Idaho Incubation Fund Program

2nd Quarterly Progress Report Form

Proposal No.	**IF12-014**
Name:	**Dr. Dean B. Edwards**
Name of Institution:	**University of Idaho**
Project Title:	**A High Performance, Horizontal Plate Battery for Plug-in Hybrid Electric Vehicles (PHEVs)**

Information to be reported in your progress report is as follows:

1. Provide a summary of project goals/milestones for the period just completed, accomplishments for the period just completed, and plans and goals for the coming quarter:

   Although this is the 2nd Quarterly Report, we only started working on this project in September. Because an agreement between the University of Idaho and the State Board of Education (SBOE) had lapsed in January 2011, the funding for this project was delayed two months so that this report only represents about four months of work. The costs shown under the budget summary therefore only represents about a quarter of the total amount of the project funds (i.e. about $10.7k out of $44k).

   The schedule for the project is shown below. As per the schedule, we have been working on all the Tasks except Task 4 which has been delayed until the graphene coating is further evaluated. A summary for each of these tasks is provided below:

   Task 1. Fabrication of Horizontal Plate Test Chamber (HPTC)
   We started work on this task in September, 2011. A number of design modifications were made to the HPTC and these were fabricated and evaluated. However, we found some water-proof polypropylene containers that we could buy and modify for use as the test chamber. These containers cost about $5.00 each and can be modified for our tests. We have fabricated four horizontal test cells with these commercial, off-the-shelf containers and are presently testing cells in them.quarter. (See Appendix A for more information)

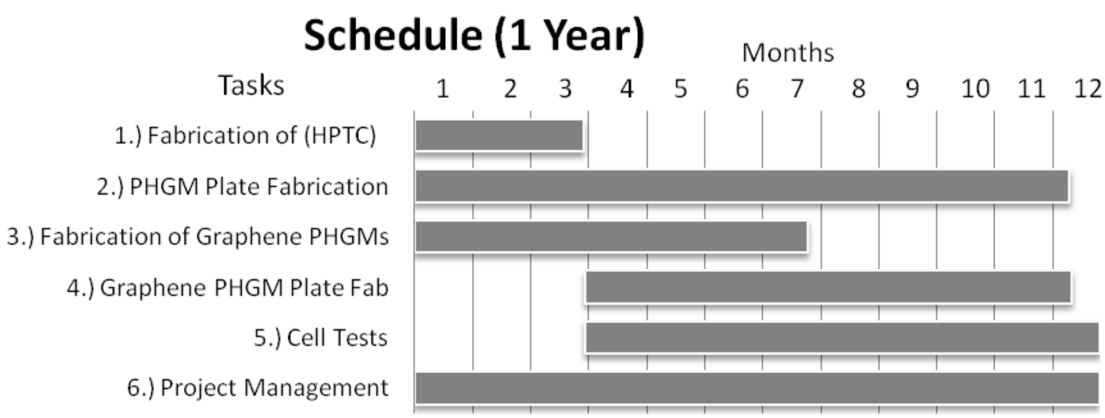
   Task 2. Porous Hollow Glass Microsphere (PHGM) Plate Fabrication
   This quarter, we fabricated more of the PHGMs required for this work from hollow glass microspheres (HGMs) that are a 3M product called S-38. After they have been treated to produce wall porosity, we refer to them as S-38 PHGMs. In addition to fabricating the PHGMs, we are also modeling these additives in order to better understand how they can be used to increase plate porosity. This quarter, we have performed extensive modeling work and are developing a good understanding on how these additives can improve the high rate performance of horizontal plate, lead acid batteries.

Task 3. Fabrication of Graphene Coated PHGMs
We are continuing to work on coating graphene on HGMs, glass fibers, and diatoms. Although the graphene can be coated on these additives and appear to be stable even in the positive plate, the active material does not adhere well to the graphene. We are investigating methods for improving this adherence.

Task 4. Graphene Coated PHGM Plate Fabrication
No work performed on this task (i.e. see schedule).

Task 5. Cell Tests
Some initial cell tests were performed for this task and presently we have six cells being tested.

Task 6. Project Management
We are holding weekly project meetings and have started work on five of the six tasks.



