d) A bill of material that includes certification details for all critical components.
 - e) Limitations or conditions of acceptability for critical components.
 - f) Installation, operation, and maintenance manuals for the equipment to be installed.
 - g) Qualifications of the fabricator. Qualifications include adequate technical electrical/electronic and electrical safety knowledge.
 - h) Completed Custom Electrical Equipment Field Evaluation Form (Appendix 12). The form must be maintained for the life of the equipment.
- 3) **Standard(s):** The FEB should select nationally recognized standards applicable to the subject equipment under evaluation based on the equipment's design and application. Where no single standard applies to the equipment, applicable portions of related standards for subassemblies and supplementary standards should be applied.
- a) Primary Standard - The primary standard to be used should be a nationally recognized safety standard written and maintained by a standards development organization that issues safety standards.
 - b) Jurisdictional Notification - The FEB should notify the electrical AHJ (EHRS) when an evaluation is initiated and about to commence.
- 4) **Construction Inspection:** This section provides typical construction requirements that should be considered in the field evaluation. The actual requirements to be used for the construction inspection should come from the applicable primary product safety standard and electrical installation codes.
- a) Electrical Code Considerations - Ensuring that the product can be installed in accordance with the electrical code should include but is not limited to the verification of the following:
 - (i) Presence of complete equipment nameplate(s)
 - (ii) Equipment construction provides for code-compliant installation.
 - (iii) Installation instructions include sufficient detail (showing raceway entry points, supply conductor wiring methods, supply conductor types, field wiring torque values, and installer supplied overcurrent protection)
 - (iv) Adequate wire bending space for all field wiring terminals.
 - b) Construction of Enclosures - Enclosure inspection should include but not be limited to the following:
 - (i) Suitable use of metallic and nonmetallic construction materials.
 - (ii) Enclosure-type rating (e.g., 1, 3R, 4X) suitable for the intended application or installation environment.
 - (iii) Methods of corrosion protection for internal and external parts.
 - (iv) Methods of fastening doors and covers.
 - (v) Hinged doors open at least 90 degrees.
 - (vi) Bonding methods of dead metal parts likely to become energized.
 - (vii) Accessibility of live parts.
 - c) Disconnecting Means - The means to disconnect equipment should be reviewed for suitability and compliance with installation codes.
 - d) Main Overcurrent Protection Device (OCPD) - Main overcurrent protection supplied by the manufacturer or field installed should be verified as suitable for the loads involved, voltage, and interrupting rating.
 - e) Field Terminations - Field wiring terminals should be identified.
 - f) Components - The verification of equipment components should include, but not be limited to the following:

