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Battery & Electrical Systems Session

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Electrical Regulations and Battery Protection

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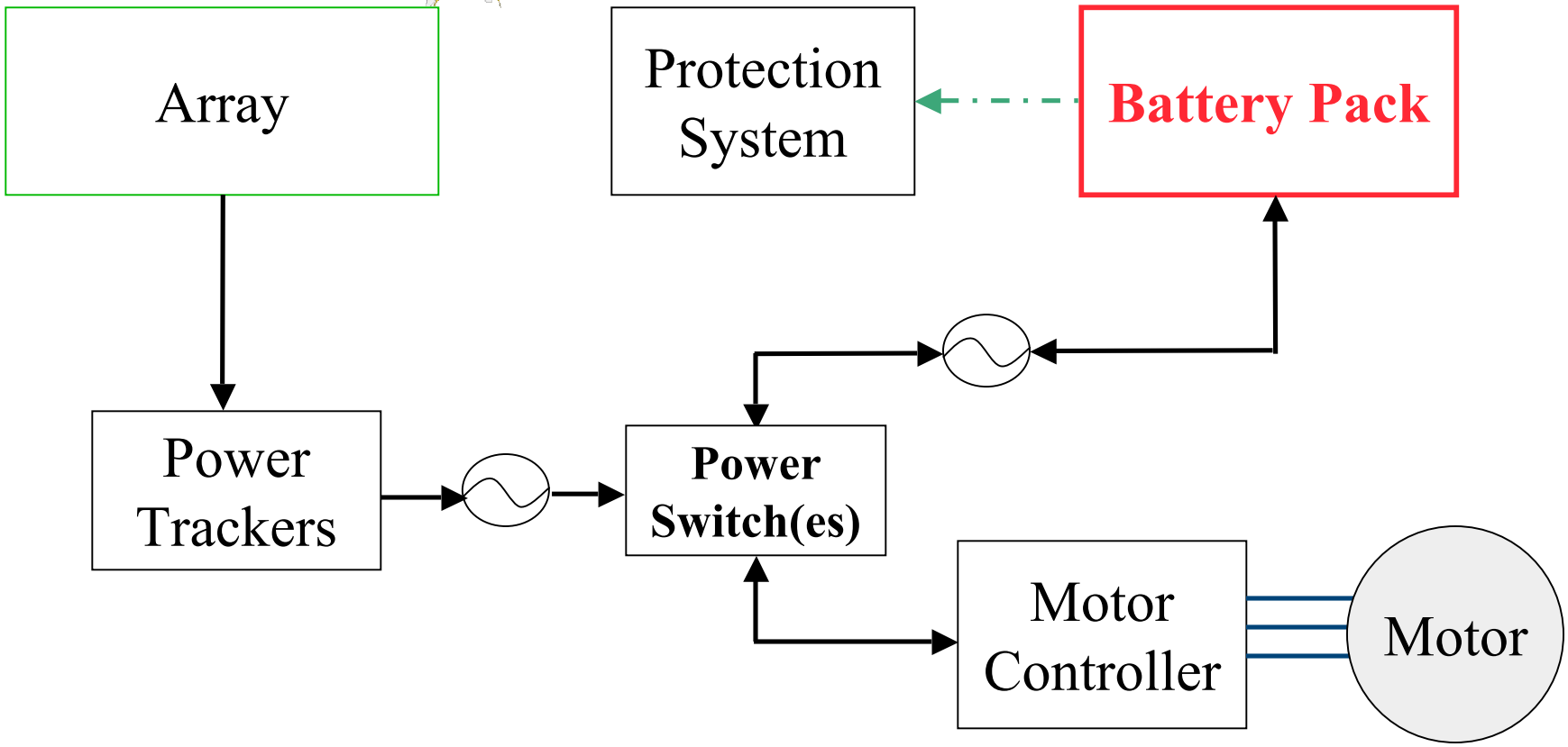

5.7 STORAGE BATTERIES

5.7. A Weight Limits

- 125 kg of sealed Lead Acid
- 100 kg of NiCad
- 70 kg of NiMH
- 30 kg of Li-Ion or Li-Polymer

Manufacturer's Weight is the "Official Weight"

5.7.B Protection Circuitry

- 5.7.B.1 Definitions
  - **5.7.B.1.a Cell** The smallest available source of energy in your battery pack that you purchase from a manufacturer. A single electrochemical cell.
  - **5.7.B.1.b Module** The smallest easily removable group in your battery pack.
  - **5.7.B.1.c String** The series group of cells needed in your battery pack that provide the required voltage.
  - **5.7.B.1.d Protection Limit** The measured level that your team decides is adequate to protect from an event
  - **5.7.B.1.e Active** Active means constantly monitored measurements where action can be taken immediately without operator intervention.

