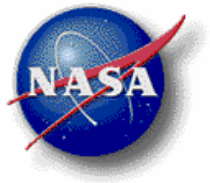

Certification Process for Commercial Batteries for Payloads

Judith Jeevarajan, Ph.D.
NASA- JSC

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Introduction

- Batteries are high energy devices that are used to power hardware for space applications
- Applications include IVA (IntraVehicular Activity) and EVA (ExtraVehicular Activity) use.
- High energy batteries pose hazards such as cell/battery venting leading to electrolyte (liquid or gas) leakage, high temperatures, fire and explosion (shrapnel).

Requirement for Safety

Major Requirement for COTS and non-COTS:

Two-fault tolerance to catastrophic failures; one-fault tolerance to critical failures

Hazard category is based on toxicity of electrolyte (chemistry) and energy density

Requirements Documents

- JSC 20793, Rev A “Crewed Space Vehicle Safety Requirements” is the top-level reference for battery safety requirements.
- Payload Safety Requirements: NSTS 1700.7B Section 200.1b - Safety Policy and Requirements for Payloads using the STS
- Space Station Safety Requirements: SSP 50021 Section 3.3.6.1.1 – Safety Requirements Document for ISS
- SSP 50094 Joint Russian and US requirements for ISS
- Space Shuttle Safety Requirements: NSTS 22254 Section 1.6 - Methodology for Conduct of Space Shuttle Program Hazard Analyses and Section 1D201.6 of NHB 5300.4 (1D-2) – Safety, Reliability, Maintainability and Quality Provisions for the SSP.
- Space Station/Shuttle Safety Requirements: JSC 28484 Section 3.3.6 - Program Requirements Document for JSC Non-critical GFE.
- Russian Requirements Document: P32928-103

Battery Requirements Document

- Two battery requirements documents:

  JSC 20793 RevA Crewed Space Vehicle Battery Requirements

  (old Manned Space Vehicle Battery Handbook)

  and

  EA-CWI-033 Battery Processing

  Currently both are found on the Internal JSC - EA website

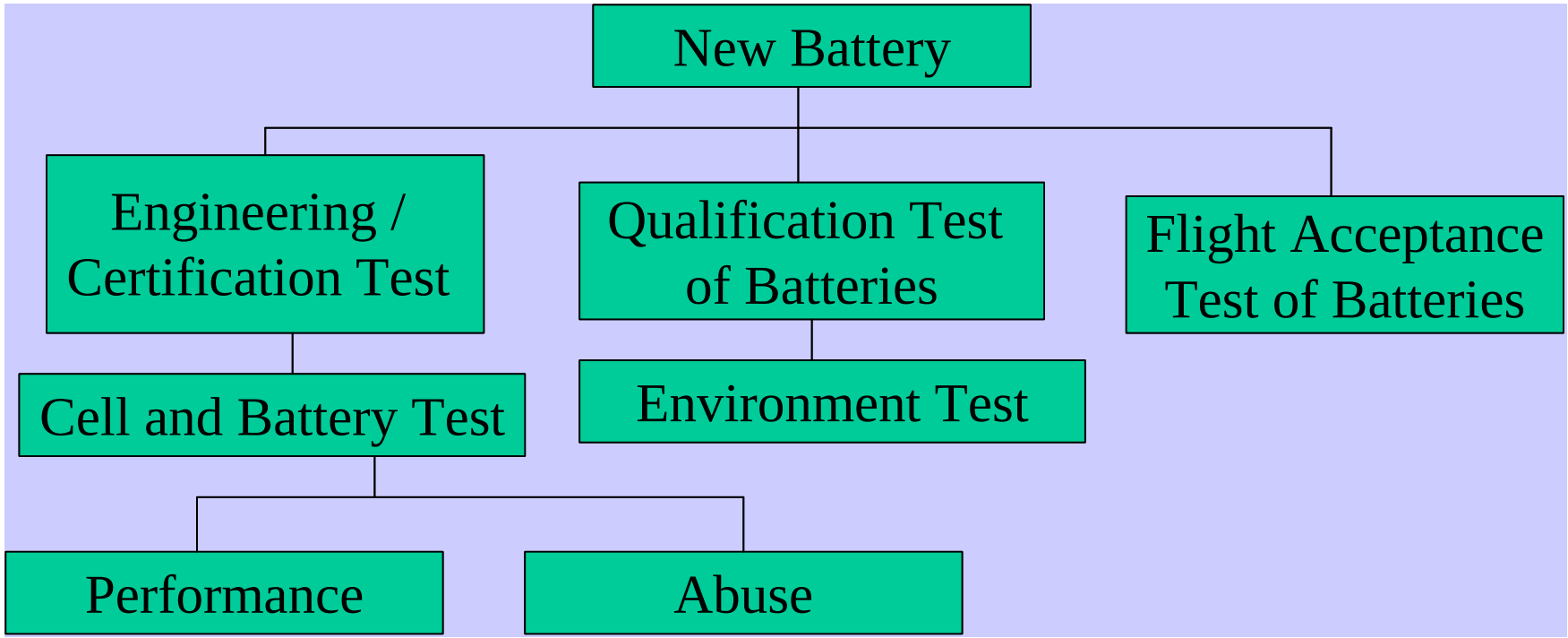
  Export Control cleared for public access

