DESIGN STANDARDS FOR ON-SITE TRANSPORT PACKAGES

I L S Gray
RM Consultants
3rd Floor
3 Highgate
Kendal
Cumbria
LA9 4DA

INTRODUCTION

The regulations governing the transport of radioactive materials are prepared by the International Atomic Energy Agency (IAEA), with the most recent edition being published in 1996 as ST-1 [1], although a slightly revised edition (designated TS-R-1) that corrected a number of minor errors was published in English only in late 2000. These regulations have been developed over 40 years [2] and contain design standards and performance requirements. However, they are only intended to be applied to the transport of radioactive material in the public domain. There is no internationally accepted set of design standards applicable to packages intended purely for on-site movements.

The IAEA Transport Regulations apply to all aspects of transport, including the loading and unloading of radioactive material into and out of the packaging within which the material is being carried. In respect of UK nuclear licensed sites, there is therefore an overlap between the regulation of loading on the sites, as activities on such sites are regulated by the Nuclear Installations Inspectorate (NII), and radioactive materials transport is regulated by the Department of Transport, Local Government and the Regions (DTLR). This is dealt with by a Memorandum of Understanding between the NII and DTLR.

As well as on-site and off-site transport of radioactive material being the responsibility of different regulators, there is also a fundamental difference between the regulation of radioactive material transport and that of nuclear licensed sites. The former takes place by specifying detailed requirements that must be met: these include requiring that all valves through which radioactive contents could otherwise escape are protected against unauthorised operation. In contrast, the NII have far less detailed requirements, and instead specify principles, such as Basic Safety Limits (BSL) and Basic Safety Objectives (BSO) for public and worker risk, against which an operator would be required to demonstrate compliance.

It is therefore not possible to take the IAEA Transport Regulations, apply them directly to on-site movements on a nuclear licensed site, and assume that such movements would comply with the NII's requirements.

Instead in the UK, suitable safety cases need to be prepared and submitted to the NII covering the use of packages for on-site movements. The NII require safety justification involving a combination of quantitative risk assessment and full engineering substantiation against appropriate design standards. These are derived primarily from the NII Safety Assessment Principles (SAPs), although the IAEA Transport Regulations,

with their specific application to radioactive materials transport packages and years of experience and development, are suitable for providing the basis for the design standards for the engineering substantiation.

The remainder of this paper considers the application of the requirements in the IAEA Transport Regulations to a package that would require to be a Type B package if it were used in the public domain and thus required to meet the relevant regulations in the IAEA Transport Regulations.

PRINCIPLES OF THE IAEA TRANSPORT REGULATIONS

The fundamental principle of the IAEA Transport Regulations is that protection during transport of radioactive material is achieved by requiring:

- containment of the radioactive contents;
- control of external radiation levels;
- prevention of criticality;
- prevention of damage caused by heat.

These requirements are satisfied by:

- applying a graded approach to contents limits for packages and transport conveyances, such as road vehicles;
- applying performance standards to package designs that take account of this graded approach;
- imposing requirements on the design and operation of packages, and on the maintenance of packagings;
- requiring administrative controls, which includes approval by the competent authorities, where appropriate.

The package standards that are required to be met are dependent upon either the total activity or the specific activity of the radioactive material to be transported. Material with very low levels of radioactivity is exempt from the regulations, with the specific activity exempt limits, which are radionuclide-specific, being typically around 10 to 100 Bq/g, with a maximum value of 10^7 Bq/g for Ar-39. Activity limits for exemption apply to consignments, and are typically about 10^6 Bq. The A_2 activity value is used in defining the package type that is required for particular radioactive material.

BASIC PACKAGE PERFORMANCE REQUIREMENTS

Package performance requirements are defined in terms of routine, normal and accident conditions of transport. For routine conditions of transport, the external radiation is important, and the package category (i.e. White, Yellow-I, etc.) provides a classification for this. Under accident conditions, it is the package type (Excepted, Industrial, Type A or Type B) that is important. Excepted, Industrial and Type A packages are not required to withstand accidents, whereas Type B packages are expected to withstand all

but very severe accidents. The basic Type B package performance requirements are summarised in the following table.

