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SENDING ALL IRRADIATED FIR 1 TRIGA FUEL TO REUSE AT USGS

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ABSTRACT

The FiR 1 TRIGA reactor on the Otaniemi Campus close to Helsinki, Finland, was permanently shut down in June 2015. The reactor is under the US DOE FRR spent fuel return program, but due to political and administrative reasons, the DOE INTEC facility in Idaho was not allowed to receive the used fuel from FiR 1. In 2020 a new path for repatriation of the fuel to the United States was opened culminating in US Geological Survey (USGS) TRIGA reactor (GSTR, Denver, Colorado) receiving early 2021 all the irradiated fuel from FiR 1.

This solution between USGS and VTT was elaborated with the assistance of the Edlow International Company (EIC). It included USGS and DOE agreeing on the disposition of also FiR 1 irradiated fuel inventory and NRC accepting to expand the USGS's license limits to include the full FiR 1 irradiated fuel inventory. USGS is planning for an intensive use of the reactor during the current operating license valid till October 2036 and is therefore in need of more fuel. USGS has identified that the FiR 1 fuel is suitable to be used in the GSTR and has significant burnup capacity left.

VTT contracted EIC to transfer the irradiated fuel from FiR 1 to GSTR. EIC contracted NAC International to carry out the transfer using the NAC-LWT cask and associated fuel-handling systems [1]. Fortum Power and Heat was contracted to establish the local transport and support organization in Finland. Cask loading and road transport in Finland took place under VTT license granted by the Finnish Radiation and Nuclear Safety Authority - STUK.

The cask loading took place late December 2020, and on 29th December, the Pacific Nuclear Transport Limited (PNTL) nuclear fuel carrier Pacific Grebe sailed off from the Port of Helsinki. Failed fuel was put into five sealed failed fuel cans. A team from Idaho National Laboratory witnessed this as these cans will be transferred in the future intact to INTEC Idaho.

This article describes the arrangements for cask loading in the middle of the Finnish winter along with the actual transfer of the fuel from the reactor tank and the dry pits to the NAC-LWT cask outside the reactor building inside a weather cover tent. The intense two-week operation involved some thirty people in a Finnish-US team.

1 Introduction

1.1 Background

The FiR 1 TRIGA reactor on the Otaniemi Campus close to Helsinki, Finland, was permanently shut down in June 2015. In June 2017 VTT submitted a license application for decommissioning to the Finnish Ministry of Economic Affairs and Employment (MEAE). The main prerequisites for receiving that license were reliable solutions for both the removal of the spent fuel from the site and for the dismantling waste.

FiR 1 has been under the US DOE FRR spent fuel return program, including the exemption period started in May 2019, but due to political and administrative reasons, the DOE INTEC facility in Idaho was at this time not allowed to receive the used fuel from FiR 1. VTT prepared in collaboration with the Loviisa nuclear power plant (Fortum Power and Heat Ltd) for an intermediate storage of the spent fuel at the NPP site to be later either transported to the DOE INTEC facility in Idaho or to the Posiva repository in Olkiluoto, Finland.

Parallel to that, VTT was working with Edlow International Company ltd (EIC) to find alternative solutions, which would finally lead to the DOE INTEC facility. In 2020 a new path was opened when the US Geological Survey (USGS) TRIGA reactor (GSTR, Denver, Colorado) expressed their interest for receiving all the irradiated fuel from FiR 1.

1.2 For reuse at USGS

It was agreed that all irradiated fuel at FiR 1 would be transferred to USGS. Most of it would be further utilized in the USGS TRIGA. The failed fuel, canned in special sealed failed fuel cans (SFFC), would be temporarily stored at USGS before transfer to INTEC, Idaho. Ultimately after end of life all TRIGA fuel from USGS will be transferred to INTEC. In September 2020, an agreement between the Department of Energy and the USGS was signed for the back end post-utilization phase of the fuel cycle for the fuel received from FiR 1 (Interagency Agreement Number 1012, Amendment 005). Finnish MEAE was satisfied with this situation and concluded that the solution fulfils the requirements for the FiR 1 decommissioning licence.

In October 2020, the GSTR requested approval for a license amendment to the GSTR license from the U.S. Nuclear Regulatory Commission (NRC) to increase the amount of fuel that may be received and possessed by the GSTR. The NRC granted the requested amendment to the GSTR in early December 2020.

