# UKAEA Materials Research Facility; Into Operation

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**Abstract**

The UKAEA Materials Research Facility (MRF) is designed to test irradiated materials for both Fission and Fusion materials development programs, and will be used by UKAEA for fusion research, but mainly by industry and academia. The new facility bridges the gap between activity levels that can be handled at university or industrial laboratories and activity levels that require large facilities at nuclear licensed sites.

With the MRF, the UKAEA is working on nuclear readiness for the coming decades. It aims to achieve the following goals:

- Serve both Fission and Fusion research with input to future reactor types as well as existing reactor types
- Invest in the development of test methods for micro- and macro-sized specimens as well as in international acceptance of those methods
- Work actively to create a change in nuclear materials research by focusing on size reduction.

The MRF has the capability to receive and process activated materials with a maximum activity of 3.75 TBq Co60 (or equivalent). The MRF hot-cell line (a receiving cell and three interconnected hot-cells), provides downsizing, mounting and polishing of samples. Samples can either be transferred to one of the research rooms for on-site experiments or be transferred to an external partner or customer. Two MRF research room lines have been developed to shield samples with a maximum activity of 3.75 GBq Co60 (or equivalent). Each research room line contains 5 research rooms, all operated and controlled remotely. In the research rooms, microscope techniques (Scanning Electron Microscopy (SEM), Focused Ion Beam (FIB), Atomic Force Microscopy (AFM) and Precision Ion-beam Polishing System (PIPS)), mechanical testing (static testing, high frequency fatigue and SEM in-situ testing) and thermo-physical techniques (Laserflash, Dilatometry and Simultaneous Thermo-gravimetric Analysis & Differential Scanning Calorimetry (TGA/DSC)) are available.

Furthermore, gloveboxes lines are installed to use for research on lower activity samples, e.g. for Sample preparation (cutting, polishing, electrolytical polishing), Tritium and Beryllium based research. A setup for Thermal Desorption Spectroscopy (TDS) and rigs for corrosion of tritium loaded materials and plasma behavior at tritium and deuterium are being installed in the MRF.

In 2018-2021 the MRF is expected to increase its capabilities as follows:

- Increasing the sample preparation capabilities in the hot-cell line (EDM cutting, in-cell welding, dimple grinding, electrolytic polishing, etcetera).
- The addition of two more hot-cells which, for increased flexibility including in-hot-cell experiments, use interchangeable inner containments.
- Realization of an additional research room line with installation of additional equipment for microstructural, mechanical and physical characterization.

## 1. Introduction

The UK Government has identified that R&D is a requirement to provide informed decisions and trained staff for future expansion of nuclear power generation. This is specified in the document 'Nuclear Energy Research and Development Roadmap: Future Pathways, 2013' [1]. As part of this strategy, it is recognized that technological readiness is an important aspect; support for nuclear R&D is paramount and will encompass both skills and technological development. One aspect of this strategy is that small highly radioactive samples can be tested in various facilities, including universities and other research facilities. The collaborating organizations (including the UKAEA) are collectively known as the National Nuclear User Facility (NNUF). See Figure 1 for the structure of, and participating parties within, NNUF.

