Shipments of Teletherapy Units From Hospitals to Disposal by Special Arrangement

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INTRODUCTION

The Regulations for the Safe Transport of Radioactive Material (RAM) of the International Atomic Energy Agency (IAEA) Safety Series No.6 (1990) establish safety standards whose application provides an adequate level of protection to person, property, and the environment against the risks deriving from the use of ionizing radiation sources. Despite a quite rigid scheme of the Regulations, which establish provisions for the transport of RAM linked to the kind of material (LSA, SCO, special form, fissile), to the activity, and consequently to the type of packaging adequate for the shipment, a flexible tool is represented by the possibility to transport RAM under special arrangement.

This paper intends to illustrate the role of the Italian competent authority regarding the request to carry out some shipments of teletherapy units from hospitals to a waste disposal under special arrangement. Moreover the intention of the paper is to point out some difficulties met with the application of the criteria of the " equivalent safety "as stated in para. 211 of the Safety Series No.6 1985 Edition (As Amended 1990).

SAFETY EVALUATIONS AND PRELIMINARY ACTIONS

Years ago some hospitals, in our country, decided to substitute their teletherapy units, using radioactive sources, with other equipment, for example, linac - machines. Those operations involved the removal of the whole teletherapy unit. At that time because of the absence of a site for disposal the units, with the sources inside, were stored at the hospitals.
After some years it was decided to remove the units from the hospitals, in consideration of the fact that in some cases they were stored in rooms not suitable from the point of view of an optimum control of radiological risks.

Following of the discussions between the hospital physicists, management and the operators involved in the removal, transport, and treatment of the teletherapy units, it was decided, for various reasons, to transport the units with the radioactive sources inside. The removal of the sources should have been carried out at the waste disposal plant. The main reasons not to remove the radiation sources from the head of the teletherapy unit were:

- defects of the mechanisms for loading and unloading of the sources;

- old age of the encapsulated sources;
- uncertainty on the integrity of the encapsulated sources; and
- lack of documentation (certificate of calibration of the source, certificate of special form).

In Table 1 are reported some information regarding seven shipments carried out for redundant teletherapy units from different hospitals to waste disposal.

Table 1. Characteristics of the shipments

nuclide	type of source	activity (TBq)	distance (km)	Transport Index
^{137}Cs	special form	39,96	410	< 1
^{137}Cs ^{60}Co	encapsulated sources	41,18 23,54	700	" "
^{137}Cs	encapsulated source BRD - 1242 Oak Ridge Laboratory	40	520	"
^{60}Co ^{60}Co	encapsulated source special form source type C-146	4,7 37,5	800	" "
^{137}Cs	welded encapsulated source	65,9	380	"
^{137}Cs	capsule type B - RD - 1242	41,02	650	"
^{137}Cs	welded capsule	34,27	650	"

To proceed in a systematic and efficient manner for preparing the package, the Competent Authority asked the carrier to prepare a detailed workplan indicating the operators involved and the sharing of responsibility (Gaffka A.P. and Ord M.A., 1994).

The following phases were common for all the shipments:
- contamination and radiation survey with records of the measurements carried out by the health physicists;
- removal of the teletherapy units from the structure of support;
- removal of the collimator and fixing of the shutter with the source in safety position;
- fixing of a steel flange with a lead shield plate to reduce the radiation level in the zone of the collimator;
- placing of the head of the teletherapy unit over a steel structure and positioning into an inner drum;
- filling of the space between the inner wall of the inner drum and the head of the teletherapy unit with wood or vermiculite;
- positioning of the inner drum into the external packaging;
- measurement of the external contamination, radiation level on the surface, and transport index; and
- labeling.

PACKAGE DESCRIPTION

The IAEA Regulations Safety Series No.6 are applied in Italy, for international transport and for road mode, through the European Agreement for transport of dangerous goods (ADR 1995). Regarding the class 7 of dangerous goods (radioactive materials) the ADR is completely in line with S.S. No.6 1985 Edition As Amended 1990. The schedule 13 of the ADR Regulations gives the provisions for the shipment of radioactive material under special arrangement.

As showed in Table 1, the activity of the radioactive sources requested that a type B packaging should be used for each shipment according to ADR (ADR, 1995).

Italian legislation regarding the transport of radioactive material gives many responsibilities to the carriers. In fact, in Italy the transport of radioactive materials is allowed only to carriers authorized by a decree issued by the Minister of Industry with the Minister of Transport.

