Acceptance Test Report - TSV

ECE 492 - Spring 2015

Abstract

This document provides a final look at whether and how each requirement for the Lafayette Formula Electric Vehicle (LFEV-2015) TSV system is met. Each requirement can be proven to be met through analysis, test, and/or inspection where appropriate.

Revision 1.0.0
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Summary

The TSV system, providing the high power for the tractive system on the Lafayette Formula Electric Vehicle (LFEV), is a critical component of the overall system and accounts for a large portion of the safety and reliability of the vehicle.

The 2015 TSV team carried out significant mechanical as well as electrical redesigns but was unable to finish integrating the pack, so not all implemented functionality can be shown in this document. Due to the lack of testable components, this document will focus on showing requirements met by logic and inspection.

All requirements (including EV rules) are listed in the requirement traceability matrix along with whether and how they are met. For all requirements that are met by inspection, the inspection can be found in the later section “inspection report”.

Requirement Traceability Matrix

Requirement	Description	Functional Requirement/Interface	MET
Formula Hybrid Rules			
1.2.1	The maximum permitted operating voltage for Formula Hybrid is 300 V.	Measured from tractive system measuring points. These have yet to be created.	Yes, by analysis. The design of the system cannot theoretically generate voltage close to 300V.
1.2.4	The tractive and GLV system must be galvanically isolated from one another	Any connections from TSV system to GLV or to VSCADA must be made using galvanically isolated cables. Also the insulation between the systems will be monitored by the IMD	Not met
1.2.5	The tractive system must be completely electrically isolated from the chassis and any other conductive parts of the car.	Tractive system voltage will only be available through the TSMP and the TSV + and - terminals.	Not met
1.3	All Electrical insulating materials used must be UL recognized, be rated for the maximum expected operating temperatures at the location of use or have a minimum temperature rating of 90C. (Whichever is greater)	Each wire used will be documented and cross-checked with UL database. Additionally, there will be temperature readings taken throughout testing, and these will be cross-referenced with the UL database.	Inspection
3.1	Accumulators used must be either batteries or capacitors. Not including molten salt batteries, thermal batteries, fuel cell, atomic and flywheel mechanical batteries	LiFePO4 batteries have been used. We will provide the documentation from the manufacturer's site to show that they follow all of the requirements.	Yes, by analysis. We use LiFePO4 batteries.
3.2	All batteries or capacitors which store the tractive system energy must be enclosed in (an) accumulator container(s). Spares must be copies of the replaced packs. If the accumulator container(s) is not easily accessible during Electrical Tech Inspection, detailed	4 accumulator packs will be created for the purposes of competition. They will have a sliding window pane or similar mechanically operated access panel so that it can be easily inspected. There will be no spares in the current design plan.	Inspection

	pictures of the internals taken during assembly must be provided.		
3.3.1	The poles of the accumulator stack(s) and/or cells must be electrically insulated from the inside wall of the accumulator container by insulating material rated for the maximum voltage of the tractive system. All conductive surfaces on the outside of the container must have a low-resistance connection to the GLV system ground.	Will check that the connectors for the poles coming out of the accumulator box are rated for the maximum voltage and current coming from the pack by checking the manufacturer's specifications. The conductive parts of the battery pack will rest on the chassis of the car, which the GLV system is grounded to.	Inspection
3.3.2	Every accumulator container must contain at least one fuse.	Currently there are fuses protecting the AIRs in the pack.	Inspection
3.3.3	All batteries or capacitors that make up the accumulator must be divided into accumulator segments. A Segment Maintenance Disconnect (SMD) must be installed between each segment.	Each pack is only approximately 24V so by putting a SMD only between each pack, the specification for competition is met. This is already fulfilled through the current plan for the high voltage disconnect (HVD). However, we still must check that each segment contains less than the maximum 12MJ of energy.	Yes, by analysis.
3.3.4	The SMD may be implemented with a switch or a removable maintenance plug. There must be a positive means of securing the SMD in the disconnected state; for example, a lockable switch can be secured with a padlock or simply a clip.	The current SMD implemented through the HVD uses a plug which must be turned and locked into place before it is connected, so it cannot be accidentally connected.	Yes, by analysis/inspection
3.3.5	Contacting / interconnecting the single cells by soldering in the high current path is prohibited.	No soldering was used on the high current path.	Yes, by analysis.
3.3.6	Each accumulator container must have a prominent indicator, such as an LED, that is visible through a closed container and will illuminate whenever a voltage greater than 30 VDC is present at the vehicle side of the AIRs	A 20V indicator light will be created to show when tractive system voltage is present at the pack terminals. Our pack will not ever be higher than 30V so it is technically met, but it is good practice to have the 20V implementation of this.	Partially met. Inspection.
3.3.7	The accumulator voltage indicator (3.3.6) must be	A non-software controller circuit will be created by the TSV team which will activate when	Inspection

