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Work Package 6 – Materials and component qualification: testing,
standardization and design rules

Deliverable 6.1 – 6.1.1: Research Line 3 contribution to the call preparation: scope, expectations, expected impact, KPIs

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List of abbreviations

AI	Artificial Intelligence
AQP	Accelerated Qualification Path
FAIR	Findability, Accessibility, Interoperability and Reusability
KPI	Key Performance Indicator
QMS	Quality Management System
R&D	Research and Development
RL3	Research Line 3
TAG	Technical Advisory Group
TB	Characterization Test Bed
TSO	Technical Support Organisation

Summary

The CONNECT NM co-funded European partnership offers support for the realisation of activities focussed on boosting innovation in the field of nuclear materials. The candidate participants in the projects are asked to submit proposals for specific topics in line with the scopes and objectives of the Partnership. The activities of the third Research Line (RL3), “Materials and component qualification: testing, standardization and design rules”, are expected to be centred on the implementation of Nuclear Materials Characterization Test Beds (TBs), involving infrastructures/skills at European level, to evaluate, develop and implement Accelerated Qualification Paths (AQPs) for materials and components. Deliverable D6.1.1 provides a general description of the RL3 of the CONNECT NM co-funded European partnership. The document provides a full set of information regarding the scope, expectations, high level milestones, expected impact and Key Performance Indicators (KPIs) for the RL3 proposals, in preparation of the first Open Call for projects.

Introduction

Currently, the time for the qualification and codification of new materials for nuclear applications is too often measured in decades and to exploit the full potentiality of nuclear energy in connection with the energy transition, by deploying next generation reactors within the 2030s, qualification time needs to be reduced drastically. The approach proposed in the RL3 of CONNECT NM to achieve this target, is by combining two connected approaches:

- To evaluate, develop and implement Accelerated Qualification Paths (AQPs) that depend on the class of material, the nuclear system and the level of targeted innovation.
- To integrate, coordinate and operate test facilities under joint ‘Test Beds’ (TBs), to carry out the qualification in a realistic timeframe.

The TBs will result from the coordinated exploitation of present and future European facilities and infrastructures and their rationalized use under a Quality Management System (QMS). The optimization of data harvesting by the coordination of infrastructures will be indeed the first step forward contributing to accelerate nuclear materials qualification processes. The TBs will implement a novel approach in qualification, resulting from the integration of modelling and predictive capabilities, the use of databases, appropriate data management and harvesting techniques in current paths as accelerators. The possibility of using accelerated testing for design will be assessed and the relative standardized protocols or guidelines developed.

This document provides the guidelines for the first Open Call for Proposals for the CONNECT NM RL3 and outlines the Scope and Objectives, the expected Results and Impact as well as the key Performance Indicators to measure the progress toward the specific goals of the research line.

Scope and objectives

Materials R&D and qualification in nuclear is intrinsically a complex and time-consuming process, largely determined by the testing and irradiation requirements. To date, qualification is based on the ‘observe and qualify’ approach, i.e. by conducting primarily standardized tests of representative material batches in a sequential way. Data are then processed into engineering properties and design rules are derived and eventually included in materials design codes or fuel performance codes. The main bottleneck in this approach is the time required for long-lasting qualification tests e.g. creep, corrosion, irradiation and microstructure evolution under conditions representative of operating and incidental situations. In some cases, reducing the time needed to carry out testing is challenging, so the focus is on minimizing the reliance on long-lasting tests and, in general, experimental data that are difficult to obtain, increasing the number and quality of the information learned from the samples investigated.

This can be achieved by developing AQPs, which represent the crucial step towards the more advanced ‘design and control’ paradigm. They are based on the integration of modelling and predictive capabilities in targeted characterization procedures, which may include non-destructive testing and examination, optimizing data harvesting and management, by means of advanced (machine-learning and AI based) data analysis methods. The support of modelling, data management and data-driven design of experiments can indeed help to:

- reduce the number of long-lasting tests or data that are difficult to be obtained,
- increase the throughput of the tests,
- improve the use of testing while maximizing the acquisition of relevant data,
- develop and/or apply accelerated tests,

This last issue is addressed via:

- separate effect testing,
- use of ion irradiation to emulate neutrons,
- accelerated aging and creep,
- use of miniaturized sample testing

with the ability to extrapolate the resulting data to operational conditions.

Pre-normative R&D activity focused on innovative test methodologies that can quickly evaluate key design properties and performances through simple tests will offer efficient and effective tools for assessing advanced designs. Despite often not suitable for licensing, due to the strict constraints of the regulations regarding the geometry, size of the samples and number tests, innovative test methodologies, together with ion irradiation, can support and guide the licensing of materials. Nevertheless, the acceptability of accelerated testing for licensing should be assessed for specific issues in collaboration with regulatory bodies and their technical support organizations.

Another issue to be addressed to reduce the qualification time relates to the fact that, conventionally, data are produced in different laboratories and facilities, often with little or no coordination of the work. Such approach suffers from several limitations: different characterizations protocols and poor alignment of the tools used, as well as differences in fabricating representative samples and measuring environmental parameters.

An optimized approach should focus on increasing the completeness of the information attainable from investigations where high-quality samples are fully characterized in highly specialized facilities connected under the same quality system. We refer to such networks as Test Beds (TBs), i.e. integrated platforms that enable exhaustive and repeatable testing on materials, in accordance with specific and possibly accelerated procedures for the intended use. TBs should ideally include various experimental testing and characterization facilities, including irradiation, and be coupled to advanced modelling and data management. The optimization of data harvesting by the coordination of infrastructures across Europe will be indeed the first step forward contributing to accelerate nuclear materials qualification processes.

