Conceptual Study of a System for the Recovery, Safe Storage and Transportation of JRC Ispra High Level Liquid Wastes

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Abstract

JRC Ispra has accumulated a certain quantity of high level radioactive liquid wastes (HLLW), now distributed in several small storage vessels, which were produced during post-irradiation experiments on spent fuel, namely chemical dissolution, separation and partitioning processes.
As the Ispra site has no suitable plant to process such liquids or to collect and store them on a long-term basis, it is therefore intended to explore two alternative solutions:
- Transfer the liquids as they are to an external vitrification plant;
- Up-grade the liquids in the existing cementation facility, in order to condition them in a suitable form for subsequent storage.

In both cases, the HLLW must be characterised and relocated, to ensure their safe on-site conservation and, if requested, future off-site transportation.

While JRC Ispra has a limited number of containers suitable for handling the HLLW, they are not adequate either for long-term storage as well as for transporting the radioactive liquids on public roads. Hence, on-site refurbishment activities and the procurement of one or more authorised dual-purpose tank are necessary.

This presentation entails the transfer of the radioactive liquids from their presently distributed locations to a central site point and the development of a conceptual study of a new dual-purpose tank for temporarily containing the HLLW and subsequent feeding an on-site cementation plant or for transportation to an external facility.

KEYWORDS: *liabilities, wastes, waste management, high level liquid wastes (HLLW), radioactive liquids, storage tank.*

1. Historical and future liabilities and status of nuclear installations at JRC Ispra

The nuclear related liabilities of the European Commission, coming from its nuclear installations at the Joint Research Centres, can be divided in two groups:

HISTORICAL LIABILITIES, resulting from past activities intended to help develop a competitive European nuclear industry. They include providing appropriate waste management facilities and services, the decommissioning of shutdown nuclear installations and the management of existing and decommissioning-related wastes. Most of historical liabilities are related to the JRC Ispra site.

FUTURE LIABILITIES, covering the decommissioning of nuclear installations still used for research purposes and managing the associated wastes arising.

The management of its nuclear installations, as envisaged by Article 8 of the Euratom Treaty (1957), renders the Commission responsible of a facility throughout its life until it is de-licensed. Therefore, in keeping with applicable national and European legislation, the JRC is required to decommission its shutdown nuclear installations and manage the associated radioactive wastes. For this reason the European Commission has developed a Decommissioning & Waste

Management (D&WM) Program, which foresees the progressive elimination of its historical liabilities throughout the next two decades.

The JRC's D&WM long term action plan has been elaborated in co-operation with a group of external experts and is divided into three parts:

1. ***Management of wastes resulting from JRC activities since 1960 (Historical liabilities).***
   This phase also includes a number of generic activities:
   - the safe conservation of shutdown (and obsolete) installations;
   - removal of nuclear and special materials, which could delay the start of the decommissioning, from facilities;
   - investments in appropriate waste management facilities and services;
   - managing (manipulation, decontamination, treatment, containerisation and storage) of existing solid and liquid wastes and clearing old waste stores;

2. ***Decommissioning of shutdown facilities***, such as reactors and laboratories

3. ***Evaluation of resources necessary for future dismantling*** of nuclear facilities still in operation.

The list of nuclear installations to be decommissioned includes:

- *Safe Conservation shutdown installations*: **ESSOR nuclear reactor, Ispra1 reactor, Hot Laboratory for R&D.**
- *Installations planned for out-of-service in few years*: **STRRL, Radiochemical Laboratory, Dry Storage facility for spent fuel (dry pits).**
- *Installations, which will come to the end of their operational life*: **Cyclotron, FARO facility.**
- *Other facilities, which will become obsolete during the progress of the decommissioning general program*: **Storage and treatment areas.**

2. Inventory of JRC Ispra hllw

During four decades of research at the JRC Ispra site, about 250 litres of high level liquid wastes(HLLW), hereafter referred to as *radioactive liquids*, have been accumulated mainly in the form of nitrate aqueous solutions. The overall inventory is summarised in Table 1.

