The Transport of Radioactive Materials Under Special Arrangement

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INTRODUCTION

The *IAEA Regulations for the Safe Transport of Radioactive Material* is used world-wide for ruling the international transport of radioactive material (RAM) and provides the basis of national and regional regulations. The Regulations establish technical, operational and administrative requirements to protect against radiation risks under both normal and accident conditions of transport.

There are circumstances where, for different reasons, some of which are analyzed in this paper, it is difficult for a consignor to satisfy all the regulatory requirements. In such a sense, the provision of para. 211 of the Regulations related to the transport of RAM under special arrangement allows the transport of a consignment of RAM, even in the hypothetical case where all applicable requirements are not being fulfilled, if, at least, the overall level of safety is maintained.

This paper explains some difficulties the Argentine Competent Authority has experienced trying to compare the overall level of safety resulting from compliance with current requirements and the overall level of safety which is provided by the application of alternative provisions. As most of the experience gained comes from the transport of RAM by road, only this mode of transport is considered.

COMMON CASES OF SPECIAL ARRANGEMENT

The applications for transport under special arrangement (SA) deals in most cases with the carriage of Type B radioactive quantities usually on a non-routine basis. It seems reasonable because when lower quantities are involved it is easier to comply with all the applicable requirements of the Regulations instead of requiring the SA approval, and for routine transports, the extra cost of the alternative provisions as well as the reluctance of the Competent Authority move the consignor to comply with the applicable requirements.

In our experience, when a consignor has to transport Type B consignments and a fully adequate packaging is not available, he usually chooses among the following alternatives:

(a) Use of a suitable packaging corresponding to a Type B design approved for radioactive contents other than RAM to be transported.

(b) Design and manufacturing of an "ad-hoc" packaging not intended to be approved as Type B. That is to say, without full demonstration of compliance with the applicable requirements because considerable time and money will be spent.

(c) Use of a packaging which belongs to a package design once approved as Type B but which no longer has this status because of, 'inter alia', the following reasons:

(i) at present the approval certificate is not in force;

(ii) at present the approval certificate does not include the serial number of the packaging; or

(iii) the design was approved in agreement with older revisions of the Regulations.

The kind and degree of the alternative provisions (e.g., routing restrictions, limited speed, use of overpacks or special vehicles) are closely related to the confidence that the Competent Authority has in the packaging potential performance. Generally the approval certificate is issued for a singular shipment and has a limited time validity (e.g., some weeks), except in cases where the problem seems to be clearly administrative where longer validity time is allowed and practically no special provisions are requested.

EQUIVALENCE BETWEEN OVERALL LEVELS OF SAFETY

The Regulations allow that a consignment which does not satisfy all the applicable requirements shall not be transported except under SA, "in such a way 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." It is easy to infer the difficulties in analyzing the "equivalence" between overall levels of safety.

Ideally, it can be assumed that two levels of safety should be equivalent if the sets of probabilities of occurrence of comparable radiological consequences are similar. This should imply to full evaluation and comparison of the case of transporting using a Type B package and conventional means with the case of transporting using a non-Type B package with special vehicles, overpacks and/or operational provisions.

A comprehensive study is impossible and simplifications are needed. The Argentine Competent Authority as a conceptual approach attempts to balance the potential higher failure probabilities of the package with alternative provisions intended either to reduce such probabilities or to control the magnitude of the consequences.

The level of safety provided by a Type B package is related to the regulatory tests to withstand accident conditions of transport, but usually the performance of the package to be used in a SA is not satisfactorily known and, therefore, the difference between package performances, if any, is not well known. The basic criterion for SA is that the alternative provision should take into account this lack of knowledge and their kind and magnitude should compensate the apparent reduction of the ability of the package to withstand accident conditions with respect to the ability achieved by a true Type B design.