5.7.B.2 Li-Ion

– Electrical Isolation is required from the pack when,
  - Over-Voltage
  - Over-Current
  - Under-Voltage
  - Over-Temperature

  is exceeded at the module level as a minimum.

  The need for cell level may be required based on manufacturer.

  - Fuses are not acceptable for Over-Current protection, but are required for 5.9

5.7.B.2.a Isolation

- MOSFETs or other solid state switches are not acceptable for isolating Li-ion battery packs

5.7.B.3 Ni-MH / NiCd

Active measurement is required for;

- Over-Voltage
- Over-Temperature

At the pack level, if unavailable, isolation is recommended

- 5.7.B.4 Pb-Acid

Active measurement required for;

- Over-Voltage

At the pack level, if unavailable, isolation is recommended

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5.7.C Hybrid Battery Packs

- Based on weight allowances for type of module used
- Total weight may not exceed 100%

5.7.D Supplemental Batteries

- Replaceable batteries can power the following accessories;
  - Radios
  - Electronic panel meters
  - Driver ventilation
  - Main disconnect relay
  - Horn
  - Telemetry
  - **Not battery ventilation, battery controller, electronic mirror or vehicle controls**.

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5.7.E Other Storage Techniques

- Must be shown to contain NO energy before the start of each Day of the Rayce.

5.8 Battery Enclosures

- Must be:
  - Electrically isolated from the vehicle > 1Mohm
  - Securely attached
  - Labeled with 10mm high “Caution – Chemical Hazard” And “High Voltage” and “Battery Technology”
  - No more than two enclosures for Li-Ion, up to 4 for all other types

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5.8.A Battery Removal

- Pack removal required each Rayce Day for Impound per 7.22
- Box required to safely/securely store pack

5.8.B Battery Stacking

- Non-conductive enclosure
- Meets same requirements as Enclosure

5.8.C Battery Ventilation

- Must operate whenever pack connected electrically to incoming or outgoing power
- Must deliver 280 LPM to the exterior of the vehicle
- Must be powered by the pack, not supplemental battery

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COMPLETED BATTERY APPROVAL FORMS BY MARCH 15, 2008, but no earlier than December 1, 2007

- Manufacturer's published data for Cells
- MSDS
- Configuration description
- Protection System, don't confuse with control
  - Schematic
  - High level description
  - Things that it is to protect & Set points

For SCRUTINEERING

- Electrical schematic of vehicle, power and control
- Manufacturer's datasheets for FUSE and POWER SWITCH(ES)

Open Battery Approval Form

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- Supporting information
  - Battery Selection

    Pb-Acid
    - Is most robust to solar raycing applications
    - Need to understand voltage discharge curves
    - Need to get balance among cells/modules at start
    - Use Peukert plots to assess rated capacity
    - Still gasses if over-voltaged, thus fan operation
    - Emits hydrogen as gas - flammable, can explode