1.3 Organization

VTT contracted EIC for the transfer from FiR 1 to the unloading site at USGS. EIC contracted NAC International for the NAC-LWT transport cask and for the cask loading operations at FiR 1.

Edlow International contracted the Finnish nuclear company Fortum to arrange equipment and personnel relevant for the heavy lifting and forklift operations during SNF fuel transfers. Same equipment and personnel was also used for unloading and loading of SNF fuel handling equipment. Site and transport arrangements required co-operation of ten different Finnish companies with total of approx. 30 persons. Fortum was also supporting Edlow in the localization of the transport licensing documentation to align with the regulatory requirements in Finland.

VTT was responsible for fuel element handling, radiation protection, occupational safety as well as site security arrangements.

A team from INTEC was witnessing the loading of the damaged or suspect fuel elements to specific NAC/INTEC failed fuel cans. A member from the USGS reactor team was also witnessing and supporting the activities at FiR 1.

2 Licensing and planning documents

VTT received the transport license by STUK 7.10.2020 with requirements for approved transport plan, approved security plans, Euratom export license and nuclear liability insurance.

The transport plan was accepted by STUK 4.12.2020 and the security plans 7.12.2020. Nuclear liability insurance was acquired 7.12.2020. Euratom export license (2006/117/Euratom) was approved by STUK 8.12.2020 after US NRC had accepted the transfer to take place.

VTT prepared in collaboration with EIC and Fortum several planning documents: SNF Handling at FIR1 Site specific plan, FIR 1 Site Plan for the NAC-LWT Cask Loading, Radiation protection plan for FiR 1 SNF loading operations, FiR 1 emergency preparedness plan tailored for the fuel loading operations, security plans for loading and transport in Finland and VTT Transportation Plan, Transport of FiR 1 Irradiated TRIGA® Nuclear Fuel to USA.

A site specific description of the fuel collecting activities was documented in *SNF Handling at FIR1 Site specific plan*. Based on this general plan detailed plans for the separate steps of the work were prepared.

3 On site arrangements

3.1 Cask loading site

The arrangements at the cask loading site (see Figure 1 and Figure 2) aimed to give sufficient weather protection against rain and also harsh winter conditions which could mean -20°C and 30 cm snow coverage outside. This was achieved with a 10-15 meter high 13 by 40 meter scaffolding tent equipped with a hot air blowing heater. Physical protection was created with approx. 2,5 m high precast concrete security barrier with a plywood upper part and equipped with electronic surveillance systems.

A mobile 95 tn crane was used for handling the NAC-LWT cask (22 tn), the DTS (6 tn) and the inner shield (1,4 tn). During the loading operations the crane was outside the tent the hook hoist coming through an opening in the roof. A 5 tn diesel forklift was used for handling the ITS inner shield in the tent. An other 5 tn electric forklift was used inside the reactor building.

For operating the DTS cask on top of the NAC-LWT cask two 7,8 meter high scissor lift were used.

3.2 Collecting the SNF

The irradiated fuel at FiR 1 consisted of 99 standard fuel elements (66 Al, 33 SS clad) and 4 instrumented fuel elements (IFE). The condition of all the fuel elements - but one failed aluminium clad element in a VTT constructed sealed fuel bottle - had been previously inspected by the INTEC (Idaho) team in 2016 and 2019. During the 2019 inspection, the IFE lead tubes were cut and fitted with a TRIGA standard top end fixture and the four IFEs were transferred to the dry pits. After this of the total 103 irradiated fuel elements 73 were in the reactor tank (core and racks), 30 in dry pits. Now the number of fuel element in the tank was adjusted beforehand so that three full baskets were collected from the tank. For this only one element had to be moved from the tank into the dry pits.

3.2.1 Canning

All elements to be canned had already previously been transferred to the dry pits. A radiation shielding bunker made of concrete blocks was assembled next to the pits. The fuel elements were transferred from the dry pits into the cans using the fuel handling tool operating from the second floor. Two elements fit into one NAC Sealed Failed Fuel Can (SFFC). Filled cans were transferred to another set of unused dry pits from which they were later loaded to fuel baskets.

