

EEEL Safety Rules for Moderate and High Voltages

(Revised 10/01/2008)

1. Introduction

All safety rules presented in this document are intended to ensure safe working conditions while working with potentially dangerous voltages. It is assumed that all personnel working with potentially dangerous voltages have been trained in basic electrical safety procedures. This document is not meant to be a complete guide to electrical safety; rather, it is intended to offer specific guidelines for laboratories within EEEL involved with potentially dangerous voltages. See the references for further guidance.

It is understood that certain laboratories may possess unique requirements that would justify altering these rules to adequately meet the requirements of the laboratory. Such alterations require written approval from the Group Leader and Division Chief, and notification of the Division and Laboratory safety officers.

Summaries of the safety requirements for working with potentially lethal voltages are presented in Tables 1 and 2. Details of the requirements are discussed below.

In general this document presents specific safety procedures for systems with potentially lethal voltages on bare or exposed conductors.

2. Definitions

Definitions presented here are those deemed necessary and suitable for electrical laboratory applications present in the Electronics and Electrical Engineering Laboratory. They should not be assumed to be directly related to definitions presented in other electrical standards or codes.

- 2.1. **High Voltage:** Any voltage exceeding 1000 V rms or 1000 V dc with current capability exceeding 2 mA ac or 3 mA dc, or for an impulse voltage generator having a stored energy in excess of 10 mJ. These current and energy levels are slightly below the startle response threshold (*IEEE Trans. Power App. Sys.*, vol PAS-97, no. 6, 2243, November, 1978)
- 2.2. **Moderate Voltage:** Any voltage exceeding 120 V rms (nominal power line voltage) or 120 V dc, but not exceeding 1000 V (rms or dc), with a current capability exceeding 2 mA ac or 3 mA dc.
- 2.3. **Temporary Setups:** Systems set up for measurements over a time period not exceeding three months.
- 2.4. **Test Area:** Area in which moderate voltages are accessible, and which has been clearly delineated by fences, ropes, and barriers.
- 2.5. **Troubleshooting:** Procedure during which energized bare connectors at moderate or high voltages might be temporarily exposed for the purpose of repair or problem diagnosis.
- 2.6. **Interlock:** A safety circuit designed to prevent energizing high- or moderate-voltage power supplies until all access doors are closed, and to immediately de-energize such power supplies if the door is opened. Note that this function does not necessarily ensure full discharge of stored energy.

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- 2.7. **Bare Conductor:** A conductor having no covering or electrical insulation whatsoever (NEC Article 100 definition)
- 2.8. **Covered Conductor:** A conductor enclosed within a material of composition or thickness not defined as electrical insulation (NEC Article 100 definition).
- 2.9. **Insulated Conductor:** A conductor encased within material of composition and thickness defined as electrical insulation (NEC Article 100 definition).
- 2.10. **Exposed Conductor:** Capable of being inadvertently touched or approached nearer than a safe distance by a person. It applies to parts that are not suitably guarded, isolated, or insulated (NEC Article 100 definition).
- 2.11. **Unattended Operation:** The operation of a permanent setup for electrical measurements for a time period longer than can be reasonably attended by staff.
- 2.12. **Enclosed:** Surrounded by a case, housing, fence or wall(s) that prevents persons from accidentally contacting energized parts.

3. **Confinement**

- 3.1. **High Voltage:** All conductors on which high voltage may be present should be confined within grounded or properly insulated enclosures. Instrumentation cabinets containing high voltage conductors should have safety interlocks on access doors. If confinement of high voltage is not possible, then bare conductors at high voltage must be enclosed within grounded safety enclosures with working interlocks. Except by deliberate breach of the enclosure, contact with bare conductors at high voltage should be impossible without tripping the interlock.

The proposed test area configuration requires written approval from the following:

- One-time approval by the Group Leader for two-person operation
- Annual approval by the Group Leader and Division Chief for one-person operation
- Case-by-case approval by the Group Leader and Division Chief for unattended operation
- One-time notification of Division and Laboratory safety officers for new systems

All interlocks should be tested during Division safety reviews.

When the use of permanent enclosures would be impossible or impractical, temporary setups are permitted contingent upon operation by two people and obtaining the necessary approvals. The test area must be surrounded by a temporary grounded safety fence or by ropes. Interlocks are strongly recommended, and the absence of interlocks will require justification. The distance between the fence or rope and the exposed conductor must be 1 m or greater. Climbing over ropes is strictly forbidden, and the voltage must be controlled by a switch outside of the test area. Case-by-case written approval by the Group Leader and Division Chief is required for this mode of operation.

- 3.2. **Moderate Voltage:** All permanent setups with bare conductors at moderate voltages (voltages exceeding 120 V rms or dc, but not exceeding 1000 V rms or dc) must be

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surrounded by a safety fence or other barrier for one-person or unattended operation, with working interlocks in place for unattended operation. The distance between the fence or rope and the exposed conductor must be 1 m or greater. Climbing over ropes is strictly forbidden, and the voltage must be controlled by a switch outside of the test area. Special confinement (fences or other barriers) is not required for two-person operation, but is recommended.

