

IAEA Safety Standards

for protecting people and the environment

Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2012 Edition)

Specific Safety Guide

No. SSG-26



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ADVISORY MATERIAL FOR THE
IAEA REGULATIONS FOR THE
SAFE TRANSPORT OF
RADIOACTIVE MATERIAL
(2012 EDITION)



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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

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SPECIFIC SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

by Yukiya Amano
Director General

The IAEA's Statute authorizes the Agency to “establish or adopt... standards of safety for protection of health and minimization of danger to life and property” — standards that the IAEA must use in its own operations, and which States can apply by means of their regulatory provisions for nuclear and radiation safety. The IAEA does this in consultation with the competent organs of the United Nations and with the specialized agencies concerned. A comprehensive set of high quality standards under regular review is a key element of a stable and sustainable global safety regime, as is the IAEA's assistance in their application.

The IAEA commenced its safety standards programme in 1958. The emphasis placed on quality, fitness for purpose and continuous improvement has led to the widespread use of the IAEA standards throughout the world. The Safety Standards Series now includes unified Fundamental Safety Principles, which represent an international consensus on what must constitute a high level of protection and safety. With the strong support of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its standards.

Standards are only effective if they are properly applied in practice. The IAEA's safety services encompass design, siting and engineering safety, operational safety, radiation safety, safe transport of radioactive material and safe management of radioactive waste, as well as governmental organization, regulatory matters and safety culture in organizations. These safety services assist Member States in the application of the standards and enable valuable experience and insights to be shared.

Regulating safety is a national responsibility, and many States have decided to adopt the IAEA's standards for use in their national regulations. For parties to the various international safety conventions, IAEA standards provide a consistent, reliable means of ensuring the effective fulfilment of obligations under the conventions. The standards are also applied by regulatory bodies and operators around the world to enhance safety in nuclear power generation and in nuclear applications in medicine, industry, agriculture and research.

Safety is not an end in itself but a prerequisite for the purpose of the protection of people in all States and of the environment — now and in the future. The risks associated with ionizing radiation must be assessed and controlled without unduly limiting the contribution of nuclear energy to equitable and sustainable development. Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them.

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Section I

INTRODUCTION

BACKGROUND

101.1. Radiation and radioactive substances are natural and permanent features of the environment, and thus the risks associated with radiation exposure can only be restricted, not eliminated entirely. Additionally, the use of human-made radiation is widespread. Sources of radiation are essential to modern health care. The worldwide use of nuclear energy and applications of its by-products (i.e. radiation and radioactive substances) continue to increase.

101.2. It has been recognized that exposure to high levels of radiation can cause damage to the tissues of the human body and that exposure to radiation has the potential for the induction of latent malignancies. It is therefore essential that activities involving radiation exposure, such as the transport of radioactive material, be subject to certain standards of safety in order to protect those individuals exposed to radiation. The IAEA radiation safety standards provide a desirable international consensus for this purpose.

101.3. The acceptance by society of risks associated with radiation is conditional on the benefits to be gained from applications involving radiation. The Regulations for the Safe Transport of Radioactive Material (Transport Regulations¹) draw upon information derived from extensive research and development work by scientific and engineering organizations, at national and international levels, on the health effects of radiation and on techniques for the safe design of transport packages and from experience with transport operations. The Transport Regulations not only make use of purely scientific considerations, but also make value judgements about the relative importance of risks of different kinds and about the balancing of risks and benefits.

101.4. It is certain that some radiation exposures will result from routine conditions of transport and that their magnitudes will be predictable. Also, exposure scenarios can be envisaged for which there is a potential for exposure,

¹ Throughout this publication, reference to ‘Transport Regulations’ always refers to the latest edition (i.e. 2012) unless otherwise stated.

but no certainty that an exposure will, in fact, occur. Such unexpected but feasible exposures are termed ‘potential exposures’. Potential exposures can become actual exposures if the unexpected situation does occur. Optimization of radiation protection requires that both normal and potential exposures be taken into account. If the occurrence of such situations can be foreseen, the probability of occurrence and the resulting radiation exposure can be estimated. In the case of normal exposures, optimization requires that the expected magnitude of individual doses and the number of people exposed be taken into account; in addition, in the case of potential exposures, the likelihood of occurrence of accidents or events or sequences of events is also taken into account.

