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Operation and Utilisation of the High Flux Reactor

Annual Report 2013

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Abstract

The High Flux Reactor (HFR) at Petten is managed by the Institute for Energy and Transport (IET) of the European Commission's Joint Research Centre (JRC) and operated by the Nuclear Research and consultancy Group (NRG) which is also the licence holder and responsible for its commercial activities. The High Flux Reactor (HFR) operates at 45 MW and is of the tank-in-pool type, light water cooled and moderated. It is one of the most powerful multi-purpose materials testing reactors in the world and one of the world's leaders in target irradiation for the production of medical radioisotopes.

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1 Introduction

In 2013, NRG was faced with unplanned outage of two nuclear facilities, namely the High Flux Reactor (HFR) and the Molybdenum Production Facility. To avoid future unplanned outages, NRG has put all its facilities and related processes from 15 November 2013 in a temporary safe standby mode to focus on improvements in technology, procedures and organization. The improvements that were required to restart the HFR have been carried out and implemented. The same applies to the Facility Decontamination and Waste Treatment, the Jaap Goedkoop Laboratory and the Hot Cell Laboratories. The HFR and most other nuclear facilities were put back into operation in February 2014. The Molybdenum Production Facility followed two months later. More detailed information concerning the HFR operation is given in section 2.

2 HFR Operation

2.1 Operating Schedule

In 2013 the regular cycle pattern consisted of a scheduled number of 166 operation days and a maintenance period of 18 days during the month of August. During the repair and maintenance period between 01-01-2013 and 10-06-2013 the tritium level which appeared in the groundwater around the reactor building was reduced. A small cooling water leak from the basin cooling water system to the primary cooling water system due to a leaking seal of the bottom plug liner was repaired by installing a second seal and leak detection system. In reality the HFR has been in operation during 81 days (Figure 1). This corresponds to an actual availability of 49.07 % with reference to the original scheduled operation plan. Nominal power has been 45 MW with a total energy production in 2013 of approximately 3661 MWd, corresponding to a fuel consumption of about 4.57 kg U-235.

The planned cycles 2013-04, 2013-05 and 2013-06 were cancelled due to problems with the structural integrity of 3 control rods. The problem was investigated with an extended root cause analysis. The reactor was scheduled to return to service in February 2014.

The operating characteristics are summarized in Table 1.

Generated Energy [MWd]	**Planned [h]**	**Low Power [h:min]**	**Nominal Power [h:min]**	**Other Use [h:min]**	**Total [h:min]**	**Planned [h:min]**	**Un-planned [h:min]**	**Stack Release (of Ar-41) [10^{11} Bq]**
3661.80	3988	9:12	1947:37	0	1956:49	4761:57	2041:14	13.1
Percentage of total time in 2013 (8760 h):		0.11	22.23	0	22.34	54.36	23.30	
Percentage of planned operating time (3988 h):		0.23	48.84	0	49.07			

Table 1: Summary of HFR Operation in 2013

During the reporting period the annual 30 MW reactor training for the operators and the yearly flux measurements have been carried out in June. After the scheduled end of 45 MW operation of each cycle, these cycles were directly followed by activities performed in the framework of the regular HFR operator training.

2.2 Maintenance Activities

In 2013 the maintenance activities consisted of the preventive, corrective and break down maintenance of all Systems, Structures and Components (SSCs) of the HFR as described in the annual and long-term maintenance plans. These activities are executed with the objective to enable the safe and reliable operation of the HFR and to prevent inadvertent scrams caused by insufficient maintenance.

Main activities during the maintenance periods were:

- Periodic leak testing of the containment building as one of the licence requirements (0.02 MPa overpressure for 24 h).
- In Service Inspection of a part of the primary system in the Primary Pump Building (PPG).
- Extension of the secondary outlet pipe-line further into the North Sea.

All these activities were successfully performed.

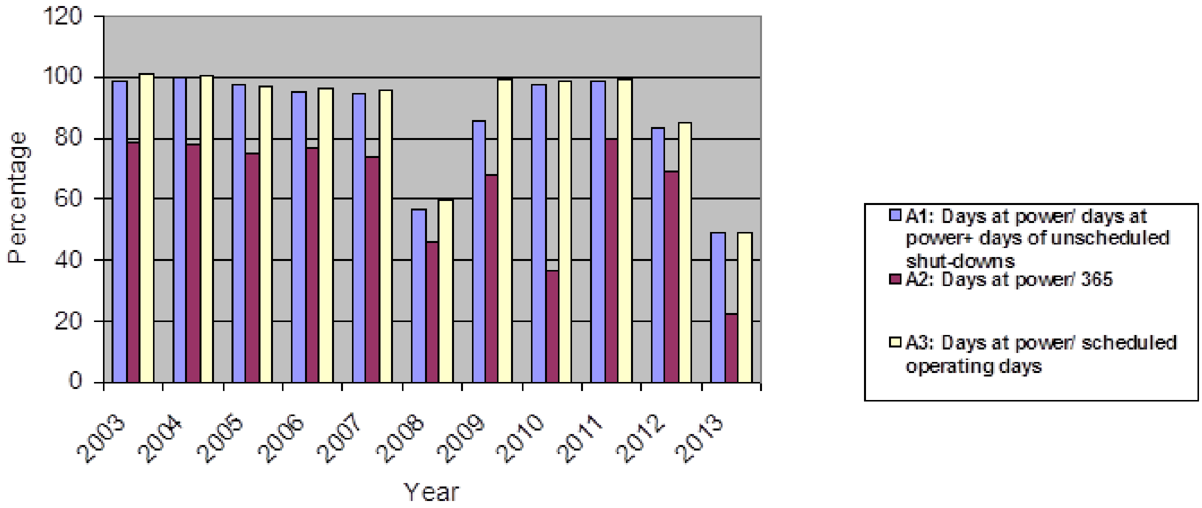

Figure 1: HFR availability since 2003

Figure 2 shows the total discharged activity of noble gas and tritium in 2013.

The licence limit is 100 RE/year. The total discharged activity in 2013 is approximately 5 RE.

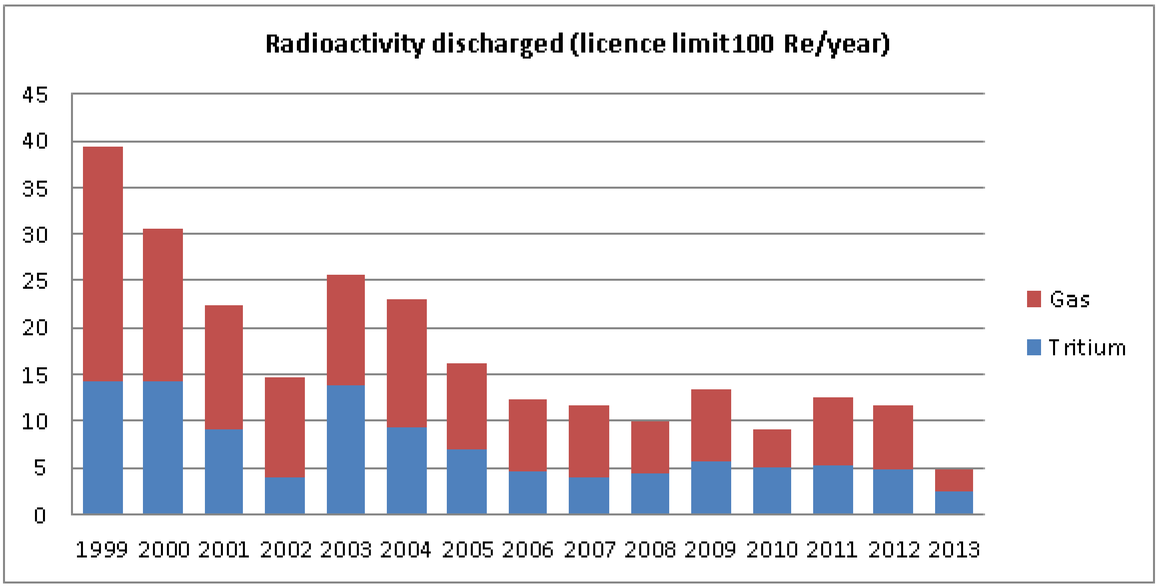

Figure 2: Radioactivity (noble gas and tritium) discharged since 1999

3 The HFR as a Tool for Research on Reactors, Materials and Fuel Cycles

3.1 *Towards a fuel cycle with less nuclear waste: The FAIRFUELS and PELGRIMM Projects*

