REGIONAL DUAL-PURPOSE CASK FOR THE STORAGE AND TRANSPORT OF RESEARCH REACTOR SPENT FUEL

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ABSTRACT

Taking into account that the deadline set for the American program of taking back foreign research reactor spent fuel containing U.S.-supplied enriched uranium – the year 2006, the five Latin American countries operating this type of reactor – Argentina, Brazil, Chile, Peru and Mexico – decided to launch an IAEA-sponsored project aiming at establishing local expertise in managing this material. Among the alternatives for an extended storage of the disused elements, the use of a dual purpose cask for both storage and transport is being seriously considered, due to its appealing advantages: expansion of the plant storage capacity without the burden of costly modifications of the reactor building, flexibility, in that the used fuel can be stored *in situ* or in other facilities outside the reactor site and the preparation of the elements for the future transportation to the final repository.

At the present stage, the cask conceptual design is being developed at the Brazilian participating institutes – CDTN and IPEN. The basic idea is to work on a concept which meets the needs and particularities of each country, in terms of fuel type and dimensions, reactor building handling and transport capabilities, expected spent fuel production, etc, and also be approved by the licensing authorities of all countries involved.

The preliminary concept is of a cylindrical cask with an internal cavity, a basket to hold the fuel elements and external shock absorbers. The main body is a sturdy structure with external surfaces of stainless steel and lead filling, which provides the necessary shielding. A double lid system with gaskets and inspection ports guarantees containment and control over any possible gas leakage. Due to the different fuel types used in Latin American research reactors – both MTR and TRIGA fuels are used – and to allow for the storage and transportation of processed fuel, different internal basket designs will be developed. The external shock absorbers are filled with high density rigid polyurethane foam.

An upper weight cap of 10 t was established for the design in order to preserve the maneuverability of the cask in the different reactor sites.

1. INTRODUCTION

Taking into account that the deadline set for the American program of taking back foreign research reactor spent fuel containing U.S.-supplied enriched uranium – the year 2006, the five Latin American countries operating this type of reactor – Argentina, Brazil, Chile, Peru and

Mexico – decided to launch an IAEA-sponsored project aiming at establishing local expertise in managing this material. Among the alternatives for an extended storage of the disused elements, the use of a dual purpose cask for both storage and transport is being seriously considered, due to its appealing advantages: expansion of the plant storage capacity without the burden of costly modifications of the reactor building, flexibility, in that the used fuel can be stored *in situ* or in other facilities outside the reactor site and the preparation of the elements for the future transportation to the final repository.

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At the present stage, the cask conceptual design is being developed at the Brazilian participating institutes – CDTN and IPEN. The basic idea is to work on a concept which meets the needs and particularities of each country, in terms of fuel type and dimensions, reactor building handling and transport capabilities, expected spent fuel production, etc, and also be approved for use in all countries involved. According to [1], besides some pin-type fuel elements, mostly in critical facilities, the dominant fuel type used in the Latin American research reactors is plate-type (MTR), LEU, oxide fuel (U_3O_8-Al) clad in Al, followed by TRIGA-type (U-Zr-H) rods. Depending on each country option, there will be also a need to transport or to store processed spent fuel elements.

The preliminary concept is of a cylindrical cask with an internal cavity, a basket to hold the fuel elements (processed or not) and external shock absorbers. The main body is a sturdy structure with external surfaces of stainless steel and lead filling, which provides the necessary shielding. A double lid system with gaskets and inspection ports guarantees containment and control over any possible gas leakage. Due to the different fuel types used in Latin American research reactors, both MTR and TRIGA fuels, and, also, the possibility of transportation/storage of processed spent fuel elements, different internal basket design will be developed. The external shock absorbers are filled with polyurethane foam.

An upper weight cap of 10 t was established for the design in order to preserve the maneuverability of the cask in the different reactor sites.

2. AVAILABLE RESOURCES

The conceptual and basic design of a dual-purpose cask for transportation/storage of Latin American research reactors spent fuel elements is being developed at the Brazilian participating institutes, CDTN and IPEN. It can be anticipated that the main efforts will be directed to the basic design of the cask and its systems and to its qualification as a Type B package as established in the IAEA´s Regulations for the Safe Transport of Radioactive Materials [2].

