Design of the JRC Ispra Site Interim Storage Facility

CASE STUDY

KP-JRC-013

16/04/2025

Foreword

In 2021, the European Commission (EC) adopted a new proposal for a Council Regulation[1] establishing a dedicated financial programme for decommissioning nuclear facilities and managing radioactive waste (RAW). 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[2] 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.

This is a Knowledge Product prepared by the JRC - Joint Research Centre, Directorate J Nuclear Decommissioning and Waste Management

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[1] Council Regulation (Euratom) 2021/100 of 25 January 2021 establishing a dedicated financial programme for the decommissioning of nuclear facilities and the management of RAW, and repealing Regulation (Euratom) No 1368/2013

[2] Council Regulation (EU) 2021/101 of 25 January 2021 establishing the nuclear decommissioning assistance programme of the Ignalina nuclear power plant in Lithuania and repealing Regulation (EU) No 1369/2013

PRODUCT DESCRIPTION

This document details the experience gained and the lessons learnt from the design, authorisation, construction, operation and maintenance of an interim storage facility (ISF) that can store all very low-level waste (VLLW) and low-level waste (LLW) generated in the past and any that will be produced during the decommissioning of the JRC Ispra site´s nuclear facilities. This information is presented in the form of a case study which conveys guidance on the design and construction process that led to the successful authorisation to operate an ISF. And shows how the European Commission´s Joint Research Centre (JRC) tackled implementing such works at their Ispra site.

ABSTRACT

An ISF is a temporary storage solution that operates for an extended period, up to 50 years in the case of this knowledge product’s (KP´s) subject matter, after which the waste it is housing will be sent to a national disposal facility. In order to construct an ISF both a well-considered design and buy-in from the relevant competent authorities is necessary. Stakeholder engagement programmes were carried out by the JRC to gain public trust, as well as to dispel any concerns about the safe storage of radioactive waste.

Following an agreement that was reached with the Italian Government which authorised the installation; the ISF of this subject matter was constructed in 2 years without delay and only minor maintenance was performed. Furthermore, while the ISF was designed and built in the absence of available waste acceptance criteria (WAC), provisions akin to an insurance policy were agreed between the Government and the JRC to cover the transport and receipt of waste that might not be completely aligned with the WAC that will be in force in the future. The primary operational purpose of the ISF is to house LLW generated across the different facilities situated on the JRC´s Ispra site.

At the time of writing, the non-conditioned amount of LLW totalled around 3,300 m^3 and the total load of conditioned LLW (equivalent volume of 5.2 m^3 prismatic carbon steel containers) on the ISF was estimated to total 1300 final waste packages (FWPs). The estimate also includes a provision for solidified liquid radioactive waste, which is stored in CC-440 stainless steel cylinders of which 6 can be held in a frame of the same proportions as the solid waste packages, totalling 171 frames of CC-440. The case study also acknowledges the decision that was made to incinerate some bituminised waste at Ispra, in order to use one of the ISF´s spare rooms to store VLLW.

OBJECTIVE

To record, convey and explain the knowledge gained during the deployment of an ISF at the JRC´s Ispra site.

APPROACH

This KP was developed using a technical document entitled ¨Knowledge Object Development on Interim Storage Facility (ISF)¨ as a key reference. The document was provided to the JRC by SOGIN, who are the Italian radioactive waste management organisation (WMO), as a contribution to the JRC´s nuclear decommissioning knowledge management (DKM) initiative.

Moreover, this document was formulated with a view of providing a readable and engaging high-level overview of the approach to designing, constructing and authorising the ISF. It begins with an introduction to the JRC site, work carried out concerning the ISF, challenges tackled during implementation and a summary of lessons learnt. This is followed by a comprehensive case study that details the extent of the work undertaken, focusing on requirements and criteria for design and authorisation, and the construction process.

RESULTS, FINDINGS AND INSIGHTS

The development and use of an ISF is a worthwhile endeavour but, in the modern day, cannot be considered a pioneering technological or novel storage solution due to its implementation at other facilities. ISFs also present some inefficiencies. Nonetheless, ISFs can be considered more cost-effective and sustainable solutions than decentralised storage at other facilities across the site. This KP also highlights that the use of prefabricated components during construction can lead to time and cost savings, as well as better quality standards.

TARGET USERS

Decommissioning operators and contractors who will utilise or need to refer to similar technical details and understand the processes of authorising and implementing an ISF will primarily benefit from this document. In addition to this, it could be useful to those among said entities who simply would like to learn more about what the process entails or compare it against their own processes.

APPLICATION, VALUE AND USE

The information contained herein could be useful to other stakeholders intending to employ an ISF at any other nuclear site in a state without a national repository. As well as those entities who would like to understand more about what the process entails or to compare it against their internal processes.

KEYWORDS

DECOMMISSIONING, INTERIM STORAGE FACILITY, WASTE MANAGEMENT.

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ACRONYMS

DKM	Decommissioning Knowledge Management
DNTP	Deposito Nazionale e Parco Tennologico / National Deposit Technologic Park
FWP	Final Waste Package
ILW	Intermediate-Level Waste
ISF	Interim Storage Facility
JRC	Joint Research Centre
KP	Knowledge Product
LLW	Low-Level Waste
NDAP	Nuclear Decommissioning Assistance Programme
NDWM	Nuclear Decommissioning and Waste Management
NPP	Nuclear Power Plant
RAW	Radioactive Waste
VLLW	Very Low-Level Waste
WAC	Waste Acceptance Criteria
WMO	Waste Management Organisation
WMP	Waste Management Plan

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1. INTRODUCTION

1.1. Background

The Nuclear Decommissioning and Waste Management Directorate of the JRC is running the Nuclear Decommissioning and Waste Management (NDWM) Programme for the nuclear sites of the European Commission, with most of the activities currently focused on dormant facilities situated on the Ispra site (located in northern Italy).

