Designation: E 2345 – 04

Standard Practice for Investigating Electrical Incidents[1]

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1. Scope

1.1 This practice covers guidelines for the recognition, documentation, collection and preservation of potentially relevant information and physical items involving electrical incidents, electrical injury, and/or the electrocution of individuals in low and medium voltage residential and industrial installations.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 620 Practice for Reporting Opinions of Technical Experts

E 678 Practice for Evaluation of Technical Data

E 860 Practice for Examining and Testing Items That Are or May Become Involved in Litigation

E 1020 Practice for Reporting Incidents

2.2 *NFPA Standards:*

NFPA 921 Guide for Fire and Explosion Investigations[3]

NFPA 70 E Standard for Electrical Safety Requirements for Employee Workplaces[3]

NFPA 70 National Electric Code[3]

2.3 *Other Standards:*

ANSI IEEE Std 81-1983 IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System[4]

UL 943 UL Standard for Safety for Ground-Fault Circuit-Interrupters[5]

U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Title 29 Code of Federal Regulations, 29 CFR, §1910.5[6]

U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Title 29 Code of Federal Regulations, (29 CFR) Subpart S, 29 CFR 1910.302 through 1910.399 of the General Industry Safety and Health Standards[7]

U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Title 29 Code of Federal Regulations, (29 CFR) Subpart K, Electrical 29 CFR 1926.400 through 1926.408 of the Construction Safety and Health Standards[8]

U.S. Department of Health and Human Services, Public Health Service, Centers for Disease and Prevention, National Institute for Occupational Safety and Health (NIOSH) "Worker Deaths By Electrocution—A Summary of NIOSH Surveillance and Investigative Findings"

IEC 479-1 Technical Report, Type 2 Effects of Current on Human Beings and Livestock

IEC 479-2 Technical Report, Type 2 Effects of Current Passing Through the Human Body

3. Significance and Use

3.1 In the United States, electrocutions in the home number about 560 per year, while industry electrocutions are the fifth leading cause of occupational deaths, accounting for 5348 deaths, or about seven percent of all work-related deaths for the period between 1980 and 1992. Electrical burns account for 4 to 6.5 % of all admissions to burn units in the United States and

[1] This practice is under the jurisdiction of ASTM Committee E30 on Forensic Sciences and is the direct responsibility of Subcommittee E30.05 on Engineering.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[5] Available from Underwriters Laboratories (UL), Corporate Progress, 333 Pfingsten Rd., Northbrook, IL 60062.

[6] 29 CFR (1999) §1910.5 (a) "Except as provided in paragraph (b) of this section, the standards contained in this part shall apply with respect to employment performed in a workplace in a State, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, American Samoa …"

[7] 29 CFR (1999) §1910.302 (2) "Every electric utilization system and all utilization equipment installed after March 15, 1972, and every major replacement, modification, repair, or rehabilitation, after March 15, 1972, of any part of any electric utilization system or utilization equipment installed before March 15, 1972, shall comply with the provisions of Sections 1910.302 through 1910.308."

[8] Subpart K of 29 CFR 1926.402 through 1926.408 of the OSHA Construction Safety and Health Standards contain installation safety requirements for electrical equipment and installations used to provide electric power and light at the jobsite. These sections apply to both temporary and permanent installations used on the jobsite.

account for approximately 800 fatalities per year in the United States from 1984 through 1987.

3.2 Recording of findings and physical data following an electrical incident is critical to determining cause and steps that can be taken to prevent future incidents. Documentation and preservation of the physical items, along with photographic and video recordings, helps convey findings to technical and non-technical third parties. The documentary data, which includes reports and statements, is used to corroborate the physical data and findings.

3.3 The examination of the events along with the scientific method may permit a reconstruction of the incident.

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3.5 Incident investigations should be conducted as soon as possible after the event. Most accidents are investigated within minutes or hours by police or regulatory authorities. Often, several authorities are at the scene at one time and each are generally required to document their findings in an official report. The documents generated by these authorities are significant since they reflect the earliest observations of the scene; however, because first responders have a primary responsibility to protect life and property and to prevent further harm, these documents may not reflect every pertinent detail.

