



FINAL WASTE PACKAGE (FWP)

Case Study at JRC Ispra Site

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



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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

Final Waste Package (FWP)

Document code	KP-JRC-014
Performed by	Mattia Visca
Revised by	Nuclear Decommissioning Knowledge Management Team
Version	V1 09/04/2025
Sent to	Andrea Piagentini
Approved by	Andrea Piagentini



EXECUTIVE SUMMARY



Overview

Management of Final Waste Packages (FWP)

An overview of the strategies and standards applied at JRC Ispra to manage FWP.

[+ INFO](#)

Objective

Share Project Experience

The goal of sharing JRC's qualification process and lessons learned for safe and compliant waste packaging

[+ INFO](#)

Target Users

EU Operators

Identifying the main audience who can benefit from this experience in waste packaging and regulatory alignment

[+ INFO](#)

Approach

Navigate the process

A step-by-step look at how JRC is qualifying the CP-5.2 container, from selection to final conditioning

[+ INFO](#)

Use

Practical guidance

How this experience can support other operators in choosing and qualifying waste packages for safe transport and disposal

[+ INFO](#)

Value

Applicable lessons learned

Key insights and practical takeaways from JRC's work to guide similar efforts across the nuclear decommissioning community

[+ INFO](#)



Use

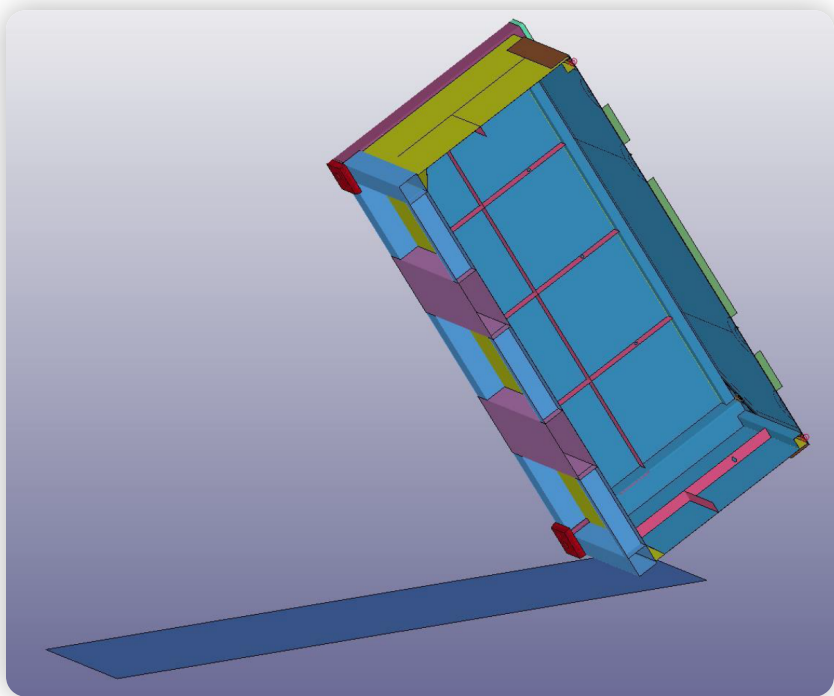


This resource offers applicable guidance on:

- Conditioning radioactive waste using concrete matrices.
- Selecting packages according to national standardization (e.g., CP-5.2).
- Applying lessons from international repository systems and acceptance criteria.
- Reducing dose to workers and cutting costs through alternative packaging of large components.
- Meeting requirements for long-term storage, transport on public roads, and future disposal at national repositories.



Objective



The objective of this Knowledge Product is to document and share the qualification process, technical procedures, and strategic decisions involved in creating compliant FWPs for radioactive waste at the JRC Ispra site. It offers insights into the use of the CP-5.2 prismatic container, including its compliance with geometrical and structural criteria, conditioning methods, and long-term storage strategies, to enhance alignment with national and EU-level waste management goals.



Target Users

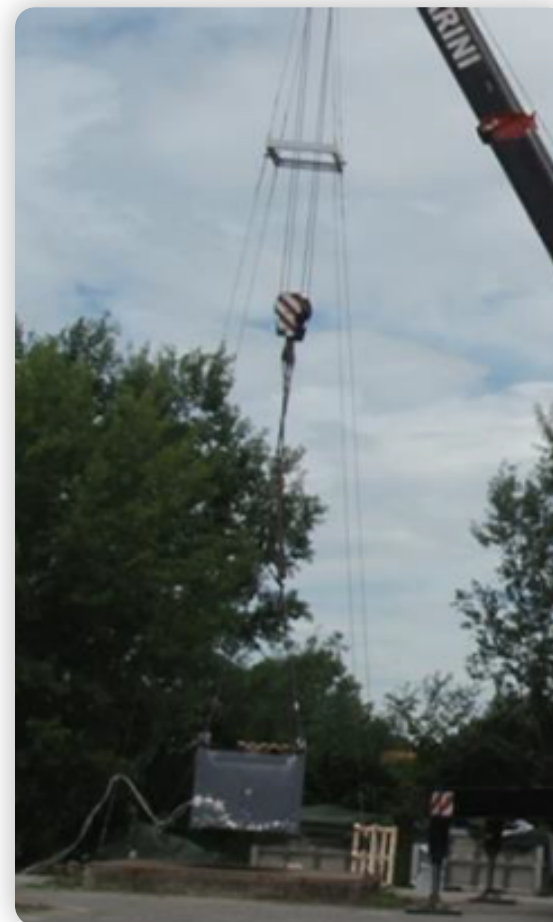


This product is intended for nuclear decommissioning operators, waste management authorities, safety regulators, and other stakeholders involved in radioactive waste treatment and storage. Special focus is given to those navigating the transition to final repositories within evolving national frameworks and who may benefit from standardization efforts like those led by ISIN, SOGIN, and the IAEA

By examining JRC's approach to final waste packaging, other institutions can learn:

- The CP-5.2 container size had to comply with regulatory standards, limiting JRC's ability to optimize internal volume.
- When using 220-liter drums, the usable volume is reduced to 1.32 m³ due to concrete thickness and structural requirements.
- JRC shifted to incinerating bituminized drums to reduce waste volume and improve packaging efficiency.
- Even with the new strategy, the average usable volume of CP-5.2 is around 2 m³—less than 50% of its total capacity.
- Final design has clarified construction costs, allowing better evaluation of future waste treatment options.
- The qualification process was completed on time and to standard, despite multiple suppliers being involved.
- The Calliope plant was excluded due to limited experience in handling ionizing radiation environments.

Value





Overview



This document presents how the Joint Research Centre (JRC) Ispra site is qualifying Final Waste Packages (FWP) in compliance with Italian and international standards. It focuses on the CP-5.2 prismatic container, used for conditioning solid low-level radioactive waste (LLW) in a concrete matrix. Developed in a national and European context, this effort aligns with ongoing regulatory evolution, the pending Italian national repository, and harmonization with practices in other EU countries (e.g., Konrad, El Cabril, Centre de l'Aube). The qualification ensures compliance with UNI standards, IAEA recommendations, and Technical Guide n. 26 by ISIN.



Approach



This case study follows JRC's practical implementation of the CP-5.2 container for conditioning LLW at Ispra. It details the grouting process, selection of packaging geometry, and compliance verification through testing.

An interactive format with step-by-step modules and multimedia materials such as images and tables supports a better understanding of waste packaging qualification.

The documentation also includes strategies to deal with oversized or non-standard components, referencing international practices and recent regulatory updates.

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



1



**THE FINAL
WASTE
PACKAGE**



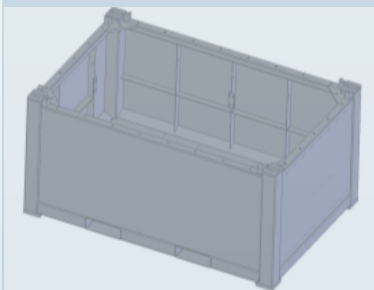
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**DECOMMISSIONIN
G STATUS AT JRC
ISPRA SITE**



3



**DEVELOPMENT
OF the FINAL
WASTE
PACKAGE**



4



**FUTURE
DEVELOPMENT
AND
CONCLUSIONS**





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THE FINAL WASTE PACKAGE

A brief description of the Final Waste Package (FWP) and its use in the storage and transport of radioactive waste

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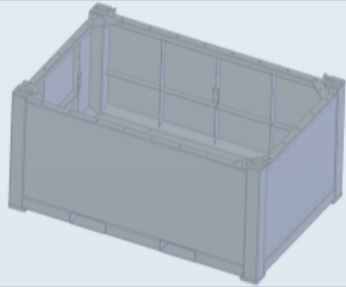
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DECOMMISSIONING STATUS AT JRC ISPRA SITE

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DEVELOPMENT OF the FINAL WASTE PACKAGE

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FUTURE DEVELOPMENT AND CONCLUSIONS

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**THE FINAL
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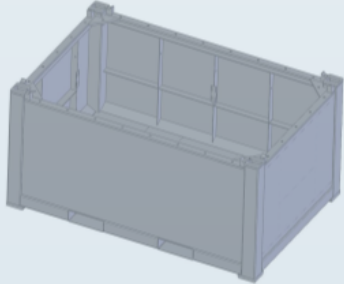


**DECOMMISSIONING
STATUS AT JRC
ISPRA SITE**

Decommissioning
status at JRC Ispra
site, including
responsibilities,
activities, and
project structure
for managing
nuclear facilities

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3



**DEVELOPMENT
OF the FINAL
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**FUTURE
DEVELOPMENT
AND
CONCLUSIONS**

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**THE FINAL
WASTE
PACKAGE**

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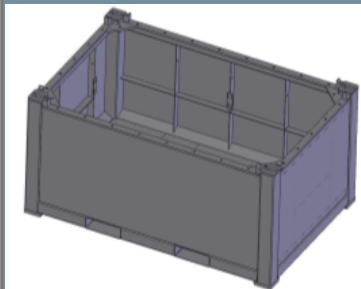
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**DECOMMISSIONING
STATUS AT JRC
ISPRA SITE**

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**DEVELOPMENT
OF the FINAL
WASTE
PACKAGE**

Description and
analysis of the
final waste
package CP-5.2
and its
capabilities

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**FUTURE
DEVELOPMENT
AND
CONCLUSIONS**

