Radioactive Waste Packaging of Conditioned Waste at Kozloduy NPP Site

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ABSTRACT

An important part of Safety Management of conditioned low and intermediate level Radioactive Waste (RAW) is their packaging and containers for transport, storage and final disposal. A reinforced concrete container (RCC) has been developed to take cemented super compacted dry waste and cement solidified liquid waste at Kozloduy Nuclear Power Plant (KNPP). The container is to be used as a packaging of transportation, storage and final disposal of RAW conditioned by cementation

KNPP specialists constructed and performed tests on the container. These tests were possible thanks to a review of European Community States experience, USA experience and IAEA documents. The container was tested by a team of specialists from KNPP, project specialists, fabricator of the containers and from Bulgarian Regulatory Body under IAEA Safety Standards, Safety Series, TECDOC, TRS and Bulgarian Standards. An expert from IAEA was a member of the testing group for RCC examinations.

INTRODUCTION

All activities of Spent Nuclear Fuel Management and Radioactive Waste Management at Kozloduy NPP, Bulgaria are carried out under the Joint Convention on the Safety of Spent Fuel Management and on the Safety Management of Radioactive Waste.[1]

The Republic of Bulgaria signed the Convention in IAEA, Vienna, Austria on September 22, 1998.

The Joint Convention is ratified by the Law (promulgated in State Gazette No 42/2000) and is in force in the Republic of Bulgaria as of June 18, 2001.

The objective of RAW Management is to deal with the waste in a manner that protects human health and the environment now and in the future without imposing undue burdens on future generation.[2]
Definition of waste package and packaging are given in IAEA Safety Series No 112[3] as follows:

- • Package shall mean the packaging with its radioactive contents as presented for transport.
- • Packaging shall mean the assembly of components necessary to enclose the radioactive contents completely.

The purpose of safe packaging of conditioned RAW is to ensure protection of humans and the environment from the effect of radiation during the storage and final disposal of the waste.

Both the waste form and container are important for the safety of waste packaging during handling and interim storage, as well as the post closure phase of a repository.[4]

Each waste packaging must meet a general set of criteria in addition to requirements specific to the waste form and waste container. Waste acceptance criteria are applied to waste packages and generally includes as follows:

- Seal integrity;
- Free liquids;
- Gas generation;
- Flammability;
- Radionuclides inventory;
- Fissile mass;
- Decay heat;
- Radiation dose rate and surface contamination;
- Configuration and weight;
- Identification mark[5]

There is not any repository in Bulgaria for final disposal of RAW from NPP.

REINFORCED CONCRETE CONTAINER USE AT KOZLODUY NPP

The basic concept underlying the Reinforced Concrete Container System is to achieve stability of the RW Disposal facility. RCC modules are used to create a structurally stable package around every waste container shipped to the disposal facility.

RCC package is constructed in the shape of a cub. It has a main body and a lid.

A ferro-concrete used is a Bulgarian material with additives used in its manufacture to ensure firmness and to reduce water penetration. A sample of the supplied material had a density of 2.23 g/cm^{-3}. The reinforcement in the concrete is provided by steel reinforcing bars of approximately 12 mm diameter in a standard square mesh pattern, but without welds at the intersections to minimize corrosion.

The steel for RCC body is type BCt3PC, class AI, Bulgarian Standard 2592-71. The steel in the lid is type 35 GC, class AIII and St3, class AI.

The RCC concrete is class B 25 with micro silica powder added.

RCC is equipped with four hooks in the upper four corners of the body to facilitate transportation and handling. To permit stacking the base has four corresponding box indentations to accommodate the hooks.

The formulation of the concrete includes combined usage of active mineral aggregates, which elevates the corresponding compression strengths from 25% to 75% (over 40 MPa on the 28th day) and water permeability from 2 to 7 times compared with conventional cement mixtures. The lid of RCC has a port in the center for filling.

The construction of RCC allows the lid to be welded to the body and sealed so that the conditioned waste rests reliably and safety isolated from the population and environment.

RCC has a special external and internal coating depending on the chemical properties of conditioned waste. It has a resistant to alkalis hydroxides, acid and corrosion.

All four external walls of each container are marked with an embossed mark containing identification number and a radiation symbol.

Each container has a certificate of compliance, guaranteeing the program to ensure quality production and handling of RCC.