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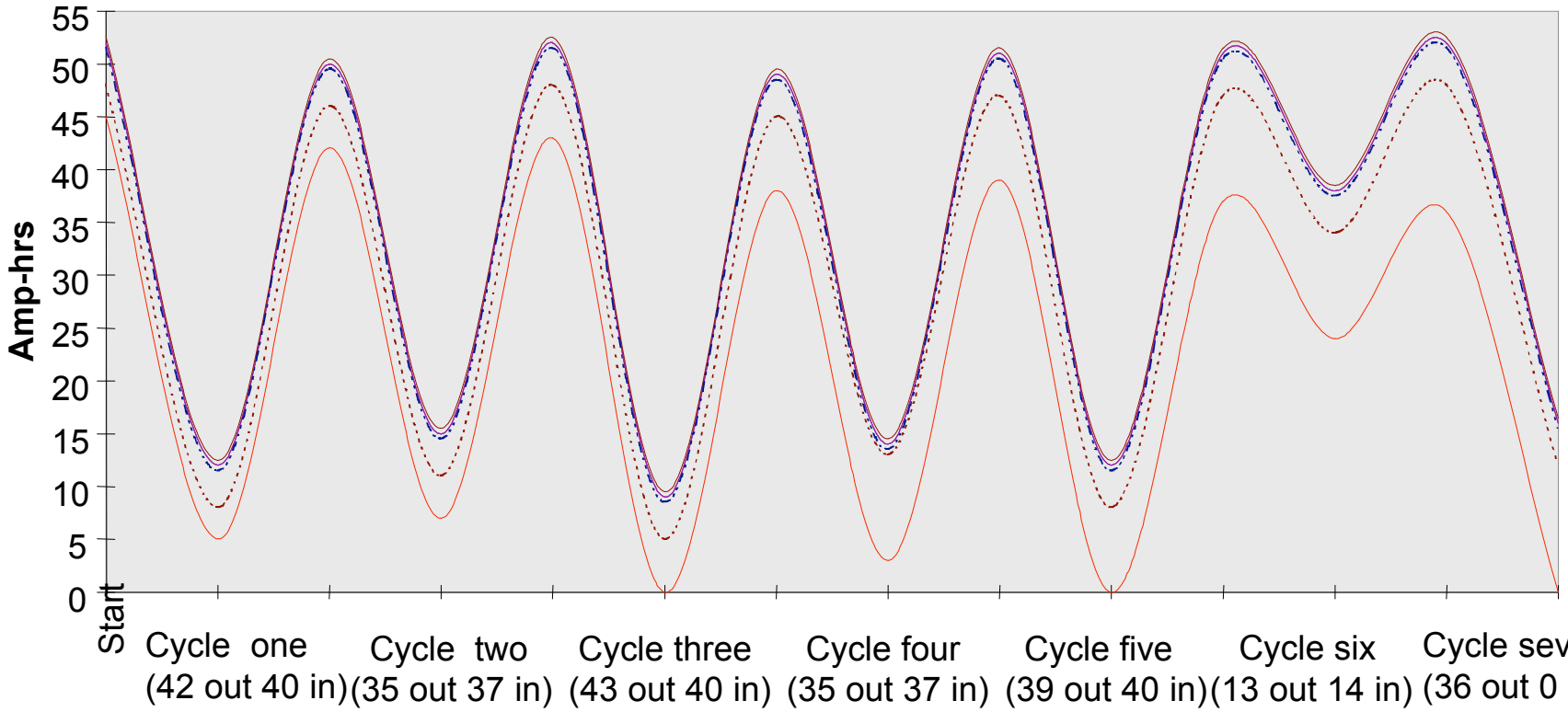
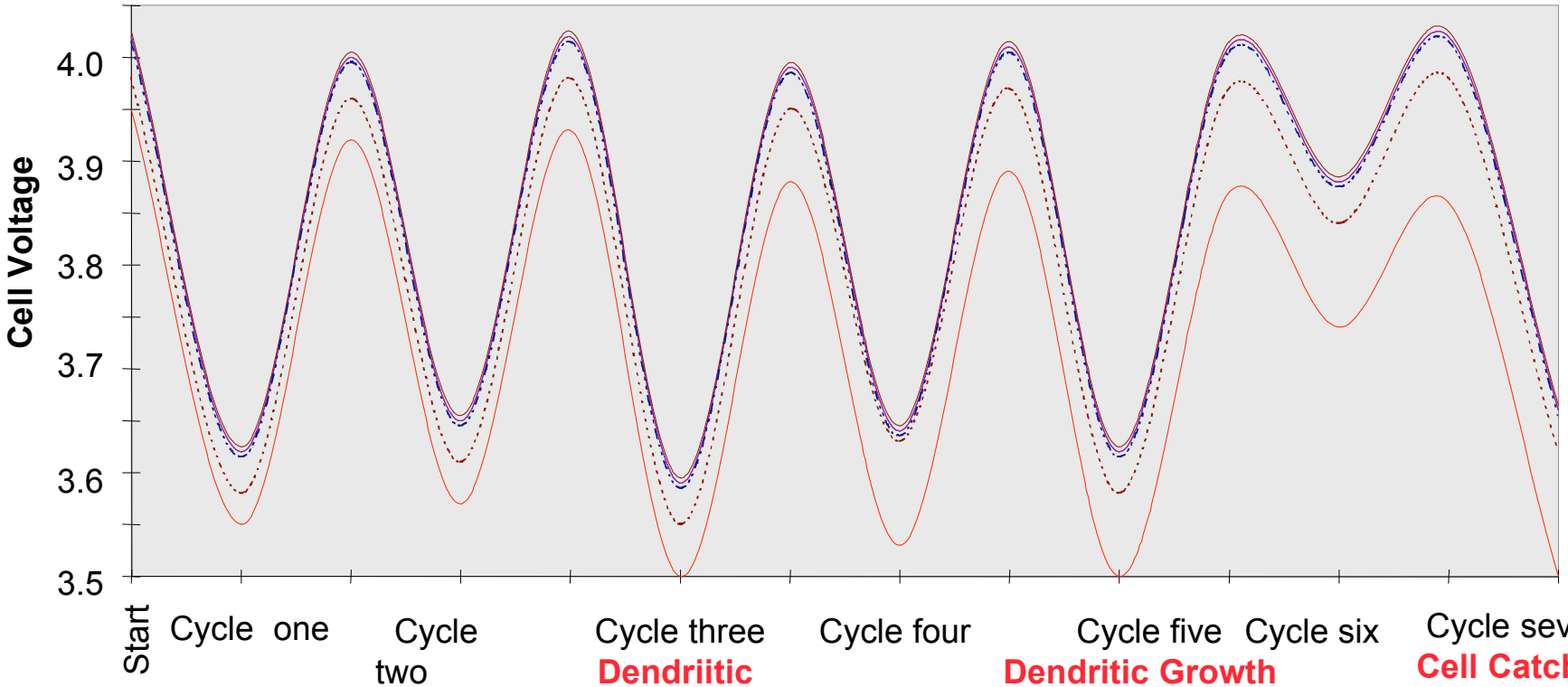
Battery Pack Cycling
52 ah cells-7 days