  International Partner POCs at ESA and RSCE have copies

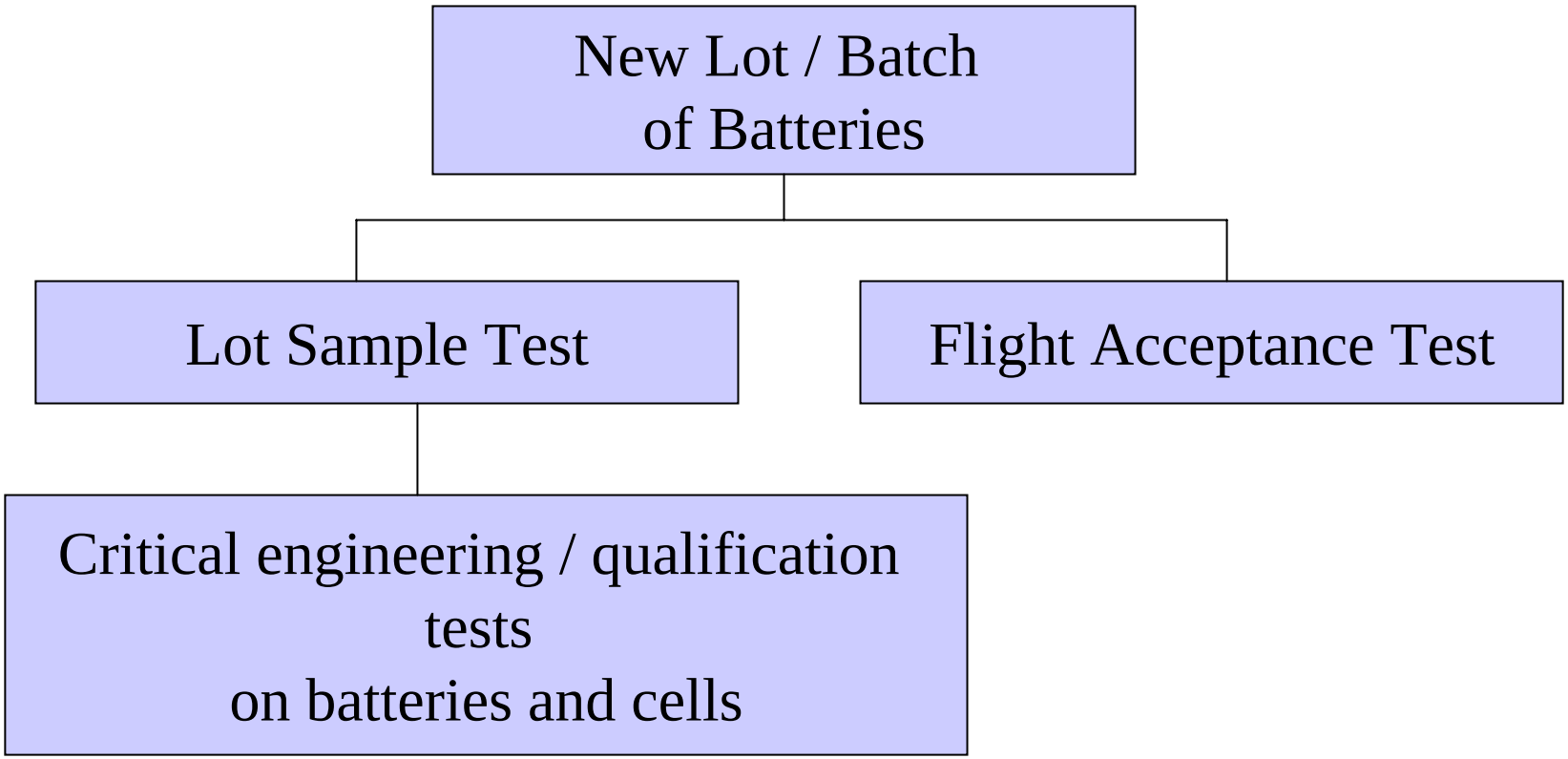
Compliance

- Compliance with these established requirements for COTS and non-COTS requires data.
- Certificate of Compliance (C of C) from the vendor is insufficient for safety certification.
- Exemptions exist for batteries that fall under the non-critical hazard category

COTS Battery Certification Process



Subsequent New Lot of Certified Batteries



Current Safety Certification Process

Exemptions

- Alkalines : 12 V and 60 Wh; only in series or only in parallel; no combinations of series-parallel, no gastight battery compartment
  - **Flight cells and batteries should pass acceptance tests that include visual examination, OCV, CCV/functional check, vacuum leak check (0.1 psia for 6 hours)**
  - **Application and protective circuit schematic to be reviewed and approved by each agencies appointed Battery approver/team.**