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CONTENTS

1



**THE FINAL
WASTE
PACKAGE**

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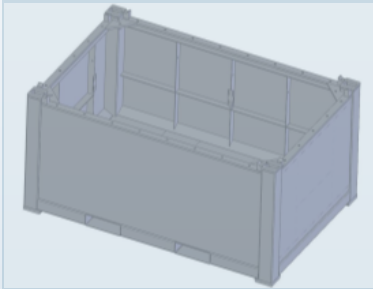
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**DECOMMISSIONIN
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ISPRA SITE**

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**DEVELOPMENT
OF the FINAL
WASTE
PACKAGE**

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**FUTURE
DEVELOPMENT
AND
CONCLUSIONS**

Future
development and
conclusions of
CP-5.2 packaging

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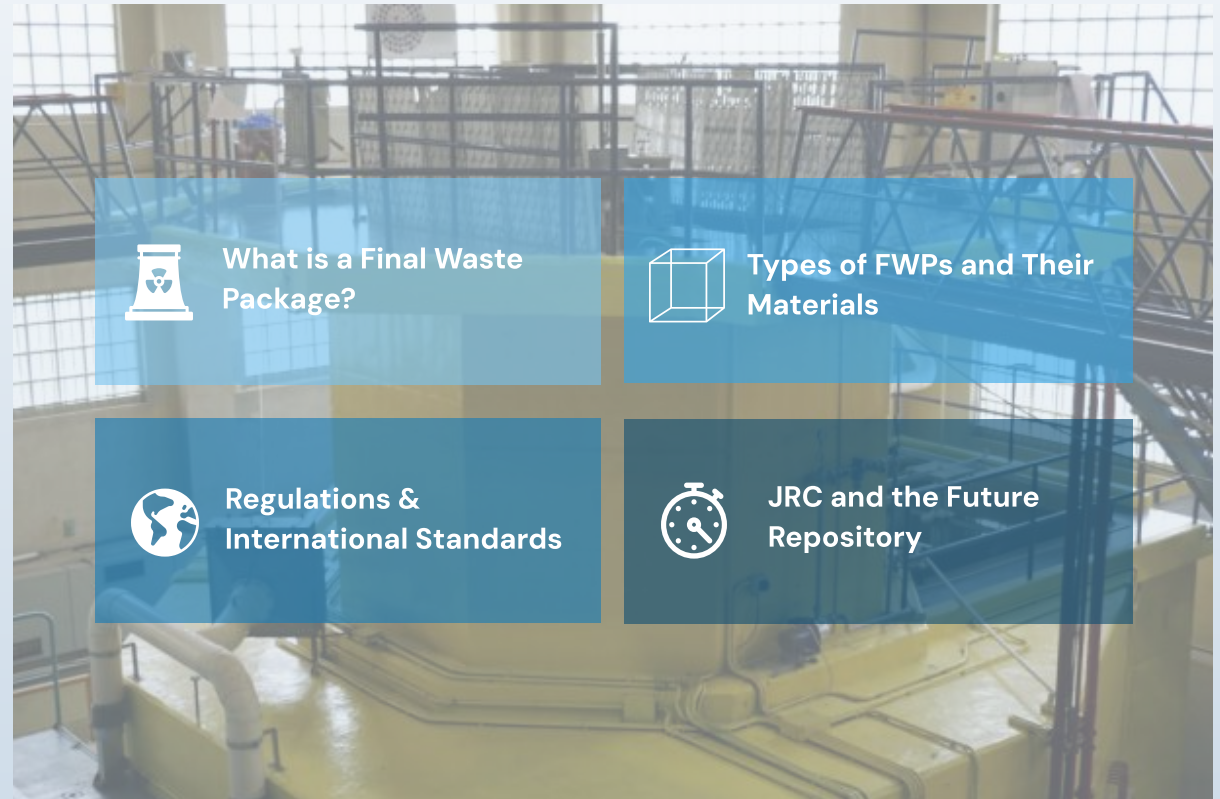


THE FINAL WASTE PACKAGE

Introduction

When a nuclear facility is dismantled, one of the key challenges is managing the radioactive waste safely. The Final Waste Package (FWP) is the last step in this process. These specially designed packages hold solid radioactive waste, ensuring that it can be safely transported, stored, and ultimately disposed of in a final repository.

FWPs are used worldwide, with different designs depending on national regulations and the characteristics of the waste. Countries like Germany, France, and Spain have well-established repositories that accept different types of FWPs. However, in Italy, the final repository is yet to be decided, which influences how waste is packaged and managed.



What is a Final Waste Package?



Types of FWPs and Their Materials



Regulations & International Standards



JRC and the Future Repository

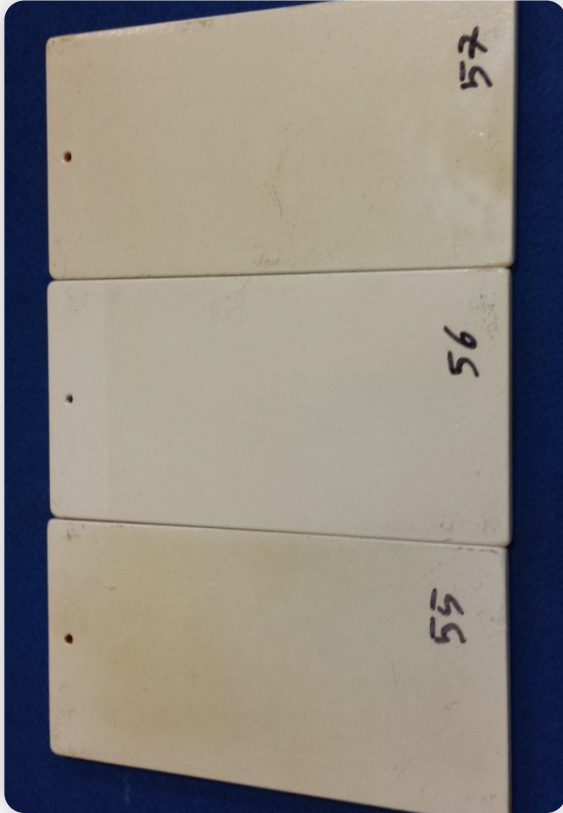


JRC and the Future Repository

Italy is preparing for a future national radioactive waste repository by standardizing waste packaging through the UNI 11196 norm, which defines cylindrical and prismatic container types.

The Joint Research Centre (JRC) is qualifying a CP-5.2 concrete container for conditioning low-level radioactive waste (LLW) at the Ispra site. Compliance with ISIN and SOGIN requirements is essential for acceptance at the repository.

Although the final location is still pending, Italy is aligning its approach with international standards to ensure safe and efficient waste management.



Regulations & International Standards

FWPs must comply with both national and international regulations. Key references include:

- IAEA GSG-1 – Defines global radioactive waste classification.
- UNI 11196 (Italy) – Standardizes container dimensions.
- ISIN Technical Guide 26 – Sets conditioning requirements for LLW.
- IAEA Transport Regulations – Introduced Surface Contaminated Object – Type 3, allowing large nuclear components (e.g., reactor vessels) to be transported without additional packaging.



What is a Final Waste Package?

The Final Waste Package (FWP) is a solid radioactive waste container designed for:

- ✓ Transport on public roads.
- ✓ Long-term storage before disposal.
- ✓ Final disposal in a national repository.

Types of FWPs and Their Materials

FWPs come in different shapes, sizes, and materials to suit different waste types. The EPRI document on low-level waste storage lists FWPs with volumes ranging from 200 to 3,000 liters, made from:

- ✓ Concrete; Provides radiation shielding.
- ✓ Cast Iron; Strong and durable.
- ✓ Steel / Stainless Steel; Corrosion-resistant

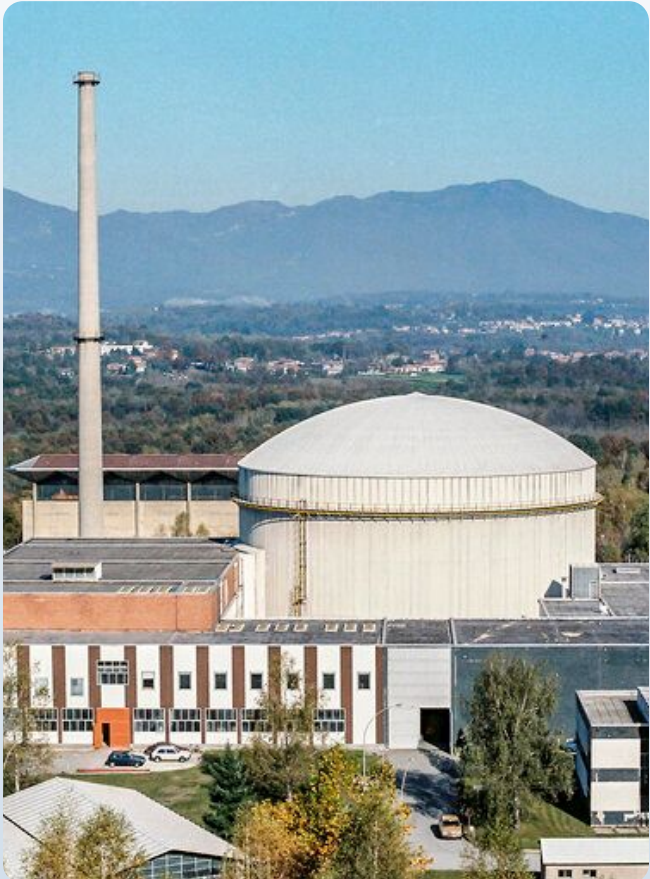


In Italy, standard FWPs (as per UNI 11196) include:

- **Cylindrical drums** (220 L, 440 L, 500 L).
- **Prismatic containers** (2.6 m³, 5.2 m³).



DECOMMISSIONING STATUS



JRC Radioactive Waste Management

The Joint Research Centre (**JRC**) in Ispra has a long history of nuclear activities, including research reactors and nuclear facilities. Over the years, these facilities generated radioactive waste, much of which is still awaiting final disposal.

+ INFO

Organization

The Nuclear Decommissioning and Waste Management Department (**NDWMD**) is responsible for the decommissioning of all nuclear installations at the site.

