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**PowerCore^{TM}, NiMH Production Prototype for Portable
Electronics**

**Quarterly Report
R02**

Inventions and Innovations
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PowerCore^{TM}, NiMH Production Prototype for Portable Electronics

I. Restatement of end objective:

Build a production prototype of Power Core structural battery for application as a hard case for portable electronic devices.

II. Summary of work completed since last report (Sept. '97):

- Finished specification based on IBM 760 lap-top.
- Redesigned panel assembly for 8 cells to accommodate voltage specification for IBM
- Built several fully functional NiH₂ prototypes as pathfinders for panel assembly
- Completed first draft of manufacturing plan for limited production run
- Started negotiations for three-fold increase laboratory floor space
- We are now consistently fabricating good-performing negative metal hydride electrodes with over 230 mAh per gram of active material
- Corrugated and laminated electrode stacks are now being tested. They are sized to match the design to accommodate the IBM 760. They are being tested in an open-cell configuration for now.
- Started work with NREL, under this grant, on nickel nano-particle materials to be included in the positive electrode. Developed plans to start experimenting with lithium cobalt dioxide / carbon electrochemical couple in a PowerCore embodiment. Need to request permission to expand our scope of work (separate letter to DOE Headquarters).
- Began using 8-channel, Arbin, automated battery tester at NREL. Evaluating equipment for possible purchase as Boundless Corp. capital equipment.
- Conceived of revised manufacturing process for impregnation of positive electrodes. Planned experiments to check our concept. If successful, this technique will improve our structural performance and greatly simplify manufacture. We expect to submit a patent application if our experiments show the technique to be viable.

III. Related Business Development Activity:

- Detailed business plan completed by T. Feaver, 12/98.
- Presented paper at 13th Annual Battery Conference in Long Beach on Jan 16th
- Submitted abstract for IECEC conference coming up in Colorado Springs
- Started private stock offer. Presently at about 30% of escrow.
- Submitted SBIR proposals to DOD.
- Some progress at CU on advanced materials for metal hydride negative electrodes (parallel grant under Rocky Flats Entrepreneurs' Technology Assistance Program.

IV. Problems:

1. Our panel assemblies are made with polysulfone piece parts to form the edge closures and face sheets. We are having trouble getting good seals when these are bonded together. We need to have tighter specifications on the piece part tolerances or invent a gasket approach to seal the panel assemblies.

2. In our open-cell tests we are not controlling the amount of electrolyte in the electrode stacks. Sometimes the stacks dry-out, causing an apparent drop in capacity.

V. Details of progress vs. statement of work task definitions:

Task	Progress/Status
Task Group 1, Build Production Prototype	
1.a. Refine requirements & requirements review:	Panel Specification is through engineering release (Dwg. 003100, Initial Release, Nov. 11, 1997). Key Requirements are for IBM 760 series of computer.
1.b. Preliminary Design: 1.c. Design Review: 1.d. Detailed Design and Analysis 1.e. Design Review	Redesign of panel assembly and electrodes has been performed consistent with the final specification, above. Preliminary design is documented in Technical Notes 003-TN001, 002 and 004. Detailed design and processes are documented in drawings 003201 through 003203 and 003301. Tooling is defined in 003501-003503.
1.f. Fabricate Electrodes & Test - Stand-alone stacks - Production units for prototype panel assy.	MH electrodes now have consistently good performance (>230 mAh per gm of active material. Corrugated, monolithic stacks are being tested as stand-alone assemblies in an open-cell configuration. Production units are not yet started.
1.g. Bond Electrodes into Blocks of Honeycomb	Built a number of small scale prototype panel assemblies using NiH_2 . Electrochemistry to prove-out assembly techniques.
1.h. Panel Assembly Test Plans and Procedures	Procedures are being practiced and documented in the laboratory notebooks. Preparation of the formal documents to be used as the basis of quality checks during limited production has not started.
1.i. Assemble Panel	Not Started
1.j. Start Panel Testing	Not Started