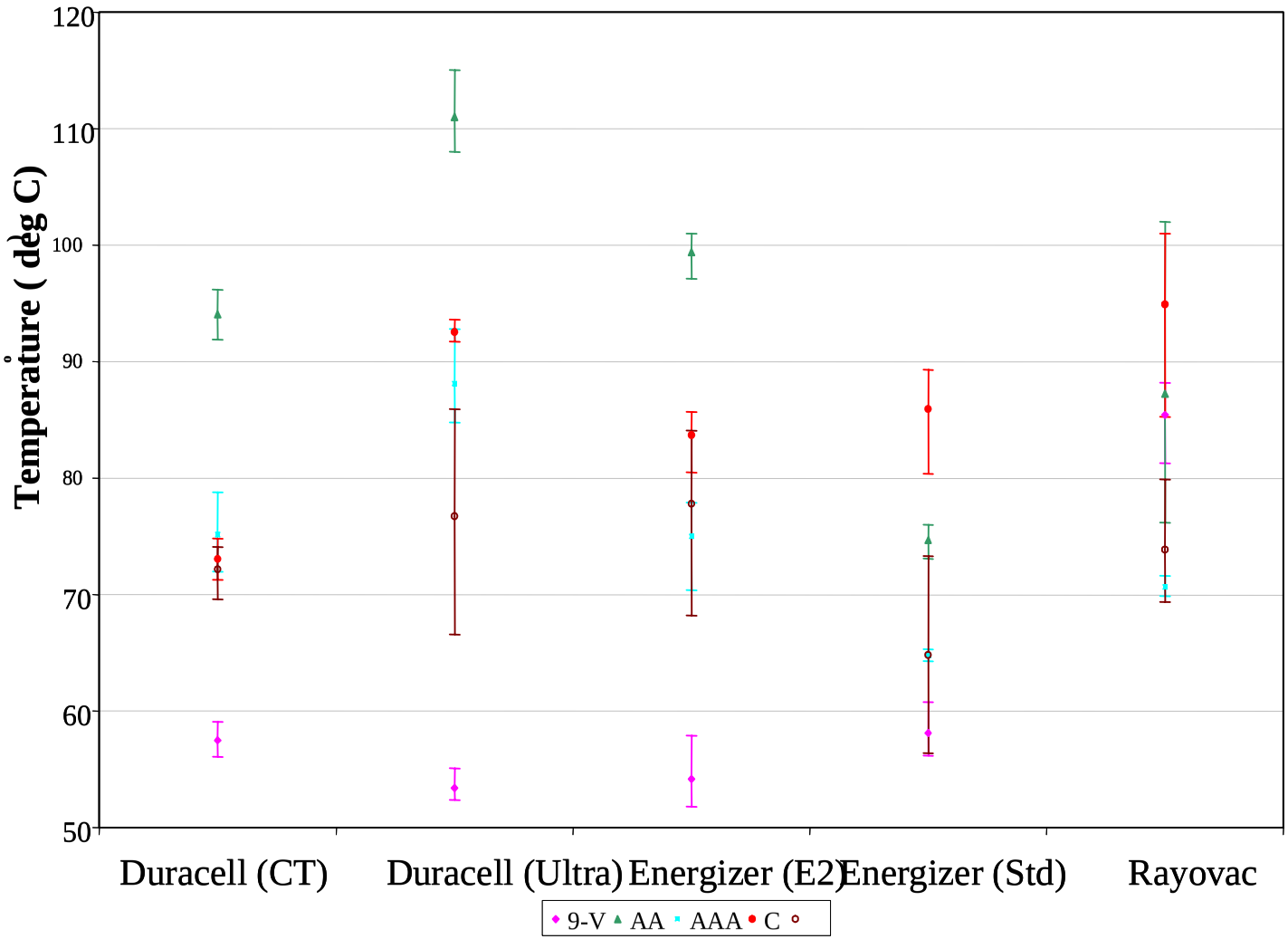
Need for Vented Battery Compartment:

Energy Content: Water: KOH electrolyte is 30 -45 % weight in water. KOH is electrolyte in alkaline cells. If electrolyzed by inadvertent charge or overdischarge, it yields a H_2/O_2 mixture that has an equivalent of 5783 Btu/lb (Oxygen is non-flammable but supports and vigorously accelerates combustion of flammables; hydrogen is in itself a fuel).

Note: D cell is 18 Ah capacity

Wh: V x Ah (Voltage x Capacity)

Short Circuit Test on Alkaline Cells



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Exemptions

- Button cells of Li primary types ($LiCF_x$, $LiMnO_2$, $LiFeS_2$, LiV_2O_5, Li-iodine, etc.), Li rechargeables (includes all li-ion, LiV_2O_5, $LiMnO_2$, etc.), NiMH, NiCd, Ag/Zn, of 300 mAh or less and cells are not in a gas-tight compartment.
- No LiBCX, $LiSO_2$, $LiSO_2Cl_2$ or $LiSOCl_2$
  - Flight cells and batteries should pass acceptance tests that include visual examination, OCV, CCV/functional check, vacuum leak check (0.1 psia for 6 hours)
  - Application and protective circuit schematic to be reviewed and approved by each agencies appointed Battery approver/team.
  - Above acceptance testing for button cells in Section 9.2 which are soldered to a circuit board in commercial equipment (not applicable to those button cells in a spring-loaded clip) is limited to a functional check of the equipment utilizing the subject battery.

Exemptions for Reduced Testing

- COTS NiMH, NiCd and Ag/Zn cells and batteries for IVA use up to 20 V and 60 Wh
  - Cells and batteries purchased in one lot; pass acceptance tests that include loaded and open circuit voltage measurements, visual examination, leakage check under vacuum (e.g 6 hours at 0.1psia) and vibration to workmanship levels with functional checks which include charge/disc
  - Require the use of Form-03 for the approval process. Manufacturer's specification, battery protective features and charger schematic shall be provided for approval from the respective Battery approver/team for each agency.