Many consignors, in particular hospitals, that do not perform shipments on continuous basis, prefer then to give the responsibility of the shipment to an authorized carrier. Therefore, for the disposal of the redundant teletherapy units , the management body of the various hospitals gave the responsibility for the shipments to an authorized carrier.

The Italian authorized carrier provided, in agreement with the health physicists and management body of the hospitals, the documentation necessary to obtain the special arrangements certificates from the competent authority. The need to perform the shipments under special arrangement was given to the fact that no Type B packaging currently in use met all the requirements for those shipments. In particular the major difficulties were found for the size and mass of the teletherapy heads (about 1,000 kg). The carrier decided to design and to manufacture an ad hoc packaging, not intend to be approved as Type B package, taking in account the time pressure to avoid radiological risks that could arise from the precarious storage of the units at the hospitals.

The package proposed for the shipments is described in Figure 1. It was designed and built by the carrier according to a quality control program (MIT Nucleare, 1990). The external packaging consists of a component of cylindrical shape (35 mm thickness), a hemispherical welded bottom, and a hemispherical head linked to a flange with 16 bolts. Two rubber gaskets on the top of the flange define an annular space by which it is possible to perform a leak test before the shipment. The inner drum (400 or 200 liters) containing the teletherapy unit is centered inside the outer cylinder by wood elements having a fire resistant paint on the surface. The head of the teletherapy unit inside the inner drum is surrounded by a layer of a compound of concrete plus vermiculite.

For the shipments the package is fixed, by a very robust tie down system able to resist to acceleration values of 10 g, 5 g, 2 g in longitudinal, horizontal, and vertical direction, respectively.

COMPETENT AUTHORITY EVALUATION

The Regulations S.S. No.6 establish that a consignment under special arrangement can be performed if the provisions, approved by the Competent Authority, are adequate "to ensure that the overall level of safety in transport and in transit storage is at least equivalent to that which would be provided if all the applicable requirements had been met" (IAEA Safety Series No.6, 1990).

The definition of para.211 of the Regulations is a very generic one. Nevertheless, it represents, on one hand, a very flexible tool for the various situations that the consignor can find in his job experience, but on the other hand, it introduces a large margin of subjectivity in which professional judgment plays an important role. The lack of quantitative safety criteria gives sometimes a high degree of uncertainty in the evaluation process to verify the effectiveness of the provisions regarding the ability of the package to withstand routine and accident conditions. In our case we established an evaluation process addressed to verify the package behavior in routine and accident conditions taking into account the actual condition for the specific shipment.

Following are described the evaluations carried out for the shipment of the teletherapy head unit, containing a ^{137}Cs source whose characteristics are reported in Table 1 (grey area).

PACKAGE EVALUATION IN ROUTINE CONDITIONS

The routine conditions of transport were evaluated taking into account the adequacy of the provisions of the applicant regarding the radiation shielding, containment, and thermal dissipation (Biaggio A.L. and J.R.L. Vietri, 1992).

Radiation Shielding

The radiation shielding was assured mainly by the head of the teletherapy unit itself. The other material surrounding the head of the teletherapy unit (150 mm of concrete lightweight and 35 mm of steel) offered further shielding. The radiation levels measured on the surface of the package and at 1 meter from the surface were very low as shown in Table 1.

Containment

The containment function was provided by the sealed source. As reported in Table 1 in some cases the radioactive sources were not classified as special form, but in generic way as sealed sources.

For some of the sources, the only documentation available was the calibration certificate in which no indication was found about the Regulations followed to design and to test the sealed source. Because in the Regulations S.S. No.6 1964, Revised edition, the special form is described and the test conditions are provided, it was assumed that, taking into account the documentation available, the generic indication of sealed source written on the calibration certificate after 1964 was synonymous with special form. However, in all the cases, a contamination check on the head of the teletherapy unit and in particular on the zone of the collimator was prescribed, before packing the head into the inner packaging (particular attention was given to the heads containing the ^{137}Cs source due to its physical state). The evaluation also considered the other devices present on the external packaging (flange with bolts, sealing gaskets) and the means to perform the leaking test before the shipment.

Thermal Dissipation

Thermal analysis was finalized to verify the behavior of the various components of the package regarding melting, thermal stress for the materials, and check of the internal pressure. Regarding the internal pressure, the reference value, for stress in the structure and closing devices of the external packaging, was represented by the stress that the external packaging suffered during the hydraulic test that was performed at the internal pressure of 16 bar for 60 minutes with water at the temperature of 16° C.