In the frame of the EURATOM 7th Framework Programme (FP7), the two closely linked 4-year projects FAIRFUELS (Fabrication, Irradiation and Reprocessing of FUELS and targets for transmutation, http://www.fp7-fairfuels.eu) and PELGRIMM (PELlets vs. GRanulates: Irradiation, Manufacturing and Modelling, http://www.pelgrimm.eu) aim at a more efficient use of fissile material in nuclear reactors by implementing transmutation. Transmutation provides a way to reduce the volume and hazard of high level radioactive waste by recycling and converting the most long-lived components into shorter lived species. In this way, the nuclear fuel cycle can be closed in a sustainable manner producing less and shorter-lived radioactive waste.

The FAIRFUELS consortium consists of 10 European research institutes, universities and industry. The project started in 2009 and is coordinated by NRG. The PELGRIMM consortium consists of 12 European research institutes, universities and industry. The project started in 2012 and is coordinated by CEA.

Both NRG and JRC-IET work closely together on the HFR irradiations that are scheduled as part of the FAIRFUELS and PELGRIMM projects.

3.1.1 MARIOS

Objective:

The MARIOS irradiation, as part of FAIRFUELS, is the first in a series of irradiations dealing with heterogeneous recycling of Minor Actinides (MAs) in sodium-cooled fast reactors (i.e. the MA-bearing blanket concept). Minor Actinides, such as americium and curium, are long-lived elements in high level waste, which are currently not recycled. The aim of the MARIOS irradiation test is to investigate more closely the behaviour of minor actinide targets in a uranium oxide matrix carrier. In these targets, large amounts of helium are produced, which may cause significant damage to the target material under irradiation. It is the first time that americium (^{241}Am) is included in a (natural) uranium oxide matrix $Am_{0.15}U_{0.85}O_{1.94}$ to experimentally study the behaviour in terms of helium production and swelling.

Achievements:

The MARIOS irradiation experiment was successfully completed on 2 May 2012 after irradiation in the HFR core for 11 cycles (~304 full power days). After disassembly in the NRG Hot Cells the Post Irradiation Examination (PIE) programme was finished in 2013.

Pellet integrity, helium and fission gas release and results from gamma scans have been reported for pellets of two different densities irradiated at well-defined temperatures. The pellets were allowed to swell freely during irradiation. Helium production (characteristic for americium containing fuel) and fuel burn-up were determined by calibrated post-irradiation calculations.

The fuel with tailored porosity behaves as the less porous fuel. A ~100% helium release was observed for all four capsules, showing that the threshold for high helium release lies below 1000ºC.

Finally, dismantling of one of the 4 fuel pins revealed that 5 out of 6 pellets had broken into two halves of about equal size. This is probably due to thermal stresses built up during irradiation.

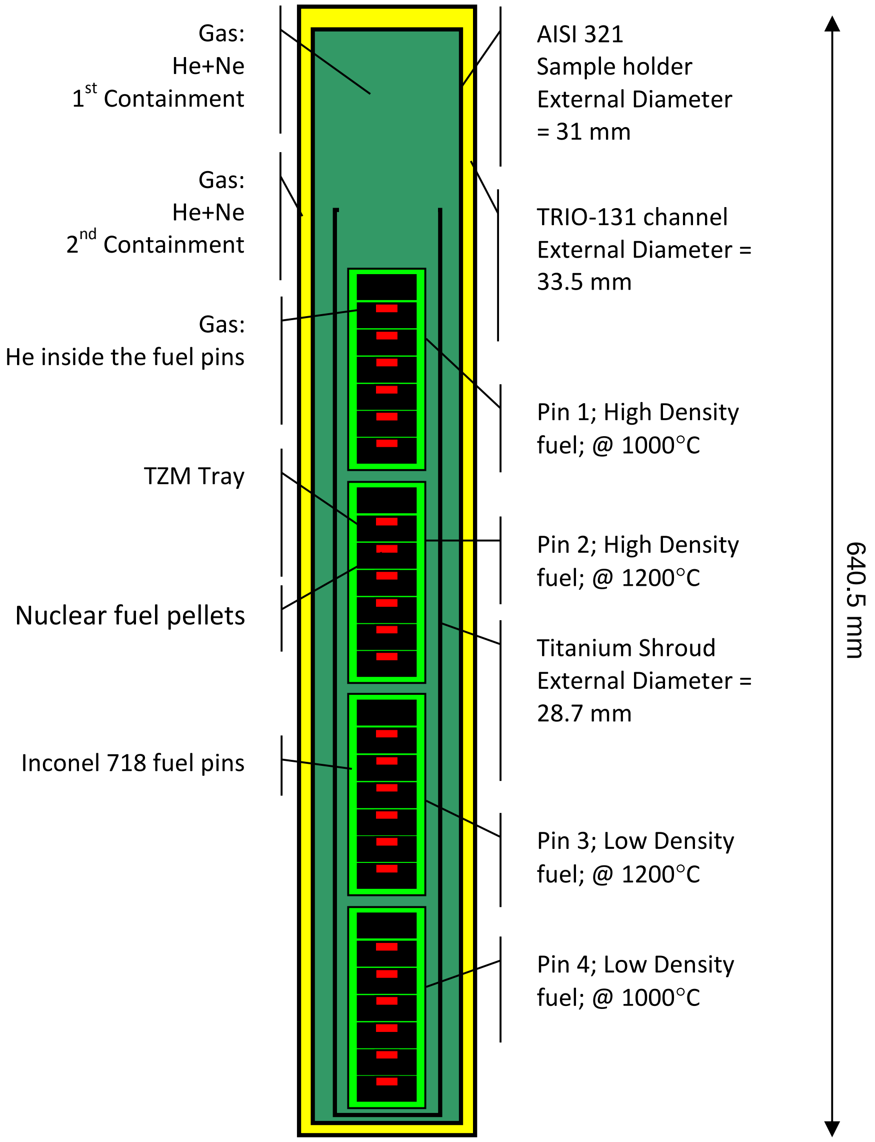

Figure 3: Schematic view of the MARIOS sample holder

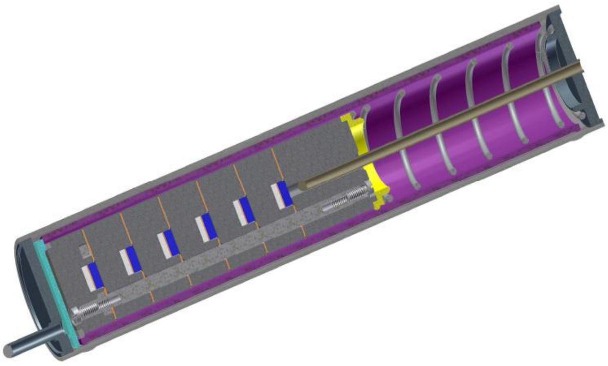

Figure 4: Sketch of a generic pin of MARIOS to show the position of the internal thermocouples