101.5. The means specified in the Transport Regulations for controlling normal exposures is the restriction of the doses received. The primary means for controlling potential exposures is by design of transport packages and operating procedures to meet requirements for dose rates, potential external contamination, activity release and prevention of criticality (significant generation of new activity through a self-sustaining neutron chain reaction). Such means are also intended to restrict the probability of occurrence of events that could lead to unplanned exposures and to restrict the magnitudes of the exposures that could result were such events to occur.

101.6. The transport of radioactive material has established itself as necessary in national and international programmes for the use of radioactive material in medicine, agriculture, industry, research and generation of nuclear power. Transport of radioactive material is, thus, generally agreed as amply justified.

101.7. For individual members of the public, the dose limits set forth in Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (the BSS) [1] apply to the representative person of the population and to the total individual dose from all sources of exposure, excluding natural background radiation and medical exposure of individuals. In practice, to take into account other sources of exposure, requirements in the Transport Regulations are formulated on the basis of conservative assumptions in the definition of the exposure conditions of the representative person, to provide reasonable assurance that actual doses from transport of such packages will not exceed certain fractions of the dose limits.

101.8. The responsibility for the development and optimization of operational procedures and for compliance with the Transport Regulations rests primarily with the operator.

101.9. The provision of information and training is an integral part of any system of radiological protection. The level of instruction provided should be commensurate with the nature and type of work undertaken.

101.10. For training provisions, see paras 311–315.

101.11. The development and application of the management system, as required by the Transport Regulations, should be carried out in a timely manner, before transport operations commence. Where appropriate, the competent authority will verify that such a management system is implemented, in compliance with the Transport Regulations.

103.1. When making national or international shipments, it is necessary to consult the regulations for the particular mode of transport to be used for the countries where the shipment will be made. While most of the major modal requirements are in agreement with the Transport Regulations, there can be differences with respect to the assignment of responsibilities for carrying out specific actions. For air shipments, the International Civil Aviation Organization's (ICAO) Technical Instructions for the Safe Transport of Dangerous Goods by Air [2] and the International Air Transport Association's Dangerous Goods Regulations [3] should be consulted, with particular regard to the State and operator variations. For sea shipments, the International Maritime Organization's International Maritime Dangerous Goods (IMDG) Code [4] should be consulted. Some countries have adopted the Transport Regulations by reference while others have incorporated them into their national regulations with possibly some minor variations.

103.2. The Transport Regulations have been developed over many years of consensus building among IAEA Member States and international transport and standards organizations (ICAO, IMO, International Organization for Standardization (ISO), United Nations Economic Commission for Europe, Universal Postal Union, etc.). These bodies used internationally accepted scientific principles, data and research in establishing the Transport Regulations. The Transport Regulations are intended to provide countries and modal regulatory organizations with consensus based transport requirements that protect the health and safety of workers, the general public and the environment, and permit international commerce.

103.3. While the Transport Regulations are non-binding for adoption or implementation by States, the adoption and incorporation of the Transport Regulations by the international transport regulatory organizations does make compliance by States mandatory.

103.4. The Transport Regulations are based, therefore, on the presumption that a national infrastructure is in place, enabling the government to discharge its responsibilities for transport safety.

103.5. The current level of safety in the transport of radioactive material has been achieved on a worldwide basis through adoption of the Transport Regulations in international, regional and modal regulations for the transport of all dangerous goods, where radioactive material is but one (Class 7) of the nine classes of dangerous goods. Related publications explain the Transport Regulations, provide advice on how they may be applied and cover topics such as emergency response, compliance assurance and a management system in greater detail.

103.6. The Transport Regulations are also recommended for adoption by Member States in their national regulations for transport of dangerous goods. Even Member States that do not have a nuclear power industry need to establish requirements to control safely the transport of radioactive material in common use, for example, in medical, industrial or research applications.

103.7. Essential parts of a national transport safety infrastructure are: legislation and regulations, competent authority empowered to authorize and inspect regulated activities and to enforce the legislation and regulations, sufficient financial resources and adequate numbers of trained personnel. The infrastructure should also provide ways and means of addressing societal concerns that extend beyond the legal responsibilities of the legal persons authorized to conduct the transport of radioactive material.

OBJECTIVE

104.1. In general, the Transport Regulations aim to provide a uniform and adequate level of safety that is commensurate with the inherent hazard presented by the radioactive material being transported. To the extent feasible, safety features are required to be built into the design of the package. By placing primary reliance on the package design and preparation, the need for any special actions

during carriage (i.e. by the carrier) is minimized. Nevertheless, some operational controls are required for safety purposes.

