

IEEE Recommended Practices for Safety in High-Voltage and High-Power Testing

Sponsor

**Power System Instrumentation and Measurements Committee
of the
IEEE Power Engineering Society**

Approved September 17, 1981
Reaffirmed March 19, 1992

IEEE Standards Board

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Foreword

(This Foreword is not a part of IEEE Std 510-1988, IEEE Recommended Practices for Safety in High-Voltage and High-Power Testing.)

Safety is of major importance and should be of major concern to all who are involved in high-voltage and high-power measurements. Most organizations and individuals who are involved in such measurements already have a system of safety rules. This recommended practice is intended to provide guidance for those who are establishing or revising their safety rules. This recommended practice has been developed to cite some of the hazards present in making high-voltage and high-power measurements, and some of the procedures and equipment which can be used to reduce personnel hazards. It is important to recognize that procedures and equipment cannot provide complete safety; the individual's attitude is the key to safety.

This recommended practice was prepared by the Safety Practices in High-Voltage Measurements Working Group of the Power System Instrumentation and Measurements Committee of the IEEE Power Engineering Society.

J.A. Staley served as the first chairman of this working group and was instrumental in guiding development of this recommended practice through the first three drafts.

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IEEE Recommended Practices for Safety in High-Voltage and High-Power Testing

1. Scope

This recommended practice is concerned with safety practices for those who are involved with making measurements on high-voltage sources or with high-power sources of various types including power-system lines, 60 Hz test transformers, direct-voltage supplies, lightning-impulse generators, and switching-impulse generators. This recommended practice is limited to safety practices with regard to electrical hazards involved in temporary measurements, as opposed to metering, relaying or routine line work.

Considerations of safety in electrical testing apply not only to personnel but to the test equipment and apparatus or system under test. This recommended practice deals generally with safety in connection with testing in laboratories, in the field, in substations and on lines, and with the test equipment utilized. Special areas involving cable-fault location, large capacitance load testing, high-current testing, and direct connection to power lines are treated separately. For applications of high-voltage test equipment and methods in areas not specifically covered, the following general guides apply:

- 1) All ungrounded terminals of the test equipment or apparatus under test should be considered as energized.
- 2) Common ground connections should be solidly connected to both the test set and the test specimen. As a minimum, the current capacity of the ground leads should exceed that necessary to carry the maximum possible ground current. The effect of ground potential rise due to the resistance and reactance of the earth connection should be considered.
- 3) Precautions should be taken to prevent accidental contact of live terminals by personnel, either by shielding the live terminals or by providing barriers around the area.
- 4) The circuit should include instrumentation for indicating the test voltages.
- 5) Appropriate switching and, where appropriate, an observer should be provided for the immediate deenergization of test circuits for safety purposes. In the case of dc tests, provisions for discharging and grounding charged terminals and supporting insulation should also be included.
- 6) High-voltage and high-power tests should be performed and supervised by qualified personnel.
- 7) Consideration should be given to safety regulations which may apply to specific circumstances; for example, other IEEE guides, union, company, or government regulations (see also Appendix B).
- 8) In the use of signal-gathering equipment, each device should be used in such a manner that it will not present a personnel hazard should it inadvertently become a part of the high-voltage circuit, or fail to function properly.

2. References

- [1] ANSI C2-1981, National Electrical Safety Code.¹
- [2] ANSI C39.5-1974, Safety Requirements for Electrical and Electronical Measuring and Controlling Instrumentation.
- [3] ANSI Z89.1-1981, Protective Headwear for Industrial Workers.
- [4] ASME 1980 Boiler and Pressure Vessel Code, Section VIII, Pressure Vessels,² Division 1
- [5] IEC 348-1978, Safety Requirements for Electronic Measuring Apparatus.³
- [6] IEEE Std 80-1976, IEEE Guide for Safety in AC Substation Grounding.
- [7] OSHA 1910.145, Specifications for Accident Prevention Signs and Tags.⁴

3. Definitions

high-voltage: For the purposes of this recommended practice a voltage of approximately 1000 V has been arbitrarily assumed as a practical minimum for these types of tests. It is further assumed that the voltage source has sufficient energy to cause injury.

Individual judgment is necessary to decide if the requirements of this recommended practice are applicable in cases where lower voltages or special risks are involved

high-power: For the purposes of this recommended practice high-power testing shall refer to testing conducted in laboratories and in the field where fault currents, load currents, magnetizing currents, and line dropping currents are used to test a product, either at rated voltage of the product or at lower voltages.

power system: An established and permanent electrical power-supply system operated by a public or private utility company or a large industrial organization.

mobile: Equipment which is readily moved to the place of operation but not carried by hand. Where the equipment is mounted in or on a vehicle this specification applies to the entire vehicle.

permanently installed: Equipment which is permanently installed at the place of operation, and has permanent power input and grounding connections.

operators: Personnel who carry out high-voltage testing or high-power testing, or both.

observers: Personnel who are responsible for observing and reporting the effects of a test or observing a specific safety hazard and giving warnings as required.

test coordinator: A person who has overall control of a test.

qualified personnel: Personnel who have been trained in correct and safe methods.

¹ANSI standards are available from the Sales Department of American National Standards Institute, 1430 Broadway, New York, NY 10018.