TABLE 1: Radioactive Liquids Inventory

Par.	Container ID	Storage Location	Volume (l)	Total U (g)	U-235 (g)	Total Pu (g)	Activity (GBq)
4.1.1	**CENDRILLON L001**	Ed 41d	78,5	409,4	16,3	3,61	220
4.1.1	**CENDRILLON ERTI**	Ed 41d	40,1	116,72	2,2	0,43	80
4.1.2	**300-LITRE TANK S1**	Ed 52	88,5		15,1	1,84	400
4.1.3	**CORBELLINI TANK**	Ed 41d	5	948			
4.1.3	**FACCHETTI TANK 1**	Ed 41d	11	79,2	73,6		
4.1.3	**FACCHETTI TANK 2**	Ed 41d	6	32,1	30		
4.1.4	**LCSR TANK**	LCSR Laboratory	15			10	20
			244,1	**1585,42**	**137,2**	**15,88**	

TABLE 2: Activity and dose rate data

Par.	Container ID	Storage Location	*Specific β-Activity (MBq/l)	**Specific α-activity (MBq/l)	Contact dose rate (Gy/h)
4.1.1	**CENDRILLON L001**	Ed 41d	4700	115	
4.1.1	**CENDRILLON ERTI**	Ed 41d	4200	131	
4.1.2	**300-LITRE TANK S1**	Ed 52			0,15
4.1.4	**LCSR TANK**	LCSR Laboratory			0,2

* Am-241, Cs137, Eu154;
** Pu-238, Pu-239, Pu-240

3. Options for the recovery and safe storage of radioactive liquids

The Ispra Site has no suitable plant to process the liquids or to store them on a long-term basis. It is therefore intended to proceed with the conditioning of the liquids and for this, two options are under scrutiny:

- *Vitrification in an external facility*;

- *In-house conditioning by means of cementation*.
  This is a second priority option in case the first solution will be unfeasible, due to limitations in transportation of HLLW.

The JRC Ispra is currently assessing the feasibility of the first option, i.e. vitrification, which should lead to:

- ***The collection at a central Ispra site point of all the radioactive liquids from their distributed locations;***

- ***The subsequent transport of the radioactive liquids to the future owner***.

Some important constraints must be taken into account for a correct execution of the above option:

- Although JRC-Ispra has a limited number of containers of type "Cendrillon", potentially suitable for handling radioactive liquids with a high activity content, they are neither designed to function as storage vessels nor are they appropriate for transporting the liquids on public roads.
- As the present partially centralised storage tank in Edificio 52 is not adequately equipped for medium-term storage, liquid transfer and assaying requirements, the realisation of an interim storage facility, possibly consisting of mobile storage containers, is needed.
- Likewise, the procurement of the necessary overpacks for transporting such container to the future owner of the radioactive liquids is required too.

In order to reach the above objectives, three main contracts are foreseen:

1. The first covers acquiring the title of the radioactive liquids and the physical acceptance of the liquids by the new owner.

2. The second covers the supply of one or more centralised storage tanks for the interim storage of the radioactive liquids on the Ispra Site.
This contract is, in turn, divided in two phases (sub-contracts):

2a. The first phase is a study, whose scope is the collection of the relevant data to allow the JRC Ispra to finalise the whole project plan and prepare the call for tender technical specifications for the design, realisation and provision of the dual-purpose (storage and transport) tank(s).

2b. The second phase will entail the execution of the technical specifications.

3. Taking into account the requirements of the Italian Regulations for road transportation of radioactive materials, the third contract covers the design, licensing, realisation and supply of one or more transport overpacks whose objective is the safe transport of the tank(s) to the future owner.

4. Extent of the study for the design, realisation and provision of the dual-purpose tank(s)

The study to be performed as indicated in point 2a. should have, as a minimum, the following extent:

- *Collect all data relevant to the radioactive liquids to be re-conditioned*, assimilating their existing life records and the history of their transfers;

- *Validate the chemical and radiological characteristics* of the radioactive liquids, by means of the existing documentation and/or sample taking and measurements;

- *Study the possibility of mixing the liquids altogether*, taking into account any eventual risk of criticality;

- *Define a system for the sample taking* from existing containers through the Cendrillon;

- *Define the different connection interfaces* between the existing storage containers and the Cendrillon to be used for internal transport up to the central collection station;

- *Carry out a detailed study of the temporary conditioning process of the liquids*, ensuring that all safety aspects and measures are taken into account;

- *Choose the most adequate tank(s)* with the aim to satisfy both on-site storage and public road transport requirements, with particular regard to licensing processes to be implemented towards the Italian Safety Authority. With respect to this, the supply of already licensed tanks will be highly desirable.

