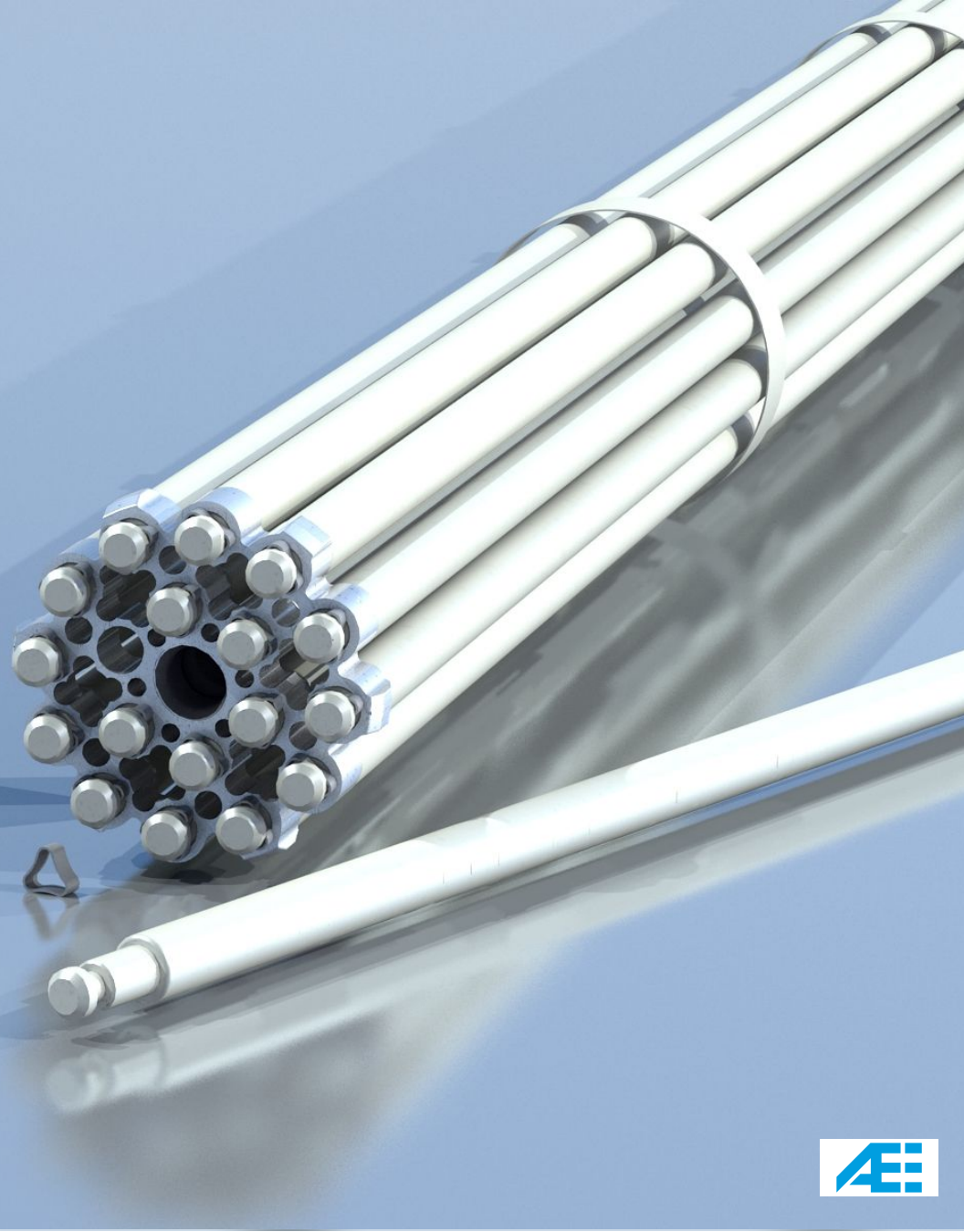




MANAGEMENT OF DAMAGED AND EXPERIMENTAL FUEL AT INPP

Case Study at INPP

This is Knowledge Product prepared by INPP for the
JRC Nuclear Decommissioning Knowledge
Management initiative NDKM



LEARN MORE



Foreword

In 2021, the European Commission (EC) adopted a new proposal for a Council Regulation establishing a dedicated financial programme for decommissioning nuclear facilities and managing radioactive waste. This instrument covers the co-funding of the decommissioning programmes of Bulgaria, Slovakia, and the decommissioning of the Joint Research Centre (JRC). A separate Council Regulation was adopted for the decommissioning programme of Lithuania.

The EC JRC is mandated to foster the spread of decommissioning knowledge across all the European Union Member States and facilitate knowledge sharing arising from implementing the abovementioned decommissioning programmes, funded by the Nuclear Decommissioning Assistance Programme (NDAP).

The decommissioning operators from the NDAP (NDAP Operators) implemented and tested a knowledge management methodology in 2021 through Project ENER/D2/2020-273. Using this methodology, the NDAP Operators can develop Knowledge Products that are currently available to share with other European stakeholders. In addition, this methodology is under implementation in the JRC Nuclear Decommissioning and Waste Management Directorate (NDWMD), which becomes a knowledge generator extracting the knowledge from the ongoing decommissioning activities at the different sites (Geel, Ispra, Karlsruhe, and Petten).

The JRC NDWMD aims to become a Centre of Excellence in nuclear decommissioning knowledge management and develop a decommissioning knowledge platform which allows exchanging information and building on the best practices in the EU inside the multi-annual financial framework (2021 – 2027) strategy. The operational phase of the project is expected to start in 2024 to develop ties and exchanges among EU stakeholders and document explicit knowledge and make it available through multi-lateral knowledge transfers on decommissioning and waste management governance issues, managerial best practices, technological challenges, and decommissioning processes at both operational and organisational level, to develop potential EU synergies.

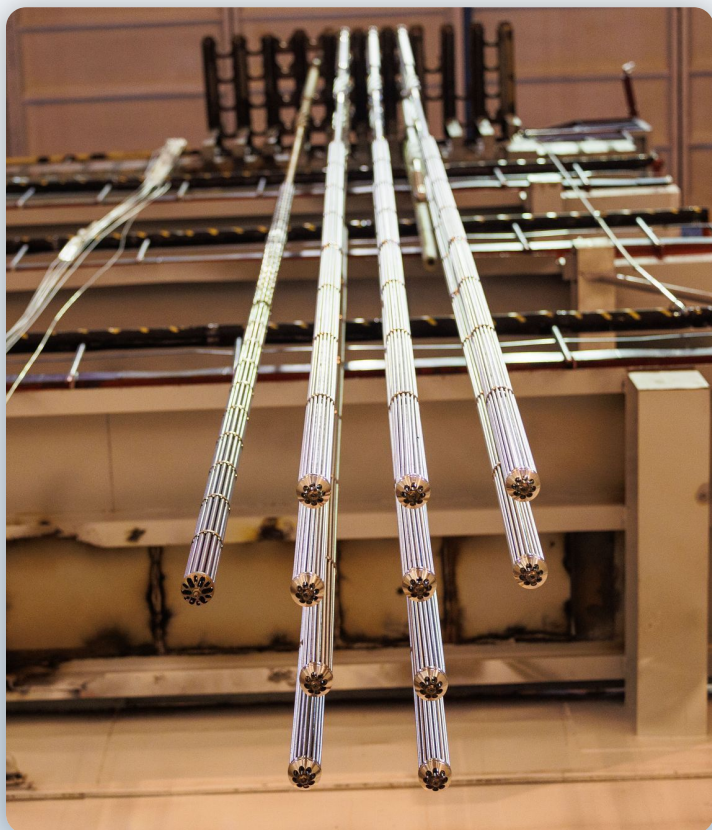




Knowledge Product Information

Management of damaged and experimental fuel at INPP. Case Study

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Version	V1 26/08/2024
Sent to	Andrea Piagentini
Approved by	Andrea Piagentini

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EXECUTIVE SUMMARY

Overview

Management of damaged and experimental fuel

An overview of how spent nuclear fuel is managed and stored at Ignalina NPP

[+ INFO](#)

Objective

Share Project Experience

Document the technologies, processes, and lessons learned in managing and storing damaged fuel at INPP

[+ INFO](#)

Target Users

EU Operators

Primarily decommissioning operators although technologists, regulatory bodies, safety inspectors, etc. may also benefit

[+ INFO](#)

Approach

Navigate the process

This product allows the user to interactively dive into the processes and experience at INPP

[+ INFO](#)

Use

Practical guidance

Guidance for efuel management, transport, accident mitigation and regulatory compliance

[+ INFO](#)

Value

Applicable lessons learned

Other operators can extract tips, recommendations and insights based on Ignalina NPP experience

[+ INFO](#)[→ Menu](#)



Use

The experience of INPP in the DFHS Project demonstrates the viability of proactive solutions to tackle problems associated with damaged and spent fuel. Users can use this experience to improve their:

- Management of damaged spent fuel inventory
- Design of specialised transport and storage solutions
- Compliance with safety standards and regulatory requirements
- Mitigation of potential incidents

Objective



The objective of this Knowledge Product is to document and share the technologies, processes, and lessons learned in managing and storing damaged spent nuclear fuel (SNF) at Ignalina Nuclear Power Plant (INPP) to enhance safety, regulatory compliance, and process efficiency.



Target Users



The target users of this product are nuclear decommissioning operators, regulatory bodies, safety inspectors, and stakeholders involved in nuclear waste management across the European Union.

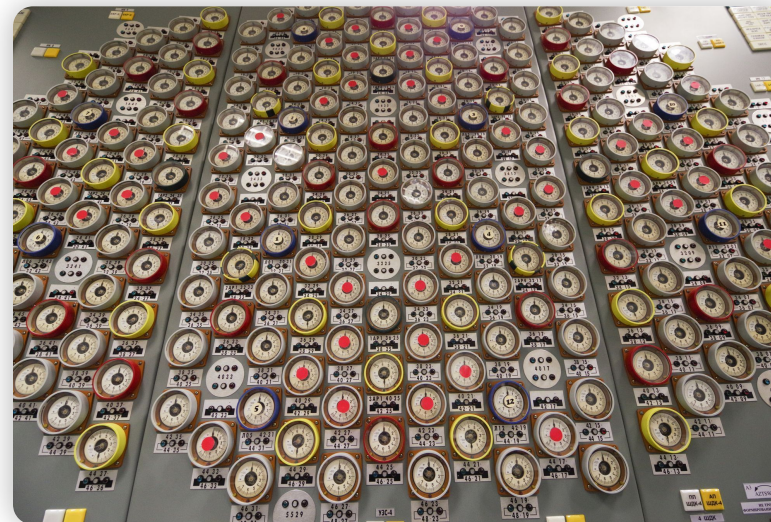


APPLICABLE EXPERIENCE FOR OPERATORS

Value

This product provides a detailed and practical resource on managing damaged spent nuclear fuel, a critical aspect of nuclear decommissioning, including:

- Real-world examples and case studies from INPP.
- Safety protocols and regulatory compliance measures.
- Innovative methodologies and technologies to enhance process efficiency.
- Insights and lessons learned during project execution
- Detailed training programs and organizational strategies to ensure effective implementation and management.





MANAGEMENT OF DAMAGED FUEL

Overview



This knowledge product provides a detailed case study on the management of damaged Spent Nuclear Fuel (SNF) at INPP, presented in an interactive format with multimedia elements. It includes:

- INPP Experience in the initial assessment and challenges of damaged SNF.
- A Step-by-step implementation of the process used by INPP to manage SNF during the DFHS project.
- Lessons learned during the project implementationUtilization of multimedia materials such as 3D models and video content for better understanding.



Interactive Case Study

This knowledge product has been developed as a case study on the management of damaged SNF at INPP, presented in an interactive format with multimedia elements.

- Initial assessment and challenges of damaged SNF.
- Step-by-step implementation of the DFHS project.
- Utilization of multimedia materials such as 3D models and video content for better understanding.

Don't forget to click on every button on the screen! It might lead you somewhere new!



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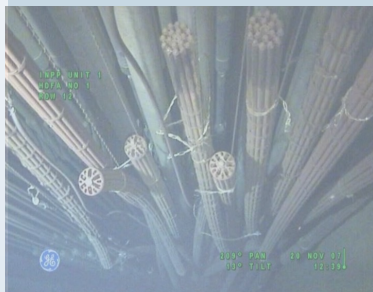
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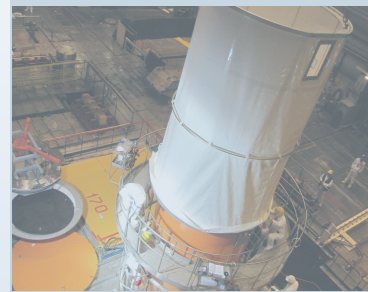


The Case

Handling of
damaged fuel
with the DFHS
and DRS



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The Experience

Lessson Learned
and Takeaways



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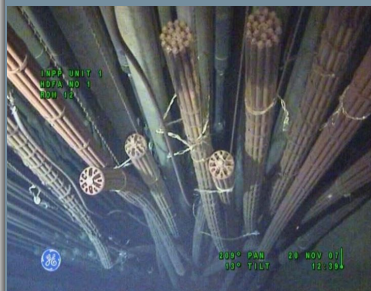
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The Experience

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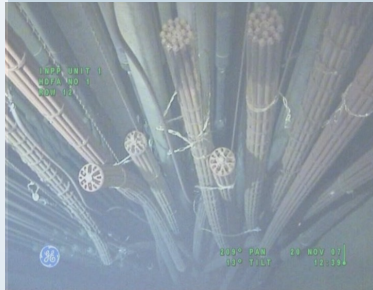
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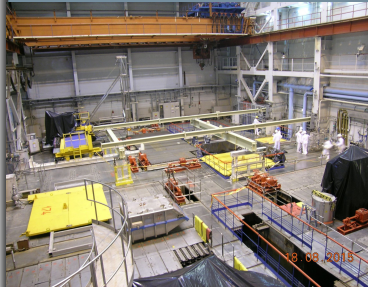


The Context

Management of
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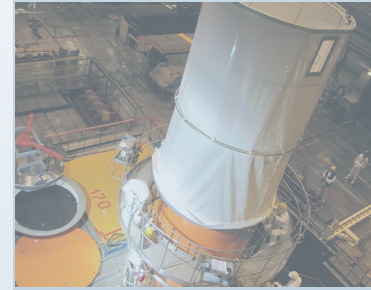
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Process and systems
for fuel handling

How fuel is handled
at INPP with the
Damaged Fuel
Handling System
and the Debris
Recovery System



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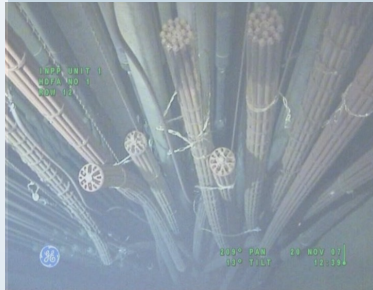


The Experience

Lessson Learned
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The Context



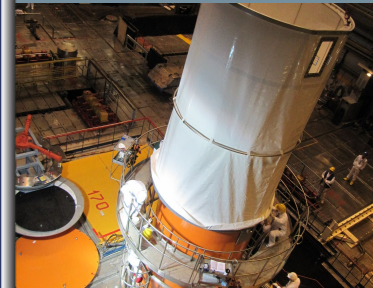
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The Experience

What was learned
at INPP and how to
transfer this
experience to other
operators in Europe





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THE CONTEXT

Ignalina NPP



Construction

The first NPP in Lithuania

Construction started in 1978. It was closed in 2009

+ INFO

Design features

RBMK-1500

Two soviet-designed water-cooled graphite-moderated channel-type power reactors

+ INFO

Operation

More than 20 years

Units 1 and 2 operated for 21 and 22 years respectively

+ INFO

Decommissioning

2004

The first decommissioning project of a Lithuanian NPP

+ INFO

Ignalina Nuclear Power Plant (IAE)

[View larger map](#)



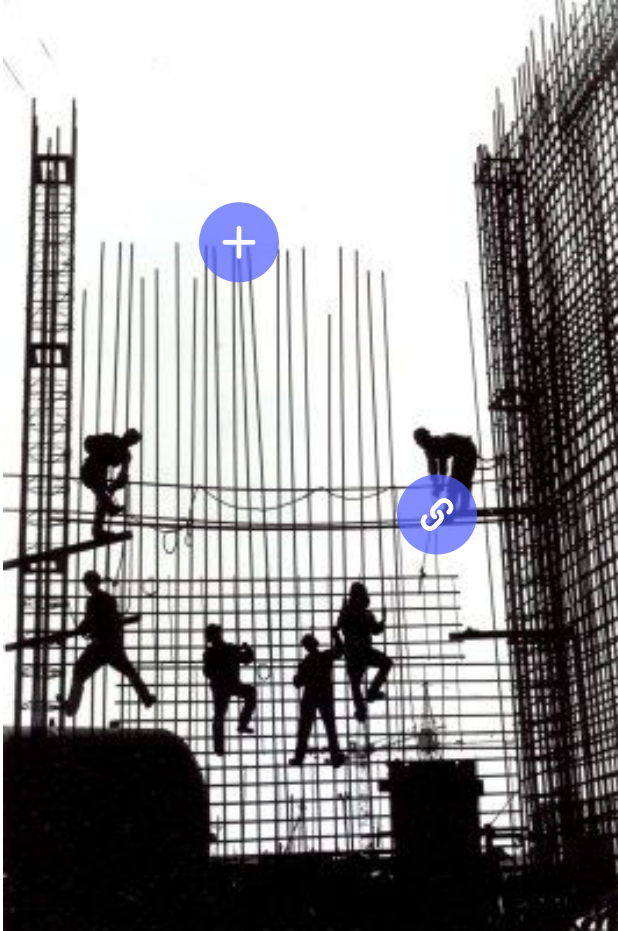
Map data ©2025 Imagery ©2025 CNES / Airbus, Landsat / Copernicus, Maxar Technologies | [Report a map error](#)

Virtual Tour



Ignalina NPP

The mission of the enterprise is safe and timely implementation of a globally unprecedented project decommissioning of the nuclear power plant, which operated two RBMK-type reactors, and handling radioactive waste to ensure that the future generations do not have to carry the unreasonable burden of radioactive waste management.



Ignalina NPP

It was planned to build 4 reactors, but only 2 RBMK-1500 graphite nuclear reactors were built and launched. Unit 1 was launched in 1983 and Unit 2 – in 1987. These were the most powerful nuclear reactors in the world: the thermal capacity of a single unit was 4,800 megawatts (MW) and the electricity generating capacity – 1,500 MW. At the end of 1978, there were 5067 employees working at the construction in 1982 - 11,286 employees. 10 ministries of the USSR and 45 factories had to ensure that Unit 1 was put into operation in 1982.





Social

The construction of Ignalina NPP required constructing 142 km of roads, 50 km of railways, 390 km of communication lines, 334 km of electricity lines, 133 km of sewerage lines, and 164 km of thermal lines. 3,544,000 m³ of concrete and reinforced concrete and 76,480 tonnes of reinforcement was used for the construction. During almost four decades of operation the plant provided employment to thousands of workers.



Clean

In the 26 years of operation, Ignalina NPP produced 307.9 billion kWh of electricity: 136.9 billion kWh in Unit 1 and 170.2 billion kWh in Unit 2.



Reliable

During the 26 years of operation Ignalina NPP has produced the 70% of Lithuania's electricity demand.

Key Design Features



- **Graphite Moderator:** The core contains graphite blocks that act as a neutron moderator.
- **Fuel:** The reactor uses slightly enriched uranium dioxide fuel, contained in zirconium alloy fuel rods.
- **Boiling Water Reactor:** The RBMK 1500 uses water as a coolant. The water boils directly in the reactor core, generating steam that drives the turbines to produce electricity.
- **Channel Type:** Each fuel assembly is contained within a separate pressure tube, allowing for individual cooling channels, which enables on-line refueling.



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The need for safe management of damage fuel

During the operation of nuclear-spent fuel pools (SFP), some spent fuel may be damaged by physical impact on the fuel element cladding, releasing radioactive material.

To minimise the risks, INPP proactively launched the Damaged Fuel Handling System (DHFS) Project to adequately handle and load damaged fuel into storage casks

THE CONTEXT

The need for safe management of damaged fuel



Damaged spent fuel inventory



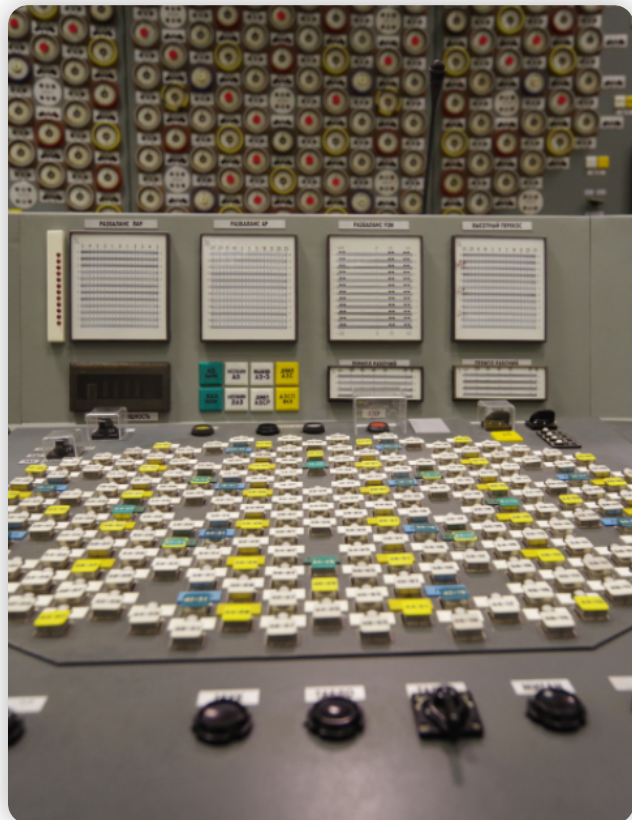
Compliance with safety and regulation



Proactively mitigating potential incidents



Specialised transport and storage solutions



Incident mitigation

Design-basis and beyond-design-basis accidents such as damaged fuel drops, fuel element cuts, etc. must be proactively prevented and mitigated

Safety Assessment Report (SAR) must explicitly address these

The DFHS works with systems such as ventilation, pool water treatment, and pool water cooling and can handle the release of radioactive material and the fuel spill/tablet collection system, demonstrating the commitment to integrated safety measure



Worker Exposure

The DFHS Project includes features to limit workers' radiation doses, using protective equipment,



Continuous monitoring

It also includes features for the continuous monitoring of the management of damaged fuel ,



Nuclear material control

It incorporates strict operational and nuclear material accountability controls.



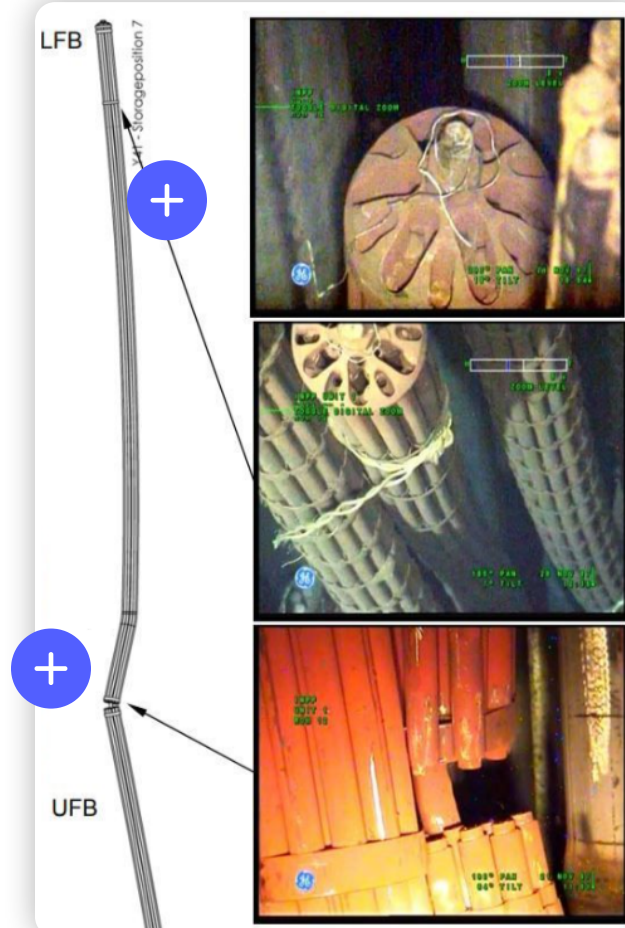
Specialised transport and storage solutions

1

INPP needed a system capable of handling damaged fuel from the storage phase to loading into Spent Nuclear Fuel casks.

2

The plant also required a system that could handle Spent Nuclear Fuel pellets and spillage



Damaged spent fuel inventory

Spent Fuel damage can range from minor surface defects to severe cracks in the fuel element cladding, including damage to the fuel itself.

In addition to SNF with various defects, INPP also had experimental fuel, which handling was also not foreseen.

INPP tackled the processes and systems to handle Spent Fuel inventory via two projects that are described in this case study



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Opportunities related to the safe management of damaged fuel



Improve process efficiency

Design a more efficient system to handle Spent Nuclear Fuel



Build regulatory confidence

Implement advanced tools that help build trust in the process



Contribute to nuclear safety knowledge

Share the experience with other Members States to improve safety



A basis for future innovation

A stepping stone for other Member States





Contribute to nuclear safety knowledge

The experience gained in this project provides an opportunity to contribute to the wider nuclear energy sector by improving safety in the handling, transport and storage of Spent Nuclear Fuel.



A Basis for future Innovation

State Enterprise Ignalina Nuclear Power Plant (INPP) foresaw and opportunity to gain experience in the development and implementation of the DFHS Project, laying the foundation for future innovation at INPP and other nuclear facilities.



Build regulatory confidence

INPP sought to meet regulatory requirements and build confidence with regulators (VATESI, the State Nuclear Power Safety Inspectorate) and other stakeholders.