SCOPE

106.1. Transport includes carriage by a common carrier or by the owner or the owner's employee where the carriage is incidental to the use of the radioactive material, such as vehicles carrying radiography devices being driven to and from the operations site by the radiographer, vehicles carrying density measuring gauges being driven to and from the construction site, and oil well logging vehicles carrying measuring devices containing radioactive material and radioactive material used in oil well injection.

106.2. The scenario referred to as 'routine conditions of transport (incident free)' is intended to cover the use and transport of packages under everyday/routine operations (i.e. conditions of transport in which there are no minor mishaps or damaging incidents to the packages). However, a package, including its internal and external restraint systems, is required to be capable of withstanding the effects of the transport accelerations described in para. 613.1. (Appendix IV (Tables IV.1 and IV.2) details the typical accelerations that may be applied.)

106.3. The scenario referred to as 'normal conditions of transport (minor mishaps)' is intended to cover situations in which the package is subjected to mishaps or incidents that range in severity up to the applicable test requirements for the package type concerned (i.e. Type IP-2, Type IP-3 or Type A). For example, the normal conditions of a free drop test for a Type A package are intended to simulate the type of mishap that a package would experience if it were to fall off the platform of a vehicle or if it were dropped during handling. In most cases, packages would be relatively undamaged and would continue their journey after having been subjected to these minor mishaps.

106.4. The scenario referred to as 'accident conditions of transport' is intended to cover situations in which the package is subjected to incidents or accidents that range in severity from those having a severity greater than that covered by normal conditions of transport, up to the maximum severity levels imposed under the applicable test requirements for the type of package concerned (i.e. up to the damage severity resulting from the applicable tests for accident conditions of transport detailed in paras 726–737). For example, mechanical test requirements for Type B packages were first introduced in the 1964 Edition of the Transport Regulations, replacing the requirement for withstanding a 'maximum credible

accident'. On the assumption that Type B(U) or Type B(M) packages are likely to be used in all modes of transport, Type B(U) or Type B(M) test requirements are intended to take into account a large range of accidents for land, sea and air transport which can expose packages to severe dynamic forces, although the severity levels indicated by the test criterion are not intended to represent a worst case accident scenario. The potentially more severe accident forces in an air transport accident are taken into account by the Type C test requirements.

107.1. The Transport Regulations are not intended to be applied to:

- (a) Radioactive material that forms an integral part of a means of transport, such as depleted uranium counterweights or tritium exit signs used in aircraft, or
- (b) Radioactive material in persons or animals for medical or veterinary purposes, such as cardiac pacemakers or radioactive material introduced into humans or animals during diagnostic or therapeutic procedures, or
- (c) Radioactive material in or on a person who is to be transported for medical treatment because the person has been subject to accidental or deliberate intake of radioactive material or to contamination.

The treating physician, medical practitioner or veterinarian should give appropriate advice on radiological safety. Skin decontamination of persons should be considered prior to their transport, when the associated delay is estimated to have no health impact.

107.2. Consumer products are items available to the general public as the end user without further control or restriction. These may be devices such as smoke detectors, luminous dials or ion generating tubes that contain small amounts of radioactive substances. Consumer products are outside the scope of the Transport Regulations only after sale to the end user. Any transport, including the use of conveyances between manufacturers, distributors and retailers, is within the scope of the Transport Regulations to ensure that large quantities of individually exempted consumer products are not transported in an unregulated manner.

107.3. The principles of exemption and their application to the transport of radioactive material are dealt with in para. 402.

107.4. The scope of the Transport Regulations does not include ores and natural or processed materials containing naturally occurring radionuclides, provided that the activity concentration of the materials does not exceed 10 times the

exempt activity concentration values (Table 2 or calculated in accordance with paras 403–407).