	directly controlled by voltage being present at the connectors using hard-wired electronics. (No software control is permitted). Activating the indicator with the control signal which closes the Accumulator Isolation Relays (AIRs) is not sufficient.	tractive voltage is present at the poles of the pack.	
3.3.8	The accumulator voltage indicator must always work, e.g. even if the container is removed from the car.	The accumulator voltage indicator will be powered by the batteries themselves, and will not be connected to the GLV system of the car.	Inspection
3.3.9	The minimum spacing or creepage distance for conductive materials at different voltages in the Accumulator shall be ⅛" over air and ¼" over surface.	When designing the new pack, these requirements have been taken into consideration.	Inspection
3.5	At least two “normally open” isolation relays must be installed in every accumulator container, one at each pole. If these relays are open, no TSV may be present outside of the accumulator container. The fuse protecting the accumulator circuit must have a rating lower than the voltage and current ratings of the isolation relays.	The current system design has this implemented already. There is one “normally open” AIR which are controlled by the PacMan and cover the + terminal of the tractive system.	Yes, by analysis.
3.6	AMS must measure individual cell voltages, temperatures. If voltage measurement is interrupted, AMS must report critical voltage problem. Must measure temperature of at least 15% of cells. Any voltage or temperature errors must shutdown the IC drive system and open AIRs, reset must come from someone other than driver. AMS board must be dedicated to AMS, and must have watchdog timeout. Must have an AMS test port.	The current system measures voltage, but temperature sensing must be added. Additionally, the AMS testing port and protocol for testing must be developed. Lastly, it must be verified that critical failures of temperature or voltage will open the AIRs and shutdown the IC drive system.	Partially met
4.1	Electrical separation of GLV and TSV systems	The TSV and GLV systems will only interface where documented in the ICD, and the ICD will	Inspection

	must be at least 1cm for non-PCB materials, and 6.4mm for PCB materials. All of this must be documented in the ESF	follow the specifications given by the Formula Hybrid rules.	
4.2	All parts of the tractive system must be safely attached to the car. This includes all aspects of the the TS within the envelope of the car, and the TS being protected from collisions, as well as not protruding from the bottom of the vehicle.	This will not be scoped for this year of the project	N/A
4.3	All accessible parts of the vehicle must be within certain resistance tolerances to be considered a safe ground.	This will not be scoped for this year of the project	N/A
4.5	The Tractive System must have all of its wires properly insulated as per requirement 1.3, and must be labelled. Additionally, the TS must be enclosed and protected from water, strain, vibration and unable to be breached by a 10cm long .6cm diameter probe.	All of the cables will be checked to the manufacturer's specifications to ensure that they are appropriate. These will be labelled in plain sight. The case will be designed with the stress tests in mind, and will have minimized openings.	Partially met. Inspection.
4.6	Any tractive system enclosure must be labelled with a "High Voltage" sticker if its voltage exceeds 30V DC.	In each pack, the voltage does not exceed 30V, but when all packs are connected in parallel, the voltage will exceed 30V. However, for good practice, we will include the stickers.	Inspection
4.7	It must be possible to positively break the current path of the tractive system accumulator quickly by turning off a disconnect switch or removing an accessible element, fuse or connector. An interlock must open the shutdown circuit when the HVD is removed. It must be labelled HVD and operable without the use of tools. It also must be able to be secured in the disconnected state.	The current connection port for the TSV + terminal is labelled HVD and satisfies most of these requirements. This will most likely be expanded to the the overall system HVD once all of the accumulators are connected together.	Inspection
5.1	The shutdown circuit must directly carry the	The AMS shutdown situations communicate with the PacMan to open the AIRs.	Analysis

