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A REVIEW OF ENVIRONMENT EXPERIENCED BY PACKAGES IN TRANSPORT

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ABSTRACT

As the transport conditions were defined 50 years ago, it seems legitimate to raise again the issue of their pertinence. A review of routine, normal and accident conditions of transport is then necessary to take into account the new transport environment as the impact of climate changes, the new transport practices... Additionally, the very less likely accident that is to say beyond the regulatory requirements should be considered especially taking into account the Fukushima lessons. The IAEA General Conference requested a review of the environment experienced in the transport as inputs for next edition of the regulations and its guidance and the Secretariat addressed these issues and envisaged eventual inputs for next edition of the regulations and its guidance. Such a meeting was convened in July 2013 in Vienna (TM).

As for the review of the routine and normal regulatory requirements/guidance performed during the TM, presentations were made during the first two days of the TM by experts in transport environment and it has been recommended to TRANSSC the formation of expert working groups to review Appendix IV "Package Stowage and Retention During Transport" of Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (TS-G-1.1), air/maritime transport practices, and segregation of radioactive material from other dangerous goods for all modes of transport. It has also been recommended to consider in the current review/revision cycle proposals on the shipment of packages that includes mechanical cooling systems, accumulation of packages, whose content generates heat, on the same vehicle and impact of the conveyances on the temperatures. TM has also recommended Member States to collect data about extreme ambient temperatures and insolation.

For accident conditions of transport, TM has also recommended to consider in the current review/revision cycle the increase of duration for the immersion test for packages containing fissile material and a modification of an applicability condition for the dynamic crush test.

TM has also recommended to introduce as an urgent issue in the current review/revision cycle of the SSR-6 a clear requirement on emergency preparedness. In addition, TM has recommended the revision of the TS-G-1.2 guidance to be done in this cycle. Concerning very less likely accidents (that is to say beyond

regulatory requirements), it was agreed that some guidance would be necessary in TS-G-1.2 which is under revision and that no change in the regulation is expected.

Concerning the various environment stresses to which a package is likely to be subject for the routine, normal and accident conditions of transport, the current regulatory test regimes were considered to remain appropriate except for the minor changes TM has identified. .

INTRODUCTION

As the transport conditions were defined 50 years ago, it seems legitimate to raise again the issue of their pertinence with regards to present transport environments and changing public perception. A review of routine, normal and accident conditions of transport is then necessary to take into account the new transport environment as the impact of climate changes, the new transport practices... Additionally, the very less likely accident that is to say beyond the regulatory requirements have to be considered especially taking into account the Fukushima lessons. The IAEA General conference requested a review of the environment experienced in the transport and the IAEA Secretariat convened a Technical Meeting to address these issues and envisage eventual inputs for next editions of the regulation and its guidance. Such a meeting was convened in July 2013 in Vienna to review the regulation/guidance dealing with the above mentioned environment including Fukushima lessons. .

ROUTINE AND NORMAL CONDITIONS OF TRANSPORT

Climate change

Concerning this issue, UNECE took coordinated steps to address climate change adaptation in the field of transport. Adaptation action aims at reducing vulnerabilities and increasing the resilience of transport systems to climatic impacts. Resilience refers to the ability of a system to withstand negative impacts without losing its basic functions. A Group of Experts on climate change impacts and adaptation for International transport networks was established in 2011.

Furthermore, Type B(M) packages are permitted, subject to Competent Authority approval, to use alternative values for ambient temperature ranges and insolation other than those prescribed in the IAEA's Regulations for the Safe Transport of Radioactive Material. In the UK, the agreed values were based on BS3895:1976, and recommended an ambient temperature range of -10 °C to +26 ° C, and half of the insolation values in Table 13 of TS-R-1 for Type B(M) packages for use solely within the UK. This standard was withdrawn in 2006, and along with a growing appreciation of the impact of climate change, prompted a review of UK climatic conditions. A technical research proposal was developed with industry and regulators, and conducted by the UK's Met Office. A wide range of statistics were produced, including peak maximum, minimum and average figures for insolation and temperature, and averages of these figures over periods of 8 and 24 hours. Criteria were applied to ensure relevance of the input data. Computational modelling was used to predict trends over the next two decades to 2030. The results of the research suggest that the previously accepted range of -10 to +26 °C and half of the insolation values are exceeded although they are still be bound, in the main, by the B(U) requirements. Implications for package design were discussed, as previously approved packages may have increasingly limited operational availability as a result, as prevailing conditions may exceed their approved safety envelope, and package design authorities may wish to consider the operational requirements of the package against the cost of meeting more challenging thermal parameters.

