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IRSN'S EXPERIENCE FEEDBACK LIST FOR THE TRANSPORT PACKAGE DESIGN SAFETY APPRAISALS

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ABSTRACT

Since 1996, IRSN, the technical support of the French Competent Authority for the safety of transports of radioactive materials, has recorded the list of the difficulties most frequently encountered during the appraisal of the safety reports of package designs. This so-called "REX (experience feedback) list" takes into account the most recent evolutions of the regulations and the last technological knowledge (the risk of perforation of a package by a punch after a 1 m free drop when the package is in oblique position, the 9 m drop test of a package with slap-down, the thermal dissipation under canopies, the brittle fracture analysis at – 40°C…). IRSN's experience feedback list for the transport package design, which is published annually, is used as a guide by IRSN for their appraisals of the design safety reports and by applicants to improve their design safety reports.

INTRODUCTION

The activity of transportation of radioactive materials is in constant evolution; air transport of radio elements for medical use is growing rapidly as well as transport of instruments equipped with radioactive sources for inspections of buildings (controls of presence of lead in paintings) and in industry (non destructive examination of welding by gammagraphy, controls of density on building sites). Transports associated with the recycling of plutonium for the production of electricity by nuclear energy are now accomplished in routine. Globally, 900.000 packages are shipped each year in France; among them, approximately 100.000 packages belong to the category for which design approval is required.

To maintain a high level of safety for this activity by limiting the probability of occurrence, the severity and the consequences of the incidents and accidents, strict rules are implemented under the control of the Safety Authority.

According to the systematic approach of defence in depth, which is defined by the three principles of safety in design, of operational reliability and of effectiveness of emergency response, the robustness of the design of the package is of primary importance [1]. It is based on regulatory requirements relating to the functions of safety (containment of radioactivity, protection against radiation and prevention of the risks of criticality) that must be ensured by the package in routine conditions of transport as well as in accident conditions.

These rules and the way of applying them evolve with time. Indeed, on the one hand the regulation is re-examined periodically; on the other hand, the technical knowledge on the behaviour of the packages subject to the above mentioned conditions and the means of evaluation of this behaviour progress permanently.

Since 1996, IRSN, the technical support of the French Competent Authority for the safety of transports of radioactive materials, has developed an "Experience feedback-TRANSPORT" document which lists the difficulties most frequently encountered in design safety reports assessments and takes into account the most recent evolutions of the regulations and the last technological knowledge.

DEVELOPMENT OF A "REX-TRANSPORT" DOCUMENT

The role of IRSN in the field of transport safety

As a national technical support organisation (TSO) of the French Nuclear Safety Authority (ASN), the Institute for Radiation Protection and Nuclear Safety, IRSN, has several missions in the field of transport safety.

First the institute is in charge of the assessments of the safety analysis reports of the package designs. Such assessments are relative to the licensing of new designs as well as to any design modification impacting safety.

IRSN is also systematically collecting information relative to declared events that occurred during the transport of radioactive materials in France. This information is collected in a database that can be used for further investigation. IRSN eventually draws recommendations of various natures either on an individual event basis or annually; these recommendations may concern design, operations, reactive or follow-up inspections by the ASN, or proposals to change the applicable regulation and the emergency response organisation of either the operators or public authorities.

IRSN is also involved in the international cooperation including IAEA technical committees for the definition of the evolutions of the regulations.

Moreover, IRSN develops R&D actions and tests for basic data acquisition, overall test or codes qualification activities. These actions aim at identifying emerging issues or qualifying data used in the assessments. Part of these activities can be achieved in cooperation with applicants. In this case, the following conditions apply simultaneously:

- the action aims at collecting basic data that are not directly related to a safety case,
- the approval by IRSN of the conditions of the tests does not commit it to any further position.

Based on this extensive data collection, IRSN has developed specific approaches for assessing the safety cases as presented hereafter.

The package design review

Considering this evolution of the rules, knowledge and techniques development, a process of periodic review of the design of the packages has been implemented. This has been facilitated by the current practice of renewal, every three to five years, of approvals of the package designs.

During these renewals, a re-assessment of the conformity of the package design to the current regulation is carried out systematically. This assessment takes into account the evolution of knowledge on the behaviour of the packages in the different considered situations of transport; it also takes into account the evolutions of the regulation applicable to the considered design and lessons learned from the analysis of the incidents recorded in the course of use.