	current driving the accumulator isolation relays (AIRs). It consists of at least 2 master switches, 3 shut-down buttons, the brake-overtravel-switch, the IMD, all required interlocks and the AMS. If opened, the motor must free-spin.		
6.1	All electrical systems must be properly fused. The fuse protecting a circuit or must be physically located at the end of the wiring closest to an uncontrolled energy source.	All of the fuses and connections in the pack will be referenced to the manufacturer's specifications to ensure that every requirement is met.	Analysis + inspection
8.1	Whenever the accumulator containers are opened the accumulator segments must be separated by using the maintenance plugs and whenever the accumulator or tractive system is being worked on, only appropriate insulated tools may be used.	These are safety requirements which must be met whenever the packs are being worked on. These specifically refer only to the competition, but it is good practice to follow these guidelines anyway.	Safety Plan
8.2	These guidelines refer to safety precautions for charging the packs during competition. (See the Formula Hybrid rules)	These are safety requirements which must be met whenever the packs are being charged. These specifically refer only to the competition, but it is good practice to follow these guidelines anyway.	Safety Plan
9.1	All teams must submit clearly structured documentation of their entire electrical system called the Electrical System Form (ESF). The ESF must illustrate the interconnection of all electric components including the voltage level, the topology, the wiring in the car and the construction and build of the accumulator(s).	As each piece of the TS is designed, it will be documented, and in the end these documents will be compiled into the ESF.	Not met.
9.2	Teams must submit a complete failure modes and effects analysis (FMEA) of the tractive system prior to the event. (Available online)	The format and specifications for this document will follow the template online.	N/A, We are not competing yet.

2014 LFEV Design Bugs/Errata			
R001,R004	Fix issue where pack will not charge once depleted.	This occurs, because in order to charge the cells, the AIRs must be closed. However, these are controlled by the PacMan which also derives its power from the cells. A new charging circuit must be desgned.	Not met. But design should satisfy if implemented.
R001,R004	Implement ambient temperature sensors in pack.	Ambient temperature sensors must be installed in the pack. These should feed information to the PacMan, which should then make that available to SCADA.	Not met. But design should satisfy if implemented.
R001,R004	Implement full system reset button.	Currently, all of the reset buttons are not accessible from the outside of the pack. Also they are all separate. All of the resets should be linked to a single button.	Not met. But design should satisfy if implemented.
R001,R004	Correct AMS board errata.	Fix the documented errata from the LFEV 2014 technical memos.	Analysis. The AMS hardware was updated and the software rewritten. Previous errata are no longer present.
R001,R004	Implement new LCD display	The current LCD display only contains minimal information, and should be replaced or updated to show additional and more relevant info.	Inspection
R001,R004	Implement an indicator for low battery warning.	Currently, charge is monitored by the pack, but there is no indicator if the charge is running low. This will most likely be a simple LED.	N/A
R001,R004	Update PacMan source code to follow coding guidelines.	The current documentation for the PacMan source code is severely lacking, and this should be corrected so that future years can use it easily.	Analysis. The PacMan software is completely rewritten for a different chip. We followed coding guidelines while doing so.
R001,R004	Create a better charge algorithm	The current charge determination algorithm uses only voltage, and should be improved to take other factors such as temperature into account.	Not met.

Inspection Report

R000 - EV 1.3

Each wire and insulating connector used in the project was first inspected for UL listing before being added to the collection.

