# Electrical Safety in Battery Maintenance and Testing

**By Dennis K. Neitzel, CPE**

## INTRODUCTION

Electrical safety in battery maintenance and testing carries essentially the same requirements as any other work that involves working on or near exposed energized parts of electrical equipment and systems operating at 50 volts to ground or more. These requirements also apply to equipment and systems that operate at less than 50 volts, if there is an increased exposure to electrical burns or explosion due to electric arcs, which is often the case with batteries and battery systems. OSHA 29 CFR 1910.331-.335, "Electrical Safety-Related Work Practices" as well as NFPA 70E-2004, "Standard for Electrical Safety in the Workplace" provide the most up-to-date requirements for working safely with this type of equipment and systems.

There are specific hazards associated with working on or near batteries and associated equipment. The most common issues associated with performing maintenance and testing on various types of batteries as well as battery rooms and service areas will be addressed. Employees must recognize the particular hazards associated with maintenance and testing of batteries and understand the protective equipment and procedures required to avoid being injured by these hazards. NFPA 70E-2004, Chapter 3 addresses the specific electrical safety requirements for working with batteries and battery rooms.

## QUALIFIED ELECTRICAL WORKERS

NFPA 70E-2004, Article 205, "General Maintenance Requirements", Section 205.1, "Qualified Persons" states: "Employees who perform maintenance on electrical equipment and installations shall be qualified persons as required in Chapter 1 and shall be trained in, and familiar with, the specific maintenance procedures and tests required."

Article 100 defines a qualified person as: "One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training on the hazards involved." When evaluating the qualification level of employees remember, there is a difference between ten years of experience, and one year of experience repeated ten times.

One of the key issues related to being a qualified person is to be trained in the hazards involved. This paper will address the hazards associated with working on or near batteries, battery systems, and equipment, as well as the personal protective equipment (PPE) and safe work practices that must be used to protect workers from the hazards.

## BATTERY HAZARDS

Storage batteries are an extremely useful, and consequently a widely utilized, source of reliable electrical energy. With the proper care and maintenance, storage batteries can also be a very safe method of storing electrical power. However, storage battery systems have been involved in some extremely serious personnel accidents in the past which, without a clear understanding and appreciation of the hazards posed by storage batteries, will continue to occur.

Since storage batteries utilize an electrochemical reaction to produce energy, they present a combination of safety hazards. Batteries not only present an electrical hazard but also present a chemical and explosive hazard. The chemical hazard is due to the acid or

caustic electrolyte, while the explosive hazard exists due to the production of hydrogen gasses during the electrochemical process. Certain mixtures of oxygen and hydrogen are extremely explosive and can be ignited by any arc, spark, or open flame.

NFPA 70E requires ventilation in order to ensure that the concentration of liberated hydrogen gas does not exceed 1%. The NFPA 70E further requires that access to battery rooms be restricted to authorized (qualified) personnel only.

## BATTERY SAFETY EQUIPMENT AND PROCEDURES

Storage battery systems present a significant potential for electrical shock hazards. Consequently, standard electrical safety precautions must be observed whenever any inspections or maintenance procedures are being performed on battery systems. In the event that electrical shock does occur, use standard medical treatment for electrical shock.

Working around storage batteries is also a significant chemical hazard due to the presence of either a strong acid (typically sulfuric acid) or caustic (typically potassium hydroxide) electrolyte. NFPA 70E requires the following personal protective equipment be used to protect against acid/caustic burns:

**"320.8 Personnel Protective Equipment.** The following protective equipment shall be available to employees performing battery maintenance:
(1) Goggle and face shields
(2) Chemical-resistant gloves
(3) Protective aprons
(4) Protective overshoes
(5) Portable or stationary water facilities for rinsing eyes and skin in case of electrolyte spillage"

As noted above, "(5) Portable or stationary water facilities for rinsing eyes and skin in case of electrolyte spillage." In addition to this requirement, OSHA 29 CFR 1910.151(c) requires: "*Where the eyes or body of any person may be exposed to injurious corrosive materials, suitable facilities for quick drenching or flushing of the eyes and body shall be provided within the work area for immediate emergency use.* The following figures illustrate typical eye/body wash facility. ANSI standards require that eyewash facilities be located such that they may be reached within 10 seconds. Industry practice dictates that individuals must not be required to change floors, elevation or working level, or pass through doors to reach eye/body wash stations.


**Examples of Eye/Body Wash Facilities**

Because of the possibility of an explosive mixture of oxygen and hydrogen being formed during the battery's electrochemical reaction, special hand tools must be used for battery maintenance. These tools are made of non-sparking materials to eliminate them as a possible ignition source. These tools are also insulated to provide protection against electric shock, short circuit between terminals or ground, and to prevent acid/caustic damage to the tool. NFPA 70E, Section 320.9 states:

"Tools and equipment for work on batteries shall comply with the following:

(1) Be of the nonsparking type
(2) Be equipped with handles listed as insulated for the maximum working voltage"

**Example of Insulated Hand Tools**

In addition to using personal protective equipment and special hand tools, the following general safety precautions should also be observed:

1. Prior to entering the battery room, ensure that the ventilation system is operable and in service.
2. Ensure there is sufficient acid/caustic spill neutralizer present. A typical acid neutralizer is bicarbonate of soda (baking soda) while common caustic neutralizers are vinegar or boric acid.