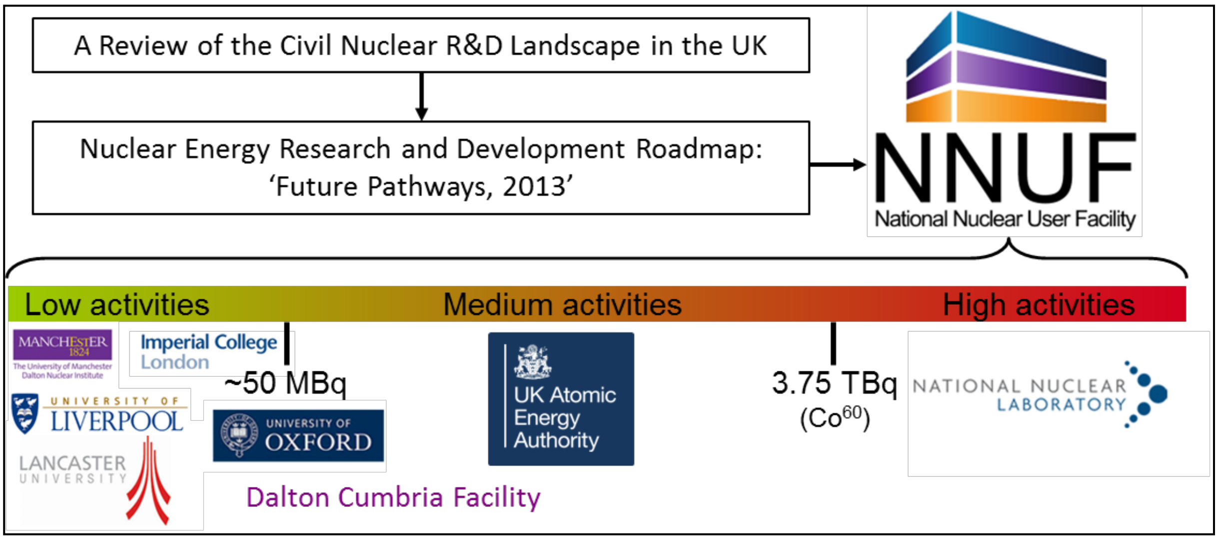


**Figure 1 Development and cooperation within the UK to fulfil the Governments' requirements for the future nuclear R&D programs**

The UKAEA-MRF, located at Culham Science Centre for Fusion Energy (CCFE), is well placed to contribute towards this strategy cooperating with researchers from UKAEA, academia, industry and other organizations to investigate the post-irradiation properties of both materials in service in existing operational nuclear power stations and candidate materials for use in future fission and fusion power stations. In addition, there is considerable scope for UKAEA to undertake its own fusion research and collaboration with other users for fission research. The combination of fission and fusion materials as well as accelerator materials research will increase knowledge in all fields.

In the MRF (see Figure 2 for the layout and current status of development), scientists will investigate the change of material properties due to irradiation damage (e.g. comparing the effects of neutron-irradiation with both proxy ion beam irradiation and un-irradiated samples); gas (including tritium) retention; embrittlement and size effects from full size to micro- and macro-scale. Future fission and fusion devices will profit from access to the facilities, techniques and competences developed within the UKAEA-MRF. The main focus at the MRF will be research to implement technological readiness (as defined in [1]) by using state of the art equipment not vulnerable to relatively low level radiation from aforementioned reduced sample volumes. Size reduction of the specimens (sub-sized, macro-sized or micro-sized specimens) will allow the use of modern techniques as well as increase of data points due to the low volume of the required material(s) per data point.