- (i) Accuracy of and correlation between component identifications in drawings, the bill of material, and marking within equipment.
 - (ii) Critical components listed or recognized and labeled by a nationally recognized testing laboratory (NRTL).
 - (iii) Critical Components used in accordance with their listing or the “conditions of acceptability” defined by an NRTL.
 - (iv) Suitability of mounting methods.
 - (v) Suitability of components to perform as intended considering the critical/safety function of the device, mechanical and electrical loads, and other factors affecting the immediate environment or performance of the component.
- g) Overcurrent Protection - Overcurrent inspections should consider suitability of applications that include but are not limited to the following:
- (i) Overcurrent protection of conductors per the conductor ampacity.
 - (ii) Power supply overcurrent protection.
 - (iii) Transformer overcurrent protection for power and control.
 - (iv) Motor overcurrent protection, including short circuit, ground fault, and overload protection, provided and properly rated.
 - (v) Maintenance receptacle overcurrent protection.
 - (vi) Heater load overcurrent protection
 - (vii) Plug strips and portable power taps overcurrent protection.
 - (viii) Overcurrent protection for control circuits and control circuit devices.
- h) Wiring - Wiring should be inspected for the following:
- (i) Correct color code or other identification used.
 - (ii) Insulation types rated for the application and intended environment.
 - (iii) Conductor temperature ratings adequate.
 - (iv) Ampacity for load served and overcurrent protection provided.
 - (v) Flame rating of VW-1 or equivalent insulation.
 - (vi) Correct use of flexible cords.
 - (vii) Correct use and physical protection of flexible cables.
 - (viii) Separation of low voltage, Class 2 or Class 3 conductors from power conductors.
- i) Markings - Markings should be inspected for the following:
- (i) Access warnings for shock hazard.
 - (ii) Multiple source warnings.
 - (iii) Environmental restrictions such as “Indoor Use Only”
 - (iv) Field wiring type such as “Copper Conductors Only”
 - (v) Component designations that match the layout and schematic drawings.
 - (vi) Control device functional identification.
 - (vii) Equipment grounding terminal marking.
 - (viii) Fuse replacement markings or chart.
 - (ix) Replacement elements and ratings for overload relays provided with changeable elements.
- j) Grounding - Grounding/bonding provisions should be inspected for the following:
- (i) Provision for terminating the supply equipment grounding conductor.
 - (ii) One conductor per terminal for all equipment grounding conductors in ground fault paths.
 - (iii) Equipment grounding conductors identified by color coding (green or green with one or more yellow stripes) or by other suitable markings.
 - (iv) All conductive enclosure doors and panels are correctly bonded.
- k) Distances Between Exposed Energized Parts - Distances between exposed energized parts should be inspected for adequate creepage distance and clearance distance for the voltage provided.

- 5) **Electrical Testing:** The electrical testing program should follow the applicable standards as closely as practical, considering the limits of a nonlaboratory setting and the need for the equipment to perform all required functions after the test. The following typical tests and measurements on complete units or subassemblies should be completed as specified in the applicable standard:
 - a) Insulation resistance test on power circuit with all sensitive electronic components such as line filters and Rf filters disconnected.
 - b) Ground continuity of bonded parts to supply equipment grounding conductor termination point.
 - c) Measurement of the input voltage while under maximum design load.
 - d) Measurement of the input full load current while at the maximum design load normal operation.
 - e) Temperature rise testing of terminals and heat producing devices (transformers, power supplies, coils, heaters) and components that could be affected by an elevated ambient temperature caused by other heat producing components.
 - f) Safety interlock circuit function testing.
 - g) Emergency stop.
 - h) Electrical Tests - The following electrical tests should be completed as required by the applicable product standard where identified as production or routine tests:
 - (i) Leakage current on cord-and-plug-connected equipment.
 - (ii) Dielectric withstand (hipot) on power circuits.
 - (iii) Other production tests.

- 6) **Reporting and Documentation** - Each evaluation should result in a complete report detailing the results of the evaluation and a statement of conformity made from the results.
 - a) Discrepancies and Nonconformities - Discrepancies and nonconformities that have to be resolved in order to comply with requirements should be promptly brought to the attention of the appropriate parties.
 - (i) Where successful correction of nonconformance occurs, the report should include detail of the corrective action.
 - (ii) Discrepancies and nonconformities brought to the builder's attention should also be brought to the attention of EHRS.
 - (iii) A copy of the report including the Custom Electric Field Evaluation Form shall be submitted to EHRS.
 - (iv) Conditions of Acceptability – A statement or series of statements establish specific conditions of acceptability to be adhered to in order to maintain the label as valid should be included.
 - b) Standards - The complete citation of the primary and any contributing support standards used to complete the evaluations should be included.
 - (i) The citation should be complete so that any subsequent audit can clearly identify the exact edition and revision of the standard(s) used.
 - c) Equipment Identification and Nameplate – The equipment nameplate information should be documented for each manufactured piece of equipment that evaluated as follows:
 - (i) Designation of equipment
 - (ii) Manufacturer
 - (iii) Model identification
 - (iv) Serial number
 - (v) Electrical ratings
 - (vi) Mechanical ratings as applicable
 - (vii) FEB label Serial Number
 - d) Evaluation procedures – The detailed procedures used to inspect, test, and evaluate the product should be documented.