In 2020 the Council of the EU issued Council Regulations 100 and 101 in which they provided co-funding to the decommissioning programmes in three EU Member States (Slovakia, Bulgaria and Lithuania). This initiative is now commonly known as the Nuclear Decommissioning Assistance Programme (NDAP), and it also provides full funding to the internal NDWM Programme of the European Commission, run by the JRC.

The same regulations also mandated the JRC to initiate a project on knowledge management in NDWM, based on the collection of experience and lessons learnt running the JRC and NDAP programmes. The primary products of the knowledge management project, referred to as KPs, will be disseminated to European stakeholders to support new operators entering NDWM activities, enabling them to profit from knowledge generated by previous experience and programmes.

Figure 1. JRC - Joint Research Centre Ispra site, Italy

This KP builds on the progress of the NDWM in the past years. It details the experience gained in the design, authorisation, construction, operation and maintenance of an ISF able to store all VLLW and LLW generated in the past and those which will be produced during the decommissioning of the JRC Ispra site´s nuclear facilities.

Not only does this KP elucidate the practicalities and challenges of implementing an ISF at the JRC´s Ispra site, it also provides useful information for other stakeholders that intend to implement an ISF and/or are already in the process of developing an ISF. And can be considered an independent reference to compare their procedures against; this could be particularly useful for stakeholders in Member States without a national repository as well as without any clear plans to develop a national repository.

1.2. Motivation

The use of ISFs is not unique, with many being utilised at nuclear facilities around the world. However, the experience of implementing ISFs is often closely guarded by decommissioning operators and relevant stakeholders. It is for the aforementioned reasons, and in the spirit of the NDWM Programme, that this KP has been developed.

Collecting the knowledge gained from experiences with similar storage facilities at a national and international level helped to inform the decision-making process when selecting the ISF's main characteristics and structure, as well as its implementation. This document aims to record and disseminate the findings gained from a valuable contribution to the NDWM Programme from SOGIN. Furthermore, capturing the core details of the entire process could be considered a unique contribution because of the nature of the research site and that there are a sparse number of publicly available documents covering the topic in the style elaborated herein.

1.3. Scope

This KP focuses on the three core steps that were followed to implement the ISF: design, authorisation and construction. Attention has also been paid to notable aspects of the ISF´s operation and maintenance, and additionally to the interdependencies between the said steps with relevant laws and regulations.

1.3.1. Design requirements and criteria

The ISF´s storage capacity was established using the estimated LLW inventory of all nuclear facilities to be decommissioned at the Ispra site. It should also be noted that the ISF represents the only brownfield installation on the site. Whereas, as the JRC´s final goal, the end states of all other nuclear facilities certified by the authorities should be deemed as greenfield sites that do not present any residual radiological hazard.

1.3.2. Construction phases

The construction activities covered in this KP broadly align with the following phases:

Incipient phase

Establishment of a temporary working yard separated from the JRC´s main fence and with its own access road.

Main phase

Primary construction activities including grouting of the main platform on site, building of ISF constituting four (4) storage areas, a few small rooms and a control room.

Operation and maintenance

ISF operations to store LLW and some packages containing non-conditioned VLLW.

2. CASE STUDY

2.1. The JRC Ispra site

Figure *2* presents the JRC Ispra site´s layout displaying all the nuclear facilities to be decommissioned at the site. It is the JRC Directorate J´s responsibility to decommission all nuclear facilities at the Ispra site wherever nuclear research reactors and nuclear installations operated in the past. The decommissioning works will cover the following seven (7) facilities:

- INE – ESSOR reactor and pulsed neutron facility
- Tank farm liquid waste treatment and storage
- Hot laboratory for research and study
- Cyclotron
- ISPRA 1 reactor
- Area 40:
  - Waste treatment facility (WTF) and
  - Stazione Gestione Rifiuti Radioattiv (SGRR)
- ISF

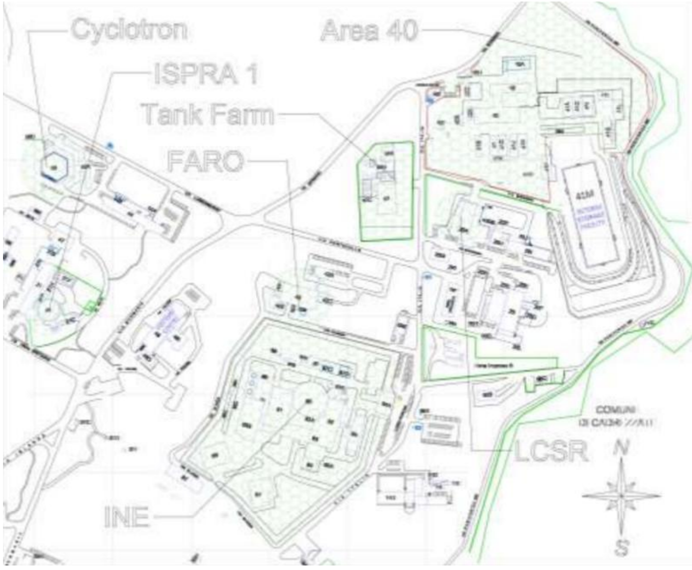

Figure 2. JRC Ispra site's layout displaying all nuclear facilities to be decommissioning (highlighted in green)

2.2. Sources of Information

An extensive range of over 40 references were relied on to elaborate this KP in order to: correctly represent the chronology of the activities undertaken at the ISPRA site, to accurately report the technical details and to connect everything with a view of the JRC´s NDWM programme. The core technical references that were drawn on are shown below, excluding any internal reference to project management, schedule and other documents that are not considered relevant to the practicalities of the work undertaken or are otherwise considered beyond the scope of this KP.

