Development and Qualification of Steel Waste Container for ILW to be Disposed in Geological Repository – 14274

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ABSTRACT

The Swedish geological repository for the disposal of low and intermediate level radioactive waste (SFR) consists of four types of rock vaults. Intermediate level waste with the highest activity concentrations will be disposed in the Silo, which is the vault designed for more than 90 percent of the total activity in the repository.

Based upon a common need, Studsvik has, in cooperation with NPP Ringhals developed a new steel waste container concept for metallic and non-metallic scrap with a contact dose rate of up to 500 mSv/h and with a significant content of long lived beta-emitting nuclides. The packages should be acceptable for disposal in either the Silo or in the second vault for intermediate level waste, BMA.

The aim of the project was the development and qualification of a modern steel container with a low tare weight, but with a large net volume which fulfills the requirements for disposal in SFR Silo. The package should resist a drop from 9 meters and a pile of 42 fully loaded containers. Furthermore, the concept should ensure that the void inside each package should be as low as reasonable achievable and that the net payload (i.e. the waste weight) as high as possible within the maximum package weight of 5 metric tons.

INTRODUCTION

The Swedish geological repository for disposal of low and intermediate level radioactive waste SFR, for which the Swedish Nuclear Fuel and Waste Company (SKB) is the license holder and operator, consists of four types of repository sections. See Figure 1.

The rock vault for low level waste (BLA) is intended for waste with a dose rate up to 2 mSv/h, the rock vault for concrete tanks (BTF) is intended for certain waste packages with a dose rate up to 10 mSv/h, intermediate level waste with dose rates up to 100 mSv/h will be disposed in the rock vault BMA and intermediate level waste with dose rates up to 500 mSv/h will be placed in the Silo which is the vault designed for more than 90 percent of the total activity in the repository. The destination for the packages is not only depending on the dose rates. The content of long lived nuclides is an even more important parameter.

The Silo consists of a cylindrical concrete construction with shafts of different sizes for waste packages. The concrete cylinder is approximately 50 meter high, with a diameter of approximately 30 meter. The waste packages are placed in engineered shafts inside the Silo, sized for layers of four mould containers or 16 drums. The spaces between the waste packages are gradually back-filled with porous concrete. The walls of the Silo are made of reinforced concrete. In between the walls and the surrounding rock there is a bentonite backfill. The concrete floor at the bottom of the Silo is placed on a layer of sand/bentonite mixture. A concrete lid will be placed on top of the Silo when the disposal is completed. The lid will after closure be covered with a thin layer of sand, a layer of sand/bentonite mixture and the remaining space will be filled with sand, gravel or sand stabilized with cement.