Concerning the low temperature margins observed by reference to B(U) temperature requirements, though the UK climate is temperate, it was felt the need to better know the ambient temperature ranges that are

observed in different regions of the world. It was decided during the TM that countries will provide the highest and the lowest temperature in their country relating transport routes and if available insolation values over the past ten years in order to compare them with the values given in the regulation.

Air transport practices

ICAO is studying the current environment experienced by a package in an aircraft cargo hold. The results of this study will be available at the end of this year. Two major aircraft manufacturers had provided data on typical environmental conditions for both in-flight and on ground conditions that may be encountered in their compartment holds; these conditions are prescribed by airworthiness requirements in Annex 8 to the Convention on International Civil Aviation. The concept of ICAO Standard Atmosphere was explained in relation to pressure measurements as were the minimum operational performance standards for humidity, vibration and shock as contained in EUROCAE ED/14 and RTCA DO160. Data for recommended acceleration values were based on military aircraft for normal flight whereas that for emergency landing conditions was based on that in the US CFR Title 14, 25.561. Information was provided about an air packaging environmental conditions research study presently underway using instrumented packages in the air cargo handling and transport system, including that for express carriers. It is hoped that preliminary analyses of the data collected may be available for the next TRANSSC meeting to be held in November.

The problem presented by explosive or rapid decompression in an aircraft and its impact on the structural integrity of that aircraft together with its contents was illustrated by a number of aircraft accident examples which had resulted from a variety of causes e.g. improper maintenance, metal fatigue and corrosion. It was explained that the 'useful time of consciousness' for a pilot to don an oxygen mask in the event of an explosive decompression was only between 5 to 10 seconds and that 63 accidents had been recorded in the period 1983-2012.

The large increase in cargo containing dangerous goods was discussed and it was suggested that radioactive material should be segregated from such cargo, particularly if a leakage or fire emanating from the other dangerous goods cargo could potentially damage the radioactive material packaging.
TM has recommended the formation of an expert working group on segregation of radioactive material from other dangerous goods for all modes of transport.

Stowage and tie down system

TS-G-1.1 should be the most important source for load case data under routine conditions of transport. A closer look, however, reveals deficiencies or at least a too wide range of interpretation how to apply those values. Therefore the improvement of the guidance material is recommended.
Several options exist how to improve the values and guidance. At first the goal has to be discussed and agreed, how the guidance should be improved. Is there a need of more reasonable values for different package masses? How to combine acceleration values? And other questions should be discussed and agreed in the framework of TRANSSC.
Load case values are always connected to the entire design concept. Therefore design criteria should be considered as well, if acceleration values are defined.
To get information about world-wide application and acceptance of values, BAM proposes to start a survey as a first step. The survey shall collect applicable acceleration data and criteria among the Member States to make standards and codes comparable. Beyond this, an important outcome could be an up-to-date reference list on applicable design standards regarding acceleration values and criteria.
Another approach based on dynamic response of the package and conveyance system is an alternative to the more common static assessment approach. To use the power spectrum density approach, new experimental data applicable to main types of packages and conveyances would be needed. This approach could

also be used through an intercomparison assessment to check the safety margins that may be embedded in the static approach.

TM has recommended the formation of an expert working group to review Appendix IV of TS-G-1.1 and air/maritime transport practices.

Cooling system and interaction between packages and conveyances

The IAEA Regulations for the Safe Transport of Radioactive Material (TS-R-1 - 2009 Edition, and SS-R-6 – 2012 Edition) control radiation doses in the vicinity of the vehicle loaded with single or multiple packages through the Transport Index (TI), similarly to the way criticality is controlled when transporting a single or multiple packages through the Criticality Safety Index (CSI). Compared to this, thermal safety is controlled for single packages only, not directly accounting for multiple heat generating packages or other heat sources. Regulations and guidance limit surface temperatures of packages at various ambient ranges to protect people and environment, but these regulations do not directly consider the reverse effect of the environment on the package itself, except some hints in paragraphs 554 (a), 565, 809 (g), 836 (l), 837 (g) and 838 (q) in SSR-6. Generally, conveyances do not present any additional dose or criticality hazards, but some of them may require additional thermal considerations because of heat sources such as engine rooms, and confined enclosures, restricted air flows etc. The existing regulations are therefore questioned by asking if they are sufficient to control thermal aspects introduced by the conveyance, even though they were not designed for this purpose, or whether existing provisions should be made more explicit or further provisions should be made.