- *Define an area*, inside the Ispra site, suitable to store in medium-term the new tank(s) for the radioactive liquids.

5. Preliminary activities to be performed at Ispra site

The execution of the new centralised storage station falls under the responsibility of the unit NDWM, with the assistance of one or more contractors, implying the following preliminary activities:

- Functional verification and, if necessary, refurbishment, of the two Cendrillon (Super Géante series, model CEN 15/130 with an operating capacity of about 114 L) to enable their use as on-site transport vessels;
- Preparation and set up of all operating equipment for the collection of radioactive liquids, with particular regard to health physics and accident prevention measures;
- Set up of a sampling method for the analysis of all liquids to be conditioned, in order to ensure a complete characterisation;

With regard to LCSR, the recovery of the radioactive liquids will be performed after the conclusion of that facility's pre-decommissioning activities.

Likewise, the recovery of the radioactive liquids from STRRL must be undertaken before pre-decommissioning of that facility commences.

5.1 Functional verification of existing vessels and sampling procedure

5.1.1 CENDRILLON type LR22

There are two vessels of this type filled with radioactive liquids, their identification being L001 and ERTI. They are in very good conditions (see picture) and can be easily filled and emptied by means of the existing equipment in Edificio 52, linked to tank S1.
Sampling of radioactive liquids shall be performed by means of the standard system of the cendrillon.

5.1.2 300-litre tank S1 in Edificio 52

Both sampling and emptying tank S1 shall be performed by means of the same equipment used for the cendrillons.
The content will be first transferred to a cendrillon and samples will be taken from such vessel.

5.1.3 Blue drums

Due to the low specific activity of the content, the sampling shall be done directly from the tank with a simple manual procedure.

5.1.4 LCSR tank

This is the most critical tank, both because of its location and the difficulty for an eventual sample taking.
After a visual inspection with the scope of verifying its integrity, it is envisaged to set up a docking system, in order to lift the tank and place it into a shielded vessel.
The tank shall be transported by means of a shielded trolley up to an area suitably equipped for sample taking. Another area is foreseen to empty the tank.

5.2 Preparation of the working area and set up of operating equipment

On the basis of the first preliminary results of the chosen new tank(s), all activities of preparation and set up of equipment to be used for the transfer of radioactive liquids can be summarised as follows:

- Review and refurbishment of the existing draining and sample taking systems of tanks S1 (capacity 300 l, standard system is cendrillon);

- Restoring the exhausted air system, including a verification of the adequacy of the existing fan-filter group;

- Modification of the civil structures (access door to the room where tanks S1 is installed), in order to allow the forklift with the cendrillon to enter the facility;

- Fabrication/supply of a shielded trolley devoted to the on-site transportation of the tank from LCSR to the sampling station;

- Fabrication and/or purchase of the following parts of the operating draining station for the installation of the new tank(s) 380-litre capacity:

  a) Weighing platform, to check exactly the weight of the transferred liquids into the new tank(s)

  b) New glove box to transfer the radioactive liquids from blue drums into bottles and from these to the new tank

  c) Homogeniser, to ensure that a single-phase liquid is present inside the tank(s)

  d) Lifting and transport equipment for the new 380-litre tank

- Installing the new operating draining station, including parts assembly, pneumatic and electrical connections, weighing system calibration, health physics systems.

