UNITED STATES ADVANCED BATTERY CONSORTIUM LLC

DEVELOPMENT OF THERMAL MANAGEMENT SYSTEM FOR LITHIUM ION BATTERIES USED IN VEHICLE APPLICATIONS

REQUEST FOR PROPOSAL INFORMATION (RFPI)

USABC DEVELOPMENT OF THERMAL MANAGEMENT SYSTEM FOR LITHIUM ION BATTERIES USED IN VEHICLE APPLICATIONS

REQUEST FOR PROPOSAL INFORMATION (RFPI)

TABLE OF CONTENTS

DEVELOPMENT OF THERMAL MANAGEMENT SYSTEM
FOR LITHIUM ION BATTERIES USED IN VEHICLE APPLICATIONS

REQUEST FOR PROPOSAL INFORMATION (RFPI)

1.0 Statement of Purpose/Objectives

The United States Advanced Battery Consortium LLC (USABC), an organization whose members are FCA US LLC, Ford Motor Company and, General Motors defines and conducts pre-competitive, vehicle-related research and development (R&D) in advanced battery technology. USABC has carried out a number of battery development programs, focusing on low-cost, long-life, high-energy, high-power technologies, including several programs in which the development of an improved thermal management system was necessary for the successful outcome of the program. The USABC, in recognition of the importance of thermal management technology to advanced battery systems, intends to further extend development of this critical component.

The purpose of this RFPI is to identify single developers or collaborative teams having Li-ion battery system technologies which have the capability of meeting the USABC goals for Li-ion battery thermal management, as listed in the attached Appendix, as well as meeting or approaching USABC goals for PHEV or EV systems as listed on USABC's website (http://www.uscar.org/guest/article_view.php?articles_id=85). USABC seeks industrial-scale development consistent with intended high-volume automotive usage, supported by a detailed cost model for the battery system. The USABC expects that this work will be partially funded by the US Department of Energy through a cooperative agreement awarded to the USABC. The USABC is currently working under a cooperative agreement with the United States Department of Energy (USDOE) for the development of high performance batteries. The USABC has concluded that it is now appropriate to solicit proposals from developers who have the potential of meeting the criteria noted in the Appendix.

The USABC intends to capitalize on the knowledge it has gained through the 48V, HEV, PHEV, and EV research and development activities it has been engaged in. We expect developers to bring past experiences and lessons learned from their high power and/or high-energy work to bear on developing energy storage system technologies for this application. If the developer believes that their proposal would be strengthened and could more likely meet the requirements through strategic collaboration with other partners, a broader team-oriented proposal is encouraged.

Although project goals can be set that approach but not meet all of the USABC goals, a credible plan toward achieving all the USABC goals must be provided. If the applicable USABC goals are not achievable, but a credible business case exists for the battery system to be used in alternate applications, please provide a description of the intended application and supporting business case. Proposals with a plan for meeting USABC cell-to-system performance goals however, will be given preference in the rankings over those with alternative business cases. All proposals will be evaluated using standard USABC test procedures.

2.0 Business Objectives

This USABC RFPI represents a unique opportunity for developers to leverage their resources in combination with those of the automotive industry and the federal government. For the auto makers, this type of pre-competitive cooperation minimizes duplication of effort and risk of failure, and maximizes the benefits to the public of the government funds.

Beyond the efficient and timely usage of resources, the auto makers recognize that successful commercialization of these technologies will only be completed when a supplier base has been established for the selected components and subsystems. It is, therefore, a major business objective of USABC to enhance a supplier base as the development progresses. All developers submitting proposals will be requested to demonstrate that they have the potential to develop a commercially viable business, which can produce sufficient volumes to meet automotive requirements, and provide engineering and testing support to meet automotive implementation requirements. Research and other organizations with current, direct affiliations with businesses that derive a majority of their income from related product sales, will also be considered. At the time of submittal, all developers will be required to have demonstration hardware and test results available for USABC inspection. Existing testing performed in accordance with the USABC battery test procedures is preferred, however not mandatory. Inspection and testing of samples by the USABC may be included in the selection process. Developers who do not have test results available for examination by USABC at the time of submittal need not respond. Proposals should be meaningfully different from other proposals previously offered to USABC.

