Test Module 02: Start-up
(Version 1.16, 14 March 2017)

Objective and Scope
This test module deals with the start-up procedure of solid oxide cells/stacks needed to achieve operating conditions. Start-up includes the heating step and if needed, the gas tightness and electrical contact optimization, the reduction and the conditioning of the SOC stack or cell. The start-up procedure should be given by the manufacturer. However, if there is no start-up procedure available, a recommendation is given in this test module.

Main Test Input Parameters (TIPs)

<table>
<thead>
<tr>
<th>Static TIP</th>
<th>Variable TIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of oven temperature change ($\Delta T_{oven}/\Delta t$)</td>
<td>Temperature of the oven ($T_{oven}$)</td>
</tr>
<tr>
<td>Temperature of the pre-heater ($T_{PH,in}$)</td>
<td>Flow rates of inlet gases ($f_{in}$)</td>
</tr>
<tr>
<td>Composition of inlet gases ($x_{in}$)</td>
<td></td>
</tr>
</tbody>
</table>

Test Procedure
- Set the flow for the negative ($f_{neg,in}$) electrode to $N_2$ or Ar. Set the flow for the positive electrode ($f_{pos,in}$) to air.
- Increase cell/stack temperature by setting $T_{oven}$ to the required sealing temperature. Increase the gas inlet temperatures (if possible) by adjusting $T_{PH,in}$.
- Hold time at sealing temperature according to setup requirements.
- Change $T_{oven}$ to the reduction temperature required by the SOCs. Initiate the reduction process (e.g. by increasing $H_2$ flow stepwise).
- Change $T_{oven}$ to the operating temperature; change the reactants to nominal operation flow/composition.

Critical Parameters and Parameter Controls
- A large temperature gradient between the gas inlets and the cell/stack should be avoided to reduce the risk of cell/stack damage

Main Test Output Parameters (TOPs) and Derived Quantities

<table>
<thead>
<tr>
<th>TOP</th>
<th>Derived Quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage of cell/stack (V)</td>
<td>Maximum temperature difference during start-up ($\Delta T_{max}$)</td>
</tr>
<tr>
<td>Temperature of gas streams at cell/stack inlet/outlet, temperature of cell/stack (T)</td>
<td></td>
</tr>
</tbody>
</table>

Data Post Processing and Representation

Representation examples of start-up:

Schematic example of startup procedure for non-reduced 5-cells SOC stack

SOCTESQA:
Solid Oxide Cell and Stack Testing, Safety and Quality Assurance
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