Lithium-ion Cell/Battery Design, Manufacturing and Testing for Safe Operation

Rob Gitzendanner, Frank Puglia, Dave Haines, Paul Cryan

Yardney Technical Products, Inc.

Pawcatuck, CT

Factors Effecting Safety

- Cell Chemistry
  - Inherent to the chemistry of the various active components
  - The relative stability of the chemistry and how it responds to abuse conditions
  - Typically linked to energy density
    - Higher Energy Density => Less stable chemistry
- Cell and Battery Design
  - Design for safety, design for thermal management, design for mechanical stability/protection, design for controlled reactivity and safe response to abuse
- Cell and Battery Manufacture
  - Care taken during manufacturing process to ensure proper construction, no FOD, no folded electrodes, proper welds/tabbing to prevent thermal heating, uniformity of coatings and separator to prevent non-uniform utilization
- System design and operation
  - Battery and/or external systems to prevent Overcharge, External Short or other abusive conditions
  - Proper handling, storage, maintenance and use of the cells/batteries to prevent problems and preserve service life

Cell Chemistry

- Most Lithium-ion cells utilize basically the same chemistry
  - Commercial and Aerospace cells typically utilize a layered and/or spinel LiMO cathode, Carbon/Graphite anode, and organic solvent based electrolyte
    - Phosphate cathodes are somewhat different in that they do not generate their own Oxygen on thermal decomposition, but still use similar anodes and electrolytes
- Two fundamental failure modes
  - Electrical – due to excess voltage, leads to electrolyte decomposition, reactivity of lithiated carbon/graphite anode, and decomposition and oxygen generation on cathode
  - Thermal – high temperatures (sometimes localized) lead to similar failure modes including increased volatility and flammability of electrolyte

Cell and Battery Design

- Cells and Batteries can (must) be designed for safety
  - Chemical component selection appropriate for performance and application
  - Thermal management must be considered
    - Especially large or high power batteries, or systems in aerospace environments where convective cooling is not available
  - Structural integrity, mechanical support and containment
    - Physical protection of cells
      - Stainless steel cases, battery housing
    - Vent before burst
    - Design for Shock, Vibe and Acceleration environments
      - Analysis and Test to validate
  - Electronic protection, Battery Management Systems
    - Design to meet application needs

Cell and Battery Manufacture

- Care and attention taken during Cell and Battery Manufacture turns into quality, reliable product delivered to field
  - Proper selection, specification and inspection of incoming materials
  - Establishment and documentation of processes and procedures
  - Monitoring of assembly steps
  - In-process inspections and checks
  - Documentation checks and traceability
  - Monitoring, measuring, and tracking (SPC) of key parameters and processes
- Flows into Cell and Battery testing
  - 100% Formation and Cell Acceptance Testing
  - 100% Battery Acceptance Testing
  - Extensive Pre (development, qualification) and Post (life cycle, extended performance) Delivery Testing to verify and validate all parts of design and processes

System Safety

- Proper Operation
  - Use within prescribed conditions
  - Charge monitoring – Battery and System level
  - Thermal, Mechanical and Power levels monitored and controlled
- Electronics Protection
  - Prevent overcharge, overdischarge, overtemperature or external short
  - In-line protection for high voltage systems
  - System-level monitoring and control
- Proper battery handling and maintenance
  - Defined procedures and trained end-user
  - Equipment appropriately sized and designed to adequately charge, discharge, monitor and maintain the battery

Conclusions

- Key factors for cell/battery safety need to be understood and properly addressed
- These factors are tailored to the application
  - Proper design for proper use
- Aerospace companies required (by design, by spec, by customer) to understand AND address appropriately these issues