3.0 Developmental Timing

The proposals must be accompanied by a development time chart specifying the following:

1. Length of time the technology has been under development by the developer;
2. Projected length of time remaining to full scale availability; and
3. Projected time line for commercialization, including any preproduction phases that may be planned.

4.0 Business Case

The submittal must be accompanied by a business case, divided into two sections. The first section shall state the cost assumptions used that will lead to the cost targets listed in the Appendix. These assumptions should be in general terms, broken down by major components, including material cost, processing cost and other costs. These costs should be presented in sufficient detail such that they can be used by the USABC to build confidence that its cost targets can be met by the proposed technology.

The second portion of the business case should address the anticipated capital investment required to support this initial program investment, including anticipated non-vehicle markets for the technology, sources of capital, etc. A copy of the USABC cost model, which is a multi-stage spreadsheet, is available on the USABC website:
http://www.uscar.org/guest/article_view.php?articles_id=143.
Please note that USABC will not provide funding for capital expenses.

5.0 Technical Challenges

Proposals must be accompanied by a clear description of the remaining technical and other challenges that the developer still needs to meet in order to commercialize the proposed technology and meet USABC's long-term criteria. A narration of the technical challenges that have already been met in order to reach the present state of development will also be useful. Any testing, by USABC, of pre-contract demonstration hardware will be done in accordance with the USABC battery test procedures. These procedures can be found on the USABC website, http://www.uscar.org/guest/article_view.php?articles_id=86.

6.0 Information Requested

The information USABC is requesting from interested parties is specified in the following subsections. It includes: (1) a brief description of your company(s) background; (2) a description of the thermal management system technology being proposed and an associated cost model; (3) the development plan for the technology; (4) the proposed program deliverables, timing, and cost-share; (5) any formal or informal teaming/partnership arrangements planned, and (6) acknowledgement of export control compliance. Note that the demonstration of the thermal management technology must occur as described in the Appendix as well as the battery performance to associated USABC system goals. Relevant background information regarding USABC performance targets can be found on the USCAR website, http://www.uscar.org/guest/teams/12/U-S-Advanced-Battery-Consortium-LLC .

USABC does not expect to award contracts on the sole basis of responses to this RFPI. All responses will be considered by representatives of the partners and other participants, and will be ranked according to their merit. The submitters of the most promising proposals will be contacted by USABC to enter into negotiations that may lead to firm contractual arrangements. If the government and other funding become available, as now expected, USABC intends to award one or more development contracts. However, nothing herein should be interpreted as a commitment to award a contract.

The information requested below should be answered as thoroughly as possible within a maximum of twenty-five pages, in total, for the response to the RFPI. Your submission package should be sent via electronic mail and shall contain a cover letter, a complete copy of your proposal and, a signed copy of the RFPI Agreement. All technical and financial material submitted to the USABC must be in English. If you have any questions concerning the RFPI, please contact Brian Robert @ brobe145@ford.com or Maureen LaHote @ (313) 910-3720.

NOTWITHSTANDING PROPOSER'S MARKINGS TO THE CONTRARY, ALL INFORMATION SUBMITTED IN RESPONSE TO THIS USABC RFPI SHALL BE TREATED ON A NON-CONFIDENTIAL BASIS.

ALL PROPOSALS ARE TO BE SUBMITTED TO THE CONSORTIUM IN ACCORDANCE WITH THE ATTACHED RFPI AGREEMENT WHICH MUST BE EXECUTED WITHOUT MODIFICATION AND ACCOMPANY THE PROPOSAL. NO PROPOSAL SHALL BE EVALUATED BY THE CONSORTIUM WITHOUT PRIOR EXECUTION OF SUCH RFPI AGREEMENT.

SEND, VIA ELECTRONIC MAIL, YOUR PROPOSAL (including signed RFPI Agreement) TO:

Maureen LaHote
Business Manager
United States Advanced Battery Consortium
E-mail: mlahote@uscar.org

6.1 Company Background

In order to become fully familiar with your company(s), the USABC needs information about your business. If your proposal is for a team, furnish the requested information for each company that makes up your team. Please answer/furnish the following information:

- Describe your company's structure, ownership, product lines, and customer base, including domestic and foreign facilities for research and production.

- Please describe how previous R&D successes (especially with USABC or DOE) have been incorporated into the current proposal.

