

Ground Handling of Batteries at Test and Launch Site Facilities

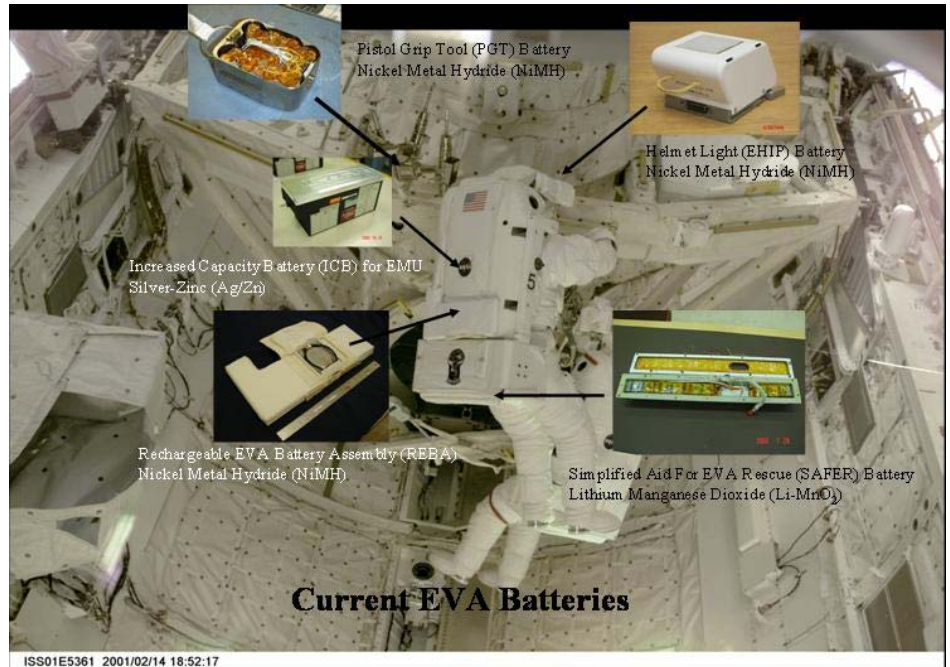
Judith Jeevarajan
NASA-JSC

Alan R. Hohl
Lockheed Martin

The 3rd IAASS Conference
Rome, Italy
October, 2008

Introduction

- Batteries are energetic devices and should be handled with safety in mind.
- Ground handling and testing are sometimes regarded as routine and safety is overlooked.
- For personnel and equipment safety and maintaining battery integrity, documents are prepared to provide both guidance and discrete requirements for ground handling, transportation, testing and operation of batteries used for flight applications.
 - These could be engineering units, prototypes, qualification or flight units.



Ground Support Equipment Requirements

Electrical Ground Support Equipment (EGSE) may be Commercial-off-the-shelf (COTS) or custom- designed or a combination of both.

- EGSE shall have redundant controls to not impose any hazard on the batteries, due to malfunction, especially when used for testing of flight batteries.
- Battery charging and discharging processes in the ground test environment shall be continuously monitored by personnel if monitoring by personnel is stated to be a safety control per the hazard analysis.
 - Personnel monitoring cannot be used as one of the first two levels of control
 - Personnel training should include the basics of the relevant chemistry, and the hazards and controls associated with each unique design.
- EGSE shall be current-limited by design to prevent overloads or overcurrents on the batteries.
- EGSE shall provide monitoring and protection for voltage, current, and temperature to prevent battery damage or failure.



Ground Support Equipment Requirements

- The polarity of EGSE terminals shall be marked.
 - And battery connectors shall be designed to prevent reverse polarity.
- Test equipment interfacing with batteries, especially those used for flight battery programs shall be periodically calibrated per the equipment manufacturer's recommendations.
- Battery design, testing and operations should be in accordance with the chemistry used.
- The battery test protocols (eg., charge and discharge for rechargeables), shall be assessed by the launch site's safety approval authority.
- EGSE shall be verified to operate correctly prior to first operational use at the launch site, including all safety devices, prior to connecting a battery for charging.



Ground Support Equipment Requirements

- EGSE shall have two independent controls for fault detection to an overcharge condition in the battery. These can be a combination of software and hardware controls.
- Test protocols programmed into EGSE shall have tolerance ranges for all parameters used for testing or operation.
- Test protocols programmed into the EGSE shall have design limits specified for the test parameters.
 - Design limits will be based on those specified by the manufacturer or those that the battery has been certified to for the application.
- Test protocols for EGSE shall have safety limits specified. Conversely, EGSE should prevent the batteries from exceeding the safety limits.
 - Example: EGSE should prevent lithium-ion (cobaltate cathode) cells from exceeding 4.4 V or driving the cells to less than 2.5 V.

Ground Support Equipment Requirements

- Test equipment shall be designed with limits that prevent restart of equipment or a continuation of the test in the event of a power, test equipment or battery failure.
- EGSE shall monitor and record battery parameters as required per the battery provider's handling plan, wherever possible.
 - For lithium-ion batteries, individual cell or parallel cell bank monitoring of voltage, current, and temperature and recording is required during charging and discharging
 - Exception: where small-cell lithium-ion battery designs are used, cell string monitoring capability shall demonstrate an equivalent level of safety to the safety approval authority via the hazard analysis and verification testing program
- Battery test data sampling rate during testing should be adequate enough to provide information in the event of failures.
- Prior to connecting the battery, support equipment (ground or flight) shall be verified to operate safely at the launch processing site including all fault tolerant devices.