PACKAGE EVALUATION IN ACCIDENT CONDITIONS

The accident conditions of transport are represented by the mechanical and thermal test described in the Regulations S.S. No.6. The consequences of those tests on the package are normally evaluated by actual tests on the prototype and they are part of the safety report for approval of a Type B design.

Mechanical Analysis

In this case with the use of an ad hoc package it was quite difficult to demonstrate the ability of the package to withstand the stresses and strains produced by the dynamic input load corresponding to a 9 meter drop test. The analysis was made considering the actual condition of a hypothetical impact and therefore taking into account the maximum speed of the truck, the energy absorbed by the truck and trailer structures, and by the tie down system.

The above considerations were used to establish a reference value for the acceleration to evaluate some structural components of the package. Some specific evaluations were made regarding the steel shutter fixed by bolts to the head of the teletherapy. In fact it was considered that a critical situation could arise by the rotation of the shutter following an accident. This condition could cause an increase of external radiation level.

Taking into account the speed limit of 60 km/h for the truck, an acceleration value of 20 g was considered adequate, for accident conditions, to verify the bolts fixing the shutter to the head of the unit and the other components like the bolts between the flange and the cover, the tie down attachments on the package, etc.

Thermal Analysis

The thermal analysis of the package, in accident conditions, was carried out by the computer code SCALE 4.1 with the test parameters as reported in the Regulations (temperature = 800 °C, test length = 30 minutes) (Oak Ridge National Laboratory,1989). That was possible due the approximately cylindrical shape of the various components of the package, which is a condition provided in the model for the computer code.

Two different calculations were performed taking into account two different characteristics of the layer of the concrete lightweight surrounding the head of the teletherapy unit. The first calculation was performed with the data of components of the concrete lightweight (percentage of cement, vermiculite, and water) provided by the applicant. The second calculation was performed using the data contained in the library "HEATLIB" of the SCALE computer code.

According to the input model for SCALE, the package was sketched in three zones as showed in Figure 2. The zone 3 was the critical one due the presence of the lead radiation shielding. In the sketch it was not considered the external packaging and the wood with the fire resistant paint. The graphics in Figures 3 and 4 show the temperatures of the external surface of the zones of the package. It can be seen that in the "critical" zone 3, for both calculations, the temperature is lower than 100 °C after 3 hours of cooling time compared with melting temperature of the lead equal to 327 °C. As far as thermal analysis is concerned, the uncertainties due to the materials composition are overcome by the fact that to not consider the external packaging and the wood components in the analysis, means to suppose a very severe mechanical accident.

OPERATIONAL CONTROLS

Apart from the results of the performed analysis, it was decided to prescribe to the applicant some operational controls: exclusive use of vehicle, escort of the shipment, emergency procedure, and notification to civil authorities, in particular the fire brigade and police department along the route. Those operational controls for the shipment were prescribed in order to decrease the probability of accidents or to mitigate its consequences.

On the other hand, most of the operational controls had the scope to take into account certain doubts and uncertainties about the ability of the package to assure effectively all the requirements of containment and radiation shielding requested by the Regulations. Very helpful information was found in para A - 721 in Safety Series No.37 about some operational controls that under special arrangement can be employed in the shipment (IAEA Safety Series No.37, 1990).

CONCLUSIONS

The seven shipments were carried out without any problem, and in some cases inspections were performed by the Competent Authority to verify the regularity of the operations carried out by the consignors and the carrier. All the operations were carried out according to written procedures, with the supervision of the health physicists of the hospitals and the radiation protection specialist of the carrier (qualified expert).

That experience showed that in only a few cases, when a good knowledge of the parameters, for example, the state of old sealed sources, value of acceleration for mechanical analysis, and characteristics of material of the package for thermal analysis, the Competent Authority can carry out a quantitative safety analysis. In many cases, the analyses have to be supported also by the professional judgment and "human experience". That involves a certain degree of uncertainty that is covered in many cases by the adoption of very stringent operational controls.

A standard approach in this field, for the consignor or carrier, that takes the responsibility to prepare the shipment and for the Competent Authority that takes the responsibility to perform its evaluations and to issue the special arrangement certificate, a technical guide at the international level should be very useful. Moreover that technical guide could be an important tool in case of international shipments regarding the "ad hoc package" because of the multilateral approval for special arrangement.

REFERENCES

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Gaffka A.P. and Ord M.A. *The Disposal of Redundant Teletherapy Units From NHS Hospitals*, International Journal of Radioactive Materials Transport, Vol.5,No.5, p.113 (1994).

Oak Ridge National Laboratory *A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation (SCALE 4.1)* Oak Ridge, Tennessee (1989).