- IAEA – Safety Guide WS-G-6.1 – Storage of radioactive Waste
- UNI 11196 Radioactive waste packages - Containers for the final repository of Category 2 packages
- Legislative Decree 101/2020 Implementation of Directive 2013/59/Euratom
- D.M. 14.01.08 Technical standards for construction
- D.I. 7/8/2015 Classification of radioactive waste, pursuant to Article 5 of Decree Legislative Decree No 45 of 4 March 2014
- DM IMP/89/0 Interministerial Decree of 03/05/2011 - Temporary Storage of Solid Radioactive Waste solid radioactive waste (Interim Storage Facility - ISF)
- TG 26 Management of radioactive waste (now TG.33)
- TG 30 - ISIN Safety and radiation protection criteria for temporary storage facilities of radioactive waste and irradiated fuel

2.3. Challenges: Design Criteria and Authorisation Requirements

The experience acquired from similar installations at a national and international level were useful to informing the main characteristics and the structure of the ISF. The main operational factor is that the ISF will primarily contain LLW in solid form in prismatic or cylindrical containers for up to fifty (50) years (considering the expected operational period and corrosion of the FWPs etc.).

Design criteria

An important design decision needed to be made between the use of cast-in-place concrete structures and prefabricated concrete structures. A study was carried out to investigate this.

Storage capacity

Established based on the estimated inventory of all of the LLW stemming from the facilities that had been decommissioned at the JRC.

Specific requirements

It was a necessity to satisfy the Italian law for concrete structures and to integrate relevant findings from the analysis of past nuclear power plant (NPP) projects.

Authorisation

The ISF represents a unique brownfield site, whereas the end goal for the other facilities is to be certified as greenfield.

2.3.1. ISF design criteria: structure

Two types of installations were studied: prefabricated concrete structures without cranes and cast-in-place concrete structures with three bridge cranes. The study identified several advantages and disadvantages related to prefabricated concrete structures without cranes and cast-in-place concrete structures with cranes, as displayed in **Table 1** and **Table 2** respectively.

2.3.1.1. Concrete structures

As can be observed when comparing **Table 1** and **Table 2**, the advantages identified for prefabricated concrete structures without cranes exceed the number of advantages for cast-in-place concrete structures with three bridge cranes. Whereas the opposite can be seen when disadvantages are compared in the same manner.

The main reason prefabricated concrete structures were preferred and, in some instances, selected instead of the cast-in-place approach, was the high cost and time burdens that would be associated with building and dismantling the facility. In addition to the fact that dismantling is generally much easier with prefabricated concrete structures.

Table 1. Advantages and disadvantages of prefabricated concrete structures without cranes

PREFABRICATED CONCRETE STRUCTURE WITHOUT CRANES

Advantages	Disadvantages
• Easy and quick construction • Less complicated seismic analysis due to not using a loaded crane • Significantly less risk of falling to workers • Finer aspect of internal and external surfaces • Easy decommissioning • Cheaper	• Greater deformability for a bridge crane • More complex removal of damaged packages

Table 2. Advantages and disadvantages of cast-in-place concrete structures with three bridge cranes

CAST-IN-PLACE CONCRETE STRUCTURE WITH THREE BRIDGE CRANES

Advantages	Disadvantages
• Rigid structure • Stable with a bridge crane • Crane able to remove a single pile	• Time consuming construction • Many workers working at height level with falling risk • Taller structure due to the bridge crane presence and its maintenance room • Large dimensions / thickness of structural elements due to seismic events with the loaded crane • Significantly more expensive to build, operate and maintain • Difficult decommissioning due to continuous concrete structure

While there are many advantages and few disadvantages to utilising prefabricated structures, prefabricated concrete structures tend to be less stiff / durable than cast-in-place concrete structures. However, the JRC overcame this challenge through using an electrical fork-lift instead of a bridge crane. In addition to this, final checks of the operational arrangements were incorporated by seeking the expertise of an expert European operator of a similar installation. The checks covered the verification of other aspects of the ISF´s implementation, such as the use of a fork-lift and the identification of any weak aspects of the ISF´s configuration.

All the suggestions received from the experts were accepted except the use of a diesel fork-lift and the reduction of the distance between package piles; the former decision could be justified based on the benefits to the environment being considered to outweigh the slight economic benefits of utilising such a fork-lift. And the latter was made based on ergonomics considerations since the licensing authority requires at least one side of the package to be inspectable.

2.3.2. Meeting the criteria at the JRC Ispra site

The decommissioning requirements of the facilities mentioned in **Section 2.1** differ, and the extent of the work that will be undertaken exceeds the scope of this KP. However, a notable difference in requirements is that the decommissioning of the ESSOR reactor is solely the duty of the NDWMD, while for the ISPRA 1 reactor only the radioactive waste must be treated and stored. Furthermore, there is a clear distinction between the approaches to solid and liquid waste treatment.

