

Standardization in SOFC Testing

Abstract

The fuel industry has begun to pursue standardization of testing methods to enable comparison of results among participants: within laboratories, among different institutions, and perhaps most importantly, between supplier and customer. The solid oxide fuel cell (SOFC) industry has lagged in this pursuit, partially because of the uncertain relationship between material parameters, processing and performance, and partially because individual players have adopted individual testing methodologies. The lack of testing standardization has led to poor communication within the industry, inconsistent materials and component performance and to skepticism over results that are presented in various forums.

This paper offers methods to enhance comparability of results in the SOFC industry, including industrial efforts to standardize performance testing of SOFC trilayers, both in button format and moderate sized planar sheets.

SOFC Testing Fixtures, Test Protocols, and Standards

Two important challenges for testing in any industry are the determination of the essential parameters at every stage of manufacturing, and standardization of testing, an agreement among all stakeholders as to how the parameters should be measured. Standardization often requires a multi-year process to coordinate and compromise amongst the various measurement methods for each parameter, followed by round-robin testing to determine precision (reproducibility) and bias (difference of the average from an accepted ideal value if one is available). In many cases, a single parameter can be measured by multiple methods, and each method has its own standard methodology.

While standard test methods exist for physical properties of ceramic powders and the sintered parts, and consensus exists over which SOFC performance parameters are important (e.g. OCV and ASR), there is little agreement over testing apparatus, procedures or reporting at the cell, stack or device level. There are literature recommendations for preferred approaches to cell testing (1,2), but these have not been widely adopted. As a consequence, many laboratories have developed an assortment of individualized devices and testing procedures. This is particularly prevalent for “button” cells, which are single cells approximately 25 mm in diameter (or square). It is also true though to a lesser extent at the larger sized cell level. Examples of testing variations include cell shape, sealed versus seal-less designs, central gas flows versus edge flows, cell start up conditioning and property measurement procedures. Unfortunately such variations can lead to disagreements among labs as to the performance of an individual material or to the whole cell.

While the industry may not be ready for proscribed measurements of standard test methods, it is moving towards coordination of conditions, data analysis and data reporting. At least three organizations are engaged in such efforts, including the US Fuel Cell Council (USFCC), ASTM International in conjunction with the American Ceramics Society, and FCTESTnet in cooperation with the European Union’s RealSOFC project. The USFCC effort has recently released a SOFC related testing document. The document entitled “Introduction to Solid Oxide Fuel Cell Button Cell Testing”(3) is available for download from the USFCC website.

The purpose of this document is to describe typical apparatus and conditions for evaluating polarization (I-V) and AC impedance. The apparatus (Figure 1a) described in this Introduction consists of two chambers well sealed to the cell via gold, mica, glass or other sealing method. One of the “chambers” is spring loaded in order to apply pressure to the cell/seal. Fuel and air/oxidizer gases are fed via concentric tubes placed very close to the cell. Current collectors of platinum, nickel or gold meshes are connected to the cell utilizing metal pastes. Attaching the current collector to the cathode must be approached with some caution as migration of metals to the electrolyte-cathode interfaces can negatively impact cell

performance. For this reason the authors suggest using a minimal amount of metal ink be used to “tack” the current collecting mesh to the cathode followed by a more encompassing layer of cathode paste to provide the final bonding. In the “typical” design, the leads for electrical connection are fed through the seal materials. Ideally for I-V testing four leads should be used – two for current and two separate leads for voltage sensing. For AC-impedance three leads and special cell configurations are described.

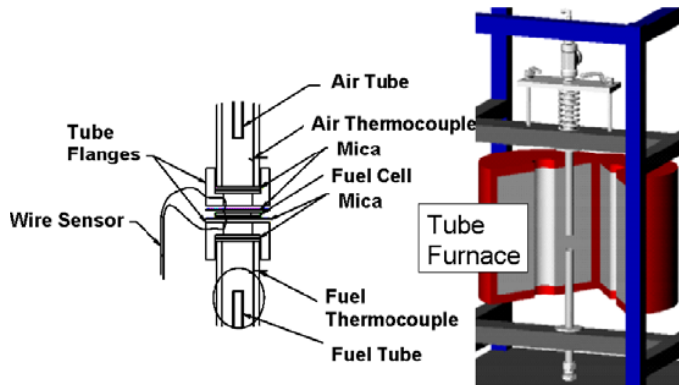


Figure 1a - Schematic of typical button cell test fixture [from (3)]