The re-examination of the package design safety reports made it possible to IRSN to gradually constitute a data base of experience feedback known as "REX-TRANSPORT" document. IRSN supplements this document from its assessments of design safety reports but also from its data related to the transport accidents, incidents and operating deviations and its

R&D results. Each time an evaluation highlights the potential or confirmed repetitive nature of a defect or lack in justification, this defect is recorded in the base.

The base, which thus grew rich gradually since 1996, is published annually or as soon as the number and the importance of the new defects justify it. The contents of this base are transmitted by the nuclear safety authority (ASN) to all applicants for package design approval. The topics traced in the "REX-TRANSPORT" document are, for instance, the risk of perforation of a package by a punch after a 1 m free drop when the package is in oblique position, the drop of a package with effect of slap-down, the thermal dissipation under canopies, the radiolysis phenomena in hydrated materials or organic mixtures, the brittle fracture under – 40°C …

This document makes it possible to the applicants to level the justifications included in their safety reports, to even correct the package design, before applying for approval. This improvement step is likely to accelerate the instruction of these files by the authority and its technical support, IRSN. This document is also used as a guide at the time of the periodic re-examination of the safety cases by IRSN. It helps in identifying, in a systematic way, the defects in the safety justifications provided in the safety cases. This approach is thus likely to reinforce confidence in the conformity of the package design to the applicable regulatory provisions.

EXAMPLES OF TOPICS IN THE "REX-TRANSPORT" DOCUMENT IMPACTING SAFETY OF PACKAGE DESIGN

Some examples of difficulties traced in the experience feedback which had important repercussions on the design of the packages.

Free drop onto the regulatory punch of a package specimen is in oblique position

Specific attitudes of the specimens to be subjected to drop testing have been identified as more penalizing than the current attitudes: the risk of perforation of a package by a punch after a free drop test from a height of 1 m is strongly increased when the package is in oblique position compared to the horizontal top end of the punch (Figure 1).

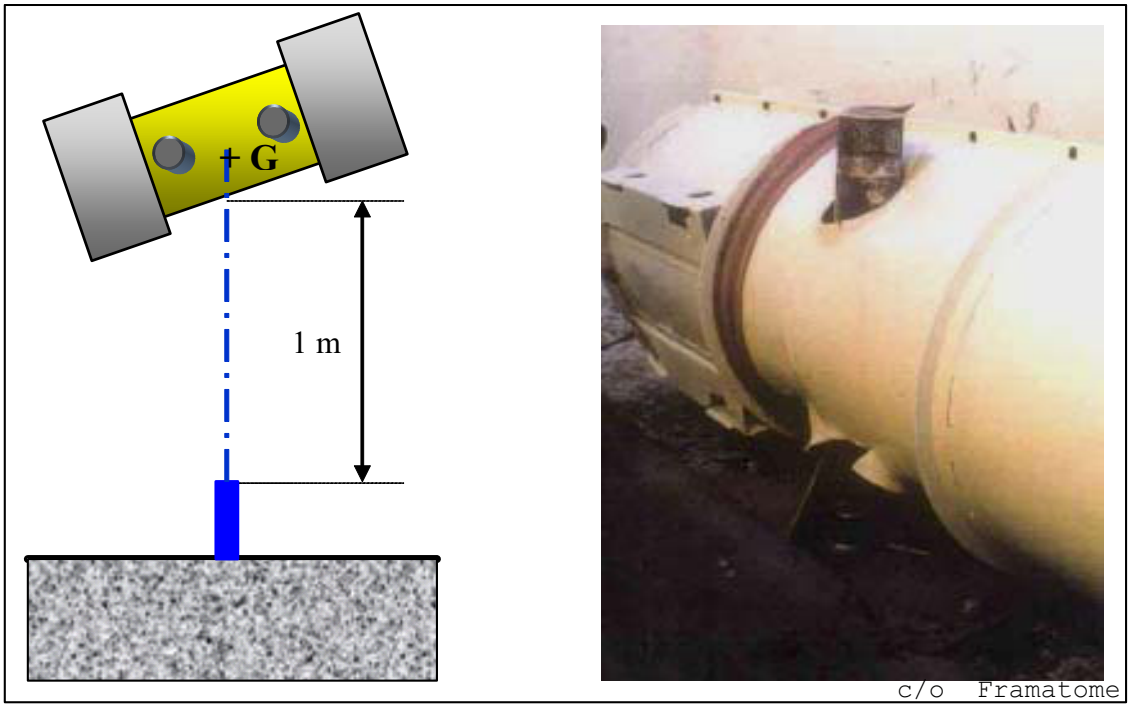

Figure 1: Double-perforation of a prototype of package by the regulatory punch. Resistance to perforation is lo in oblique.