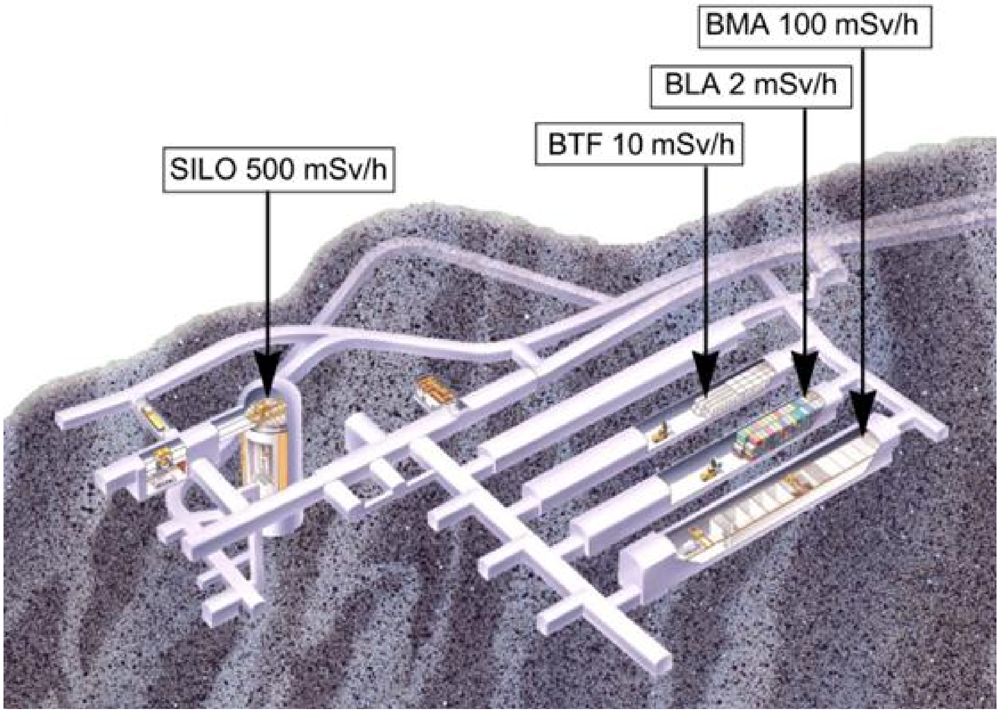

Fig. 1. Principal layout SFR repository (source SKB).

Based on the above prerequisites the Swedish nuclear industry has developed a number of waste type descriptions. One waste type description is only applicable for disposal in one repository section. For the category dry active waste and scrap metals, there are in principle three categories of waste type descriptions: Type 12 for disposal in BLA, type 23 for disposal in BMA and finally type 24 for disposal in the Silo.

Each facility/license holder manufacturing waste packages of a certain type needs to write and qualify his own waste type description. For type 24 no waste type description has been qualified for disposal up to now.

It is of great importance that both short term and long term safety is in focus. An improperly designed container or a poor package concept can be both problematic and costly to handle in case problems are discovered when packages are conditioned with waste or, in the worst scenario, already have been disposed in the Silo. For this reason, the principle of precaution has been ruling within the project. In case of any hesitation, further analyses/evaluations have been performed.

BACKGROUND

Studsvik and NPP Ringhals decided in 2008, based upon a common need, to perform a project to develop and qualify a container and a package concept for disposal of scrap metal and other inorganic waste material in SFR Silo. The basic need of the waste type description has been more related to the inventory of long lived beta emitting nuclides than high dose rate materials.

NPP Ringhals has among other waste material treated nine retired PWR steam generators at the

Studsvik waste treatment facilities. The rest products from these treatments as blasting residues, tube materials and slag from the melting process have been loaded and conditioned in type 24 containers for disposal in SFR Silo.

To avoid unnecessary transports of radioactive waste NPP Ringhals has decided that the rest products from the treatment of the steam generators should be packed and conditioned in Studsvik and then directly transported to SFR.

Two alternative containers are included in the concept and the related waste type description, one made of steel and one made of concrete. This paper is focused on the steel container.

OBJECTIVES

The project objectives were to a large content set before the start-up of the project. During project execution some objectives were updated or revised.

The final list of project objectives became as follows:

- Development of a container and a package concept that will be approved for disposal in SFR Silo as well as in the second vault for Intermediate Level Waste, BMA
- The package concept shall be able to license for several license holders waste
- The developed concept should contain a controlled waste package manufacturing process with clear limitations and boundary conditions
- A waste container, that meets the strength requirements without taking the waste matrix into account
- One concept − several waste disposal destinations
- One concept – several waste type descriptions
- A structured definition of defined normal and maximum content in packages – to generate an overview and flexibility
- Stand-alone waste type descriptions – should consider but do not be mixed up with facility and transport limitations
- Maximised payload and net volume combined with minimised void
- Motivated and clear requirements on documentation of the loaded waste – introduction of loading plan and datasheets with mandatory fields, fields to be filled in when applicable and a structured way to register other information of value.

OVERVIEW

The basic design is a cubic container with the dimensions 1.2x1.2x1.2 meter.

The type 24 concept consist of two variants:

- Reinforced steel mould container with bolted lid
- Concrete mould container with bolted lid

The main waste types intended to be disposed in the containers are metallic scrap and inorganic waste as concrete. Organic waste is accepted in very small amounts.

The remaining void within the loaded container will be filled up with a mixture of an inorganic filing material, foam glass, and a special form of grout designed to have good floatability.

To maximize the payload from both a volume and weight perspective the steel mould is designed with a special feature to fill up the corner pillars from outside.

