QUALIFICATION TESTS FOR A TYPE B (U) PACKAGE

G. Vieru
Institute for Nuclear Research
0300 Pitesti, P.O.Box 78, Romania

Abstract - The primary objective for the safety of radioactive materials transport is to protect human health and the environment taking into consideration its potential risks and radiological consequences ([1, 2.])
Romania as a Member State of the International Atomic Energy Agency has implemented national regulations for the safe transport of radioactive materials (RAM) in accordance with the Agency's recommendations as well as other international specialized organizations.
The paper will describe the qualification tests performed for a type B (U) package, intended to be used for the transport of the radioactive sources Am-241 and Cs-137. For this kind of package the tests were performed the first time in Romania and include: *the water spray test, the 1.2 m free drop test, the stacking test, the penetration test, the 9m free drop test, the thermal test and the submersion under a head of water of at least 15 m.*
The test facilities used for performing qualification tests for the type B (U) package as well as experience and conclusions will be also presented.

INTRODUCTION

Packages of radioactive materials must have the capability of retaining their contents under routine and accident transport conditions [(2, 3, 4)]. The Regulations provide package test requirements and post-test acceptance requirements that provide us with a means of predicting the field performance of the package.
The post-test acceptance criteria to be met by the package design during and following the normal conditions of transport are [(1, 3, 6)]:

- Prevent the loss of its radioactive contents to no more than 10^{-6} A_2 per hour, according to the paragraph 656 (a) of the TS-R-1 IAEA Regulations;
- Prevent the loss of shielding integrity that would result in more than a 20% increase in the radiation level at any external surface point of the package according to the paragraph 646 (b) of the TS-R-1 IAEA Regulations.

The type B (U) package is made from steel and has the following dimensions:

- Height, H = 576 mm;
- Diameter, Φ = 220 mm;
- Weight (empty) = 35 kg; weight (with contents) = 95 kg

The O-ring seal in the lid is made from copper and has a diameter of 232 mm.
The radioactive sources to be transported – **^{137}Cs** and **^{241}Am** have the following characteristics:
Activities:

- ^{137}Cs – 1,122 GBq (30,4 mCi);
- ^{241}Am – 37 GBq (1 Ci)

Capsules:

- ^{137}Cs is encapsulated in a capsule model PHILIPS (The Nederland) type Q 4674;
- ^{241}Am is encapsulated in a capsule model OHMART – US, type BG-60

The package is designed to contain five ^{137}Cs radioactive sources or three ^{241}Am radioactive sources, each encapsulated as described above.

QUALIFICATION TESTS FOR DEMONSTRATING ABILITY OF THE PACKAGE TO WITHSTAND NORMAL CONDITIONS OF TRANSPORT

Type B (U) packages must be designed to withstand the normal conditions of transport tests specified in the Regulations. Those tests, and the response of a Type B (U) package design to them are described in detail in this section.
The qualification tests and the post-test acceptance criteria are equivalent to those which apply to the Type A packages, except that the quantitative criteria given above is specified for the allowable release of the activity for type B (U) packages.
For the purpose of the test the content of package was simulated with sand and lead so the total weight of the specimen prepared for the qualification tests was 95 Kg.

The sample to be subjected to the qualification tests is shown in the Figure 1:

Figure 1. The type B (U) package

The water spray test

This test was performed in accordance with paragraph 721 of TS-R-1 and was conducted using the same sample before each of other normal conditions of transport test, according to the paragraph 719 of TS-R-1: the free drop test, the stacking test and the penetration test. The water spray test has to be applied for at least one hour.
The specimen was placed on a flat horizontal surface, in whichever orientation is likely to cause most damage to the package. A uniformly distributed spray was directed onto the surface of the package for a period of 15 min from each of four directions at right angles and changes in spray direction have been made as rapidly as possible.
The water spray test simulated rainfall at a rate of approximately 5 cm per hour and lasted two hours. The specimen being subjected to the water spray test is shown in Figure 2:

Figure 2 the type B (U) package subjected to the water spray test

After the test the lid of the specimen was removed and no water was found inside the package.

Stacking Test

In the stacking test, according to paragraph 723 of the TS-R-1 Regulations, the sample is required to withstand for a period of 24 hours, a compressive load equal to the greater of five times the mass of the actual package (approx. 95 Kg) or the equivalent of 13kPa multiplied by the vertical projected area of the package.
The specimen being subjected to a compressive load of 1,000 Kg for a period of 24 hours is shown in Figure 3:

Figure 3 the type B (U) package subjected to the stacking test

This test is designed to simulate the effect of loads pressing on a package over a prolonged period of time and is intended to ensure that the effectiveness of containment and shielding is maintained when the package is submitted to the kind of environment that is likely to be sustained by having other packages stacked on top.
After the test, the package was visually inspected and no damage or change that would affect the configuration was observed.