5.3 Envisaged sequence for emptying and final washing of existing tanks

In order to perform this operational sequence, two empty Cendrillon will be made available to ensure the performance of following activities:

1. Transportation of empty Cendrillon to Edificio 52 up to the loading area, close to tank S1, and connection to the system;
2. Draining radioactive liquids from tank S1;
3. Tank S1 washing and liquids pouring into the new tank via Cendrillon;
4. Removal of the loading system of Cendrillon from S1;
5. Re-assembly of the loading system of the Cendrillon in the working area, connection to the new tank(s) and their filling;
6. Transfer of radioactive liquids in blue drums into suitable bottles, of appropriate dimensions to fit the glove box;
7. Transfer of the content of bottles into the new tank via the glove box;
8. Transport of LCSR tank in the working area of Ed 52.
9. Emptying of LCSR tank via Cendrillon and subsequent washing
10. Emptying of Cendrillons and their washing
11. After completion of the above activities, all connection tubes to the new tank will be removed and the cover lid positioned.

6. First preliminary results:proposal for a new storage tank

A relevant part of the study was devoted to the project of a suitable new tank to collect all the different wastes coming from JRC-Ispra site. To comply nuclear regulations and standardise the project, JRC-Ispra decided to focus on a tested commercial tank, suitable to accommodate activated components from the core area of nuclear reactors, provided that they are put under water. Nevertheless, JRC envisaged the need to customize the standard type container to facilitate loading operations as were described in previous paragraphs. The manufacturer will be requested to modify the standard container respecting all the safety, pressure sealing, operability criteria adopted for the standard container.

Technical Data	
Outer Height (mm)	1500
Outer Diameter (mm)	1060
Interior Height (mm)	1140
Interior Diameter (mm)	740
Wall Thickness (mm)	160
Lead Insert min.-max. (mm)	0-140
Empty Weight ca. (kg)	8000
Filling Volume (dm^3)	380

The outer vessel of the cask is made of cast iron with spherical graphite nodules of GGG 40 quality. The inner jacket is made of a sheet steel 3 mm thick, pressure tight welded. To reduce the radiation dose rate at the outer surface, it is possible to interpose a further lead sheet. This shield is positioned in an interstice created between outer and inner wall, reducing the container's capacity to 320 dm^3.

