DISMANTLING AND WASTE MANAGEMENT PLANNING FOR FIR 1 RESEARCH REACTOR DECOMMISSIONING

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ABSTRACT

FiR 1 TRIGA Mark II research reactor, which was operated in Espoo, Finland, in 1962–2015 is in decommissioning phase. The Government of Finland granted VTT Technical Research Centre of Finland Ltd. the decommissioning license in June 2021. Preparatory measures are now ongoing and dismantling is scheduled to commence in the beginning of 2023. In March 2020 a comprehensive contract on decommissioning services was signed between VTT and Fortum Power and Heat Ltd. which covers dismantling and necessary nuclear waste management services of FiR 1 decommissioning as well as waste management procedures for adjacent OK3 research laboratory decommissioning. In this paper we give an overview of the FiR 1 decommissioning project status concerning the detailed waste management and dismantling planning by Fortum.

INTRODUCTION

In this paper we present the current state of the decommissioning project of FiR 1 TRIGA Mark II reactor concerning waste management and dismantling. Reactor was operated in Espoo, Finland, in 1962–2015 by VTT Technical research Centre of Finland Ltd. The contract of VTT and Fortum, signed in March 2020, encompasses the planning of decommissioning, dismantling of the reactor, and the transfer of the waste management obligation from VTT to Fortum when the dismantling waste has been transported to Loviisa NPP for final disposal. FiR 1 is the first nuclear facility to be decommissioned in Finland and thus frequent updates of the project's progression have been given, for example in RRFM2021 -conference [1].

VTT applied a license for decommissioning of the reactor from the Government of Finland, and the license was obtained in June 2021. [2] While VTT as the licensee remains to be responsible for the nuclear and radiation safety of the reactor and the decommissioning site, Fortum as the main contractor will take significant responsibility on implementing the decommissioning.

By the mid of 2022 the detailed planning had been completed. During 2022 VTT performs initial on-site preparations for non-activated material for initiating the actual dismantling work at the site in the beginning of 2023. For on-site preparations Fortum finalizes necessary procurements and before the dismantling work can be started Fortum performs licensing process of the final disposal of FiR 1 waste to Loviisa LILW repository.

PROJECT MAIN PHASES AND SEQUENCES

Now that the preliminary planning phase and detailed planning of dismantling has been completed, the remaining main phases of the project are preparations for waste management, work-site preparations, dismantling, waste management and clearance of the site. The planned schedule is presented in Figure 1.

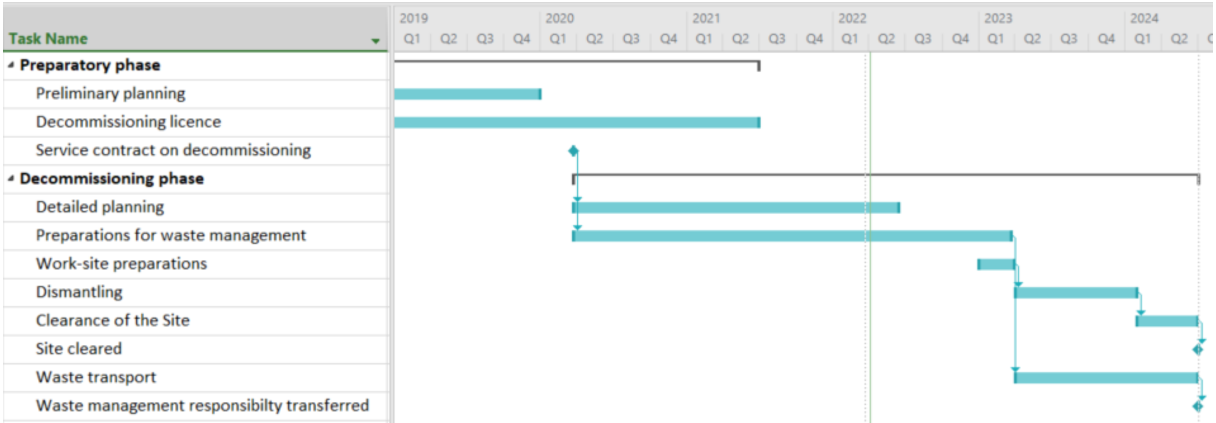


Figure 1: Schedule for FiR 1 decommissioning.