It was foreseen that liquid waste would be completely treated by an external operator, which could be at the Ispra site or off-site (even abroad). This is particularly pertinent to the liquid and solid waste stored at the tank farm which requires a solidification process and to be stored in a CC-440 container prior to being stored at the ISF. Whereas solid waste will be conditioned by a grouting station that is under construction at the site. However, the unique contribution of the ISF is that it will centralise the LLW generated from the above-mentioned facilities, and the ISF can also be used to store VLLW.

2.3.2.1. Waste inventory

The latest report by the Italian inventory of radioactive waste published by ISIN in 2020 provides details on the total amount of non-conditioned waste at the JRC´s Ispra site, reproduced below in **Table 3**.

Table 3. Total amount of non-conditioned waste at JRC Ispra site

NON-CONDITIONED WASTE

Waste type	Volume (m^3)	Activity (GBq)
VLLW	1433.30	8.09
LLW	3281.28	497.17

The resultant storage load on the ISF depends on the final volume when conditioned, which is a product of several factors including: the treatment facility, partially known contamination and activation levels of waste, waste/packaging dimensions, safety requirements, cost and decommissioning phase etc. The foreseen conditioned waste inventory was estimated as a [(3)]CP-5.2 equivalent volume. Considering the best available information at the time of writing, the estimated conditioned LLW waste at the JRC´s Ispra site totals 2540 [(3)]CP-5.2 equivalent volume. The full breakdown of the estimate can be seen in **Table 4** to **Table 6**.

Table 4. Total amount of estimated conditioned LLW existing waste as CP-5.2 equivalent volume

WASTE STREAM: EXISTING WASTE

Existing waste	Nominal inventory	Spare	Total
Main stream	67	27	94
Technological waste	24	10	34
Sludges	96	40	136
Bituminised drums	1056	0	1056
TOTAL	**1243**	**77**	**1320**

[3] *CP-5.2 stands for a 5.3 m^3 prismatic container in carbon steel containing solid waste in a concrete matrix.*

Table 5. Total amount of estimated conditioned LLW decommissioning waste as CP-5.2 equivalent volume

WASTE STREAM: DECOMMISSIONING WASTE

Existing waste	Nominal inventory	Spare	Total
Main stream	501	191	692
Technological waste	303	119	422
Sludges	75	31	106
TOTAL	**879**	**341**	**1220**

Table 6. Total amount of estimated conditioned LLW total waste as CP-5.2 equivalent volume

WASTE STREAM: TOTAL WASTE

Existing waste	Nominal inventory	Spare	Total
TOTAL	2122	418	2540

2.3.2.2. Waste packages

The ISF was planned and built to store FWPs, referred to as [3 above]CP-5.2 packages which constitute a 5.3 m^3 prismatic container in carbon steel containing solid waste in a concrete matrix, and a CC-440 container which is a cylindrical container containing solidified liquid waste, for a period of up to 50 years in agreement with national and international safety requirements. This is in addition to concurrent aims of minimising doses to workers and the public, periodically controlling FWP conditions, recording all waste data, as well as ensuring that FWPs meet WACs for final transport to and acceptance at the national repository.

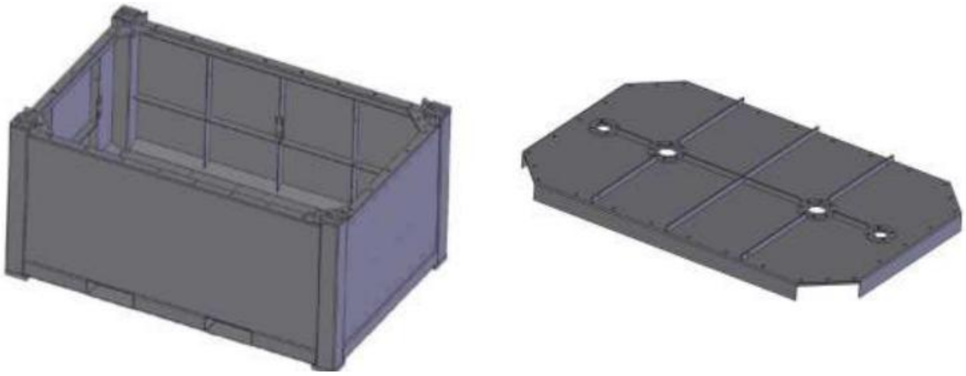

Figure 3. Computer generated representation of a CP-5.2 external steel structure and lid

The ISF is arranged so that [3 above]CP-5.2 packages (displayed in **Figure 3** above) can be stacked up to 5 levels for a total height of 6.25 m. When loaded with 6 drums (equating to a capacity of 220 L volume) the filling ratio for a [3 above]CP-5.2 package is 25%. The maximum allowable mass is 15 tonnes, and the dimensions are 2500 x 1650 x 1250 mm as shown in **Figure 4**.

A filling ratio of 25%, that is observed for the CP-5.2 FWPs detailed above, is considered very low, which is why one method of improving it was found to be reducing the volume of asphalt waste by incineration.

There are three configurations that can be used to position waste inside a (3 above)CP-5.2 container: position inside the container with a single basket, use two half baskets (**Figure *5***) or a special frame for 6 x 220 L drums (**Figure *6***).

