IGT Stack No. 6 (SDG&E-1) Test Plan and Component Specification Document

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For
U.S. Department of Energy
Office of Fossil Energy
Federal Energy Technology Center
Morgantown Site
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
M-C Power Corporation
8040 S. Madison Street
Burr Ridge, Illinois 60521-5808

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IGT STACK NO. 6 (SDG&E-1) TEST PLAN AND COMPONENT SPECIFICATION DOCUMENT

I. PURPOSE

The purpose of Stack-6 (SDG&E-1) is to scale up and demonstrate the long-term performance and endurance characteristics of the IMHEX stack design and the Generation No. 2 cell components (improved pore matching electrodes) in a 20 cell subscale stack test.

II. TEST GOALS

Performance:

Voltage, mV/cell:	650
Current Density, mA/cm ² :	160
% Fuel Utilization:	75
% Oxid. Utilization:	10 - 50

Life: 4000 hours

Decay Rate: <10 mV/1000 hours

Cell-to-Cell Uniformity: ±20 mV

III. ASSEMBLY PROCEDURE

The specifications of the components and current collectors for Stack 6 (SDG&E-1) are presented in Tables 1 and 2.

- Complete documentation and tracking of planform, and step heights of separator plates dimensions via digital and analog methods
 - Integrated with numerical cutting of anode, cathode, and anode/cathode current collectors
- Complete macroscopic inspection of separator plates
- Complete thickness mappings of all components
- Component cathode and anode "packages" are matched with plate electrode step "cavities"
- Each plate has its own anode and cathode "packages" installed into its own "cavities" as separate "subassemblies"

Subassemblies are then built up into a stack in the IGT clamping fixture in a separate "ready-room," whose humidity is controlled

-- Electrolyte matrix tapes separate the plate subassemblies.

IV. STARTUP PROCEDURES

- Heatup Schedule (See Table 3)

The diagnostics given below will be employed during the monitoring of the stack startup.

- Monitor key temperatures and thickness of stack throughout the heatup period
 - Clamping fixture bellows pressure is adjusted continuously to maintain constant holding pressure on stack
- Heatup control strategy is to allow stack heaters to "lead" throughout the heatup period
 - Gas heaters are never to add heat to the average temperature of the stack. Instead, they follow the stack furnace.
- Periodically monitor "dry" and "wet" seal efficiencies via volumetric balances of in-versus-outlet flow rates.
- Hold time is determined by GC/mass spec. analysis results on stack gas outlets
- Binder burnout completeness determines both hold time and gas changeover time
- Closely monitor and record dimensional shrinkage of stack, especially through carbonate tape melting.

V. STEADY STATE AND OPERATING PROCEDURES

Process Gas Composition:

Fuel: Humidified 75% H₂, 25% CO₂

Oxidant: 30% CO₂, 70% Air

Current Density: Reference TARGET - 160 mA/cm²

Temperature: 650°C

Pressure: 1 atm

Frequency of Data Acquisition: Dependent on data being acquired.

- **Polarization Run:** OCV incrementally up to 160 mA/cm² (149 A/ft²)
 - Every channel, 1 sample/8 seconds, noiseless, 16 power line cycles integrated
- **Resistance via interrupt method and high speed scope:**
 - Single channel basis, 1 sample per 20 micro-seconds
- **Steady State:** At a constant load
 - Every channel, 1 sample per 45 seconds; can be varied as required.

VI. DATA ACQUISITION

Stack Instrumentation

- All cell, stack and equipment temperature, flow, pressure, power, voltage, current, resistance, and level data channels are redundantly acquirable both manually and digitally.
- All flow, pressure, heater power/temperature, and level control channels are redundantly controllable, both manually and digitally.
- **Data acquisition and control approach: distributed control.**
 - Main, Hewlett-Packard technical computer serves primarily central data acquisition, control supervisory, and alarm monitoring and action functions
 - All data is stored on rigid disk; backup rigid disks is used for quick turn around of test run variables as a function of time. Historical backup is on 3 in. disks. Data transfers to an IBM environment are used for supplementary data reduction/analysis.
 - All flow, pressure, temperature and level control functions are performed by distributed, "smart" controller microprocessors.

- The main computer continuously monitors data channels for alarm conditions. Alarm actions are either manual or main-computer initiated
- Uninterruptible power supply assures 90 minute emergency operation of key flow controllers as well as vital temperature, current, voltage, and data channels.
- Gas flow compositions are monitored via an on-line Carle GC
 - Inlet/outlet port samples are drawn via a vacuum pump downstream of the GC
 - Future readiness goals of the facility include complete integration of GC with the computer DAC data, especially flow rates. Then, real time mass balance calculations will be regularly reported.
- Internal resistances are determined via a Tektronix high speed digitizing scope, software trigger, and IGT's solid state load device.