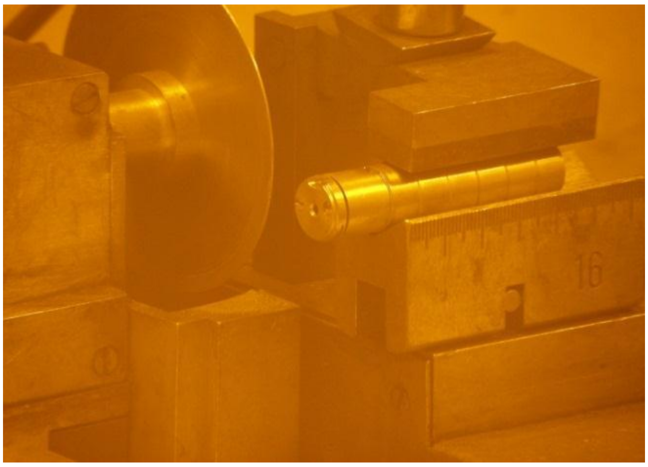

Figure 5: Dismantling of MARIOS for the Post Irradiation Examination

3.1.2 SPHERE

Objective:

Within the FP7 FAIRFUELS project the irradiation test SPHERE has been planned. SPHERE has been designed to compare conventional pellet-type fuels with so-called Sphere-Pac fuels under similar irradiation conditions. The latter have the advantage of an easier, dust-free fabrication process. Especially when dealing with highly radioactive minor actinides, dust-free fabrication processes are essential to reduce the risk of contamination.

To assess the irradiation performance of Sphere-Pac fuels compared to conventional pellet fuel, an americium-containing driver fuel for fast reactors (both in pellet- and sphere-pac form) was fabricated at JRC-ITU in Germany. These fuels are irradiated in the HFR in a dedicated test facility. It is the first irradiation test of this kind, as americium-bearing sphere-pac driving fuel has never been irradiated before.

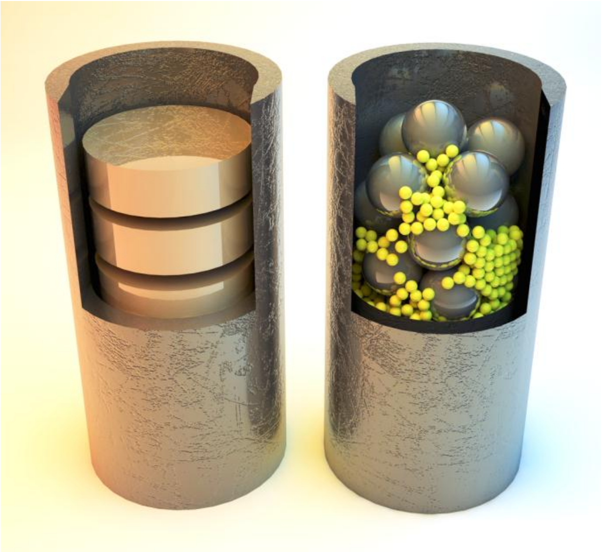

Figure 6: Sphere-Pac versus pellet concept

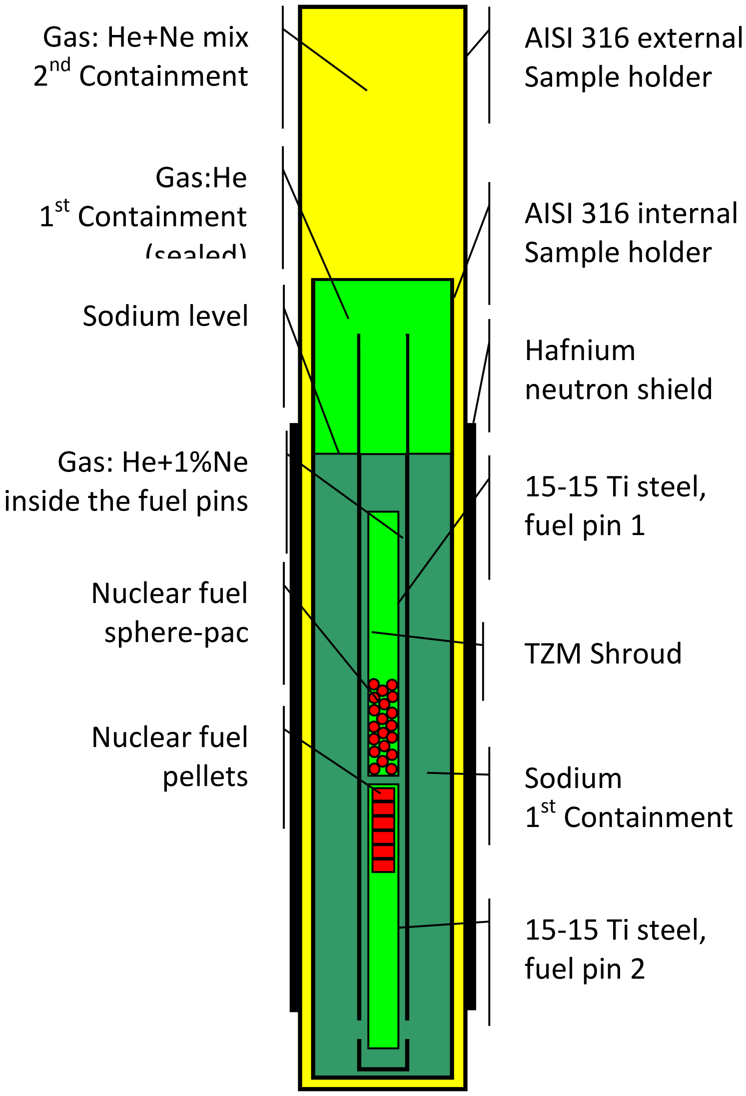

Figure 7: Schematic view of the SPHERE irradiation experiment

Achievements:

The SPHERE irradiation started on 28 August 2013 in the HFR core and is planned to last for approximately 300 full power days. The temperatures obtained are in good agreement with the predictions and the target values (cf. Figure 8, Figure 9). In 2013 a pre-irradiation neutron radiograph (cf. Figure 10) has been taken to be compared later with a neutron radiograph after the first cycle. This will enable to verify the expected fuel restructuring in the sphere-pac. The first irradiation cycle was completed in 2013.