The implementation of an advanced system, such as the one presented here, contributed to this goal



Improved Process Efficiency

INPP identified an opportunity to streamline the processes for handling and storing damaged spent nuclear fuel (SNF), reducing operating costs and improving the overall plant efficiency.

The Damaged Fuel Handling System (DHFS) Project was designed for this purpose



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CONSTRAINTS

INPP found several constraints during the development of the DFHS Project



Safety

Implement advanced tools that help build trust in the process



Technological

Implement advanced tools that help build trust in the process



Schedule

Implement advanced tools that help build trust in the process





Technology constraints

- Only one set of DFHS equipment was delivered and installed in Unit 1 after the loading of intact fuel was completed.
- Only after the handling of damaged fuel in Unit 1 was completed was the DFHS equipment moved to Unit 2 to handle SNF.

Main implication

It was impossible to operate the two units in parallel because the removal of intact fuel was still in progress at Unit 2.



Safety Constraints

Ensuring the safety of handling damaged SNF was the top priority for the DFHS project. This meant:

- **Strict protocols:** Procedures, test records and radioactive measurement records for handling damaged fuel had to be followed at all project stages.
- **Control of exposure:** The project required state-of-the-art technology and best safety practices.



Schedule constraints

The project was carried out within a tight timeframe to remove all nuclear fuel from the containment pools of Units 1 and 2 to obtain a licence to dismantle the INPP facilities.

Main implication

The acceleration of the deadlines forced the project management to optimise some processes in handling SNF with different types of defects and the subsequent loading of SNF into storage casks.



Schedule

FUEL LOADING

Years



Loading of non-damaged fuel at the unit 1	75 casks, 3 years 11 month or 47 month or 1423 days			
Loading of damaged fuel at the unit 1			11 casks, 10 month or 312 days	
Loading of non-damaged fuel at the unit 2	93 casks, 4 years 4 month or 52 month or 1567 days			
Loading of damaged fuel at the unit 2	The fuel loading process took approximately 6 years in total		11 casks, 10 month or 303 days	

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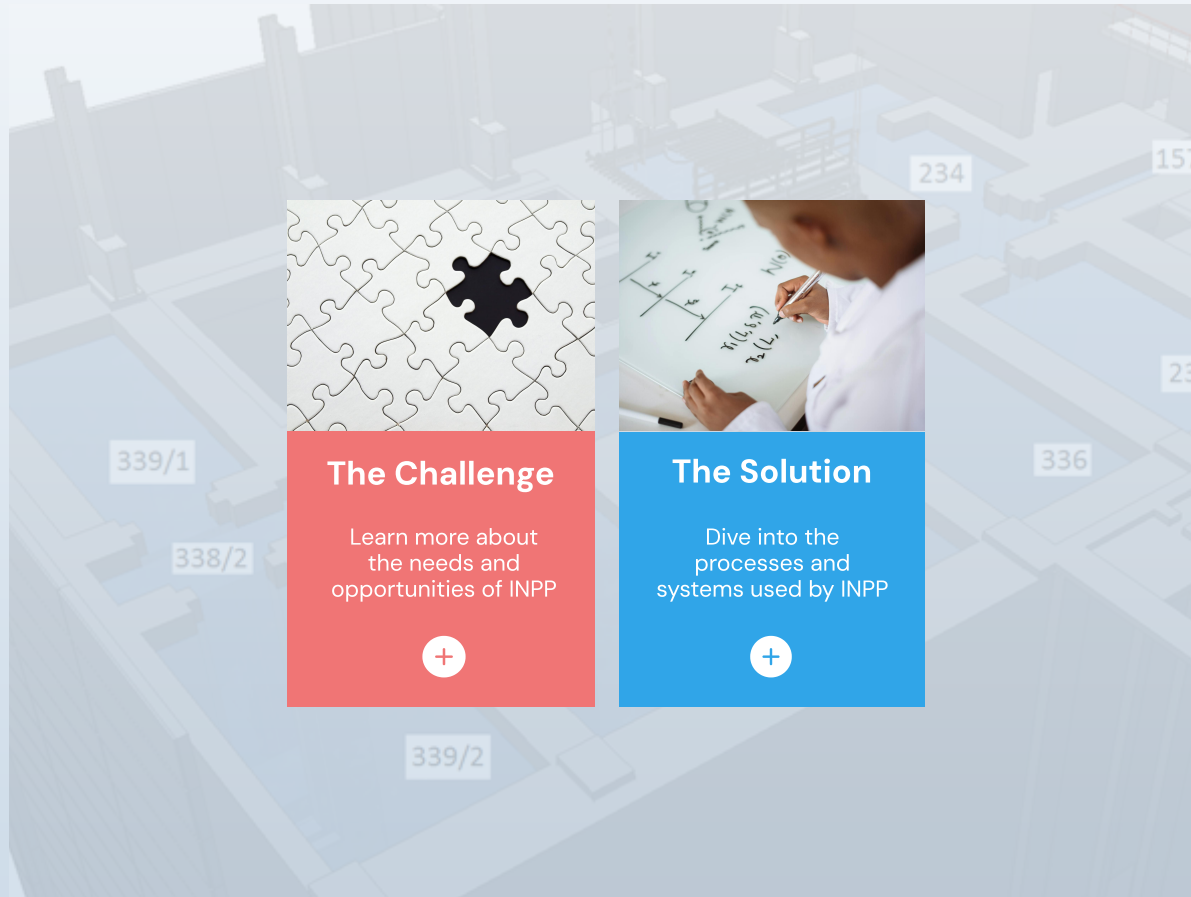
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THE CASE



Case Study Description

This case study presents the experience of INPP in the design and implementation of a process to improve the identification, removal, handling and storage of damaged SNF in protective casks.

The case will focus on the DFHS (Damaged Fuel Handling System) and Debris Recovery Systems used by INPP to safely handle damaged, experimental, and leaking fuel, providing nuclear safety and radiation protection for personnel and the environment.

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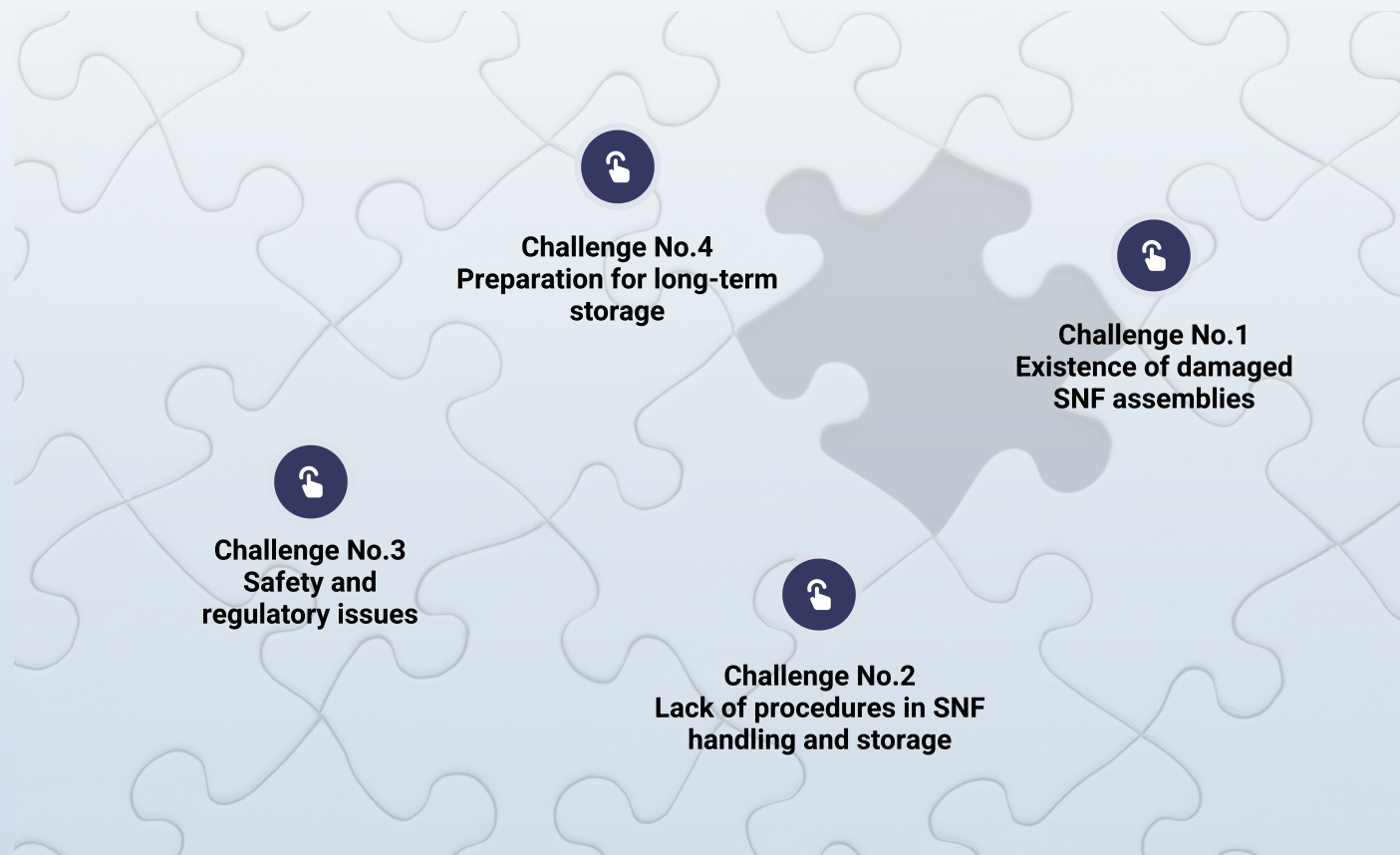
THE CASE

Case Study Baseline. Challenges

Challenges

The initial situation before the implementation of the DFHS Project can be characterised by four key challenges related to SNF management: existence of damaged SNF assemblies, lack of procedure, regulatory issues and preparation for long term storage

Check details clicking on the interactive buttons on the picture =>

[THE SOLUTION](#)



Preparation for long-term storage

One of the challenges for INPP is the need to prepare damaged SNF for long-term storage.

This includes the safe and secure storage of SNF and considerations for future retrieval, reprocessing, or disposal.

Developing a system that could adapt to changing storage and regulatory requirements was necessary to tackle the abovementioned challenge.



Lack of Procedures

Before the DFHS was introduced, no dedicated system was in place to safely recover, handle, and store damaged SNF assemblies. Therefore, no procedures for handling & storage were available



Lack of License

Existing VATESI (regulator) licenses and procedures were not fully adapted to address the specific challenges associated with damaged fuel, including transport, cutting or segmentation, and encapsulation.



Existence of damaged SNF assemblies

INPP has encountered problems with damaged SNF assemblies, including minor mechanical damage that does not affect the integrity of the cladding and major damage resulting in possible fractures and loss of fuel pellets.

The need to effectively manage these damages of varying severity has been paramount.



Safety and regulatory issues

The handling and storing of damaged SNFs is critical from the safety point of view and is subjected to close regulatory surveillance.

Safety challenges include the potential for radiation exposure to personnel, the risk of pool water contamination, and the need to comply with strict nuclear safety regulations.

Ensuring the protection of personnel and the environment was a critical consideration in the development of this project.

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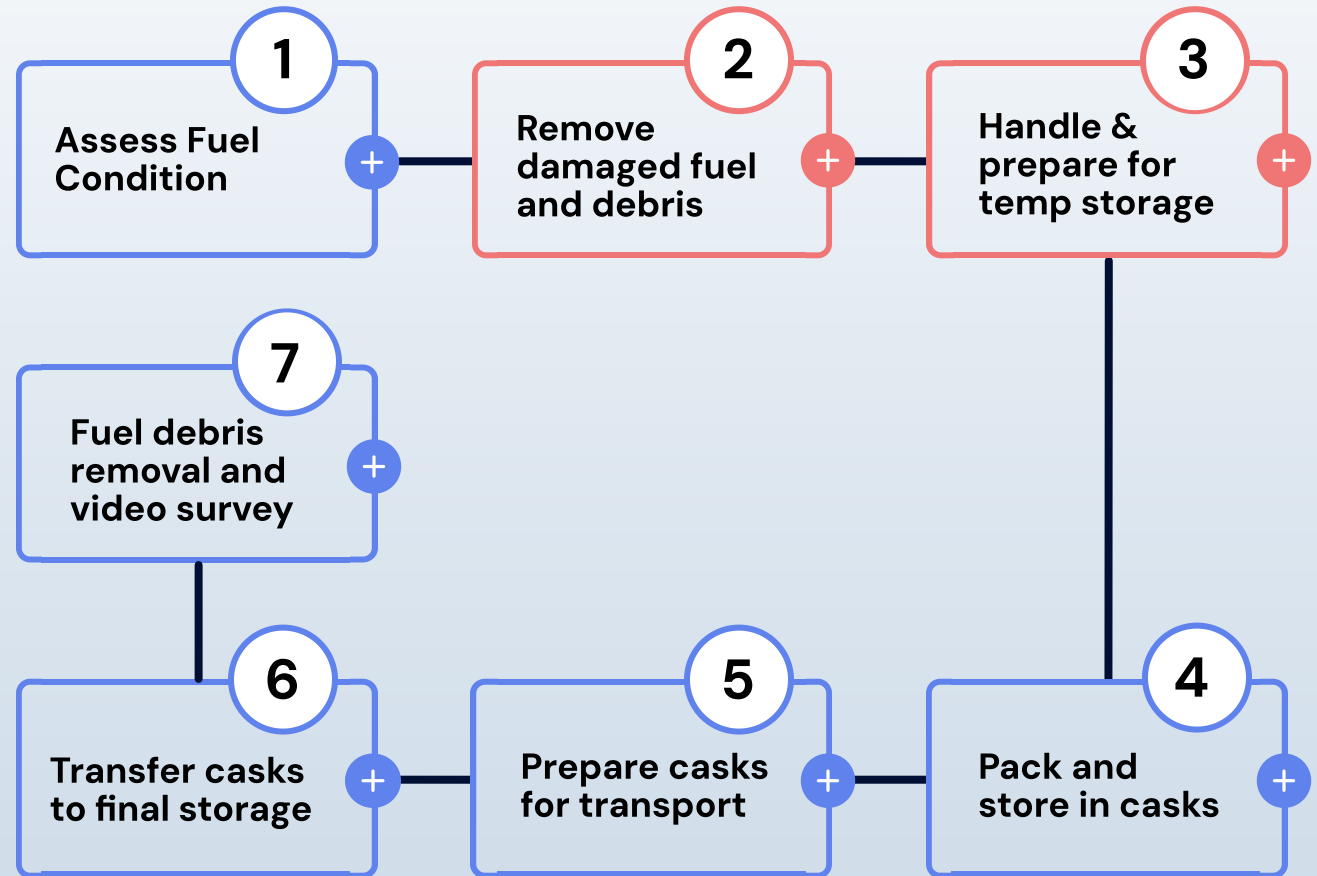
THE CASE

The solution adopted by INPP.

Dive into the process

Click on each one of the 6 steps of the process to learn how INPP assessed fuel condition and handled, dried, transported and stored damaged, experimental, and leaking fuel.

If you need more details on the technology used by INPP feel free to contact INPP staff directly and / or click the link below

[THE DFHS PROJECT](#)

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Safety
Trail



Traverse



Gripping
Fork



Grab for
fuel
bundles



Separati
on Tool



Cartridges



Working
Tray



Service
Platform



The solution

Damaged Fuel Handling System (DFHS)

The Damaged Fuel Handling System (DFHS) is designed for underwater handling of damaged and experimental SNF in one of the converted spent fuel pools

The DFHS includes several key processing steps tailored to the condition of the SNF assemblies:

- Underwater
- Segmentation and loading
- Transfer to storage facility
- Fuel spill and pellet recovery

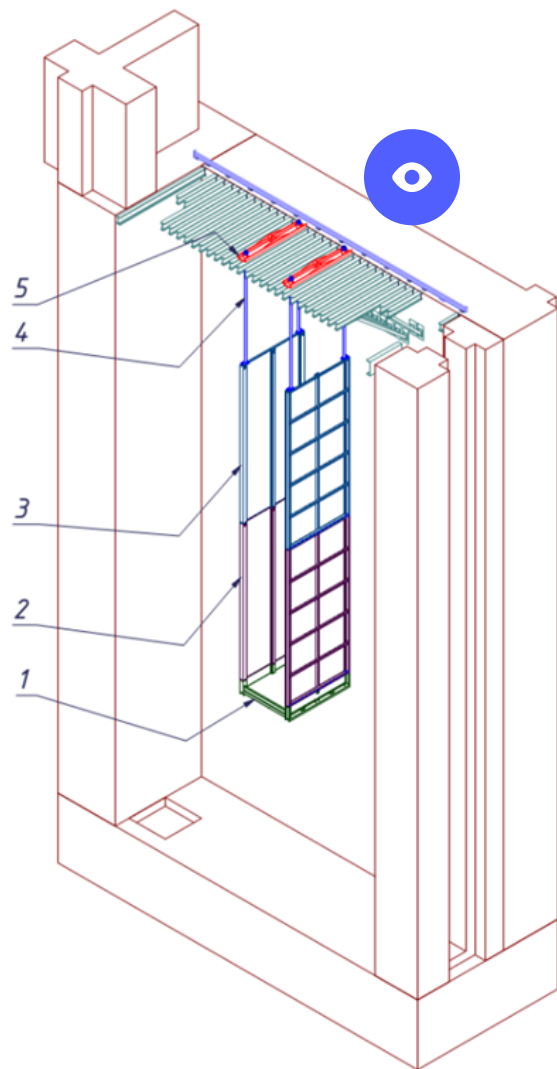


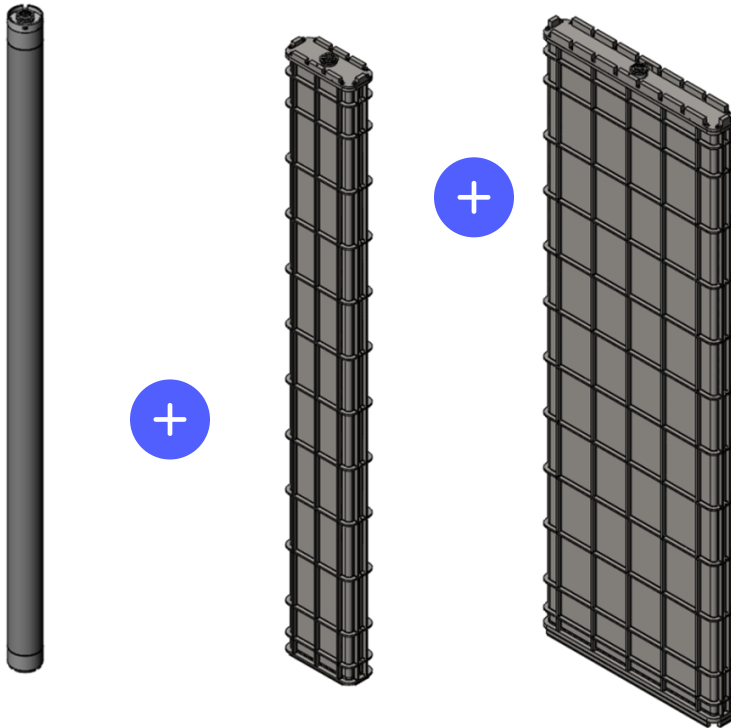
TO THE PROCESS



Safety Trail

A safety trail intended for the enclosure of the damaged SFA storage place in the 236/1 pool of the SPH INPP Unit-1





Cartridges

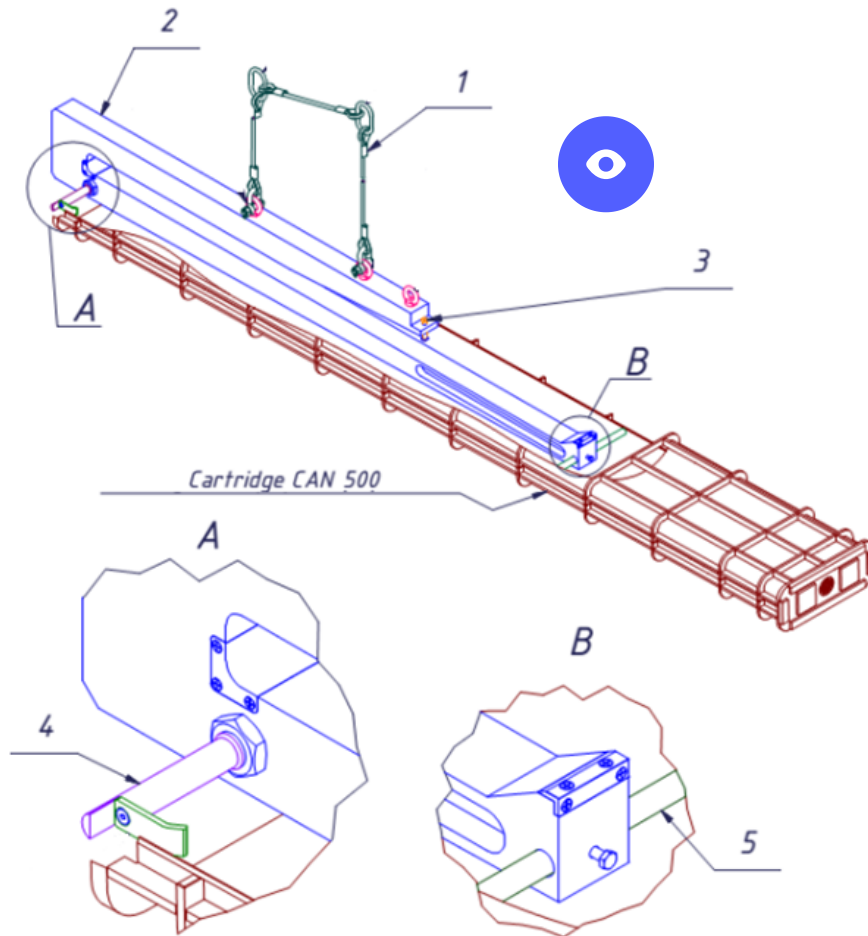
The three types of different-dimension overpack cartridges, CAN 160, CAN 500, and CAN 1200 (see Figure), are developed for insertion and further storage of the heavily damaged fuel bundles.

The dimensions of the cartridges are defined based on the results of the heavily damaged fuel inspection at INPP Unit 1 SPH. All three CAN types have similar designs. Each CAN consists of two parts: the body and the cover.



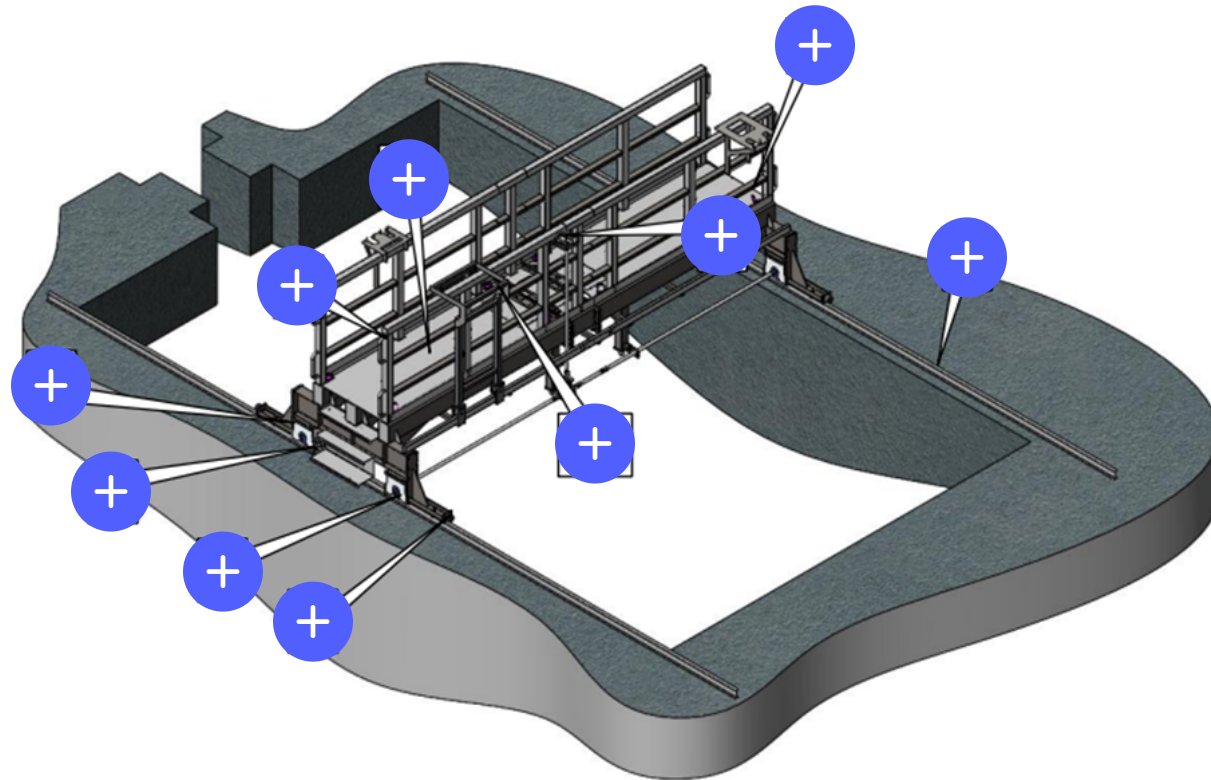
Gripping fork for rectangle cartridge

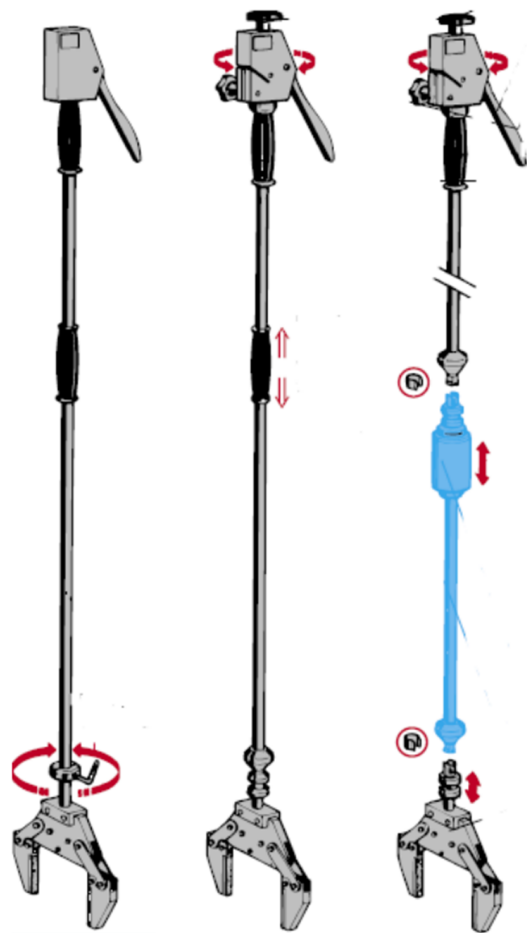
This fork is used to transfer the Cartridges CAN 500, CAN 1200, and CAN 160 from the SPH ground floor, at the 25,200 level, to the Working Tray that is mounted onto the level 22,400 in the pool 236/1 Unit 1





Service Platform of the DFHS





Handle grab "pedi"

Grab for damaged SFA

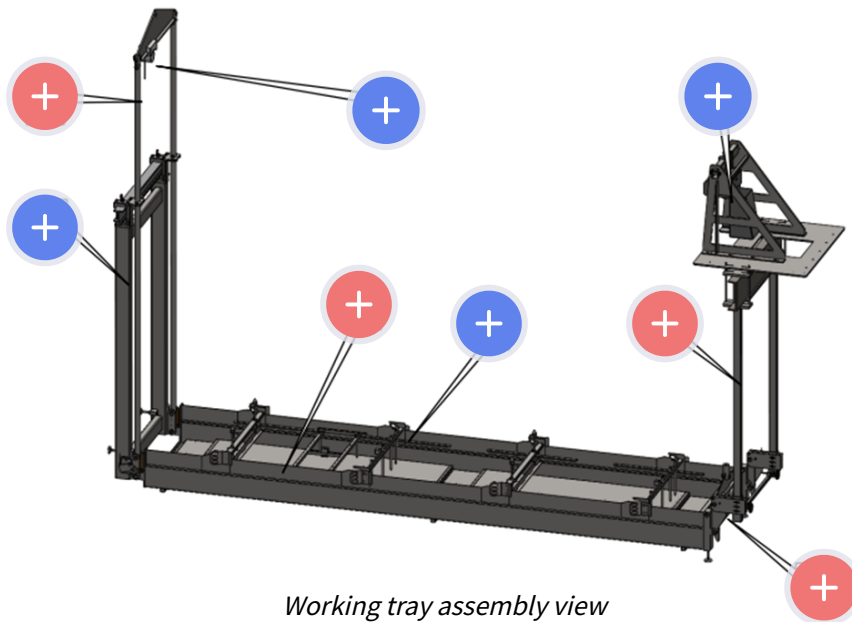
The grab for damaged SFA is used for moving the damaged SFA suspended on the wire at the semibars to the place where the damaged SFA will be loaded on the working tray

Handle Grab "pedi"

This tool is collet-style holder type grab for collection of small parts and pieces.



