## 2014 — Manufacturing Research and Development (R&D)
Summary of Annual Merit Review of the Manufacturing R&D Sub-Program

Summary of Reviewer Comments on the Manufacturing R&D Sub-Program:

According to reviewers, the objectives and progress of the Manufacturing R&D sub-program were clearly presented and prior successes were described. The reviewers noted that the sub-program thoughtfully—and with industry collaboration—considered the needs and intent of the U.S. Department of Energy's Hydrogen and Fuel Cells Program (the Program) and generated a strategy to develop appropriate solutions. The reviewers suggested that continued collaboration with regions and clusters as well as industry and stakeholders would be helpful. In fiscal year (FY) 2014, one manufacturing project, which addressed fuel cell stack in-line testing, was reviewed.

Manufacturing R&D Funding:

Funding for the Manufacturing R&D sub-program was $3 million for FY 2014, and $3 million was requested for FY 2015. The FY 2015 request-level funding will continue existing Manufacturing R&D sub-program projects and provide funding for new analysis projects on supply chain development and global manufacturing competitiveness through a competitive funding opportunity announcement, subject to appropriations.
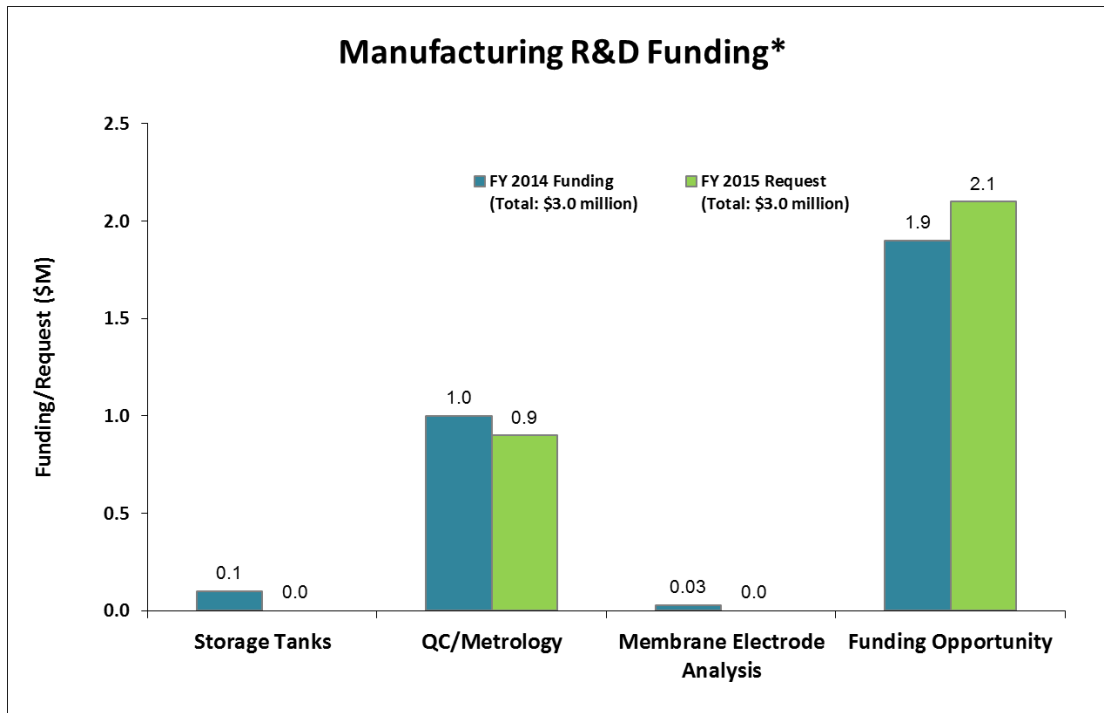
* Subject to appropriations, project go/no-go decisions, and competitive selections. Exact amounts will be determined based on research and development progress in each area and the relative merit and applicability of projects competitively selected through planned funding opportunity announcements.

Majority of Reviewer Comments and Recommendations:

One Manufacturing R&D project was reviewed, earning a score of 3.4. Reviewers judged the project to be highly relevant to Program activities and to feature an excellent technical approach. They noted that project progress and accomplishments were extremely good. The project team was judged to be strong; participation and contribution from industry partners were identified as useful and coordinated.

Fuel Cell Membrane Electrode Assembly (MEA) Manufacturing: One project was reviewed in the area of fuel cell MEA manufacturing, with a score of 3.4. Reviewers noted that the approach for the project was very good and that collaboration with industry has been, and continues to be, very good. Reviewers also noted that NREL made significant progress this year in further developing diagnostic techniques and implementing them at Ion Power. The reviewers encouraged NREL to reach out to additional companies for technology transfer as well as correlate defect size (as detected in a webline) with fuel cell performance.