CHARACTERIZATION PLANNING

Radiological characterization is one of the most important tasks in waste management of nuclear facility whether the facility is in operation or under decommissioning. The data gained through characterization is fundamental in planning of waste management (including final disposal) and dismantling procedures and also for example radiation protection measures. In FiR 1 decommissioning the characterization planning is done in cooperation between VTT and Fortum.

VTT as the reactor operator has composed an activity inventory by computational basis which is partly validated with sampling. [3] Samples from inactive materials have been analyzed to validate the materials' composition including impurities while samples from activated materials have been used to determine nuclide specific activities. Fortum has created a characterization plan for the dismantling phase and concurrently a long-term safety assessment for disposal of FiR 1 decommissioning waste in Loviisa LILW repository.

Activity content of the decommissioning waste will be mainly measured by using gamma spectrometry (ISOCS in FiR 1 case) accompanied with material specific nuclide vectors for difficult-to-measure nuclides. [4] FiR 1 research reactor also contains special materials for which a gamma active key nuclide cannot be determined (e.g. Fluental neutron moderator and bismuth). These will be characterized by sampling.

A total of 15 nuclide vectors are planned to be used in the characterization of decommissioning waste. 13 vectors are for different activated materials and two for contaminated waste (one for primary circuit contamination and one for waste contaminated by different research actions). Nuclide scaling factors in vectors are based on sampling results or are computational. [5] Sampling is used for nuclides whose estimated total activity is considerable and/or the nuclide has a distinct effect on long-term safety aspects of the final repository. Guidelines presented in standard ISO 21238:2007 have been used as a basis in the nuclide vector determining process [6].

Some of the vectors will be formed as preliminary computational vectors before the dismantling begins. During the dismantling phase the preliminary vectors will be supplemented with samples gathered from more activated structures/components which are only accessible after certain dismantling actions. For example the concrete of biological shield is most activated in the vicinity of the reactor tank structures. Samples cannot be drilled from this concrete before the tank is drained from water (which is done after the most active core components are removed).

DISMANTLING PLANNING

During 2021 Fortum carried out a major updating process for all of the previously composed preliminary dismantling plans resulting in a comprehensive worksite plan and detailed step-by-step working instructions from the preparatory phase to building clearance phase. In total there are 7 work phases with their own work instructions. In addition to the dismantling work instructions Fortum decided to create an additional instruction for the waste management workers covering the waste management procedures over the whole dismantling phase. The latter considers every assumed waste item generated from decommissioning activities telling i.a. the planned waste package and nuclide vector to be used in the characterization measurements.

Dismantling plans have been refined so that they include all practical aspects regarding to the dismantling work. Dismantling, waste management, site logistics, radiation protection and conventional safety operations are integrated to fully support the actual dismantling actions. A lot of planning has also been done to ensure that requirements (e.g. waste acceptance criteria) placed by the Loviisa LILW repository are met.

