EEVC NEWSLETTER

Published by the Eastern Electric Vehicle Club

Peter Cleaveland, Editor **Vol 35 No 3**
Club Address: P.O. Box 134, Valley Forge, PA 19481-0134 **MARCH, 2015**
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PHYSICS OLYMPICS 2015 AT MALVERN PREP
Oliver Perry

The temperature was in the twenties when Al Arrison, Ken Barbour, Aimee, his wife, and I set out for Malvern, Pennsylvania, early Saturday morning March 1st. We arrived at Malvern Prep shortly after 8:00 A.M., impressed with the facility from outward appearances. With temperatures still in the mid twenties, the Malvern Prep boys' lacrosse team was practicing outside on their artificial, snow cleared, turf. When back home I asked a local lacrosse player what he knew about Malvern Prep lacrosse. "One of the best!" was his reply. Does this surprise us?

Paul Kelly (l) and Kiran Seoni, Henderson High School, winners of the Eastern Electric Vehicle Club (EEVC) "Ron Groening" Best Electric Car Award for Excellence in Engineering in the 2015 Physics Olympics and also Silver Medal Winners for performance in the Electric Car Pull in the 2015 Southeastern PA Physics Olympics League.

When we entered the gymnasium we discovered that our "early arrival" was not so early. Most of the eight to ten schools in the league were already present, and over 100 students were going about their event preparation. (As a side note, I always like to point out to the public that the teachers sponsoring the Olympics must be doing something right if dozens of students are participating on a freezing cold Saturday morning.)

For over twenty years, the Eastern Electric Vehicle Club has supported the electric car event by providing both judges and a special award. EEVC members attending this year's event to help out, in addition to those mentioned above, were Dan Monroe, his wife, Ann, their daughter Taley, and Carl Grunwald.

EEVC Over-all Best Electric Car in the 2015 Physics Olympics: The Ron Groening Award For Excellence in Engineering

Our job, before the electric car event actually begins, is to help the judges during the registration of cars. Each car entered into the event competition is inspected to see if it meets the legal requirements for that particular event. The car this year, as always, had size limitations as well as a specific required electric motor. No cars that we inspected exceeded the maximum length dimensions. All had the required small DC electric motor. The battery specifications as well as other requirements are listed in the attached rules' appendix at the end of this article.

Objective of the event

The objective of this year's electric car event was to drag a specific cardboard box (referred to as the sled) loaded with as many weights as possible, across a given distance on the gym floor in the smallest amount of time possible. The score was based upon mass dragged, percent of required distance traveled, and the time it took to complete the pull. The score went up as the mass dragged increased. It went up as the time for the pull went down. The winning team discovered that their scores could be maximized if they used a maximum weight limit. Exceeding this weight limit, although adding to the mass component of the score, slowed the car down sufficiently enough to actually lower the combined mass and time score.

After placement scores for each school and individual medal winners were determined, the EEVC judging team went to work selecting the car that would win the 2015 EEVC Over-All Best Car Award. Not all cars had the required EEVC emblem on their flag and body. Thus, disappointingly, a number of well-designed and crafted cars were ineligible.

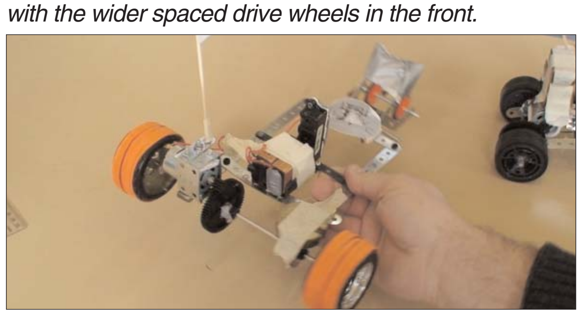
In choosing a winner our judges considered a number of points. Our selection had to finish in the upper one half of successful entries. The car should have a transmission gear ratio with sufficient torque to overcome both the starting friction and the inertia of the mass added to the sled. (However, the gear ratio had to also allow for speed as well as a minimum torque.) The car should be heavy enough to have good traction. And, the car had to travel in a straight line, a characteristic harder to accomplish than one might think.

As always our winning entry reflected creativity, above average craftsmanship, and durable construction. In addition it was well engineered. Our 2015 selection not only passed our requirements but also earned the silver medal for its second place performance.

Winners of the 2015 EEVC Ron Groening Engineering Award: Kiran Seoni & Paul Kelly from Henderson High School

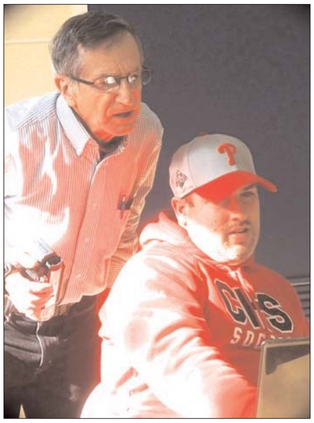
Frequently Physics Olympic projects, such as the electric car, are completed by several students working together. Both Kiran Seoni and Paul Kelly, sophomores from Henderson High School, were involved in this year's winning effort. We think that they are the youngest students to ever win our award (Past winners have been juniors and seniors). Neither of these two Henderson sophomores have taken physics. They are currently enrolled in chemistry and pre-calculus. Some Physics Olympic teams open up participation to younger science students in order to field a competitive team.

The rear of the car is where the small wheels are close together. The car is somewhat like a tricycle design with the wider spaced drive wheels in the front.