- Please describe the company's experience (if any) in the high volume manufacture of thermal management systems and integrated solutions for Li-ion batteries.

- If publicly owned, include the last 3 years of Annual, 10k, and 10Q Reports. If privately held, include the last 3 years of Balance Sheets, Income Statements, and a Sources & Uses of Funds Statement.

- Enclose a copy of your company's Business Plan for areas related to electrochemical energy storage technology and/or thermal management systems.

- Describe the resources (headcount, expenses, and facilities) devoted to electrochemical energy storage and thermal management system technology development for the previous three years, currently, and forecasted through the expected project period of performance.

- Describe the modeling methods your company uses to estimate costs at sales volumes listed in the respective USABC goals for PHEV or EV noted on USABC's website, http://www.uscar.org/guest/article_view.php?articles_id=85.

- Do you currently hold any licenses and/or patents or pending patent applications for advanced electrochemical energy storage and/or integrated thermal management technology and manufacturing processes? If so, please describe. Are there any restrictions on licensing this technology to the Consortium?

- Provide any projections on potential production for the proposed technology. Also, describe key technical innovations that could lead to high performance and cost effective electrochemical energy storage subsystems.

- Provide a brief resume on key personnel to be dedicated to the project.

6.2 Proposed Thermal Management System Technology

The proposed thermal management system technology should provide a significant improvement over current technologies while still meeting the respective USABC system goals. These improvements must be demonstrated while maintaining or exceeding current state-of-the art parameters in the other areas.

A thorough technical review of each proposed technology is required prior to the award of any contract for development. In preparing a reply to the RFPI please provide a response to each of the following points:

- Provide a brief technical description of the proposed technology that will meet the thermal management system goals and characteristics listed in the Appendix as well as that of the respective USABC vehicle system (e.g. PHEV, EV) goals.

- Summarize the present status of the proposed technology, with experimental data and test methods used to acquire the data, including:

    - Physical, performance, and life characteristics of all relevant materials developed and tested at your facilities, or at independent test facilities.

    - Any environmental and safety issues relating to manufacturing, recycling, use and disposal of the proposed technology.

    - Dominant failure mechanisms that limit the operating life of lithium-ion batteries using this technology, and use restrictions desired/required to maximize the life of the subsystem.

- Summarize the characteristics of the current technology by using Table 1 provided in the Appendix.

- Provide any relevant quality-related metrics.

6.3 Proposed Technology Development Plan

Propose how the technology would be developed to meet the USABC technical criteria including:

- Barriers that must be overcome (should be closely based on the objectives listed in the Appendix as well as that of the referenced USABC program goals for PHEV or EV);

- Task objectives needed to overcome the barriers, approaches, success criteria, and demonstration tests (A work breakdown structure is helpful but not required.);

- Feasibility and scale-up issues that must be resolved; and

- Transition from feasibility demonstration to prototype hardware.

Separately propose how the technology could be produced in high volume. Define the raw materials, processes, capital equipment, and labor required at the desired production levels. Discuss the overall timing required to achieve initial production, including prove-out. Define any intermediate steps required to reach initial rated production including pilot plants, technical challenges regarding the manufacturing process, and their time frame.

Define any additional technical issues, and their possible resolution, concerning the proposed technology relevant to vehicle applications. Propose a warranty structure for the subsystem corresponding to the initial commercial production level.

Provide a projected cost breakdown of the proposed technology, including costs projected for the desired production volumes. Costs related to warranty and/or replacement, and recycling should be clearly indicated. The manner in which the projected costs, volumes and time schedules are expected to be achieved should also be provided.

6.4 Proposed Program Schedule, Deliverables, Cost, and Cost Sharing

Developers must clearly identify their milestone objectives. The setting of major milestones and timing will be reviewed and agreed upon between each USABC Work Group and the corresponding subsystem developer/supplier team. It is anticipated that there will be intensive interaction between both parties in setting program milestones. The involvement of all team member organizations in the setting of program milestones is strongly encouraged.

