2008
FORMULA HYBRID™
RULES

THAYER SCHOOL OF
ENGINEERING
AT DARTMOUTH

2008 Formula Hybrid™ Rules

The Formula Hybrid competition is based upon the Formula SAE™ rules. Teams must have a copy of the currently valid Formula SAE rules to refer to while reading this document.

The official rules for Formula Hybrid are the current (2008) Formula SAE rules as modified and expanded by this document.

The 2008 Formula SAE rules are available for download from:

http://students.sae.org/competitions/formulaseries/rules/rules.pdf

Teams and vehicles must comply with all current Formula SAE rules except where those rules are explicitly modified by the contents of this document. Where there are apparent contradictions between the Formula SAE rules and the Formula Hybrid rules, this document will take precedence. If there is a section in the Formula SAE rules that is not referenced in this document, then the Formula SAE rule is valid and must be complied with.

Those sections in the Formula SAE rules that appear to refer to only Formula SAE also apply to Formula Hybrid unless modified below.

We encourage teams to use the forum at the Formula Hybrid website to discuss rules issues.

http://www.formula-hybrid.org

Formula Hybrid Rules Format

Where text follows a section heading with no italicized comments, then that text replaces the entire text in that section of the FSAE rules. Otherwise, the rule is modified as specified.

1. Modifications to FORMULA SAE RULES

1.2 Vehicle Design Objectives

FSAE Section 1.2 is changed to allow a $32,000 maximum cost for the prototype.

1.3 Judging Categories

(The events and points distribution are modified as follows)

Static Events	
Presentation	100
Engineering Design	200
Dynamic Events	
Acceleration - Electric	75
Acceleration - Unrestricted	75
Autocross	150
Efficiency & Endurance	400
Total Points	1000

2. ELIGIBILITY

2.1.2 Society Membership

Team members must be members of at least one of the following societies: (1) SAE, (2) SAE Australasia, (3) SAE Brasil, (4) ATA, (5) IMechE or (6) IEEE. Proof of membership, such as a membership card, is required at the competition. Students who are members of one of the societies listed above are not required to join any of the other societies in order to participate in the Formula Hybrid competition.

Note: Students can join SAE online at: *www.sae.org/students* or IEEE at: *http://www.ieee.org/web/membership/join/join.html*

2.2 Registration Requirements

Teams may enter a vehicle as many years as they like, provided they can demonstrate evidence of substantial development (mechanical and/or electrical) since the last time the vehicle was entered.

Teams may enter an electric-only vehicle for one year only. (This is based on the assumption that the vehicle is a "Hybrid-in-Progress". – See section **FH-1**)

Registration must be done on-line at *<insert FSAE registration page URL>*

Registration will open on October 1st, 2007 at 10:00 am EDT and close on December 27th 2007 at 11:59 pm EST.

2.2.6 Withdrawals

For Formula Hybrid withdrawals contact: *Wynne@formula-hybrid.org*

3. VEHICLE REQUIREMENTS AND RESTRICTIONS

3.2.5 Brake Systems

*(Add the following after the first paragraph of **FSAE 3.2.5**)*

Up to the first 50% of brake pedal travel may be dedicated to activating regenerative or other advanced braking systems, but the remaining travel must mechanically activate a hydraulic system as described in the remainder of **FSAE 3.2.5**.

3.2.5.2 Brake over Travel Switch

A brake pedal over-travel switch must be installed on the car. This switch must be installed so that in the event of brake system failure such that the brake pedal over travels, the switch will be activated and must shut down all drive systems and must trip the accumulator isolation relays. Repeated actuation of the switch must not restore power to these systems and it must be designed so that the driver can not reset it.

3.3 Structural Requirements

*(Append the following to **FSAE 3.3**)*

Note: Many teams will be retrofitting Formula SAE cars for Formula Hybrid. In most cases these vehicles will be considerably heavier than what the original frame and suspension was designed to carry. It is important to analyze the structure of the car and to strengthen it as required to insure that it will handle the additional stresses.

The technical inspectors will also be paying close attention to the mounting of accumulator systems. These can be very heavy and must be adequately fastened to the main structure of the vehicle.