The number of elements requiring canning was 10 and so the number of cans 5.

Figure 1. Site arrangements during fuel loading operations. On the left the transfer station of the Intermediate Transfer System (ITS). Here the inner shield with the loaded basket is lowered into the outer shield of the transfer station. In the middle the dry transfer system (DTS) and on the right the NAC-LWT cask. When the DTS is on top of the NAC-LWT for lowering the basket into the cask the total height of the system is 8 meters.

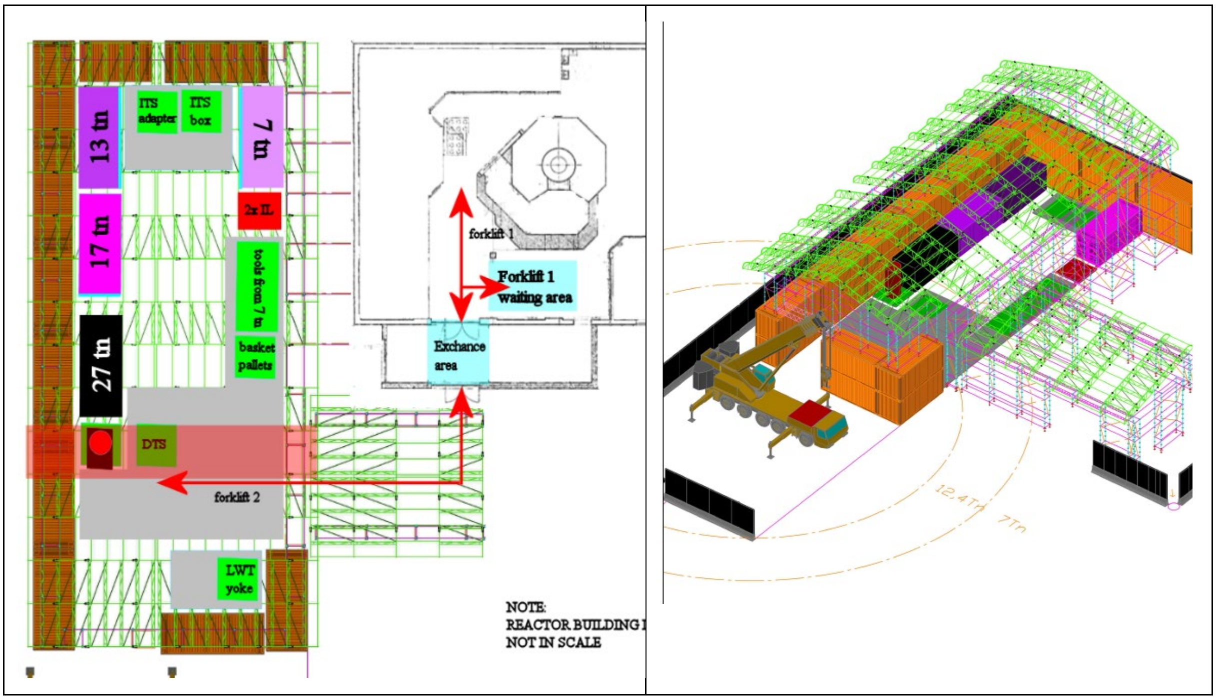

Figure 2. Movement of two 5 tn forklifts while loading cask. Exchance area is used to prevent spread of contamination (if any) and free access from tent to reactor building. Inner or outer doors of exchance area are always kept closed. Part of the tent roof is removed when lifting operations with crane are made (light red area). Roof was closed for the night time.

3.2.2 Loading from the dry pits

The inner shield was positioned on the 1st floor near the dry pits surrounded by concrete blocks for radiation shielding. The standard fuel handling tool was used to lift the fuel elements one at a time from the 300 cm deep dry pits into the basket; operating from the 2nd floor (Figure 3). The SFFC's were lifted using the NAC can lifting tool mounted at the tip of a pole long enough to reach to the bottom of the dry pits.