4. Apparatus

4.1 Equipment may include but not be limited to the following:

4.2 *Analog or Digital Voltmeters*, with appropriate probes, cables and connectors suited for range of typical voltages.[9]

4.3 *Inductive Type "Clamp On" Current Meter.*[9]

4.4 *Neon Lamp Voltage Test Indicator*.

4.5 *Grounding Resistance Tester*.

4.6 *Lock Out, Tag Out Tags, Locks, Keys*.

4.7 *Appropriate Personal Protective Equipment (PPE)*—Gloves, boots, goggles, etc.

4.8 *Photometer and Sound Level Meter*.

4.9 Other equipment determined to be needed and in the range suited for the measurement required.

4.10 Properly calibrate equipment at regular intervals and verify calibration prior to use.

5. Safety

5.1 Follow the safety measures in 2.2, the regulatory requirements invoked through Title 29 Code of Federal Regulations (see 2.3), and the safety practices and requirements established by the local authorities or governments, and the safety policies and procedures of the activity owning and/ or operating the investigated equipment and system. Where there is a conflict, follow the most stringent requirement unless relaxed by the authority having jurisdiction.

6. Procedure

6.1 *Scene Security*—The first priority is to prevent further injuries or loss of life. All personnel should be equipped with appropriate Personnel Protective Equipment (PPE) as identified in NFPA 70 E.

6.2 Prior to securing power, if there are no risks to personnel or equipment, record state and position of scene-related equipment including local and remote control switches, levers, alarm/monitoring noise makers, annunciators, beacons, lights, switches, levers, CRT displays, mimic panel indicators, and system data-logging tapes.

6.3 Secure all electrical power supplying scene and scene equipment. Apply lock-out, tag out procedures identified in NFPA 70 E.

6.4 The following scene details should be noted, where applicable.

6.4.1 General description of the scene, plant, purpose, product manufactured or service, installation /commissioning date, location, time, date, temperature, and weather conditions, etc. Details concerning plant-working environment should also be noted, such as lighting, noise levels, ventilation, odors, etc.

6.4.2 Victim details, including, name, age, address, length of employment, work hours, shift work, work title and responsibilities, certifications, licenses.

6.4.3 What victim was doing at time, tools and equipment used and other personnel engaged with victim in the work activity.

6.4.4 Witnesses, co-workers, supervisors (chain of command), on-duty supervisors, and on duty safety officers.

6.4.5 Safety officer(s) and supervisor certification and refresher training status.

6.4.6 Power generation/distribution electrical architecture, service, and configuration of power system (for example, frequency, voltage, grounded, ungrounded, high resistance grounding, etc.).

6.4.7 Configuration of Switchgear (integrated, split-plant, etc.) and alignment of Switchgear at time of incident.

6.4.8 Type of equipment and circuit serviced, (Variable Frequency Drives (VFDs), pump motors, etc.) and equipment functioning, or process being conducted at time of incident.

6.4.9 Configuration of supply transformers:

6.4.9.1 Delta, ungrounded,

6.4.9.2 Corner grounded-delta,

6.4.9.3 Open Delta,

6.4.9.4 Wye, grounded, ungrounded, derived grounding (for example, grounding transformer), and

6.4.9.5 Solid-ground, resistance, inductive grounding.

6.4.10 Electrical characteristics of supply transformer: (nameplate data)

6.4.10.1 Impedance,

6.4.10.2 Primary/Secondary voltages,

6.4.10.3 Taps, and

6.4.10.4 kVA rating.

6.4.11 Configuration and electrical characteristic of generator: (nameplate data)

6.4.11.1 Rated kVA,

6.4.11.2 Power factor,

6.4.11.3 Volts, Amperes,

6.4.11.4 Duty rating (2–hour, 1–hour rating, etc.), and

6.4.11.5 Wye, Delta, grounded, ungrounded, etc.

6.4.12 Over-Current Protective (OCP) devices; manufacturer, model, listing data, ratings, settings, enclosure, and condition of all OCP devices between victim and power source

[9] Equipment shall be properly calibrated.