Package Type	Normal Conditions		Accident Conditions	
	Containment	Radiation	Containment	Radiation
Type B	A loss of no more than 10^{-6} A_2 per hour	An increase of no more than 20% at the surface	A loss of no more than one A_2 (10 A_2 of Kr-85) in one week	No greater than 10 mSv/h at 1 m from the package surface

For packages containing fissile material, additional requirements are specified to ensure that subcriticality is maintained under normal and accident conditions of transport for both individual packages and arrays of packages.

The A_2 activity value is given for most radionuclides in the IAEA Transport Regulations [1], and these values are derived by determining the radiation exposure, either external or internal, to persons in the vicinity of a Type A package involved in a severe transport accident. Five dosimetric pathways (external photon dose, external beta dose, inhalation dose, skin and ingestion dose due to contamination transfer, and submersion dose due to gaseous isotopes) are considered, with the most limiting activity from these pathways being that used in the determination of the A_2 activity value.

The following radiological criteria are used in determining the A_2 activity values:

- the effective or committed effective dose to a person exposed in the vicinity of a transport package following an accident should not exceed a reference dose of 50 mSv;
- the dose or committed equivalent dose received by individual organs, including the skin, of a person involved in the accident should not exceed 0.5 Sv, or in the special case of the lens of the eye 0.15 Sv.

It should be noted that these are not consistent with the BSOs and BSLs, and so using the A_2 values directly in on-site movements should only be done with care and proper understanding of the BSOs and BSLs and the basis for the A_2 values.

Furthermore, the acceptable doses on packages used for off-site transport can be higher than would generally be acceptable for on-site movements with typical occupancy factors. For example, a TI of 10 corresponds to a dose rate of 0.1 mSv/h at 1 m from the package surface, and a target annual dose of 5 mSv would only permit an operator to be close to the package for 50 hours in any year, which is potentially restrictive.

TYPE B PACKAGE PERFORMANCE REQUIREMENTS

Normal Conditions of Transport

The permitted release from a Type B package of 10^{-6} A_2 per hour after it has been subjected to the tests to represent normal conditions of transport is based on this quantity of material being released into a room with a volume of 3000 m^3 and four air changes per hour. For an individual spending 2000 hours in a year in this room, which is pessimistic, the exposure to the individual would be less than 20 mSv, which is the dose limit for workers, averaged over five years, given in ICRP 60 [3]. For the more likely scenario of the package being out of doors, the dose to a worker would be much less than 20 mSv.

The tests to represent normal conditions of transport comprise water spray test, free drop test, stacking test and penetration test.

For packages and arrays of packages containing fissile material, subcriticality is to be maintained under a range of specified conditions, including after the normal conditions of transport tests.

Limits are also given for the increase in the radiation level at the external surface of the package after it has been subjected to the normal conditions of transport tests.

In addition, there are requirements relating to the securing of the package to its transport conveyance, e.g. rail wagon or road trailer. These requirements are not clearly laid out, but useful interpretation is given in the advisory material [4]. These general requirements are interpreted in the UK in AECP (TCSC) 1006 [5] in terms of the loadings to be taken account of in the design of the package attachment points, conveyance anchor points and the tie-down members between these two points, together with the basis for the design stresses for these components.

Accident Conditions of Transport

The permitted release in one week following tests to represent accident conditions of transport is not more than ten A_2 for krypton-85 and not more than A_2 for all other radionuclides. This accident is assumed to take place out of doors, as a severe accident in doors would be expected to necessitate immediate evacuation of people in the vicinity of the accident. The maximum effective dose via inhalation to persons exposed in the range 50 to 200 m downwind from the damaged package under average weather conditions would be 1 to 10 mSv, increasing by a factor of five under generally less probable and persistent stable meteorological conditions.