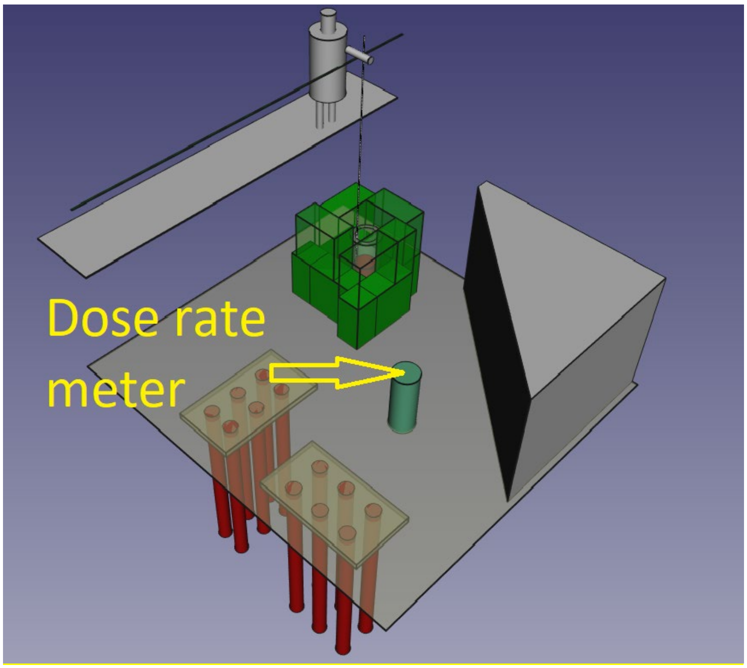

Figure 3: An illustration of the dry loading phase with ITS inner shield in a shielded bunker. The location of a recording dose rate meter is indicated. The underground dry pits on the left were used for individual elements, pits on the right for sealed failed fuel cans.

3.2.3 Loading from the tank

Fuel from the core was lifted first to the racks at tank wall before loading into the baskets. Fuel identification was performed at this point. Chainfalls were used for lowering the inner shield into the tank to the height of the fuel racks at a depth of appr. 180 cm.

TRIGA fuel handling tool was used to transfer the fuel elements. When loading a cell each cell has to be fitted first with a TRIGA basket loading fixture which guided the four fuel elements to proper alignment. After filling the cell the fixture was moved to the next cell.

After the basket was full the chainfalls were shortened to the transfer length keeping the shield at the same time submerged by lowering the crane hook. The shield was raised from the water and kept above the tank until it had drained empty. Then the shield was transferred into the forklift cradle on the ground floor.

3.3 Radiation protection

All workers were trained and licensed before entering the site. The total number of radiation workers was 27, mainly classified to class B. VTT staff at FiR 1 reactor are classified to radiation worker class A.

The whole reactor building was classified as controlled area. All workers in controlled area have to use personal dosimeters. Contamination check was done before leaving the controlled area. The loading site outside of the reactor building was classified as supervised area. Workers accessing these radiation working areas, both controlled and supervised areas, had to wear personal protective equipment (PPE). Basic outfit in the radiation working areas during the campaign was: Laboratory coat, working trousers, overall suites, safety shoes, helmet, dosimeters TLD/electronic dosimeter and ID card.

To estimate the personnel radiation doses and plan the radiation protection procedures, dose rate calculations for all the fuel transfer shields and configurations were performed using Serpent [4]. Estimated cumulative doses in different work phases are listed in **Table 1**. Calculations are based on highest activity (fuel element 6536), typically dose rates are 1/3 of that [5]. Also time estimations for the work phases are conservative.

Table 1. Estimated doses in different work phases.

Working distance / Work phase	0.5 m	1 m	3 m	5 m	TOTAL
Preparation	0.1				0.1 mSv
Can loadings	0.4		0.05		0.45 mSv
Tank loadings	0.64	0.2			0.84 mSv
Dry pits loadings	0.42	0.2	0.13	0.05	0.8 mSv
Basket transfers and preparation for transport	0.31				0.3 mSv
total effective $H_p(10)$ dose estimation	1.87	0.4	0.18	0.05	2.5 mSv

3.4 Emergency preparedness management

FiR 1 emergency preparedness plan was tailored for the fuel loading operations. Two new accident scenarios were added. 1) Dropping the inner shield on top of a still partly with fuel occupied reactor core. 2) Dropping of the inner shield or the DTS with full basket of fuel in the outside area.