Wire collection for the project

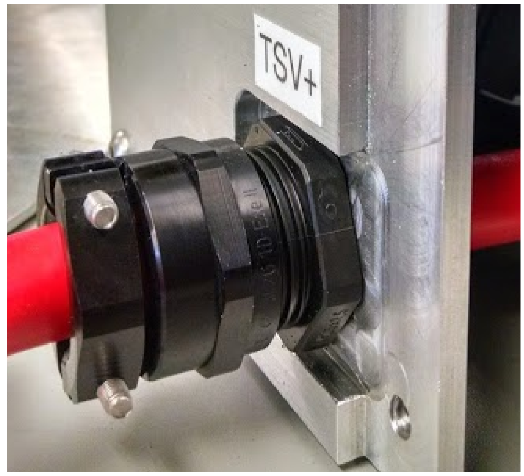
Examples of wires with their UL marking

R000 - EV 3.2

The completed vehicle will need four battery (accumulator) packs. Each pack will have a complete metal casing enclosing the accumulator energy. The pack is easily accessible through the top with a removable top panel, or relatively easily from the side by removing the side panels. In addition, detailed pictures of the internals are provided below.

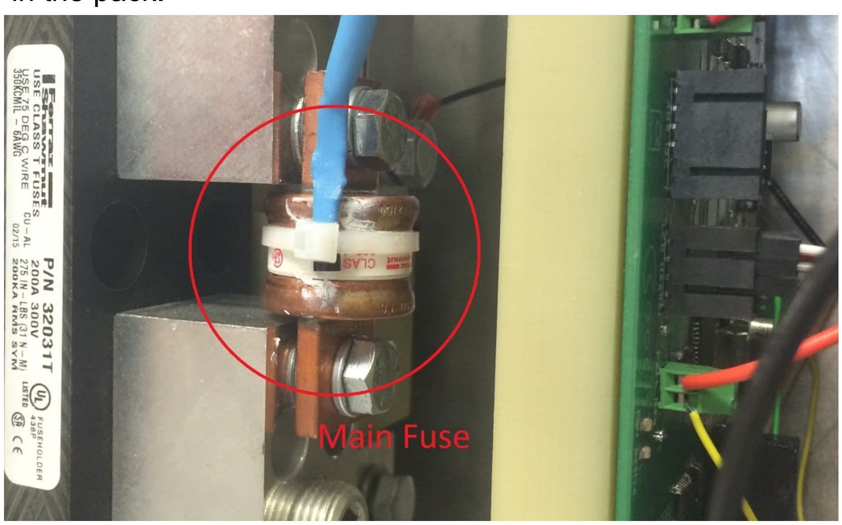
R000 - EV 3.3.1

The connectors for the poles coming out of the accumulator box are rated for the maximum voltage and current coming from the pack according to the manufacturer's specifications. The negative pole coming out of the pack is insulated with a twist lock connector. The positive pole is insulated with a wire and strain relief mount. The conductive parts of the battery pack include the entire aluminum casing, and was designed to be bolted securely to the chassis of the car, to which the GLV system is grounded.



R000 - EV 3.3.2

Each pack (accumulator container) includes a fuse on the main current path that is capable of breaking the circuit going through the accumulator poles. This is one of the most important fuses in the pack.