Working Tray



The Working Tray is a multifunctional device for the following defect fuel handling processes:

- Tilting of the damaged SFA in vertical position;
- Tilting of SFA in the horizontal position;
- Cutting of suspension rod from SFA;
- Lifting the SFA in horizontal position
- Cutting and trimming of SFA in two bundles in horizontal position;
- Insertion of FB into the cartridges in horizontal position;
- Lifting the cartridges with FB in vertical position;
- Installation and tightening of the cartridge lids;
- Connection of the cartridges with suspensions.



Separation tool

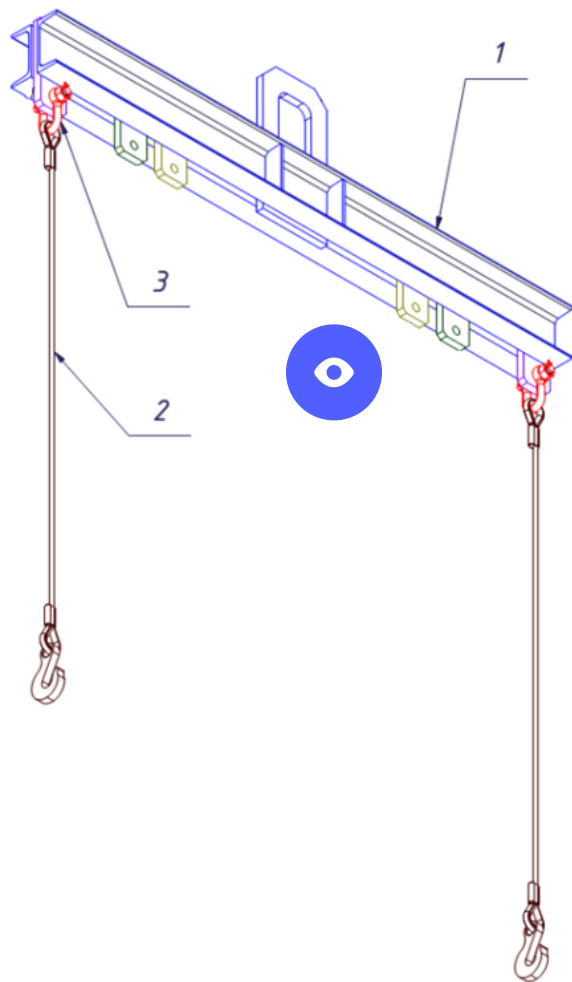
A separation tool for handling operations with damaged fuel bundles in pools 236/1 at unit 1 and 236/2 at unit 2.

The Separation Tool is designed as the 4 meter length rod with the fork at the end, mass is 6 kg



Traverse

A traverse serves as the hoisting appliance for the SPH 20-ton crane





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**3D FUEL
ASSEMBLIES**



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INPP FUEL
ASSEMBLIES**



**VIDEO
INSPECTION
OBJECTIVES**



**VIDEO
INSPECTION
SYSTEM**



**PREPARATION
OF 3D CAD
MODELS**



**DEVELOPMENT OF
FUEL HANDLING
SYSTEMS**



**DAMAGED
ASSEMBLIES**



**PLAY
VIDEO**

Step 1. Identification and assessment of damaged SNF

This initial assessment relies on diagnostic tools and technologies to accurately classify the extent and type of damage of spent nuclear fuel (SNF)

It is critical in determining the strategy for subsequent processing and remanufacturing steps to handle and overpack cartridge size for the heavy-damaged fuel assembly



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CAM 2



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HDFS experimental SF



Video Inspection System

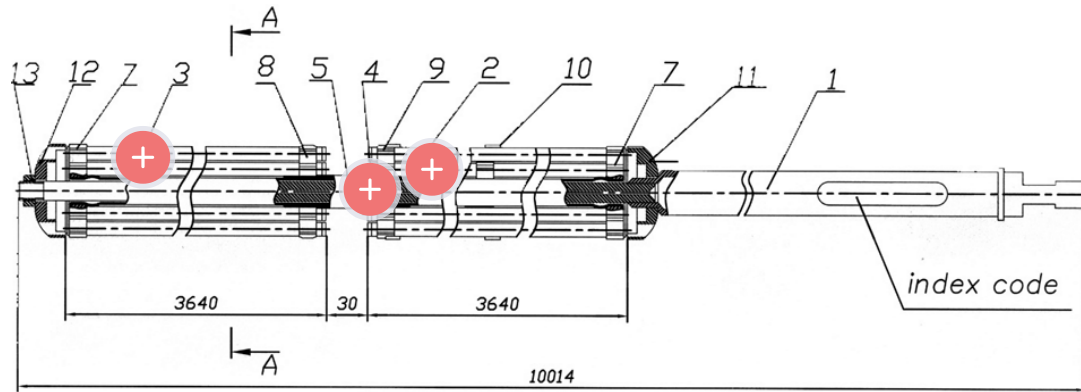
VIS

The Video Inspection System (VIS) supports the operating personnel of the Damaged Fuel Handling System. The complete VIS consists of following main components:

- Inspection head – colour camera with controlled focus, zoom, pan and tilt;
- Two halogen lights;
- Power supply cable;
- Central control unit.
- Handheld remote control.

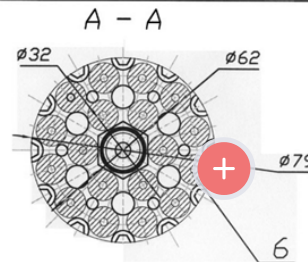


The DFHS uses rigorous inspection and monitoring techniques to accurately identify and classify the extent of damage to spent fuel assemblies at INPPs. This initial step is critical in determining future safe handling and processing practices.



Description:

- | | |
|---------------------|--|
| 1—extension rod | 8—spacer grid |
| 2—upper fuel bundle | 9—spacer heat exchange intensifying grid |
| 3—lower fuel bundle | 10—heat exchange intensifying grid |
| 4—central tube | 11—upper cap |
| 5—guard sleeve | 12—lower cap |
| 6—fuel rod | 13—fixing nut |
| 7—end grid | |



Fuel Assemblies

The full-size RBMK-1500 fuel assembly consists of two subassemblies (fuel rod bundles)(figure 1), end fittings, a central rod or tube with an extension, fasteners, and fixators. Each bundle contains 18 fuel rods (fuel elements) secured in a frame.

The fuel elements are tubes filled with fuel pellets and arranged in grids along two concentric circles.

The frames of the lower and upper bundles have different designs.



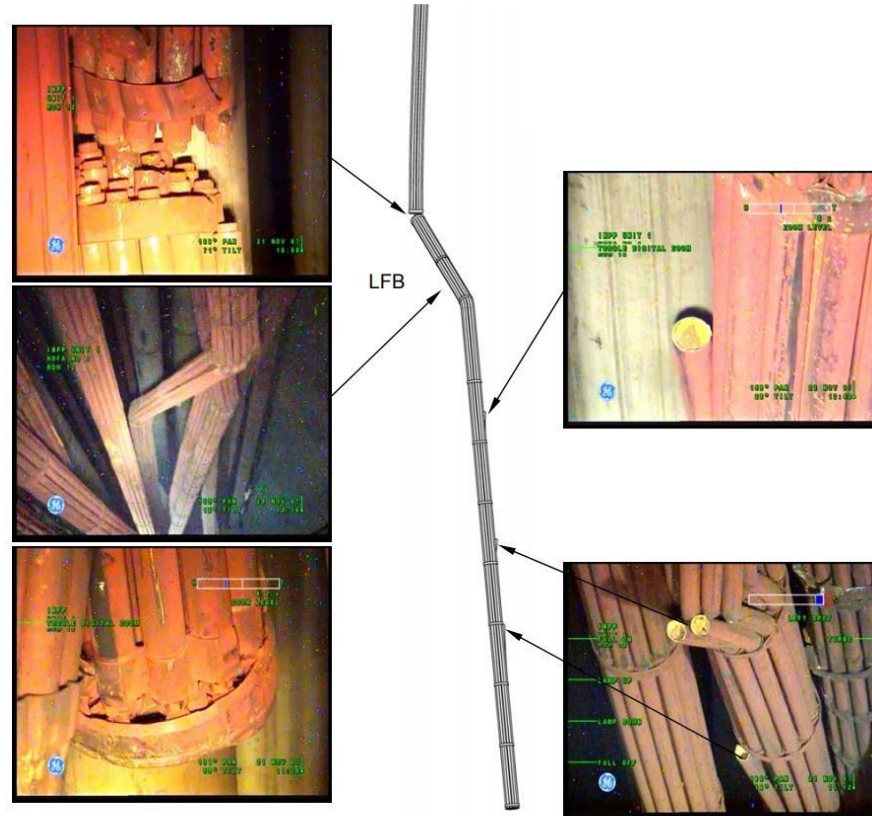
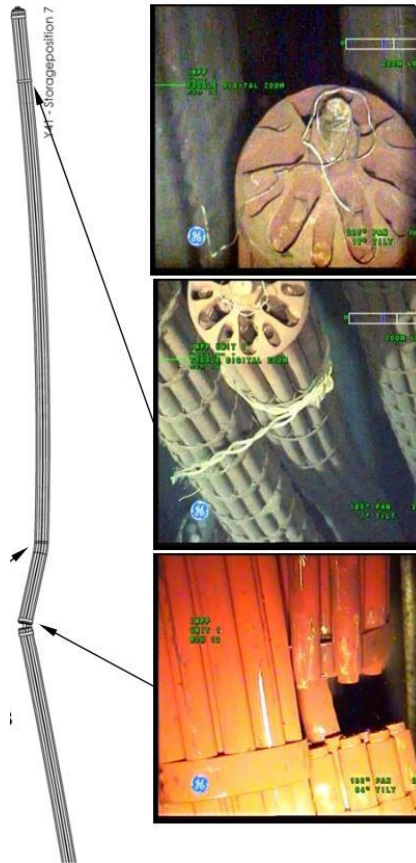
Video inspection results were used to prepare the 3D CAD models of each damaged assembly.

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CAM



Heavily damaged assemblies in Pool 236/1 of Unit were inspected using video, with 4 main objectives

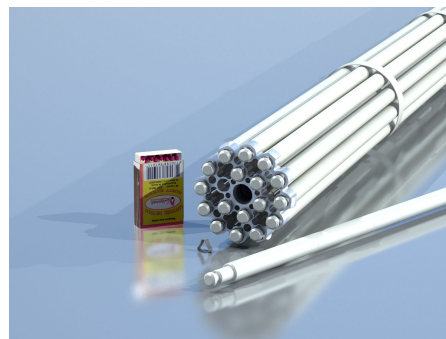
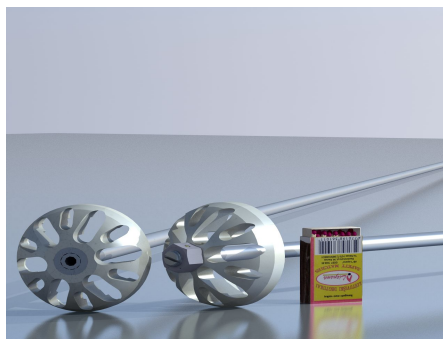
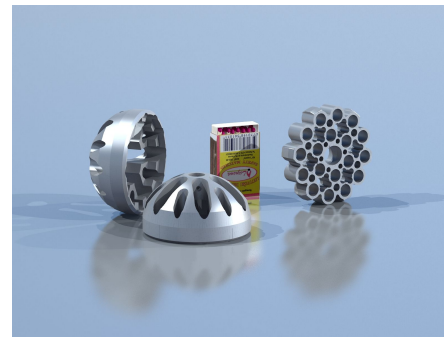
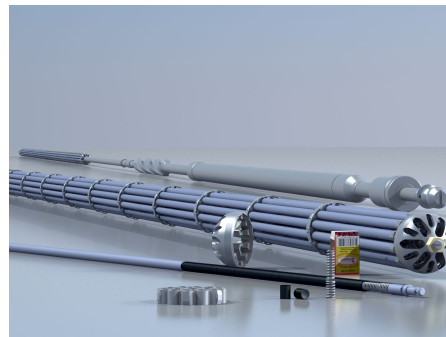
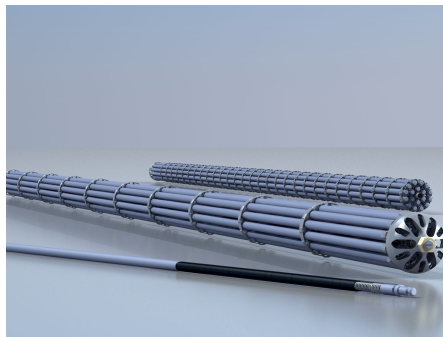
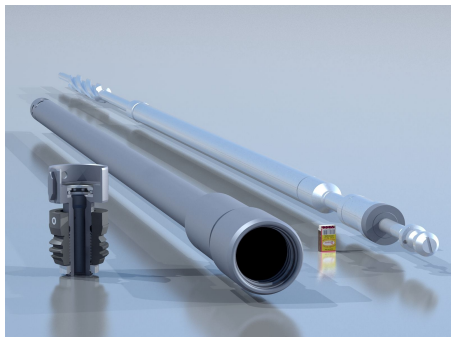


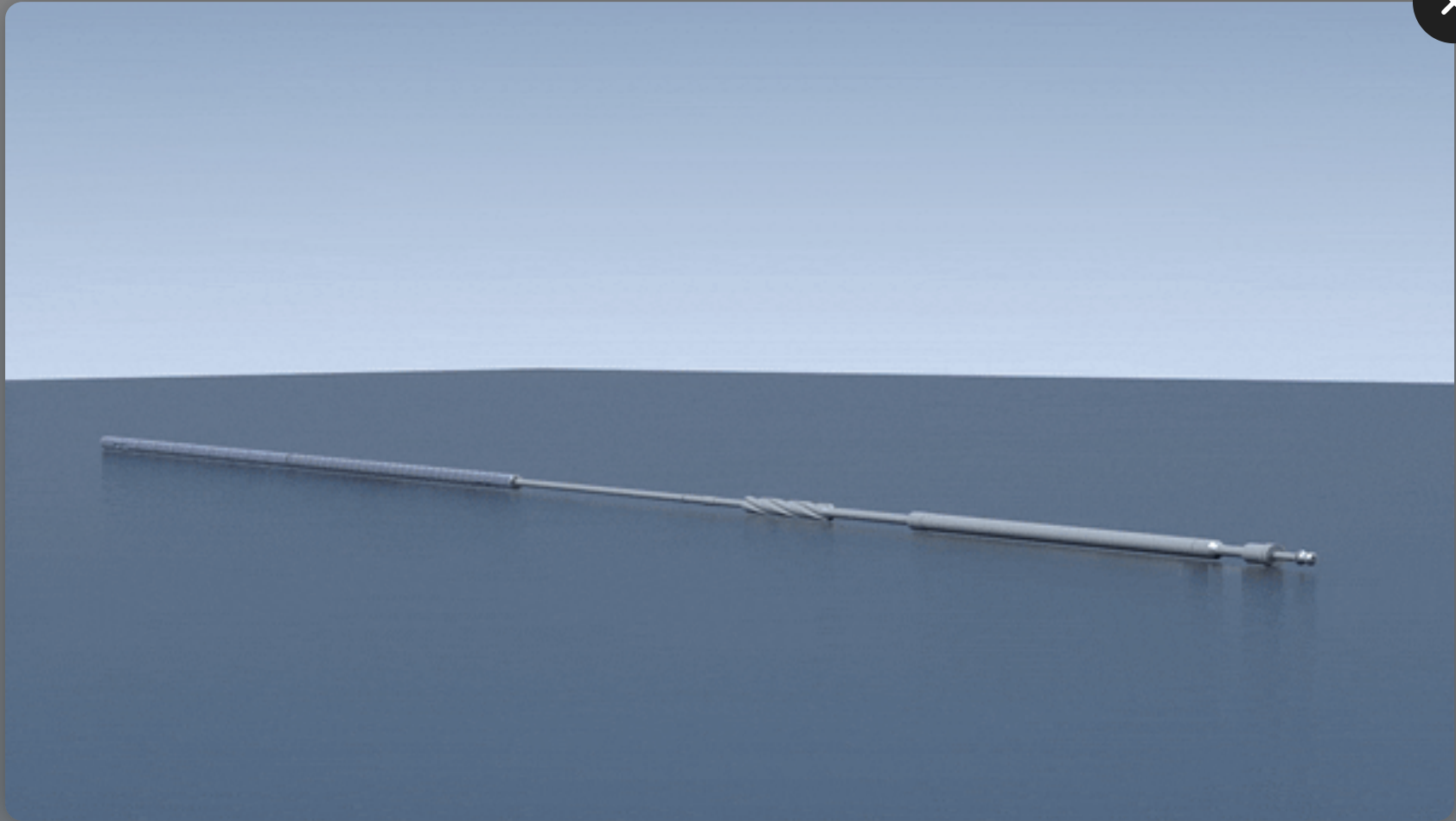


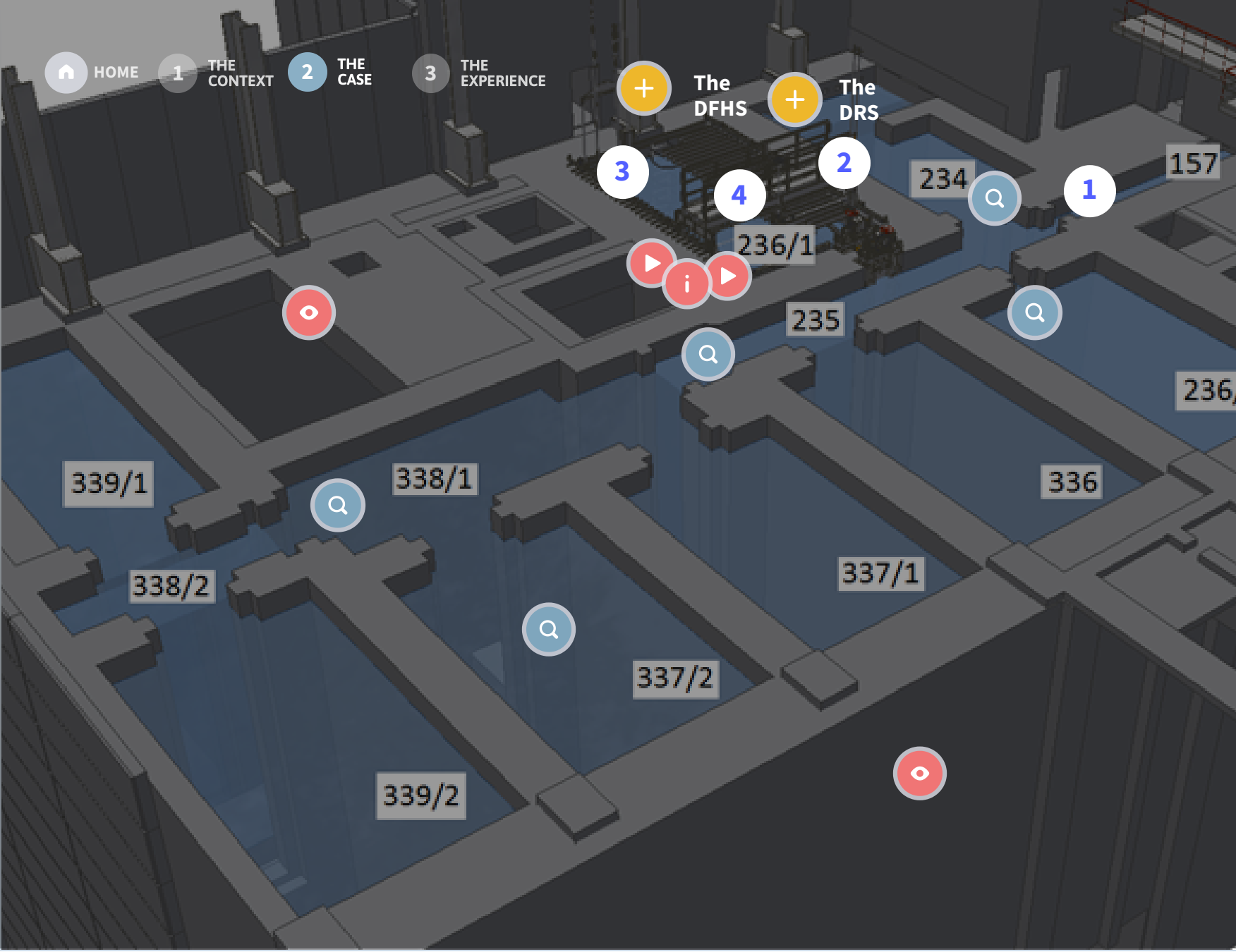
The main challenge in this step is to identify and assess the extent of damage to spent fuel assemblies, which can range from minor mechanical damage to severe damage resulting in the loss of fuel pellets.



These CAD models are used as a basis for developing damaged fuel handling systems and designing over-pack cartridges.







The DFHS The DRS

3 4 2

Step 2. Removal of damaged SNF from the SFP

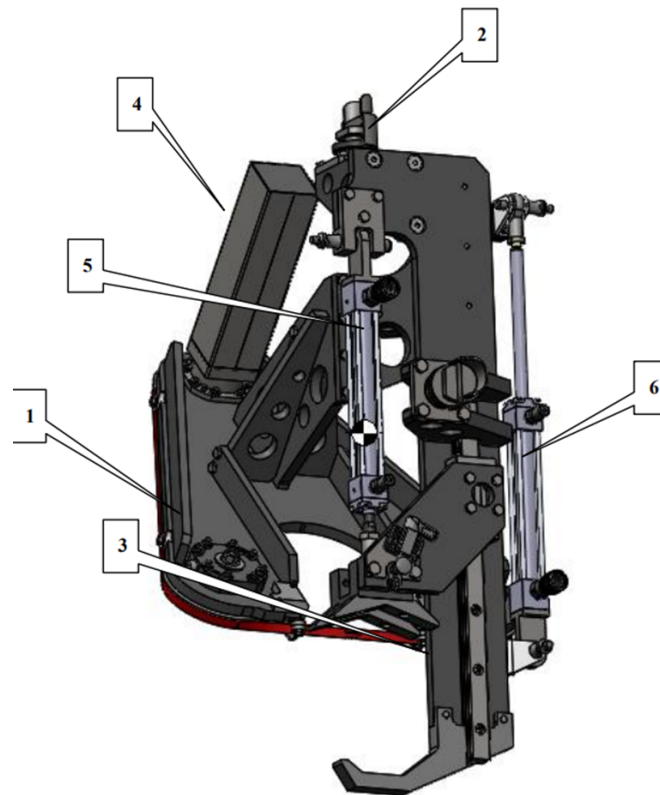
Damaged SNF assemblies are safely removed and segmented from the pools using specialised underwater equipment designed to minimise human radiation exposure and prevent further damage during transport.

