INSPYRE
Investigations Supporting MOX Fuel Licensing in ESNII Prototype Reactors

D9.4 – Synthesis of the First User Group Meeting

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SUMMARY

This deliverable presents a synthesis of the exchanges of the INSPYRE project with its User Group that took place during the first meeting organised on August 29th, 2018 in Paris Charles de Gaulle, France. This report first recalls the scientific approach and the objectives of INSPYRE and the role and composition of the User Group. It then presents the research programmes of the users and their needs in the area covered by the project. Finally, the specific and common needs of these stakeholders are analysed and topics for the future exchanges, as well as a possible schedule, are proposed.

CONTENT

GLOSSARY

ALFRED	Advanced Lead Fast Reactor European Demonstrator
ALLEGRO	Gen-IV helium-cooled fast reactor
ASTRID	Advanced Sodium Technological Reactor for Industrial Demonstration
FALCON	Fostering Alfred CONstruction: International consortium targeting the design of ALFRED
FUROM-FBR	Fuel performance code used at MTA EK
Gen-IV	Generation IV International Forum
JOG	Joint Oxyde-Gaine
JPNM	Joint Programme Nuclear Materials
LFR	Lead Fast Reactor
IAEA	International Atomic Energy Agency
INSPYRE	Investigations Supporting MOX Fuel Licensing for ESNII Prototype Reactors
MACROS	Fuel performance code used at SCK•CEN
MOX	Mixed Oxide
MS	Milestone
MTA EK	Hungarian Academy of Sciences Centre for Energy Research
MYRRHA	Multi-purpose hYBrid Research Reactor for High-tech Applications
NEA	Nuclear Energy Agency
OECD	Organization for Economic Co-operation and Development
ROG	Réaction Oxyde-Gaine
TAF-ID	Thermodynamics of Advanced Fuels – International Database
TRANSURANUS	Fuel performance code developed at JRC-Ka
UG	User Group
WP	Work Package

1 INTRODUCTION

The aim of this deliverable is to synthesise the first exchanges of the INSPYRE project with its User Group. This report follows the first meeting between INSPYRE representatives and the members of the User Group that took place on August 29th, 2018 in Paris Charles de Gaulle, France. It gathered

- on the one hand the INSPYRE coordinator Marjorie Bertolus, CEA, several work package leaders, Christine Guéneau, CEA (WP4), Marco Cologna, JRC-Karlsruhe (WP5), Lelio Luzzi, POLIMI (WP7), and Flora Errecart, LGI, from the project management office,
- and on the other hand the User Group members: Akos Horvath, MTA EK (ALLEGRO), Nicolas Devictor, CEA (ASTRID / SFR development programme), Marc Schyns, SCK•CEN (MYRRHA), Frédéric Laugier, EDF, as well as Véronique Garat and Dominique Favet (ORANO).

NB: Giacomo Grasso, ENEA (ALFRED) was unable to attend at the last minute and his input was given by Lelio Luzzi.

The goals of the meeting were threefold:

- to present the INSPYRE approach and activities to the users,
- discuss their specific and common needs in the area covered by INSPYRE and
- obtain feedback from the users concerning the topics of interest within the timeframe of the project, as well as longer term objectives.

This report is organized as follows. First, the INSPYRE approach and objectives are summarized in Section 2. Then the INSPYRE User Group is recalled (Section 3). Section 4 briefly describes the end-users programmes for which the activities of INSPYRE are of interest. Section 5 analyses the common needs for all the programmes with respect to INSPYRE research activities. Finally, topics of interest for future meetings are listed in Section 6.

2 INSPYRE APPROACH AND OBJECTIVES

Fuel performance predictions for licensing under normal operation and accidental conditions have relied traditionally upon extensive integral irradiation testing (full length pins and assemblies) to generate empirical laws. Though eminently successfully deployed for the four fast reactors operated in Europe thus far, they are not easily extrapolated to other conditions (high Pu content, low temperature operation, coolant interactions, etc.) prevalent for the licensing of first uranium-plutonium mixed oxides (MOX) cores for the reactor systems of the European Sustainable Nuclear Industrial Initiative (ESNII).