The general safety requirements concern, among other issues, package tie-down, lifting, and decontamination, secure and closing devices, material resistance to radiation and to thermal and pressure conditions likely to be found during transportation. The specific requirements for Type B packages establish the design tests these packages must withstand and the approval criteria.

Finally, the regulations establish requirements that guarantee that fissile material is packaged and shipped in such a manner that they remain subcritical under the conditions prevailing during routine transport and in accidents.

The design tests for Type B packages consist of mechanical, thermal and water submersion tests (Figure I shows schematically the test sequence). In drop test I – intended for packages weighing more than 500 kg or with an overall density greater than 1,000 kg/m^3 (based on the external dimensions) – the package is released in the most damaging orientation from a height of 9 m over a sturdy target (normally a concrete platform covered by a thick steel plate). If a worst-case positioning can not be undoubtedly determined, it is recommended that more than one test be performed. In drop test II, the specimen falls onto a cylindrical steel rod, the striking region being chosen in such a manner that maximum damage is inflicted to the specimen. Drop test III is meant for packages lighter and less dense than the previous ones. A square metallic plate weighing 500 kg is released from a 9 m height over the specimen, which shall be positioned on the platform as to suffer the maximum damage. The thermal test consists of exposing the specimen to a temperature of 800^0 C for a period of 30 minutes, the specimen being then allowed to cool down naturally. Finally, in the water immersion test, the specimen shall be immersed under a head of water of at least 15 m for a period of eight hours, or to an equivalent ambient pressure.

After the test sequence, the specimen must keep its shielding integrity and thermal protection and must present no leakage or, at the most, a very limited contents leakage.

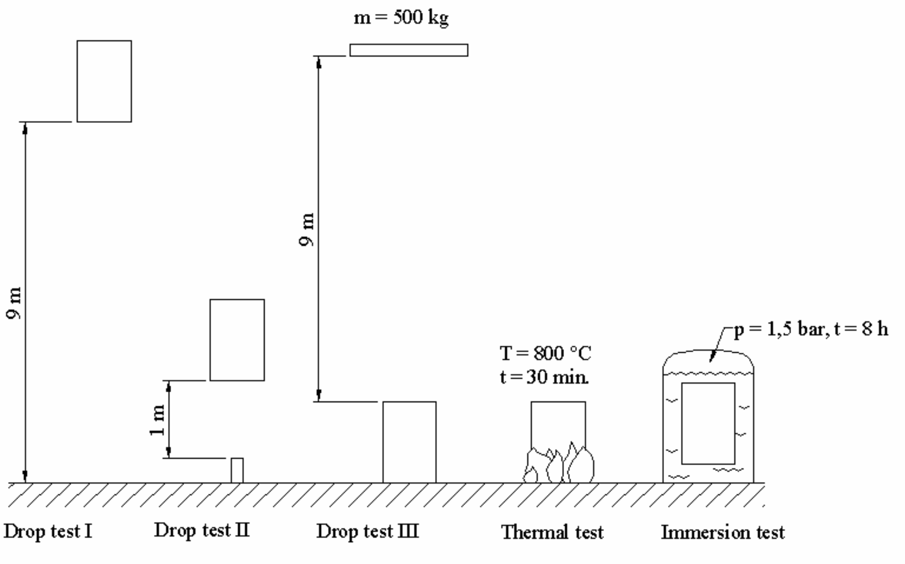


Figure I. Test sequence for Type B packages

The tests prescribed for packages transporting fissile materials are basically the same as those above, but not all of them are applicable to all specimens. In fact, the package designer has to assess and choose the most damaging of the two following test sequences: 1) Drop test I or III (depending on the specimen weight and overall density), drop test II and thermal test; or 2) Immersion test. The criteria for approval establish that one package taken solely, either undamaged or damaged by the tests, and also a specific undamaged and damaged package arrangement, as defined in the regulations, shall be subcritical.

The Brazilian institute CDTN has the basic infrastructure to test Type B package prototypes up to 3 t in weight and maximum dimensions of 2 m. The drop tests I, II and III are carried out on a 3 m x 3m x 4 m concrete platform with a 25 mm thick steel plate on its upper surface, provided with a release mechanism (Figure II) [3].

Concrete platform Release mechanism Control panel

Figure II: CDTN basic infrastructure to test Type B packages

The water submersion test is performed in a pressure tank (Figure III) and the thermal tests can be carried out in industrial furnaces of local foundries [3].

