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A TYPE B(U) PACKAGE TO STORE AND TRANSPORT MEDICAL SOURCES

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ABSTRACT

ENEA is designing a new package, called CESM, to store and transport to the final disposal all the radioactive sources collected from many hospitals in the past. The paper shows the storage requirements and all the steps carried out to prepare a safety report to get the package approval from the competent authority with the scale-up criteria and calculation codes used for thermal, mechanical and shielding analyses and the experimental planning for the drop test. The new package is the result of applying again the scale-up factors on the two packages CF6 and C66 certified in the past as Type B. The FEM analysis integrates the mechanical analysis and the 9 m drop test is planned too.

ENEA has shown its planning to the Competent Authority and it has got the first comment on the best way to follow to save time in the approval procedure.

INTRODUCTION

In Italy for many years ENEA, on committement of the Ministry of Health, in collaboration with NUCLECO S.p.a., has collected many sources of different radionuclides no more used in hospitals around the country, therefore for this activity many transports have been performed under special arrangement conditions. To improve the storage of those sources, from the safety and security point of view, and to ease the transport it has been planned to design a Type B(U) package (indicated with the acronym CESM) on the base of the experience got in the past with the other Type B(U) models CF6 e CF66.

Since the studied packaging is intended to be used for a rather large number of content types we started with the easiest as well as the most urgent one: 440 brass capsules containing needles, plaques and tubes of Ra 226 with a total activity of 1,6 TBq. The dimensions of the package are based on the contents, storing constraints and a scale-up of the previous smaller packages which underwent to many drop and thermal tests in the past at the Scalbatraio laboratory in Pisa. Although we believe that a design based on scale-up criteria could be sufficient to comply with the IAEA transport regulation, we foresee a limited series of drop tests to get details on the containment system behaviour to facilitate the design of the new structure needed to cope with its possible alternative content. In fact, while we are working to extract all the sources from several irradiators, with the collaboration of IAEA, it is likely that some irradiator must be transported as a whole using the same packaging type.

During a short presentation of the new CESM package to the Competent Authority (CA) it was agreed that:

- ENEA will present a safety report to the CA with one type of content and a planning for the tests
- While the CA is checking the safety report, ENEA will start the construction of the model under CA supervision: in this way we can save time accepting the risk of CA comments and modifications on the safety report
- ENEA will review the safety report on the base of CA comments and test results

CESM PACKAGE

Package contents

The content foreseen for the CESM is 440 brass capsules (see Fig. 1), each containing 0,444 GBq of Ra 226, piled up in 12 floors and centered with a light structure to ease the loading procedure. Although it would be possible to remove the radium from the capsules and keep all the needles, plaques and tubes in a single shielded pot, it was decide to keep the capsules to avoid doses to workers and maintain the traceability of sources.

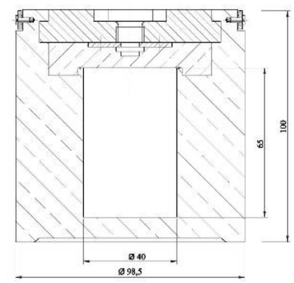

Figure 1- Brass capsule section

For future contents, ENEA is following two ways to store and transport old irradiator's sources (see Fig. 2):

- the first one is to remove the sources from the irradiators whenever possible and put them into a shielded and robust intermediate container:
- to keep the source in the irradiator and transport it as it is at the final disposal.

To remove the source ENEA is using the IAEA International Catalogue of Sealed Sources and Devicesinformation and asking help directly to IAEA to get more specific details on the devices stored at Casaccia Centre. At the present we do not foresee difficulties since large hot cells could be used and the cavity of the packaging is large enough to accommodate most of whole irradiators: in both cases we need the CA approval for the any new content.

Figure 2 – Pictures of irradiators

Packaging characteristics

As previously mentioned the new packaging dimensions have been chosen on the base of the two smaller CF6 and CF66 packagings, dimensions of some irradiators and on road transport requirements (see Fig. 3).