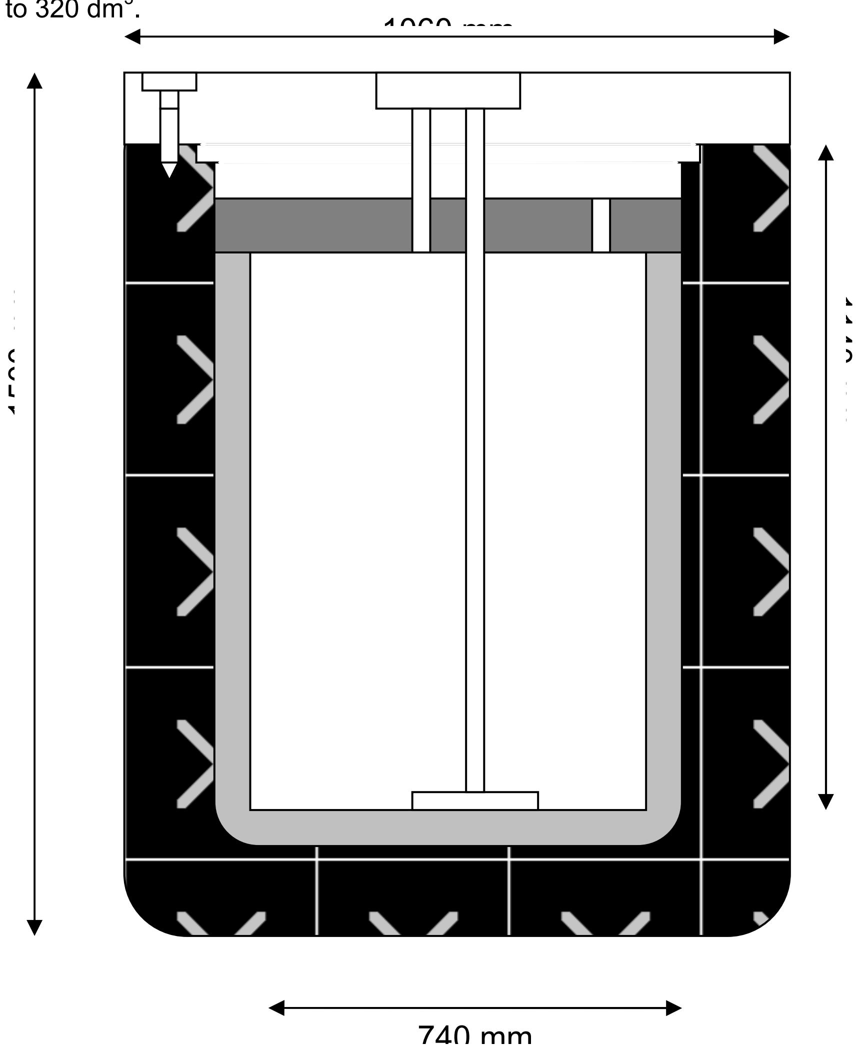


FIGURE 1: standard commercial tank structure (section)

Hereafter will be outlined the most important changes proposed for the standard container structure.

6.1 Manual stirrer

The stirrer will be positioned in the center of the lid with special double seal and holes for fixing shaft journal bearing. This device will be operated manually.

6.2 Manual load funnel.

The lid will have a mouth with loose flange to insert a manual loading funnel. The liquid wastes from blue drums, once transferred to suitable bottles, will be emptied in the cask trough a glove box passage. This procedure, which requests an operator intervention, is suitable for less-activated components.

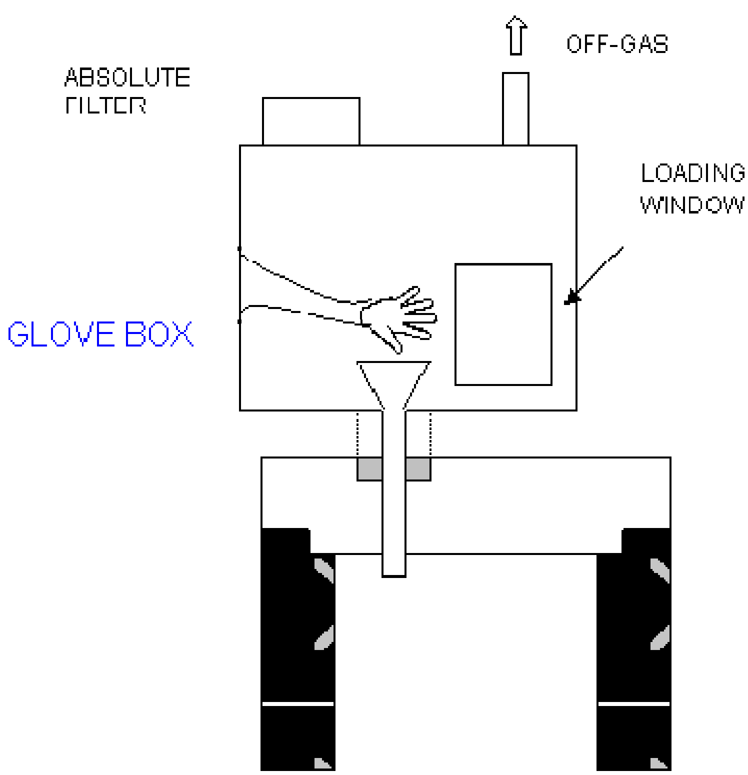


FIGURE 2: the manual load equipment arranged on the cask.

6.3 Liquid “Cendrillon” loading system.

Three mouths on the lid for liquid loading from “Cendrillon” system. Channels connecting inside with outside are bent to guarantee shielding continuity.

- The suction line is connected, trough an absolute filter, to the vacuum pump of the Cendrillon system.
- The loading/unloading line is made of a stainless steel (AISI 316) pipe (Φ = 12 mm) connecting the bottom (maximum draft) to the lid. The outer part of this consists in a tap and a T shaped connection with two ways out: one is for the Cendrillon sampling system; the other is a connection to the out-pouring Cendrillon container in the loading phase or to the storage tank during future emptying operations.
- The breathing pipe, with tap, is connected to the absolute filter placed on the lid surface. The tap is to be closed during loading operations and transport; it will serve as a vent in the storing period.

6.4 Full load level.

A Teflon ball cock stopper isolates the suction line blocking the liquid in-pouring when the liquid level is 140 mm from the top of the lid. An additional check on mass will be provided installing a weighing platform (range up to 10000 kgs) under the cask.

