BATTERY SAFETY FOR FIELD SERVICE TECHNICIANS: BASICS OF DEVELOPING SAFE AND EFFECTIVE PROCEDURES

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Abstract

Battery service technicians, be they in-house or in the employ of a commercial service operation, are required to follow established safety rules and procedures. Safety is of paramount importance when servicing a stationary battery, largely due to the fact the battery is always energized. There is no option. Most routine maintenance tasks are carried out with a battery connected to its charging source, operating on float charge. Such tasks typically include the use of portable, handheld test equipment and tools to measure and record operating parameters like cell voltage, specific gravity, inter-cell connection resistance, internal ohmic values, etc. To accomplish such tasks, a technician must be in relative proximity to the battery. Use of appropriate personal protective equipment (PPE) is essential to reduce the likelihood of an accident. Proper tools are required. Training is required based on the tasks a technician is expected to undertake. To further reduce the possibility of a mishap, proper safety techniques are required.

The objective of this paper is to raise awareness to those involved in developing training and procedures and, of course for those performing the maintenance. Examples of two common maintenance tasks will be presented with specific discussion relating to process and technique with emphasis on enhancing safety and effectiveness to make the point. While the paper does not cover all tasks and scenarios, it is hoped the ones covered will get readers thinking about how maintenance is being performed where they work and what can be done to improve safety, and thus, a reduction in the likelihood of an accident.

Introduction

Safety procedures in one form or another are a way of life across the business spectrum. Whether it is in a hospital, trucking company, warehouse, machine shop, cell site, data center or battery room, a safe and effective work procedure is needed to guide technicians through a task. A procedure must be previously proven safe and effective before being placed into practical application. It must be documented and supported by management and should include key safety points and be integrated into the work instruction. As part of a training program, a student should be able to demonstrate ability to locate a procedure for a task, read, understand, and demonstrate ability to perform the task. The text covers two work tasks a battery field service technician would routinely perform.

SME Required

Safe work procedures should be developed by those persons having direct experience and knowledge of the facts required. This is a key concept. Such a person is generally identified as a subject matter expert (SME). Non-SME personnel charged with writing procedures is the first step in creating a procedure that may well be seriously flawed and unsafe. More than casual, infrequent experience and basic knowledge working on stationary battery systems is required to author work procedures.

For example, an SME is well inside his or her wheelhouse when extensive experience performing routine preventive maintenance has been the bulk of their time on the job. Such is not the case if that person is tasked with writing procedures for the use of a sophisticated capacity test set if that person has never used it or fully understands the work. Therefore, another SME possessing those qualifications is needed.

Considerations for Development of Procedures and Training

Procedures and training are closely related to each other. Developing a safe procedure cannot be accomplished in a vacuum. So, what is needed? A good source of SMEs in an organization are in-house training instructors, team leads, supervisors and technical support staff. Several SMEs may be required to contribute to a procedure. For example, sub-procedures and training may be better produced by safety personnel, whereas the details regarding use of a capacity test set would be better handled by a test equipment SME. In the end though, everything culminates into a single homogenous document a technician can use.

A procedure should be clear, concise, and relatively free of “clutter”. Translation: do not embed an instrument manufacturer’s user manual into a work instruction and call it a “procedure”. The entire manual is not likely required. Short cuts like this are not a good idea. At the opposite end of the procedure spectrum are those written in a form of shorthand that do not provide enough detail for the technician. This too is counterproductive and can lead to insufficient instruction resulting in confusion and potential errors.

If the use of specialized test instruments and tools is infrequent, periodic refresher training may be required. Technician skills may have atrophied. This may be needed for technicians using more specialized instruments such as micro-ohmmeters, internal ohmic testers, digital hydrometers, thermal imaging cameras and related software. Refresher training does not need to start at ground zero. Such training should/can be abbreviated and built upon initial training. This can also be applied to electrical safety training. It is suggested technicians review a procedure prior to commencing the work in an environment when it has not been performed recently.

Technicians should not be expected to use tools and test equipment where a need for training is clearly required. To perform work on batteries, including the use of test equipment for which a person is not trained, automatically makes that person unqualified.