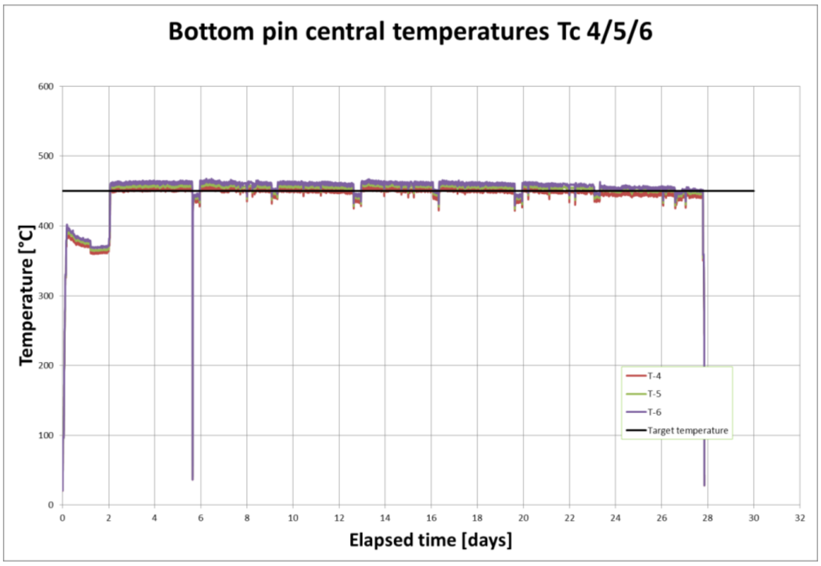

Figure 8: Cladding temperature reading after the first cycle of SPHERE (pellet fuel)

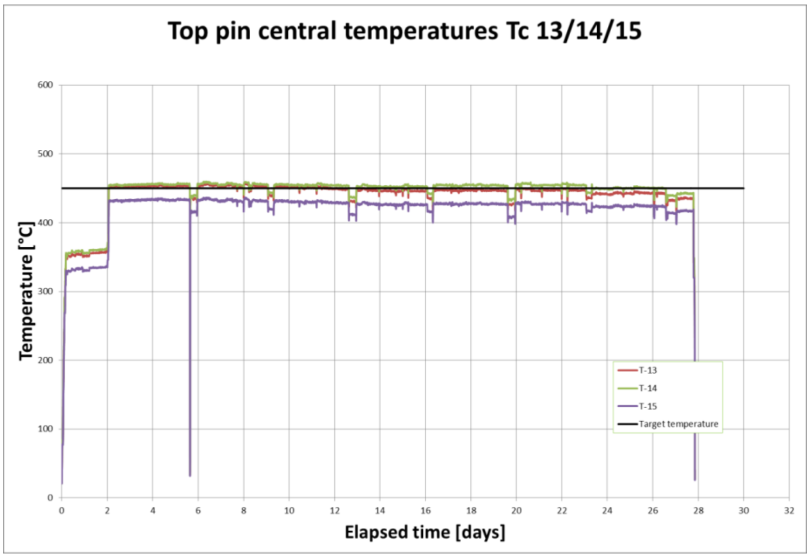

Figure 9: Cladding temperature reading after the first cycle of SPHERE (sphere-pac fuel)

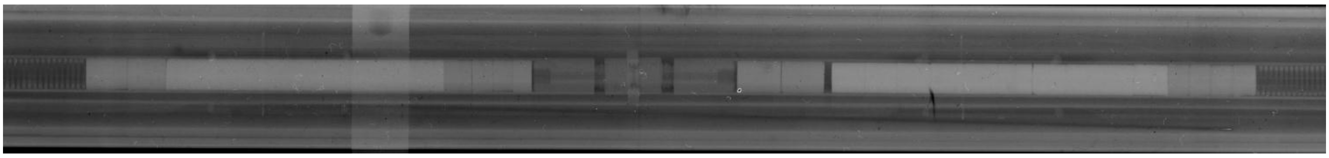

Figure 10: Pre-irradiation neutron radiograph of the two SPHERE pins (left: sphere-pac, right: pellet fuel)

3.1.3 MARINE

Objective:

MARINE is planned as part of the FP7 PELGRIMM project. MARINE has been designed to compare conventional pellet-type fuels with the so-called Sphere-Pac fuels described above. The goal of the MARINE irradiation is to determine He release behaviour and fuel swelling in $^{241}Am_{0.15}U_{0.85}O_{2-x}$, which is representative of the minor actinide bearing blanket (MABB) material to be used for transmutation in Sodium Fast Reactors (SFR).

Americium-containing fuel will be fabricated at JRC-ITU in Germany. These fuels will be irradiated at the HFR in a dedicated test facility. The irradiation will be equipped with internal pressure sensors monitoring online the production of helium, which is characteristic of this kind of americium-containing fuel. The MARINE irradiation is expected to start in early 2015 and will last for approximately 300 full power days.

Achievements:

During 2013, the design of MARINE has been finalised with the development of a new system to connect the pressure transducer (fabricated in Halden) with the fuel pins (fabricated at JRC-ITU). Safe connection and transportation of the fuel pins with the pressure transducers will be managed in Petten with the use of burst discs sealing the fuel pins. After the connection of the pressure lines in Petten, the burst discs (cf. Figure 11) will be intentionally broken to allow gas to freely expand from the pins to the pressure transducers. Preliminary nuclear and thermo-mechanical assessments have been performed leading to the decision to irradiate the experiment in position H8 where the blankets of an SFR (power, temperature, He production) can be reproduced as closely as possible.