However, there is a distinction between the two main reactors:

- **ESSOR Reactor**; Fully managed by NDWMD
- **ISPRA 1 Reactor**; Waste must be treated and temporarily stored, while the decommissioning itself is handled by SOGIN, the Italian company responsible for nuclear decommissioning

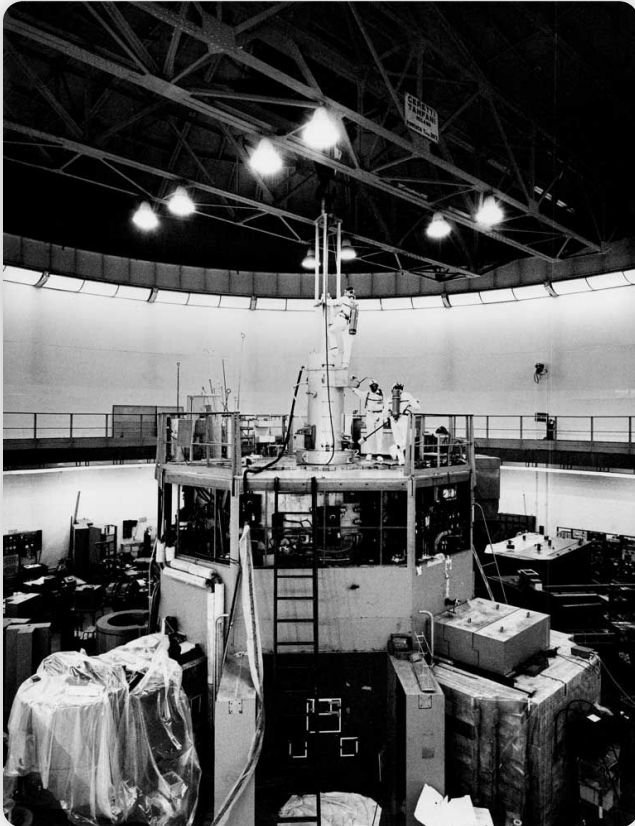
Since both reactors are being decommissioned at the same site, there is a need for strong coordination between NDWMD and SOGIN, ensuring compliance with strict safety regulations.





Ispra-1 Reactor

The ESSOR Reactor is a heavy water moderated and cooled nuclear reactor. It started its operation in 1969 and was put in shut down safety condition in 1983. INE Complex is one the facility involved in the nuclear decommissioning programme of the JRC Ispra site. Nowadays in the INE Complex there are many facilities and laboratories used for researches and for safe conserving the still present nuclear material: e.g. the fuel pond structure, hot cells, laboratories (ADECO, ATFI, PERLA, etc.) and other auxiliary buildings.



Ispra-1 Reactor

Ispra-1 is a 5 MW research reactor, the latest version of the Chicago-Pile 5 series developed by Enrico Fermi, built by the National Nuclear Research Council - then CNEN, and finally ENEA - between 1957 and 1958. Becoming operational in 1959 and used until 1973, it was the first Italian research nuclear reactor. With the establishment of the European Atomic Energy Community (CEEA) in 1957, the Ispra Nuclear Studies Center was sold by Italy, for a period of 90 years, to the same CEEA in 1959, while the Ispra-1 was entrusted to the management of EURATOM starting from 1st March 1963. The reactor was used for studies and research on core physics, new materials for the construction of commercial reactors, neutron fluxes and their interactions with living matter, and played a role in the formation of a new generation of technicians for European and Italian nuclear programs.



Project Families

PF-01: Facilities realisation

PF-02: Waste management

PF-03: Nuclear materials management

PF-04: Decommissioning

PF-05: D&WM general support

PF-06: Repository

PF-07: Italian liabilities

PF-08: Safe conservation & utility Services

PF-09: Radiation Protection

PF-10: Site laboratories

PF-11: Horizontal activities

Work Breakdown Structure

To efficiently manage decommissioning, JRC has implemented a Work Breakdown Structure (**WBS**), organizing the work into 11 Project Families, each focusing on a specific area.

Since decommissioning is a dynamic process, the WBS is continuously updated, with some projects being revised, renamed, or merged over time.



DECOMMISSIONING STATUS



Type of waste

Old waste to be packed in CP-5.2 containers



Foreseen Waste

Foreseen radioactive waste from decommissioning



Historical Radioactive Waste

In more than 50 years of nuclear activity, bituminous and cemented radioactive waste have been produced at the Ispra site and, following old authorizations, sometimes buried.

This practice is no longer acceptable today; therefore, such waste must be recovered from the soil, although no soil or water contamination has ever been found in the proximity of waste (the area is subject to periodic checks, as required by strict procedures).

KEY FACTS ABOUT OLD
RADIOACTIVE WASTE



Old waste to be packed in CP-5.2 containers

Type of old waste	Quantity m3
Metallic	20,1
Technological	151
Specific	46,6
Mixed	20,2
Undefined	45,3
Process	77,8
Derived from bitumized waste (40% of reduction)	558,6
Total estimated	919,6



Foreseen Radioactive Waste from Decommissioning

The dismantling of nuclear facilities at JRC Ispra will generate significant amounts of additional waste. The facilities undergoing decommissioning include:

INE – reactor ESSOR + Pulsed Neutron facility
Tank Farm – liquid waste treatment and storage
Hot Laboratory for research and study
Cyclotron
ISPRA 1 reactor
Waste treatment facility
Interim storage facility

Before decommissioning begins, all facilities undergo a radiological characterization process, which identifies contamination and activation levels. This data helps to predict waste generation and ensures compliance with environmental regulations.

The following table shows the LLW generated in the future decommissioning activities:

Type of old waste	Quantity m3
Metallic	680
Concrete	658
Electrical-Plastic	251
Total estimated	1589



In the last 20 years, waste has been stored without conditioning in metallic drums with detailed radiological characterization.



Only LLW will be considered in this document, although the amount of VLLW is more significant as it is for clearable materials too.



Due to a large amount of buried waste with approximate and/or old radiological characterization, only the total amount of LLW generated in past activity can be estimated.

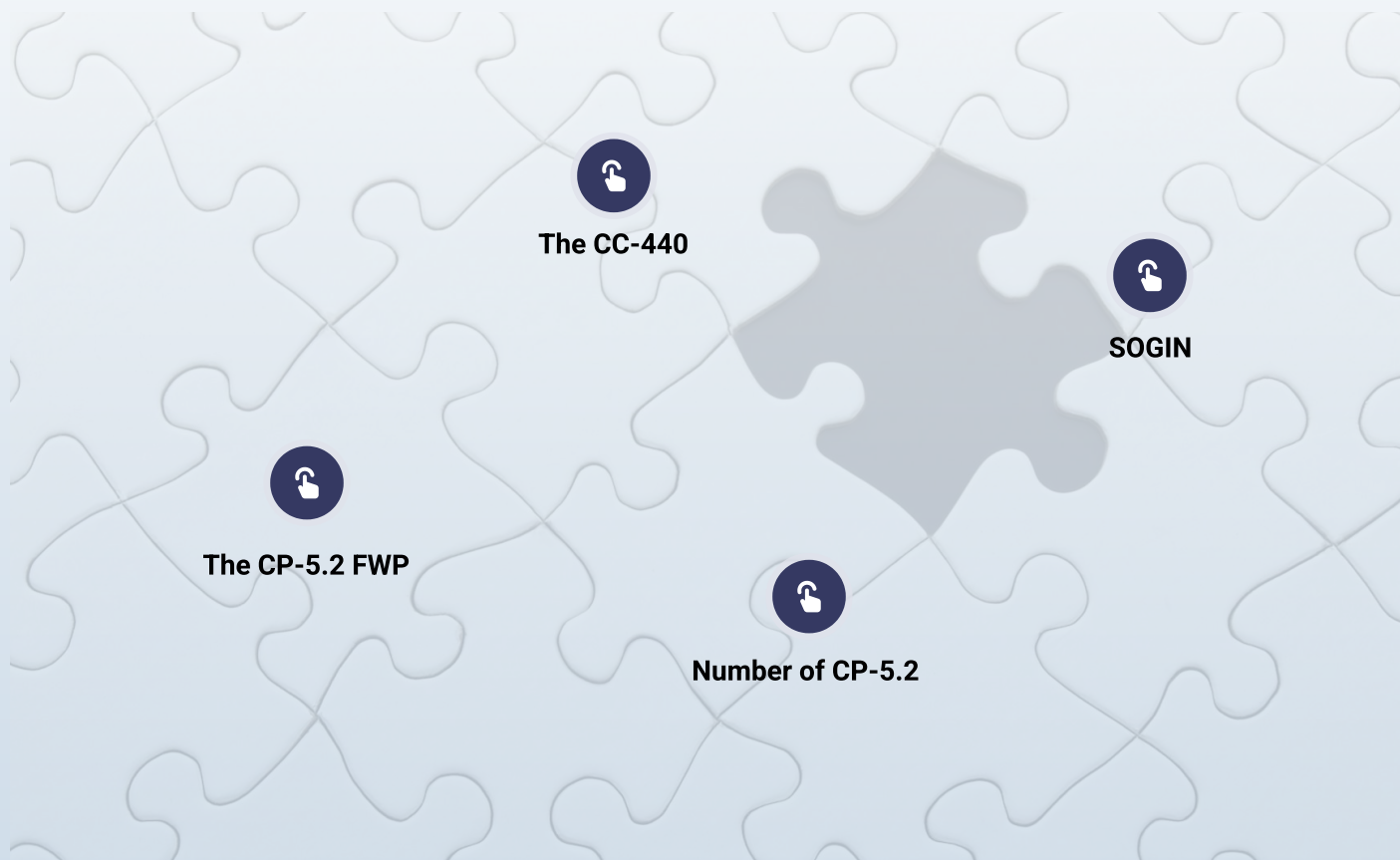


DECOMMISSIONING STATUS

Final Waste Package

All solid LLW listed in the previous paragraph will be conditioned in FWP CP-5.2 and stored at ISF. Other LLW can be prepared in CC-440 or CC-500 by a contractor capable of supplying the container and the conditioning service, on-site or off-site, depending on the authorization process and cost and timing aspects.