Two nine volt batteries and the switch on top of the motor box housing. Rubber bands on drive wheels for better traction.

Kiran informed me that it took approximately ten days for them to design, build, and



EEVC President Oliver Perry looks at the lap top scoring sheet with one of his former Cinnaminson High School A.P. Physics students and Physics Olympian, Kevin Merrill, currently the calculus instructor and head baseball coach for Cinnaminson High School. The P on his hat stands for Physics… or something like that.

test their car. Paul and Kiran received help from seniors on the team who understood electrical wiring. They were provided a set of gears to play with. They tried a few different gear ratios, eventually coming up with a winning combination. During their "sled pulling" trials they added weights over the front of their front wheel drive vehicle to provide more traction. The hook on their pulling vehicle was set to provide a maximum angle between the string connection and the sled. The string pulled at an upward angle on the sled helping to reduce sled friction and downward on an angle to the puller increasing its traction. Through experimentation they found out that the maximum score achievable (using the formula incorporating mass, length, and time) occurred when they pulled 500 grams.

Paul Kelly added in his interview, that had they begun their project earlier, the duo would not have had such a close call with almost failing to perform on "D Day." Their axle gear came loose the day before. In many cases students have difficulties keeping the gear on the output shaft of their motor when it has to remain in close contact with the drive gear on the output drive axle under load. The Henderson team's motor was not mounted as well as it could have been. Eventually the weight above it had to come off and the motor remounted with hot glue in a fast fix. It was a hasty repair but sufficient for the team to get at least one good run at Saturday's competition and finish second place.

Far too many students enter cars that are held together with duct tape, hot glue, and rubber bands. These "quick builds" frequently lack precision and durability. In a world of instant gratification with more to do in an hour than can possibly be done, maybe this is considered a sign of cleverness. In students' minds, "Good enough is good enough!" Sometimes it is.

Not surprisingly Kiran is an honor student. He has an interest in economics and applied math. Kiran plays varsity first doubles on the high school tennis team and also participates in a business club called FBLA.

As far as Kiran's future college plans are concerned, he listed the University of Texas, UCLA, and the University of Florida as schools of interest. At this time he seems to be more interested in economics and math than engineering and science.

Parents and family are most influential in determining the career path students take. Kiran' father, originally from India, is from Western Ontario. He is a Columbia University graduate and is president of a diverse pharmaceutical business. Kiran's mother is a speech therapist from LSU. Kiran also has an older brother who is a senior in high school.

Paul Kelly's dad is an accountant who received his education at Ursinus College. His mother is a psychologist who earned her degree from Widener. Paul has a sister who is a freshman in high school.

Outside of the classroom, Paul said he loves to fix his own computer and is involved in computer programming. For academic subject matter Paul prefers chemistry and physics above the others. When it comes to attending college in a few years, his dream right now is to attend RPI in Troy, New York. Penn State and Widener are also on his list of possibilities for pursuing an engineering major.

Congratulations to both Paul Kelly and Kiran Seoni of Henderson High School for winning the EEVC Ron Groening Engineering Achievement Award at the final meet of the 2015 Southeastern Pennsylvania Physics Olympics League. These two students are most worthy to win this award.

We would also like to honor their physics coach, Mr. Scott deLone. Outstanding student results do not often happen spontaneously without the inspiration, guidance, and advice of an involved instructor. Mr. deLone has done an excellent job in preparing his team for the Physics Olympics. His students won gold and silver medals in the electric car event as well as the EEVC award.

Henderson High School physics instructor Scott Delone and Olympic Physics team coach (front left) with his Physics Olympic team. The students are holding up their end of season team overall placement trophy.

More details regarding the Physics Olympics

Those of you who read our annual coverage of the EEVC electric car event, held at the Southeastern Pennsylvania Physics Olympic League's last meet of the year, are familiar with the format of the Southeastern Pennsylvania Physics Olympic League. The league hosts three competitive meets per year. Each meet is broken up into three categories: rotational events, a traditional physics problem-solving segment, and "build it - bring it to the meet" events. The electric car event is a "bring it to the meet" event.

The rotational events consist of timed competitive physics related activities set up for each high school team to cycle through on schedule. In a rotational event teams have approximately 15 minutes to complete a team task such as building a tower out of spaghetti sticks, flying a paper airplane the longest distance, solving for the focal length of a mirror, or making a catapult out of a bag of trash and flinging a hunk of clay. The highest tower, farthest flying plane, most accurate focal length, or furthest hunk of clay launch would be recorded for the "best" score and all teams ranked to that standard for placement. All of the guidelines for these rotational events are published in advance in order for teams to practice them before the meet. Each season new and modified rotational events are designed and implemented by the teachers of the participating schools.

Every meet also consists of two "pre-design and build it" events that must be completed beforehand and physically brought to the meet for competition. Mousetrap cars, egg drop devices, model basswood bridges, and model rubber band driven airplanes are several examples. The last meet of the season always features a model electric car that is designed to meet a particular requirement. Last year the car was designed to knock over soda bottles like a bowling ball knocks down pins. This year the objective for the electric car was to drag the most mass in the shortest time over a given distance on the gym floor.

Many of the Physics Olympics' events require judges who will supervise and accurately record the scores. Both teachers and parents are utilized for this purpose. It is important to note that without the large participation of parents, the Southeastern Pennsylvania Physics League would not be as successful as it has been. One of the larger groups of participating parents over the years have come from Penncrest High School.

Medal Winners

It is important to understand that all competitive events in the Physics Olympics are worth points. Points earned are credited to the overall team score and to team awards. In addition to having team point value, some events, such as the electric car event, carry individual Olympic medal recognition for individual performances.