For certain packages, considering this new configuration of test simply resulted in supplementing the analysis of safety by a suitable argumentation; for others, it involved the need for reinforcing the thickness of the steel plates of the external protection; for others still, as for the packages designed to transport unirradiated fuel assemblies, the whole fleet of packagings had to be replaced.

Drop of a package with effect of slap-down

The free drop test of a package from a height of 9 m with a low angle with the horizontal line can be until twice more penalizing than in the case of a drop of a perfectly horizontal package (Figure 2). Indeed, for such a drop concerning a slant shaped package, the first shock of an end of the specimen of package on the target produces a conversion of kinetic energy of translation into energy of rotation of which the effect is to increase the severity of the second shock on the other end. The analysis of this configuration of drop revealed weaknesses in the fixing devices of the shock protective covers for certain package designs. New concepts with stronger fixations were then developed and successfully tested.

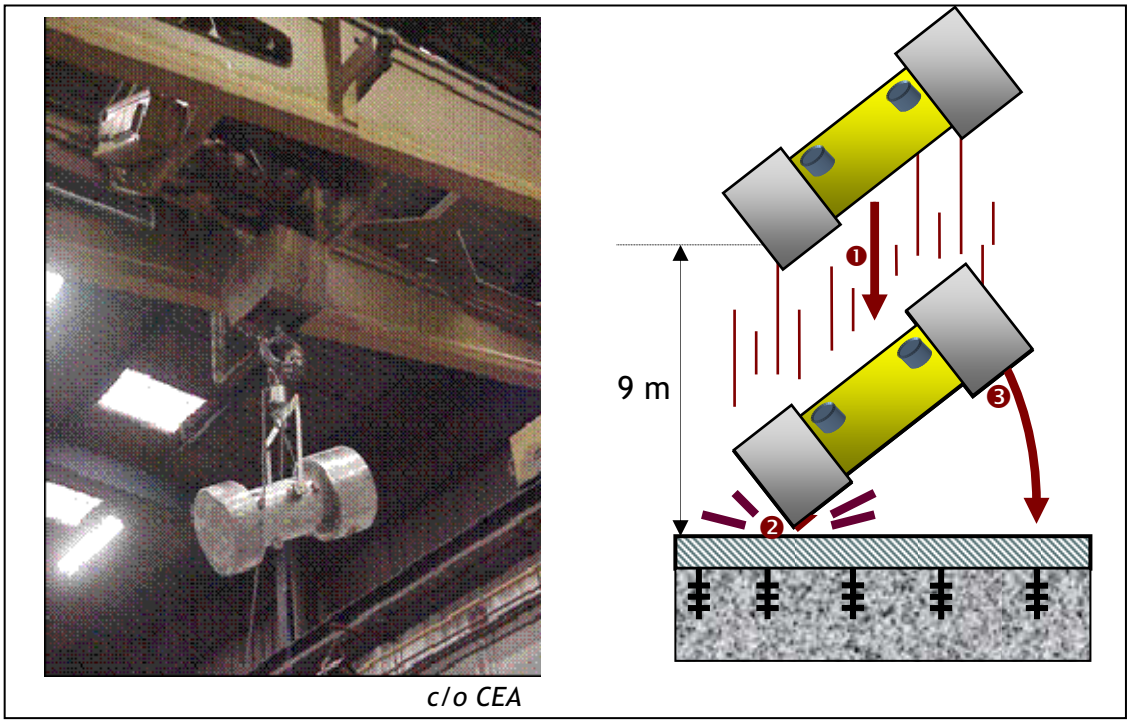

Figure 2: Position of drop with slap down

Capacity of thermal dissipation of tarpaulins and canopies

The use of systems protecting packages against the bad weather during transport is obligatory in France for the packages which are loaded underwater and which are likely to present a contamination on their external surfaces. These systems which should limit the hazards of propagation of contamination by the elements consist either in tarpaulins for the semi trailers or in canopies for the wagons (Figure 3). When the packages are loaded with irradiated fuel or high activity waste, they are likely to dissipate a high thermal power. In this case, the protection systems are especially conceived to allow the natural ventilation necessary to the good cooling of the packages. IRSN had noted that the temperatures of the packages under tarpaulins or canopies were not calculated; it was pointed that all the numerous configurations of tarpaulins and canopies should be indexed and that the real capacities of thermal dissipation should be justified. This action led to a considerable reduction in the maximum allowed thermal powers in some of these systems.