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





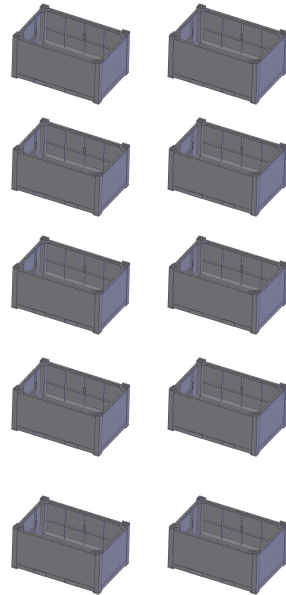
SOGIN, the Italian public company responsible for decommissioning Italian nuclear plants and facilities, has qualified for a similar type of CP-5.2 package.



The CC-440

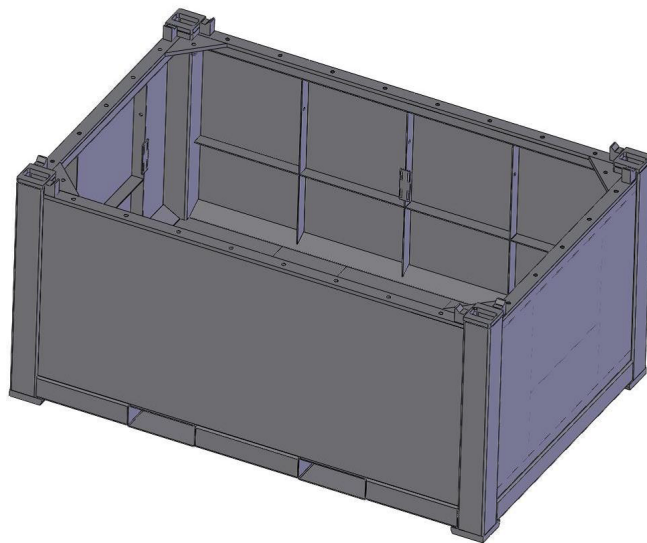
The CC-440, a cylinder-shaped packaging with 440 l capacity and a maximum gross mass of 800 kg, will be used to solidify liquid waste.

The contractor is responsible for qualifying the package; thus, this type of package is not reported in this document.



Number of CP-5.2

Based on the total volume of waste listed before, the number of CP-5,2 necessary to decommission all nuclear facilities at the Ispra site has been estimated at 1.300 items, which is estimated to decrease if possible.



The CP-5.2 FWP

The CP-5.2 FWP, with an internal volume of 5,2 m³ and a maximum total gross mass of 15 t, will contain solid radioactive waste conditioned with concrete in a new grouting station (currently under construction) placed inside the SGRR, representing a “home-made” FWP, qualified to be used under the current authorization



DECOMMISSIONING STATUS

Strategy to Produce Final Waste Package



Main interface
with other
projects



Laws,
authorisations,
isn technical
guides, and uni
standards



Uncertainties of
requirements



Agreement
with the
italian
government





UNCERTAINTIES OF REQUIREMENTS

The FWP described in this document will have to face two main constraints. First of all, specific approval is required by SGRR to treat any different stream of waste and compliance with the WAC of the Italian national repository, which is still open where it is placed.

The first constraints can be satisfied only when the grouting station is operational in a few years, looking carefully at the stream waste to check the compatibility whit container and concrete.

The license for DNPT, containing the WAC, is far away, but it does not matter if the process is authorized by ISIN and agreed upon by SOGIN.

Laws, authorisations, ISN technical guides, and UNI standards

The use of Final Waste Packages (FWP) in Italy must comply with national laws based on international practices, categorizing conditioned radioactive waste for surface or geological repositories. Nuclear activities are authorized by MASE with input from various local and central authorities, requiring strict adherence to authorization prescriptions. While most requirements are technical, some involve lengthy approval processes, creating uncertainties that impact operations and decommissioning.

Italian nuclear law mandates that ISIN issues Technical Guides to implement legal requirements. Specific guides exist for waste storage, disposal, and decommissioning, including an update to Technical Guide No. 26 on radioactive waste management. While this guide does not define a single conditioning material, it effectively limits choices to concrete and glass (for high-level waste). The updated Technical Guide No. 33 incorporates UNI standards, which establish norms for FWP dimensions, characteristics, packing, and labeling. Although UNI norms have the lowest legal enforcement in the nuclear sector, they have played a crucial role in defining FWPs.

LLW Italian
activity limits

UNI 11193
qualification test



AGREEMENT WITH THE ITALIAN GOVERNMENT

The reason to have a FWP with no WAC for the repository is based on the agreement signed by JRC with the Italian Government. This agreement, ratified by a law, foresees that a FWP, agreed by ISIN and SOGIN, will be accepted by Italian Government in any case since is covered by a sort of insurance.



Main interface with other projects

An FWP can be completed when packaging CP-5.2 is available and solid radioactive waste is ready for grouting. The grouting station, operational with radiation protection personnel, is located where all waste is managed. This includes waste in metal drums or concrete cylinders that must be removed and conditioned for the final repository.

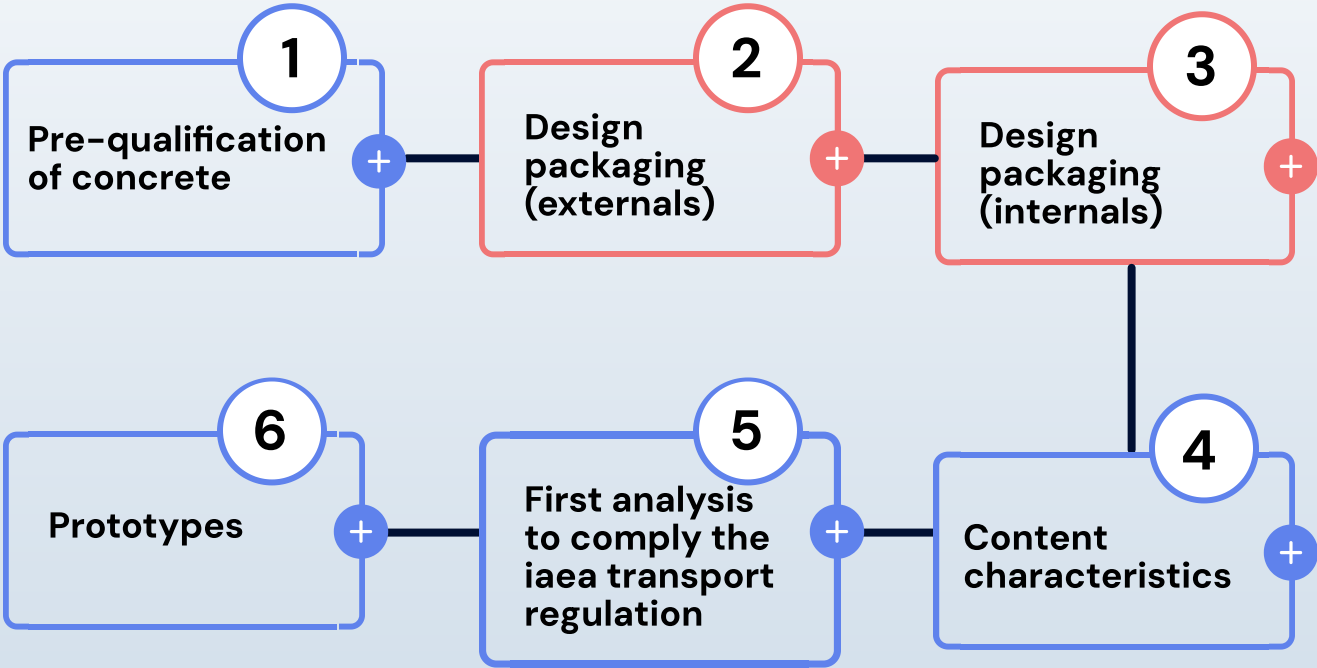
Since a contractor will handle packaging in small batches and other operations are performed at the JRC site with external contractors, coordinating activities and avoiding interferences is essential. The movement of materials, vehicles, and personnel in this controlled area is complex and requires proper coordination.



DEVELOPMENT OF FWP CP-5.2

Basic Design and Prototypes

The design and development of the FWP (Full Waste Package) required a meticulous approach to ensure the suitability and safety of the materials used.



CONTENT CHARACTERISTICS

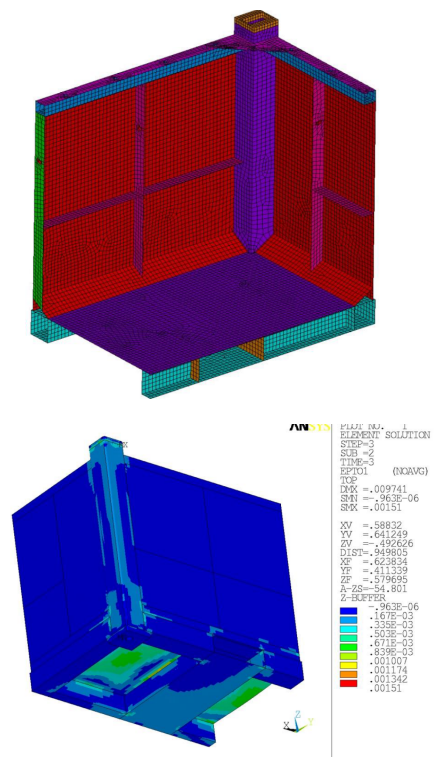
The content of FWP can be radioactive waste in metallic, concrete, plastic or technological in super compacted drums form, with radionuclides below the limits for LLW and LSA-III as partially shown in the table.

Waste type	Co60 Bq/container	Cs137 Bq/container
Metallic (Existing Waste)	6,09E+08	3,55E+10
Technological (Existing Waste)	5,73E+06	3,40E+08
Metallic (Decom. Waste)	6,09E+08	3,56E+10
Technological (Decom. Waste)	5,80E+06	3,45E+08

The maximum total mass of a FWP is 15 t and 5 cm of concrete and 5 mm of steel is the minimum of shielding thickness around the waste.