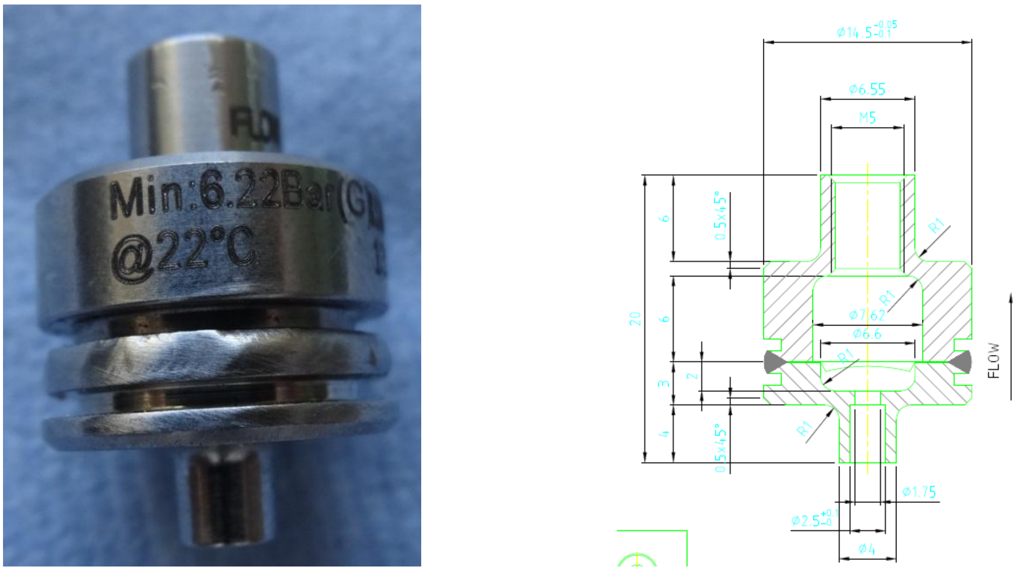

Figure 11: Burst disk housing to be mounted in the MARINE fuel pins

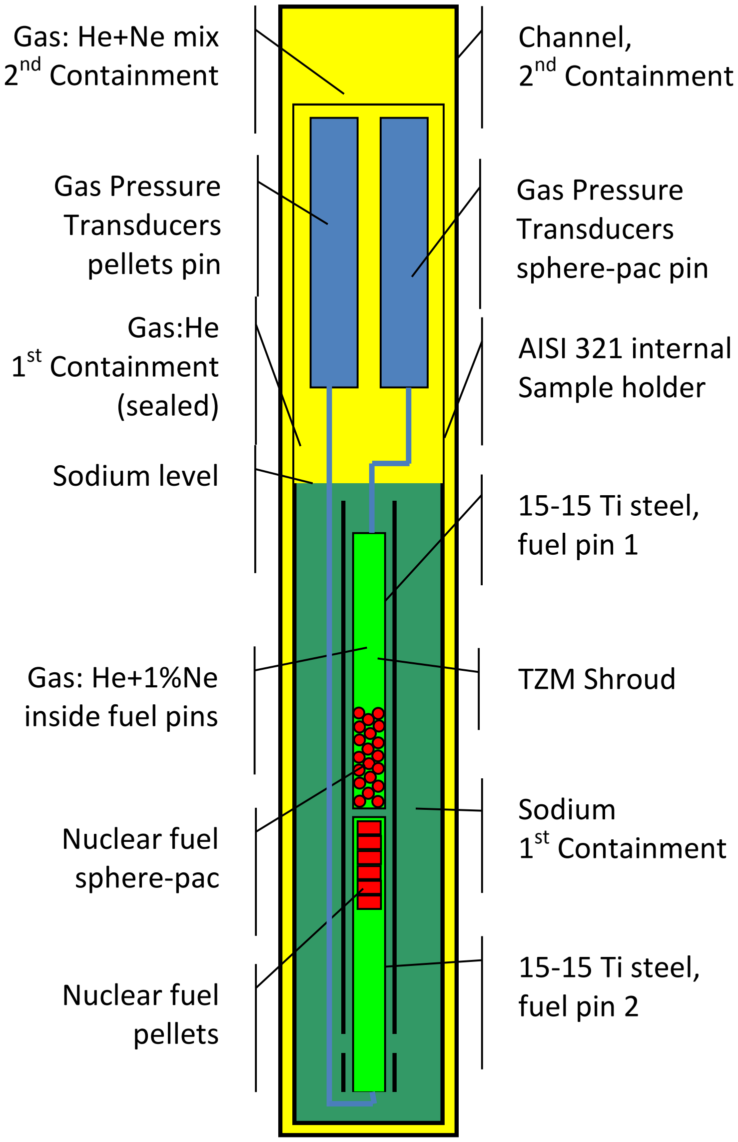

Figure 12: Schematic view of the MARINE irradiation experiment

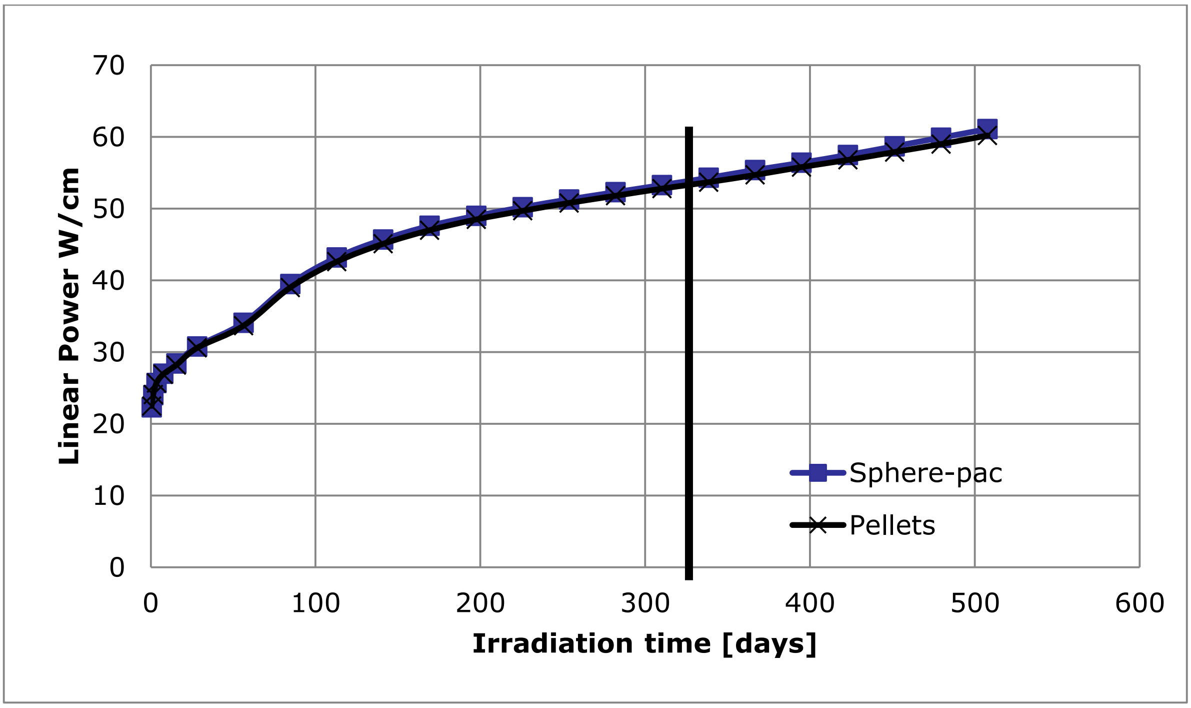

Figure 13: Predicted linear power evolution of MARINE

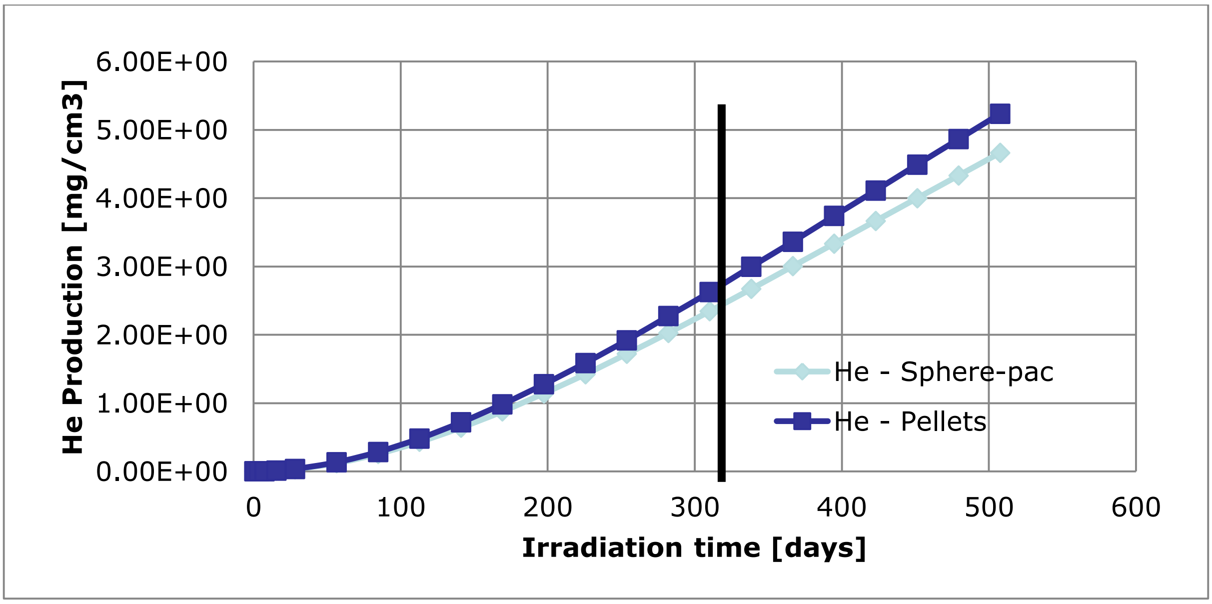

Figure 14: Predicted helium production evolution of MARINE

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3.2 Fuel and Graphite Qualification for High Temperature Reactors

High Temperature Reactors (HTR) are being investigated in a number of countries as a safe and efficient source of energy, in particular for cogeneration of industrial process heat and electricity. Related new demonstration projects are either existing or envisaged in several countries (e.g. Japan, China, US, South Korea) and are subject to current R&D in Europe. The HFR is used in particular for the qualification of fuel and graphite which are decisive elements for the benign safety performance of this type of reactor.