Although the above mentioned criterion has proved to be an useful general guide, there is a high degree of uncertainty when evaluating the decrease of accident probabilities to be achieved or the increase of the package ability to be reached once alternative provisions are implemented.

Therefore, professional judgement always plays an important role and a significant degree of subjectivity will be present.

PRACTICAL CRITERIA

Taking into account the difficulties and the conceptual approach described above, the authors have considered some practical criteria. The object of these criteria, which are described below, is to establish a method and to show some tools in order to evaluate approximately the ability of the package and to justify the associated safety-oriented alternative provisions adopted.

USE OF A PACKAGING CORRESPONDING TO A TYPE B PACKAGE DESIGN APPROVED FOR A RADIOACTIVE CONTENTS OTHER THAN THE RAM TO BE TRANSPORTED

In the case where the authorized radioactive contents is other than the RAM to be transported, the main problem is the impact of the new contents on the containment, radiation shielding and structural and thermal ability of the package in both normal and accident conditions of transport.

The radioactive contents (including fastening devices or primary containers) are not usually part of the structural components of the package. Therefore, when evaluating possible modifications of the structural ability of the package, it is highly probable that should be enough to compare the masses of new and authorized contents. If the masses are similar, or at least the mass of the new contents is only a small fraction of the mass of the packaging as it generally happens, the mechanical test results and, therefore, the structural ability to withstand crushes will not be modified.

With respect to thermal ability, an analogous analysis should be enough. Therefore, the comparison between the thermal power of new and authorized contents should show a crude estimate if there is an adequate dissipation of heat generated under normal conditions of transport and if the results of the thermal test of the Regulations can be considered still valid. The latter allows a decision about package withstanding a severe fire without excessive containment or shielding degradation.

In general, a mere calculation shall be enough to verify shielding ability under normal conditions of transport. At any rate, a radiometric control before shipment shall be enough to verify that shielding satisfies the applicable requirements of the Regulations for normal transport.

With respect to the containment effectiveness, if the package to be used was approved to transport special form RAM and the new contents is special form RAM too, it seems enough to control its non-fixed contamination level. In case the new contents is other than special form RAM and, particularly, if it is in a high dispersible form, the containment effectiveness is not so easy to evaluate. In those cases it shall be necessary to evaluate carefully the containment system of the approved package and, possibly, it should be most desirable to request the use of a primary containment to assure an appropriate containment effectiveness independently of the quality of the packaging closing device.

USE OF AN "AD HOC" PACKAGING BUT WITHOUT REQUIRING ITS TYPE B PACKAGE APPROVAL BY THE COMPETENT AUTHORITY

In this case it is desirable to consider the analysis divided into two parts, the first one related to the evaluation of the ability of the package in conditions likely to be encountered in routine transport and the second one dealing with the estimation of the potential ability of the package in accident conditions of transport.

- **Routine Conditions of Transport**

When evaluating routine conditions, radiation shielding, containment effectiveness and thermal dissipation should be considered.

With respect to radiation shielding and thermal dissipation, applicant evaluations are revised in order to estimate whether the expected values are acceptable. In thermal analysis, maximum package temperatures shall be evaluated to verify that package structure shall not be adversely involved (e.g., any component melting, differential expansions or thermal stresses). Finally, related to radiation level and temperature values, it seems important to implement a suitable radiometric control and, in some cases, temperature measurement before the shipment.

with respect to containment effectiveness, the problem does not seem to be difficult if the contents is special form RAM. It appears to be enough to evaluate closing devices (e.g., cover bolt fittings, thread cover fittings and sealings) and to limit the non-fixed contamination of the external surface of the radioactive contents. The problem is complex when the new contents is other than special form RAM and, particularly, if it is in liquid, gaseous or powder form. In such cases it seems convenient to agree with the applicant on the use of an appropriate primary containment, or the performance of leak tests methodology, *ISO Standard Leakage Testing on Packages for the Safe Transport of Radioactive Materials, ISO 1992; ANSI Standard for Leakage Tests on Packages for Shipment of Radioactive Material, ANSI 1977.*