3.3.6.4 Impact Attenuator Data Requirement

*(**FSAE 3.3.6.4** is modified as follows)*

The defined mass of the vehicle for the impact attenuator calculation must be 450 kg (992 lbs) instead of 300 kg (661 lbs) for a FSAE vehicle.

3.4.9 Master Switches

There must be a minimum of three shutdown buttons (Master Switches), one on each side of the car just behind the driver's compartment at approximately the level of the driver's head, and one on the instrument panel easily reachable by the driver. These buttons, when pushed, must break the flow of current holding the accumulator isolation relays closed (see section **FH-2.5.2**) thus isolating all the energy storage elements.

These buttons must also shut down the engine and any other energy generation systems.

The buttons must be red, 60mm diameter, latching type that once pushed, must stay in until manually pulled outward to reset the system. (Omron A22E-LP-01[1] or equivalent – Digikey Z1503-ND)

3.4.11 Batteries

*(Note: **FSAE 3.4.11** refers only to the low voltage i.e. 12V. systems – for high voltage requirements refer to section **FH-2**)*

[1] Omron is a Formula Hybrid team sponsor. See the Formula Hybrid website for more information.

3.5.1.1 Engine Limitations

Engines must be Internal Combustion, four-stroke, with a maximum displacement of 250cc and be either:

1. Modified or custom fabricated. (See section **3.5.4**)

Or

2. Stock -- Any 250cc single or any 250cc twin from a motorcycle approved for licensed use on public roads. (Other engines may be approved upon application to the organizers. – Those additional engines[2] will be listed on the Formula Hybrid website as they are approved.)

Permitted modifications to a stock engine are:

- Modification or removal of the clutch, primary drive and/or transmission.
- Changes to fuel mixture or timing settings.
- Replacement or modification of any exhaust system components.
- Replacement or modification of any components upstream of (and including) the air filter.
- Modifications to the engine casings. (This does not include the cylinders or cylinder head.

3.5.1.7 Starter

(**FSAE 3.5.1.7** is deleted)

3.5.2 Fuels

93 Octane[3] pump fuel, E-85 and Biodiesel will be provided.

[2] All "stock" engines must have manufacturer-supplied data that would permit scrutineers to confirm its non-modified status in the event of a tear-down.

[3] $\left(\frac{R+M}{2}\right)$

3.5.3.1 Fuel Tank Size Limit

Any capacity tank may be used.

The fuel system must have a drain fitting for emptying the fuel tank. The drain must be at the lowest point of the tank and be accessible from under the vehicle. It must not protrude below the lowest plane of the vehicle frame, and must have provision for safety wiring.

3.5.3.2 Filler Neck and Sight Tube

(Append the following to **FSAE 3.5.3.2**)

The sight tube is optional for Formula Hybrid.

All filler caps and necks must have provision for a seal to be attached such that the filler cap may not be removed without the removal of the seal. This should consist of two 1/8" holes, one on the neck and one on the cap. When the fuel cap is secured, these holes should be located within ¼ inch of each other.

3.5.4 Throttle, Throttle Actuation and Intake Restrictor

Note: Section 3.5.4 applies only to those engines that are not on the approved stock engine list, or that have been modified beyond the limits specified in section **3.5.1.1**.

Non-stock engines (See section **3.5.1.1**) must be fitted with an air inlet restrictor as listed below. All the air entering the engine must pass through the restrictor which must be located downstream of any engine throttling device.

The restrictor must be located in such a way that its diameter may be easily measured during technical inspection.

The restrictor must be circular with a maximum diameter of:

Gasoline fueled cars - 12.9 mm (0.508 inch)

E-85 fueled cars - 12.3 mm (0.483 inch)

Biodiesel fueled cars – no inlet restrictor required

Turbochargers and Superchargers - Turbochargers or superchargers are permitted. The compressor must be located downstream of the inlet restrictor. The addition of a Turbo or Supercharger will move the engine into the Modified category.

3.6.3 SAE & IEEE Logos

SAE and IEEE logos must be prominently displayed on the front and/or both sides of the vehicle. SAE and IEEE logos will be provided to the teams on-site or may be requested ahead of time by emailing the organizers.