(left to right) Tim Stavrakos, (Collin Vastine, not pictured), Radnor High School Bronze Medal : Kiran Seoni, & Paul Kelly, Henderson High School Silver Medal Yanick Cloarec, Robert Varney, & William Rich, Henderson High School Gold Medal, Medal winners for performance in the Southeastern PA Physics Olympics League 2015 Electric Car Pulling Event.

(left to right) Yanick Cloarec, Robert Varney, and William Rich Henderson High School, Gold Medal Winners for performance in the Electric Car Pull in the 2015 Southeastern PA Physics Olympic League.

Team Cup Award

A team award is also given for success in the electric car event. A trophy, which was provided many years ago by PSE&G (energy company in New Jersey), is passed on each year to the high school team that utilized the most electric cars in the event. Usually the electric car event is limited to about five cars per school. Each school may enter up to five cars, but they are also allowed to enter only their best car. If there are five heats in the competition they may enter the same car in all five heats or a different car in each heat, or some combination of available cars. A school that scored well in the five heats by using five different cars would be ranked higher towards winning the team cup than a school scoring higher using the same car in all five heats.

Marian Venturini, Electric Car Event coordinator and Physics Olympic Team advisor for Interboro High School.

Congratulations to the Interboro School System, the parents, the students, and their Olympic team coach Marian Venturini for becoming this year's "Team Cup Champion." We would like to especially recognize and thank Marian for coming up with the rules and regulations for this year's event, for posting these rules, and for supervising the event.

(left to right): Matt Cleaver, Kevin Karch, Kelvin Lu and Alyssa Evans, Interboro High School, winners of the PSE&G Team Cup for overall best "team" performance in the Electric Car Pull in the 2015 Physics Olympics.

The Mysterious PSE&G Team Cup

Usually the team cup is passed directly on to the winning team from the previous year's team winner. However, a problem popped up regarding the whereabouts of the cup. No one presently seems to know where the cup is. Checking our newsletter past articles I discovered that there was no mention of the cup in last year's report. I may have simply forgotten to include it in my article or possibly we didn't have a winning "team" award.

The following is a record of the PSE&G cup winners, according to EEVC Newsletter archives.

Winners

2010 Harrison High School…. a picture in our newsletter showed the Harriton team holding the cup.

2011 Penncrest High School ... article said that Harriton passed the cup to Penncrest at the meet… could have been a figure of speech.

2012 Penncrest High School …the last

school to supposedly have had the trophy in their possession.

2013 Harriton High School… the trophy was not brought to the event.. the Harriton students were pictured holding up an imaginary trophy. My guess is that they never did receive the real one.

2014 No posted winner in the Newsletter… is it because we didn't have a winner or is it because we lost track of the trophy? I can't remember whether or not we had a team cup winner last year in the electric car bowling event.

2015 Interboro High School…. A winner…looking for their cup.

Rules and Regulations Appendix

Electric Car 2015 Marian Venturini Interboro High School

Objective: Build a fast electric car that can pull the greatest mass for the longest distance (min 1 m, max 5 meters).

Number of Cars: Each school may enter up to five cars in this event.

Requirements:

- The car must use ONE official motor (Pitsco motor 385, www.pitsco.com/Motor_385) powered by ONE OR TWO standard 9-volt batteries.
- The car must be activated by a switch which is pressed at a RIGHT ANGLE to the direction of motion of the car to activate it.
- The car must be student-built and not from a kit.
- The car must have exactly two axles, with as many wheels on each axle as the student wishes, but only ONE axle may be powered by the motor.
- The car must have a hook securely affixed on the back, located 3 cm above the floor, for attaching a small sled containing student chosen masses.
- The car must have a 3 x 5-ich index card mounted such that it will break a laser-photogate beam 20 cm above the floor.
- The school name and student name(s) must be clearly written on the index card.
- The car must not fall apart in any way from when it starts to when it crosses the 3-m line.
- The car must operate autonomously once the switch is pressed, with no remote control of any kind.

Options

- Commercial parts including gears or belt systems may be used, up to two gears or two pulleys connected by one belt.
- Any wheels may be used, provided they will not mar the gymnasium floor. In other words, no studded tires, rough metal wheels, sandpaper, etc may be used for traction. Questionable tires will not be allowed on the track at all.
- Any axles and bearings may be used.
- Any hook-like item may be used as the hook.

The Race:

The track will be 2 meters wide and 5 meters long. There will be a starting box at the "start" end of the track, 2 m x 1 m. One sled, one 2-kg mass, two 1-kg mass and two 0.5 kg masses will be available at each track (two tracks will run simultaneously). Each vehicle must start within the starting box (anywhere), but the sled may start outside the starting box if desired. Competitors will have 1 minute to attach the sled, place masses in it and start their car once they are called to the start.

Each run will be timed by three timers using stopwatches and an average time (t) will be recorded. If a car stalls for 5 seconds before crossing the finish line, the time will be called (including the 5 seconds stall time) and the distance achieved (Dx) will be measured and used in the calculation.

Schools may run any number of cars, but each school will have a total of five runs. School names will be drawn randomly to determine the race order.

The Sled:

The sled will be a small corrugated-cardboard box (no more than 6 x 6 inches on the bottom) with an open top and with a loop of cotton string attached for pulling. The student will select as few or as many of the masses (m) provided and place them on the sled (of mass M). The string loop will be at a height of 3 cm above the floor, so the car will pull the sled horizontally when the hook is in the correct position. After a mass is pulled down the track, the bottom surface will be wiped free of dust with a dry rag before it may be used by another school.