The DFHS system is designed to cut, handle and transfer fuel bundles into over-pack cartridges to the interim storage in the spent pool hall





The main challenge in this step is to safely remove damaged SNF assemblies from the pools without further damaging them or exposing workers and the environment to radiation.



Wire band saw

Cutting

The hydraulic scissor is used for:

- Fuel bundles separation to provide required gap for cut operation.
- Emergency cutting of the wire band of the wire band saw.

The wire band saw is used for:

- Cutting of damaged FA extension tube;
- Cutting of temperature measurement fuel rods of experimental fuel;
- Cutting of damaged FA into two bundles in case if the gap between them less than 25 mm;
- Cutting of the central rod end near the nut if necessary.

The wire band saw can be used for under water cutting in vertical and horizontal orientation



Transport and handling systems

The transport and process rooms furnished with heavy equipment are served with lifting and conveying machinery such as cranes, electric overhead cranes, power hoists and manual pulleys, conveying self-propelled transport trolleys.

The rooms are linked together by a system of transport and railway corridors, which allow the transfer of materials and equipment along the appropriate routes.

10-06-2021 08:54:25

CAM 2





The DFHS Project has developed specialised underwater equipment and procedures to safely handle and load damaged SNF assemblies into storage containers.

This involves the use of cranes, tools, remote handling equipment, and underwater video cameras to minimise human radiation exposure and prevent further damage to the SNF assemblies.





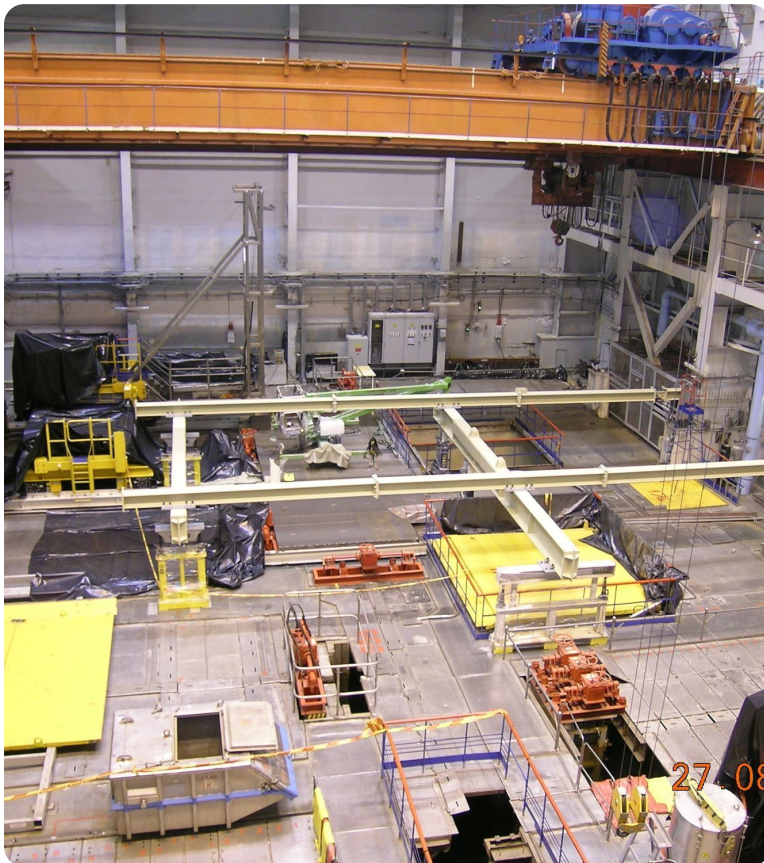


Spent fuel assemblies (SFAs) are stored in the SFPs of the Spent Fuel Hall (SPH)

Pool 157 is intended to transport fuel assemblies between the Reactor Hall and the SPH.



Pool 234 is intended to transfer fuel assemblies to the “hot” cell;



Spent Fuel operations hall

Each INPP unit has its own spent fuel pool hall (SPH). The Spent Fuel Storage and Handling System (SFSHS) equipment is installed in the reactor building.

The spent fuel assemblies extracted from the reactor and spent fuel bundle cases are stored in the SPH's storage pools.

This hall performs all process operations for handling the spent fuel.



Some SFA are damaged differently, e.g., bent, broken, etc. and can't be loaded into containers as usual.

Damaged SFA are treated using newly developed equipment and stored in Pools 236/1 and 236/2 together with the suspensions, cartridges and auxiliary system equipment



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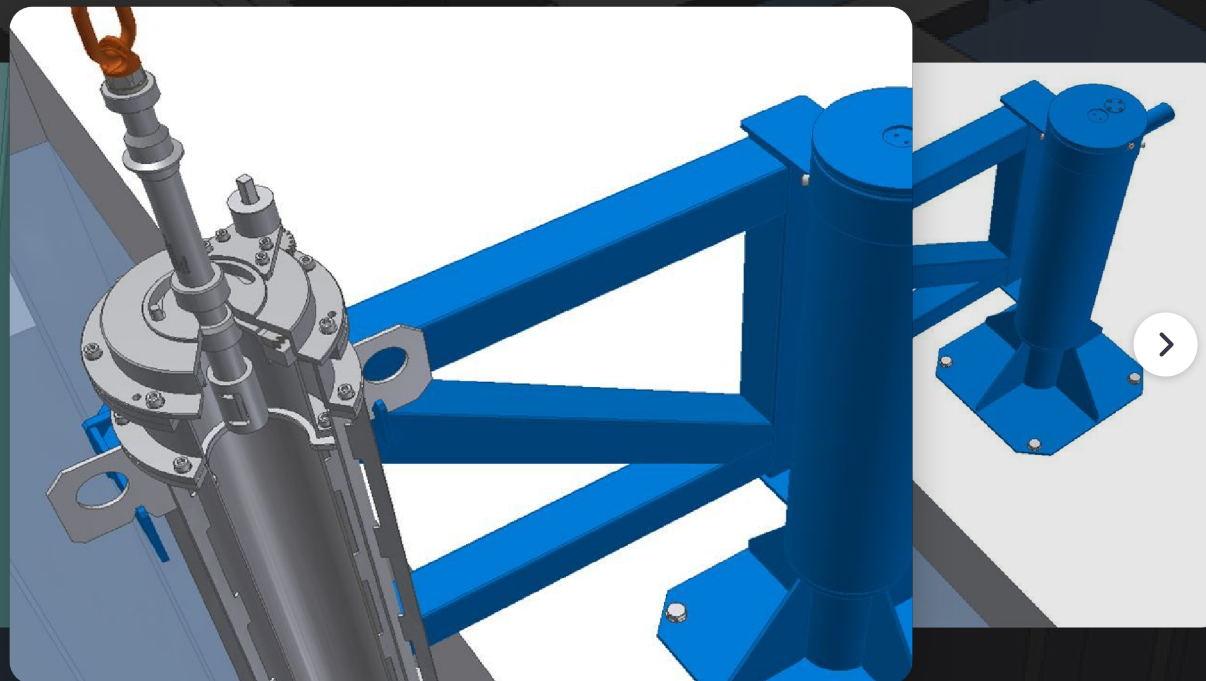
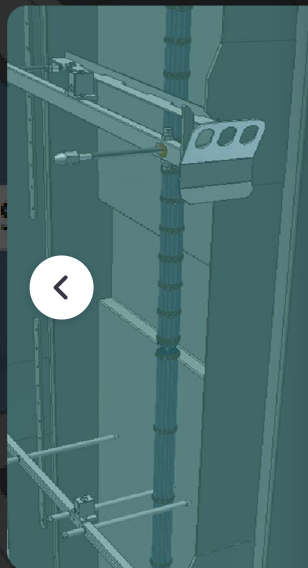
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Installation of SNF (Spent Nuclear Fuel Assembly) on the WS (Workstation)

Step 2. Removal of damaged SNF from the SFP

Damaged SNF assemblies are safely removed and segmented from the pools using specialised underwater equipment designed to minimise human radiation exposure and prevent further damage during transport.

The DFHS system is design to cut, handle and transfer fuel bundles into over-pack cartridges to the interim storage in the spent pool hall



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The main challenge in this step is to safely remove damaged SNF assemblies from the pools without further damaging them or exposing workers and the environment to radiation.



The DFHS Project has developed specialised underwater equipment and procedures to safely handle and load damaged SNF assemblies into storage containers.

This involves the use of cranes, tools, remote handling equipment, and underwater video cameras to minimise human radiation exposure and prevent further damage to the SNF assemblies.





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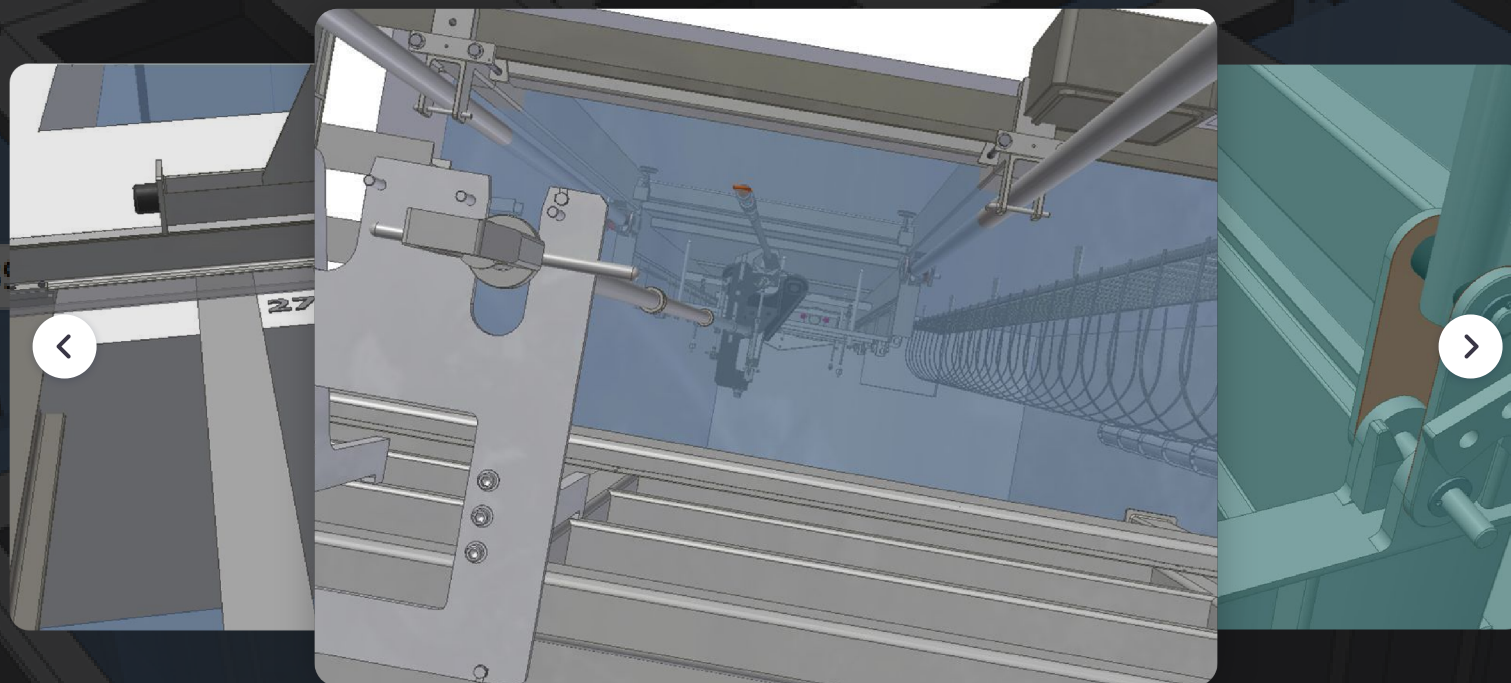
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Separation of the support tube of the SNF assembly

Step 2. Removal of damaged SNF from the SFP

Damaged SNF assemblies are safely removed and segmented from the pools using specialised underwater equipment designed to minimise human radiation exposure and prevent further damage during transport.

The DFHS system is design to cut, handle and transfer fuel bundles into over-pack cartridges to the interim storage in the spent pool hall



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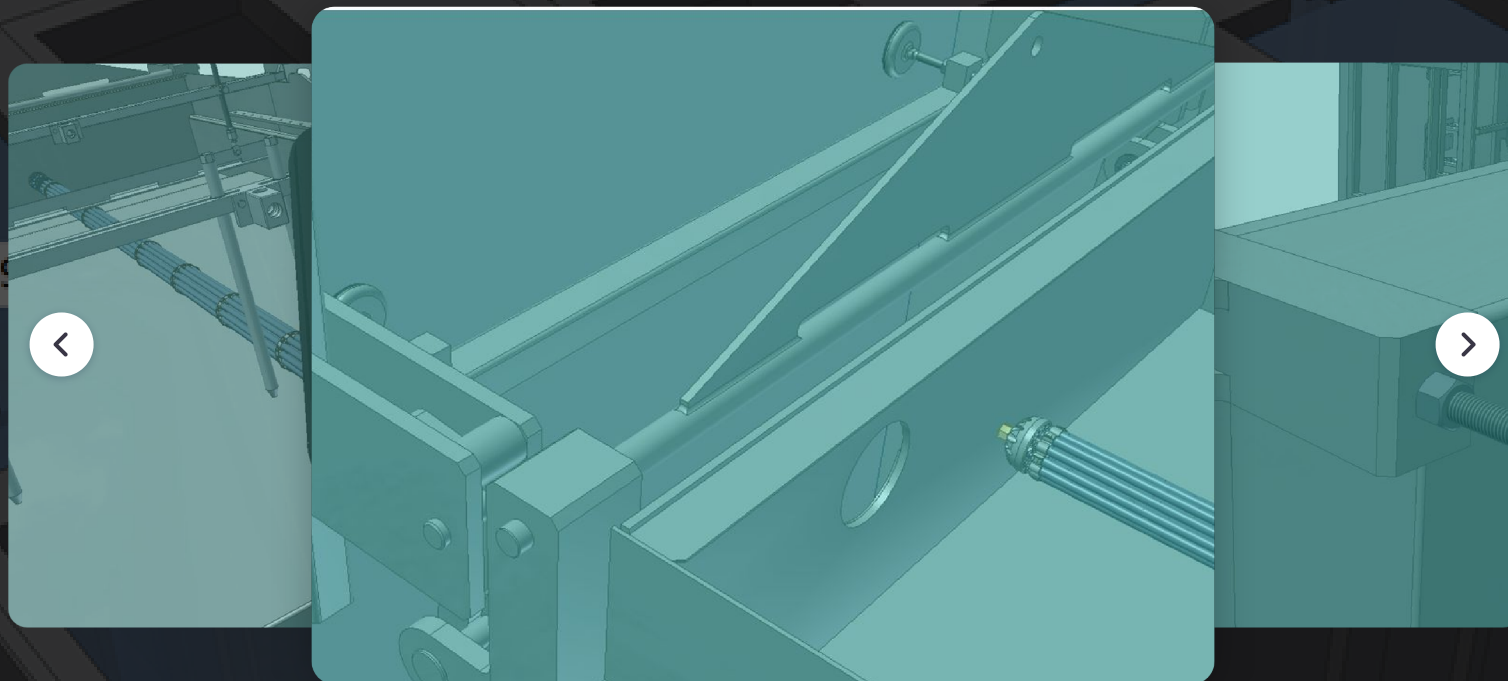
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Cutting the SNF assembly simulator into two

Step 2. Removal of damaged SNF from the SFP

Damaged SNF assemblies are safely removed and segmented from the pools using specialised underwater equipment designed to minimise human radiation exposure and prevent further damage during transport.

The DFHS system is design to cut, handle and transfer fuel bundkes into over-pack cartridges to the interim storage in the spent pool hall



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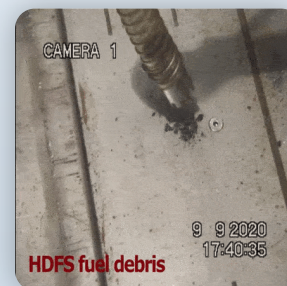
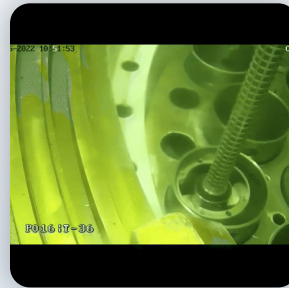
The main challenge in this step is to safely remove damaged SNF assemblies from the pools without further damaging them or exposing workers and the environment to radiation.

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Debris management

- Collection of fuel pellets and debris from the storage fuel pool and/or DFHS working tray using the Debris Recovery System
- Insertion of the DRS Filter element filled with fuel pellets and debris into the cartridge (CAN 160)
- Transfer the cartridges to the interim place in SPH

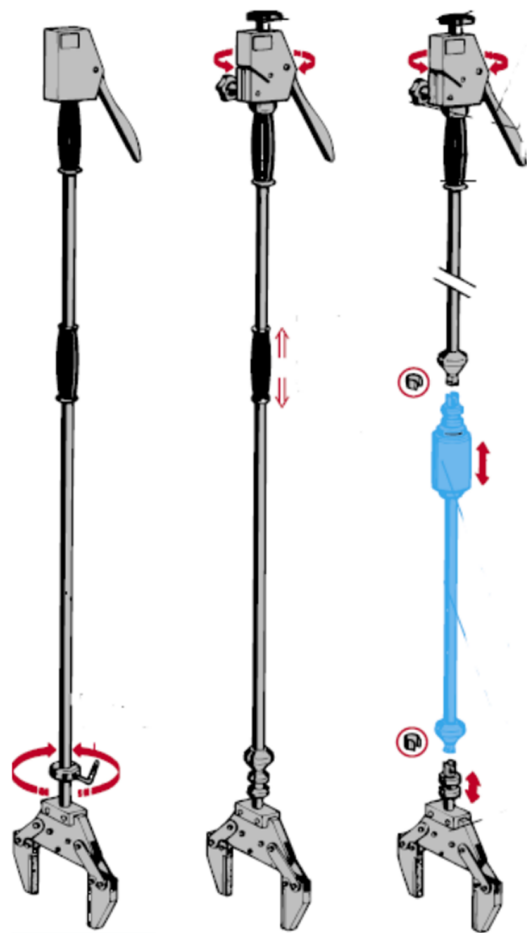
[+ DRS](#)

Collection of fuel pellets and debris

The Debris Recovery System (DRS) collects fuel pellets and their particles from the DFHS work table and/or the bottom of the spent fuel pools.

The DRS has an underwater unit (DRS-UWU) and a Mobile cabinet (DRS-MC) that is powers and controls the system from the SPH floor

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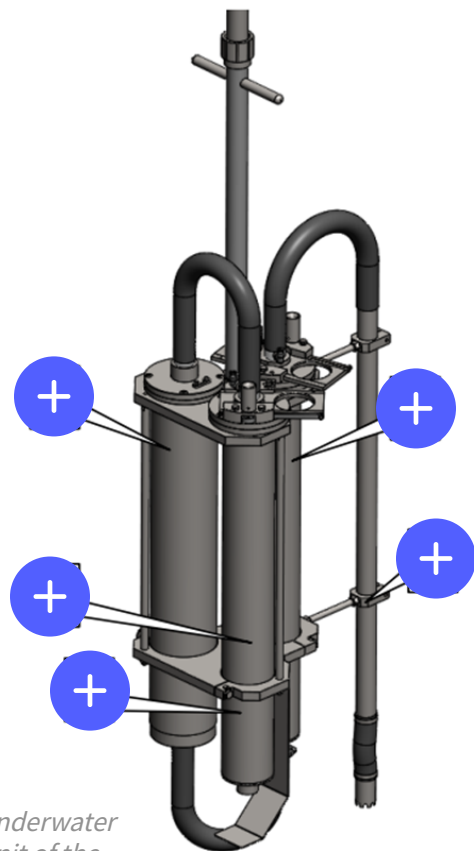
Handle grab "pedi"

Grab for damaged SFA

The grab for damaged SFA is used for moving the damaged SFA suspended on the wire at the semibars to the place where the damaged SFA will be loaded on the working tray

Handle Grab "pedi"

This tool is collet-style holder type grab for collection of small parts and pieces.



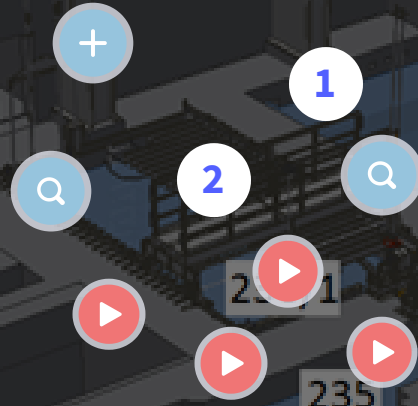
*Underwater
Unit of the
DRS*

Debris Recovery System (DRS)

The DRS collects pellets and debris from the pond bottom and from the inside of the working tray in pools of the SPH INPP Unit 1 and 2. It is powered and controlled by a mobile electric cabinet on the SPH floor. The DRS has two components:

- DRS Under Water Unit (DRS-UWU) ;
- DRS Mobile Cabinet (DRS-MC).

The DRS-UWU mainly consists of two filters and one pump. These three components are placed between two frame plates. The plates stabilize all parts to a solid unit. The DRS is equipped with housings for filter elements and a pump.



Step 3. Loading, handling and transfer to temporary storage

Individual fuel bundles are inserted into over-pack cartridges (CAN160, CAN 500 or CAN 1200).

The cartridges are then sealed and transferred to an interim storage location in the Spent Fuel Hall

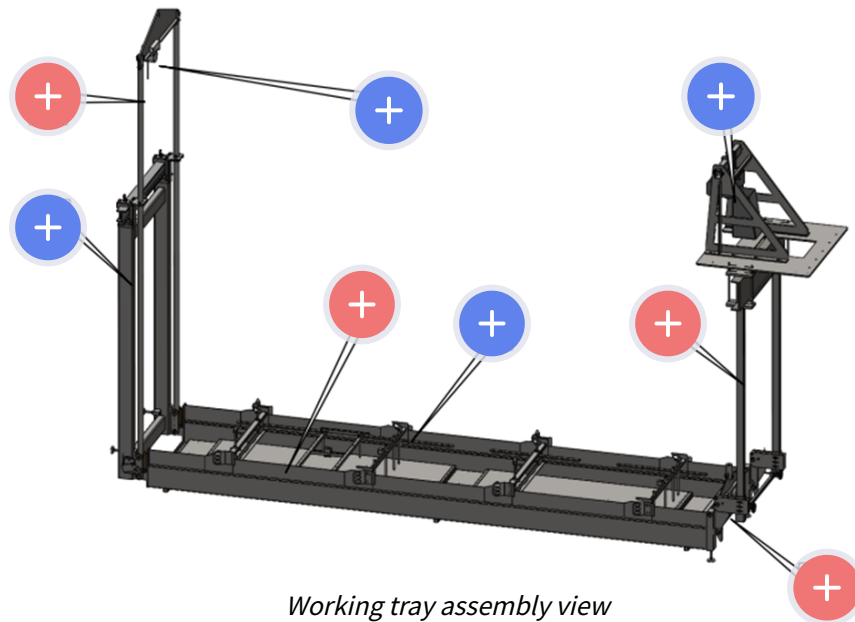




The main challenge in this step is to develop methods to safely handle different types of damaged SNF assemblies for storage, as their condition can vary considerably.



Working Tray



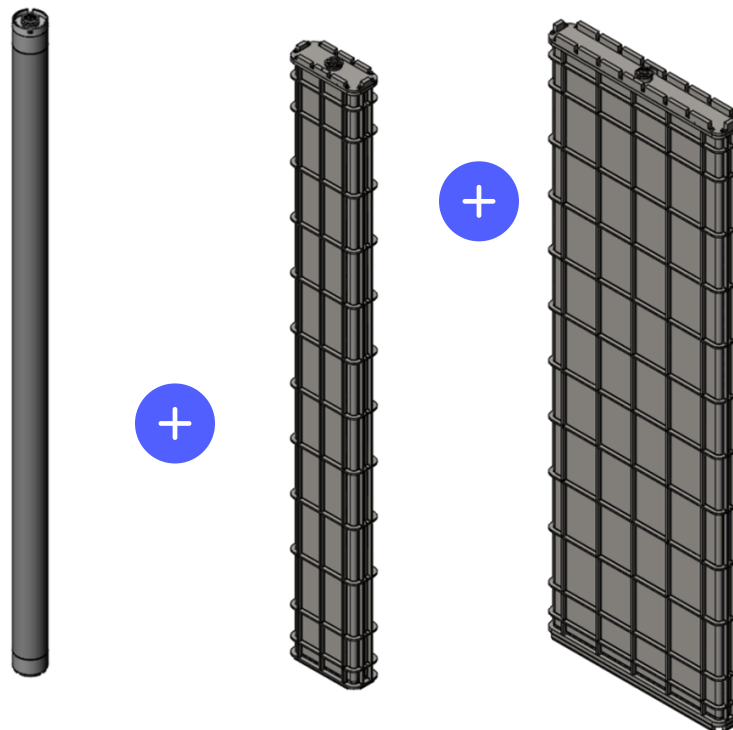
The Working Tray is a multifunctional device for the following defect fuel handling processes:

- Tilting of the damaged SFA in vertical position;
- Tilting of SFA in the horizontal position;
- Cutting of suspension rod from SFA;
- Lifting the SFA in horizontal position
- Cutting and trimming of SFA in two bundles in horizontal position;
- Insertion of FB into the cartridges in horizontal position;
- Lifting the cartridges with FB in vertical position;
- Installation and tightening of the cartridge lids;
- Connection of the cartridges with suspensions.



The DFHS describes specific procedures for cutting, segmenting or repackaging damaged SNF as required. This includes separating the assemblies into two fuel bundles, removing fuel spillage (if necessary) and preparing them for loading into storage casks.

This step is necessary to make the SNF assemblies safe for long-term storage and minimise environmental contamination risk.



Cartridges

The three types of different-dimension overpack cartridges, CAN 160, CAN 500, and CAN 1200 (see Figure), are developed for insertion and further storage of the heavily damaged fuel bundles.

The dimensions of the cartridges are defined based on the results of the heavily damaged fuel inspection at INPP Unit 1 SPH. All three CAN types have similar designs. Each CAN consists of two parts: the body and the cover.