The classes of materials that need continued R&D and qualification has been identified by the Technical Advisory Group (TAG) in the ORIENT NM Project (Grant agreement No. 899997)

- Structural metallic materials,
- Cladding materials,
- Fuels,

- Concrete.

The implementation of the above-described optimized approach, based on AQPs and TBs, is the objective pursued by this research line. It will lead to the integration of specialized European infrastructures and laboratories into a single delocalized entity, acting as hub for pre normative research.

The implementation of stable organizational and legal structures for the TBs for nuclear materials will be part of this effort, especially in order to make these TBs open, i.e., to create a single entry point for nuclear materials qualification in Europe, open to any potential customer, according to appropriate rules of intellectual property protection.

Expected results

Projects proposed in this research line are expected to establish a characterisation TB on specific issues and contribute to the development of AQP's by adopting a novel approach resulting from:

- integration of modelling and predictive capabilities and/or non-destructive testing and examination tools in current paths as accelerators,
- development of new accelerated tests with relevant protocols and/or suitable data harvesting methodologies and management,
- development of protocols for currently non-standardised tests, including small specimen testing,
- alignment of tests, protocols across participating partners and/ or labs, as well as sharing/exchange of dedicated test material across partners.

The definition and development of AQPs are expected to be carried out with special applications in mind as case-studies (i.e. specific nuclear system and/or material) based on the priorities and urgencies to support deployment, according to the choice of the proposing consortium.

- For the implementation of AQP's, the proposals must include the cooperation with the regulatory bodies, their technical support organizations and the relevant stakeholders across Europe (e.g., CEN, CENELEC, ETSI, ISO, IEC, ITU, EEEIC, industry), identify the standardization framework, existing standards and the testing plan towards standardization.
- The development of harmonized guidelines, best practices and standards will be considered as pillars, and projects devoted to these aspects will have the priority. Round robin tests to assess the quality of the protocols are advised,
- For the correct operation, in application of standardized and accelerated qualification paths, the proposals will necessarily require the implementation of a TB Quality Management System,
- Proposal shall implement advanced data analysis and storage: collect data in dedicated shared points for the consultation between the partners of the TB. The

accessibility and reusability of data produced will be assured by a complete set of metadata in agreement with WP4 data management,

- Proposals should include actions designed to facilitate cooperation with the projects of the other RL's of CONNECT NM and enhance their involvement,
- The proposals shall provide a clear description of how the activities will effectively contribute to take a step forward towards the selected objectives and address all the legal, political and managerial aspects.

The final output of this effort will be the implementation of stable organizational and legal structure, a single entry-point for specific issues for the accelerated qualification of materials and components, open to any potential customer.

Expected outcome and impact

A project proposal should clearly indicate its expected outcome and impact, and should align with the higher level objectives, as laid out in the Grant Agreement

“Structured consolidation of the European research community on nuclear materials”

The construction of TBs, by integrating and coordinating the use of infrastructures for qualification of nuclear materials, will represent a strong step forward towards the consolidation of the relevant European research community and will allow effective resource allocation, avoid redundancies, inefficiencies, and missed opportunities.

“Improved interaction of the nuclear materials research community with nuclear industry, private companies, European nuclear regulatory bodies and their technical support organisations”.

Within this research line the interaction with industry, regulators and TSOs will be indeed an integral part of the relevant projects, also via direct involvement in the RL projects, supporting the work performed. Proposals including at least one end-user (industry, TSO, regulator ...) in the project consortium will have the priority.

“Contribute to maintaining the high level of safety of nuclear installations for current and future fleets, in full compliance with relevant European regulations”.

The definition of AQPs, with the approval of the regulators, by enabling the fast deployment of better performing materials will provide a strong contribution not only to maintaining, but in fact also to strengthen the level of safety of current and future European nuclear installations. Standardized and quality controlled experimental procedures and methodologies will enable the reliability of the data to be drastically increased, and thus the reliability of the qualification process, with subsequently increased safety.

“Develop scientific knowledge and technological expertise applicable to the nuclear materials domain, including the coordinated use of infrastructures for materials qualification with sustainable quality assurance, and the production of reliable nuclear databases that meet FAIR principles”.

The TBs will constitute an effective way to coordinate the use of infrastructures for nuclear materials. Their correct operation, in application of standardized and accelerated qualification paths, necessarily will require quality assurance practices to be followed, as well as FAIR data. Such joint approach will help European players to remain at the

forefront of the nuclear materials R&D assuring improved competitiveness of Europe at the world scale, in this dynamic technology domain.

“Promote a culture of continuous improvement and change of paradigm in materials science, supporting the growth of sustainable practices within the nuclear industry”.

The scope of the action is focussed on the faster exploitation of innovative materials and materials solutions by adopting a method that is in many ways revolutionary for the qualification of materials and components, compared to the conventional ‘observe and qualify’ approach. The implementation of this innovative approach within the RL projects has the potential “per se” to be a game changer in the adoption of an innovative approach in characterization and qualification of nuclear materials fostering the development of new knowledge and skills to shift habits of practice towards sustainable practices within the nuclear industry.

Key Performance Indicators (KPIs)

On-time Delivery

Metric: average time delay with respect to the schedule (dd) in the delivery of project Deliverables + average time delay with respect to the schedule (dd) in the achievement of Milestones (40 dd Max)

Development of AQPs for materials and components, harmonized guidelines, best practices and standards

Metric: number of code evolution proposals filed (at least 2)

Collaboration effectiveness with industry, regulators and TSOs

Metric: number of joint publications in (gold) open access peer reviewed journals completed with industry, regulators and TSOs. (at least 2)

Research output rate

Metric: number of research papers on the RL3 domain in (gold) open access peer reviewed journals (at least 5)

Reference

Section 1.2.2.2 of the Annex I to the Grant Agreement.



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