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TECHNICAL REPORT

Fuel cell technologies –
Part 7-3: Test methods – Status of accelerated tests for fuel cell stacks and components and perspectives for standardization

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FOREWORD

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IEC TR 62282-7-3 has been prepared by IEC technical committee 105: Fuel cell technologies. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
105/1091/DTR	105/1103/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62282 series, published under the general title *Fuel cell technologies*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

The scope of accelerated testing is to reduce the time for qualification of the degradation or the long-term performance of a specific cell, cell component, stack, stack module or stack component compared to testing at nominal operating conditions. To generate an accelerated test, operating conditions stress a test item or one of its components, usually through the exaggeration of one of the testing parameters (the so-called stress factor). The results of this test are expected to provide a comparative assessment of the robustness (or degradation) of the test item and possibly – through an established transfer function – an estimation of the projected lifetime of the test item under nominal (non-stressed) conditions.

An accelerated test thus cannot be a self-standing experiment, since it cannot be applied universally to all cell technologies, architectures or material combinations. Degradation phenomena are different and occur heterogeneously for different fuel cell (stack) technologies and in different operating modes. Also, different fabrication process of cells and components can lead to different responses under stressed conditions (although the responses at nominal conditions could be similar). In any case, for each accelerated test, a benchmark test item (operated at nominal conditions and adequately characterized) is necessary in order to have a meaningful reference against which the accelerated test can provide the required understanding of long-term durability of that same item. Nevertheless, actual long-term testing under normal operating conditions could be the only method to obtain an accurate degradation rate.

Tests on components (ex-situ tests) would only be relevant for comparison of such components, since the relevance for performance within a system can only be provided in the integrated assembly. For systems and end products, a generally applicable accelerated test for a given application (without the need for benchmarking) is certainly useful and is possible in the same way as there exist standardized drive cycles for vehicles/propulsion systems. However, it is still considered a major challenge to define an operating cycle that represents the actual application including events that contribute to degradation like start-stop cycles, air-air-starts, freeze starts, pressure and humidity cycles, temperature cycles etc. Nevertheless, standardized types of tests could be defined, generic for all types of fuel cells, with specific test conditions and cycles adapted to each application case and to each mission profile to be represented.

It is important to understand whether existing standards for testing performance of cells or stacks (e.g. IEC 62282-7-1 and IEC 62282-7-2, or IEC 62282-8-101 and IEC 62282-8-102) are sufficient for the definition of the testing approach, and only need a specific (quantified) definition of the required test parameters for them to be suitable for the accelerated estimation of durability or lifetime degradation. For example, an increase in operating temperature can be an accelerating test in solid oxide fuel cells (SOFCs). However, the measurements of electrochemical performance of cells/stacks at higher temperatures can be carried out according to the normal standard method (i.e. IEC 62282-7-2 or IEC 62282-8-101). The accelerated test is expected to enable an inference, from measurement of performance degradation at high temperature in this example, of the long-term durability of the tested cell/stack at nominal conditions (i.e. nominal temperature), and – crucially – in a shorter period of testing time than at nominal conditions. However, the increase of operation temperature (for example) can change not only cationic diffusion at the electrode/electrolyte interfaces but also the performance of electrodes/ionic diffusion. In this case, the one stress factor of increasing temperature can affect multiple performance degradation mechanisms of the SOFC, possibly with different time scales. Therefore, it will be difficult to univocally correlate an accelerating factor between degradation/lifetime in the test conditions and degradation/lifetime in nominal conditions. Defining a window of acceptance where the effects of one accelerating stress factor can be called representative of a single degradation mechanism can be a viable approach, even if other intrinsic mechanisms are affected to a lesser degree. To do this would likely require support from dedicated modelling activities, as well as by gathering the experience from manufacturers and comparing results with real long term durability tests.

In other cases, new, dedicated test procedures can be formulated to accelerate specific degradation mechanisms (e.g. controlled oxidation of solid oxide cell (SOC) electrodes to estimate redox stability).

In order to validate the reliability and representativeness of accelerated test procedures, post-test characterisation on samples having undergone tests are indispensable, also to compare the morphological/chemical state of test items after accelerated testing with samples from "real-time" ageing. Though this would fall outside the scope of TC 105, there is a description of such techniques and their applicability in Clause 4.

In this document, only intrinsic degradation mechanisms are considered, inherent to the operation of the cell/stack, and excluding degradation caused by externalities (impurities, shocks, etc.). Nevertheless, it is noted that an approach on contamination is still missing in the standards portfolio, both on fuel and air sides.

Finally, operating fuel cells in electrolysis mode will be considered, either for systems that can operate in reverse mode, or because it has been found that electrolysis mode can be a means to accelerate degradation mechanisms that occur in fuel cell mode.

This document has been compiled based on input from several National Committees and experts, convened in Ad Hoc Group 11 of IEC TC 105, and from two European projects funded by the Fuel Cells and Hydrogen Joint Undertaking (ID-FAST and AD ASTRA). The current Report represents a consensus on the status of accelerated tests for fuel cell stacks and components and outlines the perspectives for standardization of accelerated test procedures.

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1 Scope

The objective of this document is to answer several questions that have been circulating in the area of fuel cell development for many years: "What do we know about influencing fuel cell degradation, can we control it and accelerate it in a predictable way, is there a need for accelerated test procedures and can these be formulated adequately enough to be captured in international standards?"

This document is a generic assessment of the feasibility of standardizing accelerated test procedures (both proton exchange membrane (PEM) and oxide ion-conducting solid oxide cell (SOC) technologies) for fuel cell stacks that have been engineered for a specific system application. This document comprises a review of literature and projects, a discussion of the main physical phenomena of interest in accelerated testing campaigns (focusing on the cell and stack levels, not looking at the system as a black box), a compendium of measurement techniques that are applicable, and it suggests a macroscopic approach to the formulation of a representative accelerated testing campaign.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1.1
accelerated lifetime test
ALT
process of testing a product by subjecting it to aggravated operating conditions (stress, strain, temperatures, voltage, vibration rate, pressure etc.), thus in excess of nominal service parameters, in an effort to uncover faults and modes of failure in a short period of time to define explicitly its full lifetime

Note 1 to entry: This is thus a test for fast-forwarding time, and it is a destructive test in principle. Usually, it is conducted applying the more relevant failure stresses (this means that they are previously identified), aggravating normal conditions of use.

For example, if a manufacturer/supplier wishes to guarantee a product for e.g. 10 years, by ALT it can verify what is the risk to be accounted for, without waiting 10 years or more. This type of test is particularly relevant for components or systems that are to be introduced to the market.