²ASME standards are available from the Sales Department of the American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

³IEC Standards are available in the US from the Sales Department of American National Standards Institute, 1430 Broadway, New York, NY 10018.

⁴OSHA documents are available from the Superintendent of Standards, US Government Printing Office, Washington, DC 20402.

4. Hot Line Tools and Rubber Protective Equipment

- 1) Adequately rated insulated equipment should be used when switching or maintaining electrical equipment while it is energized. Electric equipment and lines should be considered energized until determined to be de-energized by tests or other appropriate methods or means.
- 2) Rotating machinery should be considered energized even when unexcited, due to the residual magnetism which may produce hazardous voltages at the terminals of the machine.
- 3) Rubber-protective equipment should be in accordance with the provisions of National Consensus Standards with regard to such protective devices as rubber-insulating gloves, matting, blankets, hoods, line hoses, and sleeves.

5. Safety Practices — Laboratory Work

5.1 Test Areas

5.1.1 Permanent Test Areas

Permanent test areas should be completely enclosed by walls or some type of physical barrier. Entrances to such areas should be interlocked with the high-voltage power supplies so that test voltage cannot be applied while the gates are open.⁵

Appropriate warning signs, for example, DANGER — HIGH VOLTAGE, should be posted on or near the entrance gates. (Refer, for example, to OSHA 1910.145 [7] for colors, proportions and composition.)

In some cases it is necessary to operate permanent test areas without completely enclosing barriers. In such cases the procedures for temporary areas should be used.

5.1.2 Temporary Test Areas

Temporary test areas should be completely enclosed by some type of barrier. Some examples are:

- 1) Portable fencing which is grounded and equipped with interlocked entrances (see 5.4.1).
- 2) Distinctively colored safety tape supported approximately waist high to which suitable safety signs (see 5.1.1) are attached. No one may cross this barrier. When the test is completed and the test voltage has been removed, the tape must be removed before anyone may enter the area. Alternatively, a gate carrying a suitable warning sign can be made in the tape barrier with the tape or *tennis* netting. This gate can be opened only after test power has been removed. If possible, this gate should be interlocked or an operator-activated foot switch interlock should be used.
If the taped-off area cannot be viewed completely by the operator, one or more observers should be stationed so that the entire area can be monitored. A taped-off area should never be left unattended while the test power is on.
- 3) A loud speaker system is sometimes desirable for the purpose of communicating with all personnel in the area.

5.2 Interlock Systems

Interlock systems should be designed where possible to be *fail-safe*. Where this is not possible, visual or audible signals should be provided to warn personnel of system malfunctions. (See Appendix A for some examples of typical interlock systems.)

⁵The numbers in brackets correspond to the references listed in Section 3 of this standard.

5.3 Access to Test Areas

A systematic procedure must be developed and implemented to control access to the test areas so that an area will not be energized with a person in it. A key switch system for accomplishing this is detailed in Appendix A. In special cases it may be necessary to place an observer within a test area. This should be done only after special permission has been granted and a safe working procedure has been established. This procedure may be patterned after those given in 5.1.2. Alternatively, it involves placing the person within or behind a grounded barrier or having him sit or stand on a special switch which removes the high voltage if he moved off the switch. The wiring to such a switch should conform to 5.5.2.

5.4 Safety Within Test Areas

5.4.1 Grounding Practices

All specimens should be properly grounded so that personnel hazards do not exist. It is necessary to ground the high-voltage circuit before working on it or on the test object.

Insofar as practical, automatic grounding devices should be provided to apply a visible ground on the high-voltage circuits after they are de-energized. In some high-voltage circuits, particularly those in which elements are changed from one setup to the next, this may not be feasible. In these cases the operator should attach a ground to the high-voltage terminal using a suitably insulated handle. In the case of several capacitors connected in series, it is not always sufficient to ground only the high-voltage terminal. The exposed intermediate terminals should also be grounded. This applies in particular to impulse generators where the capacitors should be short-circuited and grounded before and while working on the generator.

Safe grounding of instrumentation should take precedence over proper signal grounding unless other special precautions have been taken to ensure personnel safety.

All conductors and cables used for grounding should be of an electrical size capable of handling the maximum possible currents.

5.4.2 Direct-Voltage Power Supplies

Due to the dangerous nature of the residual charge which may exist on high direct-voltage power supplies, on ungrounded capacitive elements, and on ungrounded metallic objects, the following safety procedures should be adhered to:

- 1) Prior to energizing a direct voltage power supply, personnel in adjacent test areas should be alerted since dangerous charges can be induced on ungrounded capacitive elements and ungrounded metallic objects. Such capacitive elements and large metallic objects, both in adjacent test areas and in the immediate areas, should be short-circuited and grounded before energization of the direct voltage.
- 2) After de-energization, the test voltage should normally be allowed to decay to a low value before personnel enter the area. However, in special cases it is permissible to enter the area immediately, providing the ground stick [see 3.4.2(3)] is long enough to reach the high-voltage terminal without endangering the operator.

Upon entering the area, the first action taken should be to place a ground on the high-voltage terminal and any other exposed terminals. A grounding conductor with a suitably insulated handle should be used for this purpose.

NOTE — In the case of high-capacitance specimens such as long cables or large rotating machines, the initial grounding should be accomplished through a resistor followed by a direct ground. In some cases the direct ground should be left in place for an extended period of time (see 5.1).