RCC is manufactured according to “Technology for production of RCC” and “Quality Assurance Programme”, documents and Bulgarian Design Standards.

The container has been licensed for transportation, storage and final disposal of conditioned RAW by the Bulgarian Regulatory Body under Council of Ministers, standardised as a Bulgarian Standard OH 01 85755-92.

The RCC is the property of Kozloduy NPP.

Characteristics of RCC

The general characteristics of RCC are the following:

1. RCC has a body and a lid;
2. External dimensions 1,95 $\times$1,95 $\times$1,95 m;

3. Thickness of the bottom of the RCC is 140 mm, of the walls from 100 mm to 140 mm, of the lid – 80 mm;
4. Weight (empty) – 6 tones;
5. Full container with cemented RAW weights up to 20 tones;
6. The storage capacity is 5 m^3, correspondingly the storage capacity/total volume ratio is 67,4%,
7. Depending on the radionuclide content of the waste packages, the maximum contact dose rate of full RCC by conditioned RAW must be as follows:
    a. RCC surface contact – lower than 2 mSv/h;
    b. RCC surface 1 meter distance – lower than 0.1 mSv/h.
8. RCC has a waste disposal life – up to 300 years.

Scope of RCC Tests

RCC has a comprehensive testing program. The goal of the program is to demonstrate the properties of the container as a transport package and as a package for storage or disposal of conditioned radioactive waste.

The storage and disposal part of the program includes:

1. Influence of mechanical factors:
    a. resistant to corrosion;
    b. strength of material.
2. Atmospheric effects:
    a. stacking four high;
    b. thermal and humid expansion.
3. Vibrations:
    a. seismic tests at Kg = 0.15 g.
4. Shock load:
    a. crushing of the container walls at drop.
5. Thermal factors:
    a. fire, low temperature, thermal shock.
6. Chemical factors:
    a. resistance to decontaminating solutions;
    b. resistance to negative electrochemical charges occurring in case of fire.
7. Water infiltration:
    a. water tightness;
    b. water resistance.
8. Bacteriological factors:
    a. resistance to mould, bacteria, fungi

The transportation part of program includes:

1. Mechanical factors:
    a. water spray test;
    b. free fall test;
    c. test on compression;
    d. test on penetration.
2. Tests in accident conditions:
    a. drop through 6 m. high;
    b. fire test;
    c. seismic test;
    d. permeability to water.

Basis of Reinforced Concrete Container Tests

The tests of RCC are conducted in according with the requirements of the following documents:

1. IAEA transport regulations, Safety Series No 6;
2. Bulgarian standard OH 01 85755-92;
3. Methods for reinforced concrete container testing;
4. Test Program.

Tests Succession: Criteria for Success

The IAEA Transport Regulation clearly specify the Low Specific Activity (LSA-III) material, industrial packages Type 3 (IP-3) and Type A packages.

The RCC tests were provided in three Sections and its goals were as follows:

I. To prove that RCC can use for transport, storage and disposal of conditioned waste in normal conditions:

1. Radiation shielding test of empty container;
2. Water resistance test of empty container;
3. Watertight test filled by water container;
4. 30 cm free fall test of filled by concrete container (This test and following other free fall tests were performed onto a foundation from 2m thick concrete plate covered by 14mm thick sheet steel.);
5. Stress test of filled by concrete container;
6. Borehole test filled by concrete container.

II. To prove that RCC can bear up against transport, storage and disposal in emergency conditions were made mechanical damage test of the container filled with concrete.

The testing includes 3 different free drop tests of the container filled with concrete as follows:

1. Free fall test of filled container from 6m onto a foundation from 2m thick concrete plate covered with 14mm thick sheet steel;

2. Test for penetration of filled by concrete container free fall from 1m onto test bar by dimensions L=0.20mxD=0.15m±0.05m;
3. Free fall test of metal rod with dimensions 1mx1mx0.20m and weight 500kg onto lid of the container;
4. Fire test container filled with sand.

III. To prove that RCC can bear up against extreme situation:

RCC filled with concrete and the lid welded closed was subjected to the fire test and then penetration tested as follows:

1. Test to penetration;
2. Free fall test from high 0.30m;
3. Free fall test from high 6.0m;
4. Free fall test of a metal rod by dimensions: 1.0mx1.0mx0.20m and weight 500kg from high 6.0m onto the lid of filled container;
5. Free fall test of filled container from high 1m onto test bar by dimensions: L=0.20mxD=0.15m±0.05m.