Furthermore, a study dealing with the loss of mechanical cooling system on a ship carrying high active waste indicates that without intervention, loss of containment of the flask would be very unlikely but some loss of neutron shielding performance is probable. Temperatures would not be sufficient to ignite the ship fuel oil if confined.

TM has proposed to consider some modifications of the regulations concerning the accumulation of packages on the same vehicle, the impact of the conveyance on the temperatures of the packages and the consequences of the loss of mechanical cooling system. Shipments requiring a mechanical cooling system could be subject to competent authority shipment approval, providing as part of the application the important information on the time duration in which the package remains within its safe operating envelope in the case of failure of the cooling system.

ACCIDENT CONDITIONS OF TRANSPORT

Immersion test

There was discussion on the conditions set for the water immersion test (para. 729 TS-R-1), the enhanced water immersion test (para. 730) and the water leakage test (para. 733). These issues are derived from lessons drawn from past events that showed that there could be safety implications of the depth and period of immersion.

Though at low depth (15 m), recovery of cylinders trapped in the hold of the Mont Louis cargo took 40 days during which water ingress took place, which, if concerning fissile material, would correspond to higher hazard than what is covered by the current regulatory test condition (limited to 8 hours). This contributed to think to change the time period of the water immersion test and water leakage test to 1 week or so instead of 8 hours.

The intent of the 200 m immersion test is to facilitate recovery of the package on the continental shelf. Therefore, the acceptance requirement is that the package would withstand the immersion "without rupture". Studies have demonstrated that the doses associated to seafood consumption after a release of radioactive material following a deeper immersion are tiny. Another issue was raised about impact of radioactive material immersion on fishing activities that may sometimes concern depths greater than 200 m.

Tests, and calculations in some instances, allowed assessing the behaviour of packages after an immersion deeper than 200 m. The packages which were considered include packages for plutonium oxide (PuO_2) powder, spent fuel assemblies, high activity waste and fresh mixed oxide (MOX) fuel assembles. The result is that these packages can withstand immersion with a depth ranging from a few times the regulatory depth up to several thousands of meters.

One important lesson from these experiences is that compliance with all the regulatory requirements leads to high performance regarding each of them. For instance, packages designed to transport spent fuel assemblies or high activity waste include a body which is very thick in order to provide adequate gamma shielding. This shielding provides strong mechanical resistance and a capacity to withstand an immersion test significantly more severe than was is strictly required. As a conclusion, the 200 m immersion test has sound technical basis: the Regulations are adequate. Nevertheless, a better knowledge of time necessary to retrieve packages lost at sea is necessary and can contribute to consider that corrosion phenomena may develop in the meantime with possible impact on the mechanical resistance of the containment system. This raised the issue of increasing the period of the enhanced water immersion test to 6 months or more with due account for corrosion phenomena but more study is needed on this point and no modification of the regulation is recommended by the TM.

Crush test

TM has recommended considering in the current review/revision cycle the review of the condition on the density of package since there is no clear justification provided in the technical background of the regulation.

Fire

The U.S. NRC performed the research and presented the results of severe fire accidents of railway and roadway transportation in the United States. They analyse severe fire scenario case study in railway and roadway accidents occurring in open field and within a tunnel, and the actions taken to mitigate the risk of fire accidents. The results conclude that for the severe fire accidents for transporting spent nuclear fuel on railway and highway, the frequency is very low and the consequence is not significant. The U.S. NRC concludes that regarding such accidents the current regulatory framework is adequate and there is no need to change the regulations at this time. TM agrees with NRC's.

FUKUSHIMA LESSONS

Identification and classification of transport incidents potentially caused by natural events

The technique of identifying and classifying transport incidents potentially caused by natural events is proposed to respond issues from gap reviews of the Fukushima accident. Expert judgment is employed to identify potential incidents comprehensively using the hazard matrix. The concept of probabilistic risk assessment has been introduced to evaluate the identified incidents using risk indices. Then they are

placed on the risk matrix to focus on the group of incidents requiring special attention, or the bounding cases. It is useful to simply evaluate using risk index of small numbers of ranks, representing an order of frequency magnitude or the grade of package test condition. Also, an application example of domestic spent fuel transport case is shown for demonstrating the use of the technique. It would be helpful to finish gap reviews in Japan and also support the present approach in the Regulation.