Battery Pack Cycling
Lithium Technology



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Pb-Acid cont.

- Usually terminated with lugs
- Must be properly torqued and inspected frequently
- Utilize entire surface area of battery terminal
- Looseness results in high resistance connections, resulting in localized heating, losses, and loss of battery
- Corrosion will negatively effect electrical conductivity
- Elyte spillage must be neutralized – baking soda
- Hold-downs are to be used, otherwise entire surface area should be in contact with restraint mechanism.

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NiMH & NiCd

- Still requires balance among modules
- Nickel based internal resistance increase as SOC increases
- Sensitive to over-temperature when recharging
- Electrolyte is caustic
- Requires mild acid as neutralizer – Boric Acid powder
- Typically more specific energy than pb-acid
- Provides larger capacity per cell than most lithium
- Typically have longer deep cycle life than pb-acid
- Utilize entire surface area of battery terminal

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Lithium Technology Cells

- **Delicate**, must be handled carefully
- Mounting and restraining are a challenge
- Vibration isolation for cell, but more so for termination is important
- Great Solar Battery, Efficiency is in the **99%** range (charge in to charge out)
- Desired, High specific energy – Whrs/kg
- State of Voltage is good indicator of SOC
- Understand effects of welding/soldering terminals to cell operation, heat affects the cell seal and may ultimately shorten the life of the cell.