The maximum height of the packaging is less than 2.5 m and so it is smaller than that derived with a scale-up factor 4 applied to the CF6: usually a reduction in height does not reduce the mechanical characteristics and reliability of a packaging. The containment system (CS), with a cavity 700mm in diameter and 1200 mm height, is more robust in comparison with the CF6 where the shielding is made of lead instead of steel and so it can assure high resistance to the fire when stored without the mechanical and thermal protection.

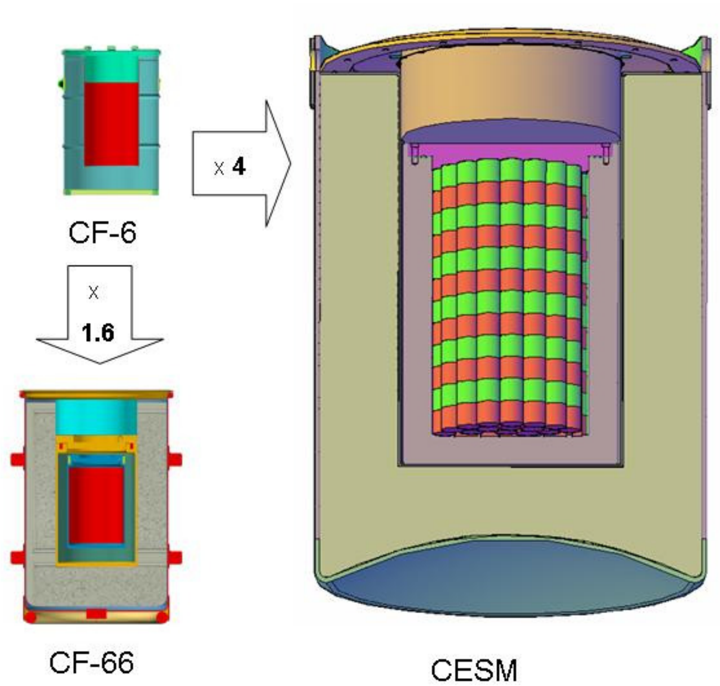

Figure 3

The shock absorber and thermal shield is made of a mixture of concrete and vermiculite containing absorbed water enveloped into a steel linear: such material has been tested at open fire and furnace test many times in the past, keeping the inside temperature well below 100°C due to the free water. Since the packaging will be used for a long storage and then for the transport, the lid has a hole to fill the cavity with a noble gas and two o-rings; the first is made of metal to guarantee the leaktightness and the second elastomeric one only to check the seal. The external surface of CESM was modified, compared with CF6 and CF66, to facilitate the handling of the package with a mass greater than 10000 kg.

Shielding calculation

The shielding analysis was performed for 444 capsules containing each 0,1 Ci of Ra 226, which is the maximum activity allowed in a capsule, while the average activity is about 0,9 Ci. The radium is considered at secular equilibrium with its daughters and the major contribution to the dose is due to Bi 214. With EASY 2003 we calculated the activity of Ra 226 (See Fig. 4) and the dose rate at contact (see. Fig. 5)

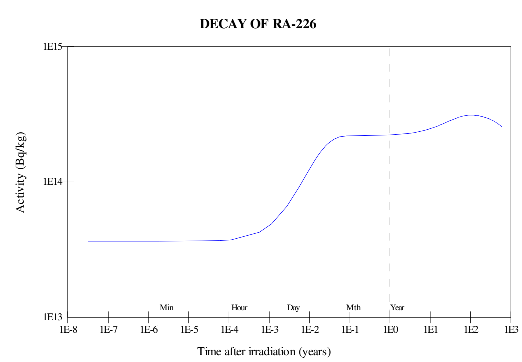

Figure 4 – Activity of 1 kg of Ra226 (EASY 2003)

The dose rate for the CESM was calculated with the code MCNP5 (release 1.40) using cross section based on ENDF/B-V. The equivalent dose rate calculation is based on the ICRP-74.