3. To prevent any explosion, prohibit smoking, open flames, and any possible arc producing activities in the immediate vicinity of the battery room or enclosure.

## ELECTRICAL HAZARDS FOR BATTERY CHARGING EQUIPMENT

We must first understand what the hazards of electricity are. All of the studies reviewed have revealed three major hazards of electricity, which are: 1) electrical shock, 2) electrical arc-flash and 3) electrical arc-blast. Each of these hazards will be addressed as to the physiological effect on the human body.

### *Electrical shock*

It takes a very low value of current, flowing through the human body, to cause death or serious physical harm. Many studies have been performed in this area with different values of current that causes each effect. The following chart shows average values of current and the effects as taken from the published studies:

| ***Current*** | ***Effect*** |
|---|---|
| **1 mA** | **Barely perceptible** |
| **1-3 mA** | **Perception threshold (most cases)** |
| **3-9 mA** | **Painful sensations** |
| **9-25 mA** | **Muscular contractions (can't let go)** |
| **25-60 mA** | **Respiratory paralysis (may be fatal)** |
| **60 mA or more** | **Ventricular fibrillation (probably fatal)** |
| **4 A or more** | **Heart paralysis (fatal)** |
| **5 A or more** | **Tissue burning (fatal if vital organ)** |

**Physiological Effects of AC Current on the Body**

| **A.C. (60Hz)** | **D.C.** | **Effects** |
|---|---|---|
| **(ma)** | **(ma)** | |
| **0.5 – 1.5** | **0 – 4** | **Perception** |
| **1 – 3** | **4 – 15** | **Surprise (Reaction)** |
| **3 – 22** | **15 – 88** | **Reflex Action (Let Go)** |
| **21 – 40** | **80 – 160** | **Muscular Inhibition** |
| **40 – 100** | **160 – 300** | **Respiratory Block** |
| **> 100** | **> 300** | **Usually Fatal** |

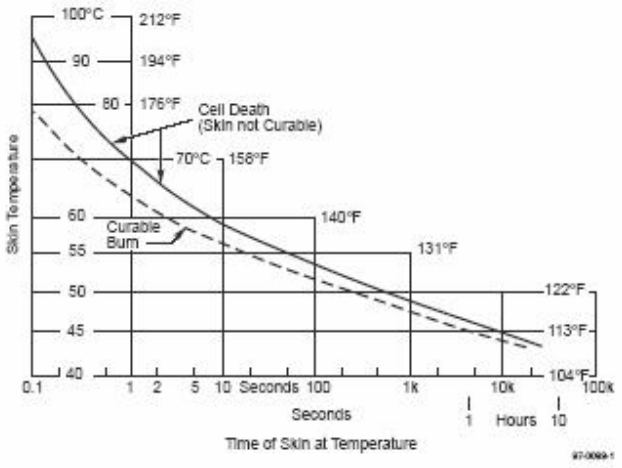
**Comparison of AC to DC Shock Effects**

OSHA 29 CFR 1910.333, as well as NFPA 70E, Chapter 1 requires employees, who are exposed to the electrical shock hazard, to be qualified and that the circuits or equipment be deenergized and properly locked and tagged. However, if they must work the circuits or equipment energized then they must use safe work practices and procedures, and the appropriate personal protective equipment and insulated hand tools.

### *Electrical arc-flash*

There are two different issues with this hazard, the arc temperature and the incident energy. The main concern with the arc temperature is the flash flame and ignition of clothing. At approximately $203^0$F ($96^0$C) for one-tenth of a second (6 cycles), the skin is rendered incurable or in other words a third-degree burn. With only 1.2 cal/cm$^2$ of incident

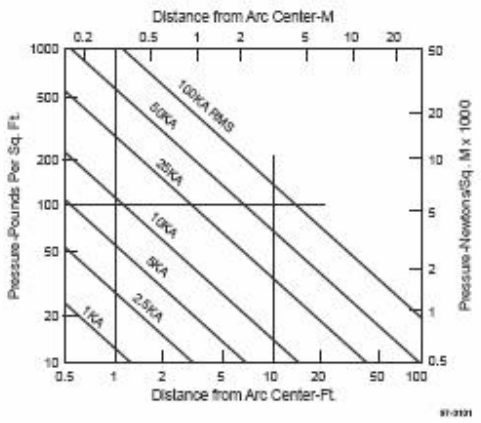
energy, we have the onset of a second-degree burn. It does not take a very high temperature or very much energy to cause extreme pain and discomfort or even death to the worker.