Exemptions for Reduced Testing

- COTS Li-ion batteries up to 10 V and 60 Wh for IVA use
  - Batteries and charger shall be from a single lot; shall show one-fault tolerance at battery level and shall pass acceptance tests that include loaded and open circuit voltage measurements, visual examination, leakage check under vacuum (e.g 6 hours at 0.1psia) and vibration to environment or double the workmanship level, whichever is higher; and functional checks which include charge/discharge cycles.
  - Require the use of Form-03 for the approval process. Battery protective features and charger schematic shall be provided for approval from the respective Battery approver/team for each agency.

Note: Other levels of control shall be from hardware using battery, and/or charger; existing data from past experience; crew member procedures in the event of an emergency

New Battery Approval Forms

Multilateral Battery Meeting was held between:
US, RSC-E, ESA and JAXA at NASA-JSC

Updates generated as a result of these meetings:

- EP-Form-03 will be necessary for approval of US and ESA batteries.
- EP-Form -17 and EP-Form -17R for information exchange with RSC-E
  - **After approval of the Form-03, the Battery expert will complete a EP-Form-17 on the US side.**
- The EP-Form-17s have less information but will let the counter-agency know that the battery safety has been approved by the Battery expert.
- EP-Form-17 will be submitted by the Battery expert along with the Form 1230 and Form 907 submitted by the hardware owners.
- Unique Hazard Reports need not be submitted to counter-agency if the EP-Form-17 is submitted. However, Unique Hazard Reports shall be submitted to the respective agencies in the Safety Data Package for approval by the Battery expert.
- Updated Form 907 to be consistent with Form 1230.

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EP-Form -03

- Requires the location and environment (temperature, pressure, etc.) of hardware/battery
- Requires information on preflight, on-orbit and post flight battery processes
- Requires information on two-fault tolerance
- Verifies if approvals for toxicity and materials compatibility were obtained

Refer to EA-CWI-033 for details on Battery Processing

Battery Chemistries and Hazards

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Commonly Used Lithium Primary Batteries

Li-MnO_2 (Manganese dioxide)

Li-$SOCl_2$ (thionyl chloride)

Li-BCX (thionyl chloride with bromine/chloride additive)

Li-SO_2Cl_2 (sulfuryl chloride)

Li-SO_2 (sulfur dioxide)

Li-CF_x (poly-carbon monofluoride)

Li-FeS_2 (iron disulfide)

Li Primaries with Organic Electrolytes Hazards And Controls

Types: $LiMnO_2$, $LiCF_x$, LiV_2O_5, $LiFeS_2$, etc.

Hazards:

- Electrolyte leakage- corrosive, flammable, irritant
- Venting and fire at high temperatures

- **Failure Modes – inadvertent charging, overdischarge into reversal, short circuit and high temperature exposure**
- **Controls**
  - **Lot testing, 100 % flight ATP testing with leak checks**
  - **Demonstrate tolerance to internal short, manufacturing quality control record, or screening of flight batteries (eg. Vibration)**
  - **Test data on external short, inadvertant charge, overdischarge into reversal with protection against all three**
  - **Temperature monitoring where necessary**