Leveraging the knowledge from past integral irradiation testing programmes is essential to overcome the challenges of timely cost-effective licensing of ESNII first cores. The solution lies in a basic science approach to develop the intricate models underpinning the empirically derived performance laws, so that they can be extended into other operational regimes. A first proof of principle of this approach was made on uranium dioxide in the F-BRIDGE project (2008-2012).

The goal of INSPYRE is to bring a thorough understanding of performance issues of fast reactor MOX fuel in normal and off-normal conditions through harnessing of basic and applied science. To this aim it will:

1) Utilise out of pile separate effect investigations to underpin basic phenomena governing fuel behaviour with soundly based physical models. This approach is applied to four important operational issues: margin to fuel melting; atom transport and fission product behaviour; evolution of mechanical properties under irradiation; fuel thermochemistry and interaction with the cladding.
2) Perform additional examinations on selected irradiated samples to yield data when too little is currently available.
3) Combine the results of the separate effect experiments, physical modelling and simulation, and integral neutron irradiation tests to extend the reliability regime of traditionally deduced empirical laws governing various aspects of nuclear fuel under irradiation.
4) Use the models developed to enhance the efficacy of operational fuel performance codes and to improve their reliability in normal and off-normal situations.

3 PRESENTATION OF THE USER GROUP

The INSPYRE project aims at transferring the approach developed and the progress made in the project with the industrial actors in charge of the present and future development of nuclear fuels, and as well with the manufacturers of these fuels and with the designers and utilities operating the reactors using these fuels. For this reason, a User Group involving representatives of ESNII, of the specific ESNII prototypes targeting the use of MOX fuel (ALFRED, ALLEGRO, ASTRID, MYRRHA), as well as of fuel manufacturers, utilities and TSO, was constituted within INSPYRE. The regular interaction between the partners of INSPYRE and the members of the User Group will ensure an efficient two-way transfer of knowledge between INSPYRE and the industrial scene. Several User Group meetings are planned during the project.

Table 1: List of the INSPYRE users

Initiative/Role	Organization	Representative	Title
ALFRED	Ansaldo Nucleare ENEA	Alessandro Alemberti Giacomo Grasso	Head of the Nuclear Science and Development Department Core designer of FALCON consortium
ALLEGRO	MTA EK	Akos Horvath Zoltan Hozer	Director General Head of Fuel and Reactor Materials Department
ASTRID	CEA	Nicolas Devictor	Head of CEA/DEN programme on Gen IV nuclear reactors
Fuel manufacturer	ORANO	Véronique Garat Dominique Favet	In charge of R&D on safety of nuclear fuels Consultant, ex AREVA fellow expert in MOX fuel fabrication plant
MYRRHA	SCK•CEN	Hamid Aït Abderrahim Marc Schyns	Deputy Director General R&D Programme Manager of the MYRRHA project
Utility	EDF	Frédéric Laugier	Expert on back-end of nuclear fuel cycle

4 END-USERS PROGRAMMES

In the following, the specific needs of each user are synthetized, followed by a summary of their common needs in the area of the INSPYRE project activities.

4.1 ASTRID / Sodium Fast Reactor development programme

The ASTRID programme had the purpose to demonstrate, at a sufficient scale, the technological progress by qualifying the innovative options during its operation, in particular in the fields of safety and operability [1]. To pursue this long-term objective, the new ASTRID plan sets objectives to acquire experimental data and feedback experiences in support to the sodium fast reactor development program (and associated cycle). These objectives (which are closely related to research topics under investigation in INSPYRE) include: (1) the capability to demonstrate fuel performances depending on the different options for the management of actinides; (2) the acquisition of experimental data targeting the validation of simulation tools; and, as final objective, (3) the demonstration that industrial performances can be reached by sodium fast reactors.

As of 2019, the ASTRID programme has become the Sodium Fast Reactor development programme. The goals are similar but the building of a prototype reactor is not decided upon yet.