Project # MN-001: Fuel Cell Membrane Electrode Assembly Manufacturing Research and Development

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Brief Summary of Project:

The objectives of this project are to obtain quality control (QC) needs from industry partners and forums, develop diagnostics, use modeling to guide development and understand the effects of defects, validate the diagnostics in-line, and transfer the technology to industry.

Question 1: Approach to performing the work

This project was rated **3.5** for its approach.

Overall Project Score: 3.4 (6 reviews received)

The vertical hash-lines represent the highest and lowest average scores received by projects in the sub-program.

- In general, the approach is good. The approach is relatively broad-based and covers a number of defects that can occur in the manufacturing process. Collaboration with industry has helped to sharpen the project focus. So far, the project has primarily focused on detecting known defects; the real proof of the value of these diagnostics will be testing on actual manufacturing lines with unknown defects. The follow-on steps that need to be addressed are to determine the impact of performance on actual defects that are detected by these diagnostics.
- The approach is very good and is broad-based and covers a number of defects that can appear in different manufacturing processes for membrane electrode assemblies (MEAs) and catalyst coated membranes by a roll-to-roll technique.
- The tasks in this project align very well with the Manufacturing sub-program's milestones in the Fuel Cell Technologies Office Multi-Year Research, Demonstration, and Deployment Plan milestones. The relevance of the approach to actual manufacturing practices and to industry is implicit in the collaborations with MEA and membrane suppliers and the implementation of the techniques in industry.
- The National Renewable Energy Laboratory (NREL) has a very good process to overcome the problems. The progress looks very beneficial to the fuel cell industry.
- Techniques for on-line QC are reasonable if it can be shown that detection limits are appropriate. Flaws that decrease performance or durability must be detectable. So far, this has not been demonstrated.
- NREL's approach incorporates key elements including industry input, modeling, and validation to evaluate prospective QC techniques.
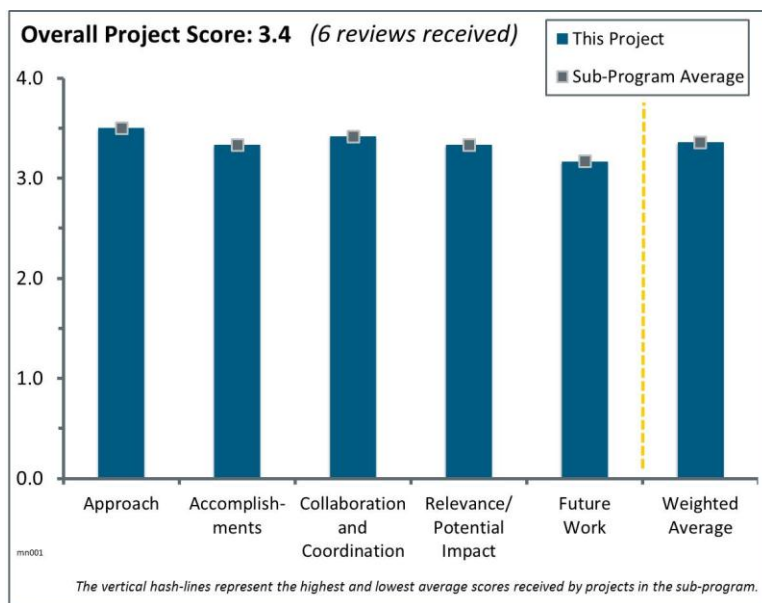
Question 2: Accomplishments and progress toward overall project and U.S. Department of Energy (DOE) goals

This project was rated **3.3** for its accomplishments and progress.

- NREL made good progress this year developing the infrared/direct current (IR/DC) diagnostic for detecting imperfections on web coating lines showed good progress this year. The method was verified on the new roller system at NREL and the data agreed with previous results. The technology was implemented on the coating line at Ion Power, and data were collected on three coating runs. Defects (scratches and excess droplets) were successfully detected at speed of the drying oven. In additional testing at NREL, the Ion Power data were replicated; excitation conditions for line speeds up to 60 feet/minute were determined.

- Development of the infrared/reactive impinging flow (IR/RIF) diagnostic was also substantial for detecting defects in moving gas diffusion electrode (GDE) sheets. Laser drilling of holes in the gas knife should decrease measurement variability. Bare spot defects as small as 2 mm x 2 mm were successfully detected on GDE sheets moving at 30 ft/min. Modeling at Lawrence Berkeley National Laboratory (LBNL) has helped to optimize knife hole geometry and spacing. Model results are in fairly good agreement with experimental results.
- Variation in capacitance due to relative humidity variability led to the no-go decision on further development of the technique for measurement of the ionomer-to-carbon ratio (I/C) in MEAs.
- The establishment of an in-house roller system should speed the evaluation of new techniques and reduce the deployment time in an industrial environment. The effort successfully deployed IR/DC equipment with an industry collaborator.
- NREL made significant progress this year developing diagnostic techniques and implementing them at Ion Power. The no-go decision on I/C determination shows that the project is grounded in practical development of techniques and not wasting time on tasks that are not feasible.
- NREL shows excellent results at current manufacturing speeds; the results can be applied to the industry.
- Good progress has been made for the IR/RIF technique in an open environment with very high moving rates.
- Good progress in technique development has been made.