4. STATIC EVENTS

4.1 Static Events

The maximum possible scores in the static events are:

Technical Inspection	0 Points
Presentation	100 Points
Design	200 Points
Total	300 Points

4.3 Cost & Manufacturing Analysis Event

There is no Cost and Manufacturing event in Formula Hybrid.

4.4.1 Presentation Event Objectives

*(Append the following to **FSAE Section 4.4.1**)*

The judges should also be treated as if many of them are active members of the Sierra Club, and are keenly aware and concerned about environmental and energy conservation issues.

4.5.2(b) Design Specification Sheet

(The Formula Hybrid design spec. sheet will be located on the Formula Hybrid website.)

The deadline for Design Specification Sheet submission will be posted on the Formula Hybrid web site.

4.5.2.1 Vehicle Drawings / Design Report

The Design report must include all of the following drawings:

- One set of 3 view drawings showing the vehicle from the front, top, and side.
- A schematic of the high voltage wiring showing the wiring between the major components. (There is no need to detail the internals of the major components.)
- A wiring diagram superimposed on a top view of the vehicle showing the locations of all major high voltage components and the routing of high voltage wiring.

5 DYNAMIC EVENTS

Each team will be allocated a fixed amount of fuel, and all dynamic events must be run within that allotment.

Prior to the beginning of the dynamic events, the vehicle fuel tank (and if fitted, carburetor float bowls) will be drained. The tank will then be filled by the organizers and the filler will be sealed.

If the vehicles fuel tank is smaller than the event fuel allotment, the extra fuel will be stored in a sealed container by the organizers. Any transfer of fuel from the container to the car must be done under official supervision and only between events. The container and vehicle fuel tank will then be re-sealed.

The amount of fuel allotted to each team will be 85% of the organizers best estimate of what an average FSAE car would consume running the same events, adjusted downward by an amount equal to the stated energy content of the vehicles accumulators. (It is assumed that the vehicle will start the dynamic events with fully charged accumulators) The fuel/accumulator energy conversion will be based on a 27% fuel-to-mechanical engine efficiency. (See Appendix A)

Teams will have one opportunity, before the start of the endurance event, to "purchase" additional fuel at the rate of 500 points/liter for gasoline, 360 points/liter for E85, or 515-565[4] points/liter for Biodiesel. Any amount of fuel including fractions of a liter may be purchased.

There will be no extra points awarded for fuel remaining at the end of the dynamic events.

[4] The actual amount will be determined based on the blend of fuel provided by the organizers.

Hybrids-in-progress (see section **FH-1**) may use the allotted fuel to power a portable generator which may be used to charge the accumulators. The generator must comply with the fuel tank drain and filler cap seal requirements, and must be located in a prominent area i.e. not inside of a trailer or other structure. (See also **FH-2.8**).

Hybrids-in-progress may recharge their accumulators during the Endurance driver change (Not to exceed 30 minutes)

NOTE: Once the dynamic events have begun, hybrids-in-progress may *only* charge from portable, fuel-powered generators. (Multiple generators are permissible, but must share the team's fuel allotment.)

Prior to the beginning of the dynamic events, all competitors may charge from any power source they wish.

5.1 Dynamic Events

The maximum scores in the dynamic events are:

Acceleration	150 Points
Autocross	150 Points
Endurance/Efficiency	400 Points
Total	**700 Points**

5.2.1 Running in Rain

(Append the following.)

(See also section **FH-2.1.4**)

5.3 Driver Limitations

An individual team member may not drive in more than two (2) events.

An individual may not drive in both heats of any event. It is the team's option to participate in any event. The team may forfeit their second heat in any performance event.

Note: A minimum of three (3) drivers is required to participate in all heats of the dynamic events

In order to drive in the endurance event, a driver must have attended the mandatory drivers meeting and walked the entire track with an official.

The time and location of the meeting and walk-arounds will be announced at the event.

5.4.3 Acceleration Heats

There will be a minimum of 2 acceleration runs. One must be run electric-only, with the engine shut off (See also section **FH-1**). The second run may be done in any configuration the team chooses. Teams have the option of making up to two additional runs in each category (electric-only and unrestricted) for a total of up to 6 runs. The fastest run in each category will be the recorded acceleration time. There will be no additional fuel allotment for additional runs. It is permissible for one driver to make all the acceleration runs.