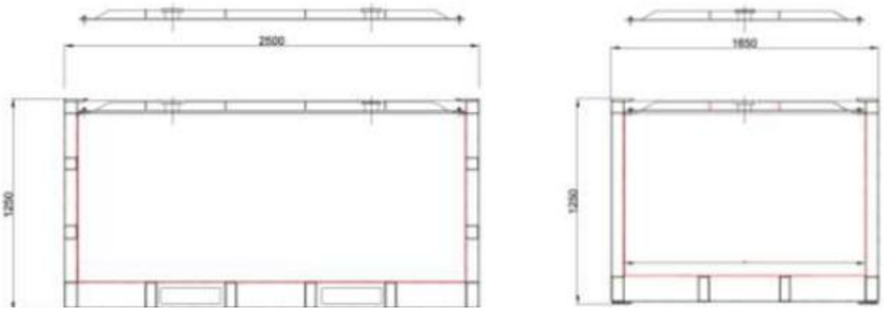

Figure 4. Longitudinal and lateral sections of a CP-5.2 (mm)

Figure 5. CP-5.2 half basket for 2 small items

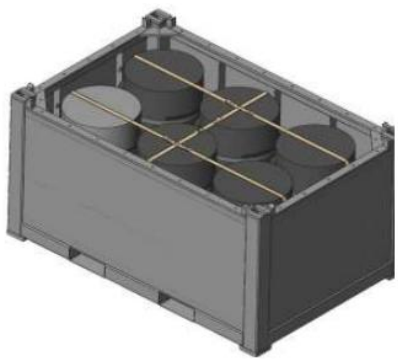

Figure 6. Diagrammatic representation of a CP-5.2 with 6 drums

The liquid radioactive waste packages (referred to as CC-440) include cylindrical stainless steel containers (the dimensions of which are shown in **Figure *7***) are placed in a steelwork frame (with the same external dimensions as the (3 above)CP-5.2 package) that can house up to 6 drums, of which each of the drums have a maximum mass of 1200 kg.

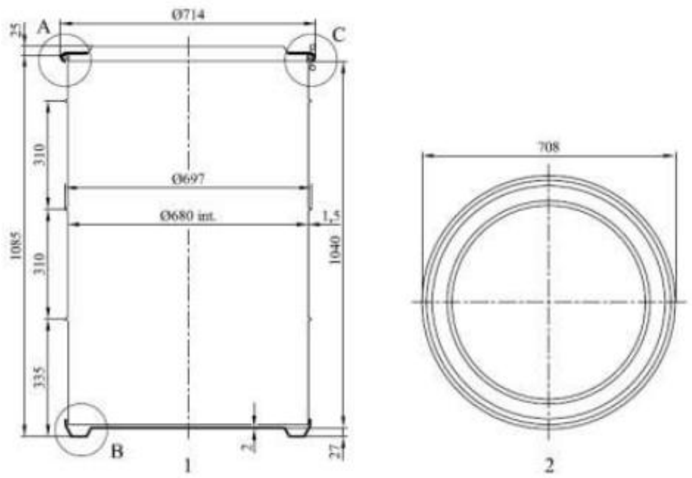

Figure 7. Diagrammatic Section and plant of CC-440 (UNI 11196) with the main dimensions in mm

The initial expected load on the ISF was estimated to be 2100 CP-5.2 packages. However, following deliberation of how to reduce the inventory, incineration of bituminised waste was selected as a viable option. As a result of this, the new expected load is estimated to be 1300 CP-5.2 packages and 171 frames of CC-440.

2.3.3. Authorisation and specific requirements

The Legislative Decree 230/95 (D.Lgs 230/95) was in force during the approval of the ISF. It has since been superseded by Legislative Decree 101/20 (D.Lgs 101/20). Notwithstanding this change, the requirements for the ISF were considered to be the same. Although it needed to, and proceeding future updates should, be checked carefully to adjust the authorisation if deemed necessary.

The authorities involved in authorisation are the:

- Ministry of the Environment and Energy Security
- Ministries of the Environment, Land and Sea Protection
- Ministry of the Interior
- Ministry of Labour and Social Policy
- Regional authority
- National Inspectorate for Nuclear Safety and Radiation Protection (ISIN)

Although it would have been possible to expand the SGRR authorisation to include the ISF, a decision was made to apply for a new and independent authorisation because it was considered easier to manage at the Ispra site.

While clearly defined and easily traceable agreements have been made with the Italian Government, there are some changes to circumstances which, if they occur, would result in the Italian Government being charged a fee for the JRC´s waste to be reconditioned.

The primary reason that could lead to the government being charged, as alluded to above, would be the WAC of the National Deposit Technologic Park (DNPT) not aligning with the JRC´s FWP characteristics for reasons such as:

- site specific characteristics,
- design of barriers,
- concentration and total amount of radioactive materials,
- global safety assessment,
- the authority´s approved conditions not covering the JRC FWP´s specifications.

The main prescriptions for the authorisation were mandatory inspections by the ISIN, such that:

- A design plan and program, with the list of documents to be produced, must be sent to the ISIN well in advance; these documents must be transmitted upon request, and made available on the site in any case, before the start of the related construction operations.
- Manufacturing and control plans relating to the construction phases, as well as the functional organisation of the storage for testing and operation purposes, must also be sent to ISIN.
- A planned test program must be sent to the ISIN, based on the results of which the storage operation can start, in compliance with any requirements that will be defined by the ISIN and communicated to the Ministry of Economic Development and to the other administrations.