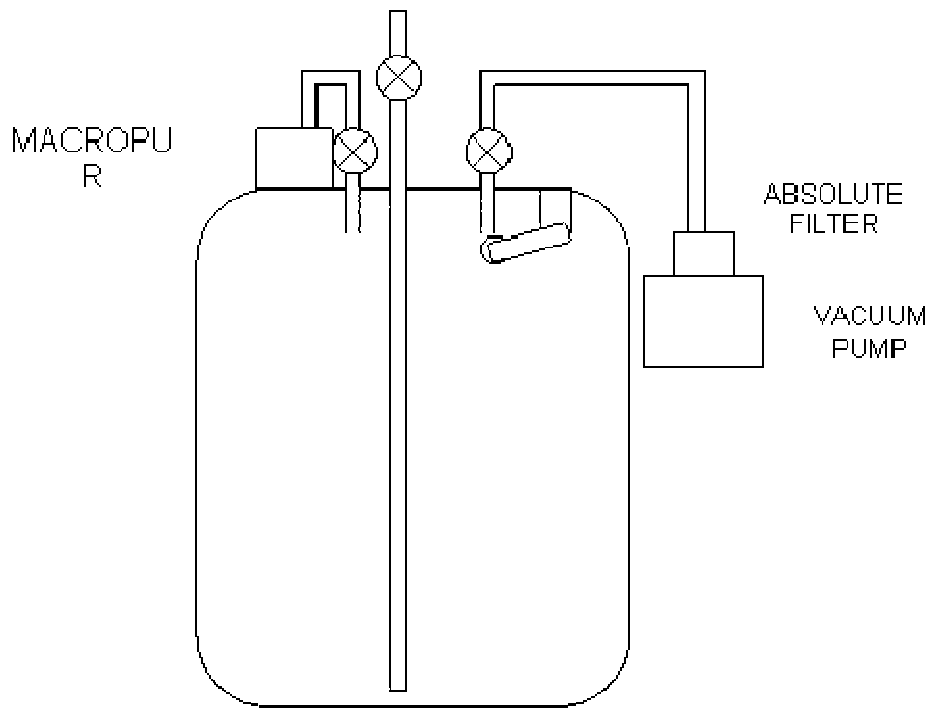


FIGURE 4: conceptual chart of the connections from the cask to the Cendrillon loading system.

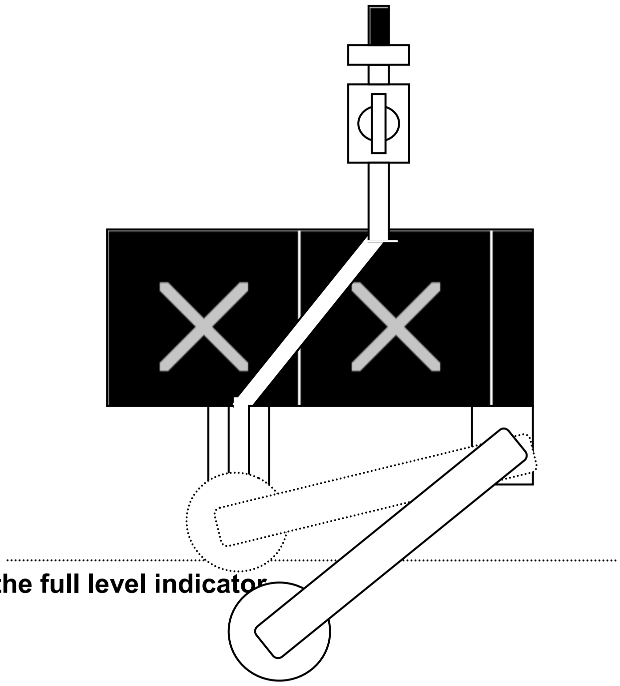


FIGURE 3: the full level indicator

6.5 Exterior protective lid.

The original MOSAIK outer shape will be preserved mounting a double purpose extra cap. The main function is to protect the many devices mounted on the modified lid, but a special gasket will suit also to confine incidental leakage due to thermal overpressure in the container.
At the end of the loading operations, after taking all the connections off and opening the vent tap, 18 long screws will fasten the cap to the container. The cap will be provided with standard lifting hooks.