Following the conclusion of the IAEA Coordinated Research Project (CRP) on Regulatory Control for the Safe Transport of Naturally Occurring Radioactive Material (NORM) [5], it was agreed that this exclusion does not depend on the prior or intended use of the material, i.e. whether it is to be used for its radioactive, fissile or fertile nuclides or not. The CRP modelling and analysis of realistic transport scenarios found that in cases when the provision of 10 times the exempt activity concentration values for this material is applied, the maximum annual dose from unregulated transport of the material would generally be substantially less than 1 mSv (referring to para. 71 of ICRP 104 [6], an annual dose criterion of 10 μ Sv does not apply to exposure situations involving natural sources, as this value is at least one or two orders of magnitude below the variability of the background radiation). The BSS [1] set an annual dose criterion of 1 mSv for exemption for NORM. The CRP concluded that the exclusion is appropriate from a radiological protection consideration and from a risk based regulatory consideration since the potential radiological dose from the material during transport is dependent on the activity concentration of the material. Guidance for determining activity levels and basic nuclide values is provided in paras 403–407 for reference in the use of Table 2.

For ores and other natural or processed materials containing natural occurring radionuclides of the uranium–radium and/or thorium decay chain, the basic nuclide values for exempt activity concentration as given in Table 2 for U(nat) and Th(nat) can only be used if the radionuclides are in secular equilibrium. If this is not the case, this means that owing to processing activities such as chemical leaching or thermal treatment, the natural radioactive equilibrium state does not exist and the formula for mixtures of radionuclides according to para. 405 has to be applied to calculate the exempt activity concentration.

As the value of activity concentration for exempt material of the Transport Regulations, Table 2, for example, for Th-228 is lower by a factor of 10 than the values for Ra-226 and Ra-228, as well as Pb-210 and Po-210, the limit of activity concentration decisively depends on the fraction of Th-228 (fTh-228) in the nuclide mixture, when applying the formula in para. 405.

This issue is illustrated by the following example:

In the process of extracting crude oil and natural gas, scaling takes place at the inner walls of the production pipes. The scales consist, in most cases, of barium

sulphate in which radium isotopes co-precipitate, while the parent nuclides (U-228, Th-232) do not occur in the scale deposit. Accordingly, the secular equilibrium of the U–Ra decay chain and/or Th decay chain is disturbed. While Pb-210 and Po-210 are slowly ‘regrowing’ from Ra-226 (equilibrium is reached after about 100 years), Th-228 ‘regrows’ from Ra-228 with a so-called ‘flowing equilibrium’ within a few years. Therefore, the Th-228 fraction of the total activity increases with time (reaching an equilibrium of 1.46 times the Ra-228 activity concentration). The insertion of the measured activity concentrations as provided in Ref. [7] into the formula of para. 405 leads to the following exempt activity concentration (sum activity):

$$(f_{\text{Ra-226}} + f_{\text{Pb-210}} + f_{\text{Po-210}} + f_{\text{Ra-228}}) = 0.84 \text{ and } f_{\text{Th-228}} = 0.16$$

From this, it follows that $0.84/10 + 0.16/1 = 0.244$, and that $1/0.244 = 4.1 \text{ Bq/g}$ as exempt activity concentration, i.e. the sum activity of all relevant nuclides. This value can now be multiplied by 10 according to para. 107(f), while the specific activity of each radionuclide is given by its fraction.

However, there are ores in nature where the activity concentration is much higher than the exemption values. The regular transport of these ores may require consideration of radiation protection measures. Hence, a factor of 10 times the exemption value for activity concentration was chosen as providing an appropriate balance between the radiological protection concerns and the practical inconvenience of regulating large quantities of material with low activity concentrations of naturally occurring radionuclides.

107.5. For checking exemption levels for surface contamination, see para. 413.7.

108.1. Although the Transport Regulations provide for the requisite safety in transport without the need for specified routeing, the regulatory authorities in some Member States have imposed routeing requirements. In prescribing routes, normal and accident risks, both radiological and non-radiological, as well as demographic considerations should be taken into account. Policies embodied in the routeing restrictions should be based upon all factors that contribute to the overall risk in transporting radioactive material and not only on concerns for ‘worst case’ scenarios (i.e. ‘low probability/high consequence’ accidents). Since the authorities at the State, provincial and even local levels may be involved in routeing decisions, it may often be necessary to provide them with either evaluations to assess alternative routes or with very simple methods which they can use.

108.2. In assessing the radiological hazards and ensuring that the routing requirements do not detract from the standards of safety specified in the Transport Regulations, analyses using appropriate risk assessment codes should be undertaken. One such code which may be used, INTERTRAN [8], was developed through a CRP. This computer based environmental impact code is available for use by Member States. In spite of many uncertainties stemming from the use of a generalized model and the difficulty of selecting appropriate input values for accident conditions, this code may be used to calculate and understand, at least on a qualitative basis, the factors significant in determining the radiological impact due to routing alternatives involving the transport of radioactive material. These factors are the important aspects that should be considered in any routing decision. For routing decisions involving a single mode of transport, many simplifying assumptions can be made and common factors can be assigned which result in easy to use relative risk evaluation techniques.