The criteria for a successful RCC test is that it keeps its mass, its shape and is not dispersion of its content.

IMPLEMENTED TESTS AND RESULTS

Section I.

1. Radiation shielding test
The testing was implemented according to “Test Procedure for radiation shielding investigation of reinforced concrete container for conditioned waste”.

The test on shielding efficiency performance from a point source prior to all these tests constitutes a criterion for the assessment of the suitability of the container. Three containers were investigated.
Conclusion:

- Difference in the exposure rate between RCC should not exceed 20%;
- RCC protects human health and the environment from conditioned low- and intermediate waste in it.
- The test is successful.

2. A water resistance test
Water was poured over the RCC for 1 hour at speed 5 cm/h.
Conclusion:

- There is not any damage to container.
- The test is successful.

3. A watertight test
The container was filled with water for 48 hours and underwent a side impact after drying its outer walls.
Conclusion:

- After testing RCC has proved watertight.
- The test is successful.

4. A 30 cm fall test
The container was filled with cement mixture (like cemented RAW) and kept 7 days. The mixture had compression strengths greater than 3.5 MPa according to Bulgarian standard OH 0185755 92. The lid was installed and welded closed. The weight of the container was 17060 kg. The sample falls from 0.30m high according IAEA regulations. The weight of CCR is 15 000 kg onto the foundation.
Conclusion:

- RCC kept his entirety.
- The test is successful.

5. Penetration test
A metal rod with dimensions L=1mxD=0.032m and weight 6 kg falls onto the lid of RCC from a high of 1m, 1.5m and 1.7m. After testing light tracks of the impact maybe seen on the lid of RCC.
Conclusion:

- After testing RCC kept its integrity.
- The test is successful.

6. Compression test
Three RCC with common weight 34 460kg were stacked on top the other. After 48h the containers were unstacked and ground level RCC examined for damages.
Conclusion:

- The container kept its integrity.
- The test is successful.

Section II.

Mechanical damages tests

Purpose of the tests is to insure that RCC can sustain accident conditions for transportation, storage and disposal of conditioned waste.

Three different drop tests were conducted as follows:

1. Drop test from 6.00m
The full concrete container falls onto a foundation from a high of 6 m. The 6 m height is based upon stacking four containers on top of each other in the storage facility. There were some small damages on one side and the base of the RCC. The lid, sides and base are strong after testing.
Conclusion:

- RCC kept his entirety and there is not any waste out of the container.
- The drop test is successful.

2. Penetration test
A filled RCC was drop from height of 1m onto metal rod L=0.20mxD=0.15m which was fixed vertically in to a foundation. No damage other than a light mark was found after inspection.
Conclusion:

- The sample kept its integrity.
- The test is successful.

3. Dynamic destruction drop test
A metal body by dimension 1mx1mx0.20m and weight 540 kg. falls from 6m onto the lid of concrete filled RCC.

After testing there was no damage on the lid of container.
Conclusion:

- RCC kept his entirety.
- The test is successful.

4. Fire test
RCC was filled with sand simulating cemented radioactive waste and put in a bathtub with 220l of diesel fuel. The fire enveloped the bottom and four sides of the container with flames no higher than 3m for 30 minutes. The temperature attained during the burning of the diesel fuel was 1100-1200 ^{0}C.

After putting out the fire small damages was observed on the surface of the concrete walls. There were no cracks in the lid or walls of tested sample.
Conclusion:

- RCC kept its integrity.
- The test is successful.

Section III.
The purpose of the test is to demonstrate the RCC can sustain extreme conditions. After a successful fire test, the sand was removed from the RCC. The TCC was filled with concrete and cured for one day. The lid was installed and welded closed. The following tests were implemented:

1. Penetration test
A metal rod with dimensions L=1mxD=0.032m and weight 6 kg falls onto the lid of RCC from a height of 1.00m, 1.50m and 1.70m. After testing light tracks of the impact may see on the lid of RCC.
Conclusion:

- After testing RCC kept his integrity.
- The test is successful.

2. Free drop test from 0.30m
The Sample is dropped from 0.30m onto a foundation. After testing insignificant damages on the lower edge of side “C” dimension L=0.25mxH=0.10mxdepth=0.03m may be seen.
Conclusion:

· RCC kept his integrity.
· The test is successful.