Arc Flash and PPE

Knowing the incident energy that could occur in a circuit to be serviced is essential. Therefore, an arc flash calculation is first needed. Once it has been determined, the appropriate personal protective equipment (PPE) can be selected and made part of the PPE list in the procedure. Too often, technicians wear too much PPE for the hazard. This can, among other things, make an individual less dexterous when working with hardware such as nuts, bolts, and washers. For example, using leather gloves over rubber gloves is required by OSHA only when working above 375 volts dc. In the example procedures that follow, the battery is a 60 cell, 120 volt system. Extra dexterity is afforded without the incumbrance of the gloves. Hole testing of the rubber gloves after use is required. Another is the use of arc rated clothing such as coveralls and hoods which exceed the needed protection. If incident energy calculations indicate that energy is 4 cal/cm^2, do not require 12 calorie suit and a hood. A technician can quickly become overheated, resulting in a need for frequent breaks. The situation becomes exacerbated when ambient conditions involve high temperature.

The example battery system consists of a quantity of 60 ABC-13 vented lead-acid cells. According to the battery manufacturer data sheet, the internal short circuit current (I_{sc}) is listed as 6250 amperes. Using the arc flash calculation formula from NFPA 70E, Annex D.5.1[1], the estimated dc arc flash incident energy at the maximum power point is 3.59 cal/cm^2.

Since the arc flash risk assessment was conducted using the incident energy calculation method, NFPA 70E directs us to Table 130.5(G) for the proper PPE. This should be listed in the procedure, so the technician knows what PPE is required.

When selecting arc flash PPE, if using the incident energy analysis method, the PPE category table cannot be used to determine PPE requirements (e.g., level 1). The NFPA 70E Table 130.5(G) must be used. The table addresses incident energy and the associated PPE in two ranges: 1) incident energy equal to 1.2 cal/cm^2 up to and including 12 cal/cm^2 and 2) incident energy exposures greater than 12 cal/cm^2.

With the previous arc flash calculation in mind, it is noteworthy that at least two studies have been conducted relating to arc flash duration and incident energies at various dc voltages: one by Bonneville Power Administration (BPA)[2] and the other by Hydro Quebec[3]. They were conducted under laboratory conditions. Fundamentally, results showed that sustaining an arc at 500 volts dc for 2 seconds was achieved. However, at 260 volts dc and below, sustaining an arc of 2 seconds was not achieved after multiple tests. Arc duration ranged from approximately 40 to 326 milliseconds at 100 volts dc, 50 to 715 milliseconds at 140 volts and 750 to 1300 milliseconds at 260 volts dc. Thus, the incident energy realized was considerably lower. The time used in dc arc calculations in NFPA 70E is 2 seconds. Based on the results of the studies referenced, it appears that the NFPA 70E dc arc flash calculations are quite conservative in that the incident energy is significantly overestimated. Test result data from the studies bears this out.

While the NFPA 70E standard 2 second arcing time is the default, a person performing calculations is not necessarily limited to that time. If a calculation is made using a shorter arcing time, the person who made the calculation must be able to justify their rationale to the local authority having jurisdiction (AHJ). Naturally, the incident energy will be less when a shorter arc duration is used. Therefore, lighter weight PPE may be a practical application of modified dc arc flash calculations. It is the author's opinion there will likely be more industry research and testing information forthcoming on the subject.

Job Hazard Analysis

Job hazard analysis, commonly referred to as JHA, is an analysis of the hazards and risks that focus on identifying and controlling hazards. The JHA provides a process for analyzing work activities that identify the equipment, tools, and other related materials needed to develop work methods and procedures for accomplishing a task. A detailed OSHA guide on understanding and developing a JHA is available from OSHA[4]. The form can be paper or electronic. It should be archived in accordance with a company's document retention policy. Depending on circumstances, a JHA form can be designed such to be employed to cover many types of work that are conducted in a facility. The advantage of a common form is that there is just one document. A disadvantage is one form can be quite extensive. Figure 1 is an example of a JHA form that is intended to be used primarily for electrical work but includes checklist items pertaining to related mechanical aspects that may play a role in hazard analysis. Similar to procedure writing, a team approach can be applied to the development of a JHA and the associated form(s). The form should be completed with all personnel that will be performing the work present. Everyone involved signs off on the JHA and agree it has been successfully completed <u>prior</u> to commencing work. This analysis plays an important role for the SME in the development of work procedures and should be used each time a new procedure is required. Safety first!