Handling equipment

All transport and lifting operations in the SPH are performed by existing handling equipment:

- The three-support electric crane, with a lifting capacity of 9.8 kN (1 tf), is intended for handling spent fuel assemblies and reactor assemblies.
- The electric overhead crane, with a lifting capacity of 1225/196 kN (125/20 tf), is intended to handle 102 placed fuel baskets and transport containers.



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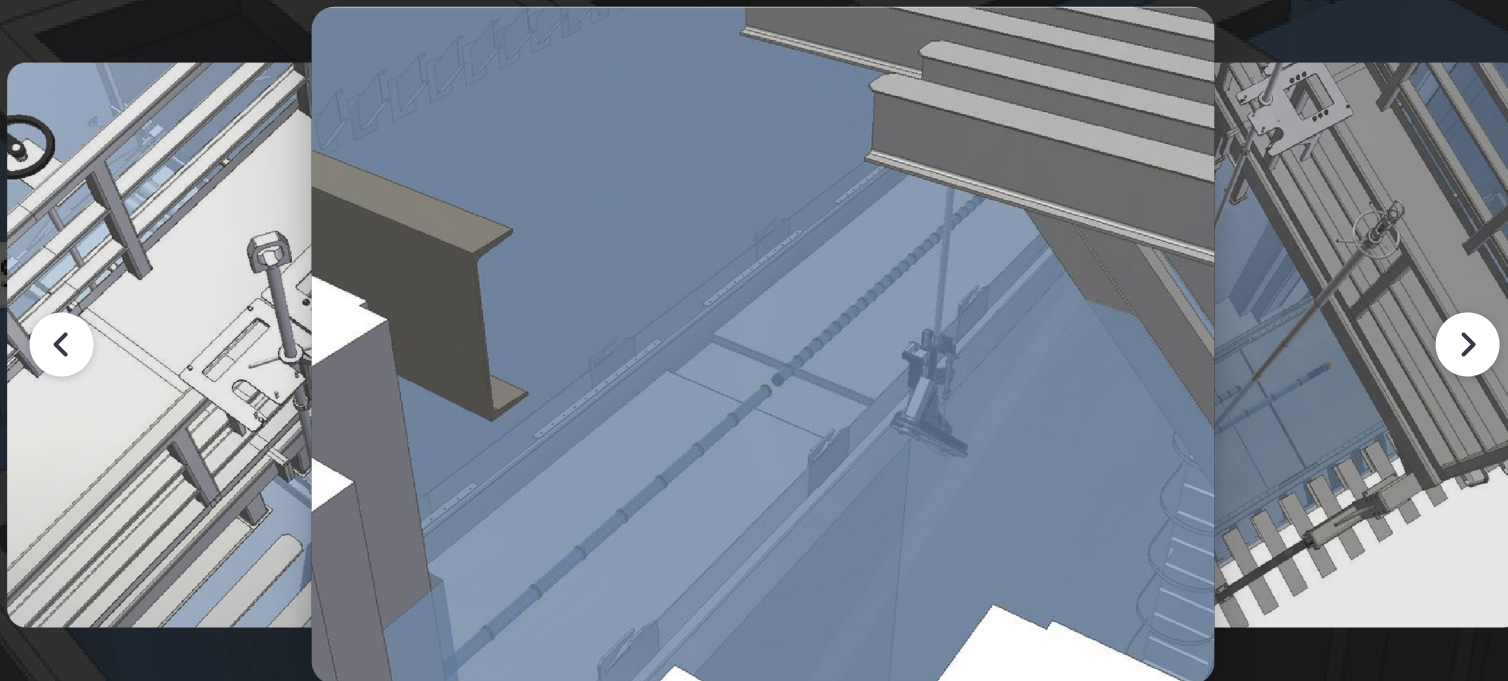
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Preparation and loading of FBTs (Fuel Bundle Tubes)

Step 3. Loading, handling and transfer to temporary storage

Individual fuel bundles are inserted into over-pack cartridges (CAN160, CAN 500 or CAN 1200).

The cartridges are then sealed and transferred to an interim storage location in the Spent Fuel Hall



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The main challenge in this step is to develop methods to safely handle different types of damaged SNF assemblies for storage, as their condition can vary considerably.



The DFHS describes specific procedures for cutting, segmenting or repackaging damaged SNF as required. This includes separating the assemblies into two fuel rod bundles, removing fuel spillage (if necessary) and preparing them for loading into storage casks.

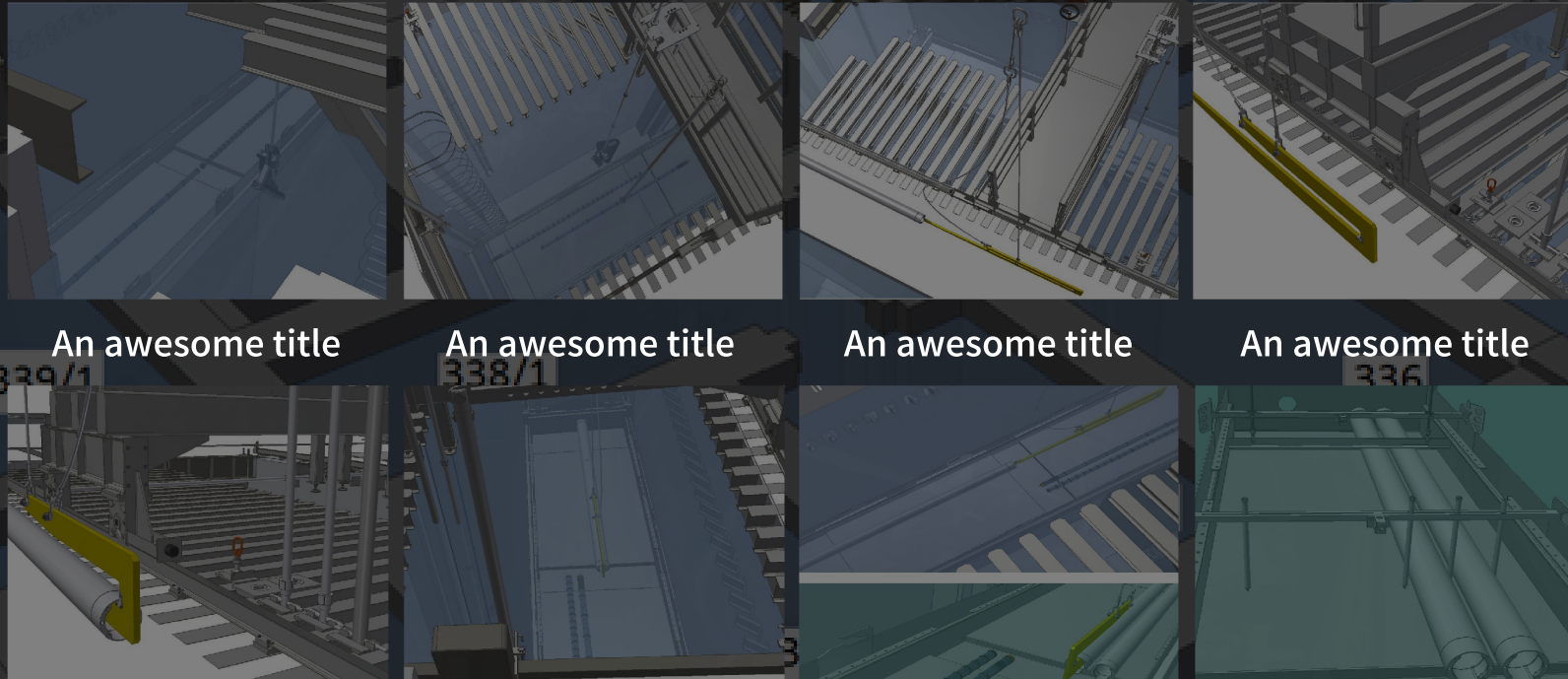
This step is necessary to make the SNF assemblies safe for long-term storage and minimise environmental contamination risk.



Step 3. Loading, handling and transfer to temporary storage

Individual fuel bundles are inserted into over-pack cartridges (CAN160, CAN 500 or CAN 1200).

The cartridges are then sealed and transferred to an interim storage location in the Spent Fuel Hall



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Sealing and moving the cartridges to a temporary storage location





The main challenge in this step is to develop methods to safely handle different types of damaged SNF assemblies for storage, as their condition can vary considerably.



The DFHS describes specific procedures for cutting, segmenting or repackaging damaged SNF as required. This includes separating the assemblies into two fuel rod bundles, removing fuel spillage (if necessary) and preparing them for loading into storage casks.

This step is necessary to make the SNF assemblies safe for long-term storage and minimise environmental contamination risk.





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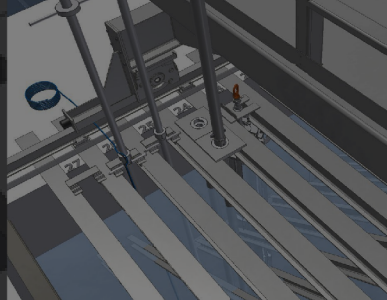
Step 3. Loading, handling and transfer to temporary storage

Individual fuel bundles
are inserted into over-
pack cartridges
(CAN160, CAN 500 or
CAN 1200).

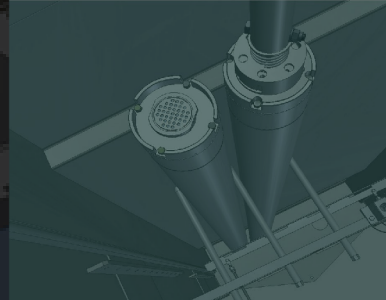
The cartridges are then
sealed and transferred to
an interim storage
location in the Spent
Fuel Hall



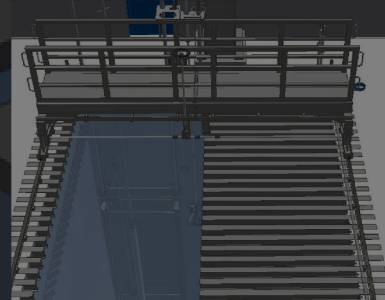
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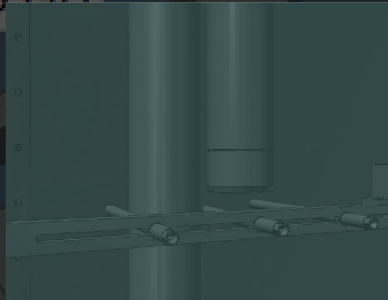
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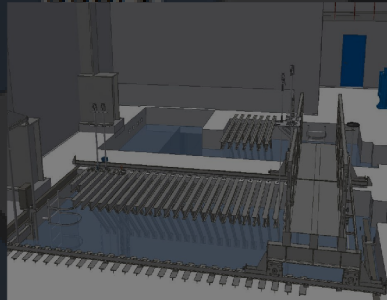
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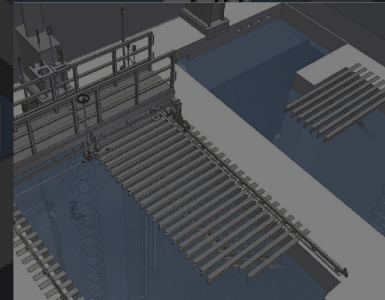
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Sealing and moving the cartridges to a temporary storage location

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The DFHS describes specific procedures for cutting, segmenting or repackaging damaged SNF as required. This includes separating the assemblies into two fuel rod bundles, removing fuel spillage (if necessary) and preparing them for loading into storage casks.

This step is necessary to make the SNF assemblies safe for long-term storage and minimise environmental contamination risk.



The main challenge in this step is to develop methods to safely handle different types of damaged SNF assemblies for storage, as their condition can vary considerably.



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Step 4. Packing and storage in casks

Empty cask equipped with damaged fuel storage basket are transferred to a drained pool in the spent fuel crane and then filled with water.

Over-pack cartridges are inserted into the basket using the crane

The cask lid is placed and bolted before the pool is drained again to start the dewatering process in Step 5.



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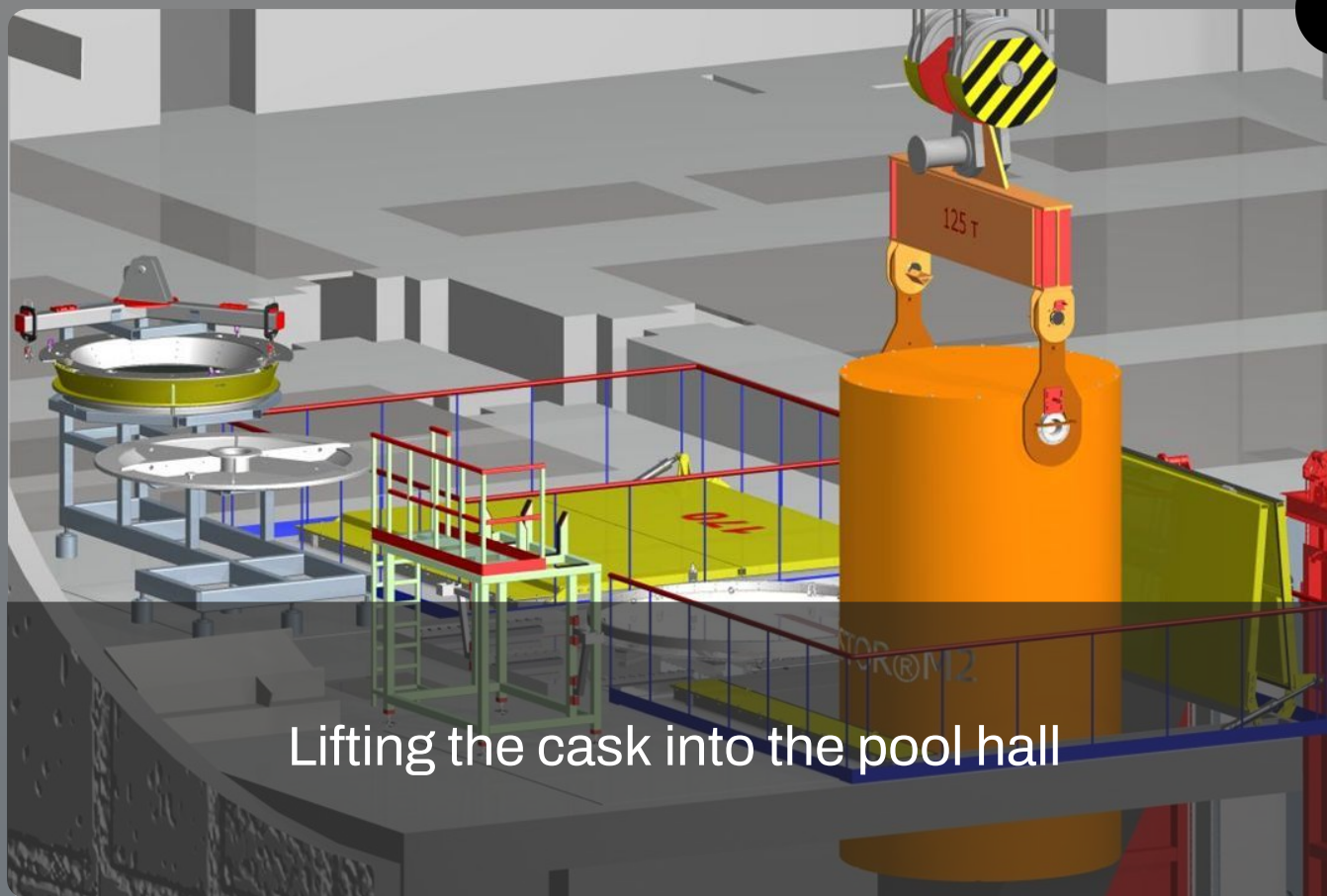
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Lifting the cask into the pool hall



The DFHS involves placing the processed fuel bundles and fuel/pillage spills into cartridges and then into protective cask that provide reliable radiation shielding and safe storage of the SNF. These casks are then transferred to a temporary storage facility for radiation monitoring, cask integrity, and IAEA/Euratom nuclear material control systems.



The main challenge in this step is to ensure the safe storage of damaged SNF assemblies and fuel/pellet spills in a manner that isolates them from the environment and prevents the possible leakage of radioactive material.



The cask on the service platform on
the pool hall floor



Spent Fuel Casks

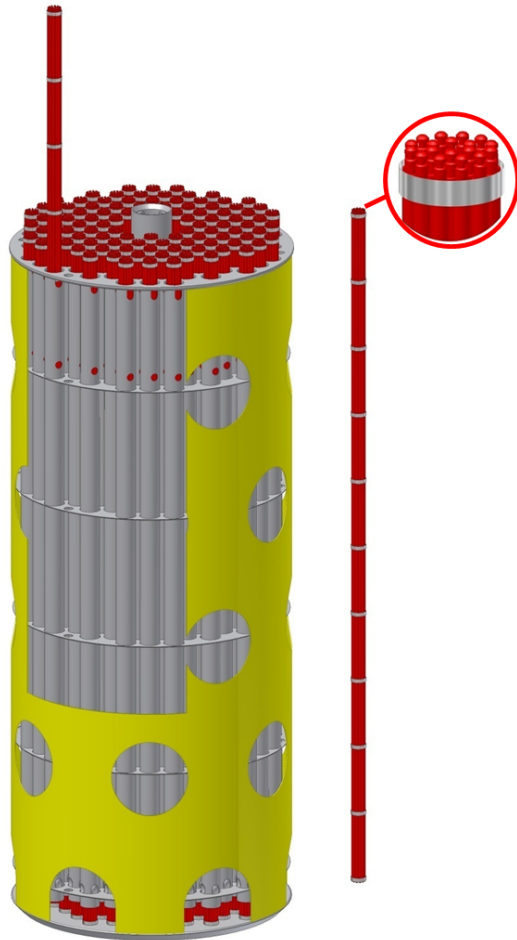
Spent Fuel is transported from the Spent Fuel building to the ISFSF inside a CONSTOR®RBMK-1500/M2 Spent Fuel Cask. They are composed of

- Cask Body
- Primary and Secondary Lid
- Protective Cover
- Ring Basket
- Spent Fuel bundles are arranged in annular 32M baskets in one of the pools



Preparation for lifting the cask into
the spent fuel pool hall





Position Basket

Spent Fuel Assemblies (SFA) are arranged in annular 32M basket in one of the Pools

The 102-Position Casing for Spent Nuclear Fuel Type 32M has the following characteristics

- Total Height – 3760 mm
- Body Height – 3560 mm
- Outer Diameter – 1460 mm
- Weight Empty (Without SNF) – 3780 kg
- Weight with SNF – 12450 kg



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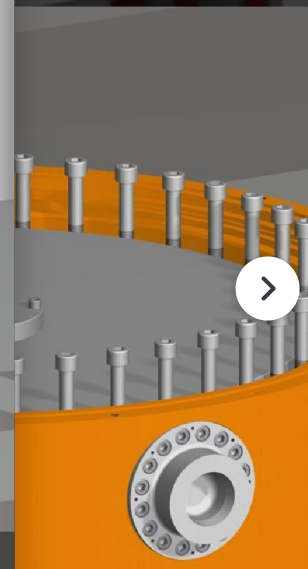
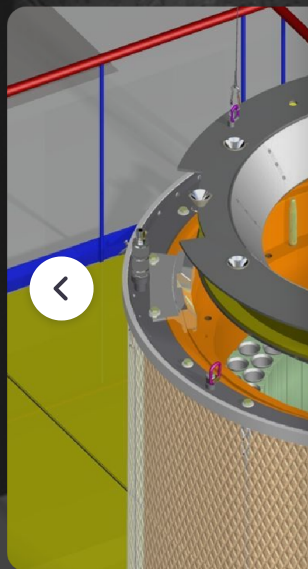
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Step 4. Packing and storage in casks

Empty cask equipped with damaged fuel storage basket are transferred to a drained pool in the spent fuel crane and then filled with water.

Over-pack cartridges are inserted into the basket using the crane

The cask lid is placed and bolted before the pool is drained again to start the dewatering process in Step 5.



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The DFHS involves placing the processed fuel bundles and fuel/pillage spills into cartridges and then into protective cask that provide reliable radiation shielding and safe storage of the SNF. These casks are then transferred to a temporary storage facility for radiation monitoring, cask integrity, and IAEA/Euratom nuclear material control systems.



The main challenge in this step is to ensure the safe storage of damaged SNF assemblies and fuel/pellet spills in a manner that isolates them from the environment and prevents the possible leakage of radioactive material.



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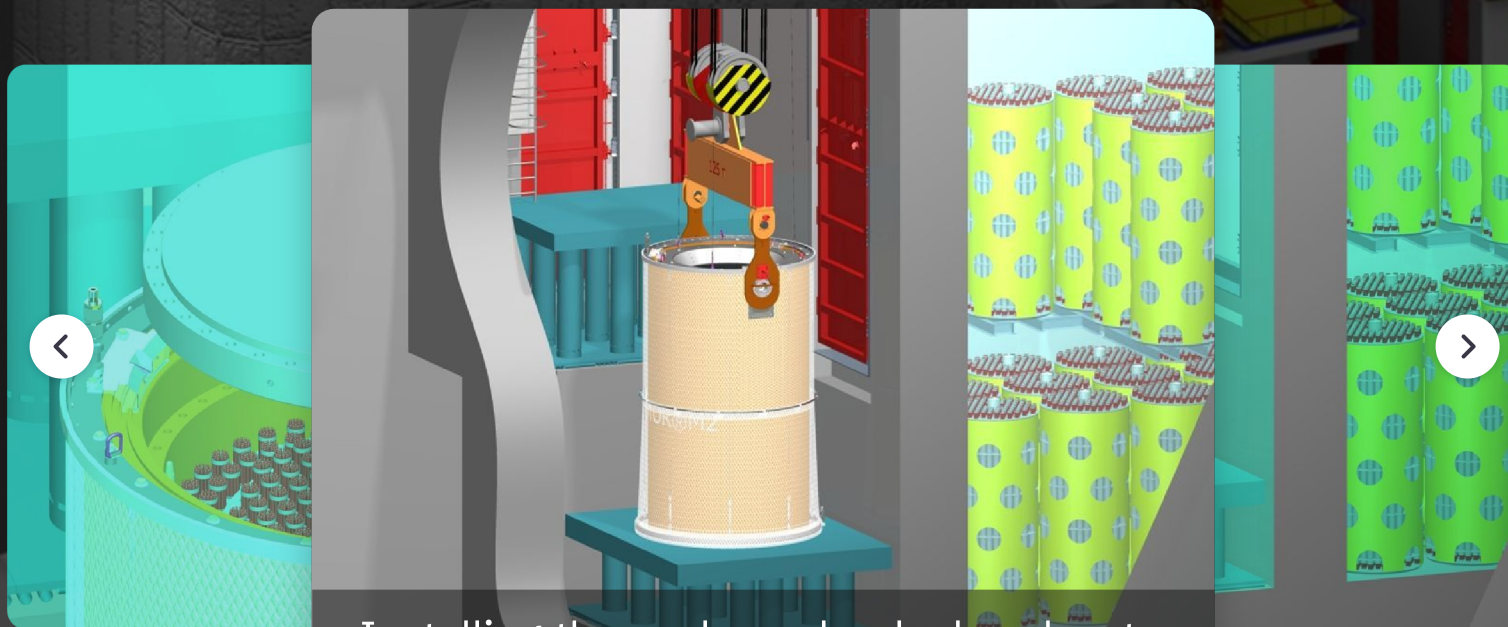
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Installing the cask on shock absorber t...

Step 4. Packing and storage in casks

Empty cask equipped with damaged fuel storage basket are transferred to a drained pool in the spent fuel crane and then filled with water.

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Dewatering

Water is removed from the cask before moving it to the work platform



Vacuum drying

Casks are vacuum dried to remove remaining water trapped in gaps and surfaces



Bolting and testing

Bolting, leak-tightness testing, cleaning and radiation measurement



He

Helium filling

Helium creates a stable and non-reactive environment inside the cask.



Step 5. Cask preparation for storage

Casks containing spent nuclear are dried and sealed to ensure the safe and effective removal of water, thus preparing the cask for long-term storage

This meticulous approach ensures that the cask is thoroughly dried and prepared for safe storage, protecting both personnel and the environment from potential radiation hazards



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Monitor the process using various instruments and valves to control and maintain the desired pressure levels throughout the drying phases. The operation involves the use of rotary vane pumps, an emission condenser, and pressure gauges, all integrated into a control system to ensure precise execution of the drying process.

Maintain detailed records to document pressure readings and valve positions, throughout the process, ensuring traceability and compliance with safety protocols. This meticulous approach ensures that the cask is thoroughly dried and prepared for safe storage, protecting both personnel and the environment from potential radiation hazards.

By adhering to these procedures, the vacuum drying process effectively prepares spent nuclear fuel casks for long-term storage, ensuring safety and stability.



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5.1 Dewatering

Before the vacuum drying process begins, the initial dewatering of the cask is performed in basin 338/1.

This step is crucial for reducing the weight of the container, facilitating easier handling and transport to the cask service station where the vacuum drying process will take place.