Regulation for the Safe Transport of Radioactive Material 1985 Edition (As Amended 1990) IAEA, Safety Series No.6.

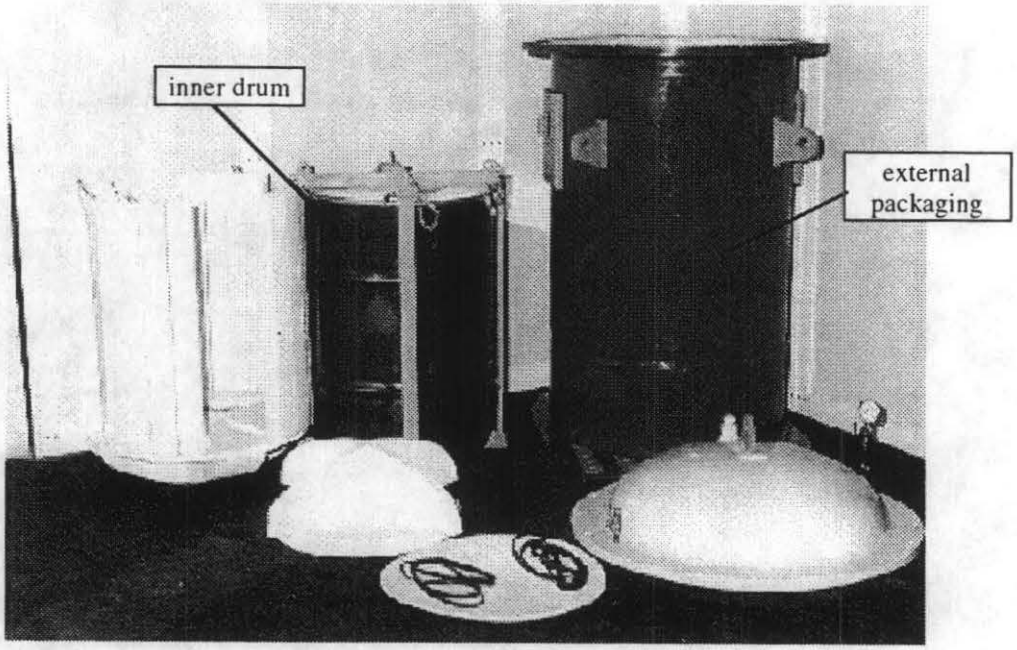

Figure 1. Components of the package used for the shipments

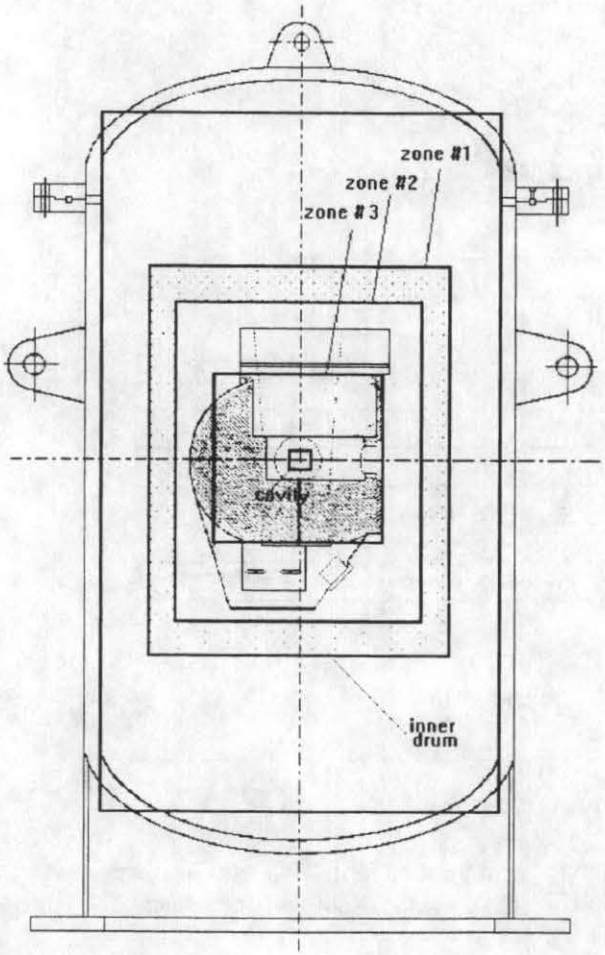

Figure 2. Sketch of the package for thermal analysis

Package weight : 3200 kg
Dimensions: height = 2062 mm
external diameter = 1000 mm