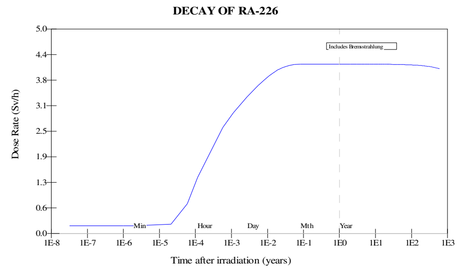

Figure 5 – Dose rate at contact of radium 226 source(EASY 2003)

The following table summarize the calculation for normal condition of transport and the value are well below the IAEA transport Regulation limit for Yellow III packages: the IAEA transport limits have been fixed for the containment system due to the long period of storage (see Table 2).

Table 1 - CESM radiation level for normal condition of transport

Position		Radiation level mSv/h
Bottom	surface	0.2262 (0.0193)
	1 m	0.0504 (0.0177)
	2 m	0.0207 (0.0168)
Lateral	surface	0.2235 (0.0108)
	1 m	0.0575 (0.0070)
	2 m	0.0246 (0.0069)
Top	surface	0.3403 (0.0283)
	1 m	0.0638 (0.0268)
	2 m	0.0248 (0.0205)

Table 2- Radiation level for the containment system (pessimistic assumption for accident condition of transport or normal storage condition)

Position		Radiation level mSv/h
Bottom	surface	2.0290 (0.0895)
	1 m	0.3052 (0.0112)
	2 m	0.0987 (0.0106)
Lateral	surface	0.9747 (0.0171)
	1 m	0.1953 (0.0050)
	2 m	0.0734 (0.0068)
Top	surface	1.0430 (0.1063)
	1 m	0.1782 (0.0145)
	2 m	0.0588 (0.0157)

Table 2 gives the dose rate that must be taken into account for the long storage and handling condition at the ENEA-Casaccia centre where several containment systems could be used.

Mechanical analysis

In order to evaluate preliminarily the impact behaviour of the CESM packaging design, a double approach was used developing the following steps:

– Setting up a preliminary general design on the basis of a similitude approach, which allowed the definition of the CESM packaging main geometry scaled from the previous CF6 and CF66 packaging (based on the same design concepts) ones.
– Definition of the principal mechanical characteristics of the dynamic load damping/shock absorbing material (used to fill the gap between the packaging outer container and the inner containment vessel) in the actual IAEA standard 9 m drop tests conditions. This definition was achieved by means of FEM model numerical simulations intended to reproduce the available experimental data obtained in the tests performed in the past for the qualification of the previously developed smaller scale packaging CF6 and CF66 already mentioned.
– Analysis and check of the CESM packaging behaviour in the same IAEA standard drop test conditions by means of numerical simulations performed on suitable FEM models.

As it was previously mentioned the three considered packaging (CF6, CF66, CESM) are characterized by geometrical dimensions roughly scaled according to factors 1 -1.6 - 4

As far as the determination of the preliminary absorbing material mechanical characteristics in impact conditions is concerned, the FEM analysis was referred to the vertical axis 9 m drop case and included:

- CF6 FEM model setting up, to be implemented in the ANSYS 10 and LS-DYNA codes with a parametric geometric approach to allow for a simple dimensions definition according to the considered specimens. In this model the RAM plus the containment system and the absorbing material were simulated, respectively as an inner steel mass and a foam like filled volume, by means of solid brick, 8 nodes and 9 dof/n elements (SOLID 164).
- The external steel shell non linear behaviour was simulated according to the Cooper-Symonds law, considering the steel deformation rate sensitivity. The sought after absorbing material mechanical characteristics were simulated by means of a bi-linear curve characterized by variable yield strength and strain hardening. The inner shell and outer absorbing material surfaces were considered tied together.
- A sensitivity analysis, through out numerous calculation runs, was performed in order to define the material characteristics most suitable to allow for the calculation of inner containment system acceleration versus time and total residual vertical displacement in reasonable agreement with the data recorded in the previous CF6 qualification 9 m drop test program. The CV acceleration and displacement as well as the stresses in the protection material were recorded, as shown in the Figs 6 and 7.
- A simulation of the intermediate dimensions CF66 packaging behaviour in the same drop test type, with the previously determined material characteristics, was carried out in order to check the reliability of the mentioned characteristics against the available corresponding experimental data. The agreement between the calculated and test data resulted to be fair, considering the type of addressed phenomena, the industrial characteristics of the specimens used in the tests and the overall purposes of the analyses.
- A preliminary analysis of the CESM packaging behaviour was eventually carried out by means of a suitable, even if up to now simplified, model implemented on the mentioned ANSYS and LS-DYNA codes, on the basis of the results achieved in the activity summarized in the steps indicated in previous points a), b) and c).