Risk management studies

The U.S. NRC has developed a Proposed Risk Management Regulatory Framework (NUREG 2150), which builds upon well-established practices and incorporates risk-informed and performance-based approaches in the agency's regulations. A Risk Management Task Force has been developed to focus on specific areas, including reactors, materials uses, waste, uranium recovery, fuel cycle, interim spent fuel storage, and transportation. The presentation emphasized the agency's use of regulatory guides and the benefits gained from operational experience. The charter for the Task Force and their recommendations related to transportation are included. Moving forward, the U.S. NRC recognizes the value added by the consensus-based international transportation standards, and the benefit of the stability of those standards over the past 50 years. Additionally, the agency recommends that a risk-informed, performance-based approach be considered for future proposed changes to the international/IAEA packaging and transportation standards. Lastly, the U.S. NRC concludes that the current regulatory framework for packaging and transportation is adequate, and that future proposed changes to the packaging and transportation standards should be focused on development/revision of guidance documents rather than actual changes to the current transportation standards.

Package burial in a marsh or under debris from earthquake or from another accident

The design of packages, developed to transport radioactive contents with high thermal power, takes into account the heat exchanges between air and external surfaces of the packaging. But, in case of burial, the heat dissipation capacity of the packages may significantly decrease with a risk of overheating package components which are important to safety.

This scenario seems to be realistic considering the transport by rail of French spent fuel packages from the Nuclear Power Plants to the French reprocessing plant located in La Hague because the spent fuel packages transport crosses a soft ground area with significant depth which is called the Carentan marsh.
In order to evaluate the consequences of burial on package thermal behaviour, France performed first a mechanical study to evaluate the burial depth and secondly a thermal study in order to assess the temperature increase of some package components which are important for safety.

The results of the calculations performed put in light that in case of complete burial of a package with an internal thermal power equal to 50 kW, the temperature limit of the containment gaskets may be reached in around 2.5 days. In this regard, emergency plans should include, for all packages transported across areas with a significant risk of burial in case of accident, specific provisions to recover heat dissipation capacity before failure time.

Behaviour of packages involved in an earthquake

The transport Regulations does not include requirements regarding the behaviour of packages during an earthquake. However, assessments have been performed on dual purpose casks, for the transport and storage of spent fuel assemblies and high active waste, as part of the storage licensing process.

Casks are considered to be in storage configuration and position, which are more damaging than the transport configuration and position.

The conclusions are that (i) the vibrations due to the earthquake do not jeopardize the leaktightness of the package, (ii) the packages are stable in most instances, and – should the package tip over – the damages will be less severe than those induced by a regulatory drop test, and (iii) horizontal displacement are limited, and consequences of an interaction between two packages or between a package and other equipment will be less severe than those induced by a regulatory drop test.

Conclusion

TM has recommended as an urgent issue to strengthen the concept of emergency preparedness in the regulations, also as an approach to cope with rare but serious events. It is proposed to introduce in the current review and revision cycle that the regulations requires explicitly emergency plans including participation of the transport operator. In addition TM recommends the revision of TS-G-1.2 to be done in this cycle.

Concerning very less likely accident (that is to say beyond regulatory requirements), it is agreed that some guidance is necessary in TS-G-1.2 which is under revision. No change in the regulation is expected.

CONCLUSIONS

The TM reviewed the regulations for the transport of radioactive material including the proposals of the current revision cycle regarding the environment of the packages as given by climatic conditions as well as the transport practice.

One important outcome of the TM was the formation of a working group on routine conditions of transport, aiming on improving the guidance on mechanical loads given in Appendix IV of TS-G-1.1 (Rev. 1). Further considerations may be necessary after completion of a study on the environment experienced by packages during air transport.

Concerning the various environment stresses to which a package is likely to be subjected for the routine, normal and accident conditions of transport, the current regulatory test requirements were considered to remain appropriate in the whole, except for some issues TM has identified as detailed in the above paragraphs and which should be reviewed under the current review cycle of the transport regulation and guidance.