Limits are also given for the radiation level at 1 m from the external surface of the package after the accident conditions of transport tests.

The tests to represent accident conditions of transport comprise mechanical tests followed by a thermal test, and separately an immersion test. These tests are intended to impose on the package damage that is equivalent to that which would occur if the package were involved in a severe accident. These tests are not intended to represent a "maximum credible accident", but risk and accident analyses have demonstrated that they represent very severe transport accidents.

Under accident conditions of transport, the package may separate from the conveyance, but the key requirement is that the tie-down system does not damage the package integrity under these conditions.

For packages and arrays of packages containing fissile material, subcriticality is to be maintained under a range of specified conditions, including after tests to represent accident conditions of transport.

ON-SITE TYPE B PACKAGE PERFORMANCE REQUIREMENTS

From the above, it can be seen that the key requirements are in the areas of containment, shielding, criticality, restraint and on-site Accident Conditions.

Detailed requirements under these headings are presented in Table 1.

The IAEA Transport Regulations [1] also contain a wide range of general requirements, including minimum package dimensions, ambient temperature and pressure ranges, enclosures to retain leakage from valves on the package, and ease of decontamination. A number of these are also applicable to on-site packages, but detailed consideration of these is beyond the scope of this paper.

CONCLUSIONS

Whilst the IAEA Transport Regulations do not apply to the on-site movement of radioactive materials, they can form the basis for design requirements for use in the engineering substantiation of packages used in the on-site movement of radioactive material. This engineering substantiation complements the quantitative risk assessment, with the combination of the two forming an overall safety case. A suggested set of design requirements is set out in Table 1.

REFERENCES

[1] IAEA, *Regulations for the Safe Transport of Radioactive Material, 1996 Edition.* Safety Standards Series No. ST-1.

[2] M C Janicki and H G Lewis, *IAEA Transport Regulations- What Has Changed in 40 Years*, RAMTRANS Vol. 9, No. 4, pp 269-277 (1999).

[3] International Commission on Radiological Protection, *Recommendations of the International Commission on Radiological Protection,* Publication No 60, 1991.

[4] IAEA, *Advisory Material for the Regulations for the Safe Transport of Radioactive Material (1996 Edition)*, IAEA Safety Standards Series No. ST-2, Draft for TRANSSAC dated 3 February 1997.

[5] Atomic Energy Code of Practice, *Transport of Radioactive Material, The Securing/Retention of Radioactive Material Packages on Conveyances*, AECP (TCSC) 1006, December 1997.

[6] HMSO, *The Ionising Radiations Regulations*, 1999 SI No. 3232.

TABLE 1: APPLICATION OF DESIGN REQUIREMENTS FOR TYPE B PACKAGES TO ON-SITE TYPE B PACKAGES

Requirements in ST-1 for Off-site Type B Packages [1]	Suggested Requirements for On-site Type B Packages	Comments
Containment		
Loss of the radioactive contents of no more than 1×10^{-6} A_2/hr under normal conditions.	Loss of the radioactive contents of no more than 1×10^{-6} A_2/hr under normal conditions, subject to the dose uptake to workers on the site being As Low As Reasonable Practicable (ALARP).	It is possible that the number of package movements along a particular route on a site would result in a dose uptake to workers on the site that was excessive and not ALARP. Hence, the requirement for dose uptake to be ALARP has been included.
Loss of the radioactive contents of no more than one A_2 (10 A_2 of Kr-85) in one week following tests to represent off-site accident conditions.	Loss of the radioactive contents following tests to represent on-site accident conditions consistent with meeting the BSO.	Modelling of a limited number of example severe accidents on the specific site could be used to establish a value for the permitted number of A_2 s that could be released in an accident during an on-site movement.
Shielding		
The package surface dose rate is limited to 2 mSv/hr, although dose rates up to 10 mSv/hr are acceptable if the package is transported under exclusive use. The dose rate at 1 m from the package surface is limited to 0.1 mSv/hr, although this dose rate is permitted at 2 m from the package surface if the package is transported under exclusive use. The magnitude of individual doses, the number of persons exposed and the likelihood of incurring exposure are to be kept ALARA. A Radiation Protection Programme covering transport is to be established.	Maximum dose rates at the package surface and/or at 1 m from the surface to be specified for the site. Dose uptake must be ALARP.	The requirements in the Ionising Radiations Regulations [6] on radiation protection would be the controlling requirements.