2. Provide a summary of budget expenditures for the period just completed:

Although this is the 2nd Quarterly Report, the funding for this project was delayed two months and so our costs only reflect the cost for about four months. We are almost fully staffed for this work so the amount is closer to the burn rate we expect for the next semester. As shown below, our total costs as of December 22, 2011 was $10,737.88.

Organization: FB2135 SBOE Horizontal Plate Battery

Account	Title	Adjusted Budget	YTD Activity	Encumbrances	Available Balance
01	Salaries	21,979.00	5,465.62	0.00	16,513.38
02	Fringe Benefits	6,894.00	2,093.94	0.00	4,800.06

03	Irregular Help	6,900.00	2,106.50	0.00	4,793.50
05	Other Expense	4,175.00	1,071.82	0.00	3,103.18
10	Trustee/Benefits	4,052.00	0.00	0.00	4,052.00
	TOTALS:	44,000.00	10,737.88	0.00	33,262.12

3. List patents, copyrights, plant variety protection certificates received or pending:

4. List invention disclosures, patent, copyright and PVP applications filed, technology licenses/options signed, start-up businesses created, and industry involvement:

   A PCT/US2010/044269 titled "Method for Making Graphene" was filed 08/03/2010 and is some of the existing technology being used under this Gap funded project.

5. Include funding burn rate:

   The present burn rate is about $3000/month but work on the project was delayed and the project is not fully staffed. We anticipate the burn rate will be about $4k per month.

6. Any other pertinent information:

   Additional details on the work completed are provided in Appendix A that is shown below.

Appendix A

In this appendix we provide additional details on the work being performed in our project, "A High Performance, Horizontal Plate Battery for Plug-in, Hybrid Electric Vehicles (PHEVs)." This additional explanation is provided below according to the task for which it was performed.

Fabrication of Horizontal Plate Test Containers (HPTC)
Progress to date:

<u>Cases</u>

The original HPTC, shown in Figure 1, with cast lead terminals and a machined case have been replaced with a water and air-tight polypropylene container, shown in Figure 2. Electrical connections into the HPTC are made via a terminal that allows an o-ring to be included in the assembly. The new cases are vented to prevent over pressure and not allow air to reenter the cell which can discharge the negative plate in non-flooded lead acid battery systems.

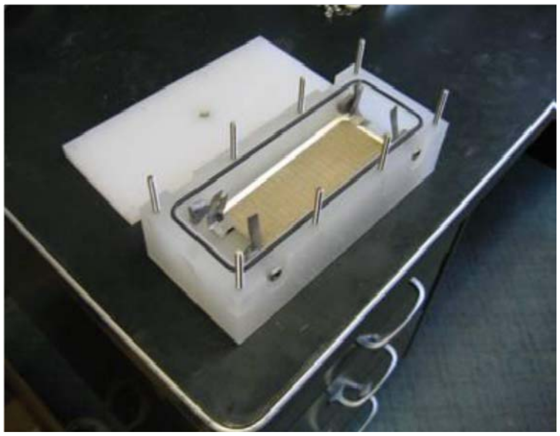


Figure 1 HPTC with glue-in terminals

Figure 2 New HPTC containers

Terminals

The first series of the new HPTC used a threaded cast lead terminal. The threaded section allows the terminal to be secured to the HPTC and provides compression to the o-ring. It also allows for quick and easy replacement of the terminal should it require replacement if it becomes corroded or otherwise damaged.

Our original design called for a stainless steel screw to attach the lead strip from the cell stack tab to the terminal. However, it was found the screws could not withstand the galvanic corrosion present on the positive side of the circuit. This problem was overcome by replacing the stainless steel screw connection with a spot weld. While this method has produced a terminal with satisfactory performance it is difficult to produce good threads in the soft lead. In addition, the use of a spot weld makes it difficult to reuse the terminal in cell construction.   We are currently testing a brass screw with a cast lead cap. This method minimizes the required labor and the lead cap is the only part exposed to the electrolyte inside the cell. In addition, brass is an excellent conductor and should help to minimize resistive electrical losses during high current tests.

Cell Stack Design

The cell stack to be used for cycling positive plates in the HPTC will consist of 3 negative plates and two positive plates. Two layers of .035" glass mat separators will be used on each side of the negative plates for a total of six layers. With 3-5 psi of compression the mat is expected to have ~20% compression for a total separator thickness of .056". The thickness of the individual components and the total cell stack height is shown in the following table.