The two acceleration categories (electric only and unrestricted) will be scored separately for 75 points each.

5.5 Skid Pad Event

There is no skid pad event in the 2008 Formula Hybrid competition.

5.7.2 Endurance Objective

The endurance event is designed to evaluate the vehicle's overall performance, reliability and efficiency. Unlike fuel economy tests that result in vehicles going as slow as possible in order to use the least amount of fuel, Formula Hybrid rewards the team that can cover a designated distance on a fixed amount of energy in the least amount of time.

5.7.3 Fuel Economy

There is no separate Fuel Economy score.

5.7.5 Endurance General Procedure

The team completing the required number of laps in the shortest time will earn the maximum points available for this event. If no teams complete the allotted laps, the required laps will be adjusted downward until there is a winner. The remaining finishing positions will be filled out by "fastest cars for *n* laps", followed by "fastest cars for *n*-1 laps", then "fastest cars for *n*-2 laps", etc.

Wheel to wheel racing is prohibited. Passing another vehicle may only be done in an established passing zone or under the control of a course marshal.

The endurance distance is 22km (13.7 Miles).

5.7.6 Endurance Fuel Fill

*(Delete FSAE section **5.7.6**)*

5.7.7 Endurance Vehicle Starting/Restarting

*(Delete FSAE section **5.7.7**)*

5.7.8 Endurance Driver Change Procedure

There must be two drivers for the endurance event. The first driver will complete 11 kilometers and then the second driver must take over.

The clock will be stopped during the driver change. The car must come to a complete stop in the driver change area with all drive and electrical systems shut down. The drivers may then switch. The second driver must indicate to the course marshal when she/he is ready to reenter the track, whereupon the course marshal will confirm proper seat belt and helmet buckling. The course marshal will then allow the car to reenter the track.

The vehicle may be stopped during the driver change for up to 30 minutes without penalty. (See section **5.7.15.6**)

5.7.9 Entering the Track

Teams may elect to push their vehicle to the staging area at the start. However all vehicle movement in the staging area must be done under control of the course marshal.

Cars will be allowed to enter the track based on traffic conditions.

5.7.10 Endurance Run Order

Endurance run order will be determined by the team's score in the autocross. Teams with the best autocross score will run first. If a team did not finish the

autocross, run order will then continue based on acceleration times, followed by any vehicles that may not have completed either previous event. Endurance run order will be published at least one hour before the endurance event is run.

5.7.12 Endurance minimum Speed Requirement

The allotted number of laps must be completed in sixty (60) minutes or less. Cars that are unable to complete 22 kilometers within 60 minutes will be flagged off the course and their actual completed laps will be tallied.

5.7.13 Exiting the Track

Timing will stop when the car crosses the finish line.

Teams may elect to shut down and coast after crossing the finish line, but must fully enter the shut-down area before coming to a stop. There will be no "cool down" laps.

The speed limit when entering the shut-down area is 15MPH. Excessive speed will be penalized.

5.7.15.6 Mechanical Problem

Repairs may be made during the event, but this must be done in the designated repair area. The clock will not be stopped during this time, and the 60-minute total time allowance (Section **5.7.12**) will still be in effect.

Repairs will be allowed during the driver change, but may not exceed the thirty (30) minute shutdown time. There will be no penalty for repairs made during the driver change, however if the vehicle is stopped for longer than 30 minutes the clock will be restarted.

Hybrids-in-progress may recharge during the shutdown time.

5.7.15.9 Poor Fuel Economy

*(FSAE section **5.7.15.9** is deleted)*

5.7.16 Endurance scoring

*(FSAE section **5.7.16** is deleted)*

5.7.17 Endurance Scoring Formula

The times for the endurance event will be based upon the sum of the times of each driver in the heat plus penalties.

The following equation is used to determine the time scores for the event:

If ***Tyour*** is < or = to **60**:

$$EnduranceScore = (Pmax - Pmin)\frac{\frac{60}{Tyour} - 1}{\frac{60}{Tmin} - 1} + Pmin$$

If a team completes all of the allotted laps, then ***Pmax*** **= 400** and ***Pmin*** **= 300**.

If a team does not complete the allotted laps, then ***Pmax*** and ***Pmin*** will be based linearly on the number of laps completed. See **Appendix B** for an example.