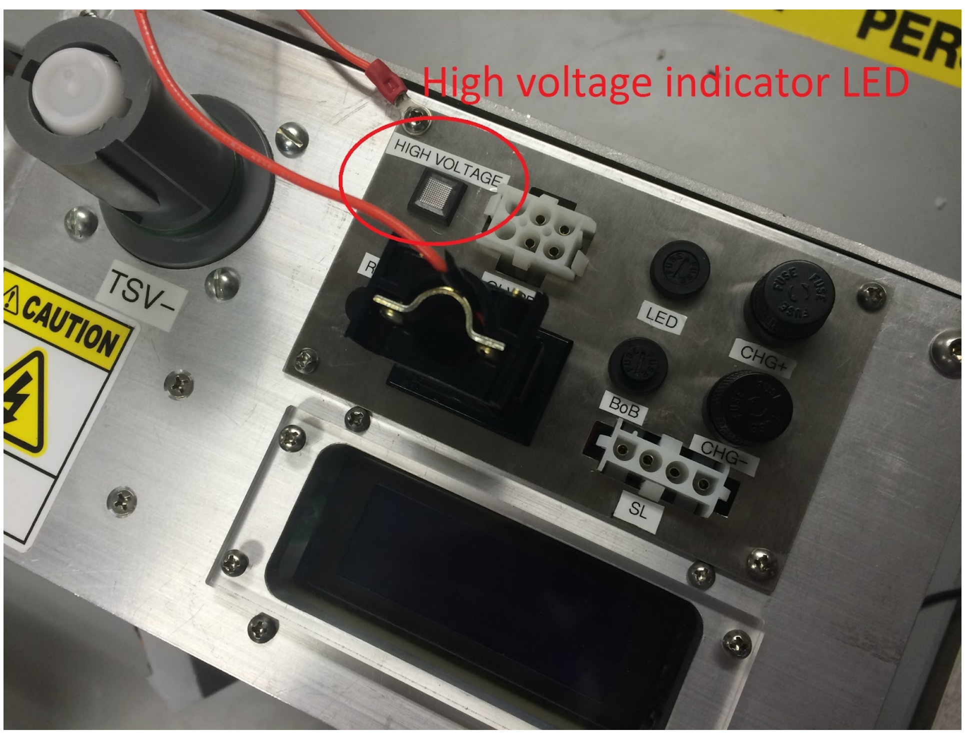


R000 - EV 3.3.4

The SMD is implemented using a twist lock plug which must be turned and locked into place before it is connected, so it cannot be accidentally connected.

R000 - EV 3.3.6

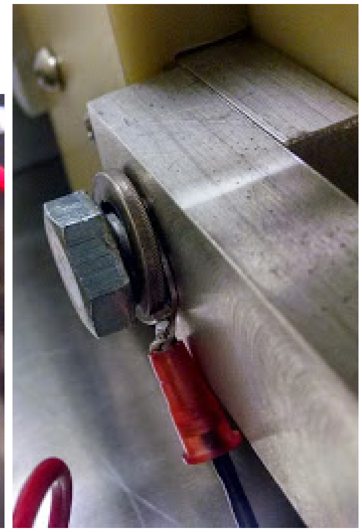
This requirement is partially met because a new design including a prominent LED indicator was added, but since the pack is not completed, this cannot be demonstrated or tested.



The indicator is designed so that whenever a voltage is present across the poles of the pack (when the AIRs are closed). It emits bright amber light, and is very visible from most angles outside of the pack.