The delivery of prototype hardware for testing and evaluation will be scheduled, on a continuing basis, as developments warrant. Details of scheduling would be agreed upon with the selected

developer(s) and the USABC Work Group. The evaluation of deliverable hardware will be undertaken at several testing facilities, such as the various National Laboratories and other USABC partners motivated by established USABC procedures (e.g. Thermal Performance Test, etc.) associated with the respective system test manual (http://www.uscar.org/guest/article_view.php?articles_id=86). The test schedule will be agreed upon by the USABC Work Group, the developer, and the test facilities. Developers who do not have the experience or capability to create or source the necessary cells for prototype hardware are required to find partners with a proven track record of producing commercial quality cells. The USABC can, upon request, provide a list of experienced cell manufacturers.

It is expected that scaled milestone deliverables will be developed enabling a stage-gate tracking and evaluation methodology for the program generally consisting of:

- Cell-level thermal characterization: establishing a baseline reference for performance test profile(s) as well as initial justification for model/simulation assumptions

- Scaled module-level proof of concept (POC): initial feasibility verification of the proposed solution scaled appropriately to the selected system (e.g. EV, PHEV)

- Multi-module prototype: targeted program demonstrator deliverable scaled to approximately ~1/2 battery pack system parameters verifying quantitative performance

Control and monitoring of scaled battery systems (e.g. POC or prototype) should be included to address minimum standards for testing and evaluation. Programs are expected to deliver design and performance estimations for a full battery pack system. Prototyping of a full system is considered a stretch goal due to complexity and validation requirements, but may be considered for follow-on activities if evaluated viable and technically competitive.

The USABC is interested in advancing the development of commercially viable energy storage products, and prefers to focus on technologies, including cell chemistries, that are most likely to achieve commercial success in the near term. The developer must clearly identify the thermal management system details and corresponding battery cells to be deployed. Battery cells for automotive scale systems are expected and details, whether developed or current state-of-the-art, should include the intended electrodes, separator, electrolyte package, the size and format of the cell, and where they will be built/sourced. The goals listed in the Appendix represent the minimum required values that every program must achieve, unless specifically stated otherwise. In addition, it is also expected that successful programs will significantly advance the state-of-the-art in battery pack design and cost, thermal management system integration, as well as related cell performance (thermal uniformity, cycle life, etc.).

All developers are expected to contribute or cost share in the developmental costs. The developer should submit proposals indicating cost sharing as a percentage of the total proposed program development amount. The extent of cost sharing may be negotiated between USABC and the development team, taking into consideration whether the company is domestic, foreign, or foreign controlled, rights to license background and foreground technology, benefits to US

economy, and other factors. However, a minimum of 50 percent developer cost share is contractually required. The developer will agree that at least 75% of the direct labor billed to the USABC for this project will be incurred within the United States.

The proposer shall provide cost breakdown between labor, materials, indirect costs, etc. and a separate analysis of total costs for each major task. The tasks that each subcontractor will complete and the funding they will receive should be clearly indicated in the cost breakdown.

Contractors will provide written quarterly reports to USABC, including test data and development progress. Additional quarterly reporting (i.e., oral) will be scheduled with the USABC Work Group. A final written report will be submitted to USABC at the end of the contract period.

6.5 Cooperative Relationships

The proposal should indicate any additional resources that may be required beyond those of the contractor to achieve program goals. This would include the development of cooperative relationships between component developers, component manufacturers, and subsystem integrators. Other cooperative relationships could involve National Laboratories or Universities for materials research, test facility development, test and analytical procedures, or other techniques available only at specialized locations.

6.6 Export Control Compliance

The proposer will be required to acknowledge that export control rules limit or prohibit the transfer of covered technology to foreign nationals and agrees to establish and maintain internal controls and procedures adequate to insure accurate determination by the proposer of whether and when its technology falls within the ranges and definitions of the currently effective export control regime.

NOTWITHSTANDING PROPOSER'S MARKINGS TO THE CONTRARY, ALL INFORMATION SUBMITTED IN RESPONSE TO A UNITED STATES ADVANCED BATTERY CONSORTIUM (USABC) REQUEST FOR PROPOSAL INFORMATION (RFPI) SHALL BE TREATED ON A NON-CONFIDENTIAL BASIS.