3.2.1 HFR-INET

The Institute of Nuclear and New Energy Technology (INET) of the Tsinghua University in Beijing, China is currently constructing the Chinese Modular High Temperature Gas-cooled Reactor Demonstration Plant (HTR-PM). The fuel for the HTR-PM is developed and manufactured by INET. INET requires qualification of their fuel to support licensing of the HTR-PM reactor systems.

The first step in the fuel qualification is performed by NRG. Five spherical HTR fuel elements (pebbles) are irradiated under controlled conditions in the HFR, at almost constant central pebble temperature, while fission gas release is measured continuously online with the sweep loop facility. The sweep loop facility was developed and built by JRC-IET and is currently used by NRG. Fission gas release during irradiation is an important measure for fuel performance and quality under operational conditions, and forms an essential part of the fuel qualification. For the qualification irradiation a dedicated irradiation test facility was designed and manufactured. The irradiation started in September 2012 in a high flux in-core position of the HFR and was continued in 2013. It will continue to 2014/2015 until the required burn-up is achieved. After irradiation, non-destructive Post Irradiation Examinations (PIE) will be performed in the NRG Hot Cells.

For the second step of the fuel qualification the five HTR pebbles are subjected to a heating test at JRC-ITU, Karlsruhe in Germany, in the so-called KÜFA-facility. The heating test is to demonstrate the integrity and proper performance of irradiated HTR fuel under accidental conditions.

3.2.2 INNOGRAPH-1C

Graphite is used as moderator and reflector material in an HTR and is known to first shrink and then swell under irradiation. This behaviour depends on temperature, neutron dose and graphite grades. Its understanding is required to enable proper design of such reactors and to put the graphite manufacturing industry in a position to produce suitable graphite grades with stable properties over longer periods of time.

The INNOGRAPH-1C irradiation is performed as part of the FP7 ARCHER project (Advanced High-Temperature Reactors for Cogeneration of Heat and Electricity R&D, www.archer-project.eu). Following earlier irradiation tests, it will complete the data set for different graphite grades at different temperatures, under a range of neutron doses. The experiment is a technical building block for nuclear cogeneration using HTRs as an alternative to fossil fuels.

The irradiation of 3 HFR cycles completed in September 2013, with dismantling completed and the first measurements carried out by the end of 2013. Measurements are expected to continue until mid-2014.

3.3 Materials Irradiations

3.3.1 AGR graphite irradiations BLACKSTONE and ACCENT

The United Kingdom operates a fleet of Advanced Gas Cooled Reactors (AGR) operated by EdF Energy. Graphite degradation is considered to be one of the key issues that determine the remaining service life of the AGR. Graphite data at high irradiation dose and weight loss is required, to allow prediction and assessment of the behaviour of AGR graphite cores beyond their currently estimated lifetimes, thus ensuring continued safe operation and lifetime extension.

The BLACKSTONE irradiations use samples trepanned from AGR core graphite to subject them to accelerated degradation in the HFR. The tests are designed to enable the future condition of the AGR graphite to be predicted with confidence.

After BLACKSTONE Phase I, which finished in 2012, EdF Energy have successfully used this data to support an updated safety case for their AGR power stations, following an evaluation of the data and methods used by the UK nuclear regulator. Phase II meanwhile completed irradiation after 12 and 16 irradiation cycles on the two capsules. The first capsule was dismantled in late 2012, with measurements taking place throughout 2013. The second capsule is scheduled for dismantling in February 2014, with measurements expected to complete in October 2014.

The ACCENT irradiations also use samples trepanned from AGR core graphite and apply a pressure to the sample during irradiation. These tests are targeted to predict microscopic variation in size of the material, to enable the future condition of the AGR graphite to be predicted with confidence.

ACCENT Phase I began at the very end of 2012, with the design and construction completed in time for the first irradiation of one HFR cycle in summer 2013. This was dismantled and measurements completed in autumn 2013. Following the success of Phase I, Phase II began an irradiation of an estimated 6 HFR cycles in February 2014, with measurements expected to be completed in December 2014.

3.3.2 LYRA-10

The LYRA irradiation rig is used in the framework of the AMES (Ageing Materials and Evaluation Studies) European Network activities with the main goal of studying the irradiation behaviour of reactor pressure vessel (RPV) steels, thermal annealing efficiency and sensitivity to re-irradiation damage. The LYRA-10 experiment is placed in the Pool Side Facility of the HFR and encompasses irradiation of different specimens representative of reactor pressure vessel materials, namely model steels, realistic welds and high-nickel welds. The model steels comprise 12 batches of steels with the basic, typical composition of Russian VVER-1000 and western PWR reactor pressure vessel materials used by the JRC-IET. The scope is to understand the role and influence of Ni, Si, Cr and Mn as alloying elements and certain impurities such as C and V on the mechanical properties of steels. The realistic welds are created at eight different heats, specially manufactured on the bases of typical VVER-1000 weld composition with variation of certain elements, such as Ni, Si, Cr and Mn. They are of importance to investigate the role and synergisms of alloying elements in the radiation-induced degradation of RPV welds. The LYRA-10 irradiation campaign started in May 2007 and had to be interrupted for technical problems several times. In 2013 it has been irradiated for two more cycles thus totalling 8 HFR cycles at an average temperature of 283°C with an accumulated fast fluence in the samples of approx. 45×10^{22} n m^{-2} (E > 1 MeV). It is planned to pursue the irradiation for 5 more cycles to achieve a fast fluence of approx. 6×10^{23} n m^{-2} (E > 1 MeV).

However, the experiment had to be put on hold for repair of leak in a gas line used for temperature control and is scheduled to resume in the end of 2014.