In the first scenario due to very low instant release fraction of TRIGA fuel [6] and five years of cooling estimated personnel doses were below 1 µSv. As a counter action only normal contamination control and monitoring measures were indicated.

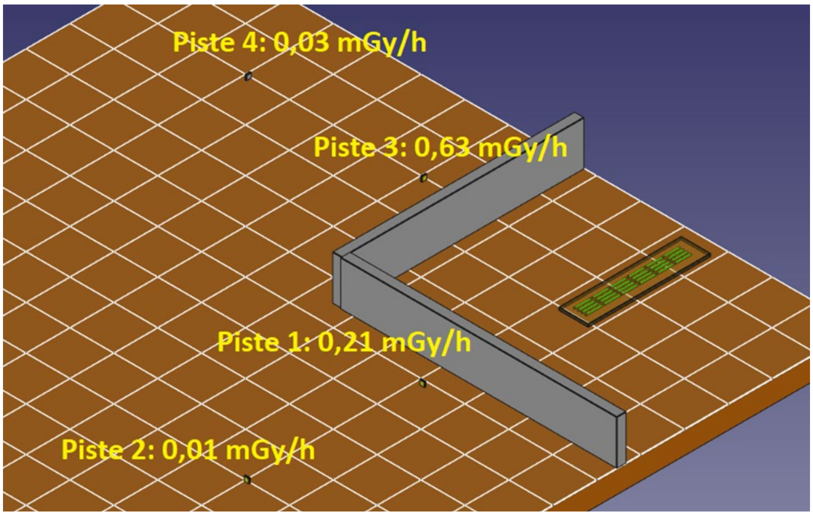

Figure 4: An illustration of the modelled geometry of 24 fuel elements shielded using 5 cm of lead blankets (transparent here for visual reasons) and 20 cm thick concrete blocks. The grid divides the area into 1 x 1 meter squares.

In the second scenario it was assumed that all the 24 fuel elements of the basket are scattered to the ground, five of them would be mechanically damaged. Concerning the released radioactivity it was concluded that the dose from tritium and Kr-85 would be neglible. Particles could cause detectable surface contamination due to Sr-90 ja Cs-137.

To be able to shield the fuel elements lead blankets were tight together in sets with two layers (2 x 6 mm of lead) and 1 x 1 meter by size. The sets were equipped with lifting loops to be manipulated with a telehandler. A telehandler to be operated by one of the forklift drivers and capable of lifting loads up to 1700 kg at 6 meter distance was stand-by for setting the lead blankets an concrete blocks and bringing the fuel transfer shield (1,4 tn) to a proper location. This would provide enough shielding so that the elements could be picked up using a 6 meter long manipulator and transported away individually in VTT's own fuel transfer shield (**Figure 4**). The emergency preparedness training included demonstration of these procedures.

4 Operation

The fabrication of long lead-time equipment (fuel baskets and sealed failed fuel cans for the NAC-LWT) had started already in autumn 2019 although the schedule to deliver the fuel to INTEC was not known. The fabrication of these parts was completed in September 2020 and they were delivered to VTT just prior to loading in December.

EIC contracted Secured Transportation Services (STS) for the transportation and transport security planning from Finland to Idaho. The target schedule for the transport was set to Autumn 2020. So the transport planning was quite advanced in summer 2020 when the new destination opened for the FiR 1 irradiated fuel. Technically this meant only rerouting in the US. In practice it meant a lot of licensing and contracting work which was finalized only at the very end of November 2020.

4.1 Transports

The main phases of transport were road transport from the FiR 1 site to Port of Helsinki (less than 1 hour), marine transport from Helsinki to a US East coast port (about 2.5 weeks), and road transport from the US port to Denver (about 2 days).

On a typical winter, the ice cover of the Baltic Sea reaches Helsinki, which set a boundary condition for the nuclear cargo ship operations. It was mandatory that the vessel sails from Helsinki in the very beginning of January at the latest. This required the loading operation to be completed in a very tight schedule, as the NAC-LWT cask and equipment arrived to FiR 1 December 18th.

4.2 Schedule

The schedule of the transport process is summarized in Table 2.

5 Lessons learned

The need for local contacts in the planning work was resolved by Edlow International by contracting Fortum also for licensing and local management. In addition VTT contracted Fortum to take care of the loading area construction. This facilitated smooth operation in good collaboration between the participating organizations.