3. Free drop test from 6m
The RCC was dropped from a height of 6m onto a foundation. After testing there were four broken lower edges of the four sides only.
Conclusion:

· RCC kept his integrity.
· The test was successful.

4. Free drop test
A body with dimensions: 1.00mx1.00mx0.20m, weight 540 kg was dropped from 6 m onto the lid of the RCC

There were no damages to the lid of the RCC upon examination.
Conclusion:

· RCC kept his integrity.
· The test is successful.

5. Penetration test
A burned and filled by concrete sample was drop from high 1m onto a metal rod D=0.32m, weight 6kg from 1.00m, 1.50m and 1.70m which was fixed vertically into a foundation. A light mark was found after inspection on the bottom of RCC.
Conclusion:

· The container kept his integrity.
· The test is successful**.**

GENERAL CONCLUSIONS*:*

1. The reinforced concrete container was designed as a transportation and a radioactive LSA III package according Safety Series No 6 for storage and final disposal of conditioned RAW;

2. RCC has passed all the tests included in the methods for testing IP-3 industrial packages, as well as an extra fire test, free fall test from 6 m, seismic test, specified for testing a Type A package under accident transport conditions according IAEA recommendation in Safety Series No 6;

3. Transport index is from 1 to 10 and max activity content is 0.1 TBq according to requirements of Bulgarian standard OH 0185755 92 and IAEA recommendation;

4. Activity of cemented waste in RCC– up to 0.1 TBq1;

5. RCC provides an integrated approach to the handling, packaging and disposal of conditioned low and intermediate RAW from NPP with VVER type reactors.

The Nuclear Regulatory Body of the country has issued a license for the RCC as a radioactive waste burial container for class A waste accordance with Safety Series 6 recommendations for transportation, storage and final disposal.

All test examples of containers were photograph and video filmed. They are shown as photos on the poster desk.

Final Cemented Product Requirements

The liquid waste solidification system end product meets or exceeds requirements of national regulatory body and recommendations of the International Atomic Energy Agency.
They are as follows:

1. Compressive strength - the compressive strength of the cemented waste to reach a minimum level of 3.5 MPa after 28 days curing and 20 ^{o}C±1 ^{o}C and greater than 90% relative humidity;

2. Thermal cycling – after curing for 28 days at 20 ^{o}C±1 ^{o}C and greater than 90% relative humidity and for a total 30 cycles at the temperatures between +60°C and –15° C the compressive strength of product should be greater than 3,5 MPa;

3. After 90 days stay in de ionized water the samples should not lose compressive strength more than 10%;

4. Cobalt – 60 and cesium - 137 leach ability – after curing 28 days were tested in accordance to the ANS/ANSI 16.1 leach testing method and it must be less than 3.0 E –3 g/cm^{3}d.

Kozloduy NPP Storage Facility

A new temporary storage facility for conditioned liquid and solid waste at Kozloduy NPP is built close to RAW Treatment Plant. The facility has a capacity to provide a safe storage of 1920 RCC filled with conditioned RAW for 30 years. It is constructed to be 72 m long and 37 m wide. The containers are stacked four height, 8 rows in width and 30 rows in length in each of the two halls. The floor and the walls of the facility are epoxy coated. The foundation slab is 1 m thick and is calculated to bear the load of containers stacked four height.
All operations are performed by two cranes with lifting capacity 25-tones each. Remote controls are supplied to grapple the containers and place them in storage. The containers are arranged according to their activity.

The positioning of the containers is computer controlled by the operators via monitors and cameras in control room.

The report for the conditioned and stored RAW is being done by “Information system for control of the processes of treating and storing the RAW”.

Special attention is paid to maintain a watertight roof and foundation slab. A drainage system for control and collection of leaks is foreseen. The floor of the facility is above grade level. Any water on the floor is collected by the drainage system and routed to a tank. Then it is pumped to a tanker-trailer and transported to a treatment facility. Heating and conditioning is not provided due to characteristics of the stored waste.

Maximum dose rate at a distance of 1m from the storage facility must not exceed 28 μSv/h.

The RW Treatment plant and the storage facility are located on the NPP guarded site.

The view of storage facility was displayed during the Poster session.

REFERENCES

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