Scoring:

Individual Score = ((m+M) Dx)/t

Team Score = Sum of the best 2 runs.

The school with the highest score will get 200 points, the school with the second highest score will get 190 points, etc. Any school with no qualifying runs (but with existing cars) will get last place minus 10 points. Any school with no cars will have zero points.

The Team Cup:

The Team Cup will be awarded to the school with five different competing (and finishing) cars with the fastest average speed. If no school has five qualifying cars, the Cup will be awarded to the school with four different competing (and finishing) cars with the fastest average speed.

The EEVC Best Overall Electric Car-Ron Groening Outstanding Engineering Award

EEVC members will award a plaque to the student or students featuring a car that (a) exemplifies high standards of engineering and craftsmanship and (b) is entered in the EEVC competition and (c) completes the competition in the fastest half of the qualifying runs. To enter the EEVC competition, the EEVC logo must be visible on the body of the car as well as the flag.

LITHIUM WITHOUT BMS
Gregg Witmer

A group of twenty lithium cells being lowered into the Saturn's rear battery box with an engine crane..

Back in December of 2010, I received three crates of brand new China Aviation Lithium Battery Co. (CALB) 100 Ah Lithium batteries for my electric Saturn. The form factor of the new batteries made short work of replacing fourteen 12 volt lead acid batteries with sixty-five 3.2 V CALB batteries in mostly unmodified battery boxes — a blessing considering the time and money that went into designing and building the original battery boxes for the lead acid batteries.

I installed the 65 CALB batteries and a new charger, reconfigured the motor controller, rewired the DC/DC converter, made some other minor adjustments and hit the road with improved performance, better handling and a range of over 80 miles, better than four times the range of the lead acid batteries.

What I didn't realize at the time was that I had stepped into the proverbial "nest of bees" by not installing a battery monitoring or battery management system (BMS) with the new lithium battery pack. By "nest of bees" I mean that opinions relating to BMSs were (and still are) quite strong with the majority falling on the side of having a BMS.

Personally, I was skeptical of the BMS requirement. It seemed to me that a properly top-balanced battery pack with cells identical in capacity, quality and age would stay balanced provided they were not allowed to be overcharged or over-discharged. Since all of the cells are connected in series, any amp-hours pushed into the pack would be identical to the amp-hours pushed into each cell. Likewise, the amp-hours drawn from the pack would be the same amp-hours drawn from each cell. In other words, in a series circuit, each cell will be subjected to the same charge and discharge current as the entire pack.

I also passed on the BMS because, at the time, I wasn't really sure what a battery management system was or what it was going to do for (or to) my pack. I didn't want to put something into my EV that I didn't entirely understand. For example, what the heck is "shunting"? By installing my pack BMS-free, I had hoped to learn what, if anything, is to be expected from a BMS. For me, the EV building experience has been about trying new and unique ideas and sometimes going against the status quo — as if building an electric car is not already in that category.

It is for the above reasons that I write this with considerable humility.

The BMS-free pack

Since there's no practical way to measure the individual voltage of each cell, I came up with a primitive method for checking if the overall pack was in balance. The pack of sixty-five cells was broken into five banks of thirteen cells; a small wire is run from the first battery in each bank to a central location where the voltage of each bank can quickly be measured with a voltmeter. Regardless of the pack's state of charge, each bank must have the same voltage. If the voltage difference between banks is off by more than a few tenths of a volt then there's cause for concern because this would indicate a cell in that bank is at a different voltage than the other cells.

Also, to check battery pack health the energy efficiency in kilowatt hours per mile (kWh/mi) is calculated after each charge. kWh/mi is determined by using a dedicated electric meter to measure the energy required for the charge in kWh and the vehicle's odometer for miles driven. The kWh required to charge the pack is divided by the miles driven. This is how it's done at 21CAC and is not to be confused with any kind of kWh/mi reading provided by your vehicle while driving. If the kWh/mi starts to read too high (an inefficiency), then the pack is not charging properly and most likely something is getting hot. If the kWh/mi is reading too low, then either the pack is not getting charged or the readings are incorrect.

In spite of the advice and insistence of several very respected members of the EEVC, I've gone BMS-free for four years and several thousand miles. Back in 2010, I spoke at an EEVC meeting about top-balancing and going BMS-free and promised the group a report on what I learned from the experience.

Here's what I've learned

My electric Saturn should have a battery management system.

The pack has been gradually going out of balance. What does that mean and how do I know? The most obvious symptom: Near the end of or after charging, the voltage difference between the five banks is growing because some cells are reaching 100% state-of-charge before other cells. The voltage difference between the cells that reach full charge and the others gets a little bigger with each charge. This difference in bank voltage can only be observed with a voltmeter when some of the cells in the pack have become fully charged. If the pack is at less than 90% state-of-charge each of the five banks will have the same voltage down to one tenth of a volt and the pack will appear to be in balance. The five banks appear to be in balance because of the very flat charge/discharge curve of lithium based batteries.

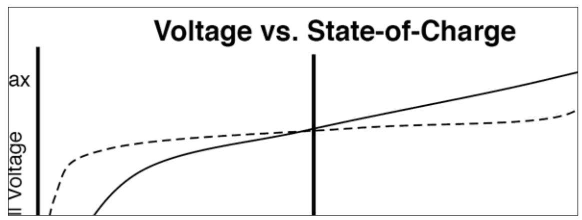


Illustration of charge/discharge curves between lithium and lead acid batteries. Notice the nearly horizontal curve of the lithium chemistry in contrast to the slope of the lead-acid.]