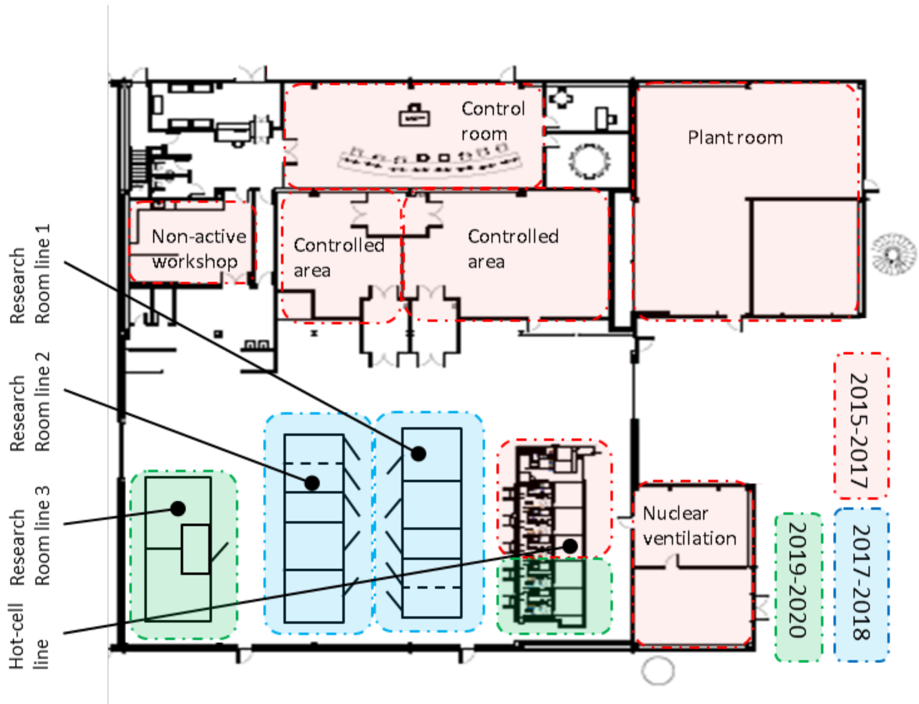


**Figure 2 Layout of the MRF and the status of development**

## 2. MRF sample preparation

The MRF is an easily accessible hot-cell facility with a mid-range activity level working field (see Figure 3). The MRF has included a specimen preparation facility in the hot-cell line to allow for specimen fabrication based upon size reduction. The reduced specimens (from sub-sized to micro-sized) can be further evaluated in the MRF hot-cell line, one of the scientific instruments in the MRF research room lines, the MRF controlled areas (≤ 200 MBq) or by being transferred to one of the universities or customers. See the flow diagram in Figure 4.

**Figure 3 Front face of MRF-UKAEA hot-cell line**

The hot-cell line is capable of cutting, mounting, grinding, polishing and evaluating the sample quality using optical microscopy. Electric Discharge Machining (EDM) cutting and welding equipment will be added to enable the fabrication of more complicated sample shapes.
In-cell gamma spectroscopy will be used to verify and/or identify the received materials.

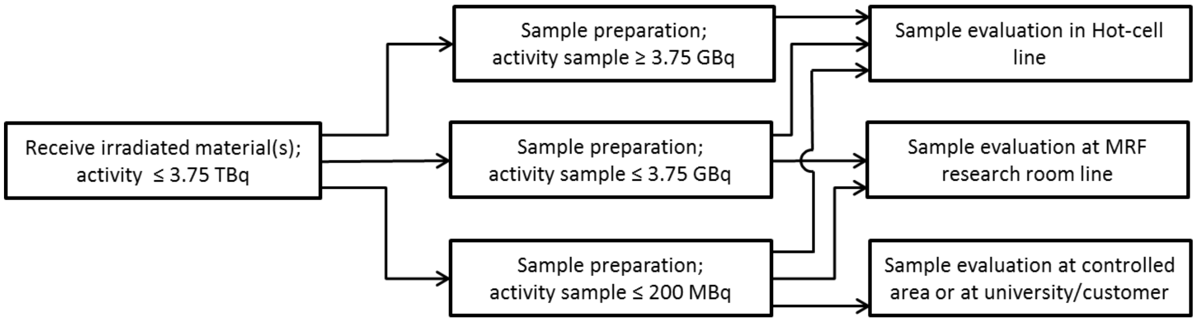


**Figure 4 Overview of sample preparation and evaluation regime in the UKAEA-MRF (activities based on $Co^{60}$ and $Co^{60}$ equivalents)**

Sample preparation of active materials (activity ≥ 200 MBq $Co^{60}$) will be prepared in a hot-cell. The complete MRF process from materials arrival is given in Figure 5. Low activity samples can be fabricated in a glovebox and non-active samples in the non-active sample preparation workshop.