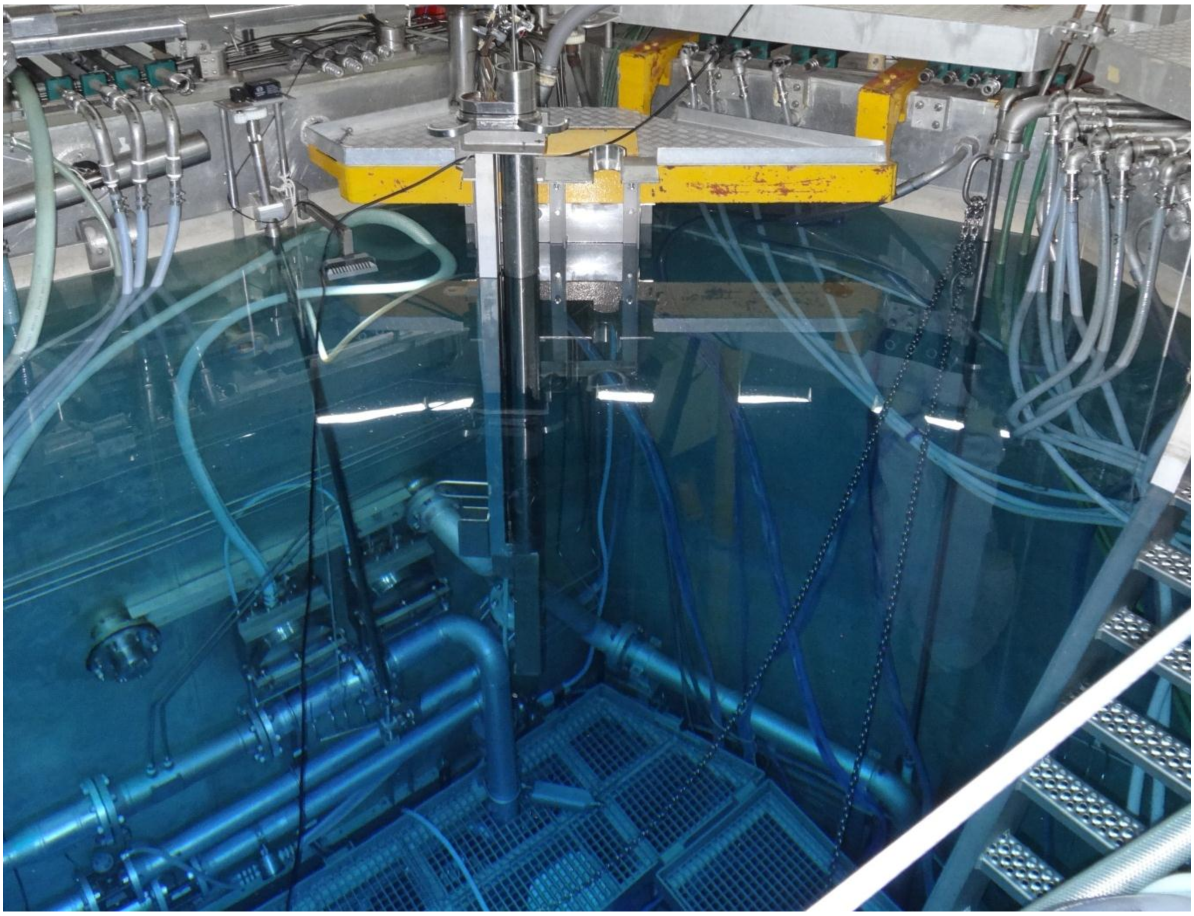

Figure 15: LYRA-10 during a functional test in the HFR basin

3.4 Irradiations for Fusion Technology

3.4.1 ITER PRIMUS

Objectives:

In 2005 an experiment was defined with the European Fusion Development Agency (EFDA) to test thermal fatigue of normal heat flux modules for ITER during irradiation. This has been planned in a pool side facility position for the duration of 22 cycles. The experiment had to be designed in a way that the stress conditions and temperatures would reflect ITER first wall conditions. Between 2005 and 2007 multiple iterations and adjustments have been made to achieve the ITER conditions. The iterations led to a final design in 2008, but could not continue because of HFR outage. In 2009 the position in the HFR Pool Side Facility was not available. In 2010 the Reactor Safety Committee gave the feedback that the thermal cycling in the HFR was not possible due to the intrinsic design of the Automatic Control Rod system. It has been discussed with F4E to perform a stagnant in-pile experiment instead to achieve 1 dpa in beryllium and to perform the thermal cycling afterwards in the JUDITH facility in Jülich.

To perform this irradiation a new experiment has been designed called PRIMUS. In 2012 a new conceptual design has been presented to F4E. Here the mock ups will be loaded in an in-core REFA facility and will be irradiated for 5 cycles in position H2.

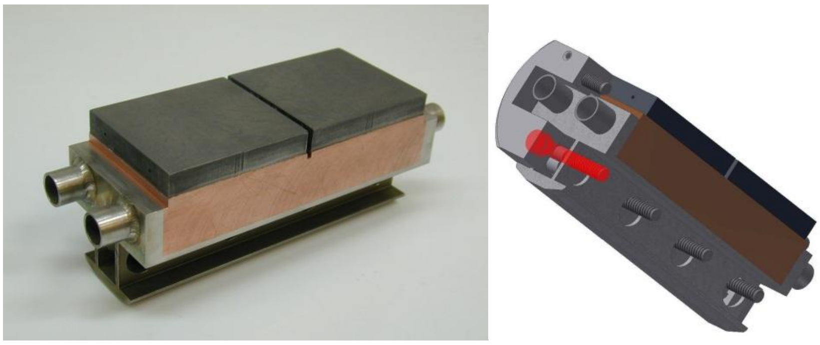

Figure 16: ITER PRIMUS heat flux module design

Achievements:

In 2013 the adapted first wall mock-ups were delivered by F4E. The stainless steel part on the back of the mock-up was reduced by 60% to lower the activation after irradiation. This was necessary to comply with the limits for activity in the JUDITH facility in Jülich. With the new geometry, new irradiation design calculations have been performed and the irradiation proposal has been drafted. This led to a design with a clamping system of aluminium blocks to allow for radial heat dissipation during irradiation. The temperature on the Cu-Be interface during irradiation will be 225°C and the accumulated irradiation dose after five cycles of irradiation in H2 will be 1 dpa. Irradiation is planned to commence in 2014.

3.4.2 CORONIS

Objectives:

In 2011 a new project started in the area of material development and characterisation for ITER. This project is conducted in the framework of F4E, the European Joint Undertaking for fusion energy, founded in 2007.

The objective is to measure the tensile, fatigue and Charpy impact properties of CuCrZr material and CuCrZr/316L joints before and after irradiation to 0.01, 0.1 and 0.7 dpa at 250°C. This material is foreseen for the shielding blanket in ITER because of the high heat dissipation of CuCrZr to the ITER cooling water. This property could be jeopardised when the material fails during its operational lifetime in ITER.

The irradiation will be performed with the Hungarian Institute AEKI, who will take care of the low level dose irradiation (0.01 dpa). All post irradiation experiments will be performed at the NRG Hot Cells. The project runs from 1 January 2011 to October 2015. The project is financed by the Dutch Ministry of Economic Affairs and F4E.

Achievements:

In 2013 the experiments CORONIS 01 and CORONIS 02 were fabricated, assembled and commissioned. After filling with sodium in the ECN workshop, the experiments were transferred to the HFR for irradiation.

CORONIS 01 will be irradiated in position H2 for one cycle corresponding to 0.1 dpa. Both experiments are operated at a homogeneous temperature of 250°C. The materials in CORONIS 01 and 02 are CuCrZr/CuCrZr and CuCrZr/316L which will be used as heat sink material for the First Wall Shielding Modules of ITER. In the end of 2013, the experiments were ready to start irradiation.

CORONIS 02 has the objective to accumulate 0.7 dpa corresponding to a 3 cycle irradiation in the HFR.

Figure 17: X-ray of CORONIS capsule to check for correct sodium level

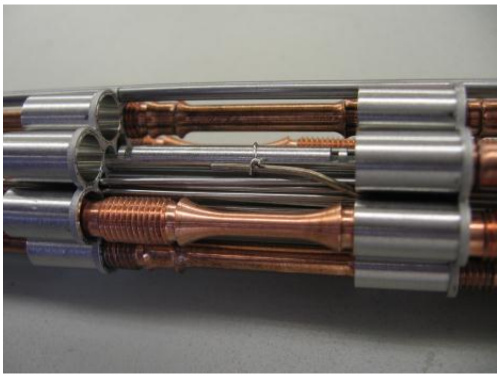

Figure 18: Part of CORONIS assembly with specimens

3.4.3 FIWAMO

Objectives:

In July 2012 a new contract has been signed between ITER, Forschungszentrum Jülich (FZJ) and NRG for the irradiation and high heat flux testing of eight enhanced heat flux first wall modules for ITER.