Tmin will be the lowest corrected time of the fastest team for each of the number of laps completed.

Tyour will be the combined corrected times of the drivers in your heat.

5.7.18 Fuel Economy

(FSAE section **5.7.18** is deleted)

5.7.20 Fuel Economy Scoring Formula

(FSAE section **5.7.20** is deleted)

5.7.22 Endurance and Fuel Economy Scoring With Two Heats

(FSAE section **5.7.22** is deleted)

FORMULA HYBRID-SPECIFIC RULES

The following sections are specific to Formula Hybrid and have no equivalents in the Formula SAE rules.

FH-1 General

FH-1.1 Definitions

Hybrid is defined as a vehicle using a propulsion system which comprises both a 4-stroke Internal Combustion Engine (ICE) and electrical storage (accumulator) with electric motor drive.

Hybrid-in-Progress (HIP) is defined as a hybrid vehicle that is still in the development stage, which is charged from an external source and operated as electric-only.

High Voltage (HV) is defined as any system (individually or in series) containing or producing a voltage greater than 30V.

FH-1.2 Hybrid

A hybrid drive system may deploy the ICE and electric motor(s) in any configuration, including series and/or parallel. Coupling through the road surface is permitted.

To qualify as a hybrid, vehicles must be capable of completing a 75 meter acceleration run in electric-only mode in less than 15 seconds.

FH-1.3 Hybrid-in-Progress

A vehicle may be entered as a Hybrid-in-Progress for only one year. These vehicles must still meet all Formula Hybrid rules.

A Hybrid may revert to Hybrid-in-Progress in the event of a systems failure after the event has started, even if the vehicle was entered in a previous year as a Hybrid-in-Progress.

FH-2 Electrical Rules

FH-2.1 High-Voltage (HV) Isolation

The Maximum voltage between any two electrical connections in the vehicle, including ground, shall not exceed 600V DC or AC RMS under all operating and non-operating conditions.

There must be no connection between the frame of the vehicle (or any other conductive surface that might be inadvertently touched by a crew member or spectator), and any part of any HV circuits.

HV and low-voltage circuits must be physically segregated:

- Not run through the same conduit.
- Where both are present within an enclosure, separated by insulating barriers such as Nomex, Formex, or other moisture resistant, UL recognized insulating materials.
- If both are on the same circuit board, they must be on separate, clearly defined areas of the board.

FH-2.1.1 Ground Fault Detectors

All vehicles shall be equipped with an on-board Ground Fault detector. This must be a Bender IR486[5] (or equivalent if approved by the organizers). The output relay of this device must be wired in series with the shutdown buttons such that a ground fault will cause an immediate shutdown of all electrical systems.

FH-2.1.2 Ground Fault Detector Test

The ground fault detector will be tested during tech. inspection, by connecting, a 40,000 Ω resistor between multiple points on the HV circuit and the grounded frame with the HV systems at full charge. (See Figure 1). This must cause the Ground Fault detector to trip, and the vehicle electrical systems to shut down.

This test may be repeated by the electrical inspectors at any time during the competition.

[5] Bender Corporation is a Formula Hybrid team sponsor. See the Formula Hybrid website for more information.

Once the Ground fault test has been satisfactorily completed, the scruitineers will seal the High Voltage enclosures. If the seals are broken, the vehicle may not participate in any dynamic events until the Ground Fault test has been satisfactorily re-done. (If a repair is simple, and done in the presence of an Electrical Inspector, the Chief Electrical Inspector may choose to waive the re-testing requirement.)