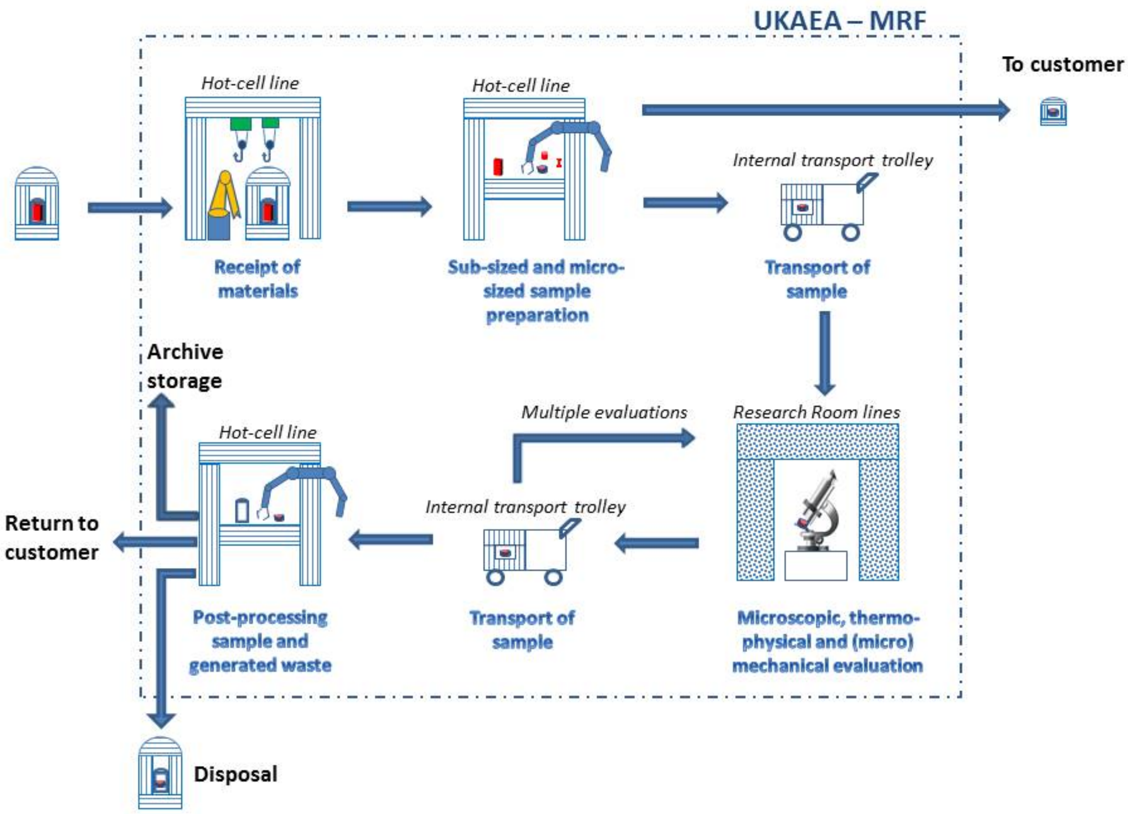


**Figure 5 Process route of active materials through the MRF**

## 3. MRF Research Rooms for material evaluation

Active samples will be evaluated in the Research Rooms as shown in the process description in Figure 5. Visiting scientists will be able to perform their own experiments from the control

room (Figure 6a), assisted by the MRF operational and scientific team. Currently 10 research rooms are available. Samples will be loaded in the instruments remotely and fully shielded with the possibility to have manned access (Figure 6b) by the operational team if the dose rate is below set levels. Both active and inactive samples will be evaluated using the same instrument located in the research room. Contamination levels will be controlled and kept low by structural decontamination regimes to assure safe working environments in the rooms and inside the scientific instruments.
New instruments were purchased in 2016/2017 and are currently being commissioned for use. Currently the instruments are planned to be installed in the Research Rooms, with allowance for remote operation. See Figure 6c– for some ongoing studies and concepts.

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b.