The five-bank monitoring system will not help locate which specific cells are at a higher voltage (there are thirteen cells in a bank), also I can only read the battery voltages when the car is at rest and I'm standing there with a voltmeter under the hood. More than half of the cells are mounted in places where it's not possible to measure their voltage individually.

While driving the car I have no way to know if some cells are sagging to a lower voltage than others — especially when accelerating. While I didn't like the idea of putting an unknown (the BMS) into my system. I really don't like not being able to monitor what's going on in the pack.

At this point, my only remedy is to dial down the charger's maximum voltage setting every month or so in an attempt to not cause damage to the cells that are reaching 100% state-of-charge before the others. Over-charging a cell can cause the cell to be permanently damaged due to overheating. The problem with the dial-down approach is that, as time goes on, some cells will never be fully charged and are more likely to become over-discharged. Discharging a lithium battery beyond its minimum discharge voltage can permanently damage the cell.

This 'dialing' down of the maximum charging voltage (without any active rebalancing of cells) is similar to what a battery monitoring system would do. My method is just less precise. Active battery management would be a system that attempts to top-balance the pack by reducing the charging current to the entire pack while also bypassing some of the current to cells that are reaching a full state of charge early, thus allowing for the other cells to catch up.

I can only speculate as to why the pack is out out balance: improper top-balancing, poor quality control at the manufacturer or maybe the smell of electrolyte during heavy regenerative braking is an indication of damaged or compromised cells. It doesn't really matter, the pack is out of balance and to what degree I can't really be sure.

What should a BMS look like?

A BMS would have two major components: a small "cell monitoring" circuit for each cell and one "master" controller tied to each of the cell monitors. Each of the cell monitors would report cell voltage and temperature to the master circuit. The master would be connected to the charger, the motor controller, some indicators on the vehicle's instrument panel, and optionally to a portable computer for detailed pack monitoring. While the cell monitors could be embedded in the same enclosure as the master, it would be preferable to have the cell monitors in the form of a small board mounted close to its respective cell to provide better temperature and voltage measurement.

What should a battery monitoring system do?

1. Monitor the voltage and temperature of each cell and report it back to the master controller.
2. Allow a laptop or tablet computer to be connected to the master controller for detailed monitoring of cell voltage and temperature.
3. Alert the driver and signal the motor controller as soon as any cell voltage drops below a predetermined threshold. The controller would reduce power or shut down completely, depending of the severity of the voltage drop.
4. Alert the driver to an overheating cell and possibly shut down the motor controller to reduce power or shut down.
5. Signal the charger to reduce the charging current or stop charging if any cell gets too hot.
6. When charging, send a signal to the charger to reduce the charging current or to stop charging as soon as one cell reaches 100% state-of-charge.

What should a battery management system do?

1. All of the above monitoring functions.
2. Perform active battery management (cell balancing) while charging. Bypass the cells that reach 100% state-of-charge early. This would be done by switching a shunting resistor across the cell terminals which in turn dissipates the charging current to the fully charged cell as heat rather than over-charging the cell. Over time active battery management would bring the pack back to being top-balanced and keep it top-balanced allowing the pack to utilize its full capacity.

EEVC club member Alan Arrison, was kind enough to review this article and also had some additional comments regarding his experience with a BMS. Here is what Alan had to say:

"It's easy to understand why a pack starts to deviate when you consider all the uncontrolled parameters like capacity, temperature, internal resistance, etc.

"As I have seen with my BMS, when a cell reaches full while charging, its voltage can quickly shoot up above 3.6 volts while the rest of the cells are at 3.4. On the other end, a cell can reach empty and its voltage drop like a rock while the rest of the pack is still above 3.2 volts per cell.

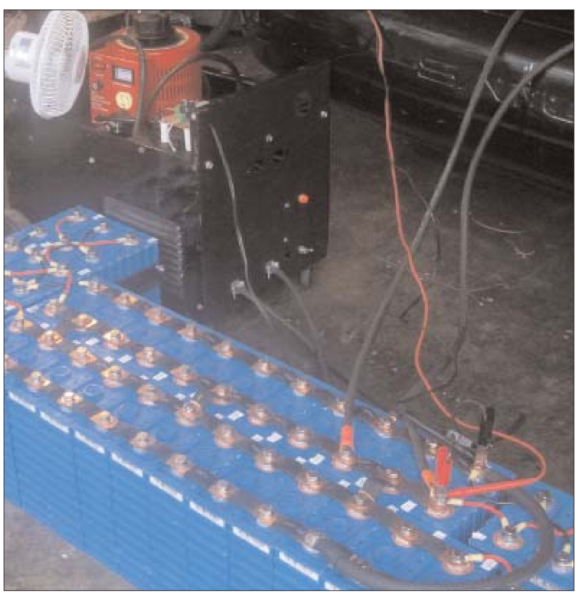
"Unfortunately, a battery pack is always limited by its lowest capacity cell. As much as I wanted to build my own BMS, I didn't have enough time and I had to get my truck finished. I am happy with the Elithion system and the Orion system looks good too. [Other club members] use the MiniBMS which I haven't investigated."

My remaining reservation about a battery management system is that a failure in the monitoring or shunting circuity could cause a cell to be fully discharged or overheated, damaging the cell it was intended to protect. Reservations aside, my Saturn's lithium battery pack needs the "insurance policy" of a BMS if I am going to continue to drive it. I know there are several BMSs available today and have just begun to explore the options.