2.3.3.1. Partial change of storage requirements and operations

As is referred to in **Section 2.3.2.2**, the process of incinerating bituminised waste was used to reduce the waste volume. As a result of this decision, a spare room in the ISF could be used to store VLLW. The VLLW was stored in 220 L steel drums that were stacked in four layers within a simple framework that holds 4 x 4 drums (see **Figure 8**). The act of incorporating the new VLLW storage solution divulged two new requirements which had to be accepted and authorised:

- The floor needed to be repainted with a new footprint because the dimensions of the 4 frames were different to the (3 above)CP-5.2 packages.
- A new safety report was prepared to extend the authorisation because VLLW does not need conditioning with cement.

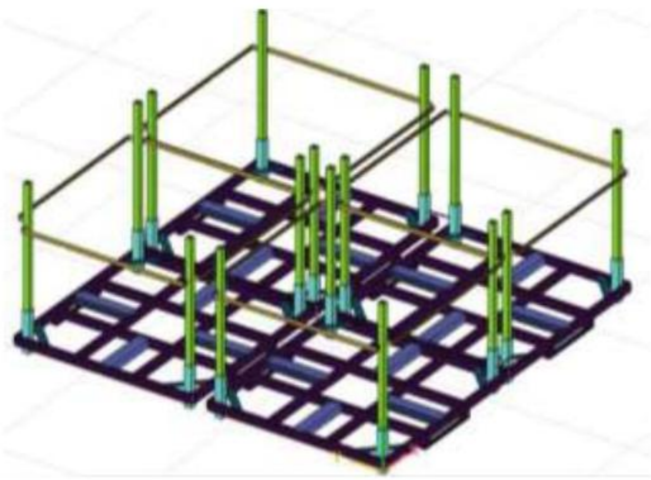

Figure 8. Computer generated model of the framework used to hold steel drums containing VLLW

The maximum permissible levels of activity concentration allowed for this waste category are 100 Bq/g (including a maximum of 10 Bq/g for long-lived alpha-emitting radionuclides).

2.3.3.2. New safety report for VLLW storage solution

The new safety report (referred to in the second bullet point in the above list in **Section 2.3.1.1**) analysed any variations with the previous documents. The main points of the analysis were that the:

- Radioactive inventory for each depot in the ISF, resulting from filling with unconditioned VLLW waste, is less than the corresponding radioactive inventory assumed in the ISF license.
- Quantity and type of waste in the single depot are compatible with the fire resistance class of the compartment itself.
- Effects of the accident scenarios of fires and falls comply with the radiation protection objectives and have been considered in tandem to the previous scenarios established.
- Effects on workers and the reference groups of the population are encompassed by the maximum accident hypothesised in the previous assessments, with respect to the maximum conceivable accident.

The process of accepting VLLW at the ISF did not change its structure and operational procedures, the extension was issued by the ISIN and all other authorities were notified of the new activity, as fixed by law.

2.3.3.3. Notable additional requirements

The ISIN asked the JRC to provide a few documents and to conduct some tests as a prerequisite preceding the commencement of storage operations at the ISF, in particular:

A system functional test schedule and procedures including uninterruptible power supply, fire detection and anti-intrusion systems. It is essential that the ability to alert the JRC´s emergency response service remains operative even with no electric power.

An extraordinary maintenance report was issued since small cracks had damaged the pavement adjacent to the ISF´s surface.

2.4. Construction of the ISF at the JRC Ispra site

The construction of the ISF was completed in two years and all works were carried out without any delays or significant problems. After the ISF was constructed, it was reclassified as a ¨controlled¨ area following the approval of the active test program and was separated from Area 40 by a fence.

2.4.1. Site preparation and foundation

To facilitate the construction of the ISF, the area of grass around Area 40 (**Figure 9**) was temporarily declassified from a ¨supervised¨ to a ¨free¨ area. The figure displays the development of the area during the construction of the ISF. Excavations were performed to even out the terrain and to construct the foundation. The resultant material was reused to create embankments on three sides of the building to provide shielding.

Figure 9. Timelapse of construction at Area 40 (left to right: before - temporary entrance in red - after)

Figure 10. View of removed foundation soil

The following constitute the ISF building´s foundation specification. Plan dimensions are 132 m x 44 m. A foundation consisting of a single reinforced 100 cm thick concrete slab was chosen. This was selected based on the geotechnical characterisation and simulated analyses carried out. The foundation was isolated from the underlying layer by 5 cm thick expanded cellular glass panels to insulate the building from the underlying ground from both thermal properties and humidity, thus providing protection against FWP corrosion and reducing humidification within the installation itself. The underlying layer in contact with the ground is made up of vibro-compacted gravel of 50 cm in thickness (as shown on the right in **Figure *11***). The foundation with a base for the prefabricated columns can be seen in **Figure 12**).