6.6 General observations.

If the total volume of the effluents (including wastes resulting from washing containers) exceeds the full load cask capacity (380 litres), JRC-Ispra will divide the total mass in two identical casks.

The container will be tested to gas tight with maximum leakage rate lower than 10^{-5} mbar*lt/sec.

7. Preliminary risk analysis

This section regards the risk analysis of a storage container for high activity α and βγ liquid wastes that are now temporarily stored at Joint Research Center, Ispra, Italy. The risk analysis deals with the major security problems that can be encountered during loading and transporting operations or, later, during final confinement; the first aspect is shielding calculations, the second is criticality risks and the third is possible accident consequences analysis. Italian regulations make provision for a particular professional figure, the Qualified Expert, to carry on those calculations during the planning of operations involving radioactive material.

7.1 Radioprotection: shielding calculations

Material and thickness of shields fit to comply with the maximum admissible dose limit have been calculated supposing that[1]:

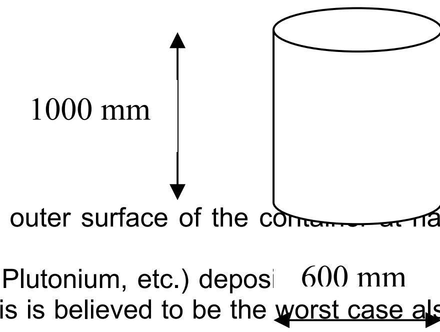
a) The tank for temporary storage of liquid wastes to be poured off in the cask container have:

[1] This is supposed to be the worst case, simulating the actual S1 Tank situation.

Φ = 600 mm

h = 1000 mm

Volume = 300 l



b) The contact dose rate (measured on the outer surface of the container at half highness) is 0.15 Gy/h.
c) All the radioactive substances (Uranium, Plutonium, etc.) deposi[illegible]ttom container with 500 mm of water on it (this hypothesis is believed to be the worst case also for criticality risk).

On those basis, is possible to suppose the presence of 50 Ci of Cs 137 on the bottom of the tank. If this radioactive content is supposed to be totally transferred in the cask, the shielding necessary to comply with the 2 mSv/h dose rate limit for transportation consists of 140 mm of iron and 20 mm of lead. Carrying this protection out would require the insertion of a supplementary lead shield in the original project of the cask, increasing the tare and reducing the spare capacity that would be useful for washing waters.
The proposed solution would be to divide liquid wastes in two identical containers. In this case the 160 mm thick iron wall of the standard container will satisfy safety requirements.

7.2 Criticality risks

At the present moment, no accurate data on fissile nuclides are available. Therefore, unofficial estimates exclude all possibilities of criticality also in the case of fissile material concentration as a solid deposition under the fluid mass. This makes unnecessary a solidification treatment of the liquid wastes; in case of need, a addition of a soluble neutron adsorber. Obviously, the first step in the analysis of the materials to be conditioned, is to determine activities and content in fissile nuclides.
If JRC-Ispra will decide to set the liquid wastes off to a final disposal site, it is advisable to solidify all the liquid to pour in the cask.

7.3 Accident analysis

Documentation material provided by the manufacturer shows that the container is licensed as a class B type packaging system.
The prescribed operating conditions, reported on the container as a metallic plate, suggest to maintain the load at 300 mm from the floor while moving it. Therefore it is assumed that the container, even if modified according to customer's requests, does not suffer any damage (liquid or gas leakages) if it overturns falling from 300 mm.
This distance from the floor is currently assumed as a parameter also because is the minimum possible for operating with a forklift.
Considering a container overturning accident leads to the following conclusions: the content stored (380 liters of liquid solution) produces a pressure on the lid that corresponds to its weight, assuming negligible fluid speeds in the accident. The pressure corresponds to 8980 Pa.
The seal of the stirrer's shaft is identified as the weakest. This is warranted for keeping without leakage 40000 Pa, that is about five times the calculated value in case of accident. If requested, it is possible to change this sealing, increasing the safety coefficient to about 80 mounting a special metallic support.