Li battery characteristics

The charge/discharge curve of a lithium battery is nearly horizontal between 10% and 90% state-of-charge. This makes it impossible to determine a lithium battery's state of charge with a voltage reading. The only state-of-charge that can be measured with certainty is 100%. This voltage is dependent on the battery chemistry and is specified by the battery manufacturer. CALB $LiFePO_4$ specifies 3.65 V as the maximum charging voltage.

Top-balancing a battery pack requires all of the cells be charged to the maximum charging voltage and held at that voltage for a period of time. If a pack of batteries is top-balanced, all of the cells are fully charged to 100% state-of-charge. I've posted a twelve minute video "High Current Low Voltage Battery Charger" on my youtube channel "zugletev" about top-balancing sixty-five lithium cells. This is a delicate process done with a sledge hammer.



Top-balancing the lithium battery pack with a mig-welder, wait…what? Well, checkout the video.

Once a pack's state of charge is 100%, a more advanced EV is able to estimate the state of charge by tracking the amount of current discharged from the pack. A less advanced system, like mine, would use miles driven to estimate the amount of discharge. I did mention my system was primitive.

About partial charging

An interesting lesson learned when charging the pack to 95% state-of-charge rather than the full 100%: Obviously the range decreased. However, the efficiency increased dramatically from 330 kWh/mi down to just below 300 kWh/mi. This is a "wall-to-wheel" calculation using a dedicated electric meter and the vehicle's odometer.

I attribute this change in efficiency to the extra energy required to take a lithium cell from 95% to 100%. The last 5% of charging — the 'elbow' of the charging curve — requires more energy and is lost in the form of heat in both the cells and the charger.

ARE YOU READY FOR THE 21ST CAC?

The 2015 21st Century Automotive Challenge will be held May 1-3 in State College, PA. The schedule is as follows (courtesy
Dr. Joel Anstrom)

FREE PRE-INSPECTION SCHEDULE AND LOCATIONS

EAST: WEDNESDAY, 7 PM, April 8 - Pre-inspection Eastern Electric Vehicle Club, Plymouth Meeting, Pa

WEST: SATURDAY, 5 PM, April 18 - Pre-inspection Three Rivers EVA, Murrysville, Pa

CENTRAL: WEDNESDAY, 3 PM, April 22 - Pre-inspection Penn College, Williamsport, Pa

THURSDAY, APRIL 30 - 21ST CAC TECH/DYNAMIC EVENTS (OPTIONAL IF PRE-INSPECTED)

8:00-4:00 Registration, Tech Inspection, and Dynamic Events at CPI Auto Tech Facility

12:00-1:00 Picnic Lunch with orientation

4:00-6:00 Dinner on your own

6:00-9:00 Pit work and charging setup at CPI

FRIDAY, May 1 - 21ST CAC TECH/DYNAMIC and RANGE EVENTS

8:00-11:30 Registration, Tech Inspection, and Dynamic Events at CPI Auto Tech Facil-

ity
8:00-11:30 Liquid and gaseous refueling, charging for Range Events
10:30-11:30 Energy Storage Research Poster Session by Penn State GATE Students
11:00 Team Range Event "flight plans" due
11:30-12:30 Clems BBQ lunch with competition orientation
12:30 Start Highway Range Event laps on I99
12:30-3:30 21st CAC Tech Inspection and Dynamic Events completed
4:00 Start Local Range Event with Rally One from CPI to staging on LTI Test Track
4:30-5:30 Picnic dinner at LTI Test Track (take-outs saved for highway range competitors)
5:30~10:30 On-track Local Range Event begins, Highway Range Event conclusion
8:30-12:00 Pit work and charging setup at LTI Test Track
10:30-6:00 Charging
SATURDAY, May 2 - 21ST CAC LIFESTYLE EFFICIENCY, DISPLAY, and UTILITY EVENTS
6:00-7:00 Charger readings, liquid and gaseous refueling
6:30-7:30 Continental Breakfast - Drivers Meeting
7:30 Start Lifestyle Efficiency Event with Rally Two from Track to MorningStar home
7:30-12:00 AM Local Route around Penn State with extra track laps
7:30-12:00 Display, Charging, Cargo, and Tailgating Competitions at MorningStar home
10:00-4:00 Public Display, Sponsor Exposition and MorningStar Home Orientations
12:00-1:00 Picnic lunch
1:00-4:00 Display, Charging, Cargo, and Tailgating Competitions continue at MorningStar home
1:00-7:00 PM Local Route around Penn State with track laps, Tour de Thor Scenic Highway Route
7:00-8:00 Dinner on your own or group walk to the Penn State Creamery
8:00-9:00 Scoring Wrap-up Meeting and Rally Three from MorningStar LTI Test Track
9:00-12:00 Pit work and charging setup at LTI Test Track
9:00-6:00 Charging
SUNDAY, May 3 - 21ST CAC Autocross Performance and Preliminary Award Events
6:00-7:00 Charger readings, liquid and gaseous refueling
7:00-8:00 Continental Breakfast at Test Track
8:00-10:00 Autocross tech inspection and course setup
10:00-1:00 Drivers meeting and Autocross Performance Event at LTI Test Track
1:00-3:00 Picnic lunch and Preliminary Awards Event at Test Track
3:00 Depart Test Track
WEDNESDAY, June 10th , 7 PM - FINAL RESULTS ANNOUNCED AT EEVC MEETING WITH SKYPE LINK
SATURDAY, June 20th, 5 PM - AWARD PRESENTATIONS AT THREE RIVERS EVA MEETING
Contact: 21st CAC Director, Dr. Joel Anstrom jra2@psu.edu
http://www.larson.psu.edu/21st%20CAC

NEWS UPDATE

Tesla in the news

The news stories abut Tesla just keep coming, from a “magical” range increase for the Model S to rumors of a sale.

