Considerations on Safe Packaging and Risk Assessment Associated With Transportation of Nuclear Radioactive Wastes to the Disposal Center in Romania

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INTRODUCTION

Growing concern and awareness, and potential risks to human health and to the environment posed by radioactive waste, its management and disposal (temporary or final), have become important issues to consider in the use of nuclear materials. Romania, like other Member States, has adopted IAEA Transport Regulations on the safe transport of radioactive material (IAEA, Safety Series No.6) as a basis for national regulations and for application to international radioactive material transportation. One of the most important basic tenets is that safety mostly relies on the package used and does not take into consideration the contribution to safety which may be made by other features of the transport operation, such as conveyance.

If referring to Type A packages, they are required to be capable to resist routine and accident conditions of transport without loss of their contents or without allowing more than a specified increase in external surface radiation and must be designed to meet additional test requirements if the radioactive contents are under the form of a liquid or gas (INR Pitesti 1990).

QUALIFICATION TESTS FOR TYPE A PACKAGES USED FOR TRANSPORT AND STORAGE OF LOW ACTIVITY RADIOACTIVE WASTES

The qualification tests performed for Type A packages used for transport and storage of radioactive waste are described in the sections that follow. The package tested is a drum, made of 1.5 mm -thick stainless steel with a volume of about 200 l. Type tests requirements constitute the compulsory minimum specifications for the manufacturer (INR Pitesti 1990) and were performed by the Reliability and Testing Laboratory of INR Pitesti. The following qualification tests were performed (Vieru 1994).

The mechanical test (free drop test)

The test was performed 2 h after the end of the water spray test which lasted 1 hour. The drop height was 1.2 m. After the test, the drum was visually inspected and no damages were observed.

Stacking test

Before testing, the drum was subjected to the 1 hour water spray test. After 2 hours, the stacking test was performed. The requirements to withstand for a period of 24 hours at 5 times the package weight (1,000 kg) were fulfilled. No damages were observed.

The penetration test

The test was performed after 1 hour water spray test, 2 hours later. A 6-kg steel bar with 32-mm diameter having a hemispherical end was dropped from a 1-m height on the surface of the package. After a visual inspection, no significant damages were observed.

The thermal test

The thermal test was performed in accordance with para. 2 of the Romanian Regulations for Transport of Radioactive Materials and para. 628 of the IAEA Regulations, Safety Series 6. The drum was fixed at 1-m height from the fire source (gasoline and wood). For 30 minutes the temperature was about 800°C, and after that it was raised at about 1050°C, when the lid of the drum jumped off. This fact helps us in improving the design for a safe packaging. After 30 minutes of burning of the contents (compacted paper) the drum was cooled naturally, which lasted about 3 hours. This thermal test was performed for the first time in Romania (Vieru 1995).

There were not observed any deformations of the drum. The emissivity coefficient was in the range 0.78 ± 0.1, and the absorbity coefficient was in the range 0.8 ± 0.1.

APPROACH OF RISK ASSESSMENT ASSOCIATED WITH TRANSPORTATION OF RADIOACTIVE WASTES TO THE DISPOSAL CENTER IN ROMANIA

Since 1985, low specific activity radwastes from Romania have been transported and stored in the disposal site, Baita.

Radioactive wastes are generated by nuclear research at the Institute for Nuclear Research (INR) Pitesti and at the Institute of Atomic Physics (IAP) Bucharest. Since 1985, a quantity of 5,100 drums (1230 m^3 of radwastes) has been stored on this site. The transportation of radwaste is performed under the authority of The National Commission for Nuclear Activities Control (CNCAN), which issues a special authorization. Two different classes of packages are used for transportation of radwastes : (a) the 200-l drum

manufactured of 1-mm-thick mild steel (This package is mostly used as Type A package for transport and storage of low activity waste), and (b) the 200-l drum manufactured of 1.5-mm-thick stainless steel and intended to be used for transportation and storage of the waste generated by NPP Cernavoda.Determination of the frequency of accidental conditions is undertaken by consideration of transport-specific or site-specific data or, if applicable, generic equipment failure and human error data using reference sources (Ericsson and Elert 1983; Blythe et al. 1986).The assessment route (by road), Bucharest to Baita, consists of 110 km of motorway, 37 km of unclassified road, and 459 km of national roads. Referring to population density (IAEA TECDOC-287-1983) information, there were defined three categories: urban, intermediate and rural.The percentage were (National Commission for Statistics 1993) : 5 % of the route is through urban areas, 45 % through intermediate areas, and 50% through rural areas.
For radiological accident consequence calculations, three sites were located, along the total route: urban-Ramnicu-Valcea; intermediate-Olt Valley; rural-Apoldu de Sus.The following typical population densities/km² were assumed: rural : 40; intermediate : 45; urban : 330, for different radii (1 km, 5 km, and 10 km).

During incident-free routine transport, the radwaste package external dose field might result in small radiation doses which may affect workers and members of the public. These doses are applicable to the followings groups of people:

- Members of the public located alongside the route
- Members of the public using roads at the same time with trucks carrying radwaste
- Members of the public being accidentally near the package
- Transport workers from only off-site transport.