The penetration test

This test is intended to demonstrate the capability of the package to withstand the kind of puncture environment that may arise in normal transport from such causes as sharp objects as well as from loading hooks [7, 8]; the penetration test is designed also to ensure that the contents will not escape from the containment system or that the shielding of confinement system would not be damaged if a slender object such as a length of metal tubing or a handlebar of a falling bicycle should strike and penetrate the outer layers of the packaging.
According to paragraph 724 of TS-R-1 Regulations, a 6 kg metal bar having a 32 mm diameter hemispherical end is required to be dropped onto the type B (U) package from a height of 1 m. The specimen was placed on a rigid, flat horizontal surface. The area of the sample subjected to the test is shown in Figure no. 4:

Figure no. 4 the type B (U) package after the penetration test

The direction and the point of the impact were chosen in such a way to produce maximum potential damage to the containment system.
After performing the test the package was subjected to a visual inspection and no damage or other physical deterioration were observed. The containment was maintained and no evidence of loss of contents was observed.

1.2 m free drop test

The free drop test is designed to produce the kind of damage that is likely to be sustained by some packages during normal handling from minor drops and shocks. According to the TS-R-1 Regulations, the specimen shall drop onto a target so as to suffer maximum damage in respect of the safety features to be tested. The height of the drop was measured from the lowest point of the specimen subjected to test to the upper surface of the target [1, 3, 7, 8].
Paragraph 722 of TS-R-1 Regulation and Table XIII of TS-R-1 Regulations indicate a free drop distance of 1.2 m for packages having a mass smaller that 5,000 kg. The target for the drop test was a flat horizontal surface of such a character that any increase in its resistance to displacement or deformation upon impact by the specimen would not significantly increase the damage to the specimen. The package being subjected to the 1.2m free drop test is shown in Figure 5:

Figure 5 The 1.2 m free drop test for the Type B (U) package

After the test was performed a visual inspection was done. No serious damage or dispersal of the simulated radioactive content was observed. The simulated content was maintained intact.

TEST FOR DEMONSTRATING ABILITY OF THE PACKAGE TO WITHSTAND ACCIDENT CONDITIONS OF TRANSPORT

The accident conditions of transport are prescribed in terms that provide the engineering basis for the design. Since analysis is an acceptable method of qualifying designs, the tests are prescribed in engineering terms that could serve as unambiguous, quantifiable input to these calculations [1, 3, 9].
The accident conditions of transport test consist of a sequence of mechanical tests, a thermal test and a submersion test.

Post - Test Acceptance Criteria

In order for a type B (U) package to pass the accident conditions of transport test series, it must, according to the paragraph 669 (b) of TS-R-1 Regulations:

- Restrict the accumulated loss of its radioactive contents, in a period of one week following the test procedure, to not more than A_2 (or $10A_2$ in case of 85Kr); and
- Not allow the radiation level at 1m from the package surface to exceed 0,1 mSv/h.

Note: Accidents of the severity simulated in the accident conditions of transport tests specified in the Regulations are unlikely to occur in a confined indoors space.
For an accident occurring out of doors, the maximum allowable release in a period of one week from a type B package is A_2, or $10A_2$ for ^{85}Kr (see also paragraph 656-b-ii of TS-R-1). In this situation, the radiological consequences may be expressed as an equivalent dose limit by considering the exposure to a person remaining continuously downwind of the damage package throughout the period of the release. In practice, it is unlikely that any accidental release would persist for a full period of one week due to effective remedial actions taken by the emergency services personnel to limit the release of activity within a period a few hours. The maximum effective dose via inhalation to person exposed in the range of 50-200m may increase by a factor of about 5 under generally less probable and persistent stable meteorological conditions [11].
After completion of relevant tests, the integrity of containment and shielding must be demonstrated by a direct leak-test with due allowance made, if necessary, for scaling. Direct measurement of shielding system integrity by means of a radiation source applied before and after the test to the package cavity is the most obvious means of determining the extent to which shielding has degraded. To determine the system integrity of the package during performing of the qualification tests for the above type B (U) package – full scale, a ^{137}Cs source of 370MBq (10 mCi) was used

Mechanical tests

According to paragraph 727 of TS-R-1 Regulations, the mechanical tests consist of three different drop tests, only two of which are required to be applied to a given package design. Because the package being tested was not of the light weight/low density category, the 1 m free drop onto a punch and the 9 m drop onto a target are the two tests required. The order must be chosen to produce the most damaging final effect with respect to the ensuing thermal test.
To test the package the two-drop tests were performed:

- The specimen was dropped from a height of 1m onto the top face of a rigidly mounted 150-mm diameter mild steel bar. The top face of the bar was flat and the edge was rounded to a radius not more than 6 mm. The bar was 20 cm long [1, 2, 3, 8];
- The specimen was dropped from a height of 9 m onto the unyielding target such as to suffer maximum damages

The 1 m free drop test was performed onto the steel bar mounted on the unyielding target.
The specimen being prepared for the 1 m free drop test onto the punch is shown in Figure 6:

Figure 6 the type B (U) container subjected to the 1m free drop test.