On the range extension matter, on March 15 David Golman of *CNN Money* reported on a tweet from Elon Musk that he would soon (March 19) reveal a significant range extension for the Model S fleet. Musk didn’t say by how much, but it could be significant. And owners would not have to do anything, the increase would be done via an automatic software download, as had the earlier upgrade that had increased the Roadster’s range from 245 miles to close to 400. Then the news came out: the software update would help reduce range anxiety by informing the driver of how many miles remained, and giving the locations of charging points on the way to a stated destination. If the driver planned to drive beyond the available range the software would scold him or her.

Elon Musk has announced that the new

home battery from Tesla would enable more people to go completely off the grid, according to a recent piece in *offgridquest.com*." Based on Tesla's lithium-ion battery technology, the new battery is expected to help the company become a leader in the growing home energy-storage market," the article says. "Speaking during an earnings conference call on Wednesday, Musk said that the design of the battery is complete, and production would begin in about six months. Although the company did not provide any date for the product's launch, Musk said that he was pleased with the result."

The question then becomes, if lots of people leave the grid, who will pay to maintain it? As Ken Barbour points out, in Florida it is illegal to have a home that is not connected to the grid. Perhaps it will become taxpayer-supported.

In the world's hottest car market Tesla has discovered that perceptions matter, according to an article in *IMPO* by Maura Falk. The company had hoped to sell 5000 cars in a year, but had sold fewer than 2500, driven, says the article, to a large extent by misconceptions about charging locations. Tesla is responding by building more charging stations; it is also laying off somewhere between 180 and 600 employees in China.

Another bit of bad news comes from Toyota, which is recalling its RAV4 EVs with Tesla technology, according to a Bloomberg story by Mark Trudell. It seems that a software glitch is causing the cars to suddenly shift into neutral while driving.

There are reports that some Apple shareholders would like the company to buy Tesla, but neither company has commented on that, to our knowledge, while business writers have listed multiple reasons for not doing it. We kind of doubt it, too. Who would expect Musk to sell his baby?

Cleaning up fracking water

One of the charges leveled at hydraulic fracking is that it produces large quantities of badly contaminated water that unscrupulous operators dispose of in inappropriate ways — like dumping it into nearby rivers. But now a team of researchers at the University of Colorado at Boulder have come up with a way to clean up that brine so it can be re-used, rather than dumped. The new technique, according to UC, "can simultaneously remove both salts and organic contaminants from the wastewater, all while producing additional energy. The new technique, which relies on a microbe-powered battery, was recently published in the journal *Environmental Science Water Research & Technology* as the cover story." Microbes digest the hydrocarbons in the brine and create electricity to desalinate it, which could be a real boon if it can be made practical. For more, see www.colorado.edu/news/releases/2015/02/24/cu-boulder-technology-could-make-treatment-and-reuse-oil-and-gas-wastewater.

Japanese utilities resist more solar

A March 3 *New York Times* article by Jonathan Soble reported that the growth of solar generating capacity in Japan has been put in doubt by resistance from the electric utilities. The electric companies claim that they are not capable of handling all the power that solar can provide, and, the article goes on, much of that is due to failure to prepare. "Like other countries that have promoted the technology with generous state support, Japan is also struggling with the financial and technical consequences of its rapid solar growth. Solar power here is costly for consumers because of high state-mandated prices, and handling the fluctuating output of thousands of mostly small solar producers is tricky for utilities. Necessary improvements in the infrastructure have not kept pace, experts say."

Since the alternatives are either run more fossil fuel-powered plans or the reactivate the nuclear plants shut down all over the country after the Fukushima-Daiichi meltdown, the country had better get moving.

SolarCity sues Arizona

Difficulties getting solar implemented are not confined to Japan. According to a March 3 Reuters article, SolarCity Corp is suing "Arizona utility Salt River Project over new electricity rates that the U.S. solar installer said penalizes residential customers who choose to put up solar panels.

"The action is the latest in a protracted battle between rooftop solar companies and Arizona utilities over how traditional power providers will preserve revenue as larger numbers of customers go solar and pay less to their local utilities.

"The lawsuit, filed in Arizona federal court, accuses the utility of violating antitrust laws, saying SRP is trying to 'destroy the competitive threat' from solar installers.

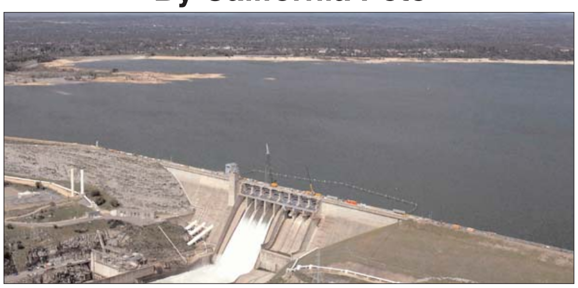
"Applications for rooftop solar have fallen 96 percent in SRP's service territory since Dec. 8, the date SRP's new plan went into effect, SolarCity said."

New material to capture carbon?

UC Berkeley reported on March 11 that the university's chemists have developed a material that can efficiently remove carbon from the ambient air of a submarine as readily as from the polluted emissions of a coal-fired power plant.