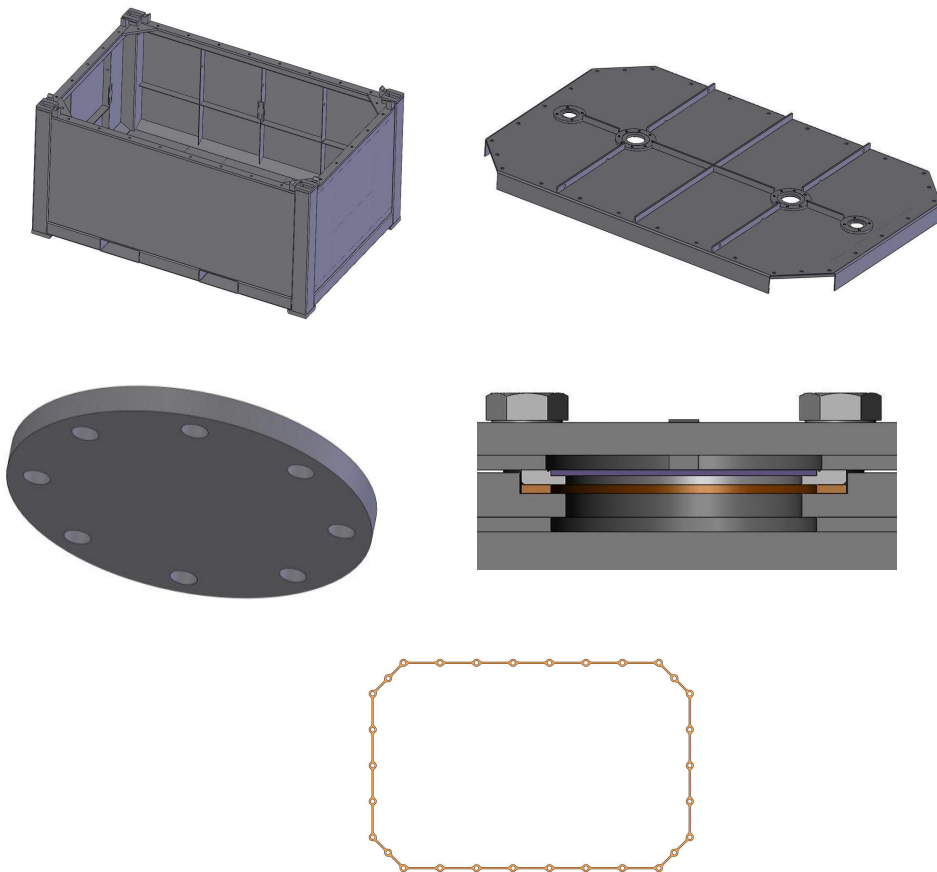
The radiation level on the surface of a FWP will be below the transport limits of 2 mSv/h and will satisfy the limits for the ISF. The maximum radiation level at the surface is 0,54 mSv/h and for 50% will be less than 10 µSv/h. The maximum value of 0,54 mSv/h was calculated as usual with a conservative method and 4 years ago, so it is probable that the real value will be much less.

When the ISF will be full of FWP it is guaranteed that radiation doses for people present around the facility will be below 10 µSv/y which is defined as no significant radiation exposure, while the average exposure for Italian people is higher than 2 mSv/y due to natural radioactive materials and cosmic radiation.



FIRST ANALYSIS TO COMPLY THE IAEA TRANSPORT REGULATION

The hydrostatic pressure of concrete is analyzed to check the wall's elastic deformation during grouting. For the staking test with a load equal to 5 times 15t, as required by the IAEA, the FEM model was reduced to ¼ due to the symmetry of the package. The figures show that the maximum elastic deformation occurs at the bottom of the FWP due to liquid concrete pressure.



DESIGN PACKAGING (EXTERNALS)

The body and lid in steel S235 JR are assembled with rolled section, flat and bent sheet (minimum 5 mm thickness) joined by welding. The external dimensions are 2500mm x 1650mm x 1250 mm with a total mass of 995 kg plus 350 kg, and an internal volume of 4 m³. 4 lifting twist-locks are welded on the upper corners, while two inferior cavities allow the use of a fork-lift. Several bolts are used to tight the lid, blind flanges and filters made with stainless steel. A paint covers all the components.



PRE-QUALIFICATION OF CONCRETE

Before starting with the design of FWP, it was decided to qualify two types of concrete. Different recipes of concrete have been tested for compression strength, fluidity, shrinking, and residual water: at the end, two recipes have been chosen. With the characteristics of a suitable concrete and a commercial steel it was possible to start the design of FWP.

The following table shows the characteristics and concrete recipe variations.

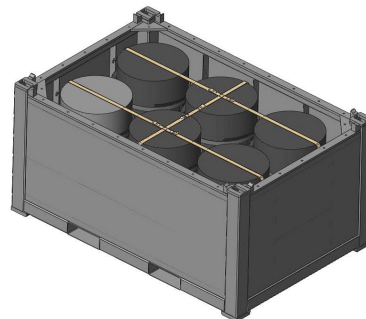
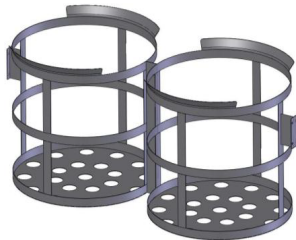
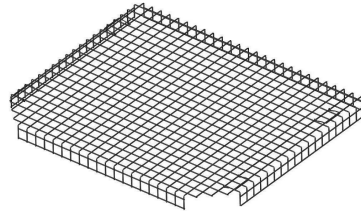
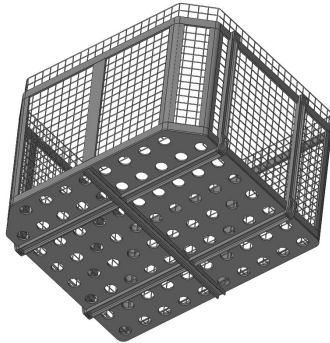
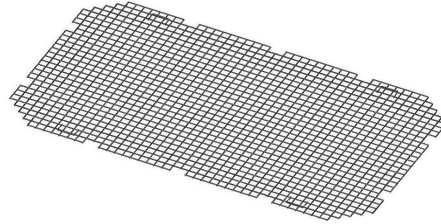
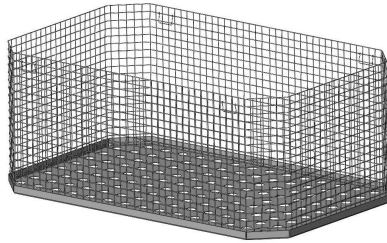
Property	Mix 131 (Mix 169 [11])	Mix 141 (Mix 170 [11])
Density (kg/m3)	2250	2215
Water/Cement	0,48	0,52
Inert/Cement	3	3
Fluidity at 2h (Marsh cone Ø 1,2cm)	100s	95s
Curing time start/end	15h30' / 22h	7h / 13h15'
Excess water	3,4%	1,7%
Compression strength 7d / 28 d	32/50 MPa	34/43 MPa
Hygrometric shrinkage 28d with film coating (µm/m)	< 100	<100



PROTOTYPES

Two full scale CP-5.2 packagings have been built. The two prototypes to be tested have been filled with inactive material and Mix 169 concrete. The grouting station, when operating at JRC, will compact the concrete poured through the two flanges on top of lid by vibration on the entire package, while in the prototype the concrete was poured without the lid and compacted with a hand mobile vibrator as a first phase.

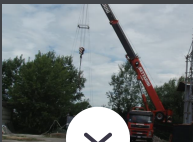
In the second phase, the lid was installed and the concrete was poured through the two flanges to fill completely the inside volume. The same procedure was applied for the prototype n. 004 and so, at the end of curing time, the n. 001 had a mass 11.190 kg and n. 004 equal to 9.070 kg.



DESIGN PACKAGING (INTERNALS)

The radioactive waste is shielded with 5 cm of concrete to avoid contact with the metal body; internal components are therefore necessary to isolate the waste, as well as other small components necessary to prevent the light material from floating on the concrete.

The following figures show the CP-5.2 internals for different configurations made with steel S235 JR to pack loosen items, preload items and drums. The free room for waste is 2 m³ while the external volume is 5,2 m³.

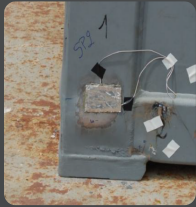


Accelerometer on concrete

DEVELOPMENT OF FWP CP-5.2

Prototype Test for Transport

The prototype No. 004 was dropped from a height of 60 cm in a flat position to qualify the numerical FEM analysis. Before the drop test, two accelerometers were installed on the concrete mass and on the flange. The lifting attachment was modified to perform the drop test; this variation does not change the mechanical characteristics of the FWP, and it is impossible to use a twist-lock system. Strain gauges were fixed on a column (one pair) close to the foot and on the vertical wall of the body to measure deformation in two orthogonal directions. A hydraulic drop device was inserted between the mobile crane hook and the prototype lifting system to free the load.



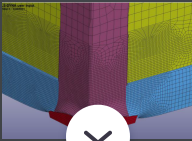
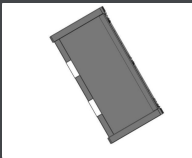
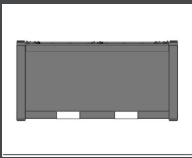
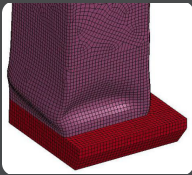
Deformation on foot 1

DEVELOPMENT OF FWP CP-5.2

Prototype Test for Transport

The drop test has deformed only the structure close to the bottom of the prototype in similar way due to the flat drop conditions as shown on the images.

The same prototype was used for the penetration test just to complete the IAEA requirements: the damage was negligible.