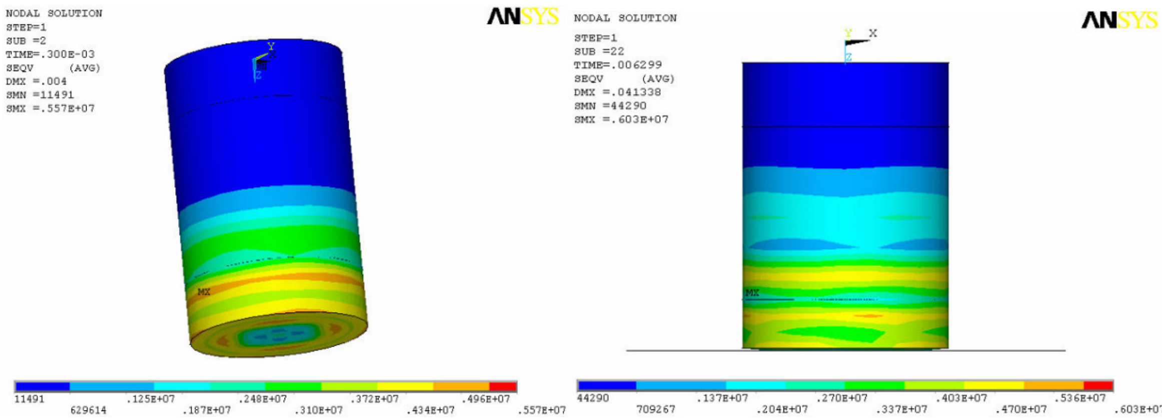

Figure 6 Stress [Pa] in the absorbing material at impact beginning and end

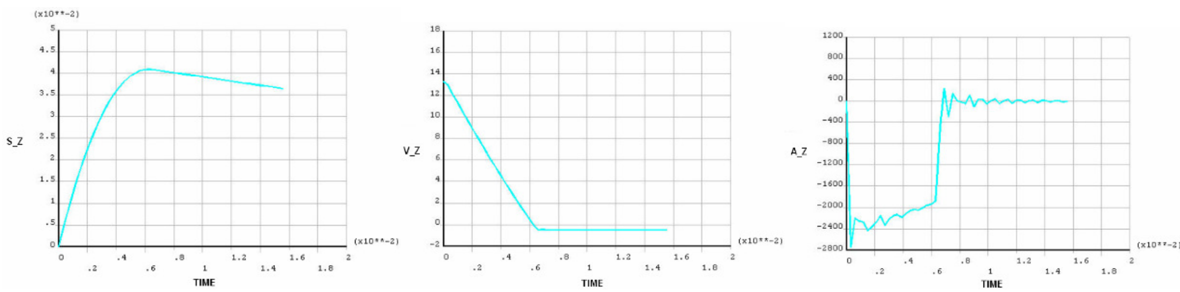

Figure 7 - CF6 CS calculated displacement[m],velocity[m/s] and acceleration[m/s2] vs time [s]

The overall results obtained with the general approach indicated above seem to be in good agreement with the ones obtained for the scaled down packagings CF6 and CF66, taking into account of the scale factor effects and the unavoidable imperfect similitude conditions, as it is possible to see in the following table.