AGREED:

BY _____

TITLE _____

PROPOSER _____

DATE _____

APPENDIX – USABC Li-Ion Battery Thermal Management System Requirements

The technical specifications provided in Table 1 will be used to guide and evaluate the development of battery thermal management technologies. While conventional approaches (e.g. air or liquid convention) still have room for improvement, emerging solutions requiring additional development – such as direct thermal exchange (i.e. immersion cooling, dielectric coolant systems), integrated two-phase solutions (i.e. heat pipe, vapor chamber, flow boiling), low-cost refrigerant/heater, etc. – are encouraged. Furthermore, the noted metrics are to evaluate pack-level performance; however proposals are required to estimate additional necessary loads to the vehicle system (e.g. electrical power, pumps, condensers, etc.).

Table 1. USABC Li-ion battery thermal management system gap chart

			USABC Goals*				
Program Targets		**Units**	**EV**	**PHEV**			**Program Target**
Key Parameters	**Parameter Details**			**PHEV-20**	**PHEV-40**	**xEV-50**	
Operational Life @30°C		[years]	15				
Operating Environment†		[°C]	-30 to +52				
Pack Temperature Uniformity	ΔT: Cell-to-Cell	[°C]	< 3				
Cell Temperature Uniformity	ΔT: Cell Surface	[°C]	< 3				
System Efficiency	Ambient (unconditioned)	[ratio] Q/P‡	> 15				
	Active		> 4				
Weight	Pack Components	[kg]	< 5.3	< 5.6	< 9.6	< 12	
Volume	Pack Components	[L]	< 13.5	< 11.75	< 20	< 25	
System Cost	@250k units	$	< 112	< 44	< 68	< 85	

* *Developer to select one system application (PHEV or EV) for the proposal and align with existing RFPI battery performance targets as listed on the USABC website, http://www.uscar.org/guest/article_view.php?articles_id=85*

† *Temperature range of normal operation with extended considerations for the system survival temperature range of -46*°C *to +66*°C as noted in the respective system test manual, *http://www.uscar.org/guest/article_view.php?articles_id=86*

‡ *Ratio of heat transfer rate (removed, in Watts) vs. electrical power (Watts)–**see details below***

Definitions:

- **Pack Temperature Uniformity (ΔT: Cell-to-Cell)** – The homogeneity of cell temperatures measured throughout the battery pack [= Max Cell Temp – Min Cell Temp]. The amount and locations of measurements to be further defined in the scope of work phase of the project with dependence on the associated EV or PHEV system selected as well as dependence on the cell type.

- **Cell Temperature Uniformity (ΔT: Cell Surface)** – The homogeneity of the cell's temperature measured in at least three separate locations on the cell's surface (to be further defined in the scope of work phase of the project with dependence on cell type).
- **System Efficiency (Ambient vs. Active)** – The ratio of the heat transferred (Q, in Watts) from the system vs. the electrical power (P, in Watts) used by the vehicle to remove said heat.
    - In an **Ambient (unconditioned) System** no energy is used to thermally manage the cells, modules, or pack except for the energy used in moving the thermal fluids (e.g. by pumps, fans, etc.); thus the electrical power (P) used relates to the fluid flow in the battery thermal management system.
    - In an **Active System** energy is used directly for cell/battery thermal control in addition to the electrical energy for moving fluids; thus the electrical power (P) is the sum of direct thermal control plus the power to move fluids.
- **In Pack Components Only** – Components that are connected and encased within the battery pack housing for the purpose of thermal control (e.g. cold plates, sensors, etc.).
- **Pack + Vehicle Connections** – Components and connections identified in "In Pack Components Only" and any items external to the battery pack housing for thermal control (e.g. fans, pumps, heat exchangers, communications, etc.).

Additional Development Considerations:

As Table 1 details the quantitative rubric in which awarded programs will be evaluated, the following considerations are encouraged to advance the state of the art. These items are less quantifiable in traditional improvements, but highlight technical challenges in battery thermal management technology.

- Development and implementation of thermal interface materials with through-plane thermal conductivity >15 W/m-K (ensuring electrical isolation as necessary) enhancing tradition cell-to-thermal management system heat transfer maintained through system lifetime requirements.
- Development and implementation of viable approaches to high heat transfer convection at the cell, effectively reducing cell-to-thermal management system thermal resistance, while maintaining electrical isolation of the cell(s).
- Development and implementation of embedded, integrated, or scalable interconnected thermal sensing mechanisms for cell-to-battery pack state monitoring.