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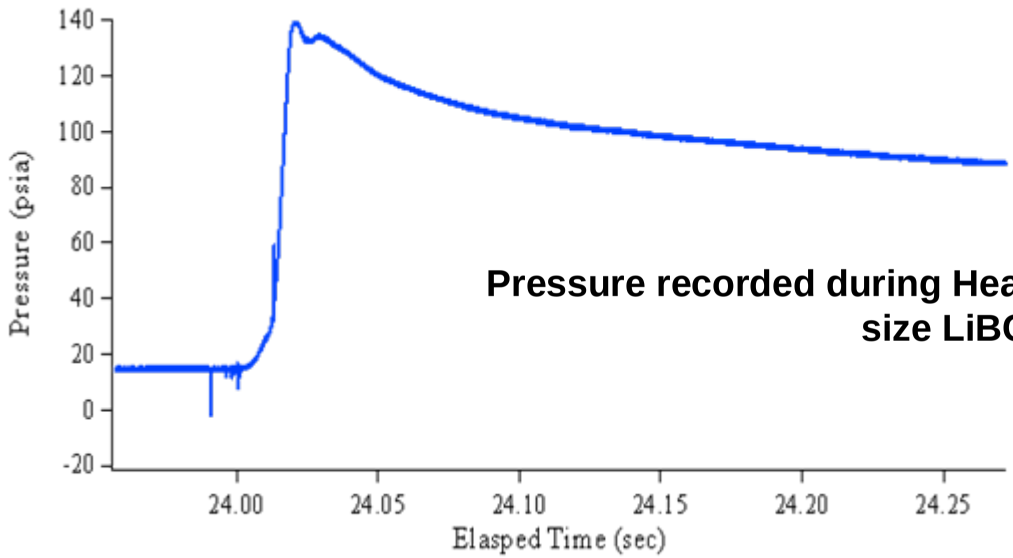
Li Primaries with Inorganic Electrolyte

LiBCX, $LiSOCl_2$, $LiSO_2Cl_2$, $LiSO_2$

TNT: 1929 Btu/lb

$LiSOCl_2$/LiBCX: 2000 Btu/lb



Pressure recorded during Heat-to-Vent test on a single C size LiBCX cell

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Hazards and Controls

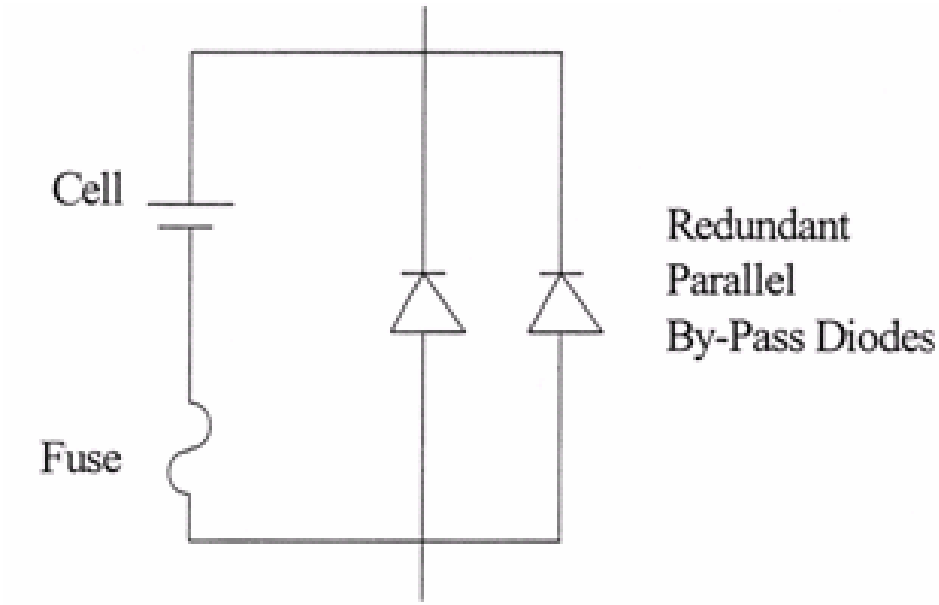
NOT Allowed in Crew Cabin on Shuttle and Station

Hazards:

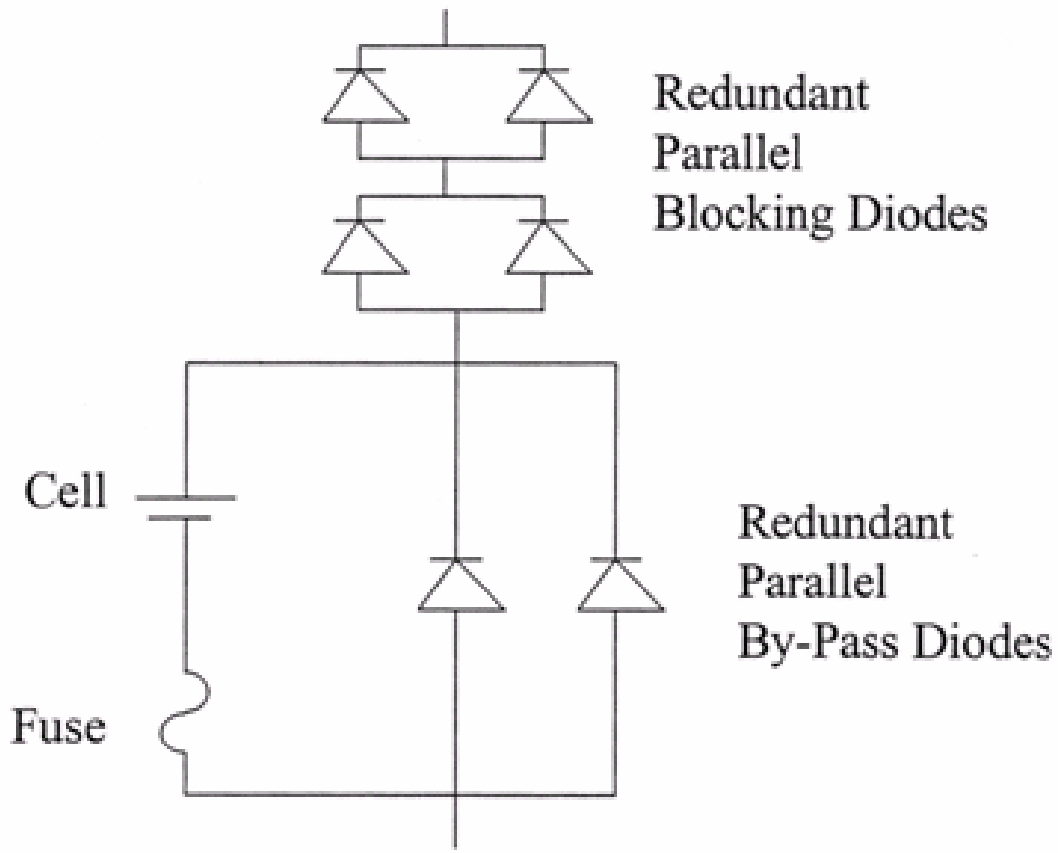
- Electrolyte leakage- corrosive- harmful to the lungs, eyes and skin, can be lethal
- Explosion at high temperatures

- **Failure Modes – inadvertent charging, overdischarge into reversal, short circuit and high temperature exposure**
- **Controls**
  - **Lot testing, 100 % flight ATP testing with leak checks**
  - **Demonstrate tolerance to internal short, manufacturing quality control record, or screening of flight batteries (eg. Vibration)**
  - **Test data on external short, inadvertant charge, overdischarge into reversal with protection against all three**
  - **Temperature monitoring where necessary**
  - Cells shall be hermetically sealed

Typical Protection against External Short and Overdischarge into Reversal

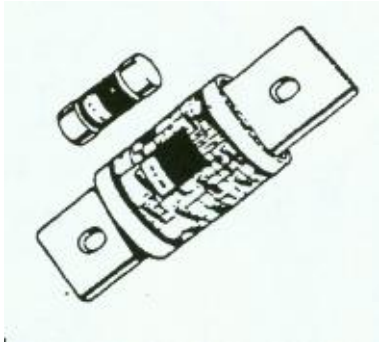


Typical Protection against Inadvertent Charge, External short and Overdischarge into Reversal