As regards human resources, the two participating institutes IPEN and CDTN have personnel with experience in radioactive materials transport regulations, Type A package design and testing, structural design, instrumentation (accelerometers, strain-gages, thermocouples, load cells), finite elements codes (ANSYS, LS-DYNA, ABAQUS), and criticality analysis (SCALE 4.4A, MCNP). Also extensive research on the use of rigid polyurethane foam as cushioning material in transport package is being carried out jointly by both institutes [3].

This expertise can be made available for the development of a cask concept, should this storage method be chosen for the irradiated fuel elements of the research reactors of the participating countries.

Figure III: CDTN pressure tank for water immersion test

3. CONCEPTUAL DESIGN

As previously mentioned, the preliminary concept is of a cylindrical cask with an internal cavity, a basket to hold the fuel elements (processed or not) and external shock absorbers.

The first shot is a cask to transport and store 17 MTR spent fuel elements from IPEN IEA-R1 research reactor. The main features of the cask are shown in Figure IV and Table 1.

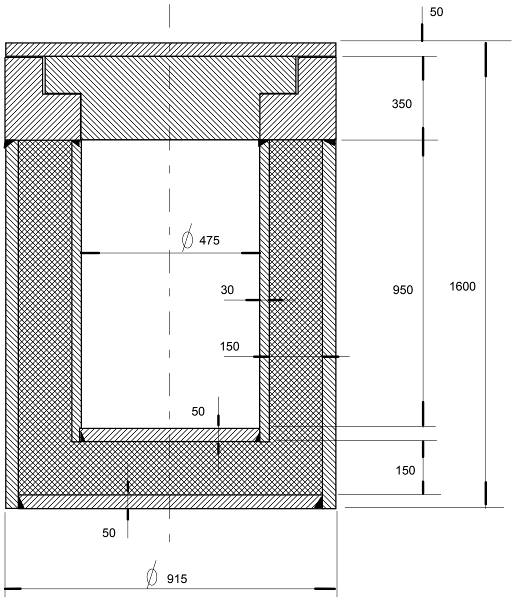


Figure IV: Storage and transportation cask (shock absorbers not shown)

Table 1: Cask materials

Position	Material
Cask body	Stainless steel type 304
Closure lid	Stainless steel type 304
Shock absorbers	Polyurethane foam
Shielding	Lead
Internal baskets	Stainless steel type 304

The materials selection, surface finishing and some design features will follow the recommendations of [4] to consider the main aspects of cask decontamination in its use.

For storage purposes the cask must have systems to dry the cask internal cavity and sealing features to keep it dried. The basic design will follow some prescriptions indicated in [5], [6].

4. QUALIFICATION USING MODELS

Considering an upper weight cap of 10 t established for the design in order to preserve the maneuverability of the cask in the different reactor sites and the available test infrastructure mentioned in section 3. above, it is necessary to use scale models for cask qualification. Based on the total cask mass of 10,000 kg and the limits of test facilities a scale model of 1:2 was selected. This results in a model with mass of approximately 1,250 kg.

5. SHOCK ABSORBER DESIGN

To develop the cask shock absorbers design it was selected polyurethane foam as filling material and the methodology described in [7].

The Janssen factor method [8] was used to estimate the more appropriate polyurethane foam specific mass considering the 9 m free-fall test. The cask diameter is 915 mm thus the cask section is 0.66 m^2. Considering the thickness of 400 mm, the shock absorber volume is V = 0.264 m^3.

