U.S. DEPARTMENT OF ENERGY
INTERNATIONAL NUCLEAR ENERGY RESEARCH INITIATIVE
DOE/Canada

ABSTRACT

High-Temperature Electrolyzer Development

Principal Investigator (U.S.): R. Doctor, Argonne National Laboratory (ANL)

Principal Investigator (Canada): R. Sadhankar, Atomic Energy of Canada Ltd. (AECL)

Collaborators: Chalk River Laboratories (CRL), Idaho National Engineering & Environmental Laboratory (INEEL)

Project Number: 2004-001-C

Project Start Date: June 2004

Project End Date: May 2007

Under DOE-EE contract 03EE49108 in coordination with the DOE-NE Nuclear Hydrogen Initiative, ANL has been building a set of tools and guidelines that the developers of steam electrolysis cells can use to speed up the process of optimizing flow distributor designs. Our work employs STAR-CD and Fluent codes for the computational fluid dynamic (CFD) modeling of a steam electrolyzer, which is being developed by INEEL in partnership with Ceramatec. The CFD model is linked to ASPEN process simulation software to analyze the balance of plant issues in a high-temperature electrolysis hydrogen production system. Under this joint I-NERI proposal, AECL will provide data on low-temperature electrolyzers for a comparison with the INEEL electrolyzer.

The two basic problems that limit the operation and efficiency of an electrolysis unit are nonuniform flow within the individual cell cavities and non-uniform flow into separate cells constituting a cell stack. Heat transfer and electrochemical efficiencies will degrade depending upon the extent of these flow non-uniformities. The key objective of the collaboration, then, is to test and compare electrolysis modules and perform computational fluid dynamics calculations to optimize the flow geometry for high-temperature electrolysis applications. ANL shall perform CFD calculations on the flow conditions for electrolysis cells and stacks of the INEEL-based design and the designs identified by AECL. AECL shall test other available electrolysis stacks and provide data for the ANL studies.

High-temperature electrolyzers can also benefit from the use of improved materials. The current approach is to use more or less conventional solid oxide fuel cell (SOFC) materials in the electrolyzer, which is treated as an SOFC operated in hydrogen production rather than in hydrogen consumption mode. There are significant operational differences, however, between fuel cell and the electrolysis electrochemical reactions, and materials developments can help to improve the performance of the electrolyzers.

Proper design and operation of the balance of plant is crucial to overall efficiency of the hightemperature electrolyzer system. In particular, because both the hydrogen-rich and the oxygen-rich product streams emerge at high temperatures, the common approach is to quench these streams, with inevitable thermodynamic irreversibilities. Quenching reduces temperatures to a range in which conventional structural materials can provide reasonable service life. Opportunities for process optimization will be pursued that will consider the trade-offs of cell costs. Possibly membranes useful in this application for separations may emerge from other research groups; such developments will be integrated into the designs as appropriate.