Procedure

- Polarization Runs
 - Frequency: variable
 - Current density is ramped, incrementally, from OCV, up to the stack's maximum allowable current density.
 - Key cell voltage, temperature, pressure and water level information is plotted as a function of time.
 - At present, current density is manually ramped. Future stack readiness goals include automated control of polarization runs and standard report plot generation.
 - Polarization run maximum current densities are defined by stack voltages less than 550 mV per cell.
 - These polarization runs are to be conducted with the stack gas flows set for the Reference Target, 160 mA/cm² current density as stack performance allows.
- Internal Resistances
 - Frequency: Once every 200 hours

- **Purpose:** To track the time dependent characteristics of cell and stack resistance, as well as to indicate the affects of typical data runs on stack component contact.
- **IGT employs a solid state load device for polarization runs, general cell loading, and to facilitate resistance data taking.**
- **The basic design concept received a technical award by Motorola.**
- **A Tektronix scope and software trigger are used to generate an instantaneous interrupt to the current from the stack when on load.**

The distinguishably faster voltage drop exhibited by resistance mechanisms is captured and decoupled from the overall voltage drops on either an individual cell or overall stack basis.

This "resistance" voltage is then re-expressed as Ohms per cell and compared to those typical from other IGT cells.

- **Constant utilization polarization runs**

- **Frequency:** At least once per stack test
- **Fuel Utilization Range:** 75% to 25%
- **Oxidant Utilization Range:** 50% to 10%

- **Anode-to-cathode over/under pressure runs**

- **Will be performed if key performance goals are met**
- **Frequency and range will be determined by stack response**
- **Range of Anode-to-Cathode under pressures:** 0 to 15 inches of H₂O
- **Wet seal efficiencies and gas inlet/outlet compositions are monitored in addition to performance-at-load as key indicators of the stack's response to these parameter changes.**

- **Mass Balances**

- **Frequency:** Variable
- **Gas flow inlet and outlet flow rates and GC data are integrated to attempt mass balances around the stack, within the limits of wet seal efficiencies.**

- **"Dry" and "Wet" seal efficiencies**
 - **Frequency: Once per day**
 - **Actual flow out divided by theoretical flow out, by manifold. Correct outlet flows for water-gas-shift reaction thermodynamics at the integrated exit flow line temperature.**
- **Key operational data:**
 - **Key temperatures/levels/pressures/flows for the stack facility, stack furnace interior, and stack internal cells are all printed out at appropriate frequency in easy to understand process diagrams**
 - **While all data is stored on hard disk, all channel data tables are printed out at programmable frequencies.**
 - **Clamping fixture bellows pressure is constantly monitored and thermal expansions of fixture components are corrected for in an algorithm which is used for automatically maintaining a bellows pressure consistent with a constant holding force.**
 - **This stack will utilize LVDTs for tracking stack thickness shrinkages during startup and throughout the test.**

VII. SUCCESS CRITERIA

- **Evolves with stack testing experience**
 - **Initial stacks emphasized preliminary verification of the IMHEX™, internal manifolded concept of MCFC operation.**
 - **Subsequent stacks will emphasize integration of improved separator plate production methods, pore matching, active area coating, and wet seal protection schemes.**

VIII. TERMINATION CRITERIA

- **This verification test is 6 months in duration**
 - **It is expected that the planned IGT Stack No. 6 will be able to operate for the entire test duration allowed.**

Table 1. COMPONENT SPECIFICATIONS FOR STACK 6 (SDG&E-1)

ANODE

Ni + 10 Cr

CATHODE

Ni large pore

MATRIX

LiAlO₂

CARBONATE

70% Li/30% K

SEPARATOR PLATES

Main Plate: Ni-clad 316 SS

Main Rail: AISI Type 316 SS

Feed Rail: AISI Type 316 SS

WET SEAL PROTECTION

Aluminum on both anode and cathode rails

Table 2. CURRENT COLLECTOR SPECIFICATIONS FOR STACK 6 (SDG&E-1)	
	CATHODE
Open Area, %	33
Material	316 SS
	ANODE
Open Area, %	31
Material	Ni

Table 3. STACK 6 (SDG&E-1) HEATUP SCHEDULE

Phase of Operation	Temperature Ramps	
	From	To
	T1	T2
	°C	°C
Binder Removal	25	160
	160	380
	380	480
CO ₃ Melting	480	490
Postmelt	490	580
Cathode Oxidation	580	soak
Ramp to Process Gas Changeover	580	620
Process Gas Changeover	620	soak
Final Ramp to Steady-State	620	650

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