A number of modern tools has been utilized during the planning. These include radiation modelling with MCNP and HVRC VRdose®, remote planning with eSiteview and precise CAD-modelling. MCNP-modelling has been used to create radiation models of the active components during the different dismantling work phases to optimize the working process in terms of ALARA-principle. MCNP-models have also been used to estimate the radiation levels inside and outside the building supporting efficient layout-planning and specify the decisions to construct additional radiation shielding for example around interim storage area (Figure 2). Also HVRC VRDose® has been used in the optimization by creating videos presenting the dismantling phases and radiation field behavior during them. [7][8]

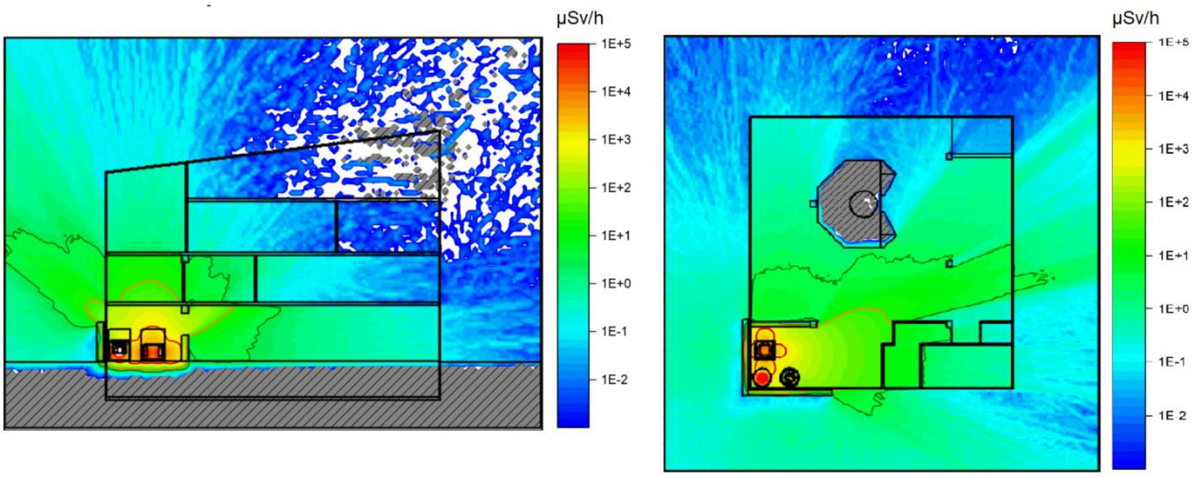


Figure 2: MCNP results. Model is made for situation where all active core parts are packed to radiation protection cylinders and final disposal packages and positioned to interim storage area. Storage area is shielded from outside with heavy concrete bars.

eSiteview is a virtual model of the building created with laser scanning and 360-camera. One can move freely in the model and take measurements of different structures with the tools built inside the software. The model has been a precious tool supporting remote planning.

During the detailed planning many precise CAD-models have been created to support and visualize the actual dismantling work. An example is presented below in figure 3.