Ground Support Equipment Requirements

- Battery Charging equipment shall be
 - Designed and tested for recharging batteries of a specific chemistry and/or battery design. If multiple battery chemistries and designs are to be charged with the same EGSE charging equipment, the equipment's capability shall be verified by test prior to qualification or flight battery testing.
- Charging benches and tables shall be coated with acid- or electrolyte-impervious coatings and shall be equipped with splash and drip trays to prevent drips or leaks from running onto the floor.
- Safety devices, mandatory inspection points and verification steps shall be incorporated into the EGSE designs or the handling/operating procedures where two-fault tolerance is not met by the battery by itself.

Battery General Design Safety

- Battery designers or handlers shall use JSC 20793 Rev B as the requirements document if imposed before contract was placed (not imposed on Orion battery)
 - Contractor-developed battery safety requirements using best NASA, Department of Defense (DoD) and commercial practices, lessons learned
- All fault protection methods, safety information/test data, handling plans and procedures, for the battery and EGSE designs shall be reviewed and approved for safe use by the SAO before arrival, usage, packing, storage, transportation, and disposal on the site.
- For ground testing, all batteries shall be accessible for electrical disconnection or electrical isolation.
- If a battery is not connected to any test system, the battery terminals or connector plug shall be given positive protection against shorting.
- Battery design and operations shall be within the manufacturer's recommended design and safety limits
- Battery design and operations, if not within the manufacturer's recommended design limits shall be certified to the required environments to confirm functionality and safety.

Battery General Design Safety

- Batteries and cells shall be treated as always having a voltage potential, therefore, connection or disconnection of a battery shall be considered an electrical hazard and a “spark” potential.

Battery Ground Operation and Test Safety

- Sufficient ventilation shall be provided for batteries to ensure concentrations of combustible gases and vapors do not reach 25 percent of the Lower-explosive-limit (LEL)
- The battery testing laboratories or test areas shall have a designated eyewash station and shower (as necessary based on operation) and devices for protecting test personnel, equipment and batteries (i.e., bollards, guard rails, etc.)
- When handling vented batteries, the following shall be followed:
 - Appropriate PPE shall be worn
 - An eye wash station shall be located nearby
 - Ample water shall be available to flood spills of electrolyte
 - No smoke, open flames or spark producing devices shall be allowed in the battery area
 - Uninterruptible power supply battery installation shall be reviewed by the safety approval authority
 - A Lith-X or Class ABC fire extinguisher, as required per the MSDSs of the batteries at the test site, shall be available in the test location

Ground Handling and Transportation

- Transportation of flight cells and batteries shall follow the appropriate Department of Transportation (DoT) (49 CFR 173) requirements for transportation.
 - When transported on publicly-accessed roadways, they shall not exceed 50 percent of rated charge (for lithium-ion)
 - When lithium equivalent content exceeds 8.0 grams per battery, transportation packaging of individual batteries shall have caution labels in accordance with 49 CFR 173.185.
 - Batteries that are transported incorporated into flight hardware shall be approved on a case-by-case basis by the Safety Authority.
- Transportation containers for flight cells and batteries shall include temperature and shock sensors that record the maximum values of temperature and shock that the cells or batteries had been exposed to during transportation and handling.

Battery and EGSE Operation and Test Safety

- Battery Test Facilities or laboratories shall have data on the critical safety tests associated with their test batteries prior to the start of any launch-site facility charging or testing (engineering, qualification and flight units)
 - The tests shall be relevant to the battery design, chemistry, capacity and voltage
 - The safety tests shall be performed at the manufacturer's facility or at the test facility
 - The tests shall provide information on the worse case results for the hazards associated with design to allow for safe build-up of test equipment and test procedures.

Battery Design Guidelines

- Flight batteries shall be safety certified for use in its designated application.
- Flight battery systems shall have two-fault tolerance to overcharge, overdischarge into reversal, external short circuits and high temperatures.
- Flight batteries shall be either tolerant to internal shorts or be screened for internal shorts.
- Lot testing shall be performed on every new flight lot procured to confirm that the hazards and controls for each new production lot remain the same.
- Battery cases that contain batteries with aqueous or flammable electrolytes shall be designed to release gases.
- The location of the circuit interrupters with respect to the battery terminal shall be designed to prevent any form of external short circuit.
- The battery terminals on the outside of the battery case shall be protected from accidental bridging.
- Cell cases shall have a minimum burst to vent pressure ratio of 2.5:1. Additionally, if the cell's burst to vent ratio is lower than 2.5:1 but greater than 1.5:1 approval is contingent on the rigors of the fracture control process specified in JSC-25863.

Summary

- These ground handling requirements have been established for battery testing to ensure the safety of personnel working with and around these batteries during launch site processing, including:
 - Design safety features of the EGSE charging equipment: independent fault detection, current limited, voltage, current, and temperature monitoring, etc
 - Design safety features of the “system” (battery and test equipment): two-failure tolerance
 - Test facility safety features, processes and equipment
 - Use of trained personnel
 - Use of validated procedures: mandatory inspection points, verification steps, CAUTIONS, WARNINGS, NOTES
 - Battery test data availability to characterize and understand battery hazard controls to prevent overcharge, overdischarge into reversal, external short circuits and high temperatures
- Personnel installing, handling, transporting and testing batteries must be trained, vigilant and aware of the potential hazards at all times.

Requirements Documents

- JSC 20793 Rev B. Crewed Space Vehicle Battery Safety Requirements
- CxP 72213 Rev A. Project Orion Ground Safety Design and Operational Requirements

Acknowledgment

The authors appreciate and acknowledge the support provided by the Electrical Power System team at NASA-JSC and the Lockheed Martin Orion Electrical Power System and Safety Team.