Full scale test

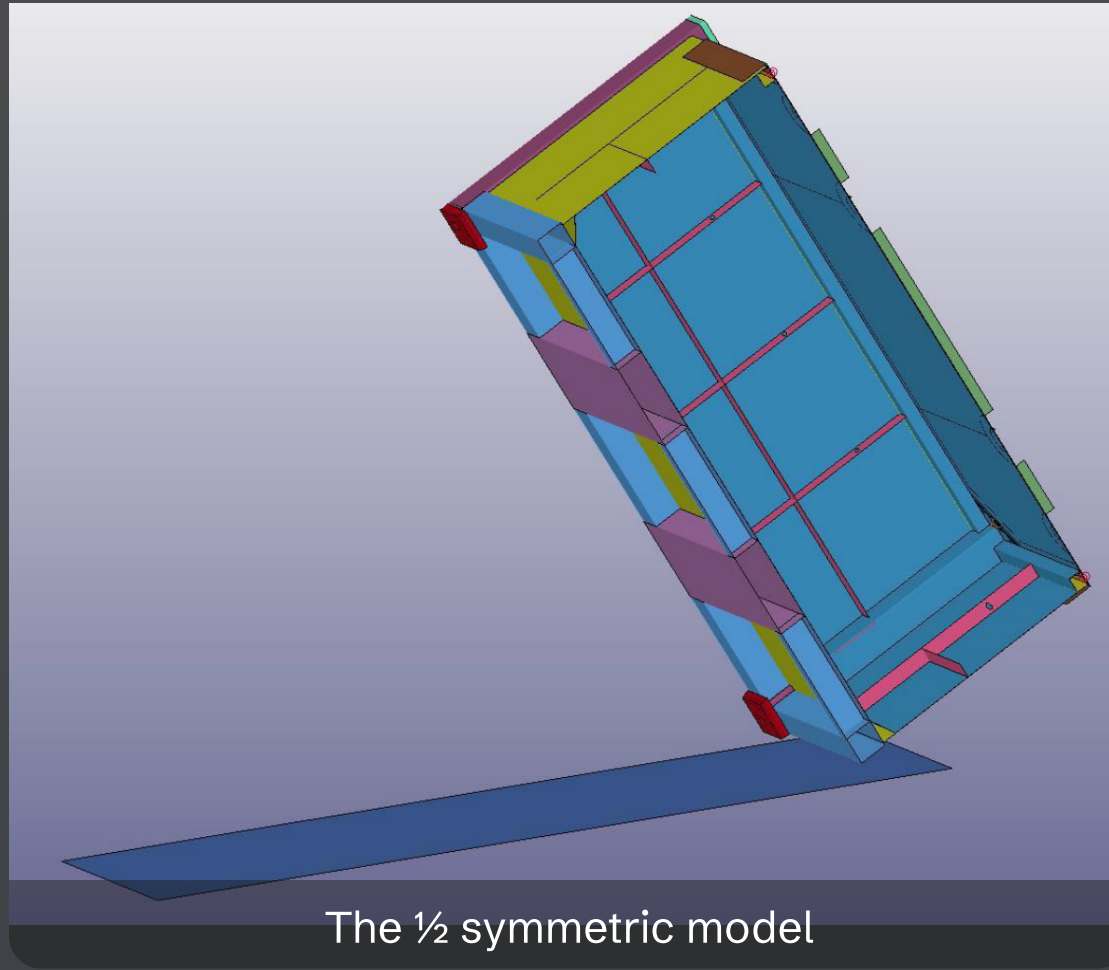
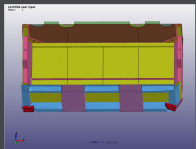
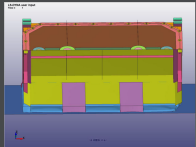
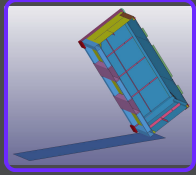
DEVELOPMENT OF FWP CP-5.2

Final analysis to comply the IAEA transport regulation

The measured values of crash acceleration and deformation during the drop test with the full scale prototype have been used to set the main parameters of FEM analysis.

With all well qualified data two drops have been analysed.

The drop height was 60 cm from the bottom to the unyielding target in both case and the total mass of 15.000 kg, the design mass. The edge drop was followed by the secondary drop on the bottom side. The flat drop test analysed with FEM has resulted only with a deformation a little more than that of the drop on full scale prototype when the mass was 9.070 kg.



The ½ symmetric model

DEVELOPMENT OF FWP CP-5.2

Final analysis to comply the IAEA transport regulation

The model used to verify a drop test with the vertical line passing through the centre of gravity and impact central point on an edge.

To allow the secondary drop, the impact angle was modified from 61°, when the container theoretically remains standing up, to 56°, so energy absorbed in the first impact is almost the same. The FEM analysis has shown no leakage and no large deformation, meaning a variation of the radiation level less than 20% as required.

The container CP-5.2 **complies with the requirements** of an IP-3 allowing the content as LSA-III and it, when will be constructed, can be marked as "I / Type IP-3 / CP-5.2/JRC" with "Mass max 15.000 kg".



**Prototype
Test for
Storage**

**High
Temperature
Resistance**

**Absence
of Free
Liquids**

**Waste
Coating**

Tightness

DEVELOPMENT OF FWP CP-5.2

Test for Storage Qualification

This section outlines the testing procedures for the CP-5.2 container prototypes to ensure they meet IAEA transport regulations.

Prototype n. 004 was subjected to drop tests to validate FEM analysis, while prototypes n. 002 and n. 003 were tested for high-temperature resistance and absence of free liquids.

The tests confirmed the container's structural integrity and suitability for transporting and storing hazardous materials.



Fig. 1: 1th face, section of prototype n. 001



WASTE COATING

The 4 face sections of prototypes n. 001 (long side) and 004 (short side) are shown at Fig. 1 and Fig. 2, Fig. 3 and Fig. 4. The 4 face sections of prototypes n. 002 (long side) and 003 (short side), subjected to the thermal test, are shown at Fig. 5 and Fig. 6, Fig. 7 and Fig. 8. As requested from UNI “The minimum thickness of the matrix layer coating the waste shall be measured.”, the coating was complete both near the container walls and near the individual objects inside the container.



High Temperature Resistance



Test Setup: The test involved heating prototypes in a gas furnace at 800°C for 30 minutes. Three thermocouples were attached to the external surfaces of the containers.

Temperature Measurements: The furnace temperature was initially over 1,000°C but dropped to 690°C when the prototype was loaded. The test began when the furnace temperature reached 800°C.



Prototypes Tested: Prototypes 002 and 003 were tested. After 30 minutes, the furnace was opened, and the prototypes were removed.



Results: The maximum temperatures recorded were 648°C for prototype 002 and 641°C for prototype 003. The differences were due to the starting times when the furnace reached 800°C again.



Post-Test Inspection: Two days after the test, the prototypes were inspected for deformation, gasket condition, concrete integrity, and lifting twist locker. The acceptance criteria were met.

Bitumen Behavior: A mock-up of a 1/6 section of CP-5.2 was tested to measure the maximum temperature at the surface of a drum. The maximum temperature recorded was 161°C, well below the ignition point of bitumen.



ABSENCE OF FREE LIQUIDS

All 4 full scale prototypes have been opened after curing the concrete to check the quantity of water close to the lid: only humidity was found.

Then the prototypes n. 001, used only for the penetration test, and n. 004, used for drop and penetration tests, were positioned to make a hole on the bottom steel sheet. No water was collected after the perforation of the steel sheet. The two prototypes have been cut with a dry diamond to check for water and waste coating: no water was found.

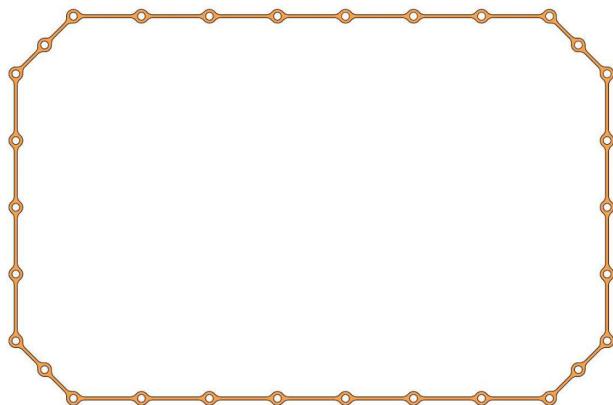
Prototype Test for Storage



Two prototypes have been built to perform the specific test for storage. The prototype n. 002 was filled with two half baskets containing loosen objects.

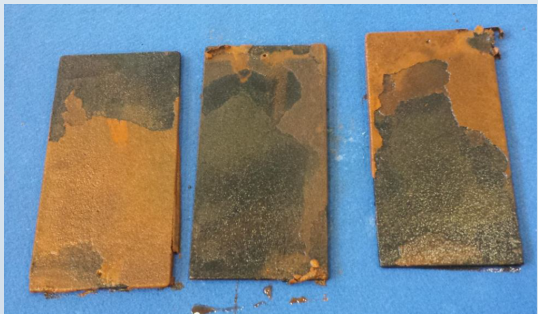


The prototype n. 003 was filled with 6 drums containing bitumen. Following the same grouting procedure applied for the prototype n. 001 and 004, at the end of curing time, the n. 002 had a mass 12.470 kg and n. 003 equal to 9.120 kg.



TIGHTNESS

The document includes the result of the leak test performed during the construction of the prototype packaging CP-5.2, n. 002 and 003, later used for thermal test. A drop pressure test was used before and after the painting, as it must check the whole packaging welds and not just the expanded graphite gasket. A Δp of 1000 Pa was applied to the packaging with blind filters, and the main parameter have been recorded for 1 hour: atmospheric pressure, internal and ambient temperature, and Δp . The design requirements $T_f < 10^{-2} \text{ h}^{-1}$, as for class 3 of ISO 10648-2, have been verified for all 4 measurements.



**COMPRESSIVE
STRENGTH BY
SPECIMEN**



**RESISTANCE TO
THERMAL
CYCLES**



**RADIATION
RESISTANCE**



**PERMEABILITY
TO WATER**



**IMMERSION
RESISTANCE**



**RESISTANCE TO
DEGRADATION**



**GAS
GENERATION**



**PERMEABILITY
TO GAS**

DEVELOPMENT OF FWP CP-5.2

Specimen Test for Storage

This section details the various tests conducted on concrete and steel specimens to ensure the integrity and durability of the CP-5.2 container under different conditions.

The tests include compressive strength, resistance to thermal cycles, radiation resistance, permeability to water, biodegradation resistance, immersion resistance, degradation resistance, gas generation, and permeability to gas.

Each test is designed to simulate specific environmental conditions and stressors that the container may encounter during its lifecycle, ensuring it meets the required standards for safe handling and disposal.



IMMERSION RESISTANCE

Three cube-shaped concrete specimens (100 mm x 100 mm x 100 mm) for each recipe have been immersed in water for 28d, checked visually and undergone to compression test. The same procedure was used with the immersion time of 90d.