4.2 MYRRHA

MYRRHA is the very first prototype in the world of a nuclear reactor with a significant thermal output driven by a particle accelerator. The MYRRHA reactor adopts MOX fuel pins with a stainless-steel cladding, cooled by lead-bismuth, to be utilized in a fast neutron spectrum. The Belgian Nuclear Research Centre (SCK•CEN) is actively working on designing and building this multifunctional research installation in Mol [2,3,4].

The INSPYRE research activities relevant for MYRRHA are:

- The benchmarking of fuel performance codes (such as TRANSURANUS and MACROS) and the availability of experimental data on in-pile fuel behaviour in past fast reactor tests is of importance for the development and qualification of the MYRRHA driver fuel.
- The compilation of material property data of MOX fuel and the subsequent derivation of material correlations that can be implemented in the fuel performance codes allows for an improved accuracy in the simulation of MYRRHA fuel and a reduction of uncertainties in the safety margins. In that latter context, better understanding of basic fuel properties (e.g., the MOX melting point), which are to be explored in INSPYRE, are of key importance to MYRRHA.

4.3 ALLEGRO

ALLEGRO is an experimental fast reactor cooled with helium being developed by the European V4G4 Consortium of the nuclear research organizations of the Czech Republic, Hungary, Poland and Slovakia associated with CEA, France [5]. Development of ALLEGRO is an important step on the way to the Gas-cooled Fast Reactor, one of the six concepts selected by the Generation IV International Forum and one of the three fast reactors supported by the European Sustainable Nuclear Energy Technology Platform.

MTA EK participates in the development of ALLEGRO gas cooled fast reactor in the framework of V4G4 consortium and is responsible for the selection and qualification of fuel for the start-up and refractory cores. The MOX fuel investigated in the INSPYRE project is one of the candidates for the start-up core, and for this reason the results of the project will be very useful for MTA EK. Following the presentations of INSPYRE representatives on the project activities, it was identified that:

- The improved MOX fuel properties could be used for the development of new physical models to be used in the FUROM-FBR code used at MTA EK.
- Furthermore, the experience of using numerical codes by INSPYRE partners for benchmark calculations could be a good example for other fast reactor fuel modellers and the valuable fast reactor history data used in the project could be of high interest for the validation of FUROM-FBR code.

Moreover, research on fabrication processes is also of high importance for ALLEGRO fuel selection and qualification.

4.4 ALFRED / FALCON Consortium

ALFRED is a research reactor aiming in the short term to demonstrate the viability of the general LFR concept and in a longer term to support the safe and sustainable operation of the envisaged fleet of industrial systems [6]. As responsible for the core design of ALFRED within the FALCON (Fostering ALfred CONstruction) International Consortium in charge of developing the latter, ENEA supports the activities related to the advancement of the knowledge and simulation capabilities for nuclear fuels.

ENEA, on behalf of FALCON, is very favourable to the activities of the INSPYRE project and acknowledges their relevance, in particular:

- What concerns the understanding of microscopic phenomena and the further development of models and tools for their analysis.
- The aim of feeding a shared database of fuel properties retrieved from the modelling and the detailed examination of samples irradiated in fast-reactor-relevant environments.
- The availability of such a database, and the benchmarking round robin performed to validate the available codes and the advanced models, are believed to be a steppingstone in the European fuel design and analysis capabilities.

4.5 EDF

EDF is the first electricity producer and supplier worldwide. The role of its R&D in the nuclear field consists in leveraging the considerable knowledge of the EDF industrial group, targeting optimization of the fleet operation, lifespan extension of the operating reactors, and back up the development of Gen-IV nuclear power plants.

Within this framework, the specific needs of EDF towards the INSPYRE project can be summarized as:

- Demonstration of FR MOX assemblies' general performances, including economical performances, enhancement of industrial processes for fabrication and reprocessing.
- As a long-term objective, understand the behaviour of FR MOX with Pu coming from the recycling of irradiated MOX, i.e., assemblies with high Pu content (about 30% and more) and with up to 4 wt.% in ^{238}Pu isotopic content. This includes the understanding of the behaviour of irradiated FR MOX during interim wet storage and of fresh and irradiated FR MOX during transportation.