- (i) The evaluation procedures should be separated in the major category areas as detailed in sections 5 and 6 with sufficient explanation for clear understanding to all parties involved, including the builder, EHRS and the end user.
 - (ii) The evaluation section should include the following:
 - (a) A brief product description of the equipment's function and its intended operation.
 - (b) Construction evaluation results found acceptable.
 - (c) Electrical testing results found acceptable.
 - (d) Discrepancies for each item found nonconforming, including a description of the nonconformance, an explanation of the hazards, the standards citation, the remedial action to resolve the nonconformance, and the final resolution.
 - (e) Test instrumentation calibration information.
 - (iii) Appendices or Attachments – The following details should be included as appendices or attachments to the report:
 - (a) Reference drawings used for the evaluation.
 - (b) Data sheet(s) documenting the test results from each of the electrical tests.
 - (c) The bill of material (critical components list).
 - (d) Photographs of the discrepancies found, the resolution, and the overall equipment.
 - (e) Field notes, checklists, or other supporting data that would benefit the end user.
- 7) **Field Evaluation Label** – After all identified issues have been fully resolved, all electrical testing has been satisfactorily completed, and the evaluation has determined that the equipment meets the applicable requirements of the standard(s), a label should be affixed to the equipment.
- a) **Label Contents**
 - (i) The label shall state Penn EHRS - “Electrical Safety Approved”.
 - (ii) The label shall contain a unique number and barcode.
 - (iii) The label should have a means to identify if the equipment has more than one major assembly and therefore has more than one serialized label applied.
 - b) **Label Location**
 - (i) The evaluation label should be installed in the area of the equipment nameplate.
 - (ii) The label must be durable enough to withstand the expected use environment. Default label is metal foil.
 - c) **Label Control**
 - (i) The label should be applied exclusively by the FEB.
 - (ii) The label shall be supplied by EHRS to the FEB upon request for installation.
 - (iii) In no case should a label be applied to a product that has not been evaluated by the FEB.
 - (iv) The evaluator should enter the label serial number(s) into the field data work sheets.
 - (v) The label information should be recorded in the report. EHRS will enter the label number and equipment data information in our Custom Electrical Equipment database.

Penn Custom Electrical Equipment Field Evaluation Form

Equipment Identification (EHRS Approval Barcode #)	
--	--

Equipment Name	
Equipment Builder	
Department	
Competent Person/Inspector	

Refer to Penn’s Electrical Safety Program for inspection criteria.

Inspection Satisfactory: (Check Box)

1	Electrical code compliance	<input type="checkbox"/>
2	Construction of enclosure(s)	<input type="checkbox"/>
3	Disconnecting means	<input type="checkbox"/>
4	Main overcurrent protection device	<input type="checkbox"/>
5	Field terminations	<input type="checkbox"/>
6	Components	<input type="checkbox"/>
7	Overcurrent protection	<input type="checkbox"/>
8	Wiring	<input type="checkbox"/>
9	Markings	<input type="checkbox"/>
10	Grounding	<input type="checkbox"/>
11	Distances between exposed energized parts	<input type="checkbox"/>
12	Electrical testing completed	<input type="checkbox"/>
13	Reporting, documentation, and labeling	<input type="checkbox"/>

NOTE: Approved equipment must be installed and used in accordance with the instructions provided by the designer/builder and the Inspector.

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 pages as necessary.

Equipment status following review (indicate status);

- Approved – Competent Person/Inspector - Form uploaded by EHRS to BioRAFT
- Conditional Approval (as documented above)
- NRTL (for items approved by an NRTL)
- Rejected (Note reason here):

Date:		
-------	--	--

Inspector - Print Name

Inspector – Signature

Submit completed form to EHRS. EHRS will review and if acceptable, provide an approval bar code label. Once approved for use, 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. 8

3160 Chestnut Street, Suite 400, Philadelphia, PA 19104
Tel. 215.898.4453. Fax 215.898.0140. www.ehrs.upenn.edu