Question 3: Collaboration and coordination with other institutions

This project was rated **3.4** for its collaboration and coordination.

- Teaming with industry is essential for the success of this project. Collaboration with industry has been and continues to be very good. NREL has interacted with component suppliers and with automotive original equipment manufacturers (OEMs) to determine the critical quality assurance (QA)/QC issues that need to be addressed and detection methods requiring improvement. Modeling by LBNL has enhanced the development of the IR/RIF technique.
- There is strong collaboration with major industry leaders and coordination with the university system.
- The project has a good mix of industrial, national laboratory, and academic collaborators providing valuable contributions.
- The project is well-coordinated and has excellent cooperation with relevant industrial partners.
- Unfunded collaboration includes fuel cell component manufacturers and stack integrators.
- The coordination and input from Ion Power is clear. However, it is unclear what the Colorado School of Mines and LBNL are doing in the project and what value is added, at least from what was presented.

Question 4: Relevance/potential impact on supporting and advancing progress toward the Hydrogen and Fuel Cells Program goals and objectives delineated in the Multi-Year Research, Development, and Demonstration Plan

This project was rated **3.3** for its relevance/potential impact.

- Successful implementation will detect defects and will allow them to be removed before the MEA is installed in a complete system. This process could improve reliability and life of the cell stacks, as there will be smaller/fewer defects that make it into the complete stack.
- The true relevance of the project will be realized when one of the methods under development is implemented on actual manufacturing lines and proves to be effective in reducing the number and rate of reject parts. The relevance would be enhanced when the impact of detected defects on performance is known. This is an important development that needs to be addressed.
- The project is targeting the main challenges of the quality control in fuel cell manufacture. The identification of the impacts of the imaged defects on fuel cell operation and durability will be more relevant.
- There appears to be a critical need for QC in MEA manufacturing, based on industry input. This project is well-coordinated with a leading MEA manufacturer, Ion Power. The coordination with other industry collaborators is unclear.

- The effort is contributing to addressing a number of program goals and is a key element in moving technologies towards viable mass production. The reactive impinging flow method needs additional characterization and validation work.

Question 5: Proposed future work

This project was rated **3.2** for its proposed future work.

- All of the proposed future work is good and important, especially the study of the impacts of the relevant defects on fuel cell performance and lifetime.
- Planned future work continues to address barriers, most importantly the effects of defects on cell performance and lifetime.
- The project has a strong path to achieving all the goals.
- Future work is briefly outlined. It includes demonstration of the RIF technique on the NREL web line, further development of the optical and infrared techniques, and most importantly, the study of the impact on performance and lifetime of relevant defects. No milestones are presented, so assessing the likelihood of success is not possible. The latter item is very important, and some details concerning the approach to the study of the effects on performance should have been presented.
- The two following activities mentioned under future work are the key to project's value and should be the main focus of future effort: (1) study the effects of relevant defects on cell performance and lifetime, and (2) develop and integrate models for optimizing diagnostics and for predicting performance effects of defects.
- Strong effort to relate detectable flaws to cell behavior must be shown, and the detection techniques must be shown to be capable of detection.

Project strengths:

- This is an all-around strong project with valuable collaborators and a methodical approach to QC technology development.
- NREL's process will be very beneficial to the manufacturing MEA industry and could have a major impact on the fuel cell industry. The project is well laid out and seeing good results. The costs/benefits of implementing in industry seem very good.
- NREL is addressing relevant issues and is adapting/improving available diagnostic techniques for use on high-speed manufacturing lines. Good collaboration with industry is evident.
- The project team has carried out excellent research and cooperates well with industrial partners.
- The integration and collaboration with Ion Power is a project strength.
- The knowledge and skill base of the collaborators are a project strength.

Project weaknesses:

- There is a lack of understanding of the identified defects' impact on the fuel cell's short- and long-term performance.
- The impact of defects on performance still needs to be understood. The NREL approach to determining the impact is not at all clear.
- Correlation of detectable flaws to performance and durability is lacking.

Recommendations for additions/deletions to project scope:

- The need for increasing the sensitivity of the measurements should be determined, which will require understanding the impact of defects on performance. The lower limit for a particular defect is not clear. Determining the I/C ratio should be included in future work despite the no-go decision on the capacitance method.
- The researchers should determine whether the reaction temperature at the surface of the catalyst layer will have an impact on fuel cell performance and lifetime when the IR/RIF technique is used.