The ITER first wall is manufactured using two technologies, Normal Heat Flux (NHF) for loading up to 2 MW/m^2 and Enhanced Heat flux (EHF) for loading up to 5 MW/m^2. The plasma facing surface of the first wall is made of beryllium tiles that are joined to a CuCrZr heat sink using hot isostatic pressing or brazing. The heat sink is attached to a supporting steel structure. The present contract concerns only the component manufactured by using EHF FW technology.

The scope of this project is to perform a pre-irradiation screening of the modules, from SWIPP (China) and NIIEF (Russia), irradiation in the HFR to 0.1 and 0.7 dpa at 200-250°C and to perform post irradiation High Heat Flux testing in the JUDITH facility at FZJ up to 5 MW/m^2.

Achievements:

In 2013 Phase 1 of the contract was concluded with the submission of a final design proposal of the irradiation capsule.

The mock-ups consist of beryllium tiles that are joined to a CuCrZr heat sink using hot isostatic pressing or brazing technology. This geometry led to the design as shown in Figure 19. The mock-ups will be clamped between aluminium blocks to allow for radial heat dissipation during irradiation. The interface between the copper and beryllium will be held at 225°C. The mock-ups will be placed in a REFA facility and irradiated in position H2 to doses of respectively 0.1 and 0.6 dpa. The irradiation is planned to start in 2015 in Phase 3 of the project.

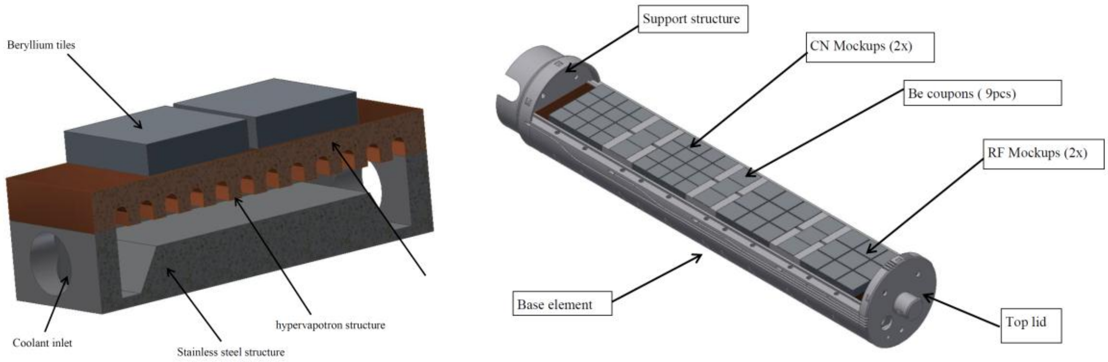

Figure 19: ITER First wall design mock-up (right) and FIWAMO design (left)

3.5 The HFR in support of standardisation in materials research

Network on Neutron Techniques Standardization for Structural Integrity (NeT)

The members of the European Network on Neutron Techniques Standardization for Structural Integrity (NeT) have met twice in 2013 to review the work progress and to agree on the way forward. NeT mainly supports progress towards improved understanding and prediction of welding residual stresses relevant for the integrity of nuclear power plant components. The JRC organizes and manages the Network and it contributes to the scientific work through residual stress measurements using its beam tube facilities at the HFR. The second NeT meeting 2013 was held in Petten in conjunction with an Expert Seminar on Weld Residual Stress topics. Both meetings were attended by more than 30 participants including representatives from organizations in the United States, Korea, Japan and Australia.

NeT is currently preparing the summary reports and the last publications on its work on a three-bead weld in an austenitic stainless steel plate. This work is likely to be the most comprehensive experimental and computational round robin type investigation on welding residual stresses currently in existence. NeT is going to complement this work with a similar activity on welding in a nickel base alloy. The specimen design for this new activity has been agreed on and specimens are going to be available for measurements in 2014.

Standardization of the neutron diffraction method for residual stress measurement

Neutron diffraction is used as a technique for measurements of residual stresses in materials and components. At the HFR this technique is employed at two beam lines mainly for the investigation of residual stresses in nuclear welds. Standardization of the method has been underway for more than 15 years. The JRC has been involved in this from the beginning based on the instruments at the HFR. An ISO Technical Specification about the method has been published in 2005. In 2013 a proposal has been submitted to ISO Technical Committee 135 on Non-Destructive Testing to establish a Working Group charged with the review of the document and subsequent submission for adoption as a full standard. Five member countries from three continents have agreed to participate. The Working Group is expected to be established in 2014.

PhD on neutron diffraction stress measurements in welded components performed at the HFR

On 12 November 2013, a scientist from JRC concluded his PhD research entitled “Residual stresses in thick bi-metallic fusion welds: a neutron diffraction study” with the public defence held at the Technical University of Delft. The neutron diffraction work, on which the PhD thesis is based, had been entirely performed using the HFR residual stress measurement facilities. The components investigated were multi-pass fusion welds designed as scaled mock-ups of real nuclear components. The need to penetrate wall thicknesses of up to 51 mm with the neutron beam pushed the technique almost to its limits. The work demonstrated the feasibility of such investigations and presented a novel approach to the assessment of the measurement uncertainty for such cases.

4 Isotope Production Performance

A severely disrupted year of operation for isotope production was experienced at the HFR in 2013, with only around 30% of the normal operating schedule available. Nevertheless, the HFR could still perform an important role ensuring security of supply of vital medical isotopes in Europe and important industrial isotopes during a period when other research reactors were out of operation.

In 2013, NRG continued to work closely with other players in the medical isotope supply network, as well as with the medical community, governments, the European Commission, AIPES, the OECD/NEA and the IAEA.

The HFR 2013 outages reinforce the need to support the coordinated efforts necessary to minimize the future risks to security of supply of critical medical isotopes. NRG and the HFR fully support the recommendations of the OECD/NEA High Level Group on the security of supply of medical isotopes and continue to work together with other international stakeholders on important issues such as full-cost recovery pricing, outage reserved capacity provision, future infrastructure investment and conversion to Low Enriched Uranium (LEU) targets for Mo-99 production.

5 Glossary

AIPES	Association of Imaging Producers and Equipment Suppliers
APD	Automatic Power Decrease
ARCHER	Advanced High-Temperature Reactors for Cogeneration of Heat and Electricity R&D
DG	Directorate General
dpa	displacements per atom
EC	European Commission
EU	European Union
FAIRFUELS	Fabrication, Irradiation and Reprocessing of FUELS and target for transmutation
FP	Framework Programme
F4E	Fusion for Energy (the European Union's Joint Undertaking for ITER and the development of fusion energy)
HB	Horizontal Beam Tube
HEU	High Enriched Uranium
HFR	High Flux Reactor
INET	Institute for Nuclear and New Energy Technology (Tsinghua University Beijing, China)
ISI	In-Service Inspection
ISO	International Organisation for Standardisation
ITER	International Thermonuclear Experimental Reactor
JRC-IET	JRC Institute for Energy and Transport, Petten (NL)
JRC-ITU	JRC Institute for Transuranium Elements
LEU	Low Enriched Uranium
MA	Minor Actinides
NRG	Nuclear Research and consultancy Group, Petten (NL)
PELGRIMM	PELlets versus GRanulates: Irradiation, Manufacturing & Modelling
PIE	Post Irradiation Examination
RE	1 RE: amount of radioactivity causing a dose of 1 Sv if inhaled or ingested

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JRC Mission

As the Commission's in-house science service, the Joint Research Centre's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle.

Working in close cooperation with policy Directorates-General, the JRC addresses key societal challenges while stimulating innovation through developing new methods, tools and standards, and sharing its know-how with the Member States, the scientific community and international partners.

Serving society
Stimulating innovation
Supporting legislation

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