Table 2. Schedule of the FiR 1 irradiated fuel transport from Finland to the USA.

Advance preparation (for the INTEC option)	
2019-03-22	VTT ordered transport planning services from Edlow International
2019-04-01	Site assessment at FiR 1 by NAC and Edlow International
2019-06	Preparing the IFEs and INTEC final inspection of the fuel for transport.
2019-08-22	VTT ordered from NAC and Edlow International the fabrication of NAC-LWT hardware
2020-02-28	NAC-LWT licensed in Finland for FiR 1 TRIGA fuel transport
Negotiations and licensing for the transfer to USGS/GSTR	
2020-07-23	Negotiations started on delivery of FiR 1 SNF to GSTR
2020-09-10	Signature of Amendment 5 to the DOI/DOE Interagency Agreement 1012 on fuel back end
2020-10-12	VTT ordered SNF transport services from Edlow International
2020-12-01	DOI confirmed to MEAE that GSTR can receive fuel from VTT
2020-12-03	NRC issued Amendment to the USGS Facility Operating License
2020-12-04	STUK approved the transport plan
2020-12-04	USGS issued Authorization to Ship to VTT
2020-12-07	STUK approved site and transport security plan
2020-12-07	VTT received nuclear liability insurance for transport
2020-12-08	STUK approved (after endorsement by NRC) the Euratom export license
Transport phase	
2020-11-30	Construction of the loading site begins
2020-12-15	Loading site construction ready. Training of crane and forklift operators.
2020-12-17	Site training for NAC, INTEC and USGS personnel STUK inspection of the site
2020-12-18	NAC-LWT cask and equipment arrival at VTT
2020-12-18	Canning of all failed fuel elements to 5 cans
2020-12-20	Dry run and loading of basket 1 from reactor tank
2020-12-21	Loading of baskets 2-3 from reactor tank
2020-12-22	Loading of baskets 4-5 from dry pits. Cask preparation for transport started.
	Completion of cask preparation and Christmas break
2020-12-29	Transport to Port of Helsinki. Departure of the vessel.
2021-01-21	Fuel received at GSTR

5.1 Operation during to Covid pandemic

In December 2020, Finland was locally undergoing a third wave of COVID-19, with the number of cases raising but remaining at a relatively low level compared to many other countries. Entry to Finland was relatively strictly controlled, and the availability of flight connections both for traveling and for freight was much more limited than normally. The participants from US did not need to stay in voluntary quarantine upon entering Finland as they were considered necessary for the security of supply based on statements given by VTT.

VTT tested both the visitors and own personnel for COVID-19 before working together, in order to identify any cases and prevent the spread of the virus in the project teams. None of the about 30 persons tested positive.

5.2 The weather protection tent

The weather protection tent worked well for the planned purposes, but opening and closing of the 2.5 m roof section shown in Figure 2 caused some extra costs and delays since specially trained roof workers needed to be called on-site every morning and evening.

Crane operations were conducted extremely well using a spotter inside the tent communicating with NAC personnel in English and then relayed the requested action to the actual crane operator outside in Finnish.

5.3 Security

The collaboration between VTT, the Finnish transport security company, the police and STUK was successful. No security incidences occurred during the project.

VTT kept tight confidentiality and secrecy about the transport preparations, especially about the timing. The information was kept inside a planned information bubble. Even the main stakeholders in the Finnish nuclear field learned about the successful transport only after the fuel had arrived at USGS, one day before the official press announcements.

5.4 Fuel transfer operations

The detailed planning of the fuel transfer operations, tailored for the situation at FiR 1, resulted in a swift action both in preparing the loading site and in the loading operations. All ten failed or suspect fuel elements were canned in one day and the loading of the NAC-LWT took only two days.

The only piece of equipment causing problems were the TRIGA fuel handling tools. The VTT original TRIGA fuel handling tool was stiff and too thick for the TRIGA basket loading fixture due to some repairs VTT had made to it. EIC supplied newer fuel handling tool turned out to be less reliable than the original TRIGA tool, but failures of the newer tool did not cause any damage.