ACME DC Power Testing and Maintenance Services	**Job Hazard Analysis (JHA)**	**REQUIRED: EVERY JOB EVERY DAY**

(If Space Is Limited Use An Additional Sheet Of Paper And Attach It To This Form)

Conducted by:	**Customer:**
Meeting Date/Time:	**Start Time:**
Type of Work Being Performed:	**Customer Site:**
	Job ID:
	List Subcontractor Companies (if any):
Arc-flash Potential / Incident Energy: cal/cm^2 Arc-flash Boundary (if IE $1.2cal/cm^2$+): inches	Shock potential: VDC VAC
Arc-flash Analysis Required by Customer? (If Required, **STOP WORK HERE** if not on hand)	Energized Electrical Work Permit required by Customer? (If Required, **STOP WORK HERE** if not on hand)
"Dry Run" required by Customer? (If Required, document below as a TASK)	

Possible Hazards (not a comprehensive list)			**Engineering / Administrative Controls (check)**		
	Yes	N/A		Yes	N/A
Shock			Inspect all tools daily (guard, bits, cords)		
Arc-flash			2-person handling of batteries		
Chemical (splash or fumes)			Housekeeping (sweeping, debris removal)		
Lead			Verify-Test-Verify (absence of voltage check)		
Pinch points			Assured Equipment Grounding Conductor Program (AEGCP)		
Stairs			GFCI pigtail / outlet		
Overhead (low clearance or falling items)			Insulated Tools		
Noise (drilling or other)			Insulated cable ends (electrical tape not allowed)		
Strain / Sprain			Material Handling Equipment (MHE)(list per task)		
Lifting			Insulating blankets (electroshield)		
Reaching / Kneeling / Ladders			Cones / Caution Tape / Barriers		
Fatigue / Stress			Lockout / Tagout (LOTO)		
Slip / Trip / Fall			Energized Electrical Work Permit		
Cutting / Laceration			Work over 50 V (AC or DC): MOP available		
Working at height			Other		
Weather			**Personal Protective Equipment (PPE) (check)**		
Environmental			Safety Glasses		
Lighting			Gloves (list glove type per task below)		
Traffic / Pedestrians / Walkways			Safety Toe Shoes		
Maintenance (condition of equipment)			Goggles / Face Shield		
Grounded system (reference ground)			Acid resistant Apron		
Notify customer of any hazards?			Arc-Flash PPE (per incident energy above)		
Heavy Equipment: reach lift, scissor lift, etc.			Hearing Protection		
Craning, Rigging, Signaling			Fall Protection		
Other (see page 2 for suggestions)			Hard Hat		
			Other		

Task	**Hazard**	**Control(s) / PPE**

Figure 1 – Job Hazards Analysis Checklist

Task	Hazard	Control(s) / PPE

The following topics were covered (in addition to all items above):

☐ Two person handling of batteries
☐ Location of fire extinguisher
☐ Location of eyewash
☐ Reporting of all accidents, spills, property damage
☐ Location of first aid kit
☐ Location of spill containment kit

Location of site, how to direct 911 to location, where is the closest emergency room:

Each attendee to print name (and company if not *ACME*):

List of General Hazards (not comprehensive)

General Hazards 10
- Uneven Ground / Slips / Trips / Falls
- Confined Spaces
- Driving, traffic, congestion
- Power Tool / Equipment Use
- Ergonomics
- Un/Loading Equipment and Material
- Safety at Heights / Scaffolding / Ladders
- Aggressive Animals / Wildlife
- High Crime Areas

Environmental Hazards 4
- Weather Conditions
- Bees, Wasps, Snakes, Spiders
- Heat / Cold stress or Illness

Health Hazards 5
- Chemical Exposure / Burns
- Noise Exposure
- Lead / Asbestos
- Hazardous Materials Transportation

Electrical Hazards 4
- Clearance Procedures / LOTO / Grounding
- Proximity to Energized Equipment
- Underground / Overhead Utilities

Public Safety 5
- Distracted, Impaired, Unsafe Motorists
- Vehicular Traffic (Work Area Protection)
- Pedestrian Traffic (Inside and Outside)
- Proximity to Railroads

Crane 9
- Crane Size / Capacity
- Lift Plans / Load Weight
- Crane Setup / Cribbing / Stability
- Traffic
- Rigging
- Rigger / Signaler Certifications
- Electrical Hazards / Clearances
- Suspended Loads

End of Day Debrief

What went Well?

What went Bad? Any Injuries or Unplanned Incidents?

If so, was it Reported?

What almost went Bad (near miss)?

Close-out Paperwork completed (MOP, drawings, etc.)?

Is the Work Area Clean?

Are Barricades Removed or Properly Erected/Tagged?

Suggestions?

Figure 1 – Job Hazards Analysis Checklist (continued)

Work Procedure Example #1

DIY Maintenance Operations
Helmsford Plant
Battery Intercell Connection Resistance Measurements

Procedure I.D.: DIY-HP-BATT-01-CR-2
Revision Level: 3.2 January 2017

Task: Battery intercell connection resistance measurements

Personnel Required: This task requires one qualified technician and one safety observer

Purpose: The purpose of this task is to measure and document all bolted battery connection resistances. Upon completion, the readings are to be forwarded to plant Reliability Engineering Group for detailed analysis and determination of whether connection resistance is adequate for continued battery operation.