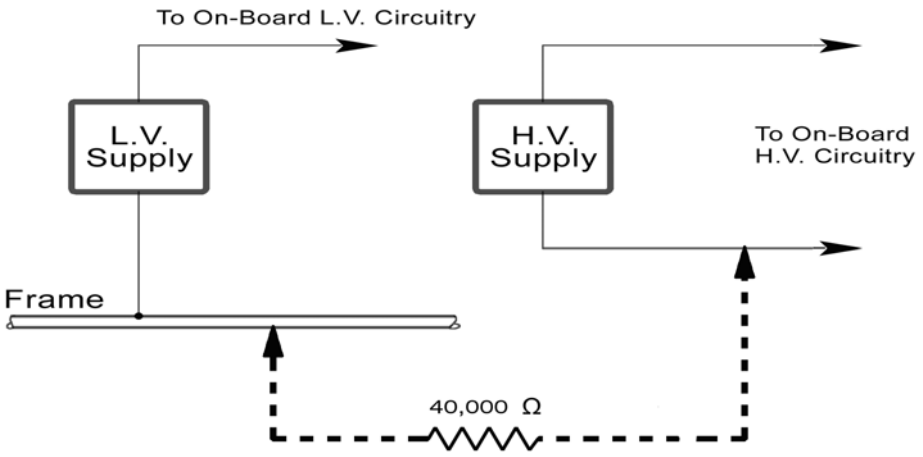

Figure 1

FH-2.1.3 Rain Certification

A vehicle may not be operated in wet conditions unless Rain Certified.

To become Rain Certified, a vehicle must first pass the Ground Fault test outlined in **FH-2.1.2**. It must then survive a 30 second water spray[6] with all systems energized without tripping the Ground Fault Detector.

FH-2.2 No Exposed Connections

No HV connections may be exposed. Non-conductive covers must prevent inadvertent human contact. This would include crew members working on or inside the vehicle.

[6] The water spray will be directed from the top, front and sides of the vehicle. The spray is intended to simulate rain and will typically have drops ranging in size between 0.1 to 5 mm in diameter. A strong stream of water will not be directed at the vehicle.

HV systems and containers must be protected from moisture in the form of rain or puddles for any car that is certified to run rain or wet conditions. (See section **FH-2.1.3**)

There will be no HV connections behind the instrument panel or any cockpit switch or control panels. All controls, indicators and data acquisition connections must be isolated using optical isolation, transformers or the equivalent.

FH-2.3 HV Insulation, Wiring and Conduit.

All insulation materials used in HV systems must be rated for the maximum temperatures expected. Insulated wires must be commercially marked with a wire gauge, temperature rating and insulation voltage rating. Other insulation materials must be documented.

All HV wiring must be done to professional standards with appropriately sized conductors and terminals, and with adequate strain relief and protection from loosening due to vibration etc.

All HV wiring that runs outside of electrical enclosures must be enclosed in orange non-conductive conduit, such as Electri-flex LNMP or equivalent[7]. The conduit must be securely anchored at least at each end, and must be located out of the way of possible snagging or damage.

All external heat sinks must be securely grounded.

FH-2.4 Fusing

All electrical systems (both low and high voltage) must be appropriately fused. Any wiring protected by a fuse must be adequately sized and rated for current equal to the fuse rating (See wire requirements in **FH-2.3**)

FH-2.5 Accumulator Type and Size

Teams must state, as accurately as possible, their accumulator capacity. There is a $6,000.00 limit on the "standardized" cost of the accumulator system. An equivalency table will be published.

[7] Graybar Electric stocks orange conduit and is a Formula Hybrid team sponsor. See the Formula Hybrid website for more information.

Energy accumulators must be of an approved type. At this time only batteries and capacitors are permitted.

FH-2.6 Energy Storage Container Electrical Configuration

All energy storage must be in closed containers containing normally open isolation relays[8] wired in such a way that when an incoming "energize" signal is interrupted no voltages will be present outside of the containers. The boxes must also include an appropriately rated fuse or circuit breaker. The relays must be rated to interrupt the rated fuse current at the maximum expected voltage.

Contactors and relays containing mercury are not permitted.

Multiple energy storage containers connected in series may be isolated by a total of two relays, provided that interconnects between the containers are protected by non-conductive conduit (See FH-2.3) anchored solidly to the containers.

All voltages outside the energy storage container must decay to below 30 V within ten seconds of when the relays are disconnected. For example, filter capacitors must have bleeder resistors across them.

The energy storage containers must have closable access ports allowing a 6" electrical probe[9] to make contact with each extreme of the HV system. These will be used to permit testing the isolation stipulated in section **FH-2.1**. Optionally, access to the same electrical nodes may be provided at another point.

Each energy storage container must have a prominent indicator, such as an LED that will illuminate whenever that container contains a voltage greater than (at a maximum) 30V. This must be clearly visible in direct sunlight. As an alternative, the battery container may contain an "embedded" analog meter clearly visible from the outside.