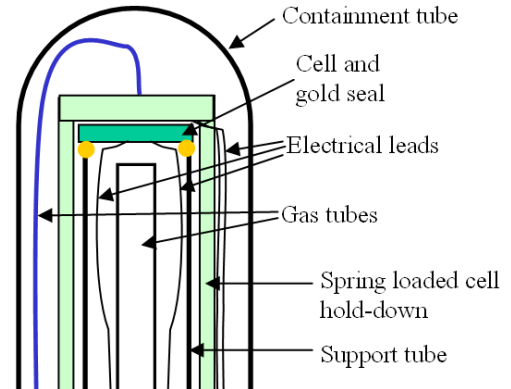


Figure 1b - Schematic of Probostat cell region

One of the challenges of the apparatus described is that it is not readily available – rather it is home-built and thus few devices will be identical. Variability in the test apparatus is a certain source of uncertainty in results. Fortunately there are now a number of commercially available test fixtures, such as the Probostat™ (Figure 1b), that conform to the basic design parameters of the apparatus described above, including spring-loading on the cell to provide sealing pressure. One benefit of commercial systems is the configuration of the electrical connections that removes the need to feed wires through the seal – thus improving the integrity of the measurement. Sealing is critical to achieving high open circuit voltage/potential (OCV).

While button cell testing is excellent for a number of purposes, mainly materials development and longevity testing, may not be indicative of performance of a cell in a stack, particularly for the measurement of fuel utilization (and in turn, efficiency). Again these measurements are typically performed in “home-built” test fixtures that are often considered proprietary, and therefore results are difficult to reproduce by design. Recent developments have led to two medium-scale (16-25 cm² active area) test fixtures being available – one commercial and one pre-commercial (4, 5). These are shown in Figures 2a and 2b respectively. In these fixtures one can additionally test thermal gradients in cells (particularly in the linear flow configuration of the 28 cm² fixtures), seal integrity and (potentially) the effects of interconnect materials and interconnect coatings. An example of fuel utilization testing with the Figure 2a fixtures is shown in Figure 3. This test uses a compressive seal with a modest amount of external compression. Note the high open OCV (indicating a satisfactory seal).



Figure 2a - Commercial 28cm² test fixture

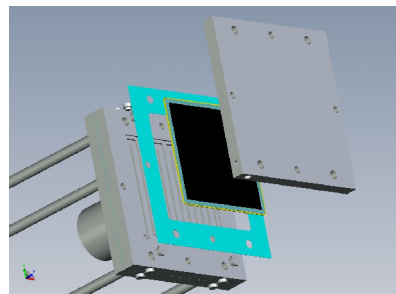


Figure 2b - Drawing of precommercial small-cell 16-25cm² test fixture/stack [from (4)]

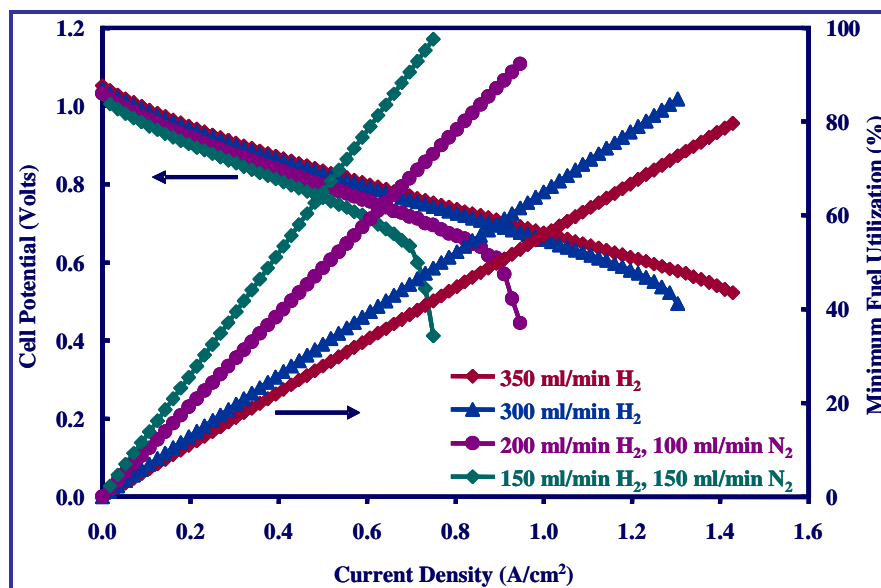


Figure 3 - Fuel utilization testing with 28 cm² test fixture

At present there is no globally accepted standard test cell against which all equipment and data can be compared. The ideal standard cell would be both easy to mount and seal, and would have sufficient, but highly reproducible performance over the entire temperature range. Sealing is quite important as without excellent sealing, fuel leaking into the air at the edge of the cell will react, lowering OCV and raising the cell temperature thus skewing the results.

Because there is no standard test cell test laboratories have two options: develop an internal standard or utilize a commercially available cell as a de facto standard. The benefit of commercial cells is the comparability of internal data against an outside source – i.e. test data provided by the supplier. Thus while internal standards provide a reasonable basis for intra-laboratory work, use of a commercial cell has the potential to provide inter-laboratory comparability.