The proposed test area configuration requires written approval from the following:

- One-time approval by the Group Leader for one-person operation
- Annual approval by the Group Leader and Division Chief for unattended operation
- One-time notification of Division and Laboratory safety officers for new systems

The requirements for temporary setups with bare conductors at moderate voltages are the same as for permanent setups, but with case-by-case approval for one-person or unattended modes of operation.

Permanent setups with covered or insulated conductors, and unexposed terminals, require one-time approval from the Group Leader, and this approval is sufficient for unattended operation.

4. Temporary Setups

- 4.1. When troubleshooting a setup with exposed or bare conductors at high or moderate voltages, it may be necessary to temporarily bypass safety interlocks. Such procedures may only be performed under two-person operating conditions.
- 4.2. In instances where troubleshooting a system or particular equipment becomes frequent (at least once every six months) Group Leader approval is required. In all cases two staff members must be present when high voltage is energized and the interlock(s) bypassed. When troubleshooting a single piece of equipment in such a way that personnel may have access to high or moderate voltage (for example, repairing an instrument), two persons should be present.
- 4.3. The “keep one hand in the pocket” rule is strongly encouraged.

5. Signs and Warning Lights

- 5.1. ***DANGER HIGH VOLTAGE*** signs must be on display on all entrances to all test areas where bare conductors are present at both moderate and high voltages. These signs should be in the vicinity of the test area *and* on the outside of the door leading to the laboratory area.
- 5.2. A warning light, preferably flashing, must be on when high or moderate voltages are present, and ideally should be activated by the energizing of the apparatus. The warning light must be clearly visible from the area surrounding the test area. In special cases where such a light interferes with an experiment, it can be omitted with special permission from the Group Leader and Division Chief.

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- 5.3. In all cases where there is direct access from the outside hallway to the area where high or moderate voltages are present, a warning light, ***DANGER HIGH VOLTAGE*** sign, a safety interlock (for high voltages) and a locked door are required.
- 5.4. For unattended setups with bare conductors at high or moderate voltage, a warning sign with the names of two contact persons and the dates of unattended operation must be posted on the door leading to the high-voltage area. In addition, written notice of unattended testing of high or moderate voltage with bare conductors must be sent to the NIST Fire Department (in Gaithersburg) or to the Engineering, Safety, and Support Division (in Boulder) clearly stating the anticipated dates of operation. A warning light on or near the door to the laboratory must be illuminated when high or moderate voltages with bare conductors are present.

6. Grounding Stick

- 6.1. Before touching a high-voltage circuit or before leaving it unattended and exposed, it must be de-energized and grounded with a grounding stick. The grounding stick must be left on the high-voltage terminal until the circuit is about to be re-energized. Grounding sticks must be available near entrances to high-voltage areas. Automatic grounding arrangements or systems that employ audible warning tones to remind personnel to ground the high-voltage equipment are strongly encouraged for two-person operation, and are mandatory for one-person or unattended operation.
- 6.2. For systems with bare conductors at moderate voltages, the use of a grounding stick is strongly recommended, particularly if the setup contains energy-storage devices.

7. Modes of Operation

- 7.1. Two-person: Two-person operation is the normal mode of operation where high or moderated voltages are present. Allowed exceptions are:
 - When all potentially dangerous voltages are confined inside a grounded or insulated box, or where the voltages are constrained in a shielded cable, or where there is no access to bare conductors
 - When one-person or unattended operation setups have been designed and approved according to the rules set out in this document and with appropriate approval.
 - It is presumed that both individuals participating in two-person operation will follow basic high-voltage safety procedures and will monitor each other's actions to ensure safe behavior.
- 7.2. One-person: One-person operation of systems using high and moderate voltages with bare or exposed conductors, may be approved, after appropriate review and authorization, in order to provide for the efficient use of staff for long-term applications where it is judged that safety would not be compromised.
- 7.3. Unattended: It is recognized that in order to run efficient calibration services and maintain appropriate delivery schedules, unattended operation of systems using high and moderate voltages may be necessary. In such cases, unattended operation is permitted

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with appropriate review and authorization, for systems having no bare or exposed conductors, and where required warning signs, lights, and barriers are present.

Unattended operation of setups with bare or exposed conductors at high and moderate voltages may be necessary under special circumstances, such as for unusually long data-acquisition periods. This is meant to be a rare occurrence. Should this mode of operation be frequently employed, then the apparatus should be modified to enclose all potentially dangerous voltages.

8. Circuit Breakers and Disconnects

8.1. Circuit breakers, disconnects or contactors used to energize a high-voltage source must be left in an open position when the supply is not in use. Laboratories should always be left in a configuration that at least two switches must be used to energize high-voltage circuits. Whenever possible a “return-to-zero-before energizing” interlock should be incorporated into the high-voltage supply.