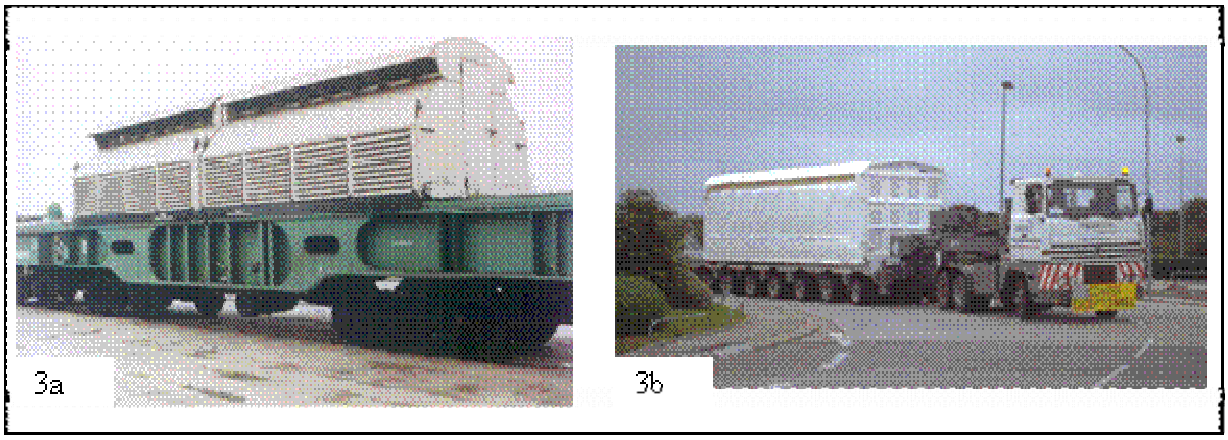

Figure 3: a - Wagon equipped with sliding canopies for the transport of irradiated fuels
b - Special cover of protection of a packages containing vitrified wastes

Modification of the geometry of the fissile contents

In accidental conditions, the transported radioactive material can be damaged with some change in geometry. A realistic evaluation of the behaviour of the fissile contents of the package is thus particularly important, insofar as a change of geometry is likely to call into question the prevention of the risks of criticality.