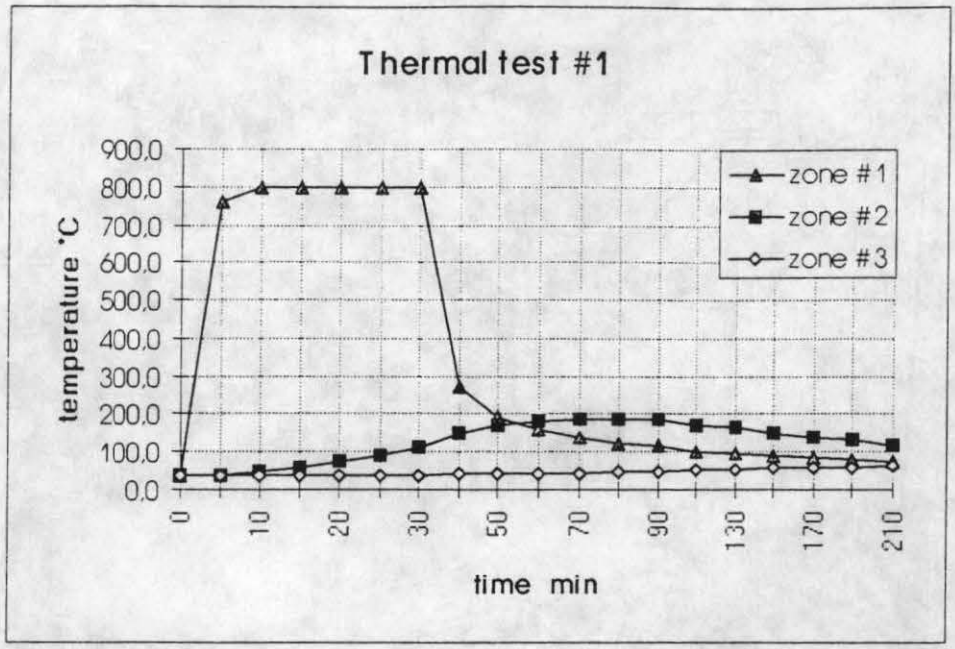

Figure 3. Graphics of the temperatures with the data for lightweight concrete provided by the applicant.

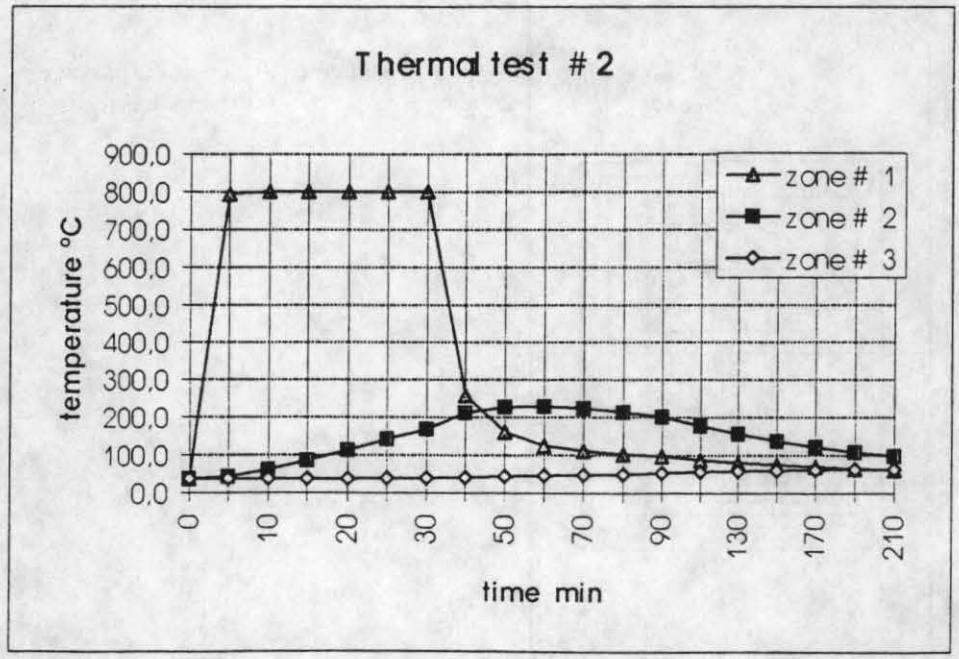

Figure 4. Graphics of the temperatures with the data for lightweight concrete provided by the library "HEATLIB" of the SCALE 4.1 computer code.

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