Regulatory Requirements

Regulation SSMFS 2008:1 Safety in Nuclear Facilities [Ref 1], general advice on the application of the regulation, advice for chapter 6 section 6:

"The design of waste type descriptions should be such that they clearly show how acceptance criteria and other applicable requirements on safety and radiation protection are met for each step of the nuclear waste management chain until after the final closure of the repository."

Waste Acceptance Criteria (WAC) for Disposal

Certain general acceptance criteria [Ref 2] apply on all waste packages to be disposed in SFR. The acceptance criteria are derived based upon the following principles:

- The waste package shall contribute to that the dispersion of radioactivity is delayed and prevented both during handling and storage.
- The waste package shall protect personnel and the environment from radiation.
- The waste package should be possible to handle in the system available for transport and storage.
- The maximum activity and the waste properties should be adapted to the technical barriers that exist so that the repository is safe after closure.

The above principles shall be maintained through an optimization based on the ALARA approach and the use of Best Available Techniques (BAT).
See reference 2 for details.

In addition, the SKB Waste Management Handbook [Ref 3] stipulates, among other requirements, that the waste package specification shall:

- Form a safety analysis report for the waste package and its disposal in the repository.
- Be a historical description of the disposed waste packages.
- The packages to be disposed in the repository must fulfill certain compression strength resistance and that a free fall from a certain height not will cause any unacceptable damage of the package.

In addition there are special requirements for the different repository sections in SFR. For the Silo the following, among other, requirements apply:

- The maximum disposal weight per package is 5 000 kg.
- The packages shall be design to resist stacking of 42 packages with maximum weight on top of each other.
- The packages shall resist a drop from 9 meters without an unacceptable damage of the container.
- The void should be as low as reasonable achievable.
- Max contact dose rate 500 mSv/h.
- The waste shall be solidified by concrete or bitumen alternatively embedded in concrete.

INVENTORY

Inventory of Radionuclides

The container is intended to be used for waste arising during operation and decommissioning of NPPs and other nuclear installations having Co-60 and other activation products as main nuclides. Fission products as Cs-137 and alpha emitting nuclides may also be present.

The following limitations have been set:

Total activity	max 2 TBq
Gamma emitting nuclides	max 0.5 TBq for the steel mould (max 1 TBq for the concrete mould)
Alpha emitting nuclides	max 5 GBq

It is expected that the ”normalkolli” (i.e. a typical package for disposal) has a total activity of less than 10 % of the maximum activity.

Surface dose rate	max 500 mSv/h

It is expected that the ”normalkolli” has a maximum dose rate of less than 10 % of the maximum dose rate at time of disposal.

Limitation of Materials

Certain limitations of materials have been defined:

Waste material	Steel mould	”Normalkolli”
Ferrous metals (including alloys)	0–4 000 kg	0–4 000 kg
– aluminium	< 50 kg	< 5 kg
– zink	< 50 kg	< 5 kg
– copper and brass	< 200 kg	< 20 kg
– lead	< 100 kg	< 10 kg
– heavy metals (other than above)	< 50 kg	< 5 kg
Non metallic inorganic waste	0–3 000 kg	0–3 000 kg
Blasting residues	0–3 000 kg	0–3 000 kg
Organic material	< 100 kg	< 20 kg
– of which cellulosa	< 50 kg	< 5 kg
Electronics, instrument etc.	< 50 kg	< 5 kg

DESIGN ASPECTS

Optimization of the Design

The steel mould container was originally designed as an extrapolation of the available steel moulds used within the Swedish nuclear industry for disposal in the BMA section of the SFR.
It was found that this strategy resulted in a heavy container with quite complex design and with a significant share of the bottom section occupied by steel structures.

As the objective for the project was to design a container with low weight and maximized net volume the approach was changed. The new approach was to redesign the entire container aiming to meet the project incentives. The designer was asked to integrate the usage of finite element calculations in the design work.

The new strategy became a success as the weight of the container was reduced significantly and the available volume was increased. See Figure 2. Furthermore is the new design less complex from a manufacturing point of view. High strength material was selected for some details based upon a cost benefit analysis.

Fig. 2. Steel container, left: exterior of a loaded container before final conditioning, right: interior of container

The objective to maximize the payload and net volume combined with minimized void inside the package has been a challenge. Minimization of void is essential to prevent free flow paths in SFR Silo in a long term perspective. Creative ideas have been implemented such as filling of the reinforcement pillars with concrete from the outside.