***Electrical arc-blast***

The pressures developed by an electrical arc can be extremely high. One study noted that copper, when vaporized, expands at a factor of 67,000 times, which one expert estimated was the same expansion as that produced by dynamite. Doors or covers must be securely latched before operating a switch or circuit breaker. Technicians or operators must place their body in the safest position possible before operating the equipment.

The resulting expansion of the air and vaporized conductive material creates a concussive wave surrounding the arc. The pressures in this wave may reach several hundred lbs/ft$^2$, destroying equipment enclosures and throwing debris great distances. Pressures as low as 50 lbs/ft$^2$ have knocked down cinderblock walls several feet away. The pressure created during an electrical explosion is directly proportional to the available short circuit at the arc location. With an up-to-date short circuit study available, the anticipated blast pressure can be estimated from tables or charts.




**Pressure vs. Distance**

## ELECTRICAL HAZARDS ANALYSIS

Recent changes in consensus standards, along with a better general understanding of the seriousness of electrical hazards have resulted in a renewal of interest in the subject of

hazard analysis. The NFPA 70E-2004 addresses the requirements for conducting an "Electrical Hazard Analysis" with emphasis on the "Shock Hazard Analysis" and the "Flash Hazard Analysis". NFPA 70E also tells us that if circuits operating at 50 volts or more are not deenergized (placed in an electrically safe work condition) then other electrical safety-related work practices must be used. These work practices must protect the employee for arc-flash as well as inadvertent contact with the live parts. These analyses must be performed before an employee approaches exposed live parts within the Limited Approach Boundary.

## SELECTION OF ELECTRICAL PROTECTIVE EQUIPMENT

Most employers, operators, and electricians are knowledgeable in the selection and inspection requirements for electrical PPE used for the prevention of electrical shock hazards, as well as head, eye, hand, and foot protective equipment. These requirements are readily found in OSHA 29 CFR 1910, Subpart I, "Personal Protective Equipment" with 1910.137 covering "Electrical Protective Equipment" which also provides requirements for the in-service care and use of electrical protective equipment.

The OSHA requirements for the hazard analysis and selection of protective clothing are found in 29 CFR 1910.132, "General Requirements for Personal Protective Equipment", paragraph (d) which states: "The employer shall assess the workplace to determine if hazards are present, or are likely to be present, which necessitates the use of Personal Protective Equipment (PPE). If such hazards are present, or likely to be present, the employer shall: "Select, and have each employee use, the type of PPE that will protect the affected employee from the hazards identified in the hazard assessment."

1910.132 (f) – Training (1) states: "The employer shall provide training to each employee who is required by this section to use PPE. Each such employee shall be trained to know at least the following:"

- When PPE is necessary;
- What PPE is necessary;
- How to properly don, doff, adjust, and wear PPE;
- The limitations of the PPE; and
- The proper care, maintenance, useful life, and disposal of PPE.

OSHA also requires protection from the hazards of electricity in 1910.335(a)(2)(ii) which states: "Protective shields, protective barriers, or insulating materials shall be used to protect each employee from shock, burns, or other electrically related injuries while that employee is working near exposed energized parts which might be accidentally contacted or where dangerous electric heating or arcing might occur."

Once it has been determined that protective clothing and/or equipment is necessary to perform the specific task, it must be purchased and the employees trained to wear it properly. Having the properly sized and rated clothing will provide protection of the employee when performing each task. The required PPE may be uncomfortable to wear, especially in hot climates but it is better to suffer ten minutes in an uncomfortable environment then ten months, or longer, in a burn center.

## SUMMARY

Safety requires careful attention to the hazards of specific types of equipment. Batteries are not only an electrical hazard but are also a chemical and explosive hazard. Personal

protective equipment, including eye and body wash facilities, must be used when working with batteries.

In analyzing and resolving the issues of electrical hazards in the industry, we must follow a path that will lead to a comprehensive analysis of the problems that exist and provide a quantified value to ensure the selection of appropriate personal protective equipment. An analysis of all electrical hazards must be completed and steps taken to prevent injuries and fatalities. The following steps could be taken to ensure the adequacy of the electrical safe work practices program and training of "qualified" electrical personnel:

1. Conduct a comprehensive Job Task Analysis.
2. Complete a Task Hazard Assessment.
3. Analyze tasks for the Personal Protective Equipment needed.
4. Conduct Training Needs Assessment for Qualified and non-qualified workers.
5. Revise, update, or publish a complete Electrical Safe Work Practices Program.

Regulatory agencies and standards organizations have long recognized the need to analyze the hazards of electrical work and plan accordingly to mitigate the hazards. Unfortunately, many in the electrical industry have chosen to "take their chances", largely because nothing bad has yet to happen. As more information becomes available on the economic and human costs of electrical accidents, it is hoped that more in the industry will recognize the need for a systematic hazard analysis, and an electrical safe work program that emphasizes hazard identification and abatement.

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