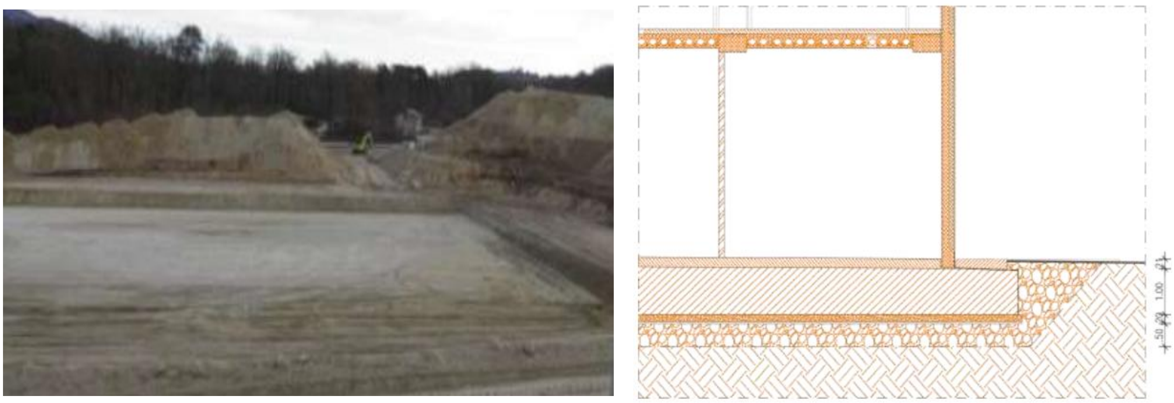

Figure 11. View of the foundation and schematic of the partial section

Figure 12. View of the foundation´s steel reinforcement

2.4.2. External structure

The building consists of a mixed structure of prefabricated and cast-on-site elements. The load-bearing framework of the building mainly consists of beams, columns and prefabricated floors / panels, all classified as REI 120 for fire resistance. There are two vertical structural joints affecting the elements in elevation at the walls that separate the loading and unloading area from the storage areas.

From a structural point of view, the building is therefore divided into three parts, arranged along the longitudinal axis, which can flex freely in the event of subsidence of the foundation soil. From the functional point of view, the three buildings house distinct functional areas: a central one for services and two lateral areas for the storage of packages (as shown in **Figure 13** and **Figure 14**).

Figure 13. Cross-section of the ISF at the corridor entrance with the main dimensions in metres

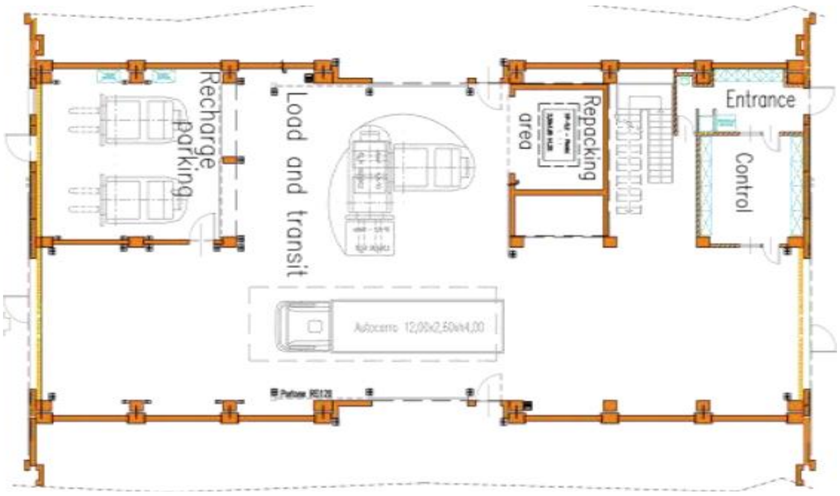

Figure 14. Layout of the plant in the main corridor

The perimeter walls were made with prefabricated reinforced concrete panels with an interposed insulating layer (the panels were anchored to the floor slab by means of stitching reinforcement). Such panels, in addition to the structural function, also have a shielding function. The roof slabs were made using prefabricated slabs in honeycomb concrete (hollow core), on which the 15 cm thick final casting was placed (this also provides a shielding function). A view of the floors and panels can be seen in **Figure 15**.

Figure 15. View of the floors and panels

A double pitch roof was used to protect the building from rainwater infiltration, considering its 50 years design life. The uppermost roof was made with metal panels on a metallic structure (see **Figure 16**) and the below roof was made with a waterproof membrane. Both rooves were provided with two pitches, an outward slope and two completely external water drainage systems. Rain is normally collected from the metal roof into the main drainage header via a buried pipe. In the event of a leak from the metal roof, the dripping water from the collector of the second membrane roof can be monitored since the pipe is cut 1 m from the ground (**Figure *17***); this allows for prompt intervention to make repairs etc.

Figure 16. The first metallic roof during construction

Figure 17. Details of rain drainage

2.4.3. Layout and equipment

The layout of the plant in the main corridor shown in **Figure 14** contains:

- a control room (above which there is a spare room and a small staircase to check the roof),
- a room with a body radiation monitor to confirm the absence of contamination of visitors,
- an emergency shower,
- two rooms to park and recharge the batteries of two electrical 20 tonne fork-lifts,
- a room to repack damaged (3 above)CP-5.2 packages.

Ventilation and humidity control was an important consideration. 20 cm thick reinforced concrete industrial flooring (protected with specialised paint), with a slope of 0.5% towards the outer longitudinal walls, was incorporated at the ISF. Any expansion/shrinkage joints are suitable for vehicles and are also waterproof.

The ISF was primarily designed without a ventilation system because of the low activities of the waste stored. Radioactive effluents or volatile contamination are not expected during operations due to this. The waste is solid in a steel packaging with a seal (this maintained a very small depression inside while the air-conditioning was installed).

The presence of water is forbidden inside the ISF. Therefore, the presence of water is monitored remotely, and a dehumidifier was employed to mitigate against condensation occurring. Furthermore, a vertical barrier of 10 cm was placed around the columns and along the walls to collect water in the unlikely event that it encroaches on the lowest parts of the ISF.

Water, generated by the system used to reduce and control the humidity inside the ISF, is collected by gravity in 4 vessels and placed at the corner of the storage rooms of Depot B and C (as shown in **Figure 18**).