To determine the probabilities and collective doses, specific input data were used and the IAEA Regulation limit of 0.1 mSv/h at 2 m from the vehicle is applied.

Road Transport Results

The collective doses assessed, assuming 10 journeys per year, are as follows :

- Dose to public alongside route : 0.75 x 10 E-3 man Sv/y
- Dose to public during stops : 1.12 x 10 E-6 man Sv/y
- Dose to package truck crew : 1 x 10 E-3 man Sv/y
- Dose to public sharing route : 0.3 x 10E-4 man Sv/y

The total annual collective dose to members of the public of *0.58 x 10 E-3 man Sv/y* can be compared with what they receive due to naturally occurring sources of radiation- 5μSv/d (0.5 mrem /d). The number of people exposed calculated from these areas is about 22,050 (therefore the annual collective dose from natural radiation is about 40.24 man Sv/year). The additional collective dose due to package movements is an insignificant percentage over this natural background level (0.00017 %). Assuming a risk factor of 0.06 Sv-1, the annual collective dose to members of the public, corresponds to 0.34 x10E-4 expected fatalities/y due to routine transport doses (Birch 1992).

Referring to individual dose and the associated latent cancer fatality risk, the following formula was used (Birch 1992):

$$D = NK\pi d^{-1}v^{-1} + NRKtd^{-2} \qquad (1)$$

where : *N* - No. of transportation /year; *K* - dose rate at unit distance;
d - perpendicular distance from package center to line of travels;
R- shielding factor; *t* - stop exposure time; 30 s; *V*- speed of truck.

The calculated value is : *D = 0,25 μS/y.* Thus, the corresponding latent cancer fatality individual risk is : *1.2 x10E-8/y.* If we consider a person exposed in a traffic jam, then the individual dose is determined by using the following formula (Birch 1992) :

$$D = NRKtd^{-2} \qquad (2)$$

where : *N*-number of shipments / y; *K*-dose rate at 1 m; *d*-distance from package center; *R*-shielding factor; *t*-stop exposure time;
The calculated value was : *D =10 μS/y* and he corresponding latent cancer fatality risk for this individual is: 1 x10E-7/y .

RISK ASSESSMENT FOR ACCIDENTS ON ROAD TRANSPORTATION OF RADWASTE IN ROMANIA

It is possible to postulate accidents which could compromise the containment or shielding performance of the package. A preliminary risk assessment of road transportation hazards for the route Bucharest - Ramnicu Valcea (170 km), based on probabilistic assessment, was carried out. Hazards were divided into impact hazards and fire hazards, fixed or mobile, as shown below.

Fixed impact hazards: *(a) Underbridges, (b) Overbridges, (c) Roadside Objects / Overturns / Embankments.*

At the speeds associated with road transport, impacts with roadside objects others than those identified above will not threaten the integrity of package and are not considered.

Mobile impact hazards: *(a) Collision with second road vehicle (truck or bus, tanker carrying flammable), (b) Collision with train at level crossing, (c) Collision with train on railway line adjacent to route.*

Package failure could occur in an accident involving impact damage followed by a major fire or in one involving a long-duration engulfing fire with impact damage.

Summarizing, the accident scenarios defined for this assessment are : *(a) impact with bridge support, (b) collision with second road vehicle or with other truck, vehicle, or bus or with a vehicle carrying flammable, (c) collision with train at level crossing, or on railway line adjacent to route.*

Accident probabilities

An important and useful experience has been accumulated in Romania and no significant accidents with radiological consequences were recorded. This experience is not a good basis to be used for the estimation of probabilities of potential accidents with radiological consequences. Therefore, it was necessary to develop accident probabilities using general road transport accident information.

Impacts

Average 1992/1993 fatal or serious accident involvement rates for trucks (National Commission for Statistics 1993) are :

- *Motorway* *3.5 x 10E-6 / (vehicle km)*
- *National roads* *2.32 x 10E-5 / (vehicle km)*
- *Other roads* *4.35 x 10E-6 / (vehicle km)*

Fire

The incidents in which collisions are involved between trucks and other vehicles carrying flammable followed by a fire give an estimated probability of a severe fire due to collision of about 0.017 per year. Assuming that all such collisions are with trucks and not cars, the probability that a truck will be involved in a collision with a tanker carrying petroleum was estimated of about 5.4 x 10E-11 / truck km.

Rail Level Crossing Accidents

Based on number of accidents of level crossing, in 1992 and 1993, and taking into consideration the average distance traveled by all vehicles in this period (excluding motorway) (National Commission for Statistics 1993), the average probability of a level crossing accident was estimated to be of about 1.45 x 10E-9 / (vehicle km).

Unyielding and other surfaces

The Type A packages were tested by dropping them onto unyielding surfaces. Most important is the fact that all the impact energy must be absorbed by the package, not by the test surface. Package damage is taken to be proportional to impact energy, i.e., to the square of the impact velocity.