Scope: This procedure applies to practices employed by technicians when working on battery systems constructed with two terminals per cell with single or dual connectors.

Training Requirements: A technician shall have completed the training below prior to assignment of this task
Test Equipment: TE-105-MICRO-OHM
Safety: ES-101-600V
Battery Training: BM-101-VLA

PPE Requirements: The listed PPE below shall be used as prescribed in Safety Policy 1B-2D and company training course ES-101-600V

- Safety glasses with side shields
- Arc rated face shield and arc rated balaclava
- Safety shoes with EH rating
- Clothing with an arc rating equal or greater than the arc flash incident energy of 3.59 cal/cm^2
- Class 00 rubber gloves
- Hard hat
- Hearing protection

Tool and Test Equipment Requirement:
Acme 325840-11 micro-ohmmeter
Acme 325900-18 micro-ohmmeter test lead set
Roto 38-160 3/8” insulated torque wrench with associated insulated socket
Roto 12-330 ½” insulated box end wrench

DIY Maintenance Form Use:
Safety Form# JHA-1 Job Hazards Analysis
Maintenance Form# BATT-01-CR-2T (Connection Resistance Log)
Maintenance Form# BTS-VLA (Battery Torque Specifications for VLA Cells)

Maintenance Form# BRV-VLA Cells (Baseline Resistance Values for VLA Cells)

Battery Status: The battery is to remain in service for this procedure

WORK PROCEDURE

✓

☐ 1. PPE applicable for this procedure shall be used in accordance with company safety policy and training. It shall be inspected and found to be serviceable prior to use. All rubber goods shall not be used if beyond the expiration date imprinted on the PPE. Obtain replacements as needed prior to commencing work.

☐ 2. Verify the micro-ohmmeter is within the calibration date range indicated on the affixed label. Instruments without a label or indicated as out of calibration are not to be used. Source another instrument and send the other to the calibration shop for service.

a. ⚠ Micro-ohmmeter test probes are to be placed across intercell connections. Never place probes across a voltage source, i.e. a battery cell. This will result in voltage being applied to the instrument, clearing (opening) the internal fuses, requiring repair.

b. ⚠ The micro-ohmmeter used for this procedure shall be operated on its internal battery only. It is not to be plugged into the AC line to provide operating power in the case of low or dead internal batteries. Batteries shall be charged overnight prior to use.

☐ 3. Inspect instrument tests leads for damage with special attention to insulation condition and spike probes. Damaged test leads shall be repaired or replaced as required. Source replacement test leads if needed.

☐ 4. Starting with cell number 1, measure and record the resistance of the connection between cell 1 and cell 2.

☐ 5. Enter the reading rounded to the nearest micro-ohm on the maintenance form associated with this procedure.

a. Connection resistance values should be consistent throughout the battery for a given type of connection.
b. A connection should be re-tested if an expected reading is not observed.

☐ 6. Moving to cell 2, continue measuring and recording all intercell connections in sequence throughout the battery until all have been measured and recorded on the form.

☐ 7. Review the readings taken to determine consistency. Refer to Form BRV-VLA Cells and locate the baseline resistance values for the battery being maintained.

☐ 8. A connection should be re-torqued when its measured resistance is more than 20% higher than the established baseline for the connection type in question. If such a condition occurs, follow

a. Refer to Battery Torque Specifications form BTS-VLA for the re-torque value for the specific make and model cell being tested.
b. Re-torque the affected connection per the above form in (a) above
c. Measure the connection again and record the value
d. If item b and c above do not result in an acceptable resistance, the connection must be fully serviced off-line during the first available opportunity
e. Report condition to supervisory maintenance personnel on the log form

☐ 9. Submit the completed log form to Reliability Engineering

EMERGENCY REPORTING
DIAL 24911 FROM ANY PLANT PHONE
RADIO: USE CHANNEL 9
CELL PHONE: 614-869-7000

Work Procedure Example #2

DIY Maintenance Operations
Helmsford Plant
Battery Cell Float Voltage Measurements

Procedure I.D.: DIY-HP-BATT-02-CFV-01
Revision Level: 1.0 June 2018

Task: Battery cell float voltage measurements

Personnel Required: This task requires one qualified technician and one safety observer

Purpose: The purpose of this task is to measure and document the overall battery float voltage and individual cell voltages per the below procedure. Upon completion, the readings are to be forwarded to plant Reliability Engineering Group for detailed analysis and determination whether they are within operational limits.