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Lithium Technology Cells

- Constant monitoring is necessary to optimize a lithium pack.
- Use manufacturer as advisor on all other facets.
- Lithium cells have narrow voltage window to operate
- Lithium cell control is the enabler to success with lithium technology
- Lithium control is independent of Protection System
- Three known vehicle events with lithium thus far, all do to inadequate control and or protection systems

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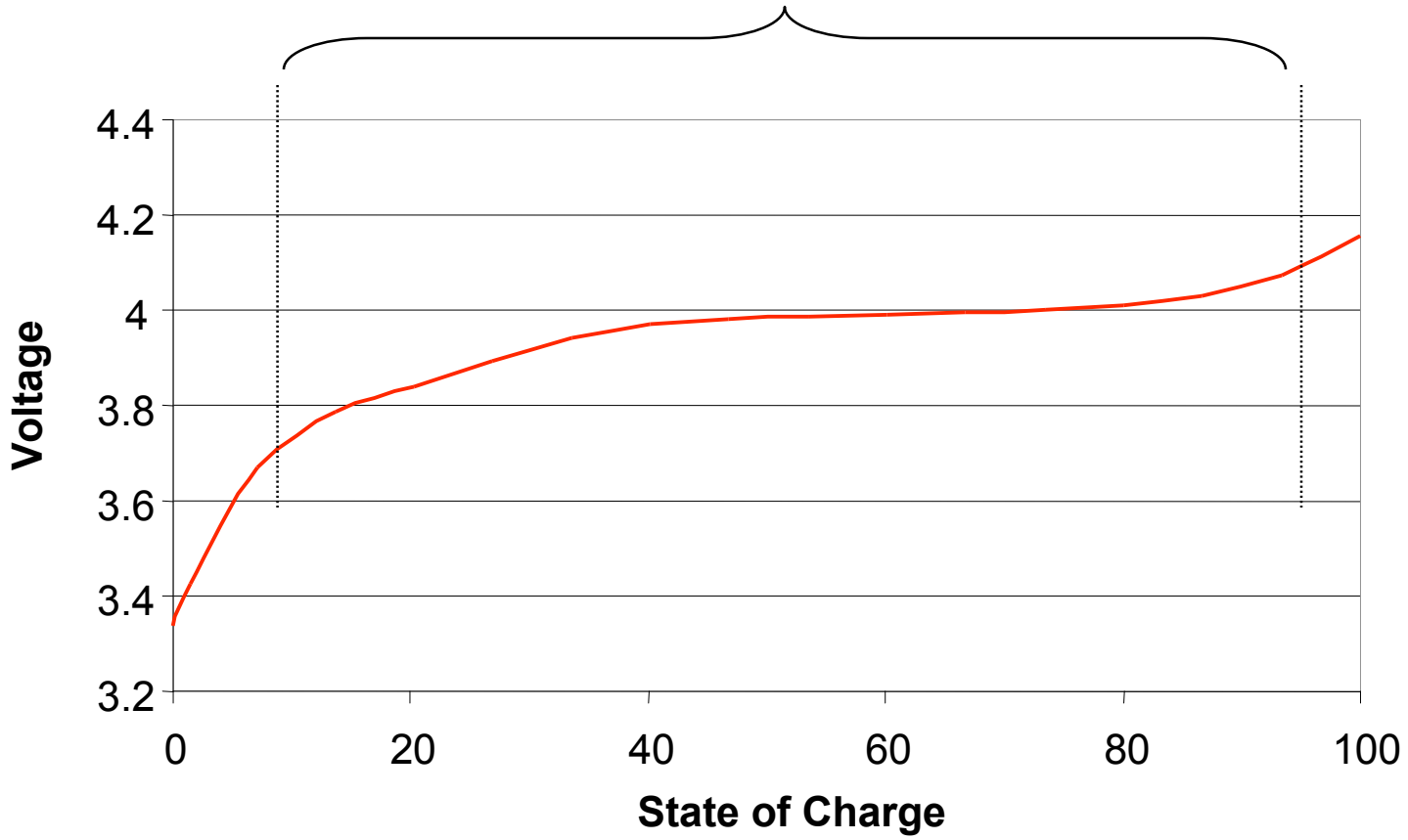
Typical “safe” range of Lithium cell operation



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Lithium Technology Cells cont.