- **Accident Conditions of Transport**

Generally, the most difficult point is the evaluation of the structural ability of the package to withstand dynamic impact loads. A detailed theoretical and experimental evaluation of stresses and strains produced during the mechanical test of the Regulations is extremely difficult and usually part of the process of approval of a Type B design. In order to determine alternative safety provisions, it may be convenient to evaluate approximately the structural ability of the package to withstand an **actual impact** and, thereafter, to select an allowable maximum traffic speed for the vehicle, and the use of other compensatory provisions (e.g., overpacks, special vehicles).

When the overall containment effectiveness is estimated, it may be enough to carry out simplified mechanical calculations to obtain strains and stresses on main structural components (e.g., clamp bolts between components, cover bolts or lifting attachments) using suitable values of acceleration representing actual (more probable) impacts. Provided that in an actual accident some components function as energy absorbers (e.g., vehicle cabin, tractor or trailer), the accelerations reached by package components shall be much lower than accelerations reached during Regulations' mechanical test (unyielding target). The authors recommend to use values in the order of 35 g for impact speeds less than 70 km/h, *L'Arrimage de colis de matiéres radiactives en conditions accidentelles, Chevallier et al. 1987; Experimental Study of Transportation Safety of Package in Side Collision of Heavy Duty Truck, Suga and Sasaki 1989.* In order to estimate shielding degradation, there are some simplified methods such as **dynamic flow pressure**, *Cask Designers Guide*, and **simplified methods for determining the impact force**, *Simplified Method for Predicting Impact Loads of Solid-Walled Transportation Packagings for Radioactive Materials, Teper and sauve 1989; Crush: A Simplified Computer Program for Impact Analysis of Radioactive Material Transport Casks, Ikushima 1990.* In some designs it is important to estimate whether the outer shell strength of the package withstands the drop II of the Regulations, e.g., steel-lead-steel designs or fireshield. In this way there are simplified mathematical expressions which show the relationship between the outer shell thickness required to withstand the drop II of the Regulations and the package mass and the material tensile strength, *Cask Designers Guide, Shapert 1970; Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1985 Edition), IAEA 1990.*

It seems specially important for packagings with low melting points (e.g., steel-lead-steel containers) to evaluate the package ability to withstand a fire. Generally, in such type of containers it is possible to make approximately unidirectional calculations because the majority of designs appear to have symmetrical characteristics. Basically, the problem is to determine heat transmission prevailing means both inside each material and in material interfaces to establish a single equation system, to establish boundary conditions and to specify its main parameters. Convection correlations are particularly important during both fire and cooling processes; indicative values can be found in specific bibliography, *Heat Transmission, Mc. Adams 1954.* When the thermal profile of the package and, as a result of that, the maximum temperatures are approximately known, it should be possible to estimate whether a structural degradation of the package shall be expected. In some bibliographies it is emphasized that lead melting and expansion on liquid phase is the main reason for the probable hydraulic fracture of the capsule steel wall (structural failure or collapse), *Thermal Test Methods and Experience in the Federal Republic of Germany, Shultz and Forberg 1976; Heat Transfer and Thermal Test of 100 Ton Class Dry-Type Spent Fuel Transport Cask, Abe et al. 1989; Thermal Test on a Spent Fuel Shipping Cask, Aohi and Shimada 1976; Demonstration Test of 100 Ton Class Spent Transport Cask, Nagakura et al. 1986.*

USE OF A PACKAGING CORRESPONDING TO A TYPE B PACKAGE APPROVED BUT WHICH HAS LOST THIS STATUS DUE TO TECHNICAL OR ADMINISTRATIVE PROBLEMS

As has been previously mentioned, some habitual cases that can be presented are (i) currently the approval certificate is not in force, (ii) the approval certificate does not include this particular serial number, or (iii) the package design was approved under older revisions of the Regulations.