After the test, a visual inspection of the package was made and no damage or loss of the content was observed.
The 9 m free drop test was performed onto the unyielding target as shown in Figure 6 (the rigidly mounted 150 mm diameter mild steel bar was removed) and the specimen subjected to the test is presented in Figure 7:

Figure 7 the type B (U) container during performing the 9 m free drop test

After the test, a visual inspection of the package was made and no damage, deterioration or loss of the content was observed.

Thermal test

Prior to the performing of the thermal test, as defined in the paragraph 728 of the TS-R-1 Regulations, the specimen must be in a thermal equilibrium under conditions of an ambient temperature of 38° C.
It must be subject to certain solar insulation conditions as well as subject to the design level of the maximum rate of internal heat generation within the package from the simulated radioactive content.
Alternatively, any of these parameters are allowed to have different values prior to and during test, providing due account is taken of them in the subsequent assessment of package response.
In accordance with the para. 728 of TS-R-1 Regulations, the type B (U) package, "*have to be exposed for a period of 30 minutes to a thermal environment which provides a heat flux at least equivalent to that of a hydrocarbon fuel/air fire* [1, 3, 8, 9] *in sufficiently quiescent ambient conditions to give a minimum average flame emmisivity of 0.9 and an average temperature of at least 800 °C, fully engulfing the specimen with a surface absorptivity coefficient of 0.8".*
Alternatively, any of these parameters are allowed "*to have different values following cessation of heating provided that due account is taken of them in the subsequent assessment of package response".*
The specimen being subjected to the thermal test, fully engulfed by fire is shown in Figure no. 8:

Figure 8 the type B (U) container during performing of the thermal test

To measure the temperature a pyrometer model Raytek Marathon- RAYMA was used.
During and following the test, the specimen was not artificially cooled so any combustion of materials of the specimen has been permitted to proceed naturally.
No damage or loss of the content was observed after the visual inspection.

Immersion test

As a result of transport accidents near or on a river, lake or sea, a package could be subjected to the submersion under water [2, 3, 8]. The purpose of this test is to demonstrate the structural integrity of the package under external pressure of a head of water of at least 15 m for a period of not less than eight hours in the position that will lead to maximum damage.
The immersion test was performed under the water of the VIDRARU Dam Lake for a period of 10 hours, at 15m deep below the level of the water of the lake. The specimen being subjected to the immersion test is shown in Figure 9 and Figure 10:

Figure 9 the preparing of the immersion test

Figure 10 the performing of the immersion test at VIDRARU DAM Lake

After test the sample was examined visually. There were observed no deformation or other damage. The period of 10 hours was sufficient to allow the package to come to a steady state from any rate-dependent effect of immersion, such as compartment flooding. The lid was removed and no water was found inside. The integrity of the shielding and the content was maintained.

CONCLUSION

The qualification tests for a type B (U) package were performed for the first time in Romania. Our experience and the results obtained were used by Romanian Nuclear Regulatory Body (CNCAN) to qualify and certify the first Romanian Type B (U) package manufactured by ***SC MOPAF Focsani-Vrancea***, to be used for the transport of radioactive materials, e. g. radioactive sources. It is to be noted that the package met all the requirements in accordance with the Romanian and IAEA Regulations for a safe transport of the radioactive materials.

REFERENCES

1**. International Atomic Energy Agency**, ***Regulations for the Safe Transport of Radioactive Material, 1996 Edition (revised***), IAEA Safety Standards Series, No. TS-R-1 (ST-1, Revised), Vienna, IAEA, (2000;

2. International Atomic Energy Agency, ***Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material***, IAEA Safety Standards Series, No. TS-G-1.1 (ST-2), Vienna, IAEA, June 2002;

3**. International Atomic Energy Agency**, ***Safe Transport of Radioactive Material***, Third Edition, Training Course Series 1, Vienna, IAEA, 2002;

4. G. Vieru, ***Some Aspects Regarding the Qualifications Tests of Packaged Used for Transport and Storage of Radioactive Waste (low activity) in INR Pitesti***;
International Atomic Energy Agency, IAEA-TECDOC- 802, IAEA, Vienna (1995);

5. G. Vieru, ***Safety criteria for the transport and storage of the Radioactive Materials, in Romania***, Romanian Nuclear Program, Internal Report, INR Pitesti, Romania, (2001);

6. G. Vieru, ***Risk and Safety Evaluation in Radioactive Waste Transport in Romania,*** **RAMTRANS, Vol. 10, No. 2, pp. 105-112, *London, UK*, (1999);**

7. G. Vieru, ***Test Facilities for Radioactive Materials Transport Packages in Romania (SCN Pitesti),*** **RAMTRANS**, ***Vol. 12, Nos. 2/3, pp. 129-134, (2001), Nuclear Publishing Technology, London, UK (2001);***

8. G. Vieru, ***The Identification and the approach of the risk and safety problems associated with the transport of radioactive materials in Romania***, Romanian Nuclear Program, Internal Report, ***INR Pitesti, Romania***, **(2002**);

9. Goldfinch, *E.P., Macdonald, H.F.**, Dosimetric aspects of permitted activity leakage rates for Type B package for the transport of radioactive materials*, **Radiation Protection Dosimetry 2 (1982);**