Item	Thickness	#	Totals
Negative Plate	.043"	3	.129"
Positive Plate	.063"	2	.126
Separator	.056"	6	.336
Total cell stack height .591"			

A trial cell stack using grids and the separator material was assembled and the spot welding techniques investigated. The method that produced the best results used lead strips between the plates with the spot welder to form a strap for connecting the individual plates together. This method helps maintain proper spacing on the grid tabs thus preventing excess deformation that would occur without the lead strips.

Cell Stack Compression

Cell stack compression is accomplished by sandwiching the cell stack between two sheets of .022" thick polycarbonate sheets. Once the appropriate compression (3-5 psi) is applied to the cell stack a series of polypropylene zip ties are used to maintain the compression, as can be seen in Figure 2. This method has the advantage of rigidly holding the cell stack assembly together even when it is not in the HPTC which aids in stack assembly, spot welding, and making the connection to the terminals in the HPTC.

Arbin Servicing and Repair

The Arbin battery testing stations were serviced and repaired in October. Servicing included cleaning the air filters, performing a calibration of all 16 channels and a general cleaning and inspection. A replacement 4 pin header was successfully soldered onto one of the boards that showed signs of corrosion.

Modelling of Battery Cells with Porous and Non-porous Additives.
Progress to date:

We have worked on modeling the discharge of various battery types. Figure 3 shows the discharge curves of three batteries that were tested and modeled at the University of Idaho. The blue curves are for a standard battery test cell with no additives. The dark green curves are for a battery test cell with about 15% porous additives that were created at the University of Idaho. The red curves are for a battery test cell with around 37% porous additives that were acquired from SRNL. The dots represent the discharge data and the solid lines are the modeled discharges in all cases. There are four discharge currents shown on the figure for each battery type approximating the 1hr, 2hr and 4hr rates as well as a 10 A discharge. The black curves represent the 37% additive mix as if the additives were not porous. We see that the test data for the 37% mix does not perform as well as the model suggests; however, it does outperform non porous additives.

The parameters that were changed in order to model the three batteries are tabulated in the following table. The critical volume fraction is the percentage of the active material that we expect to be utilized on a very slow discharge. As non conductive additives are introduced into the paste mix, the critical volume fraction declines, and we see this in the tabulated parameters. The porosity is the fraction of the active material volume that

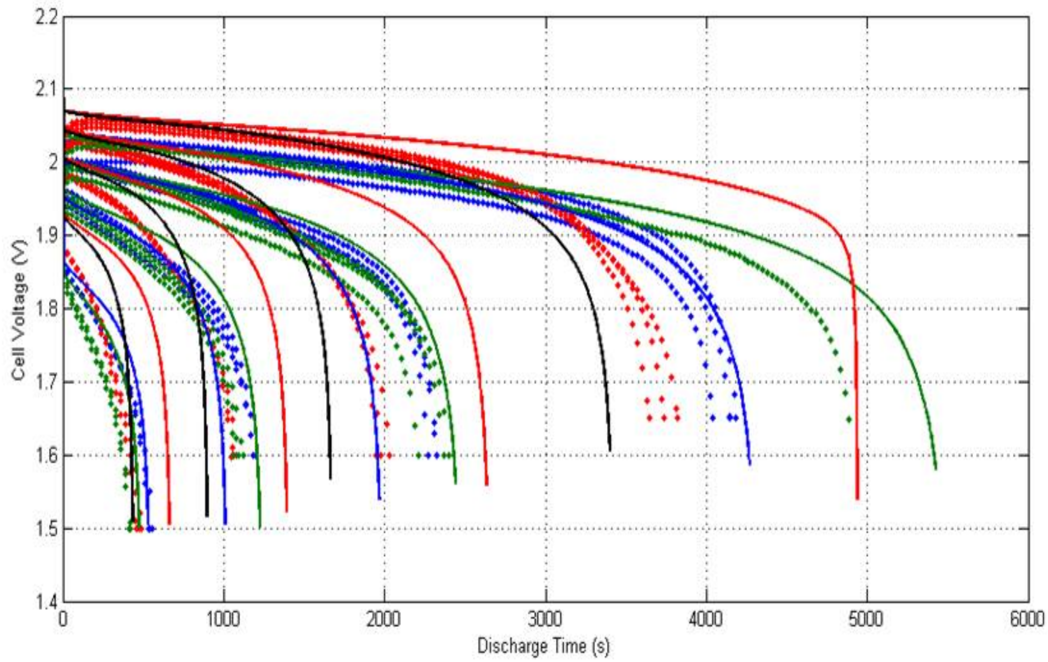


Figure 3 Discharge Curves for 3 batteries, test and model data.