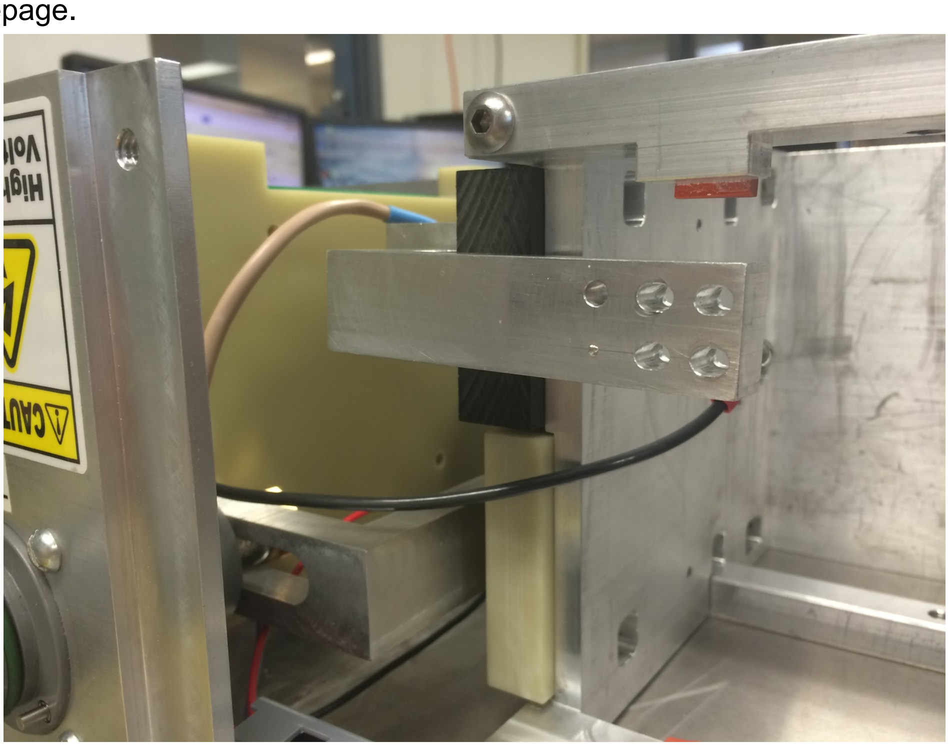
R000 - EV 3.3.7, 3.3.8

Requirement EV 3.3.6 for a high voltage LED indicator was designed using a simple circuit that connects the terminals of the LED directly across the poles of the pack through a resistor and two fuses for safety. This circuit is completely separate from the Pac-Man computer system and relies directly on the pack voltage to operate.

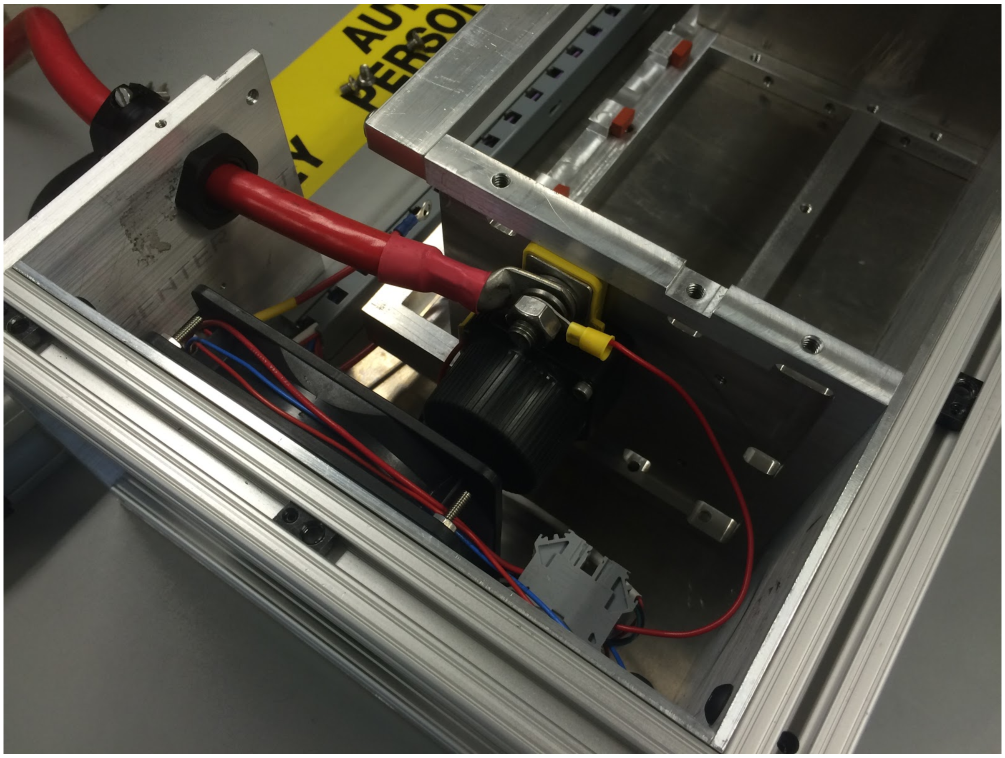


R000 -EV 3.3.9

All exposed conducting material parts are securely fastened and there is little to no visible creepage.