Intensive efforts were performed to find and qualify filling materials with a density as low as possible and properties which not will have any negative impact on the short and long term safety for the waste material, the container or the repository. Deep market surveys both inside and outside the nuclear industry combined with technical analyses and laboratory experiments in close co-operation with experts in conditioning were performed.

The project finally selected foam glass to fill up free volume in the packages. This is a material that is made of recycled crushed glass and is foamed at high temperatures to a low density material. Optimization of the viscosity of the mortar versus size of the foam glass was elaborated during the laboratory tests to secure filling up of void without causing foam glass to float and break the surface (see figure 3)

Foam glass has been verified to have a chemical composition not violating the long term safety of the repository and has high static resistance against mechanical compression. This is a material that is used in the construction industry and is available at a reasonable price.

Fig. 3. Foam glass, left: material structure, right: foam glass lifted to surface during laboratory tests

Verification of strength and fall resistance

The verification of the strength and fall resistance can be achieved in several different ways. Two concepts were evaluated within the project:

- Physical tests
- Computer simulation

The computer simulation was preferred as it has the advantage that it can simulate and analyse different situations. A physical test by a compression strength test and a drop of a loaded container is more a test than verification, especially if the drop test is done on one or a few objects.

Advances finite element analysis models were used for the simulations.

The verification simulation confirmed that both the compression strength requirements and the fall resistance conditions were fulfilled without taking the conditioning on the waste into account. The simulations were performed with waste loaded into the container up to the maximum weight without any conditioning i.e. the waste could move within the container during the fall. A fall on the bottom corner was found to be the worst scenario. See figure 4.

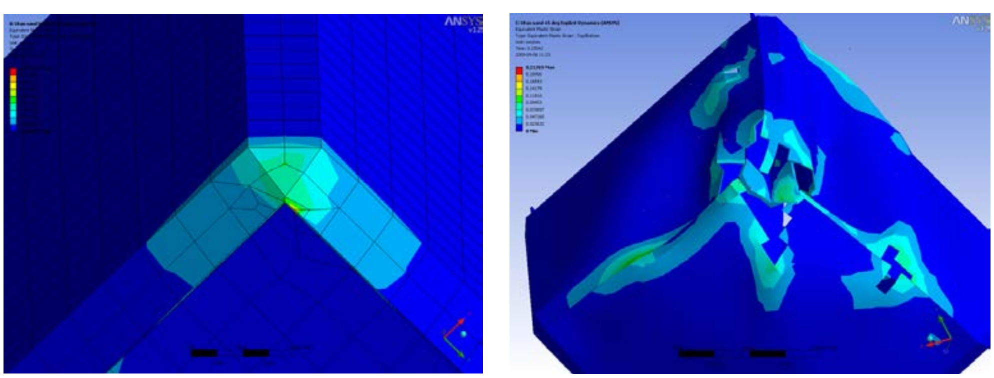

Fig. 4. Computer simulation result of drop from 9 meters, left: bottom hit the ground, right: the package hit the ground on the corner (45°angle)

Emergency Preparedness
A salvage container has been designed and manufactured within the project as a preparation in case of an accident when the loaded containers are handled.

CONCLUSIONS

The project has been a success as all objectives set out were fulfilled even though the project became somewhat more complex and time consuming than initially expected.

This new thin wall steel waste container has been tailor-made for the Swedish waste management system and especially the SFR Silo conditions. The concept with low tare weight, high volume efficiency and low density free volume filling material maximizes the payload. The specific concept has been developed taking benefit of experience and findings from decades of operation.

The concept fulfills the Waste Acceptance Criteria for long term storage in a controlled environment and final disposal in SFR and is expected to be licensed for disposal within 2014.

REFERENCES

1. The Swedish Radiation Safety Authority's Regulations concerning Safety in Nuclear Facilities, SSMFS 2008:1
2. Acceptanskriterier för avfall i SFR (Acceptance criteria for waste in SFR), SKB report 1336074
3. SKB avfallshandbok (Waste Management Handbook), SKB report 1195328
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