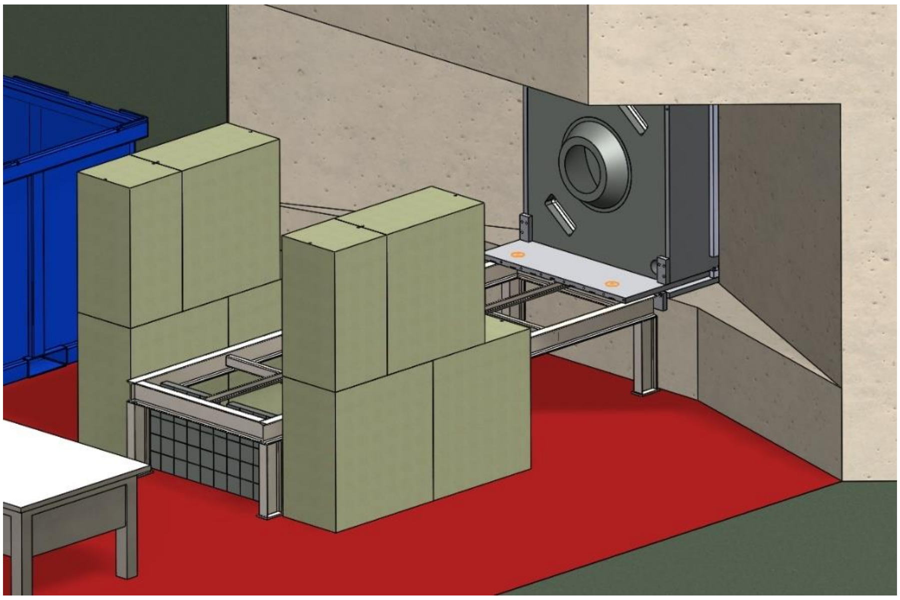


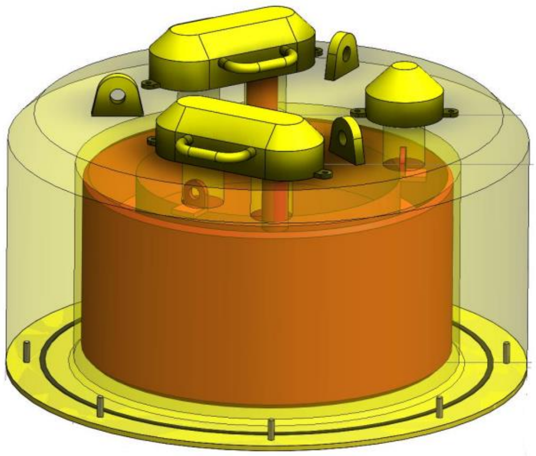
Figure 3: A CAD-model visualizing the preparation for pulling out the moderator block. Concrete blocks and lead tiles are used for radiation shielding purposes. One can also see two orange markers which indicate drilling locations (for pulling chains' installation) and a blue waste container where the moderator block will be placed.

NUCLEAR WASTE MANAGEMENT

Fortum has included the disposal of FiR-1 decommissioning waste to the license process of lifetime extension of Loviisa NPP LILW repository. Fortum submitted the EIA (environmental impact assessment) program in August 2020 and has now submitted the license permit application to the Ministry of Economic Affairs and Employment of Finland in March 2022 [9].

Nuclear waste management planning in FiR 1 decommissioning consist of packing, characterization (VTT is responsible for waste measurements), final disposal and clearance planning. In addition a plan for waste management actions at the Loviisa NPP (after the waste has been transported there) has been done.

The packing plan contains waste amount estimation, waste sorting and packing principles, waste specific packages and guidelines for maintaining the waste database. Generated waste is sorted by three main attributes: activity, material and applicable nuclide vector. Standard packing unit is 200 l barrel. A larger waste container is designed for bigger waste items such as graphite blocks from former thermal column and concrete blocks to be cut from biological shield. The most active reactor internals (irradiation ring, graphite reflector and small active steel parts) will be packed to specifically tailored radiation shields which will be further shielded with concrete disposal packages. Waste database maintenance has been planned so that the data collected at the dismantling site can be reliably and mostly automatically transferred to the waste database used in Loviisa NPP as the waste is disposed. Designed radiation shield for irradiation ring and the waste container for larger waste items are presented in figure 4.



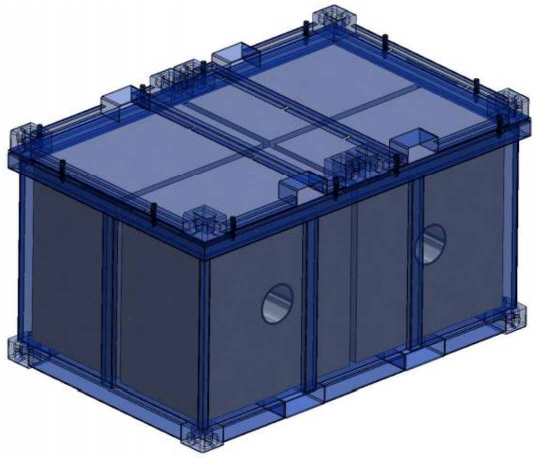


Figure 4: Left: Radiation shield for irradiation ring. Right: Waste container for big components and concrete blocks.