9. Proper Circuit Design Recommendations

9.1. Draw the circuit and study it before wiring it for operation at high voltage.

9.2. Make sure all devices that require grounding are securely grounded.

9.3. Allow adequate clearances between high-voltage terminals and ground.

9.4. Solicit a second opinion before operation for the first time.

10. Transformers and Variacs[®]

10.1. Make certain that one terminal of each transformer winding used to provide a separately derived system (this excludes the winding connected to the power supply) as well as the transformer or Variac case are properly grounded. The common terminal of a Variac should be connected to the supply neutral. Cascade transformers and, in some cases, isolation transformers are exceptions.

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| Table 1a. Summary of Safety Requirements for Working with Exposed High Voltages – Permanent Setups | | | | |
|---|--|-------------|-----------|------------|
| Exposed voltage | Safety Provision | 2-Person | 1-Person | Unattended |
| High Voltage | Written, dated notice to NIST Fire Department | | | Mandatory |
| | Safety fence | Mandatory | Mandatory | Mandatory |
| Voltages Exceeding 1000 V | Interlocks | Mandatory | Mandatory | Mandatory |
| | Automatic grounding | Recommended | Mandatory | Mandatory |
| | Warning light when voltage is on | Mandatory | Mandatory | Mandatory |
| | <b style="color: red;">DANGER HIGH VOLTAGE sign at entrance to test area | Mandatory | Mandatory | Mandatory |
| | Notification to Division and Laboratory Safety representatives | Mandatory | Mandatory | Mandatory |
| Permanent Setup | One-time Group Leader approval | Mandatory | | |
| | Annual Group Leader and Division Chief approval | | Mandatory | |
| | Case-by-case Group Leader and Division Chief approval | | | Mandatory |
| | Names of 2 contact persons and dates of operation on door | | | Mandatory |
| | | | | |

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| Table 1b. Summary of Safety Requirements for Working with Exposed High Voltages – Temporary Setups | | | | |
|--|--|-------------|----------|------------------------------|
| Exposed voltage | Safety Provision | 2-Person | 1-Person | Unattended |
| High Voltage | Warning light on door to laboratory | | | Mandatory |
| | Safety fence | Mandatory | | |
| Voltages Exceeding 1000 V | Interlocks | Recommended | | |
| | Grounding stick | Mandatory | | |
| Temporary Setup | Warning light when voltage is on | Mandatory | | |
| | DANGER HIGH VOLTAGE sign at entrance to test area | Mandatory | | |
| | Notification to Division and Laboratory Safety representatives | Mandatory | | Operational Mode Not Allowed |
| | Case-by-case Group Leader and Division Chief approval | Mandatory | | |
| | Names of 2 contact persons and dates of operation on door | | | |
| | Written, dated notice to NIST Fire Department | | | |

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| Exposed voltage | Safety Provision | 2-Person | 1-Person | Unattended |
|--|--|-------------|-------------|-------------|
| Moderate Voltage | Written, dated notice to NIST Fire Department | | | Mandatory |
| | Safety fence | Recommended | Mandatory | Mandatory |
| Voltages Exceeding 120 V but not exceeding 1000 V Permanent Setup | Interlocks | Recommended | Recommended | Mandatory |
| | Power switch outside test area | Recommended | Mandatory | Mandatory |
| | Grounding stick | Recommended | Recommended | Recommended |
| | Warning light when voltage is on | Mandatory | Mandatory | Mandatory |
| | <b style="color: red;">DANGER HIGH VOLTAGE sign at entrance to test area | Mandatory | Mandatory | Mandatory |
| | Notification to Division and Laboratory Safety representatives | Mandatory | Mandatory | Mandatory |
| | One-time Group Leader approval | Mandatory | Mandatory | |
| | Annual Group Leader approval | | | Mandatory |
| | Names of 2 contact persons and dates of operation on door | | | Mandatory |
| | Warning light on door to laboratory | | | Mandatory |

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| Table 2. Summary of Safety Requirements for Working with Exposed Moderate Voltage – Temporary Setups | | | | |
|---|--|-------------|-------------|-------------|
| Exposed voltage | Safety Provision | 2-Person | 1-Person | Unattended |
| Moderate Voltage | Written, dated notice to NIST Fire Department | | | Mandatory |
| | Safety fence or ropes | Recommended | Mandatory | Mandatory |
| Voltages Exceeding 120 V but not exceeding 1000 V Temporary Setup | Interlocks | Recommended | Recommended | Mandatory |
| | Power switch outside test area | Recommended | Mandatory | Mandatory |
| | Grounding stick | Recommended | Recommended | Recommended |
| | Warning light when voltage is on | Mandatory | Mandatory | Mandatory |
| | DANGER HIGH VOLTAGE sign at entrance to test area | Mandatory | Mandatory | Mandatory |
| | Notification to Division and Laboratory Safety representatives | Mandatory | Mandatory | Mandatory |
| | Case-by-case Group Leader approval | | | Mandatory |
| Names of 2 contact persons and dates of operation on door | | | | Mandatory |
| Warning light on door to laboratory | | | | Mandatory |