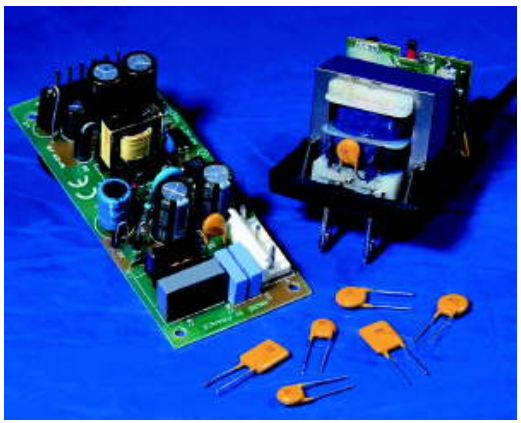
Other Protective Devices for Primary and Secondary Batteries

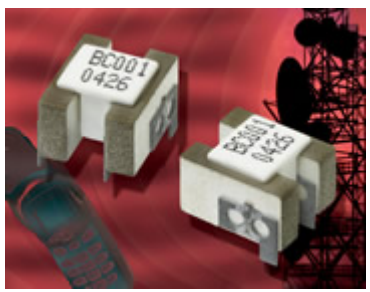
Fuses



Single Use – mostly in primary batteries

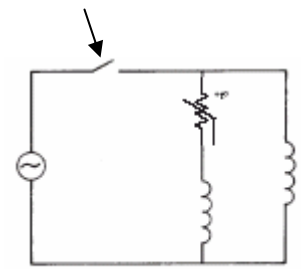
Switches/PTC

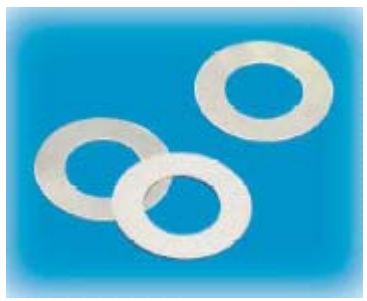




Multiple Use – mostly in rechargeable batteries

switch





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NiCd and NiMH

Hazards:

- Electrolyte leakage – corrosive, caustic
- High temperatures

Failure Modes:

- Overcharge, overdischarge into reversal, external short circuit, high temperatures

Control:

- Good end-of-charge cutoff, periodic maintenance/conditioning (to remove memory effect), good equipment or other undervoltage cutoff, good short circuit and thermal protection (polywitches, thermal fuses, etc.)

Li-ion/Li-ion Polymer Batteries

Hazards:

- Electrolyte leakage – irritant, flammable

Failure Modes:

- Overcharge, external short circuit, high temperatures

Control:

- Cell Bank voltage monitoring, protection against overvoltage, undervoltage and overcurrent (IC chips, MOSFETs, PTCs, fuses)
- Vibration screening or manufacturing control document records for internal short controls
- High temperature protection – temperature monitoring, thermal fuses

Toxicity Reference Information

Tox memo should be obtained from the toxicologist who makes the final decision.

- KOH: alkaline, NiCd, NiMH, AgZn – caustic and corrosive- will burn skin and eyes. Typically Tox 2.
- H_2SO_4: Lead acid- acidic and corrosive, will create acid fumes that can damage throat and lungs. Typically Tox 2 unless the amount is significantly large.
- $SOCl_2$: $LiSOCl_2$ and BCX- burn skin, eyes, damage throat and lungs to a higher degree than above and can be lethal. Tox 4; could be lower if electrolyte quantity is negligible.
- $Li(CF)_x$ and $LiMnO_2$, Li-ion: affects skin and eyes on contact; electrolyte is flammable and can cause fire in the presence of an ignition source. Tox 2 depending on nature of salt in electrolyte.

Conclusions

- The new process should simplify the information processing load on International partners.
- Although it requires more work on the part of the Battery Experts, it reduces the amount of data transferred between the agencies.
- The new requirements documents provide detailed information on safely processing batteries for flight.

Acknowledgment

International Partners – ESA and RSC-E

All members of the safety panels (PSRP, SMART, SRP, SSRP)

JARSWG, JCCT members