If the activity level of the nuclear waste is low enough it can be cleared from the regulatory control and sent to conventional waste management facilities/recycling. Nuclide specific clearance levels to be used in FiR 1 decommissioning waste are based on national YVL-guides created by STUK. [10] Maintenance waste (incl. concrete), metal waste and hazardous waste have had their own clearance processes developed by utilizing the practical experiences from Loviisa NPP.

The ultimate goal of the decommissioning is that VTT will clear the building and the land area to unrestricted use. Fortum has supported this by developing and preparing separate plans and processes for clearing the remaining structures left after dismantling phase.

In addition to the research reactor building, Fortum has also prepared a waste packing plan for the decommissioning waste of a radioactive research laboratory premises adjacent to the research reactor building, so called OK3 research laboratory. The packing plan includes plans for waste categorization, waste amount estimation and waste packing optimization. VTT is executing also this decommissioning project as the licensee of the laboratory. Similarly as with the research reactor decommissioning waste, Fortum will receive and dispose the waste which cannot be cleared to Loviisa LILW repository.

Final disposal has been planned in terms of final disposal repository, long-term safety and logistics. The waste from FiR 1 decommissioning will be disposed to existing waste halls of Loviisa NPP's LILW repository. The decommissioning waste from the research reactor is mostly similar with Loviisa NPP's own waste. Majority of the waste will be disposed into maintenance waste hall and the most active waste packages in solidified waste hall. Maintenance waste hall is presented in figure 5 and the whole repository in figure 6.

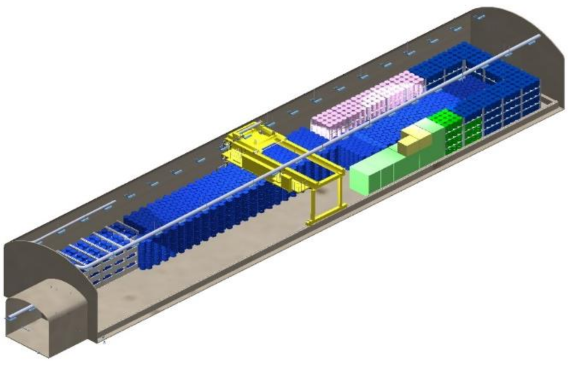


Figure 5: A CAD-model of Loviisa LILW repository's maintenance waste hall. The waste generated from FiR 1 decommissioning is highlighted in green and light yellow.

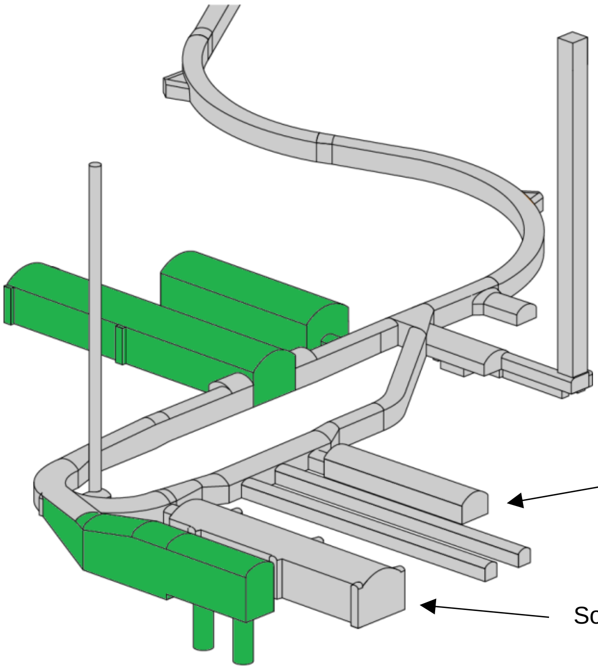


Figure 6: Illustration of Loviisa NPP's LILW repository. Waste halls highlighted in green will be built in the future.

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