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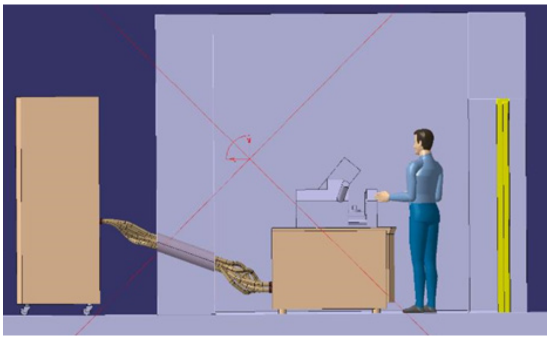
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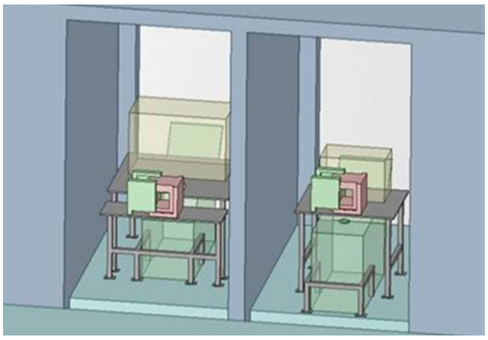
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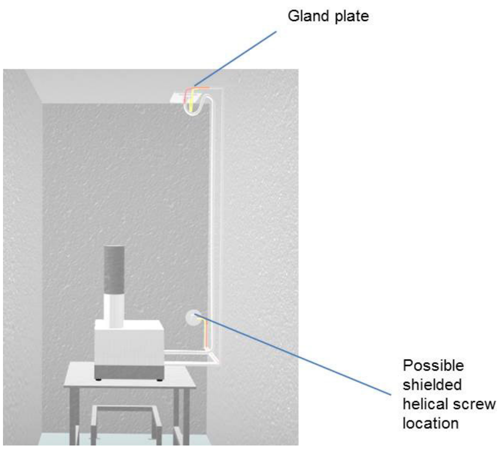

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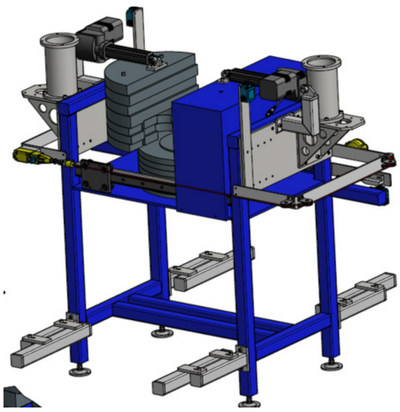

**Figure 6a. Control room with remote operation desk for visiting scientists; b. Shielded transport trolley for active sample movements from the hot-cell being wheeled into a research room; c. Study for FIB configuration in Research Room with through wall cable feed through; d. Table top configurations in small Research Rooms; e. cable route configuration through wall and roof; f. concept shielded castle for interim sample storage in a Research Room**

## 4. MRF Scientific instruments

The MRF is currently expanding its scientific capabilities, enabled by funding from the Henry Royce Institute. Besides the Scanning Electron Microscope (SEM), Focused Ion Beam (FIB), Nano-indentor and Atomic Force Microscope (AFM), all purchased before MRF opened, new investments have recently been made to increase the capabilities.

In 2017-2018 the following instruments will be integrated and commissioned in the MRF:

- Focused Ion Beam
- Dilatometer
- Scanning Electron Microscope (with EDX, EBSD, TKD, WDS and 5kN mechanical in-situ test frame)
- Simultaneous ThermoGravimetry Analysis and Differential Scanning Calorimeter
- Nano indenter
- Instrumented indenter
- Atomic Force Microscope
- Laser Flash Apparatus
- Fatigue testing
- Static mechanical testing
- Digital Imaging Correlations imaging
- Extensometers and potential drop systems
- Vacuum chambers; environmental chamber and heating systems

Also the sample preparation techniques will be expanded in order to allow for a larger variety of sample geometries and finishing. Techniques that will be included are:

- EDM wire and die-sink cutting
- Twin Jet Electro-polishing
- Sputter coating
- Dimple grinding

## Acknowledgements

We gratefully acknowledge funding from two UK Government initiatives via the Engineering and Physical Sciences Research Council: the National Nuclear User Facility http://www.nnuf.ac.uk/ and the Henry Royce Institute http://www.royce.ac.uk/. For more information on MRF see http://www.ccfe.ac.uk/mrf.aspx.

## References

[1] A Review of the Civil Nuclear R&D Landscape in the UK; BIS/13/631 (2013); available from: https://www.gov.uk/government/publications/civil-nuclear-research-and-development-landscape-in-the-uk-a-review