Figure 18. Vessel to collect water from dehumidifier

The water level in the vessel is controlled remotely and the water can be transferred by an external operator to check the presence of radioactive materials before discharge: the same procedure followed for dirty water coming from the washbasin or water collectors on the floor. There are a few windows that can be closed to reduce the humidity variations and filth inside the ISF, and all emergency exits have a double door (see **Figure 19**).

Figure 19. Lateral view of the ISF

Surveillance systems were also integrated in the ISF such that:

- All cameras, radiation monitors, thermometers, humidity registers, fire control systems can be checked in the ISF´s control room and in the security office.
- It is possible to check the identification of packages with a bar code by using specialised software and a camera.
- The position of where a package is stored can be tracked since a central database records all radioactive sources and waste at the JRC Ispra site (WITS2).
- Loudspeakers are integrated at all nuclear buildings and across open areas situated on the JRC´s Ispra site (which ensures any workers or visitors can receive calls for normal operation or for emergency events, following specific procedures).

Handling systems and vehicles to manoeuvre containers, such as those which can been observed in **Figure *20*** and **Figure *21*** respectively, are used at the ISF. For example, a damaged container can be lifted via crane and placed inside a larger container to be stored in a different manner or transported outside. The electrical fork-lift has a digital control to stop it when an object is too close. As an inherent safety feature in the ISF´s design, the concrete columns are protected by anticollision beams to defend against lorry or fork-lift collisions (see **Figure *22***).

> Light maintenance was performed to repair small cracks that occurred on the final top layer of the ISF floor. The cracks were generated by different elastic movements with the foundation (where the columns are fixed).

All cracks were enlarged and filled with resin (see **Figure *23***), then the pavement was smoothed and repainted with specialised resin. Since the cracks were caused by a lack of expansion room between the pavement and the column´s beam, a small gap was created around the anticollision beam and column.

Figure 20. Crane used to lift CP-5.2 containers

Figure 21. Test handling of a CP-5.2 container using an electric fork-lift

Figure 22. Column anticollision beam

Figure 23. Process of crack enlargement at the ISF prior to being filled with resin

3. KEY TAKEAWAYS

Several notable best practices employed during the development of the ISF are listed below:

- From the functional point of view, the three buildings house distinct functional areas: a central one for services and two lateral areas for the storage of packages. This solution will reduce the handling time and radiation doses too.
- The agreement made with the Italian Government was key to receiving authorisation to build the ISF in a reasonable time. Advantages to this arrangement include:
    - All waste can be stored at the ISF if it complies with ISIN and SOGIN requirements (although WAC for final disposal do not exist yet).
    - The storage time is limited and at the end, when the DNPT is operational, all waste will be removed.
    - The long-term responsibility of the waste will be transferred to the Italian Government at a reasonable cost.
- The FWPs will still be transportable by road after the 50 year-long interim storage period.
- The ISF is a very low risk temporary storage facility, not a disposal facility, the latter or which is much more difficult to be accepted.

All authorities receive waste data as fixed by prescriptions in the ISF¨s authorisation, and the JRC will continue to inform stakeholders about the ISF´s activities.

3.1. Perceived benefits and applicability

Inherent safety

The ISF´s stringent safety and radiological criteria ensures that the public living around the site are very well protected and local authorities provide quick answers when permissions are requested. Moreover, inherent safety was built into the ISF´s design through the implementation of: anticollision beams adjacent to the concrete columns, remote monitoring of the presence of water and the use of a dehumidifier as a control measure.

Practical performance benefits

The ISF allows for the localisation of RAW that was decentralised across different facilities at the site. Also, local reuse of soil to make embankments on three sides of the ISF building avoided heavy transport outside of the Ispra site and local authorisations for environmental constraints.

Use of prefabricated components

The use of prefabrication, in addition to allowing shorter construction times and a less invasive construction site, improved quality standards of the building, thanks to the possibility of controlling the quality and homogeneity of materials and products manufactured in the factory, compared to the defined design requirements. Use of such components did not present any safety problems and tens of workers were involved in construction.

Applicability of knowledge to other stakeholders

The knowledge detailed in this document could inspire, inform and be applied by other decommissioning operators/contractors considering designing, constructing or operating an ISF containing only LLW in solid form in prismatic or cylindrical containers for no more than 50 years. In addition to this, it would be useful to those among said entities who simply would like to learn more about what the process entails or would like to compare it against their own processes.

3.2. Lessons learnt

Rebound benefits

The market conditions changed, and the incineration of bituminised waste was determined to be a way to reduce the storage inventory; this decision was taken considering the functional benefits and the spare room that housed the bituminised waste was used to store VLLW. Furthermore, adding expansion room between the pavement and the pillar should be factored into the anticollision beams´ inherent design in the future. This feature would have avoided maintenance work on the cracks that appeared on the ISF´s pavement.

Deliberation before initiation

The first study which investigated different ways to design, build, operate and decommission the ISF was time consuming but ultimately resulted in both economic and operational gains.

Waste acceptance limitations

Only waste generated at the JRC´s Ispra site can be stored in the ISF since the procedure to host ¨foreign waste¨ is rather complex and has not been adopted in Italy. A WAC for disposal also does not exist currently. However, an agreement has been made which means any future FWPs that do not satisfy the WACs can be accepted subject to financial arrangements related to reconditioning etc.

Stakeholder engagement

The exchange of experience with other operators of similar national and international facilities was essential. In addition to this, several informative meetings were held with local authorities and the public were invited to ¨open days¨ at the JRC´s Ispra site to foster good-will and dispel any misunderstandings about the assured safety of radioactive waste management storage solutions. All of which helped the case for authorisation and mitigated against threats.