Packaging model	Scale factor	CS – Total vertical displacement (mm)		CS - Average acceleration (g)		NOTES
CF6	**1**	**40***	**40**	**225***	**220**	***Experimental data**
CF66	**1.6**	**62**		**150**		
CESM	**4**	**170**		**52**		

Thermal analysis

Conceptual verification of the CESM model in the fire test is based on similitude considerations and on the very large safety margins that the main design conceptual approach showed to possess in the several fire and furnace tests carried out for the two mentioned scaled down packagings.
As far as low temperature condition is concerned (- 40°C), the CA has raised doubts about the behaviour of the “free water” present in mixture concrete-vermiculite, although used as thermal isolator in the approved Type B(U) model CF6 and CF66, due to the dilation of water-ice phase. For this reason ENEA performed a thermal test on a CF6 packaging using a large climatic cell able to change the temperature from +200°C to – 70°C (see Fig. 8)

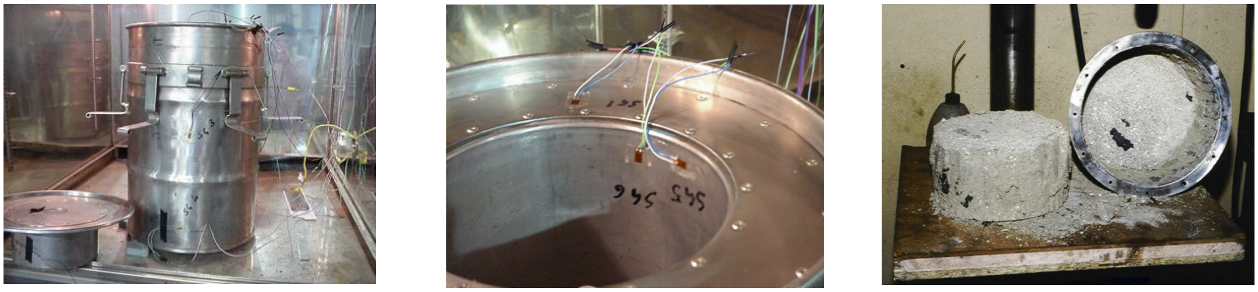

Figure 8- CF6 in the climatic cell and check on the material

The packaging was subject to several temperature cycles as shown on Fig. 9 with many thermocouples, strain gage and measurements prior and after temperature cycles. During the test it was recorded no rapid dilatation of the internal and external liner and after the test the mechanical characteristics of the concrete-vermiculite mixture were unchanged.

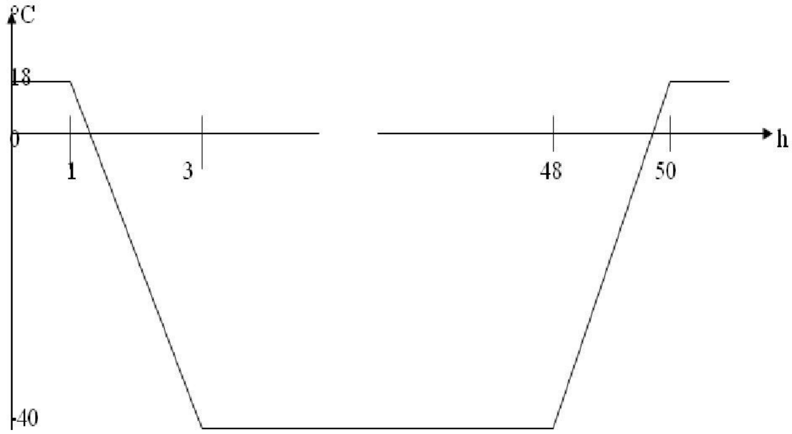

Figure 9 - Time-Temperature cycle

CONCLUSIONS

At the end of this year ENEA will present the CESM Safety Report to the CA and will start the construction of the model to be tested. Taking into account the experience gained in the past with the 9 m drop tests for the CF66, repeated 4 times on two models, and the furnace tests, it seem possible to use the CESM containment system model not only for the test but as CS for the real packaging as well. On the other end from an economical and technical analysis is not convenient to save money on a simplified scale 1 to1 model when compared with the low risk of heavy damages during the drop tests, and we do believe that the Italian CA can accept our planning.

REFERENCES

G. Forasassi – A. Orsini –B. Rapone. "Scale-Up and leaktightness" PATRAM'95- December 3-8 1995 – Las Vegas, Nevada, USA