- Some issues to Lithium Cell monitoring.
  - Should provide redundant sensing compared to the required protection system (backs up sense, improves reliability)…..
  - Since telemetry can be run on Aux Pack, this allows monitoring to continue after Protection System disconnects
  - Pack Monitoring should not be an afterthought
  - Fusing is required on any leads exiting pack

The Environment

- Rain does Happen - Prepare Accordingly
- Vibration is extreme - Design Appropriately

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Lithium Safety (why **Protection System** is **Required**)

- Electrolyte (elyte) is flammable and moisture sensitive
- Elyte exposure to moisture in air results in hydrofluoric acid which can irritate and burn skin.
- Overcharging cell causes the elyte to decompose with the formation of gas that may result in cell leakage and flame
- Over current causes elyte to decompose & boil in the cell.
- Under-voltage causes internal copper corrosion resulting in dendritic growth of copper on recharge leading to shorts and ultimate failure.
- Over-temperature leads to expansion of elyte and potential for leakage, shorts, resulting in flammable gas emissions, swelling.

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Lithium Safety Concerns cont.

- Pierced/leaky cells should be removed from operation and sealed in poly bag till properly disposed
- Mounting is a sensitive issue, must isolate vibration to terminals yet retain cells
- Be careful not to destroy cells by tension on the terminals
- Pack imbalance will leads to protection system operation.
- Sense leads must be individually fused if exiting pack
- Consider a two level control scheme; where team is alerted of impending shutdown and can act prior to Protection System engagement
- May consider solid state devices to control/monitor cells independent of Protection System.
- **Control** of cells is necessary for optimum performance and efficiency

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5.9 Main Fuse

- Separate fuse is series with the Battery System rated </= 200% of max current draw, first in series on positive lead
- Any low voltage taps exiting the main or auxiliary battery must be fused

5.10 Power Switch

- Capable of interrupting voltage and full load current
- Easy reach of driver and emergency personnel
- Relay must be normally open and may be powered from aux battery

5.10.A External Power Cut off Switch

- Switch actuation must also be present on the exterior of vehicle, either mechanically or electrically
- Must be marked according to 5.10.A

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5.11 Cable Sizing

- All cables must be sized to expected currents
- Cables should be restrained to prevent chaffing
- Cables should be marked to alleviate delay during emergencies
- Terminations should utilize entire surface of lug, terminal or spade.

5.12 Electrical Shock Hazards

- Exposes connections, terminations and junction boxes greater than 32 volts must be labeled with “High Voltage”
- Enclosures are preferred

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5.16 Accelerator

- Free Moving, returns to zero upon brake activation and starts from zero when re-engaged

5.17 Control

- Vehicle is to be is sole control of the driver

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Pack

- Dress all leads for neatness, and chaffing
- Optimize distribution cables – err on side of larger cables
- Test, test, test, understanding the voltage and current relationship on each cell or paralleled cell group(module) is very important
- Once understood, balancing is required for modules wired in series, all must operate with same energy profile.
- **Weakest cell will limit the pack**
- Lithium, with its large quantity of cells paralleled and then series'd is highest battery risk.
- AVOID Shorting, will cause failure of cell(s)

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Impound

- Daily – expect to remove pack and place in lockable box
- Design pack to safely isolate potential shorts for impound
- Battery Protection System should be included if necessary for safe storage overnight
- Watertight container if water can hurt your battery pack
- Be creative, every minute wasted during pack removal is one less minute of charging
- May be useful for over the road transport protection as well.

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Safety

- High voltage > 48 volts – respect it – it can **Kill You**
- Electrolyte Spillage – appropriate neutralizer – proper ventilation
- Explosion – uncontrolled thermal event
- Melt down – loose terminal
- Fire – appropriate fire suppression material
- ABC for all, Sand for Lithium in addition, Class D (copper powder) if Lithium alone,(no electronics)
- For contact with Lithium electrolyte (HF), flush with copious amounts of water and apply Calcium Gluconate skin cream for the resulting irritation.

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Safety cont.

- **Plan** for all these activities and **know ahead** what to do
- Assign team member to have **authority** to drive safety
- **Plan** for everything to be electrically **"HOT"**
- Rubber Gloves – rated for voltage
- Break pack wiring into safer voltage elements
- Develop procedures to safe shut down
- Develop start-up procedures for initial start-up as debugging begins

Good Luck!