EMPIR Call 2016 – Energy, Environment, Normative and Research Potential

Selected Research Topic number: **SRT-g09**
Version: 1.0

Title: Metrology for safe and secure nuclear energy

Abstract

There is a pressing need to accelerate the development of advanced clean and safe energy technologies in order to address the global challenges in energy security, climate change and sustainable development. Nuclear energy as a major player of these energy technologies contributes significantly towards this commitment. Monitoring and refining important physical parameters such as temperature, thermophysical properties of materials, degradation of structural materials via neutron interactions, and radioactivity will improve the safety and long-term security in nuclear plants.

Keywords

Nuclear energy, fission, control, ionising radiation, neutrons, thermophysical properties

Background to the Metrological Challenges

Part of the EURAMET Strategic Research Agenda for Metrology in Europe is to build a European metrology infrastructure that better characterise and monitor the physical properties that are required to safely operate nuclear power plants.

Temperature measurements are required for the determination of several important parameters, e.g. fuel/clad temperature and fuel location inside reactor pressure vessel (RPV), hydrogen release and concentrations in most important locations of primary circuit and containment, RPV lower head temperature and integrity, corium temperature and location in the reactor pit, concrete ablation depth, etc. A capability that would improve temperature sensors and characterise their behaviour and stability either in high-temperature environment or under ionising radiation exposure would support these activities.

The development of innovative materials, with increased resistance to harsh operating conditions (high radiation doses and very high temperatures), has been identified by the Sustainable Nuclear Energy Technology Platform (SNETP) as a significant way to mitigate the consequences of severe accidents. The thermal properties of these materials as a function of temperature is essential for the modelling of less understood phenomena, such as core heating, post accidental heat removal, cool-ability of overheated and partially relocated reactor core and in-vessel core melt progression.

Many nuclear reactors operate way beyond their planned operating life cycle raising concerns about the integrity of structural materials under intense neutron bombardment. Reactor dosimetry determines the neutron parameters required to evaluate this degradation, and is crucial for the safety assessment of any nuclear reactor during its operational lifetime. Activation cross sections are used to determine the neutron spectrum employed to derive reaction rates in structural materials but improvements are needed to ensure safety. Some neutron cross section uncertainties need to be reduced as they have significant impact on the performance of future reactor cores (keff, reactivity coefficients, power distributions, etc.) or to their fuel cycle (transmutation potential, doses in waste repository, etc.), especially since fast reactor fuel will be heavily loaded with minor actinides (MA).

Current radiation monitors in Nuclear Power Plants (NPPs) cannot withstand the harsh environment close to the core in the primary coolant circuit. New types of detection and spectrometry systems with appropriate signal processing are required. Calibrations or verifications have to be done in-situ during reactor outages challenging the high levels of radiation background and limited access of the personnel. New techniques and calibration procedures are needed for ensuring the proper functionality of these critical safety systems. Understanding the cooling flow dynamics has always been one of the main driving forces behind nuclear fuel research. Imaging with fast-neutrons is considered a highly promising technique to characterise 2-phase low-Z coolant flows around high-Z mock-up fuel bundles.

The nuclear fuel industry invests substantial efforts in optimising and enhancing the safety of their fuel bundle design. Such designs are typically tested with electrically heated mock ups that are full-scale and operate in prototypical conditions (high pressure, high temperature). Due to these demanding conditions, such facilities are usually equipped with relatively simple instrumentation that lack high-resolution measurement techniques. The application of non-intrusive neutron based probing techniques will make the quantitative measurement of many hitherto inaccessible parameters feasible.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the traceable measurement and characterisation of physical parameters (temperature, thermophysical properties of materials, degradation of structural materials and radioactivity) that are important for safety and security in nuclear power plants

The specific objectives are

1. To develop and metrologically characterise, in specific conditions, improved temperature sensors (up to 1500 °C) for nuclear applications and improve quantitative understanding of the ionising radiation effect on the calibration drift and failure modes of existing sensors.
2. To develop and/or improve methods and facilities that will perform traceable measurements of thermo-physical properties in advanced materials, under temperature conditions similar to those encountered in severe accidents (i.e. up to 3000 °C)
3. To improve cross section data used to determine reactor neutron spectra, and reduce the uncertainty in neutron cross-sections related to the fission process and fuel cycle (e.g. transmutation potential, doses in waste repository). To improve nuclear decay data of radionuclides relevant to nuclear safety, including emission probabilities of minor and/or major actinides, present in current and/or future NPPs
4. To develop and/or metrologically characterise nuclear instrumentation dedicated to the early detection of developing deviations from normal operation, accident and post-accident monitoring of primary circuit in nuclear reactors (fuel cladding rupture, fuel cell covering integrity breach, etc.). To also characterise methods for in-situ calibration of accident range dose rate monitors, neutron imaging methods for two-phase flow metrology, and quantify thermal hydraulic conditions in fuel bundle models.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (instrument manufacturers) and end users (energy sector, nuclear plants) and to support the development of new standards (e.g. ISO standards)

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art, and explain how their proposed research goes beyond this. In particular, proposers should outline the achievements of the EMRP project ENG08 MetroFission and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.0 M€, and has defined an upper limit of 2.3 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 35 % of the total EU Contribution to the project.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the nuclear sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.