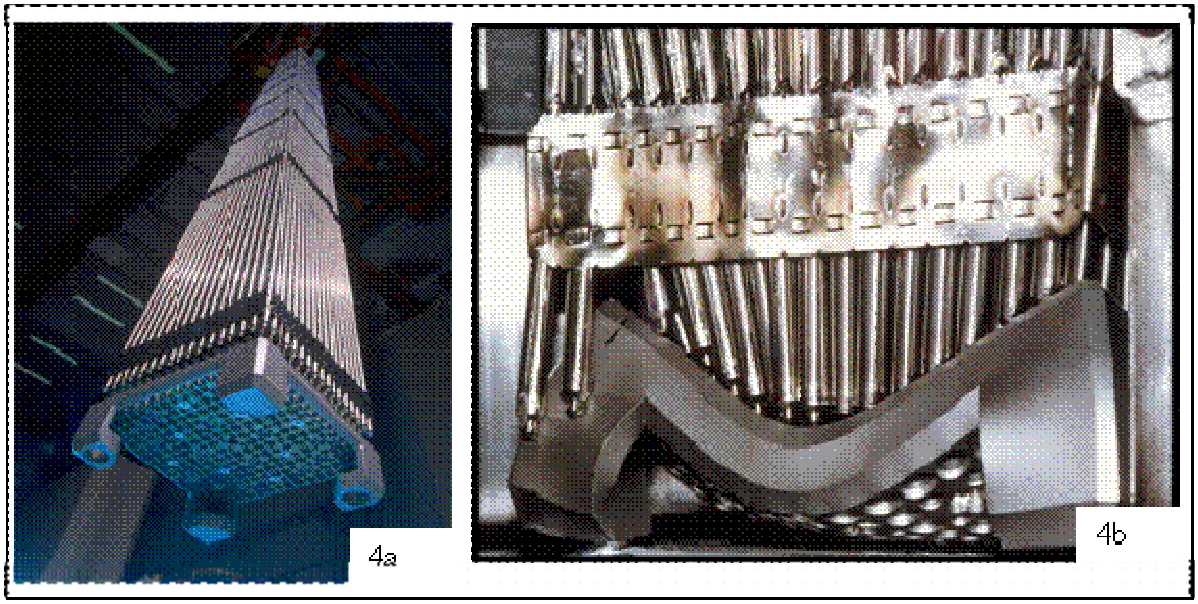

Figure 4: A specimen of fuel assembly before (Figure 4a) and after the drop and fire tests (Figure 4b) - (courtesy of TN international)

Scaling laws applicable to package drop testing

When the demonstrations of the mechanical resistance of a package are founded on tests with reduced scale models, it is needed to increase the drop heights to simulate the total potential energy that would have been received by the package at scale 1. Indeed, the potential energy depends on the total course of the centre of gravity of the specimen during the drop until its vertical speed comes to 0; this course includes the depth of crushing of the package or the penetration length of the punch into the package eventually cumulated with the movement of the end of the punch due to either crushing or buckling; the associated correction is particularly important in the event of perforation of the shock absorbers by the punch (Figure 5).

As the geometry of scale model is homothetic to package geometry with a scaling factor k, damages incurred by the scale model should be at least equivalent to the damages to the package when dropped from height H, which is translated by the law:

$\delta_{p'} = \delta_p / k$

concerning respective crushing distances on scale model, $\delta_{p'}$, and package, δ_p.

In addition, at scale 1, the total vertical course of centre of gravity of package during crushing is the sum of the package crushed distance δ_p and vertical course of the bar extremity δb, when applicable. Considering that materials are identical and have same mechanical properties (same crushing stress σ) and density, rules are developed assuming uniformly accelerated motion in vertical direction during crushing (or uniform crushed area): then, the basic principle $\delta_{p'} = \delta_p / k$ is met when the height, H', for reduced scale model is

$H' = H + (\delta_p + \delta_b)(1 - 1/k)$.