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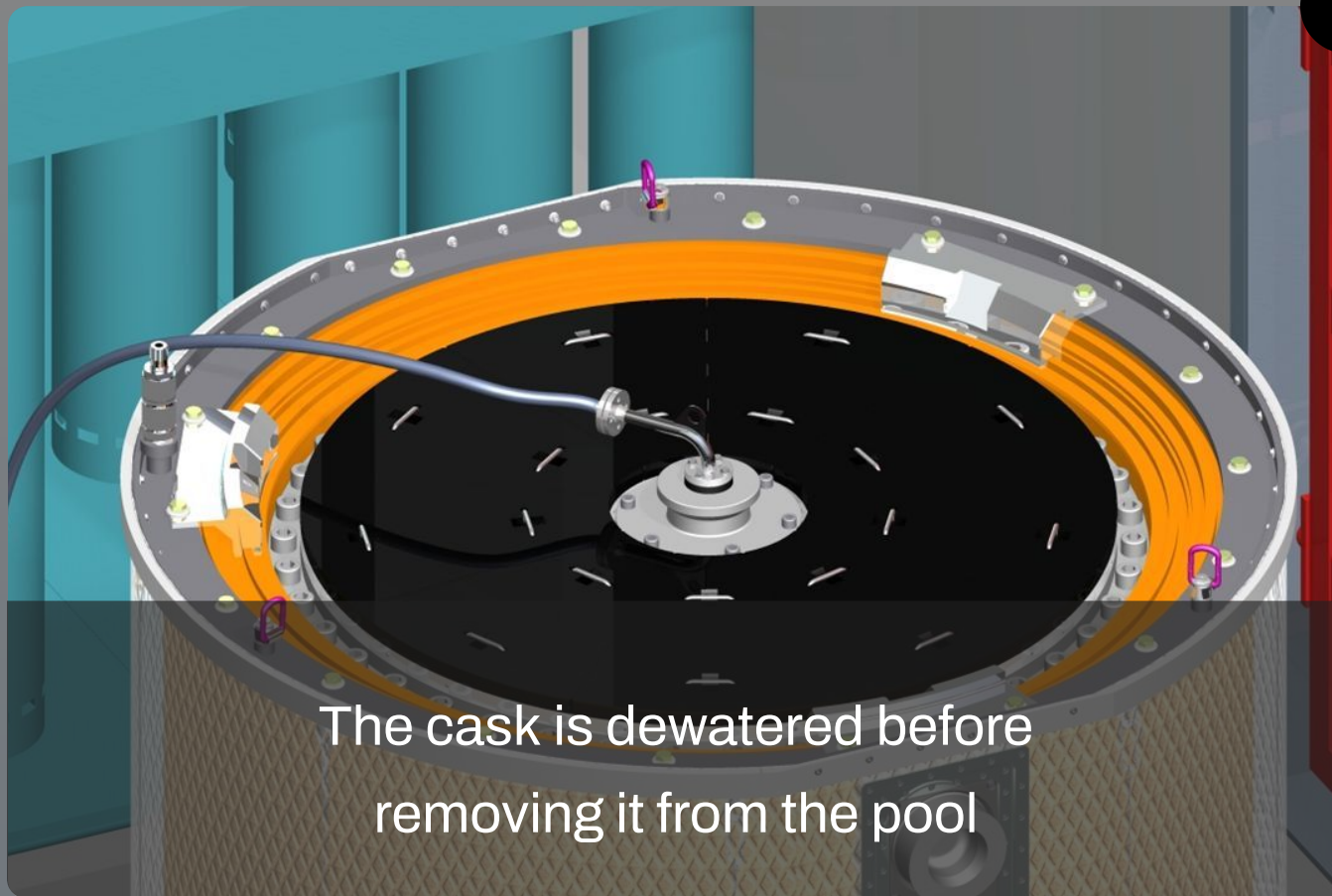
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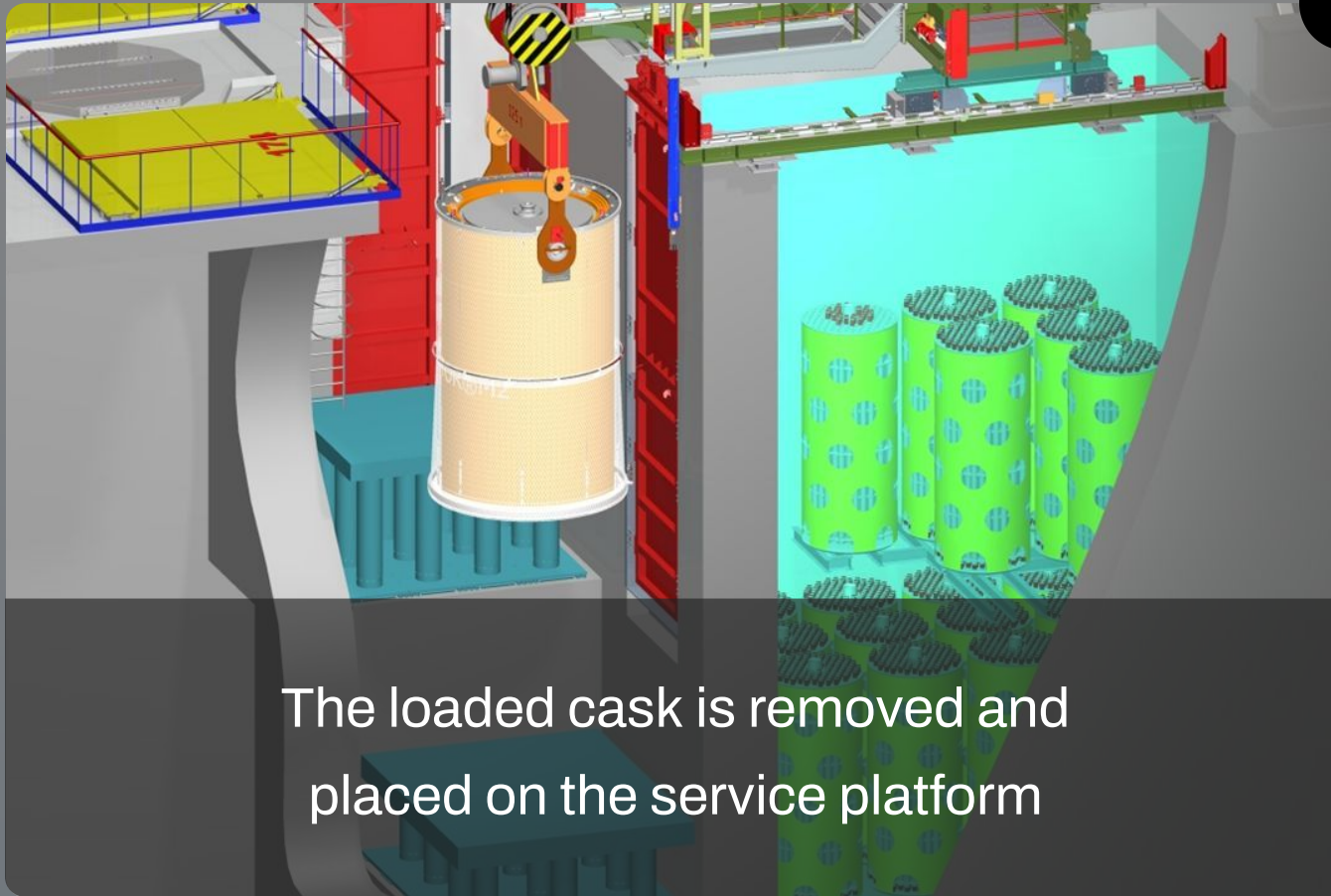
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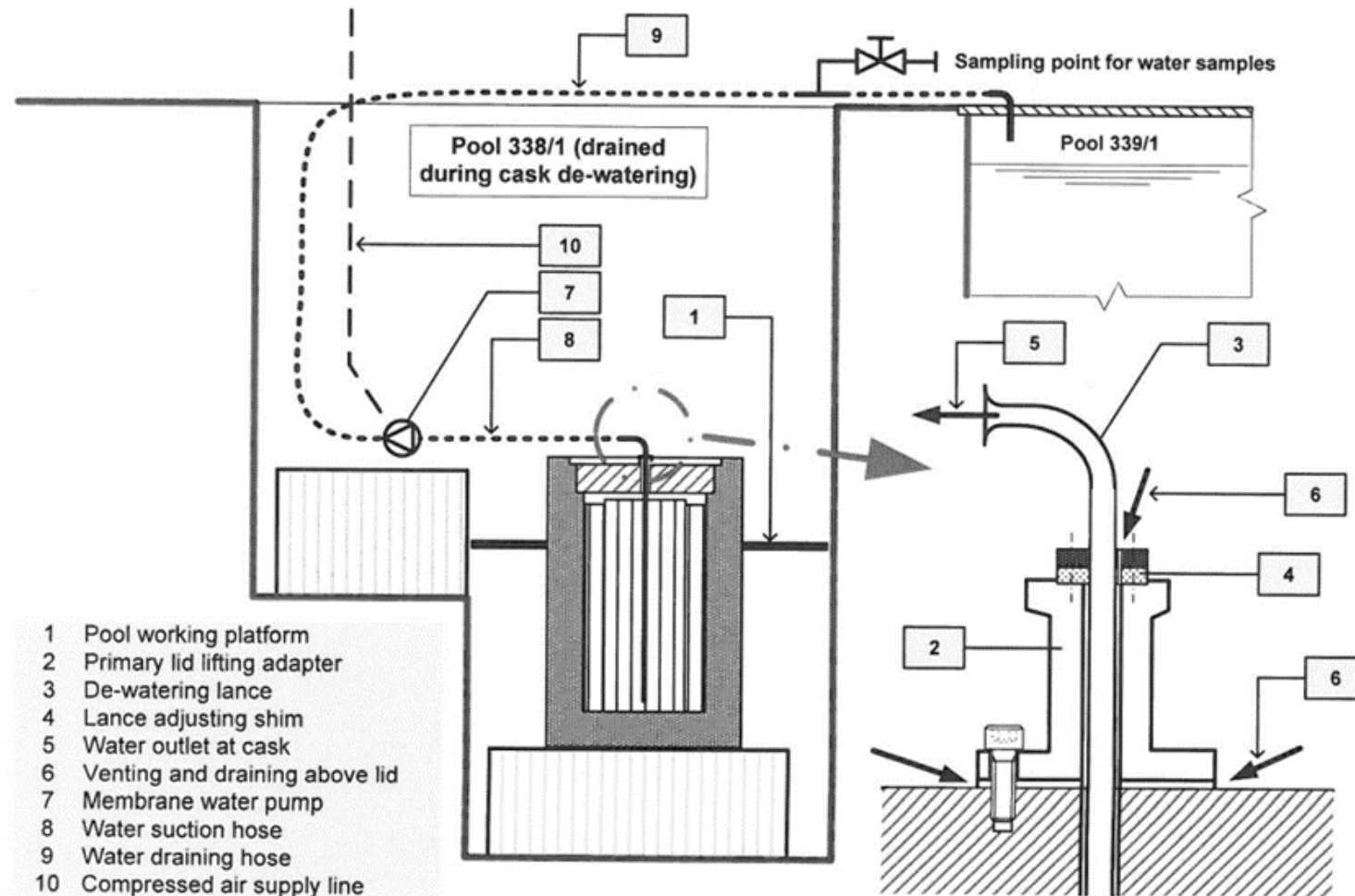


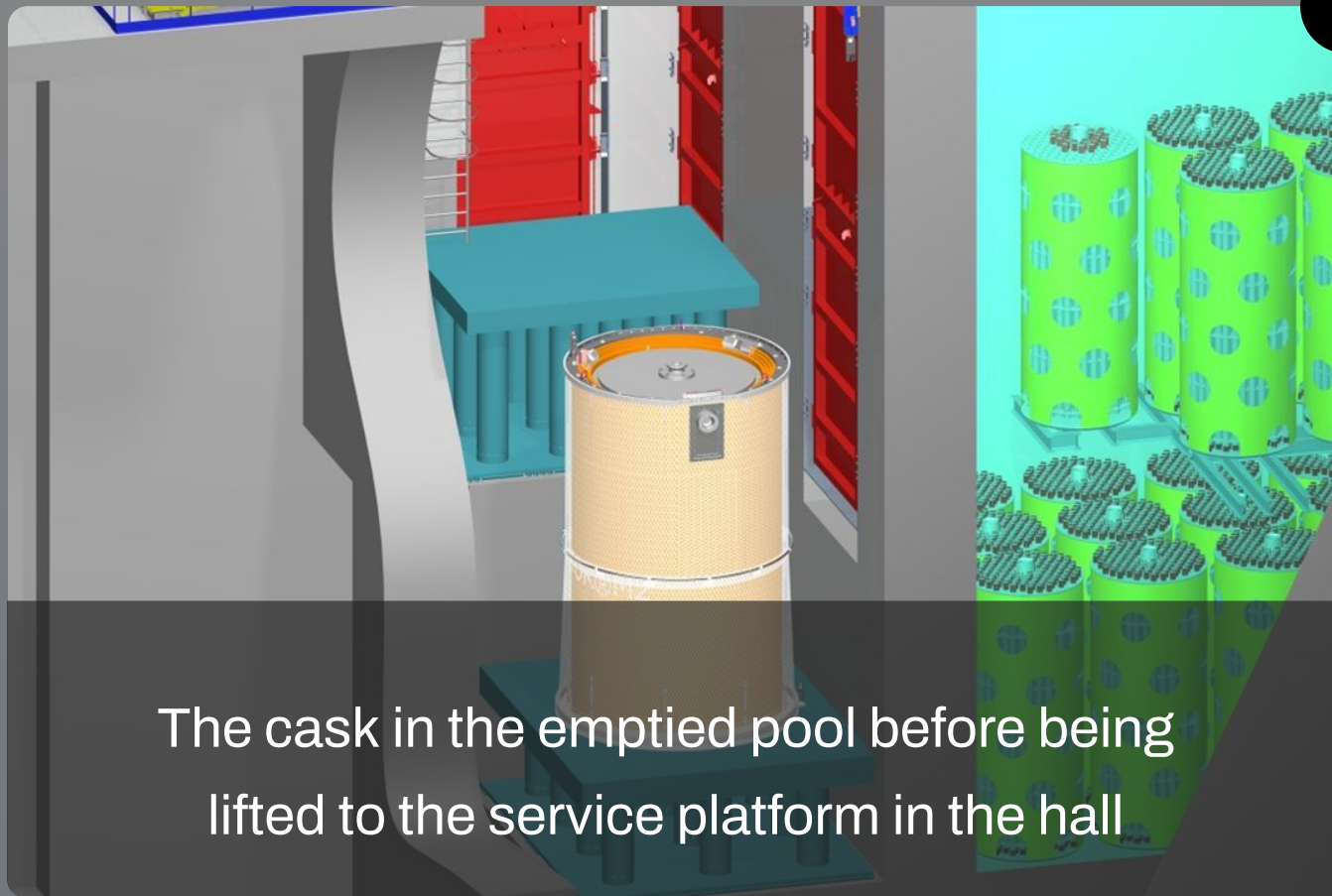
The cask is dewatered before
removing it from the pool





The loaded cask is removed and
placed on the service platform





The cask in the emptied pool before being
lifted to the service platform in the hall



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5.2 Vacuum Drying

The cask, equipped with a temporary lid, is placed at the cask service station for vacuum drying.

The cask is dried in two steps by reducing pressure to facilitate evaporation of water inside the cask and trapped in gaps and surfaces

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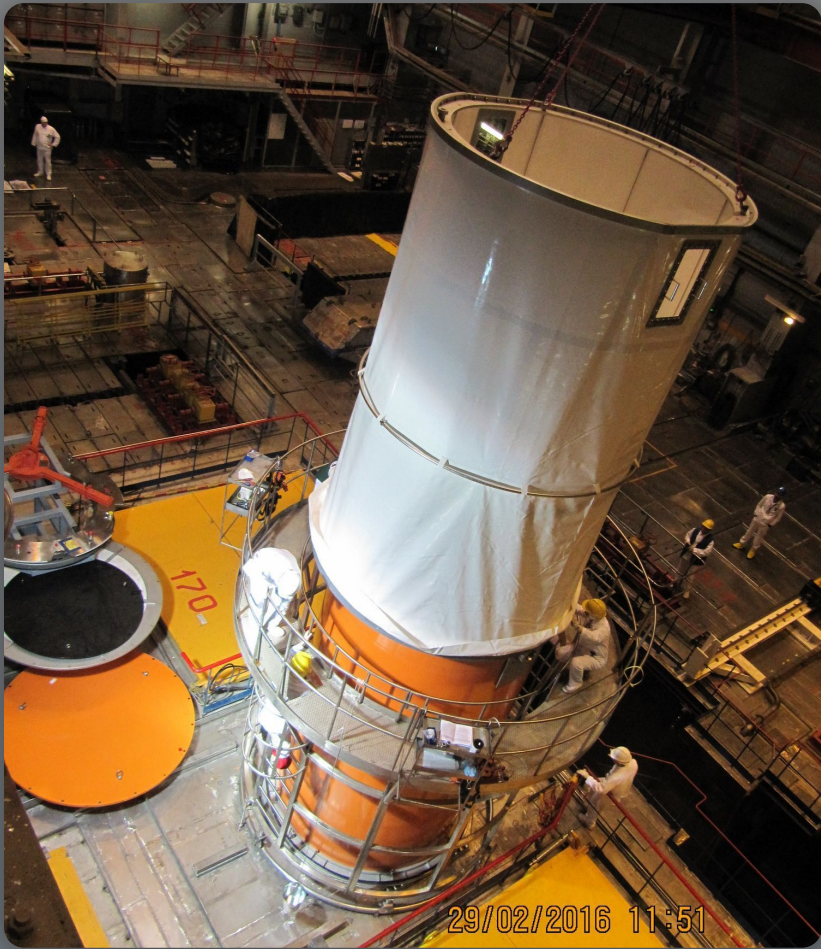
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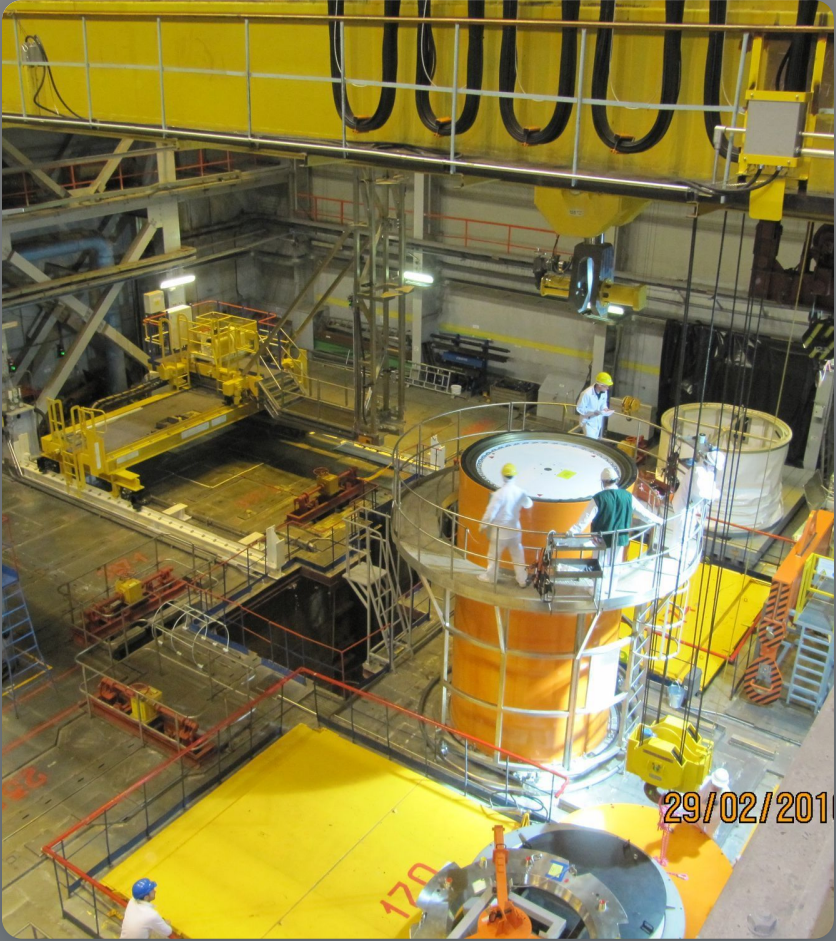
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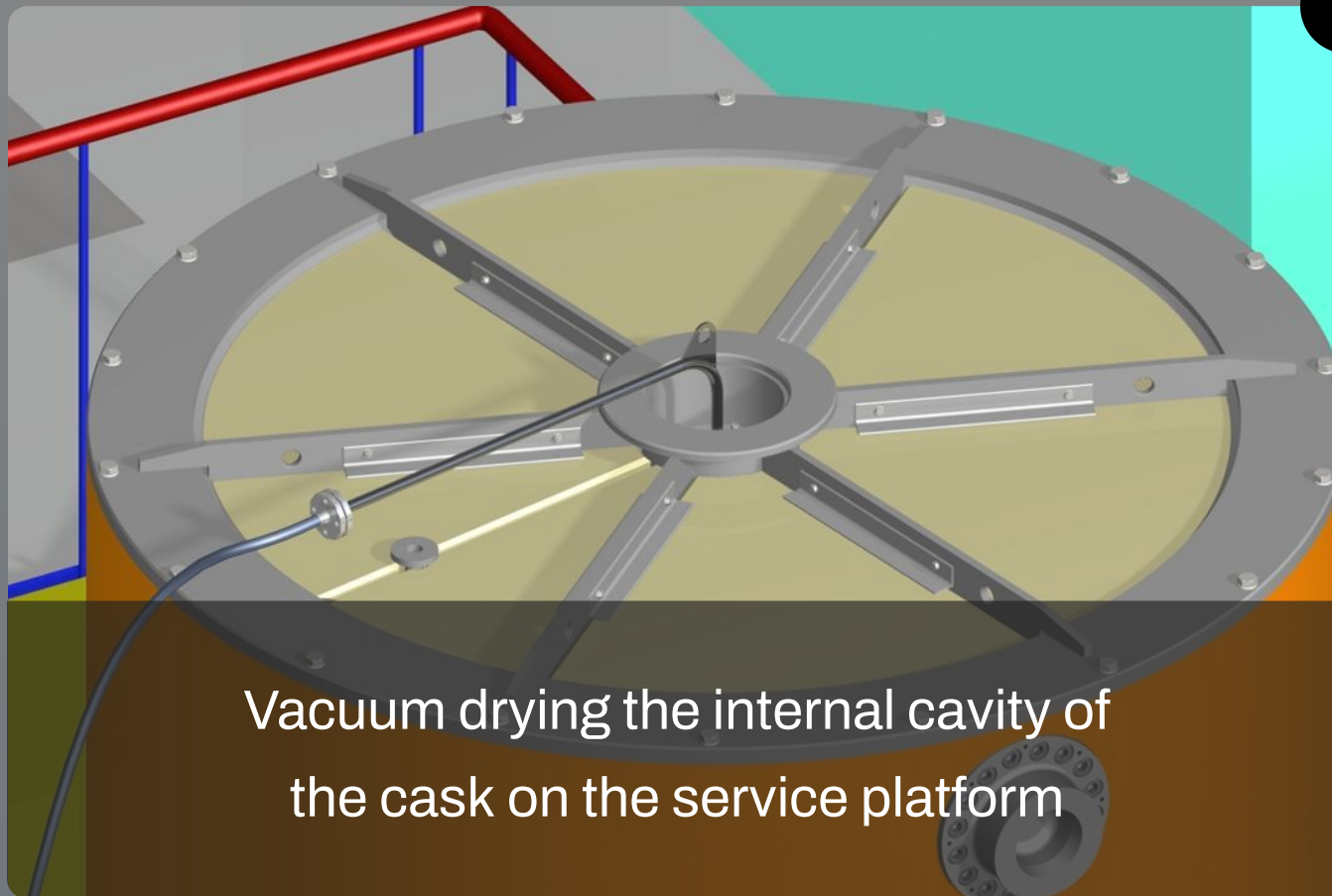
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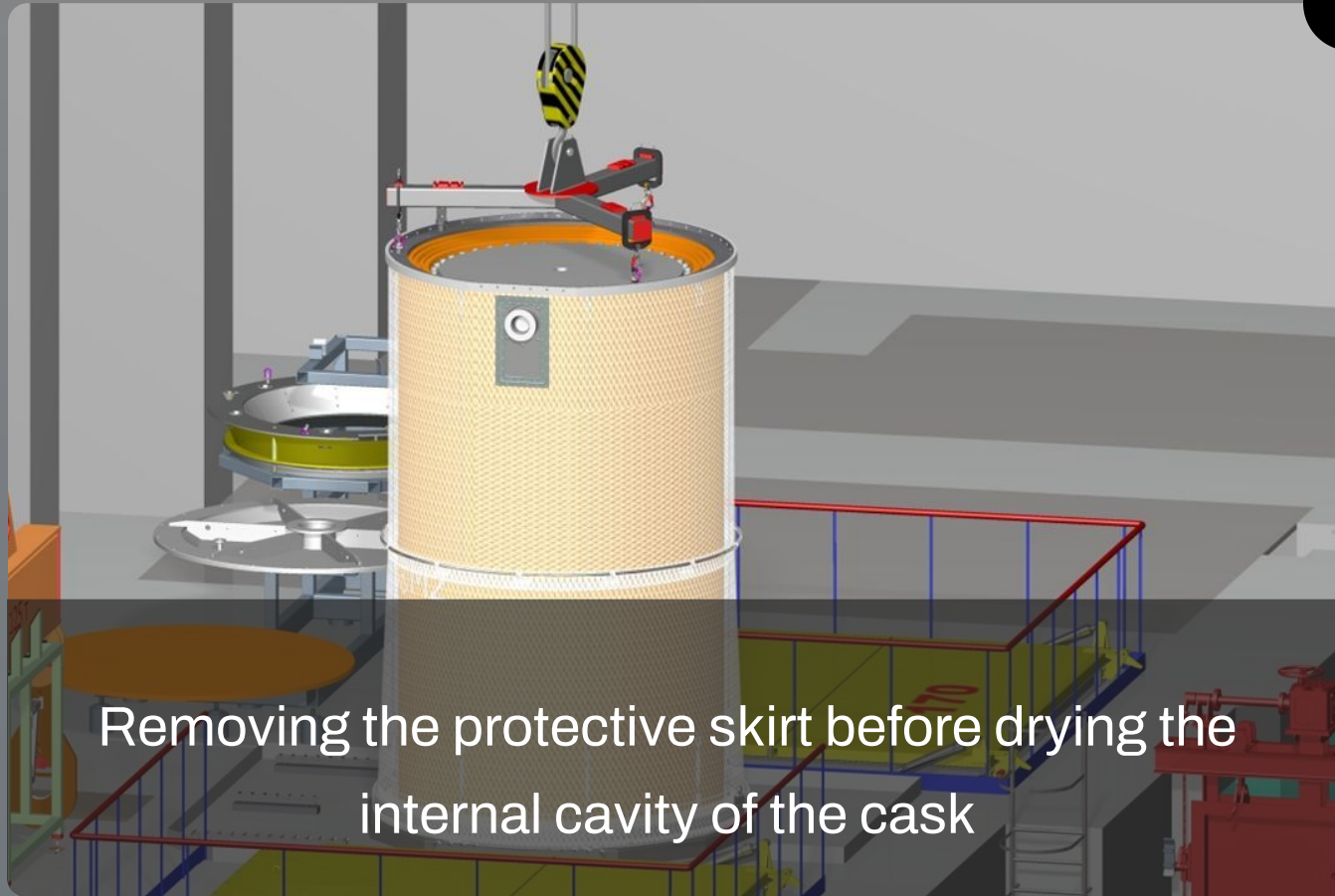








Vacuum drying the internal cavity of
the cask on the service platform



Removing the protective skirt before drying the
internal cavity of the cask



Monitor the process using various instruments and valves to control and maintain the desired pressure levels throughout the drying phases. The operation involves the use of rotary vane pumps, an emission condenser, and pressure gauges, all integrated into a control system to ensure precise execution of the drying process.