The NextCell™ is one commercial test cell available in multiple formats. Introduced in November 2004, several dozen lots of the NextCell have been produced with great consistency as demonstrated in polarization curves (Figure 4). The NextCell has acceptable performance over a wide range of temperatures, with an ASR of 0.5 at 750°C (Figure 5). As an electrolyte supported product based on scandia-stabilized zirconia for strength, this cell is quite easy to handle and mount for testing. Furthermore, its dense electrolyte support provides an excellent sealing platform at the cell perimeter. These qualities make the NextCell an excellent candidate for standardization which can be used in the mean-time for test fixture baseline testing in development laboratories.

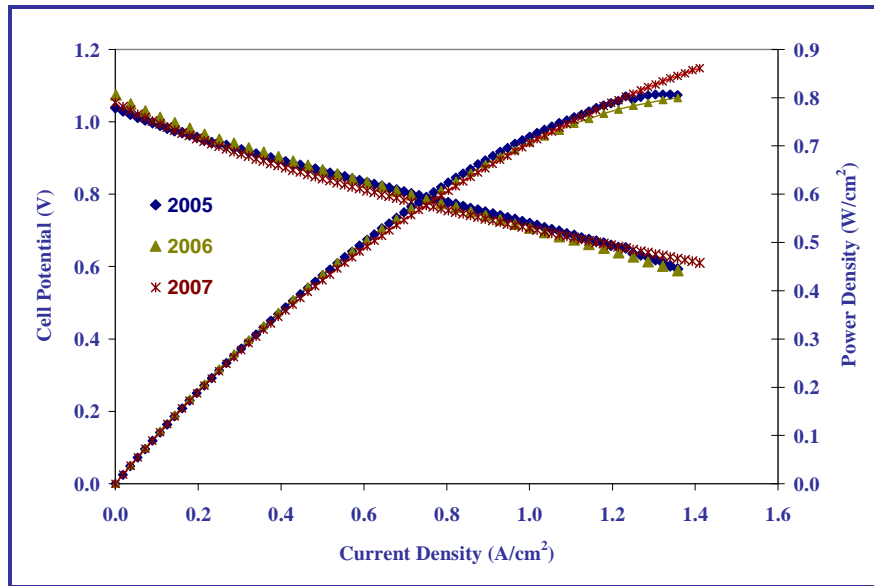


Figure 4 - Polarization and Power Curves at 850°C for 28 cm² NextCells from 3 lots over 3 years

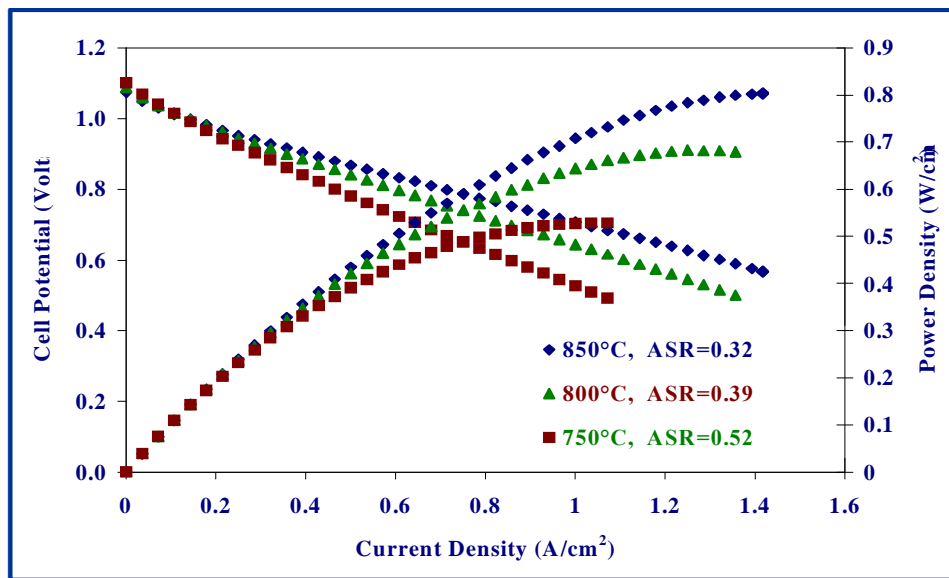


Figure 5 - Performance of NextCell over a wide temperature range

Concluding remarks

Though no standard procedure or material (cell) exists for SOFC testing, progress is being made. The USFCC document is a start in the right direction. Further work is needed, particularly on measurements for larger sized cells, stacks and systems. Additionally the variety, performance range and quality of commercial SOFC components and full cells offer the potential for improved comparability of data amongst various laboratories. By using full cells for test fixture baselining and partial cells as platforms for materials development and testing, a commonality of results can be greatly improved.

References

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