In the first (i) case the irregularity may be merely due to administrative or commercial reasons. When possible, such a situation should be corroborated. Regrettably, the Regulations do not present any mechanism for these situations for which the issue of an SA approval certificate seems to be a pure formality. At any rate it seems necessary to verify that the packaging has not received introduced any design modifications, that its general status is suitable, and that it has complied with the necessary inspection and maintenance procedures.

In (ii) precedent, it is necessary to investigate whether this packaging serial number was never covered by an approval certificate of such design. If it is the case, it should be convenient to deal with as a not approved packaging (see Use of an "ad hoc" packaging ...).

In (iii) precedent it seems convenient to consider the revision of the Regulations by which the package design was approved and to carry out a comparative analysis of the relevant requirements applicable at the light of this design, in order to determine whether the packaging in question could comply in principle with the applicable requirements of the 1985 Edition (As Amended 1990) of the Regulations.

ALTERNATIVE PROVISIONS

As was mentioned, safety alternative provisions may be of a different character. Taking into account their magnitude, it is possible to find the following extreme situations:

(i) If no alternative provision is required the approval of a transport under special arrangement becomes practically an administrative formality;

(ii) If there is not any reasonable confidence on the level of safety provided by the package, overpack, special vehicle, routing restrictions, fire brigades available all along the trip, escort and other provisions should be taken.

Between (i) and (ii) precedents, it should be ideal, but not possible in practice, to have a continuously varying system of the kind and magnitude of the alternative provisions in function of the degree of uncertainty on the knowledge of the package ability. Therefore, the evaluations before mentioned constitute an appropriate tool to estimate approximately the containment, thermal and shielding ability, in both normal and accident conditions of transport, and to establish the characteristics and magnitude of such alternative provisions.

If after the evaluations then appear to be certain doubts about containment, shielding or thermal dissipation ability of the package in normal conditions of transport, the main provision seems to be the performance of radiometrical, leakage assessment and temperature measurement tests before the shipment.

On the other hand, if after the evaluations there are doubts about the structural ability of the package under impact conditions or on its thermal resistance in fires, design alternative provisions may be necessary, e.g., to put the package into an overpack, and to transport the package into a freight container or into a closed vehicle.

In order to decrease the probability of occurrence of accidents, operative alternative provisions may be necessary, e.g., to prescribe requirements dealing with limited traffic speeds, supervision of vehicle main safety features (e.g., wheels, brakes, system of signs, beacons or lights), driver qualifications, escort vehicles, in-route stop, grade crossing of routes and railroads, and routing.

When an accident has occurred the main objective is to mitigate its consequences. In this case, alternative provisions may be required, e.g., to equip the escort with a fire extinguisher system to control minor fires, to accompany the vehicle by a motor fire engine to control major fires, and to include in the escort a radiation protection specialist with suitable countermeasure plans and adequate equipment.

CONCLUSIONS

In order to obtain a special arrangement approval certificate, the applicant must reach an agreement with the competent authority that, in the great majority of cases, requires a careful safety evaluation. Having in mind to be as objective as possible, the characteristics and magnitude of the alternative provisions of the transport of RAM under SA shall be based on this evaluation. However, for only a few cases there is enough evidence to enable the competent authority to take a decision based on firmly quantitative safety evaluations, while in the majority, complementary sound professional judgment seems to be the only tool available to make a suitable decision.

The difficulties mentioned above show the need of more international guidance on the subject, at least making a compilation of singular experiences of different countries. In addition, it is stressed that the guidance needed should be similar to the one required for a new problem, the case of specially dedicated transport systems.

Finally, it seems necessary that international community efforts should still be made to reduce significantly the degree of subjectivity which is at present involved in the transport of RAM under SA approvals. Quite probably the Agency could play an important role in harmonizing criteria and methods in this field.

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