All values are much higher than the design and UNI limits = 10MPa

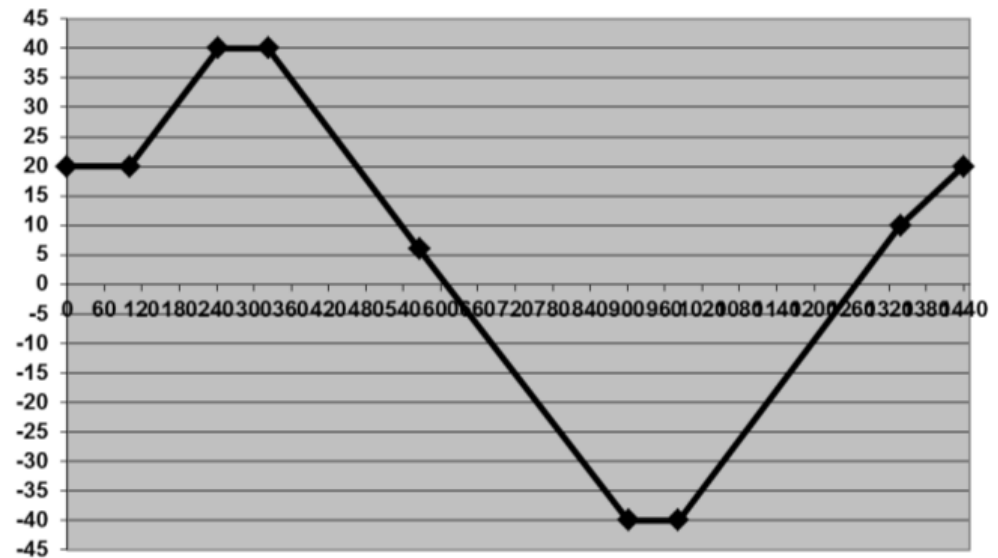
Specimen (Mix.)	Compression strength (28d) MPa	Compression strength (90d) MPa	Density (28d) Kg/m3 28d	Density (90d) Kg/m3
169	52,4	57,2	2211	2224
169	53,3	58,3	2214	2212
169	50,5	56,7	2236	2216
170	53,6	57,8	2280	2266
170	52,0	48,3	2256	2254
170	52,1	51,0	2242	2255



RESISTANCE TO THERMAL CYCLES

Three cube-shaped concrete specimens (100 mm x 100 mm x 100 mm), after 28 d, were subjected to 30 thermal cycles, before the compression test.

Property	Mix 169	Mix 170)
Density (kg/m3)	2250	2250
Water/Cement	0,52	0,48
Inert/Cement	3	3
Compression strength 28 d	42.1 MPa	49,3 MPa
Compression strength 28 d + 30 thermal cycles	46,8 MPa	46,2 MPa





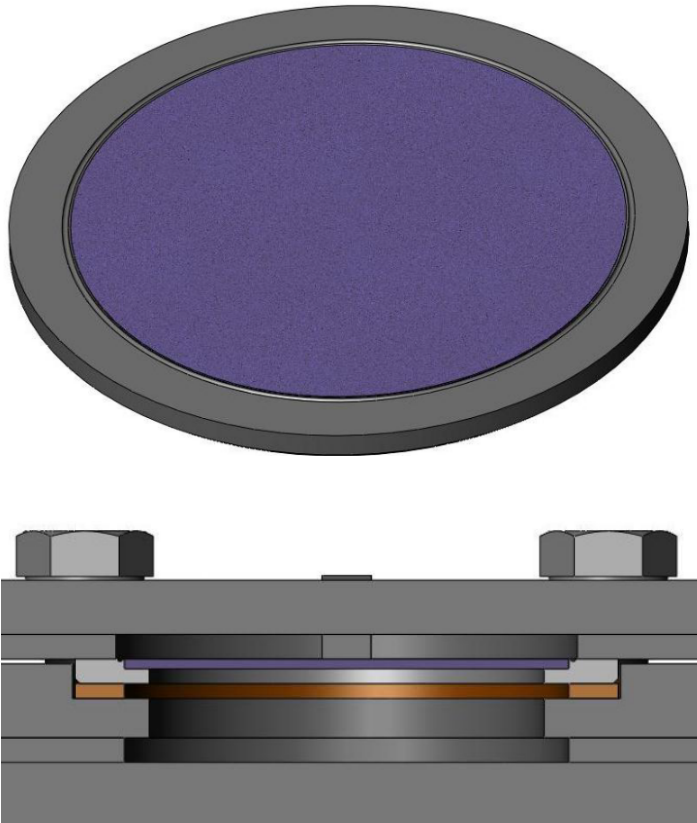
GAS GENERATION

Factors Considered:

- Chemical, radiochemical, and physical properties of the waste and conditioning process.
- Chemical and physical properties of the container and surrounding environment.
- Events leading to gas generation, such as corrosion, radiolysis, and decomposition of organic materials.

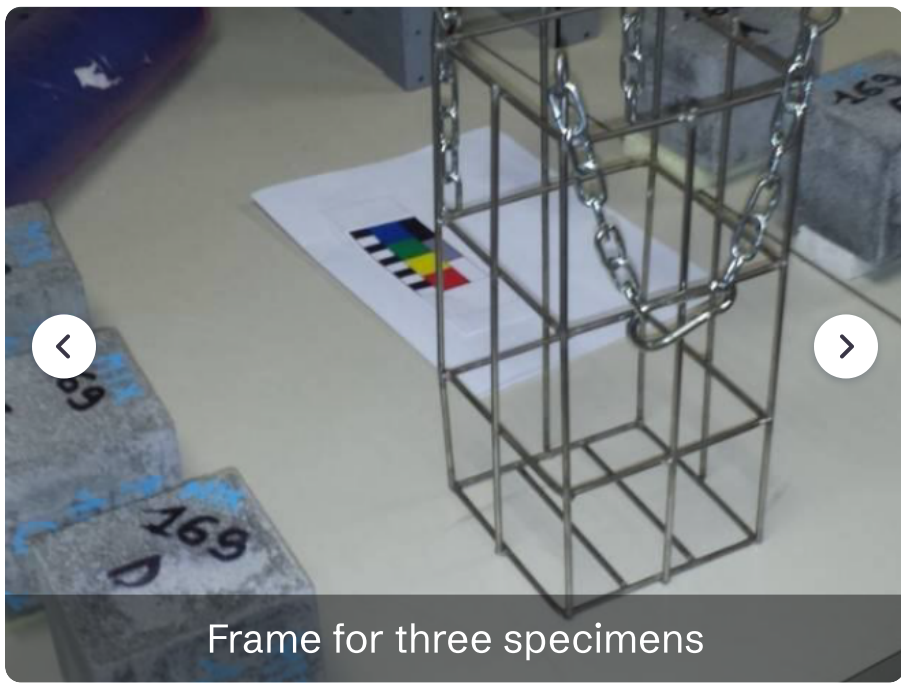
Gas Generation Calculation: Conservative parameters were used to calculate the amount of gas generated in CP-5.2. This value was used to determine the appropriate filter size to prevent pressure buildup inside the container.

Filters: Commercially chosen filters with a diameter of 90 mm and thickness of 2 mm, made of sintered AISI 316L, were selected. These filters can guarantee a gas flow much greater than the gas generated, with a pressure of 103 Pa.





RADIATION RESISTANCE



Frame for three specimens



Specimens: Three cube-shaped specimens (100 mm x 100 mm x 100 mm) made with concrete Mix 169.

Irradiation Facility: Calliope ENEA facility using a Co60 source.

Irradiation Conditions: Specimens were irradiated to an integrated dose of 106 Gy, with gamma radiation energy between 0.6 MeV and 1.5 MeV, for over 20 days.

Procedure: Specimens were centered on the Co60 source using a special frame, and their positions were adjusted to ensure an average dose higher than 106 Gy.

Results: The same procedure was applied to three specimens made with Mix 170, with all specimens receiving an average integrated dose of 1.45 MGy.



Post-Irradiation: Compression tests showed values much higher than the design and UNI limits of 10 MPa.



COMPRESSIVE STRENGTH BY SPECIMEN

After a pre-qualification procedure and results a final test on two concrete recipes was carried out by an authorized laboratory in agreement with a qualified procedure. The compressive strength was measured on three cubic specimens (100x100x100mm), aged for 28 days at 20±2°C and RH >95% and then tested according to UNI EN 12390/3:2009. 3 more specimens have been prepared as spare parts and other 3 specimens for the archive as usual. The acceptability criterion for the test provides that the compressive strength is greater than 10 MPa.

Property	Mix 169	Mix 170)
Density (kg/m3)	2250	2250
Water/Cement	0,52	0,48
Inert/Cement	3	3
Compression strength 28 d	42.1 MPa	49,3 MPa



PERMEABILITY TO WATER

Three cube-shaped concrete specimens (150 mm x 150 mm x 150 mm) for each recipe have been placed in the appropriate equipment and subjected, in sequence, to the following water pressures as required by UNI [46]:

- 100 kPa for 48 h
- 300 kPa for 24 h
- 700 kPa for 24 h

No water passed through each test specimen so the specimens were broken to measure the depth reached by the wet front.

In line with the high resistance values recorded, also the permeability to water with average values of 8 mm was about a third of the maximum expected (20 mm).



Specimen	Permeability coefficient (m2)
Mix 169 bis - 1	1,76 10 ⁻¹⁸
Mix 169 bis - 2	1,5110 ⁻¹⁸
Mix 169 bis - 3	2,1510 ⁻¹⁸
Mix 170 bis - 1	2,59x10 ⁻¹⁸
Mix 170 bis - 2	3,15x10 ⁻¹⁸
Mix 170 bis - 3	2,21x10 ⁻¹⁸

PERMEABILITY TO GAS

Test Requirement: Not a UNI test, but required by the Italian authority.

Specimens: Cylinder-shaped concrete specimens (70 mm diameter and height), with three specimens for each concrete recipe plus three spares.