V. Details of progress vs. statement of work task definitions continued:

Task	Progress/Status
Task Group 2, Production Planning	
2.a. Producibility Analysis of Prototype	Much data on production technique and analysis has been completed and is documented in our lab book and a number of drawings and process control documents we have generated. We have not performed materials cost estimates. Labor for limited production is targeted at one man-day per unit.
2.b. Process and Facility Definition	Technical Note 003, TN003 is the preliminary production plan.
2.c. Facility Design Concept	The floor space estimate and equipment locations are shown in TN003.
2.d. Identify Key Equipment and Price	Equipment costs for manufacture are targeted at under \$30K for limited production. Test equipment is much more expensive and might reach \$100K for computerized equipment for battery activation and initial cycle testing (based on Arbin 8 channel tester). Not much effort has been placed on this task yet.
Task Group 3, Project Management & Reporting	
3.a Project Management	This ongoing level of effort includes coordination with NREL work and a separate ETAP grant on improved materials for the negative electrode.
3.b Final Report Preparation	Not started.

VI. Some Details of Our Findings This Quarter

Important Findings From Task Group 1:

1. All regions of positive electrode to be bonded at higher levels of assembly must be masked prior to impregnation, because chemical change of $\text{Ni}(\text{OH})_2$ to NiOOH weakness bonds.
2. Developed techniques for maintaining flatness of honeycomb core to which face sheet adheres at higher levels of assembly.
3. Switched to polysulfone from Polypropylene for inserts. Holding flatness on inserts has been identified as a problem. Need milling machine to hold tolerances.
4. Practical/prototype activation ports and electrical feed-through. Still need resistance welding capability to weld bulk current collector to electrode tubs.
5. Designed & built tooling to corrugate electrode stacks. Corrugation occurs before sintering and before loading with Ni powder (positive) or MH material (negative).
6. We have not started to bond & expand the honeycomb core for the final production Prototype Assembly.
7. Negative electrodes were not delivering expected capacity as of the last quarterly Report. We now make electrodes from materials from two sources (Japan Metals Corp. & Rhone Poulenc) with good capacity (7200mAh/gm of active material). We had two important experimental findings.
  - We switched from N_2/H_2 forming gas to Ar & H_2 forming gas driving sintering.
  - We now charge very hard for an extended period to fully activate negative material.
8. We built small laminated electrode stacks with positive and negative bonded together. In beaker tests, we found it is important to control the amount of electrolyte in the stack.

Specific performance of one of our experimental electrode stacks is summarized in the following data and the figures on the following page.

Characteristics of Sample 97.12.03-BC-003

Negative electrode gross electrode area:	4.5 cm ²
Active material:	0.661 g
Theoretical Capacity:	192.4 mAh, (291 mAh/g)
Positive gross electrode area:	9.0 cm ² (not optimized)
Active positive material:	4.06 gm
Theoretical Capacity of positives:	1,174 mAh
Measured Capacity of stack:	144.8 mAh
Capacity of negative:	219 mAh/g
% Utilization of negative:	75.3%

VII. Progress vs. Schedule

We are 4-6 weeks behind the schedule we proposed in our grant application. However, our burn-rate is lower than we had expected. This is because P. Lyman continues to have a large work-load associated with overall operation of Boundless Corp. and is unable to dedicate as much time to this technical grant as desired. We plan to submit an amendment requesting the remaining \$22K funding and will propose a schedule slip in the amendment. We see no problem in completing the proposed work with the available funding, but would like to increase the scope of our work some and may request some additional funding.

Sample performance of monolithic NiMH electrode stack:

VIII. Plans for 1st Quarter of 1998:

- Build a two separate single cells at full-scale (1/8th panel assembly)
- Conduct honeycomb core plate shear mechanical tests on one assembly
- Seal second assembly and conduct electrochemical activation and cycle tests
- Start fabrication of full prototype
- Complete test plan and procedure for full prototype