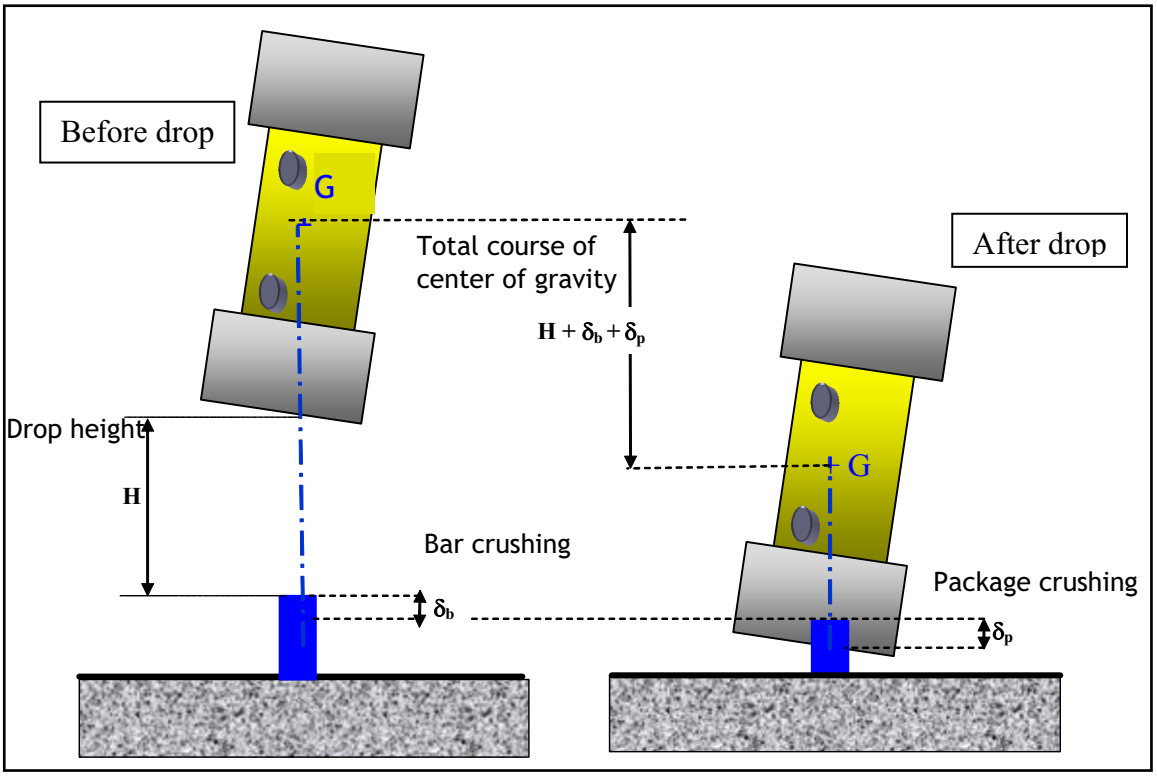

Figure 5: When the demonstrations of the mechanical resistance of a package are founded on tests with reduced scale models, drop heights should be adjusted so that the energy received by the specimen remain representative for the total potenential energy [M g (H + δ_b +δ_p)] that would have been received by the package at scale 1.

The determination of the height H' supposes that you can estimate δ_p and δ_b by analysis before testing. This can be done by simplified analysis or analogy or more colex calculations. The relative drop height increase may be of large magnitude for drop tests onto the bar when the bar penetrates into the package shock absorbers throughout a large distance. These corrections of drop height are absent in most of the package design safety reports until

ese corrections of drop height are absent in most of the package design safety reports until recently and may increase the deformations of the packages. As for currently used package designs for which such corrections have not been implemented during the qualification test campaigns, the impact of this correction on the safety of the package should be evaluated.

Phenomena of radiolysis

The taking into account of the risks of production of flammable gases by phenomena of radiolysis and/or thermolysis during transport involved operational limitations on the allowed activity of the contents as well as on the acceptable durations of preliminary storage and transport operations.

Performances of sealing

The mechanical resistance and sealing performance of the containment system of packages must be ensured until -40°C pursuant to the regulation. The leaktightness test criteria to be guaranteed by measurement before shipment were re-examined; restrictions were established for the use of certain grades of elastomer in O-rings which do not preserve a sufficient sealing at this temperature. This issue encouraged one applicant to develop a new elastomer grade [3].

FUTURE PROSPECTS

The application of the "REX TRANSPORT" document is all the more effective as the number of the applicants concerned is limited and that the components of the various designs of package are often similar, which reinforces the repetitive character of the experience feedback; it strongly contributes to guarantee the compliance with the rules applicable to package designs and to ensure an homogeneous level of safety.

Within the framework of the actions of renewal of the fleet of French packagings and certain foreign designs [2], this base showed all its interest. Indeed, the replacing new designs could profit, during their development, of the last techniques and knowledge available to justify the required performances. They now constitute a durable fleet of well optimized packagings.

Work is in hand within a European framework to work out a guide to assist in drafting the package design safety cases; integration, in this guide, of the experience feedback of the appraisals of the package design safety reports would make it possible to reach a new stage for the harmonization of the level of safety of transports accomplished in the European Union. In the long term, these results could also be integrated in a new international applicants guide if the International Atomic Energy Agency decides to develop it; the required harmonization would then be still reinforced.

CONCLUSION

The "REX-TRANSPORT" document, developed and updated annually by IRSN, is used as a guide by IRSN for its appraisals of the design safety reports and by applicants to level the justifications included in their safety reports, to even correct the package design, before applying for approval. This improvement step is likely to accelerate the assessments. The "Experience feedback-TRANSPORT" list strongly contributes to assure a high level of safety in the radioactive material transportation activities.

This assessment experience feedback process could be implemented thanks to the specific competency of IRSN in the field of transport safety, but the acceptation to use it by designers was essential to make its implementation efficient.

REFERENCES

[1] Revue Contrôle N°162, p 78-79, the safety of the transport of radioactive materials, January 2005.

[2] RAMTRANS journal, vol. 10, No 4, pp. 271-272, Situation report on compliance assurance in France, Nuclear Technology Publishing, 1999.

[3] PATRAM' 2004, paper 189, A new generation of fluorocarbon O-rings developed by COGEMA LOGISTICS with enhanced characteristics at low temperature (-40° C).