Requirements in ST-1 for Off-site Type B Packages [1]	Suggested Requirements for On-site Type B Packages	Comments
Following tests to represent normal conditions, the increase in the dose rate at the package surface is not to exceed 20%. Following tests to represent accident conditions, the dose rate at 1 m from the package surface is not to exceed 10mSv/hr.	Following accident conditions of transport, the increase in package external dose rate should not be excessive.	No specific package dose rates following accident conditions of transport need be defined, as this aspect should be addressed in the context of meeting the NII BSOs and BSLs.
Restraint		
AECP 1006 [5] provides a set of loadings for each mode of transport (i.e. sea, road, rail and air) for the design of the restraint system. Any failure of the restraints should not impair the ability of the package to meet the other criteria.	The restraint system should be designed against loadings of 1g longitudinally and vertically, and 0.5g laterally. Any failure of the restraints should not impair the ability of the package to meet the other criteria.	On-site movements typically take place at significantly slower speeds than on the public transport network, and so reduced loadings on the restraint system will result.
Criticality		
Individual packages and arrays of packages must remain subcritical under normal and accident conditions of transport.	Individual packages and arrays of packages must remain subcritical under normal and accident conditions of transport.	
On Site Accident Conditions		
9 m Drop Test	Drop Test, with the drop height to take account of the site geography, the vehicle speeds on the site and lifting heights.	The philosophy behind the drop test from 1.2 m for on-site packages is considered to be equivalent to that behind the 9 m drop test for off-site packages, taking account of the low speeds and less traffic. However, this may not cover potential accidents during lifting, and a requirement should be included to specifically address this.
1m Punch Test	Punch Test, with the drop height to take account of the site geography, the vehicle speeds on the site and lifting heights.	Comments on the Drop Test apply here.
Dynamic Crush Test of 500 kg test plate being dropped from 9 m on to package.	Dynamic Crush Test, with the drop height to take account of the site geography, the vehicle speeds on the site and lifting heights	It may be possible to eliminate this test if the risk assessment were to identify that there are no accident scenarios that would involve a crush type accident.

Requirements in ST-1 for Off-site Type B Packages [1]	Suggested Requirements for On-site Type B Packages	Comments
Thermal Test: 800°C fully engulfing fire for 30 minutes.	Thermal Test: 800°C fully engulfing fire, with the duration to take account of potential fires on the site.	The quantity of fuel available for burning (combined fuel load of the conveyance and a third party vehicle) and engulfing of the package, together with the response capability available from the site emergency response capability, should be used in determining the duration of the fire.
Water Immersion Test for non-fissile packages: 15 m depth for 8 hours.	Water Immersion Test for non-fissile packages: depth to take account of depth of watercourses on the site: duration to take account of anticipated recovery time.	It is anticipated that the water depth and duration can be reduced compared with the test in ST-1 [1]. If there are no watercourses on the site, then this requirement can be removed.
Water Immersion Test for fissile packages: accident damaged package 0.9 m depth for 8 hours.	Water Immersion Test for fissile packages: accident damaged package 0.9 m depth for 8 hours.	There is no reason to change this requirement. If there are no watercourses on the site, then this requirement can be removed.
Undamaged fuel transport package to undergo 200 m immersion test.	No immersion test for fuel transport packages.	Immersion test not considered to be necessary, as it is intended to encompass loss at sea.