FH-2.7 Energy Storage Container Mechanical Configuration

The energy storage container and mounting system must be sturdy, considering forces encountered during on-course competition and the possibility of a rollover accident.

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[8] Such as Tyco EV200 (*http://relays.tycoelectronics.com/datasheets/ev200.pdf*)

[9] The probes used during the technical inspection will be Fluke TL238 or equivalent.

The materials used to construct the container should ideally be electrically insulating, mechanically robust, fireproof, and transparent to allow easy inspection. Not all of these properties are available in a single material, but the following are required:

- At least one layer of fireproof material between the driver and the energy storage container.
- Mechanically robust, fireproof insulating material (e.g., Nomex) between live electrical parts and any conductive portions of the container.
- Adequate structural robustness for the weight of the accumulator.

The container must be prominently labeled with high voltage signs, at least 30 in^2, with a red (or white on red) lightning bolt and the text "High Voltage" or "Danger High Voltage".

Systems capable of venting H_2 gas (batteries) must have an active ventilation system that is active whenever the system is charging, whether from on-board or off-board sources.

FH-2.8 Warning Strobe Light

There must be an amber strobe light (Star Warning Systems 200Z[10], Federal Signals Renegade® or equivalent) mounted on the highest point on the roll bar, that will indicate when a vehicle is energized. Energized is defined as any time a High Voltage exists outside the accumulator containers.

FH-2.9. Low-Voltage Circuits

Low-voltage (< 30 V) circuits must be grounded to the frame of the car. (This ensures that, in the event of a fault in the isolation of the HV circuit, no HV will be present between controls or anything else that personnel might touch and the frame.)

If the low-voltage circuits are powered by a battery or other source that is not inherently current limited, proper fusing must be used.

Low-voltage and HV circuits must be segregated and isolated as described in **FH-2.1**.

[10] Star Warning Systems is a Formula Hybrid team sponsor. Refer to the Formula Hybrid web site for more information.

FH-2.10. Charging Equipment

All charging equipment must be maintained in safe working condition. High Voltage chargers and/or power supplies must be marked with appropriate High Voltage stickers. If any voltage remains outside the charger after the power is turned off then any open connections must be securely covered.

FH-3 Required Equipment

Each team must have the following at the event. It is recommended that this equipment be purchased well in advance and kept with the car during development and testing.

- Insulated cable cutters, rated for at least the voltage in the HV system. (Not simply unrated plastic handles). Long fiberglass-handle cutters, e.g., Bahco 2520S11, are recommended. These must be capable of cutting live HV cables in the event of a serious malfunction.
- Insulated gloves, rated for at least the voltage in the HV system.
- Materials Safety Data Sheets (MSDS) for the accumulator.
- Any special safety equipment called for in the MSDS, for example correct gloves recommended for handling any electrolyte material in the accumulator.
- Safety glasses. These must be worn when working on the vehicle and at all times while in the pit area.
- Fire Extinguishers. Teams must identify any fire hazards specific to their vehicle's components and if fire extinguishers/ fire extinguishing material other than those required under **FSAE 3.4.10.2** are needed to suppress such fires, then at least two (2) additional extinguishers/material (at least 5 lb or equivalent) of the required type must be procured and accompany the car at all times. During technical inspection teams must specifically identify all such hazards and present the extinguishers or extinguishing material for examination.
- Chemical Spill cleanup. Teams must have chemical spill absorbent at hand, appropriate to their specific risks.

[11] The Bahco 2520S cutters are available from *www.builderdepot.com*

Appendix A-- Accumulator pricing and Fuel equivalency

Accumulator pricing:

To avoid the distorting effect of different price breaks on the dollar value of accumulator devices, we will use the following technique to determine our official prices.

To find the price at some quantity q*x*, we use the published prices, p1 and p2, at the next lower and higher quantities, q1 and q2.