Maintain detailed records to document pressure readings and valve positions, throughout the process, ensuring traceability and compliance with safety protocols. This meticulous approach ensures that the cask is thoroughly dried and prepared for safe storage, protecting both personnel and the environment from potential radiation hazards.

By adhering to these procedures, the vacuum drying process effectively prepares spent nuclear fuel casks for long-term storage, ensuring safety and stability.



Installing the lid for vacuum
drying the cask





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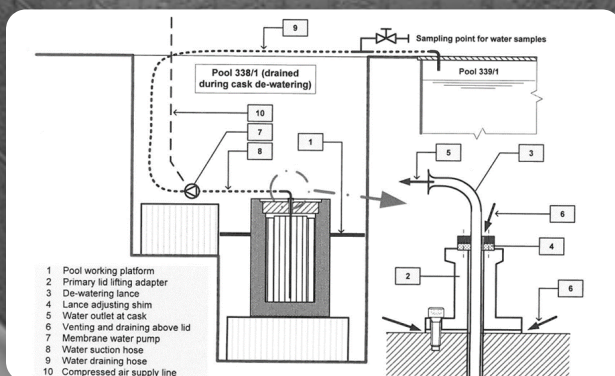
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Vacuum Drying Removal of Water

In the first phase, the primary objective is to remove any water present in the cask. This is achieved by lowering the pressure within the cask from ambient levels to approximately 10 hPa. The reduction in pressure facilitates the evaporation and subsequent removal of liquid, which is essential to prevent corrosion and maintain the integrity of the cask and its contents.



5.2 Vacuum Drying

The cask, equipped with a temporary lid, is placed at the cask service station for vacuum drying.

The cask is dried in two steps by reducing pressure to facilitate evaporation of water inside the cask and trapped in gaps and surfaces

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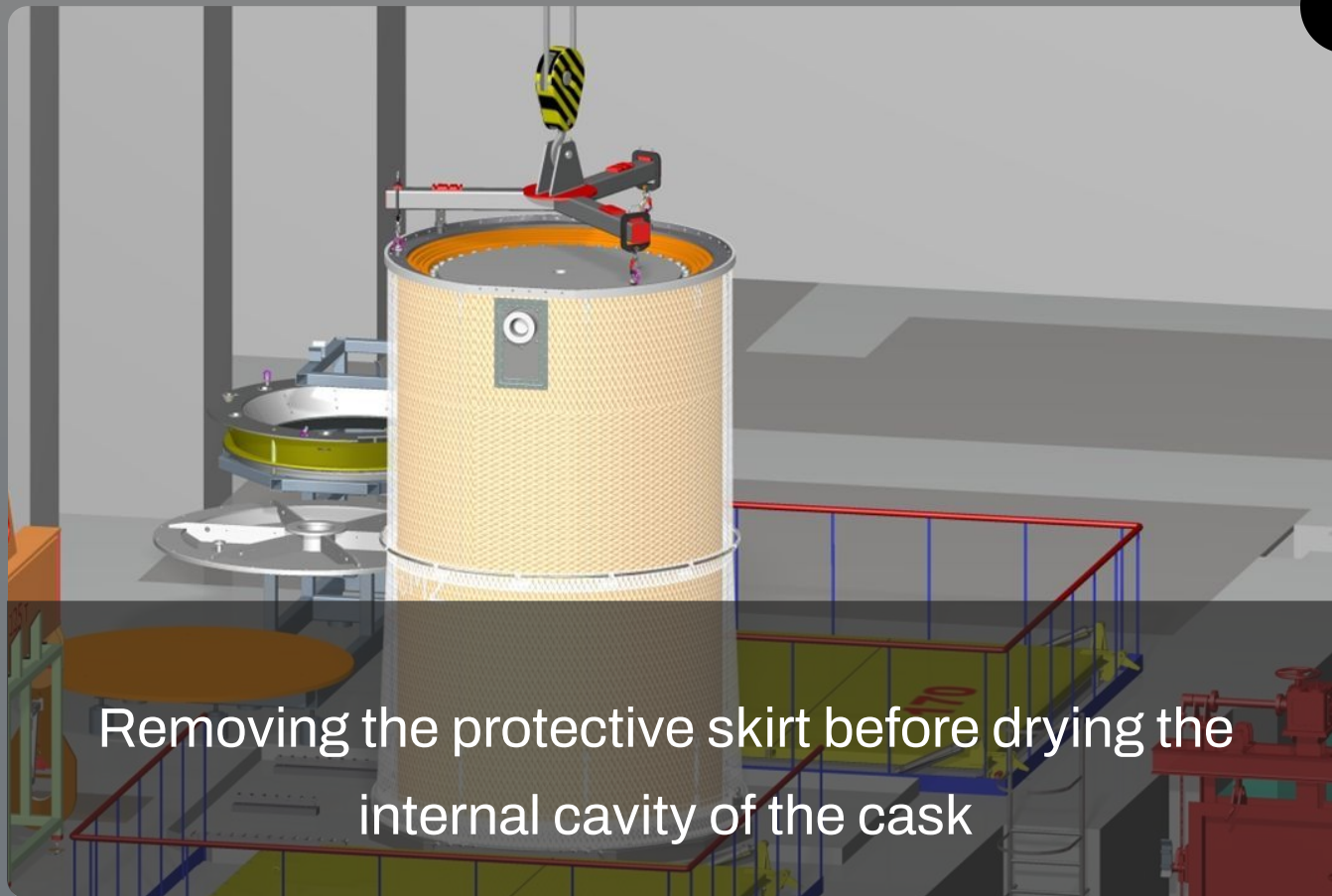
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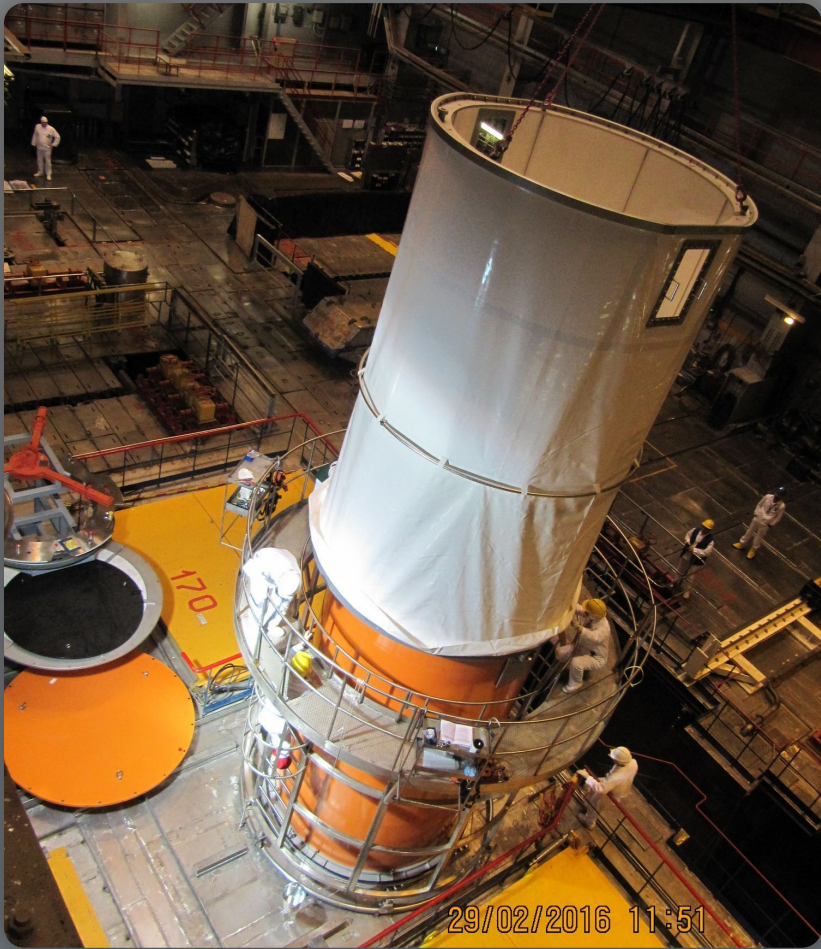
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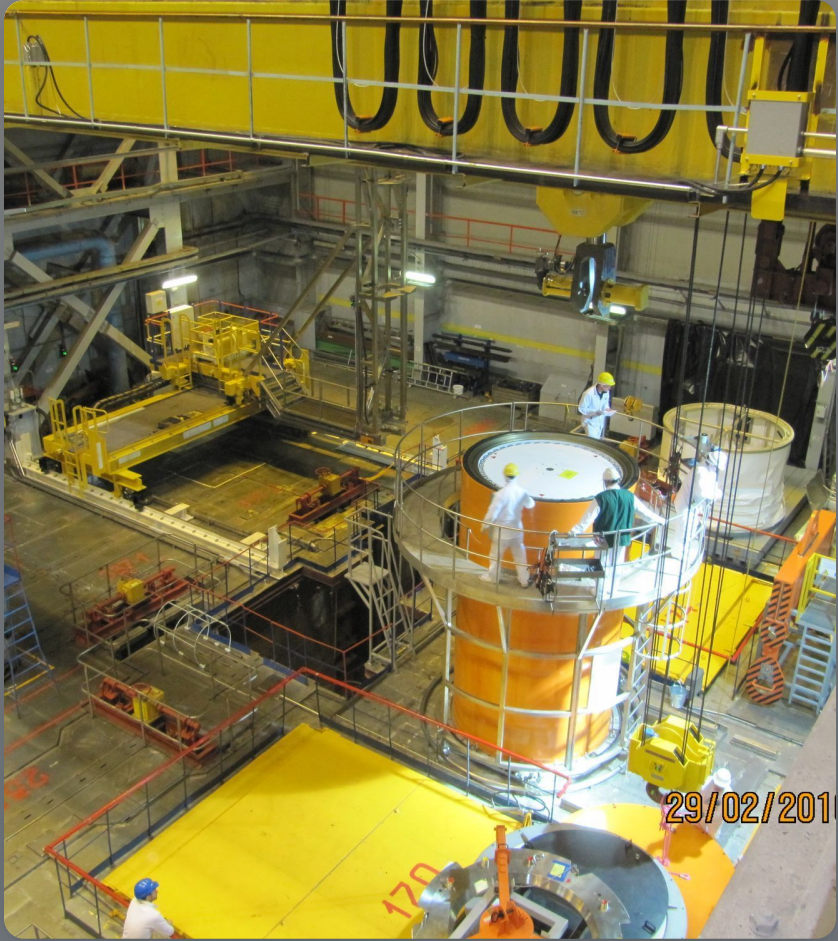
Removing the protective skirt before drying the
internal cavity of the cask





Installing the lid for vacuum
drying the cask



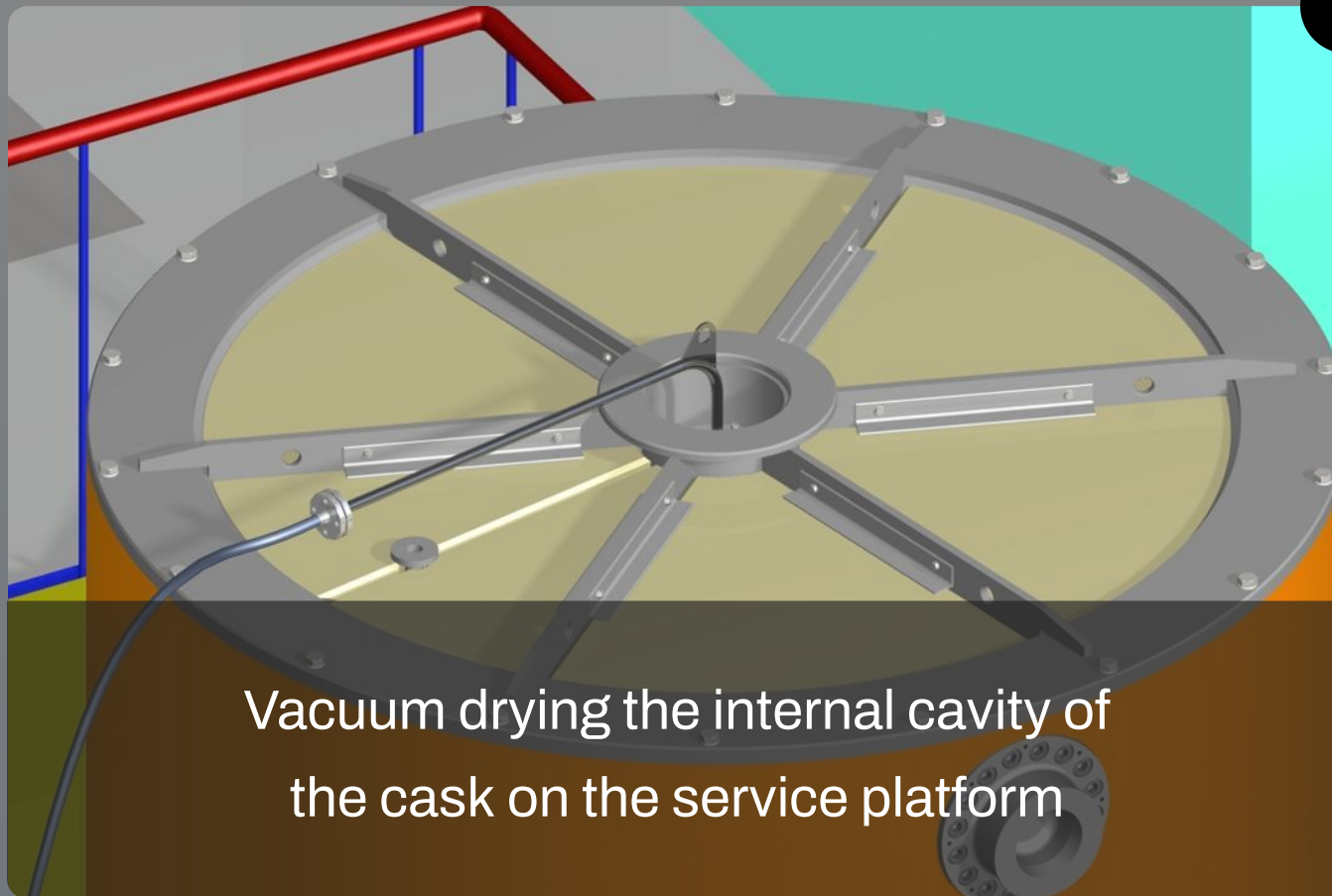




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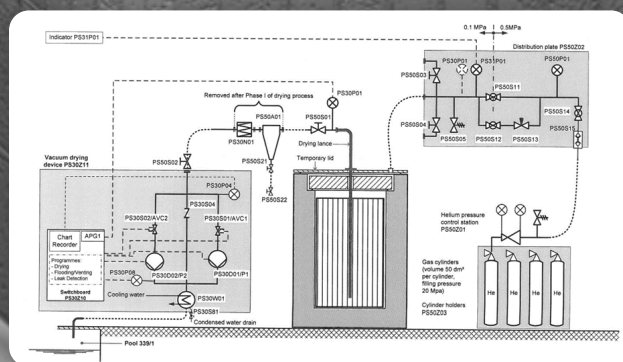


Vacuum drying the internal cavity of
the cask on the service platform

Vacuum Drying

Evaporation of absorbed water

The second phase focuses on removing water that is trapped in gaps and adsorbed onto surfaces within the cask. During this phase, the pressure in the cask is maintained at 10 hPa to avoid freezing the water, which could impede the drying process. Maintaining this low pressure ensures that even tightly bound water molecules are effectively evaporated and removed..



5.2 Vacuum Drying

The cask, equipped with a temporary lid, is placed at the cask service station for vacuum drying.

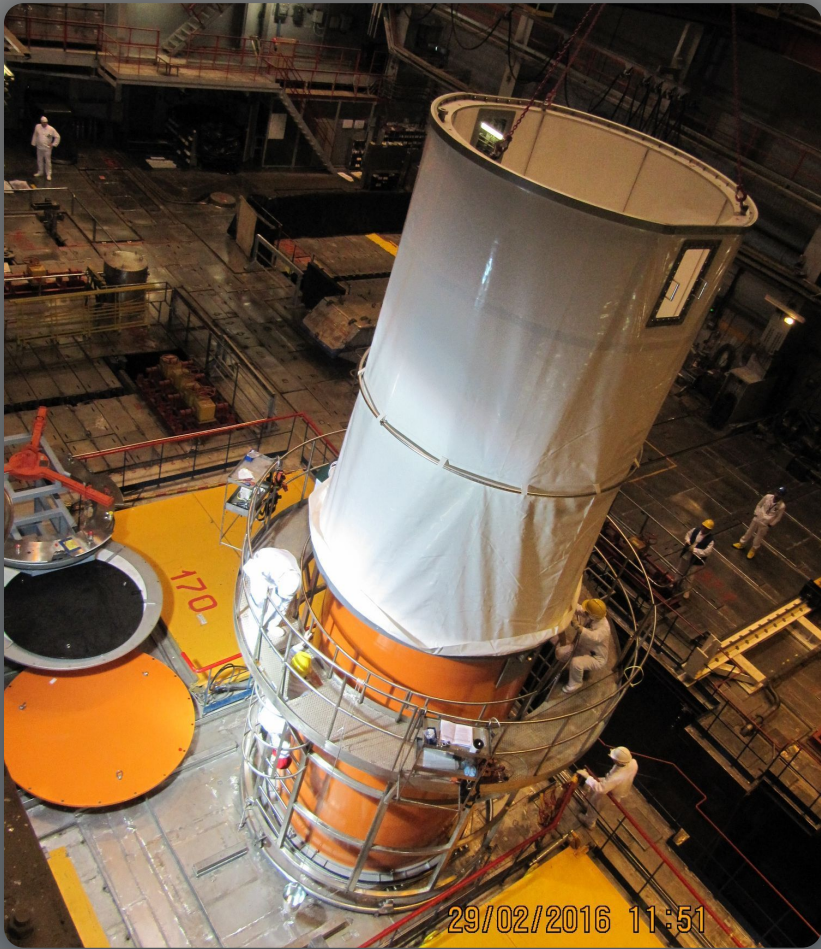
The cask is dried in two steps by reducing pressure to facilitate evaporation of water inside the cask and trapped in gaps and surfaces

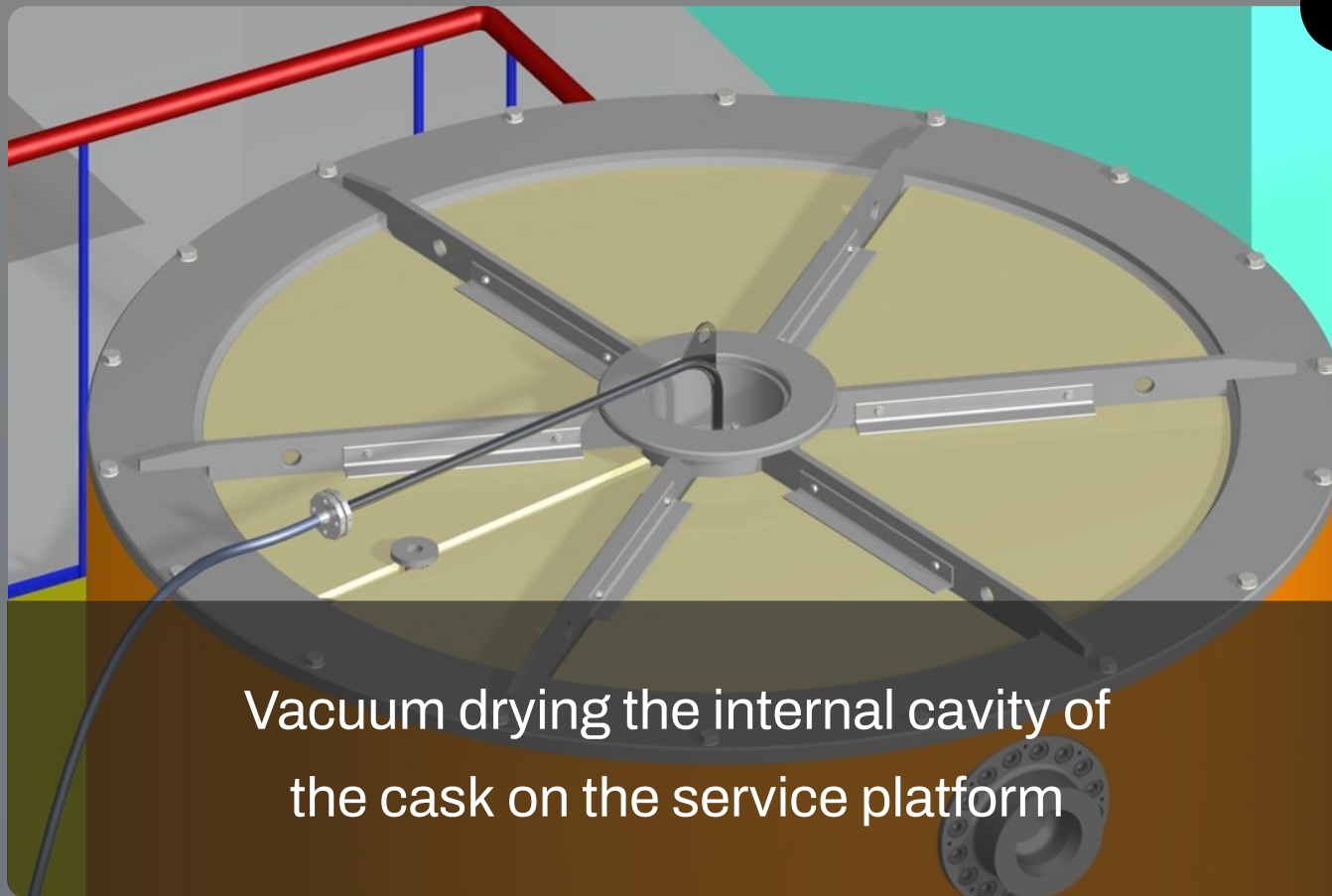
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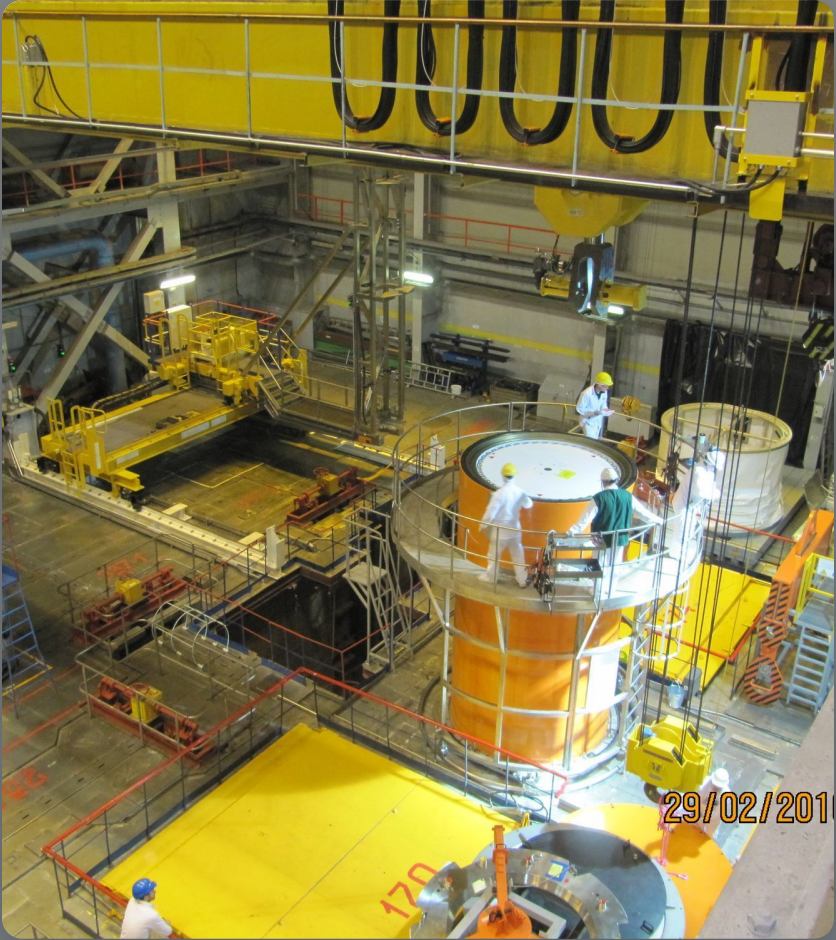
Vacuum drying the internal cavity of
the cask on the service platform

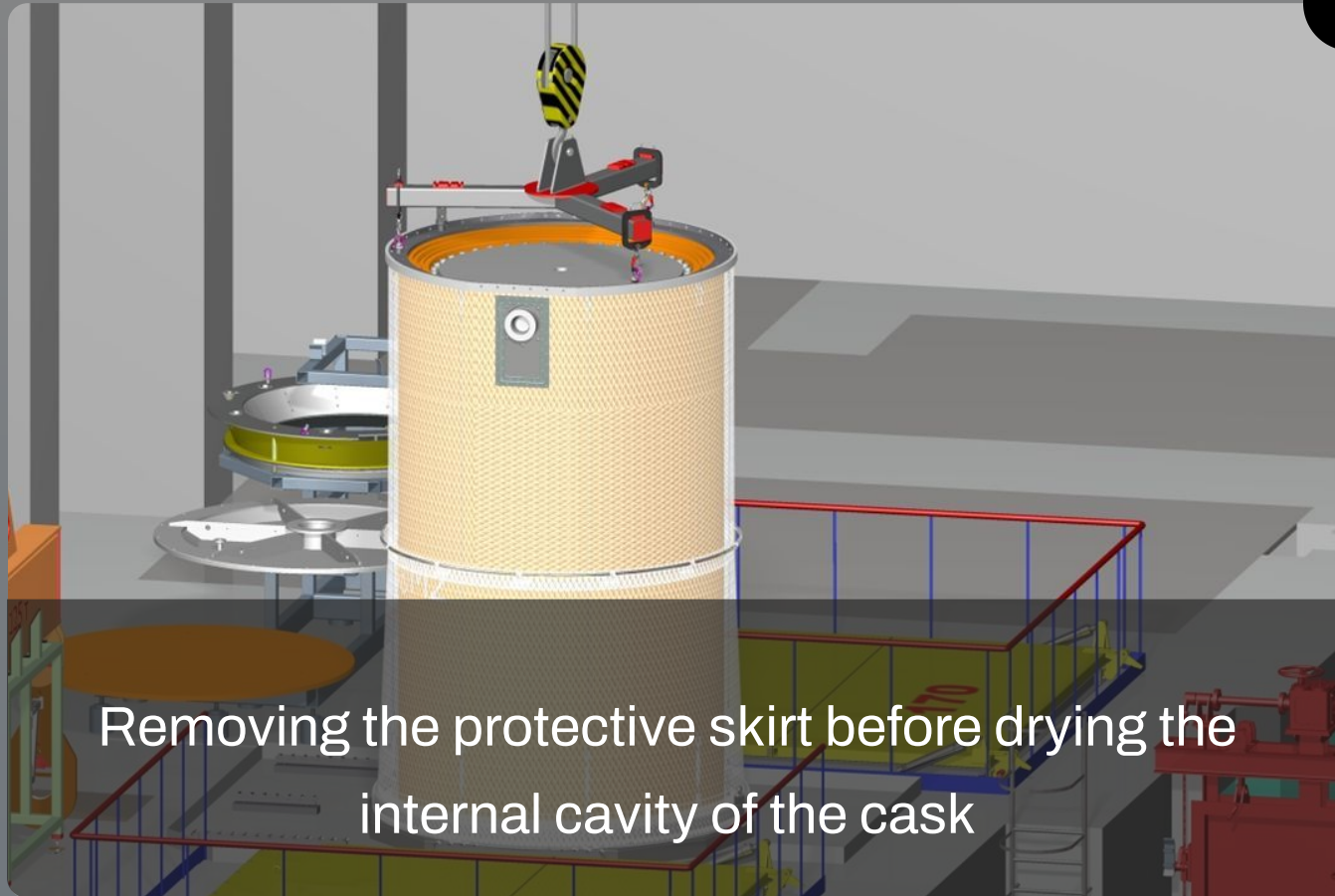


Monitor the process using various instruments and valves to control and maintain the desired pressure levels throughout the drying phases. The operation involves the use of rotary vane pumps, an emission condenser, and pressure gauges, all integrated into a control system to ensure precise execution of the drying process.