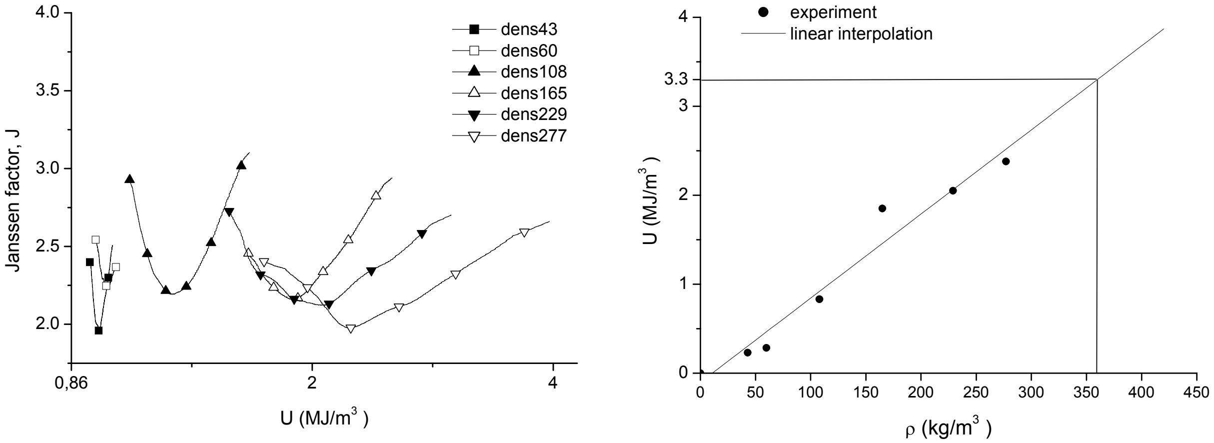
The potential energy in the 9 m free-fall is (g –gravity acceleration)

$$E_h = m\ g\ h = 10000 \times 9.8 \times 9 = 882{,}000\ J = 0.882\ MJ$$

So, the energy to be absorbed by the foam volume is

$$U = {}^{E_h}\!/_{V} = \frac{0.882MJ}{0.264m^3} = 3.3\,{}^{MJ}\!/_{m^3}\,.$$

Using the curves J – U (Janssen factor J – Absorbed energy U) from [7] shown in Figure V, it can be seen that the polyurethane foam specific mass shall be around 360 kg/m^3. With this approach it can be estimated that the g-level in the spent fuel elements inside the cask will be around 60-85 g, to be confirmed by tests or analysis.



(a) *J* curves

(b) Interpolation of the minimum *J* values

Figure V: Curves J – U for several polyurethane foam specific masses

6. NEXT STEPS

From this first shot in the cask conceptual design, the following steps may be anticipated for the next two years:

i. acceptance of this preliminary proposal from the involved parts;

ii. information on the spent fuel elements (processed and not processed) to be transported and stored to design the different cask internal baskets;

iii. development of the basic design of the cask and its systems, resulting in design drawings, design reports and technical specifications;

iv. development of two scale models 1:2 to start the cask qualification according to [2]

v. development of a cask preliminary safety analysis report

vi. contact with potential partners interested in developing the detailed design and in building the casks.

7. REFERENCES

[1] MAIORINO, J. R.; RITCHIE, I; GUARNIZO, J; NOVARA, O.; SOARES, A. J.; KLEIN, J; MAZÓN, R.; LLAMAS, I. "*Management of spent fuel from research reactors in Latin America: A regional approach",* In: The Americas Nuclear Energy Symposium (ANES 2002), Miami, FL, USA, October 16-18, 2002

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, "*Regulations for the safe transport of radioactive material".* Safety Standards Series No. TS-R-1 (ST-1, Rev.). Vienna, 2001.

[3] MOURÃO, R. P. & MATTAR NETO, M., *"Research reactor spent fuel storage in transport casks"*, In: Taller sobre Opciones de Almacenamiento de Combustibles Gastados, 2002, Villa del Dique, Argentina, IAEA, 2002

[4] INTERNATIONAL ATOMIC ENERGY AGENCY. *"Spent Fuel Storage and Transport Cask Decontamination and Modification"*, IAEA, Vienna, April 1999 (IAEA-TECDOC-1081)

[5] CLOSS, K. D., *"Treatment of spent fuels from research reactors development programs in Germany"*. In: Procedures and techniques for the management of experimental fuels from research and test reactors. IAEA, Vienna, April 1999 (IAEA-TECDOC-1080), p. 41-50.

[6] STUART, I. F., *"The development of a transportable storage cask"*, Int. J. Rad. Mat. Transp., v. 2, n. 1/3, p. 41-46, 1991.

[7] MOURÃO, R. P., *"Shock absorbers for radioactive materials transportation packages: An evaluation methodology"*, Doctorate Thesis to be presented at University of São Paulo, São Paulo, Brazil, November 2002 (in Portuguese)

[8] WOOLAM, W. E. "*A study of the dynamics of low energy cushioning materials using scale models"*. Journal of Cellular Plastics, v.4, p.79-83, Feb. 1968.