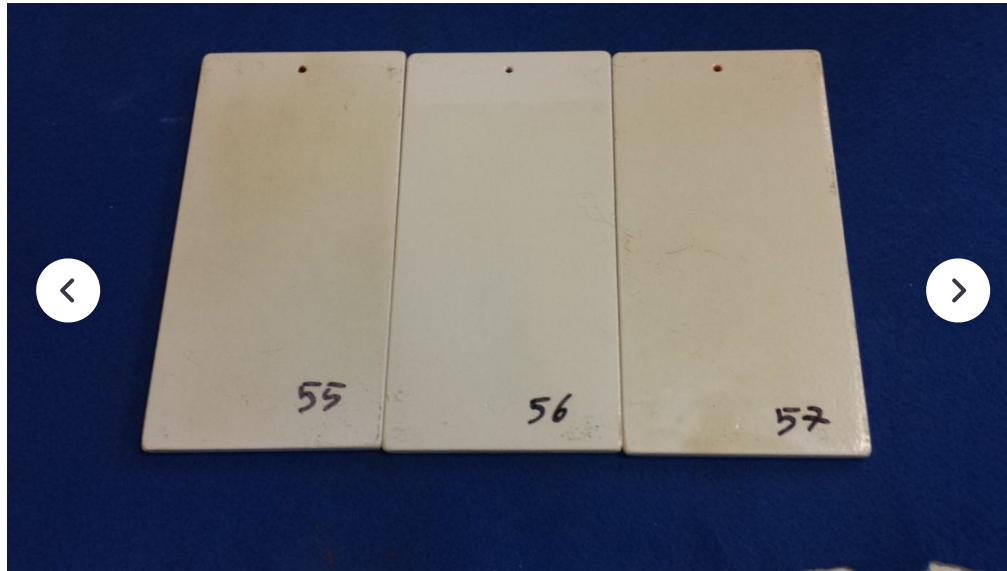
Preparation: Specimens were sealed with epoxy resin, leaving the faces exposed to gas flow.

Testing Procedure:

- Specimens were placed in a test cylinder.
- Test gas (helium) was introduced at 11 bar pressure.
- The pressure drop from 10 to 9 bar was measured once a constant leakage regime was achieved.

Results: The coefficient of permeability was calculated according to ISO 11599. There is no specific limit for this parameter, but it will be useful for future safety analysis of the disposal.

RESISTANCE TO DEGRADATION



Specimens after degradation test

Specimens: Various steel specimens with different dimensions, weldings, and surface treatments, prepared from the same steel used in the full-scale prototypes.

Testing Conditions: Specimens were coated on both sides, with a scratch mark on one side, and immersed in an aqueous solution (pH = 6, oxygen content = 5 mg/dm³) at room temperature for 90 days.

Degradation Factors: Focused on carbonatization and sulphate attacks on the container surfaces.

Post-Test Examination: Specimens were rinsed, dried, and subjected to metallographic examination to assess corrosion type and extent. Mass loss was measured for each specimen.

Results: The container demonstrated resistance to degradation, ensuring it can be handled correctly up to its final disposal, assumed to be 50 years after production.

Biodegradation Resistance: The test was not conducted as the organic content in the waste matrix was below 1%, considered negligible for testing purposes.



DEVELOPMENT OF FWP CP-5.2

Constraints



**Qualification
and
Construction**



**Supply and
Logistics**



**Grouting
Station
Operation**

DEVELOPMENT OF FWP CP-5.2

Conditioning Process for Waste in FWP

The experience gained during the construction of the full-scale prototypes has allowed to check a detailed packing procedure that must be followed when loading radioactive waste in the CP-5.2.

The main phases are shown at Fig. 1 where the small concrete shims will keep the basket 5cm over the bottom, the blue slings to avoid floating of low density waste, the large jacket used to protect the gasket surface from scratch and the external surface from contamination (Fig. 2 and Fig. 4), and how the gasket is hold with glue when the lid is placed on top of CP-5.2 (Fig. 3).

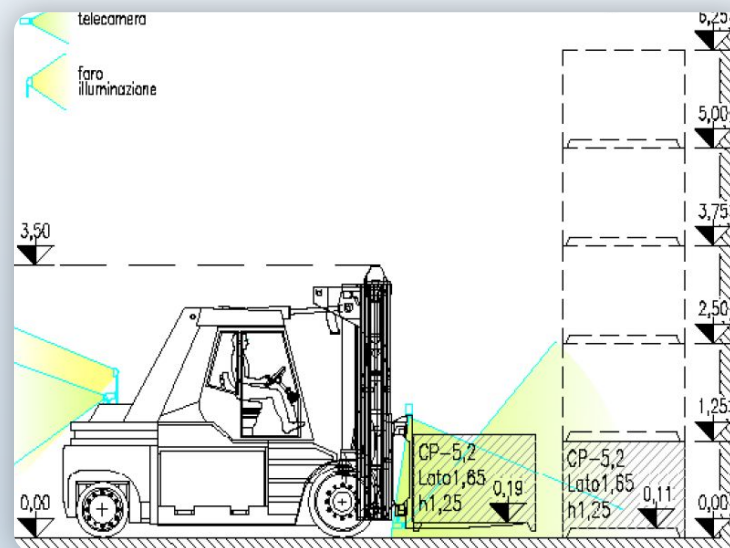
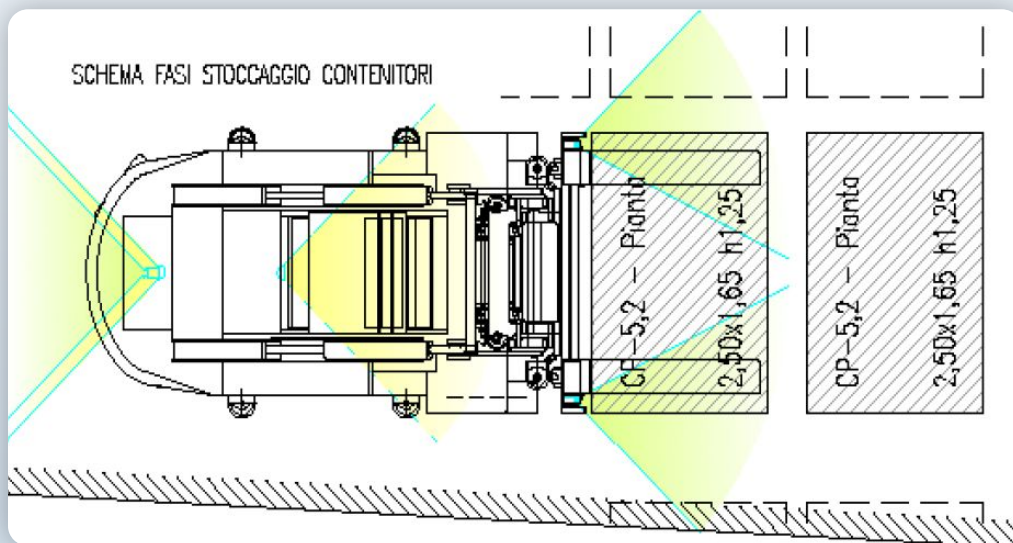
The conditioning process for waste in FWP, although well qualified, need a further approval from the safety authority for each different type of waste, as required by the license of the treatment and conditioning facility. At the end of the grouting phase, the CP-5.2 will be checked for radiation level and surface contamination, and labelled for transport and storage in agreement with IAEA and UNI. The Waste Inventory and Tracking System that covers all radioactive waste at JRC Ispra site will be updated to take care of the new CP-5.2 and its new storage site.



Fig. 1: Concrete shims and slings

Storage and Disposal of FWP

The CP-5.2 will be transferred from the grouting station to ISF, waiting for the Italian National Repository, by an electric fork-lift. The right place inside ISF will be chosen on the basis of external radiation and type of waste to minimize the workers doses during the inspections and outside the ISF.





VLLW

Currently, VLLW can be stored, in agreement with the new Technical Guide 33, without a grouting process so JRC has got the authorization to allow in its ISF the CP-5.2 packaging filled with waste inside a big bag, without any basket or frame inside. In this way the capacity of a CP-5.2 is at maximum.

At first only 220 I drums with VLLW are stored in ISF, in the near future CC-440 cylinder will be used and finally CP-5.2, mainly for concrete debris and soil contaminated.



ILW

Italian law allows ILW waste containing alpha-emitting radionuclides characterized by activity concentration levels < 400 Bq/g and containing beta / gamma-emitting radionuclides, even long-lived, to be disposed of in surface facilities with engineering barriers.

For this ILW it is possible to use the CP-5.2 packaging with conditioning procedure similar to LLW as stated in the new Technical Guide 33, but it is essential to get the authorization to store it at ISF.

JRC has planned to contact SOGIN and then the safety authority to verify the use of CP-5.2 in the future for conditioned or unconditioned ILW.

FUTURE DEVELOPMENT

The CP-5.2 packaging system is set to undergo significant advancements to accommodate various types of radioactive waste. This section outlines the future development plans for Very Low-Level Waste (VLLW) and Intermediate Level Waste (ILW).



CONCLUSION



Archive
Documentation



Feedback



Lessons Learned



Feedback

- **Regulatory Constraints:** The dimensions and requirements of the CP-5.2 packaging were strictly regulated, limiting optimization for JRC's needs. The usable volume was restricted to 1.32 m³ when loaded with 220 l drums due to concrete thickness and structural requirements.
- **Strategy Adjustment:** The lack of space for 220 l drums led JRC to change its strategy, opting to incinerate bituminized drums to reduce their number. Despite this, the average useful volume of a CP-5.2 remains at 2 m³, less than 50% of the total volume.
- **Cost and Design:** With the final design of CP-5.2, the construction costs are now better understood. JRC can explore waste treatment options to reduce radioactive waste volume and evaluate the economics of new proposals.
- **Qualification Process:** The qualification process was well-managed, with all steps performed timely and according to standards, despite involving many suppliers. The Calliope plant was excluded, possibly due to a lack of operations in ionizing radiation areas.



Archive Documentation

The qualification process for the FWP CP-5,2 has generated many more documents than the reference ones. In agreement with JRC Management System all activities have been planned and specific design, construction, testing procedures have been prepared with the relative technical requirements and acceptance criteria.

All documents are archived as paper documents and in digital files as pdf, word, drawing, excel and ppt so that they can be easily retrieved by JRC staff or other authorized persons.



Feedback

- **Constraints and Delays:** The process faced delays due to constraints set out in the Agreement with the Italian Government, requiring extensive communication between ISIN and SOGIN.
- **Qualification Process:** An industrial nuclear contractor coordinated with a concrete laboratory to find the right concrete recipe, prepare specimens, and manage other activities.
- **Irradiation:** Specimens were irradiated with a high Co60 source at the University of Pisa and the ENEA Calliope irradiation plant, which was time-consuming.
- **Prototypes:** Manufacturing four full-scale prototypes was expensive, involving a non-specialized grouting station and diamond wire cutting.
- **Duration:** The qualification process lasted three years and proceeded fairly smoothly without major issues.