can be occupied by electrolyte. Porous additives displace active material with a porous structure, and we see that the porosity increases while the active mass decreases. This produces lighter batteries with more electrolyte stored in the active material where it is needed for high rate discharges. The initial acid concentration was also changed in order to fit the initial voltage conditions.

	Critical Volume Fraction	Porosity	Active Mass (g)	Plate Thickness (in)	Initial Concentration (M)
Standard	50.0%	44.0%	34.0	0.045	4.876
PS38 15%	47.6%	48.0%	32.3	0.045	4.088
SRNL 37%	43.2%	51.9%	29.7	0.053	5.288
nonporous	43.2%	35.5%	29.7	0.053	5.288

Figure 4 represents the predicted utilization of the three battery formulations described above. The utilization is graphed here against varying specific current, or an Amps per gram basis. As before, the blue line is the expected utilization curve for the standard battery. The thicker green and red lines above the standard utilization curve represent the 15% and 37% additive mixes, respectively. The thinner green and red lines that are below the standard curve represent non porous additives. To remove one of the degrees of freedom in this modeling, all of these curves were generated with an initial concentration equal to the standard battery initial concentration. The utilization was calculated by discharging until the voltage reaches 1.5v. The downward trend at high discharge rates is an artifact of this end condition. The External resistance is also set to the same value, so the improvements for the HGMs above .5 A/g can be completely attributed to the additives.

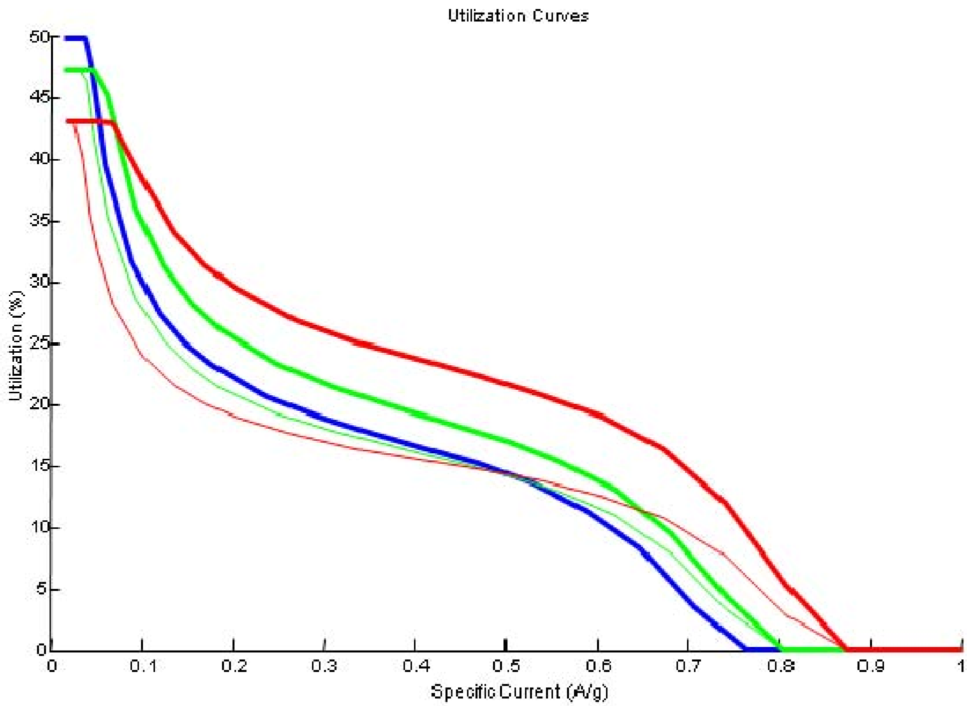


Figure 4 Predicted Utilization vs Specific Current