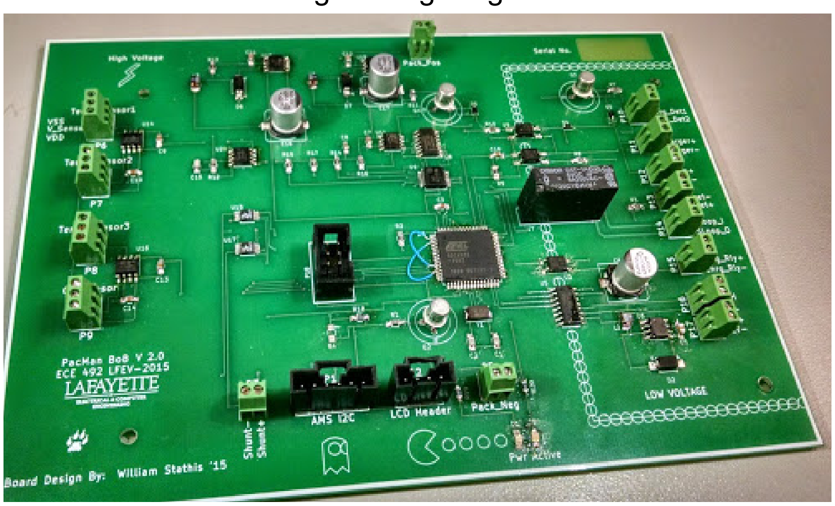
Above: The conductor bar at the end of the pack is one of the components with the most creepage due to the way it is secured. The creepage is still below ⅛”



Above: the exposed contacts show no visible creepage and are securely fastened.

R000- EV 4.1

The only interface between GLV and TSV is the safety loop portion of the BoB. The BoB was designed to isolate low and high voltage regions.



R000 - EV 4.5

All wires used in the pack are properly insulated and color coded. However, they are not labeled. The pack's mechanical resistance information should be verified with mechanical engineers who participated in the design of the pack.

Wiring inside the pack.

R000 - EV 4.6

Even though the pack does not generate a voltage greater than 30V, we included a "High Voltage" sticker on the outside of the pack for good practice.

R000 - EV 4.7

As shown in R000 - 3.3.1, both poles of the pack implemented HVDs that can be quickly detached to break the main circuit.

R000 - EV 6.1

All of the points of contact with the pack high voltage are fused at the closest possible location to the pack poles before wires travel throughout the pack. There are three points of contact at each pole, two each for the charger connection, LED indicator, and BoB power supply. The charger connections are fused at 30 A, the LED and BoB connections are fused at 1 A.

R001, R004 New LCD Display

A new LCD display was chosen, purchased, and implemented along with new software to allow control over it.

The LCD in working order.

Deliverables

Deliverable	Description	Responsibility	Accepted	Comments
D000	PDR Materials	Each Team	Yes	
D001	CDR Materials	Each Team	Yes	
D002	Users Manual	Each Team		Pending Approval
D003	Final Report & Maintenance Manual	Each Team		Pending Approval
D004	ATP	Each Team	No	
D005	ATR	Each Team		Pending Approval
D006	QA Report	Each Team	No	
D007	Project Website	Management Team	Yes	
D008	LFEV 2015 Project Demonstration	Entire Class	Yes	
D009	Conference Paper, Presentation, and Video	Conference Team	Yes	Waived
D010	Project Poster	Management Team	Yes	
D011	Calibration & Accuracy	Each Team	No	
D012	Maintainability Plan	Each Team		Pending Approval
D013	Individual Research Report	Individual Students	Yes	Individual Basis

D014	Project Status Letters & Presentation	Management Team	Yes	Weekly Basis
D015	Project Interface Control Document	Management Team	Yes	