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Intermediate-Sized Natural Gas Fueled Carbonate Fuel Cell Power Plants,
CRADA 92-003, Executive Summary

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This executive summary of the report, "Intermediate-Sized Natural Gas Fueled Carbonate Fuel Cell Power Plants", describes the accomplishments of the joint Morgantown Energy Technology Center and Energy Research Corporation (METC/ERC) Cooperative Research and Development Agreement (CRADA) No. 92-003. It contains CRADA protected information for use by the U.S. Department of Energy (DOE) and Energy Research Corporation (ERC), and is not for public distribution.

Intermediate-sized natural gas fueled carbonate fuel cell power plants with steam-bottoming cycles have been evaluated by DOE/METC and ERC. This was accomplished by mutual development of a design basis and subsequent development of computer simulation models, which characterize the performance of a 50 MW baseline plant configuration, as well as a more advanced plant configuration.

The carbonate fuel cell performance model used in this study is based on state-of-the-art ERC technology. The fuel cell performance and output voltage are supplied by CRADA protected ERC power-block models. Advanced System for Process Engineering (ASPEN) simulations, using these inputs, were developed by DOE, and compared to independent system simulations conducted by ERC. Significant sharing and comparison of system and fuel cell performance data has resulted from this CRADA.

A baseline nominal 50 MW system was configured resulting in 59% HHV (65.3% LHV) efficiency and a capital cost of \$1,150/kW. This compares favorably with smaller 2 MW fuel cell power plants (without bottoming cycles) with projected efficiency at 54% HHV (59% LHV) as well as larger 300 MW combined cycle plants with 48% HHV (53% LHV) efficiency. The baseline-system design was chosen for its near term application and its simplicity. It can be applied to both distributed power and on-site power markets. The baseline system results provide confidence in the ASPEN fuel-cell simulation to accurately simulate the fuel cell system. Building on this knowledge, the advanced fuel cell system was developed.

A more advanced 50 MW system with anode recycle utilizing a CO₂ separation process achieves 62% HHV (69% LHV) efficiency at an estimated capital cost of \$1,220/kW. The advanced carbonate fuel cell system configuration contains additional process equipment, but is more efficient than the baseline system. The advanced system features an anode-recycle stream that eliminates the steam boiler normally used to generate steam for the methane reforming-water gas shift reaction. Because the methane reforming-water gas shift reaction water is supplied by the process, the fuel cell system is water self-sufficient. Separation of the CO₂ from the anode exhaust allows a smaller catalytic converter and a fuel rich stream recycled to the anode.

A steam bottoming cycle at 7 MW for the baseline system and 12 MW for the advanced system is included in this study. Costs for these

system cycles were capacity factored from larger systems, and are believed to be reasonable.

The Advanced Carbonate Fuel Cell system has several advantages-improvements over the baseline case. First, and foremost, is the three point efficiency improvement. Much of this is attributed to higher efficiency in the fuel cell itself. The anode recycle results in improved fuel utilization of H_2 and CO in the high efficiency fuel cell, rather than the less efficient steam cycle. Secondly, water vapor created in the fuel cell is recycled to the anode in the vapor phase providing all water required for the reforming-water gas shift reactions. Energy is not needed to raise make-up water to fuel cell operating temperatures, thereby increasing the power from the bottoming cycle and improving system efficiency.

The design of the advanced system also has some disadvantages; 1) a high temperature blower-compressors; and 2) the development and expense of the CO_2 separation process.

DOE/METC has enhanced it's knowledge and understanding of the carbonate fuel cell and fuel cell systems. DOE has developed the early DOE fuel cell models to include technical improvements in fuel cell performance and for the increased power generation predicted by ERC power block performance data. The updated ASPEN models reinforce ERC projections for the material-energy balances around the fuel cell system verifying ERC results. This also provides independent methods to check the results obtained for the fuel cell system model.

The potential high efficiency and long term application of the advanced 50 MW natural gas fuel cell system is expected to promote continued investigation. Further evaluation of this improved design is beyond the scope of this CRADA, but investigation should continue with future activities.