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By adhering to these procedures, the vacuum drying process effectively prepares spent nuclear fuel casks for long-term storage, ensuring safety and stability.





Removing the protective skirt before drying the
internal cavity of the cask





Installing the lid for vacuum
drying the cask



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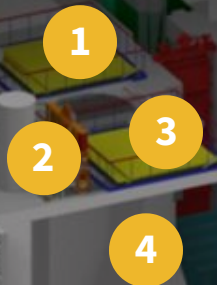
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5.3 Helium Filling

The cask is filled with helium to restore it to ambient pressure. Helium is used because of its inert properties, which help to create a stable and non-reactive environment inside the cask.

This step is crucial for long-term storage as it prevents oxidation and other chemical reactions that could occur if air were present inside the cask.

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5.4 Bolting and testing

Before the vacuum drying process begins, the initial dewatering of the cask is performed in basin 338/1.

This step is crucial for reducing the weight of the container, facilitating easier handling and transport to the cask service station where the vacuum drying process will take place.

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Dose measurement

Radiation dose
measurements and checks
for transport





Installing the protective cover of the cask



Bolt and test

Final bolting and
leak-tightness testing
of the primary lid





Decontamination

Wiping and contamination
examination of the outer
cask surface



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Step 6. Casks transport to storage

After treatment in the plant, the containers are transferred to the Interim Spent Fuel Storage Facility (ISFSF).

Handling operations, like welding of the secondary lid or transfer to the storage place, of the cask loaded with damaged and experimental fuel at the ISFSF are the same as for intact fuel.



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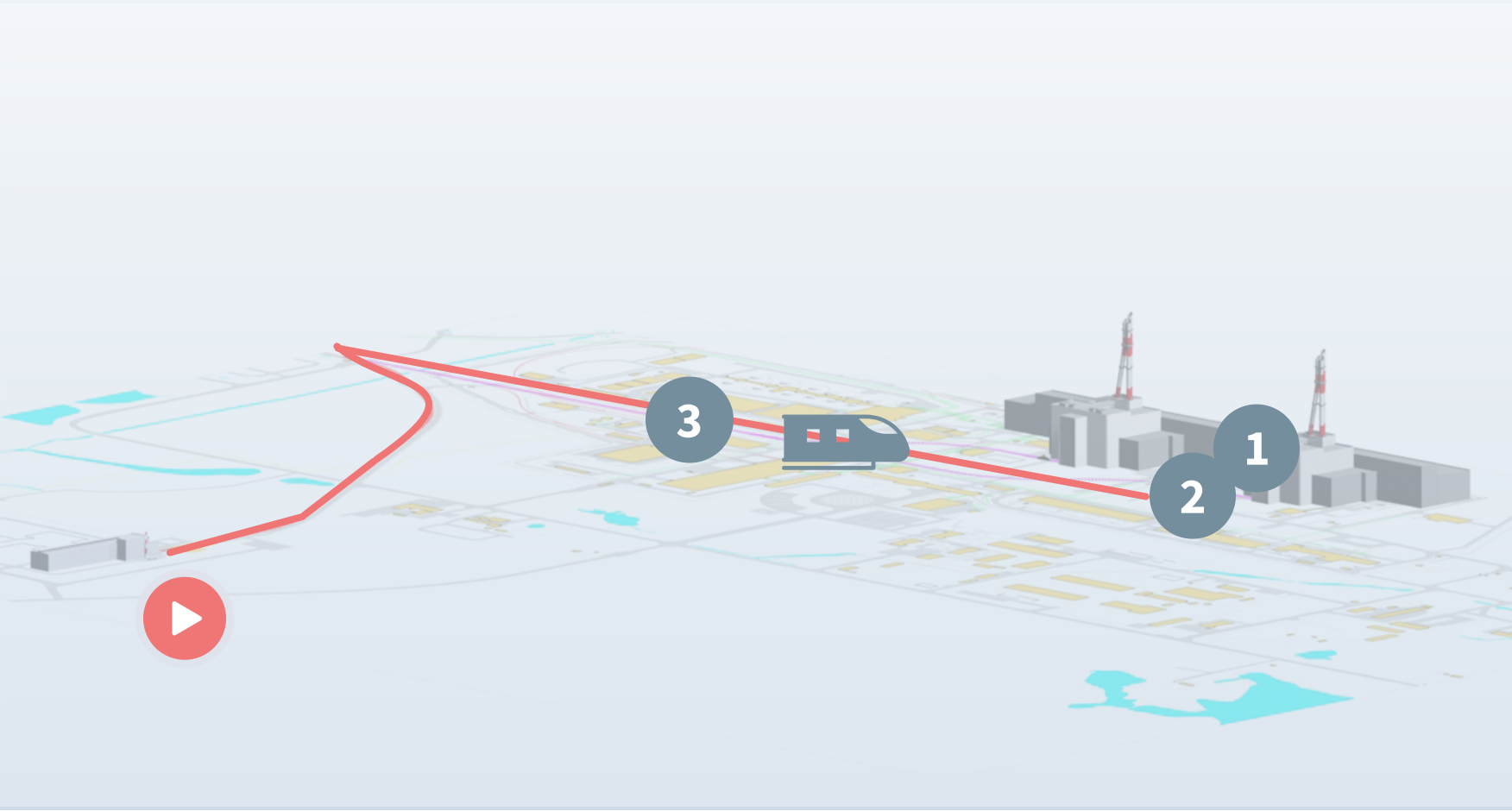
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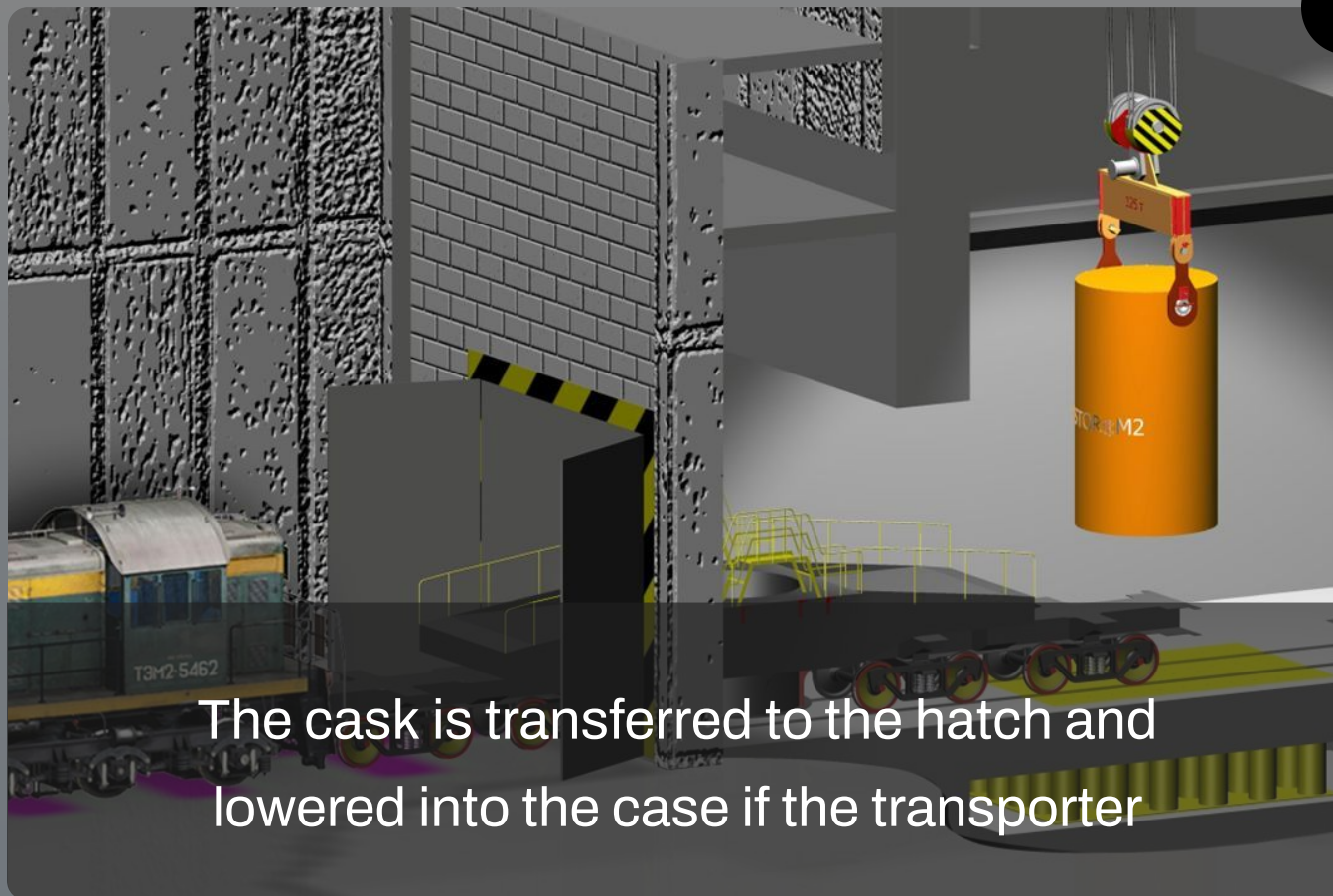
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Home icon





The cask is transferred to the hatch and lowered into the case if the transporter









The main challenge in this step is to ensure the safe storage of damaged SNF assemblies and fuel/pellet spills in a manner that isolates them from the environment and prevents the possible leakage of radioactive material



The cask is tied down to the transporter for the transfer



The DFHS involves placing the processed SNF assemblies and fuel/pillage spills into cartridges and then into protective containers that provide reliable radiation shielding and safe storage of the SNF.

These casks are then transferred to a temporary storage facility for radiation monitoring, cask integrity, and IAEA/Eurat nuclear material control systems.



**The cask is transferred to the ISFSF
reception hall**



Step 7. Fuel debris removal and video survey of the fuel storage pools

After removal of all the RBMK1500 Fuel including also the Heavily Damaged Spent Fuel (HDF) from the Spent Fuel Storage Pools of INPP Unit 1 and 2, the remaining challenge is to ensure the recovery, management and safe storage of the fuel debris and to process the residual sludge and miscellaneous waste remaining in the Spent Fuel Storage Pools.



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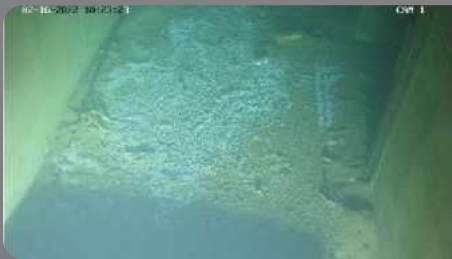
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The experience from Unit 1 informed improvements for Unit 2. By July 2022, sludge removal operations were completed more efficiently, with better equipment and an updated video survey approach, which now occurred immediately after each pool was cleaned to avoid delays caused by sludge re-accumulation. Training provided by H&B also enhanced the capabilities of INPP personnel, enabling them to conduct video surveys independently, reducing reliance on external staff.





For Unit 1, the initial timeline for cleaning each fuel storage pool was much longer than what was needed in practice, with each pool taking three to four months instead of two weeks. This delay was primarily caused by the re-accumulation of sludge at the bottom of the pools, which required additional cleaning rounds. H&B responded by modifying the cleaning equipment, such as vacuuming nozzles and sludge separators, improving the efficiency of the operation.



Project Execution

The debris removal and video survey project at the Ignalina Nuclear Power Plant (INPP) faced significant challenges due to the COVID-19 pandemic and operational constraints, requiring adjustments to the schedule and methodology. Travel restrictions prevented H&B specialists from conducting on-site work, forcing activities like training and Factory Acceptance Testing (FAT) to be held virtually. Despite these challenges, the virtual approach was successful, ensuring the project progressed without major delays while maintaining safety and operational standards.

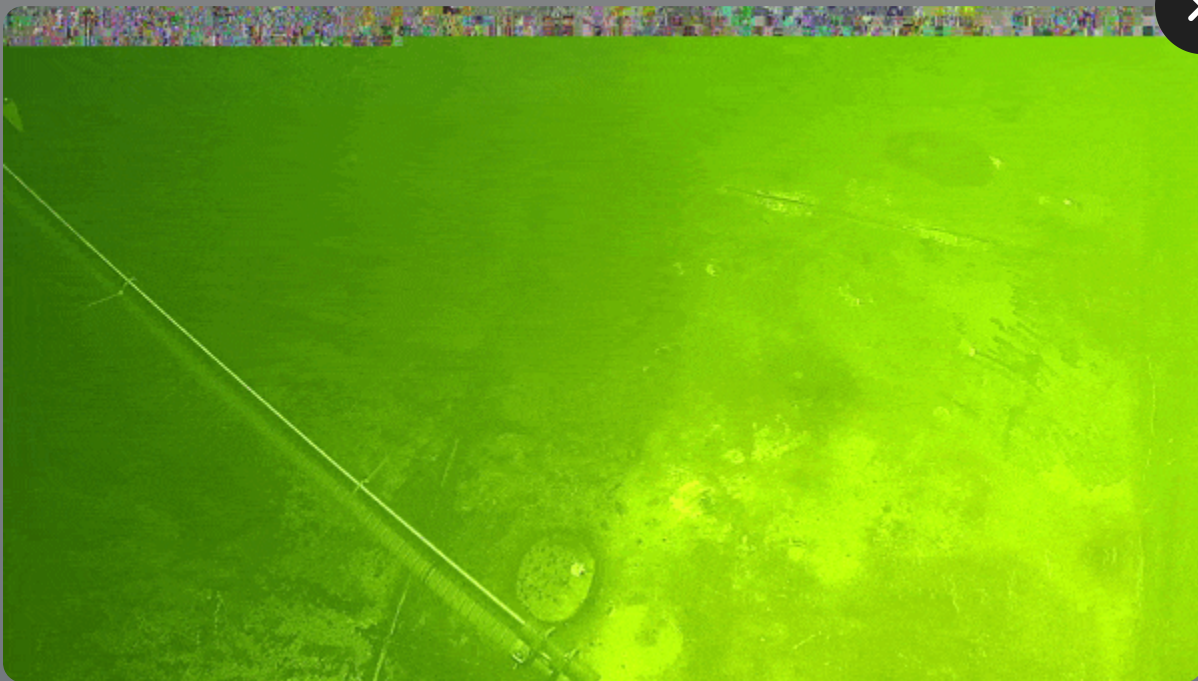






Technical Data of Unit 1 and 2

- Approximately 1300 filters were used in Unit 1 and 1200 filters in Unit 2 to clean the pools bottom.
- Approximately 1000 pieces (400 at Unit 1 and 600 at Unit 2) of large/smalls size items, lids, neutron detectors, penal lids, parts of control rods, grabs for transferring specials (special products/tools) were removed (lifted) from the bottom of the pools. The total weight is about 500 kg.
- Approximately 2,3 m³ of filter bags with wastes (e.g. sludge, sand, rubber pieces, etc.) were loaded to the K100 containers and removed from the Units 1 and 2. Then these filter bags were reloaded to Long Lived Intermediate Level Waste containers (volume of one ILW-LL container is 2,55m³).
- Approximately 12 pieces of 200 litre drums were removed from each Unit to Solid Waste Management and Storage Facility . When the drums were monitored via the facility MST6 they were loaded to the Short Lived Low and Intermediate Level Waste containers.
- The square of the pools for cleaning / video survey is 185 m² and the volume is 3000 m³ in each Unit.





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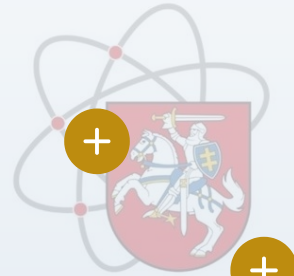
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Conclusion
and benefitsLessons
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Regulatory

Improved regulatory compliance

The DFHS has helped INPP comply with international best practices and regulatory requirements for nuclear safety and waste management.

VATEST
State Nuclear Power Safety

Training

High team competence

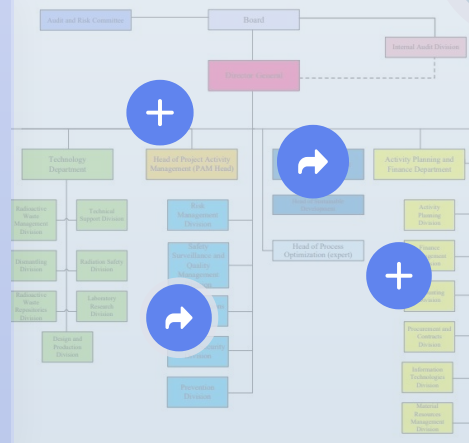
Training programmes and materials were developed by specialists who were actively involved in all key stages of managing damaged fuel.



Organizational

New organizational structure

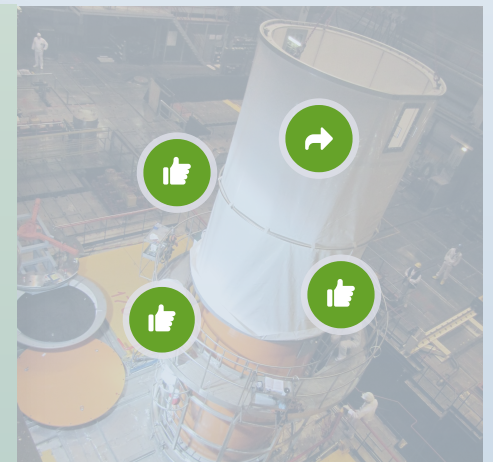
To prepare for the commissioning of the new Interim Spent Fuel Storage Facility (ISFSF), a specialised unit was organised within the Nuclear Fuel Management Shop structure



Technical

First RBMK to remove DFA and load all nuclear fuel into casks

All spent nuclear fuel, including nuclear fuel debris/pellets, has been safely removed and stored in fuel storage casks in the INPP ISFSF.





Lesson Learned #3

Packing and Safe Storage

Properly designed storage cask and facilities are crucial for the safe, long-term storage of damaged SNF, ensuring environmental protection and compliance with safety standard



Lesson Learned #1

Preparation of training materials

From January 2020, the preparation of the training materials and the training of the NFMS personnel themselves were carried out by the lead engineers who actively participated in all key stages of managing damaged fuel.

A training program prepared by personnel with field experience and involved in the DFA activities ensures a high level competence and understanding of the processes, which is important for successfully implementing the final stage of SNF management.



Benefits for other operators

The success of DFHS at INPP provides valuable lessons for other nuclear facilities.

INPP is the first and only RBMK reactor power plant in the world to have completed the loading of all nuclear fuel into storage casks in both of its units and to have confirmed that all spent nuclear fuel, including nuclear fuel debris/pellets, has been safely removed and stored in fuel storage casks in the INPP ISFSF.



Lesson Learned #5

Identification and Assessment of Damaged SNF

Accurate assessment of damage is fundamental to developing effective handling and storage procedures, ensuring safety and regulatory compliance.



RE organization (2020)

The management of damaged fuel began in August 2020. Cask with SNF cartridge covers (CAN160, CAN500 and CAN1200 mm) were used to manage damaged fuel. According to the contract, equipment for safely handling damaged SNF in the pool was delivered first to Unit 1 and then to Unit 2.

To boost the process, the organisation structure was adapted as follows:

- Section 1 consisted of 3 operators and 1 engineer at one INPP unit. The works were performed in 2 shifts, involving 8 people in total.
- Section 2 consisted of 3 operators and 1 engineer at the CWTP, working only one shift that involved four people.



Practical training with contractors

As a contract requirement, the NFMS personnel were trained under the contractor's supervision. Then, they participated in equipment acceptance, cold and hot testing of equipment and systems, and continued industrial operation.

The NFMS personnel were trained in two phases to enhance their skills and promote the safety culture at nuclear power plants.



Lesson Learned #2

Use of simulators

Using damaged fuel simulators allows personnel to learn techniques for handling underwater equipment without the risk of radiation exposure, which is an important part of loading spent fuel into casks.

Incorporate the use of simulators during practical training sessions to provide hands-on experience without the risk of radiation exposure. This allows personnel to learn techniques for handling equipment safely and effectively.



Takeaway #4

Theoretical training provides foundational knowledge, while practical training allows personnel to apply this knowledge in real-world scenarios.

Implement a two-phase training approach consisting of theoretical and practical training sessions.



Regulatory benefits

The DFHS project involved the implementation of comprehensive safety measures, continuous radiation monitoring, and regular audits to ensure that all activities related to the handling and storage of damaged SNF met stringent regulatory requirements.

Removing all nuclear fuel from the INPP units will enable the regulator (VATESI) to grant a licence for decommissioning INPP units 1 and 2.



Lesson Learned #4

Removal of Damaged SNF from the Pool

The use of advanced underwater equipment and remote handling tools is essential for the safe removal of damaged SNF, reducing radiation exposure risks.



New organization (2015)

- Section 1 was devoted to handling CONSTOR®RBMK-1500/M2 casks at INPP units 1 and 2. It consisted of 6 operators and 1 engineer at each INPP unit, meaning 14 people for both units. The work was performed in 2 shifts involving 28 people.
- Section 2 was dedicated to handling CONSTOR®RBMK-1500/M2 at SNF. At the CWTP, Section 2 consisted of 6 operators and 1 engineer. The work was performed in 2 shifts that involved 14 people.



Preparation of training materials

From January 2020, the preparation of the training materials and the training of the NFMS personnel themselves were carried out by the lead engineers who actively participated in all key stages of managing damaged fuel.

From the design to the equipment manufacture, they were present at the manufacturing plant for the Factory Acceptance Tests (FAT) and the INPP Site Acceptance Tests (SAT).



Takeaway #2

Other INPP employees, including dosimetrists, railway workers, security personnel, welders, repair personnel, nuclear material control personnel, etc., were periodically involved in various technological operations during container handling.



Other operators may benefit from involving a wide range of personnel to ensure smooth operations with damaged fuel



Other benefits

The project has also brought significant benefits, including operational cost savings, safety improvements, and improved regulatory compliance.



Takeaway #1

Evaluate and optimise the organisational structure based on each unit or site's requirements and workload to adapt the number of personnel and shifts, improving efficiency and resource allocation.



Takeaway #3

From the design to the equipment manufacture, INPP personnel that prepared the training were present at the manufacturing plant for the Factory Acceptance Tests (FAT) and the INPP Site Acceptance Tests (SAT).

Ensure that training is prepared that experts who have been present in the FAT and SAT



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28

People in handling
operations



40

Containers
per year



1

Containers with
damaged fuel per
month



1

The container removal rate was 1
damaged SNF container per month
and unit

40

The container removal rate from
both units was 40-42 SNF
containers per year

28

28 people in 2 shifts devoted
to handling
CONSTOR®RBMK-
1500/M2 casks at INPP
units 1 and 2