Scope: This procedure applies to practices employed by technicians working on vented lead-acid batteries and valve regulated lead-acid batteries

Training Requirements: A technician shall have completed the training below prior to assignment of this task
Test Equipment: Benton 375 CATIII digital multimeter
Safety: ES-101-600V
Battery Training: BM-101-VLA and BM-101-VRLA

PPE Requirements: The listed PPE below shall be used as prescribed in Safety Policy 1B-2D and company training course ES-101-600V
- Safety glasses with side shields
- Arc rated face shield and arc rated balaclava
- Safety shoes with EH rating
- Clothing with an arc rating equal or greater than the arc flash incident energy of 3.59 cal/cm^2
- Class 00 rubber gloves

- Hard hat
- Hearing protection

Tool and Test Equipment Requirement:
Benton 375 CATIII digital multimeter w/standard test leads

DIY Maintenance Form Use:
Safety Form# JHA-1 Job Hazards Analysis
Maintenance Form# BATT-01-CV-00 (Cell Float Voltage Log)
Maintenance Form# BFS-VLA-VRLA (Battery Float Specifications-VLA/VRLA)

Battery Status: The battery is to remain in service for this procedure

WORK PROCEDURE

✓

☐ 1. PPE applicable for this procedure shall be used in accordance with company safety policy and training. It shall be inspected and found to be serviceable prior to use. All rubber goods shall not be used if beyond the expiration date imprinted on the PPE. Obtain replacements as needed prior to commencing work.

☐ 2. Verify the voltmeter is within the calibration date range indicated on the affixed label. Instruments without a label or indicated as out of calibration are not to be used. Source another instrument and send the other to the calibration shop for service.

☐ 3. Inspect instrument test leads for damage with special attention to insulation condition and probes. Damaged test leads shall be repaired or replaced as required. Source replacement test leads if needed.

☐ 4. Verify the charger is operating and the battery is on float charge by confirming items *a* though d below

a. Charger AC input breaker is closed and power "ON" lamp is illuminated
b. Charger DC output breaker is closed
c. Charger DC output ammeter is indicating output current
d. Battery disconnect is closed

☐ 5. Measure and record the battery float voltage being applied to the system with one decimal point resolution. Make the measurement at the battery main + and - terminals. Do not use the charger panel meter to provide the reading. Example – 135.2 volts. Enter the reading on the cell float voltage log.

☐ 6. Divide the battery float voltage reading by the number of cells in the battery system to obtain the average float voltage per cell being applied. Example 135.0 / 60 cells = 2.25 volts per cell. Enter this value on the cell float voltage log. Use two decimal place resolution.

☐ 7. Starting with cell #1, measure and record the float voltage of each cell in the battery system. Use two decimal place resolution, entering the values on the cell float voltage log.

- ☐ 8. Review all readings, noting, if any, those exhibiting a float voltage below its minimum acceptable value (example, 2.13 V for a 1.215 nominal specific gravity VLA cell). Refer to Maintenance Form BFS-VLA-VRLA (Battery Float Specifications-VLA/VRLA) to determine the minimum acceptable value for the battery being serviced.

- ☐ 9. Questionable readings should be re-tested to confirm a suspected problem. When questionable readings are confirmed as a problem, such cells should be highlighted as such with any comments provided on the cell float voltage log.

- ☐ 10. Submit the completed log form to Reliability Engineering

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CELL PHONE: 614-869-7000

Summary

This paper scratches the surface relating to safe and effective work procedures for field service technicians. They can easily become more complex based on the task. The author's objective in writing the paper is to get battery users thinking more about how their own work procedures are developed and how well field technicians understand them. They should be simple and straightforward while at the same time, provide the needed information to the user. All bases need to be covered. The bullet list below aids this summary.

- At least one SME is needed to write a procedure
- A procedure should be proven by testing it in the field prior to release
- Track all document revision history
- Safety policy and procedures must be integrated into work procedures
- Use of NFPA 70E and arc flash calculations are essential in the development of PPE requirements
- PPE requirements must be identified and integrated into work procedures
- Tasks must be understood and well defined
- Tools and test equipment must be listed in a procedure
- Training requirements must be met and documented
- Recurrent/refresher training may be required based on how frequently the work is performed
- Reference documentation may be required and integrated into a work procedure
- Job hazard analysis is needed prior to commencing a job/project

How do your procedures measure up?

References

1. National Fire Protection Association, NFPA 70E – *Standard for Electrical Safety in the Workplace*
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https://*www.osha.gov*/sites/default/files/publications/*osha*3071.pdf