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Testing of a Multi-kWe SOFC Power Generation System

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In the last ten years, SOFC generated power has increased from tens of watts from 3 cell stacks to tens of kilowatts from 576 cell stacks. Following this growth in power capability, automatic control systems have been developed which permit unattended operation of these generators. This paper describes a 20 kWe SOFC generator system which was developed under joint sponsorship by Westinghouse and the U.S. Department of Energy and has successfully completed 3,000 hours of operation.

Reference 1 presents a description of the design features of this generator as well as the development work which proceeded its construction. This unit has the following major features:

a) Total number of individual 50 cm long cells - 576
b) Number of cells in series string - 192
c) Number of parallel cell strings - 3
d) Integral exhaust gas heated fuel reformer
e) Internal recirculation of depleted fuel
f) Operation on pipeline desulfurized natural gas with no external water addition
g) Operation on gasified naphtha with supplementary steam addition.
h) Operating temperature = 1000°C

The operation of this SOFC generator required continuous control of electrical load, fuel and air flows, and generator temperature. Because of the complex strategy required to control these parameters, a dedicated programmable controller operated the generator. Distinct operating states were defined for start up, stop, and run conditions. During the start up, the operator moved the generator through the operating states by keyboard input from a personal computer operator interface. An indicator on the display screen of the operator interface alerted the operator when a state transition was permissible. In the run state, keyboard input of certain control set points were permitted. The controller continuously monitored the status of critical parameters. If a parameter was in alarm, an
alarm message was issued to the operator interface. All alarm messages were displayed, printed and logged. If the alarm was serious, the controller placed the generator in the trip state. From the trip state, the operator could decide to restart the generator or cool the generator to room temperature. The entire cooling process was controlled automatically.

Figure 1 is a front view of the generator test facility and Figure 2 shows a closeup of the 20 kWe generator itself. The testing of this unit began on 11/7/90 and ended on 9/5/91. During this period, the unit accumulated 1850 hours on desulfurized natural gas, 725 hours on naphtha and 425 hours on hydrogen and successfully withstood 4 complete room to operating to room temperature thermal cycles. During the second thermal cycle, the unit was dormant for a five month period.

Figure 3 is a terminal voltage versus current plot for this generator running on natural gas. Figure 4 is a power characteristic based on the data from Figure 3.

Two unplanned events occurred during the test period which demonstrated the integrity of the unit design and the repairability of its subsystems. At the 75 hour mark following the initial startup, the dc to ac power converter failed and an error in the control program prevented a power transfer to a backup dc power dissipator. The unit was open circuited and full fuel flow continued for 35 minutes before an operator manually terminated the test. The fuel reformers contained carbon but the generator itself was not damaged. Also, near the end of the final test period, an electrical short occurred in the power output system and the unit was automatically shutdown. Once the short was located and repaired the unit was restarted successfully.

This power generation system met or exceeded all of its design objectives and has paved the way for field test units.

References

FIGURE 1 - GENERATOR TEST FACILITY

FIGURE 2 - 20 KW SOFC GENERATOR
FIGURE 3 – 20 kWe SOFC GENERATOR
Terminal Voltage versus Current

FIGURE 4 – 20 kWe SOFC GENERATOR
Terminal Power versus Current