6.4.13 Electric cables and conductors: manufacturer, type, listing data, cross-section, length of run, insulation/jacket type, listing data, connectors, method of routing, penetrations, cable support/hangers, and the general condition of electric cabling between victim and first OCP device. Conductors should be visually inspected throughout their entire length, and special attention be given to joins, splices, junction boxes, repairs, and fitting used. Notice should be made of any damage, including signs of over-temperature, arcing, abrasion, crushing, or corrosion.

6.4.14 Grounding conductors; material type (Al, Cu), cross-section, length of run, routing method, support, connectors (make, listing data, etc.). Grounding conductors should be visually inspected throughout their entire length and special attention given to joints, splices, junctions, repairs, and fittings used, and for any signs of physical or electrical (arcing damage). Contact areas, especially where grounding conductor contacts other steel equipments should be assessed for signs of arcing or galvanic corrosion. The grounding conductor should be assessed for signs of previous occurrences of ground-fault damage (for example, over-temperature, arcing, oxidation layers and colors).

6.4.15 Equipment grounding connections: Equipment grounded and bonding method (exothermic, clamp, etc.).

6.4.16 Ground-fault clearing equipment, including relays, sensors, solid-state controllers, etc. Note circuitry and arrangements of ground-fault protection (GFP) equipment and GFP configuration (for example, zero-sequence, ground strap sensing, residual sensing, solid-state, ground differential relaying, etc.) Pick up times.

6.4.17 Ground fault detection system(s) (lamps, meters, solid-state, etc.).

6.4.18 Charging current of system equipment connected at the time of the incident.

6.4.19 Fault damage Energy" Estimate fault damage energy of affected equipment in kilowatt-cycles using:

$$kW-cycles = (I_{gf} * E_{gf} * t)/1000 \quad (1)$$

where:

Igf = ground fault current (about 20% of available bolted fault current,

Egf = Voltage across arc (approximately 100 Volts on a 480 Volts system, and

t = arcing time in cycles.

Energy release can be estimated by visual damage to affected equipment as shown in Table 1

6.4.20 PPE used by victim at time of casualty, as well as condition of equipment.

6.4.21 PPE availability and PPE inspection maintenance schedules.

TABLE 1 Estimated Fault Damage Energy

Estimated Energy Release	Visual Indicators	Remarks
100 kW cycles	Location of fault identifiable from spit marks on metal and from smoke marks.	
2000 kW cycles	No discernible permanent or substantial damage to hardware. Equipment usually restored by cleaning and repairing insulation.	Design target value for fault energy limit. Fault energy should not be permitted to exceed this value.
10 000 kW cycles	Serious damage, but contained within electrical enclosure.	
20 000 kW cycles	Serious damage. Fault burn through enclosure and spread to other sections of system equipment.	
>20 000 kW cycles	Considerable destruction of equipment and fire. Damage in proportion to total amount of fault energy.	

6.5 Obtain statements as early as possible from all individuals associated with the incident. Collect information related to the incident, including:

6.5.1 Maintenance and testing policies and procedures,

6.5.2 Maintenance and testing logs,

6.5.3 Electrical hazards training policies and training plans,

6.5.4 Dates of initial and recurring electrical hazards training, and training schedule,

6.5.5 Certification status of electrical staff,

6.5.6 Authority Having Jurisdiction (AHJ) inspection logs and citations,

6.5.7 Electrical drawings,

6.5.8 Electrical contractor acquisition documents, including purchase orders, contract specifications, contractor as-built drawings, and contract change orders,

6.5.9 Installation and maintenance subcontractors,

6.5.10 Victim's official position and work description,

6.5.11 Victim's work record,

6.5.12 Workplace casualty history,

6.5.13 Police, Fire and EMS Reports,

6.5.14 Coroner's Report,

6.5.15 Police and AHJ reports,

6.5.16 Witness statements,

6.5.17 Determine AHJ(s) and AHJ regulations and requirements, as well as AHJ enforced codes and standards, and

6.5.18 Company own policies, codes and standards.

7. Report

7.1 If a report is developed, prepare report in accordance with Practice E 620 , or Practice E 1020, or both.