4.6 ORANO

ORANO is a MOX fuel manufacturer and operates the MELOX plant in France. ORANO would be the fuel manufacturer for future French Gen-IV prototypes and reactors. Even if no studies of fuel fabrication are explicitly included in INSPYRE, the project will help the designers in identifying with more accuracy the fabrication parameters. The INSPYRE approach involves the comparison between experimental data and modelling, which is of primary importance in order to validate the ranking of important parameters (including those linked to fuel fabrication) and to reduce the occurrence of any modelling artefact.

5 COMMON NEEDS FOR THE FUEL OF ESNII REACTORS

In view of the approach and objectives of INSPYRE outlined in Section 2, a set of common needs for the fuel of ESNII reactors emerged as of interest within the expected timeline of INSPYRE, namely:

- The benchmarking of fuel performance codes (WP7) on relevant fast reactor irradiation cases ensures improved confidence in fuel performance simulations, supporting the design (and, in perspective, licensing and operation) of Gen IV fast reactors.
- The inclusion in fuel performance codes (WP6 and 7) of improved MOX properties obtained in WPs 1 to 5 is important for the users. More generally the availability of updated and accurate MOX

properties and behaviour models, even if not yet implemented in code, will be useful for them, since it will constitute the basis for future improvements of fuel performance codes.

- The assessment of fuel performance codes for their application to fast reactor conditions is a goal of the INSPYRE project whose importance is recognized by the User Group. Extending and improving the validation results of fuel performance codes is key for their effective use.

Moreover, a set of long-term-oriented needs has been identified. These concern activities that are (at least partially) ongoing in INSPYRE, but on a more extended time frame, since they represent cutting edge research activities. These are in particular:

- The interaction between the fuel and the cladding. Within the INSPYRE project, investigation of the JOG formation is planned, with the aim of improving its modelling and description in fuel performance codes.
- The demonstration of improved predictive capabilities of fuel behaviour during accidental transient conditions. Within the INSPYRE project, modelling and simulations activities are limited to operational conditions, but the relevant cases identified within the project pave the way for the future analysis of transient conditions.

Finally, other topics of general interest, which will be considered for discussion during the next User Group meetings, include:

- The availability and use within INSPYRE of past experimental information.
- The understanding of modifications required if fuels with high Am-content are considered, and more in general research activities concerning transmutation fuels.
- Fuel fabrication processes (not considered in the INSPYRE project).

6 OUTLOOK: PERIODIC MEETINGS

The communication strategy envisaged between the User Group and the INSPYRE partners involves periodic meetings along the duration of the project.

In view of the users presentations and the analysis of their common needs, a first important topic to be discussed with the users is the progress of the activities of the INSPYRE task force on fuel performance codes, i.e.,

- the selection of relevant irradiation experiments in terms of INSPYRE goals and users' needs, on which the current predictive capabilities of fuel performance codes can be assessed. This activity is going to be reported in the INSPYRE Deliverable 7.1 (due in August 2019).
- the preliminary results of the assessment itself, in particular the code-to-code benchmark activities, whose final results will be presented in Deliverable 7.2 (due in August 2020).

The involvement of the User Group will also be essential in the definition of the relevant case studies representative of ESNII reactor conditions, to be used for the further assessment and benchmark of fuel performance codes. This will constitute the focus of the second User Group meeting, which will be organised in 2019. The final results of this assessment will be presented during the final INSPYRE workshop, to which INSPYRE end users will be invited.

A subsequent meeting could focus on the presentation of the improved properties of the MOX and JOG obtained and on the identification of gaps.

The topic of a fourth meeting could be the identification of the specific research needs for the fabrication of GEN IV MOX fuel and for the description of transient conditions, which would serve as basis for future activities.

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