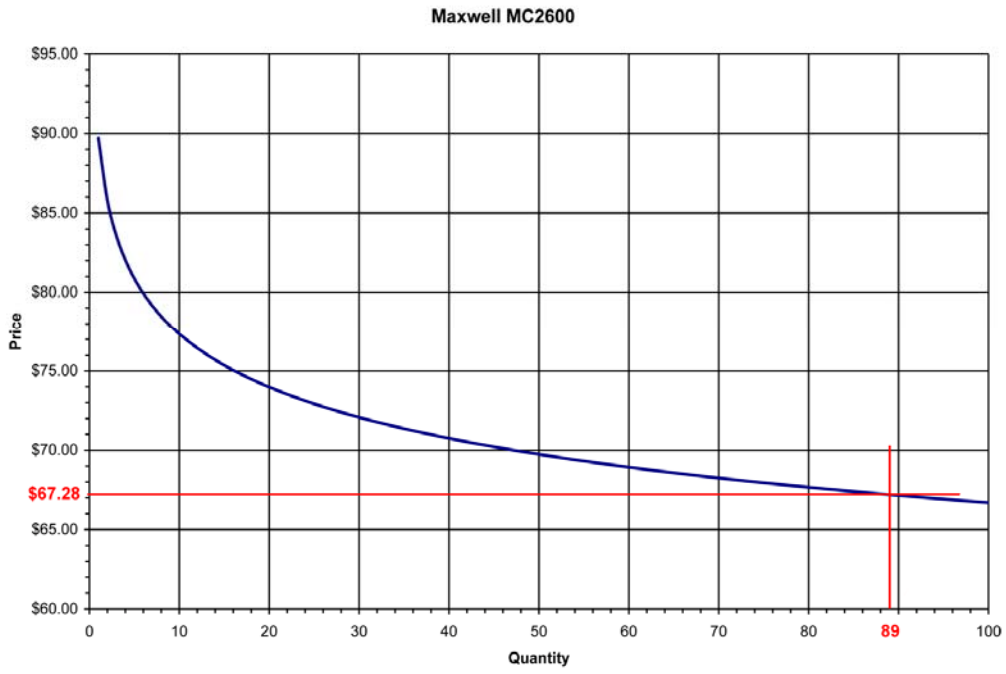
$$p_x = p_1\left(\frac{q_x}{q_1}\right)^a \qquad \text{where} \qquad a = \frac{\log\left(\frac{p_2}{p_1}\right)}{\log\left(\frac{q_2}{q_1}\right)}$$

(This formula has been shown to approximate many electronic device manufacturers pricing structures.)

For example, suppose the Maxwell MC2600 Ultracapacitor were priced at $89.70 in quantities from 1 to 99, and $66.70 for 100 to 999.

If we were to apply our $6,000.00 limit based strictly on this pricing structure, a team could use only 66 devices. However had we set a limit of $6,700.00 they could have used 100.

Using the above formula, the resultant price for the device would be $67.28, allowing the team to use 89 devices.



Typical Price vs. Quantity

Fuel Equivalency:

We will assign a fuel equivalency to each device based on the following: (Note: C, V_{nom}, V_{peak} and Ah are device name-plate values.)

Batteries:

$$Energy(Wh) = (V_{nom})(Ah)(0.8)$$

Capacitors:

$$Energy(Wh) = \left(\frac{C(V_{peak}{}^2 - V_{\min}{}^2)}{2} \right) / 3600$$

where V_{min} is assumed to be 10% of Vpeak.

Gasoline:

$$Gasoline = 2{,}414 \frac{Wh}{l}$$

(at a 27% mechanical efficiency);

For example, taking the Maxwell MC 2600 used in the example above, the fuel equivalency would be 2.606 Wh per device, or 231.9 Wh for a bank of 89, resulting in a 96cc reduction of gasoline.

Other Fuels:

Fuel Type	Wh / Liter (@ 27%)
Gasoline (regular)	2,414
Diesel #2	2,706
Biodiesel (B100)	2,472
Biodiesel (B20)	2,665
Ethanol (E85)	1,710

Appendix B

Example determination of *Pmax* and *Pmin* based on a 22-lap endurance event.

Laps Completed	*Pmax*	*Pmin*
22	400	300
21	299	286
20	285	271
19	270	257
18	256	243
17	242	229
16	228	214
15	213	200
14	199	186
13	185	171
12	170	157
11	156	143
10	142	129
9	128	114
8	113	100
7	99	86
6	85	71
5	70	57
4	56	43
3	42	29
2	28	14
1	13	0