Route Survey Results

A survey was carried out by INR Pitesti - Reliability and Testing Laboratory of the road route along which packages may be transported. The monitored route was Bucharest-Ramnicu Valcea, 170km. The hazards identified are shown below.

- *No. of Overbridges* : 27(25 having a height < 9m and 2 with height < 15m)
- *No. of Underbridges* : 16 (having a height < 9m, on the motorway route)
- *Other hazards* : - Level crossing : 4
  - Railway along side : 5 Km
  - Brickwall and rocks faces alongside: 0.2 Km / 2m off road
  - Factory/industrial enterprises : 10 m from road

The Approach of the Hazards

a. Impact Hazards

It was assumed that a package will be breached in any impact with impact velocity exceeding that experienced in the drop test. In the absence of other information, a probability of a vehicle leaving the carriageway of 0.5 was assumed here.

b. Underbridges Hazards

During travel alongside the route, there were not identified underbridges with a height greater than 15 m. The surface of the bridges is considered to be hard (not unyielding).

c. Overbridges

The majority of the overbridges identified on the route survey were large structures and the facing material of the concrete bridges will be hard rather than unyielding. A factor is included in the probability calculations to take account of this, such as :

Facing material	**Road type**	**Length (Km)**	**No.of overbridges to be considered**	**Hazard size probability**	**Conditional probability**
Concrete	National	60	20	0.0244	2.44 x 10E-2
	M-way	110	5	0.091	9.1 x 10E-2

d. Collision with a train alongside route

The route runs alongside of a railway line of about 5 Km. The hazard length and the conditional probability are :
Hazard length probability: 0.0016; Conditional probability: 1.6 x 10E-3
The level crossing is controlled with full-width barriers on both sides of the route, and it is not considered in the balance of the probabilities.

The road accident probabilities have been adopted from literature data, in accordance with the situation of Romanian roads (National Commission for Statistics 1993, Birch 1992), as follows :

	M-way	National Roads
• *Impact with bridge support*	*3.07x10E-8*	*1.99x10E-8*
• *Collision with a truck/bus*	*2.222x10E-9*	*2.1x10E-9*
• *Collision with a tanker carrying flammable*	*8x10E-14*	*8x10E-14*
• *Collision with a train at level crossing*	*0*	*8.1x10E-1*
• *Collision with train on railway line along route*	*0*	*3.3x10E-12*
TOTALS : - Impact	*3.292x10E-8*	*2.20114 x 10E-8*
- Impact and Fire	*8x10E-14*	*8x10E-14*

The probabilities of accidents in the above two categories per package journey are :
***a. probability of impact only :* 0.49 x 10E-5 /(package journey)**
***b. probability of impact and fire :* 1.36 x 10E-11 /(package journey)**

Assuming 10 shipments per year, we obtain the following accident frequencies for each category of accident :
a. probability of impact only : 4.9 x 10E-5 / year
b. probability of impact and fire : 1.36 x10 E - 10 / year

CONCLUSIONS

Low activity radwaste arises from Romanian nuclear facilities, are currently transported to and stored at the national depository. The paper describes type tests for Type A packages, and a preliminary risk assessment for road transportation is presented. Accident probabilities, and the frequency of accidents in case of different scenarios assumed are given. The Type A package will survive intact most potential road accidents. The routine transport collective dose was calculated to be 0.58 x10E-3 man Sv/y, is equivalent to 0.34 x 10E-4 expected fatalities, and represents an insignificant increase of 0.00017 % over the natural background dose. The maximum individual dose, in a traffic jam, was determined to be 10μSv/y, which leads to a probable 1x10E-7/y latent cancer fatalities per year.

It is concluded , on the basis of the best estimation of these accident probabilities, that the proposed Type A packages road transport operation would have acceptably low societal, individual, and expected risk values.

REFERENCES

Birch M. *Methodology for Calculating the Annual Population Exposure Dose for Shipments of Radioactive Material by Road and Rail for Incident Free Journeys*, UK TRDP (1992).

Blythe R.A., et al 1986, *Real, as Opposed to Regulatory Requirements, Packaging and Transportation Models* - PATRAM'86, vol. 1, Davos (1986).

Ericsson A, Elert M, INTERTRAN : *A system for Assessing the Impact from Transporting Radioactive Material*, IAEA TECDOC-287, Vienna (1983).

Institute for Nuclear Research, *The Treatment Technology for Radioactive Waste*, INR Pitesti (Internal Document), (1990)

International Atomic Energy Agency, *Regulations for the Safe Transport of Radioactive Material* - 1985 Edition (as Amended 1990), Safety Series No.6,Vienna, IAEA (1990).

National Commission for Statistics, *Romanian Statistical Yearbook*, Bucharest (1993)

Vieru G. *Qualifications Tests of Packages used for Transport and Storage of Low Activity Radioactive Wastes in INR Pitesti*, RAMTRANS, Vol. 5, Nos. 2-4, pp. 279 - 282, Nuclear Technology Publishing, London (1994).

Vieru, G. *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).