The material then releases the carbon dioxide at lower temperatures than current carbon-capture materials, potentially cutting by half or more the energy currently consumed in the process. The released CO2 can then be injected underground, a technique called sequestering, or, in the case of a submarine, expelled into the sea.

MORE WATER WOES IN CA
By California Pete



From Technology.org: The severity of California's drought is visible at Folsom Lake, near Sacramento. On July 20, 2011, the lake was at 97 percent of capacity; on Jan. 16, 2014, it was at 17 percent. NASA and California are collaborating to use NASA Earth observation assets to manage and respond to the drought. Image Credit: California Department of Water Resources.

It's not news that California is suffering a severe drought (or rather, much of the state is now listed as in "Exceptional" drought, as things get progressively worse).

The federal government has cut off water deliveries to San Joaquin Valley farms, and cut back urban areas to just 25 percent of normal. The Sierra snowpack, which provides water to the entire state once the winter rains have stopped, is at less than 20 percent of normal. The State Water Project is also cutting back. There is talk of fines of up to $500 for people who violate water-use restrictions, including watering lawns more often than twice a week, allowing restaurants to provide water at table only if requested, spraying down sidewalks and driveways, washing cars without a shutoff nozzle on a hose, and using drinking water in ornamental fountains.

NASA scientist Jay Famiglietti, in an oped piece in the *Los Angeles Times* for March 12, wrote that the state has only one year's worth of water left in storage. In his words, "it is clear that the paltry rain and snowfall have done almost nothing to alleviate epic drought conditions. January was the driest in California since record-keeping began in 1895. Groundwater and snowpack levels are at all-time lows. We're not just up a creek without a paddle in California, we're losing the creek too."

The reality is just beginning to dawn on people: this may be the new normal. While there will doubtless be wetter years on the future, the trend is clear: Northern California will become Arizona. What will happen to the original Arizona, as well as New Mexico and Southern California, looks pretty grim.

So, folks in the East: complain about the snow all you like, but how about gathering the stuff up and shipping it our way? We could sure use it.

Adding insult to injury

As mentioned, fracking causes a lot of water problems, and there is indeed fracking going on in California, but another scandal related to water and oil recently surfaced. It seems that much of the oil produced by conventional oil wells in the state consists of less than half oil, the rest being water. This "produced water" is generally salty and contaminated with hydrocarbons. The problem, as far as the oil companies are concerned, is what to do with it, and the answer for the past 30 years has been to pump it back into the earth. Unfortunately, many (171, actually) of the injection wells used for the purpose come close to aquifers carrying water that is, or could be, used for drinking. There are supposed to be strict limits on where the injection wells are placed, but the bureaucracies involved have allowed many to go ahead regardless.

The state recently required a bunch of these wells shut down, but the damage is probably already done, and remediating contaminated groundwater is difficult and expensive.

Perhaps the oil guys should check out that UC research.

California last nuke stays in the news

The Diableo Canyon facility, the last operating nuclear power plant in the state, is safe as can be, according to PG&E. This comes on the heels of two articles by David Baker in the *San Francisco Chronicle*. The first, on March 7, said that "Pacific Gas and Electric Co. replaced $842 million of equipment at the heart of the Diablo Canyon nuclear plant without first making sure the new gear could pass a vital seismic safety test required in the facility's license, *The Chronicle* has learned."

Then on March 12: "California's last remaining nuclear plant, Diablo Canyon, can withstand a major earthquake striking on multiple nearby faults at once, according to a report Pacific Gas and Electric Co. filed with federal regulators Thursday." Well I certainly feel better.

COMING EVENTS

Rally at the Raceway
March 26, Richmond International Raceway. Go to www.vacleancities.org/events/?regevent_action=register&event_id=175&name_of_event=2015%20Rally%20at%20the%20Raceway

Rush X Tesla Experience and Expo
April 3-4, 2015 - Long Beach, CA. Go to http://rushx.org/

SAE 2015 World Congress & Exhibition
April 21-23, Detroit. www.sae.org/ congress

21st Century Automtive Challenge (21st CAC)
May 1-3, State College, PA. Go to www.eevc.info/2015-21st-century-automotive-challenge.html

EVS28 — The 28th International Electric Vehicle Symposium and Exhibition
May 3-6, Goyang, Korea. Go to www.evs28.org/

The WAVE – World Advanced Vehicle Expedition electric vehicle rally
June 13-21, from eastern Germany into the Alps. Go to http://www.wavetrophy.com/en/

EV Fest 2015
June 14, Flamborough (Hamilton), Ontario. Go to www.evfest.ca

2015 World Solar Challenge
October 6-13, Australia. Go to www.worldsolarchallenge.org

The 3rd Annual China Electric Vehicle Infrastructure Summit 2015
March 26-27, Shanghai, PRC. For information go to www.eco-business.com/events/the-3rd-annual-china-electric-vehicle-infrastructure-summit-2015/

2015 Electric & Hybrid Vehicle Technology Expo
Sept 15-17, Novi, MI. Go to www.evtechexpo.com/

The Battery Show (colocated with the event above).
Go to www.thebatteryshow.com/exhibition/about-the-battery-show

Engine Expo 2015 (with an electric and hybrid pavilion).
Oct. 20-22, Novi, MI. Go to www.engine-expo.com/usa/pavilion.php

MEETING SCHEDULE

Meetings are held in Room 49, Plymouth-Whitemarsh High School, 201 East Germantown Pike in Plymouth Meeting, PA, and begin at 7:00 p.m.

April 8

May 13

June 10

July 8

August 12