EURAMET
European Association of National Metrology Institutes

TITLE: Metrology for Fuel Cells

Abstract

Fuel cells offer great promise as potential replacements or hybrid partners for gas turbine, internal combustion engine and battery technologies, but commercialisation is hampered by a number of factors such as material and processing costs, limited durability and safety considerations.

Joint Research Projects (JRPs) submitted for this topic should develop traceable measurements of fuel cells for the following parameters: temperature, gas composition, flow rate (including microfluidic flow), humidity, electrical potential and impedance, current density, and material integrity. The JRP should also develop in-situ and/or localised measurement of critical fuel cell parameters to improve model simulations that optimise fuel cell designs. The development of standardised techniques suitable for real operating conditions will enable the efficiency to be increased and contribute to improvements in performance and safety of fuel cells. JRPs should develop measurement procedures and reference materials with reduced uncertainty for fuel composition and quality. Special weight should be given to hydrogen as a fuel, given that impurities in hydrogen fuel can lead to a reduction in lifetime and performance of the fuel cell. The JRP should also detail how the knowledge obtained will be communicated to standardisation bodies such as ISO and ASTM.

Conformity with the Work programme

This Call for JRPs conforms to the 'EMRP 2008', section on "*Grand Challenges"* related to *Energy* on pages 8 and 23.

Keywords

Fuel cells, quality of fuels, fuel cell efficiency, fuel cell performance, operational parameters for fuel cells, fuel cell lifetime.

Background to the Metrological Challenges

In October 2008, the European Union and European Industry announced major plans to make fuel cells and hydrogen one of Europe's leading energy technologies of the future. A public-private Fuel Cells & Hydrogen Joint Technology Initiative has been initiated that will invest nearly 940 M€ over six years in research, technological development and demonstration of this new technology. The goal is to achieve mass-market roll-out before 2020.

European fuel cell manufacturers are principally operating in the development and demonstration phase. Lifetimes of many thousand hours are now routinely demonstrated under static load conditions. However, the reliability and durability of fuel cells remains a challenge under more realistic service conditions, i.e. stop/start, fluctuating load, fuel starvation and freeze/thaw.

The fuel cell industry recognises a clear need for the development of standardised accelerated test methods to enable manufacturers to optimise design without the expense and delay associated with long term testing. The challenge for any accelerated test is to ensure that it does not alter the degradation mechanism. Currently individual companies use their own in-house procedures, which are often not representative of service conditions. To support this nascent industry, a range standardised *in situ* and/or localised measurement techniques are required to facilitate the development of standardised accelerated test methods.

The development of *in situ* measurement techniques for fuel cells has been restricted to a small number of mainly academic publications. However, such *in situ* measurements are essential to provide insight into dynamic changes in cell characteristics. More pull-through by the metrology infrastructure to address the needs of industry is now required.

In addition, there is a fundamental lack of scientific understanding of fuel cell degradation modes and their relationship to system design and operating conditions. *In situ* and/or localised measurement techniques can be used to shed new light on the various degradation mechanisms.

One of the major factors in the development of hydrogen fuel cells is the damaging effect of impurities on fuel cell. Although 90 % of all hydrogen produced today is by the steam reformation of methane, a feature of the proposed hydrogen economy is that many different routes to hydrogen generation will be used. These will include the use of renewable sources (e.g. solar or wind) to generate electricity followed by electrolysis of water as well as through the thermo-chemical conversion of hydrocarbon fuels such as coal or oil. These diverse technologies generate hydrogen with different contaminating compounds. Further contamination may occur during storage. Although such contaminants may only be present at parts-per-million levels, they can act to cause either short-term or irreversible damage: effecting the life-time and performance of fuel cell systems.

In order to reduce the amount of impurities in the hydrogen fuel, clean-up systems are generally employed. However, the cost of fuel clean-up is proportional to the purity level achieved. The optimal level of hydrogen purity is therefore the result of a trade-off between the cost of H_2 production and the cost associated with fuel cell degradation. Determining the 'golden' balance of hydrogen purity required is a fundamental need of the fuel cell manufacturers and hydrogen gas producers.

Energy companies operating in Europe are reported to be developing specifications (e.g. ISO 14687/2, 2008) in order to initiate trade in hydrogen. It has been reported that there has been no agreement on the preferred analytical methods for the quantification of impurities. Work should focus on developing reliable and traceable (and cost effective) measurement of the "quality" of fuel, especially hydrogen, in terms of the concentrations of trace contaminant species that are known to damage the performance of fuel cells.

Overall applied metrological studies on this topic are very timely as fuel cell manufacturers throughout Europe are entering the phase in the development cycle where demonstrating reliability and durability under representative service conditions is key to successful commercialisation. In a competitive global market currently led by the US and Japan, acceleration of European development cycles is critical. The impact would be felt on a 3 to 5 year timescale.

Scientific and Technological Objectives

Proposers should aim to address all of the stated objectives. However where this is not feasible (i.e. due to budgetary or scientific / technical constraints) this should be clearly stated in the JRP protocol.

The objectives are based around the PRT submissions. As experts in the field, JRP proposers should establish the current state of the art, which may lead to amendments to the objectives - these should be justified in the JRP proposal.

1) Develop and validate measurement methods to determine the efficiency of fuel cells. These methods should be suitable for various designs of fuel cells and fuel types, and should include full uncertainty budgets.

2) Measurements to support standardisation and development of better fuel cells: Develop and validate especially in-situ / localised measurement techniques for the following parameters:
   a) Temperature
   b) Humidity
   c) Fuel composition
   d) Flow rate (including Micro-fluidics)
   e) Electrical potential and impedance
   f) Current density
   g) Material integrity

3) a) Develop measurement procedures and reference materials with reduced uncertainty for the quantification of fuel quality in terms of trace contaminant species that are known to damage the performance of fuel cells
   b) Investigate the influence of fuel components on degradation of fuel cells

Special weight should be given to hydrogen as the fuel (objectives 1 – 3). In addition, the safety of operation shall be addressed.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (eg letters of support) is encouraged.

Where a European Directive is referenced in the proposal, the relevant paragraphs of the Directive identifying the need for the project should be quoted and referenced. It is not sufficient to quote the entire Directive per se as the rationale for the metrology need. Proposals must also clearly link the identified need in the Directive with the expected outputs from the project.

In your JRP submission please detail the impact that your proposed JRP will have on the on the fuel cell manufacturing sector. Indicate how the proposed research activities will complement the activities of the Fuel Cells & Hydrogen Joint Technology Initiative (JTI).

You should also detail other Impacts of your proposed JRP as detailed in the document “Guidance for writing a JRP”.

You should detail how your JRP results are going to:

- Contribute to the further development of standards, for example ISO.
- Transfer knowledge transfer to the fuel cell manufacturing sector and producers and suppliers of hydrogen

If you proposal addresses any open issues surrounding the standardisation of measurements of hydrogen quality, then also describe how the proposed research findings will inform the development of further standards and how the knowledge will be transferred to the energy companies that are preparing to supply hydrogen.

Additional Information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

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