5.5 Radiation doses and contaminations

The surface dose rates from the loaded ITS inner shields were measured using a 5 m long telescopic dose rate meter Automess Teletektor 6112. The results were comparable with the calculated values taking into account the overestimation of the fuel activity in the calculations. Highest measured dose rate from the surface of the ITS inner shield was around 8 mSv/h.

Daily doses in different working days and working phases are shown in Table 3. Working in dry pits, canning and dry loading, caused the largest doses. Effective dose estimation was 2.5 manmSv and realised dose was 1.0 manmSv. Highest personal dose was 0.17 mSv. Collective dose Hp(0.07) to the hands were estimated 9.0 mmanSv. Several finger dosimeter were used during working in high radiation field; all finger doses were below measurement limit 1 mSv/month.

Table 3. Collective daily doses.

Days	Phases	Dose
		mmanSv
18 Dec	Canning of all failed fuel elements to 5 cans	0.413
19 Dec	Preparations of dry pits loading	0.014
20 Dec	Dry run and loading of basket 1 from reactor tank	0.002
21 Dec	Loading of baskets 1-3 from the tank	0.089
22 Dec	Loading of baskets 4-5 from the dry pits	0.504
23-29 Dec	Cask preparation for transport, transport to Port of Helsinki	0.001
TOTAL		1.023

Before, during and after campaign no contamination was found in radiation workers. Some of the NAC equipment was already contaminated when entering the site. During the campaign, only the basket loading fixture was contaminated; it was sealed in plastic before packing to the containers.

Measurements of radiation levels outside the loading site showed only background levels.

5.6 Regulator observations

STUK carried out two binding inspections: (i) when the site arrangements were complete (but before the arrival of the transport equipment); (ii) after the cold run, before giving a permission to start fuel transfer operations. In addition, the transport and transport security arrangements were inspected by STUK before and during the transport.

The regulator made some observations that VTT has since then utilized for developing the organization and internal rules and regulations of FiR 1 reactor as part of the transition to the decommissioning phase. The observations were specifically related to the command hierarchy in situations in which the supervision of work and safety responsibilities are separated in a different manner than during regular operation of the reactor. STUK approved the revised rules and regulations for the reactor organization in August 2021.

6 Summary

In 2018 VTT started a process with Edlow International Company aiming to find solutions to return the irradiated fuel to US despite political obstacles for the INTEC to receive the fuel. Finally in Summer 2020 a path was found. Delivery of the irradiated, but to a big part still usable fuel to USGS solved both their need for fuel and VTTs need to find a route which finally would lead to the INTEC facility in Idaho.

In a rapid tempo the plans were modified, preparations finalized and contracts signed showing extreme supportive attitude and flexibility of the government agencies both in the US (US DOI, US DOE, NRC) and in Finland (MEAE, STUK) as well as of the organizations directly involved (USGS, VTT, EIC, NAC, Fortum).

At FiR 1 VTT in collaboration with Fortum succeeded to put together a strong effort to load the fuel into the NAC-LWT transport cask in the middle of the Covid-19 pandemic and the winter approaching. The workforce at the reactor was doubled when the hot cell decommissioning team joined this effort.

The transfer of all the irradiated fuel from FiR 1 TRIGA, Otaniemi, Espoo, Finland to USGS GSTR TRIGA in Denver, Colorado, USA was successfully accomplished in six months after first discussions.

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8 References

[1] Jeff England, NAC LWT for VTT's FiR 1 Research Reactor Used Fuel Shipment, in these proceedings.
[2] https://tem.fi/documents/1410877/2429243/YVA-selostus.pdf/cf1f0dce-824e-4812-b0c7-a23e0025499b/YVA-selostus.pdf?version=1.1&t=1463564645000
[3] https://www.finlex.fi/fi/laki/kaannokset/1987/en19870990.pdf
[4] J. Leppänen, et al. - The Serpent Monte Carlo code: Status, development and applications in 2013. Annals of Nuclear Energy, 8:142-150, 2015
[5] A. Räty, S. Häkkinen and P. Kotiluoto, Nuclide Inventory of FiR 1 TRIGA research reactor fuel, Annals of Nuclear Energy, Volume 141, 2020
[6] Pacific Northwest National Laboratory, Credible Accident Analyses for TRIGA and TRIGA-Fueled Reactors, NUGER/CR-2387, PNL-4028, 1982