108.3. The consignor may also be required to provide evidence that measures to meet the requirements for safeguards and physical protection associated with shipments of nuclear material (as defined in the Convention on the Physical Protection of Nuclear Material) are complied with. The consignor may also be required to provide evidence that measures to meet any requirements for security of certain shipments of radioactive material are also complied with.

109.1. Additional measures may be required by regulatory agencies to provide appropriate physical protection in the transport of radioactive material and to prevent acts without lawful authority which constitute the receipt, possession, use, transfer, alteration, disposal or dispersal of radioactive material and which cause, or are likely to cause, death or serious injury to any person or substantial damage to property. (See the Convention on the Physical Protection of Nuclear Material, INFCIRC/274 Rev.1, IAEA, Vienna (1980) [9]; IAEA Nuclear Security Series No. 13, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5), (2011) [10] and IAEA Nuclear Security Series No. 9, Security in the Transport of Radioactive Material (2008) [11]).

109.2. See also Code of Conduct on the Safety and Security of Radioactive Sources, IAEA, Vienna (2004) [12] and Guidance on the Import and Export of Radioactive Sources, IAEA, Vienna (2005) [13].

110.1. See paras 506.1–506.2 and 507.1–507.9.

REFERENCES TO SECTION I

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- [10] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5), IAEA Nuclear Security Series No. 13, IAEA, Vienna (2011).
- [11] INTERNATIONAL ATOMIC ENERGY AGENCY, Security in the Transport of Radioactive Material, IAEA Nuclear Security Series No. 9, IAEA, Vienna (2008).
- [12] INTERNATIONAL ATOMIC ENERGY AGENCY, Code of Conduct on the Safety and Security of Radioactive Sources, IAEA, Vienna (2004).
- [13] INTERNATIONAL ATOMIC ENERGY AGENCY, Guidance on the Import and Export of Radioactive Sources, IAEA, Vienna (2012).

Section II

DEFINITIONS

A₁ and A₂

201.1. See Appendix I.

Approval

204.1. The approval requirements in the Transport Regulations have been graded according to the hazards posed by the radioactive material to be transported or to be covered by a design approval. Approval is intended to ensure that the design or shipment meets the relevant requirements and that the controls required for safety are adequate for the country and for the circumstances of the shipment. Since transport operations and conditions vary between countries, application of the 'multilateral approval' approach provides the opportunity for each competent authority to satisfy itself that the shipment is to be properly performed, with due account taken of any peculiar national conditions.

204.2. The concept of multilateral approval applies to transport as it is intended to occur. This means that only those competent authorities through whose jurisdiction the shipment is scheduled to be transported are involved in its approval. Unplanned deviations which occur during transport and which result in the shipment entering a country where the transport had not previously been approved would need to be handled individually. If an aircraft is scheduled to stop in a country, however, multilateral approval includes approval by the competent authority of that country (see para. 243.1).

204.3. Users of the Transport Regulations should be aware that a Member State may require in its national regulations that an additional approval be given by its competent authority for any special form radioactive material, Type B(U) or Type C package which is to be used for domestic transport on its territory, even if the design has already been approved in another country.

205.1. For unilateral approval, it is believed that the Transport Regulations take into account the transport conditions which may be encountered in any country. Consequently, only approval by the competent authority of the country of origin of the design is required.

Carrier

206.1. The term ‘person’ includes a corporate body as well as an individual (see also Ref. [1], paras 3.7–3.9).

Competent authority

207.1. The competent authority is the organization defined by legislative or executive authority to act on behalf of a country, or an international authority, in matters involving the transport of radioactive material. The legal framework of a country determines how a national competent authority is designated and is given the responsibility to ensure application of the Transport Regulations. In some instances, authority over different aspects of the Transport Regulations is assigned to different agencies, depending on the transport mode (air, road, rail, sea or inland waterway) and on the package and radioactive material type (excepted, industrial, Type A, Type B(U), Type B(M) and Type C packages; special form radioactive material; low dispersible radioactive material (LDRM); fissile material or uranium hexafluoride). A national competent authority may, in some cases, delegate the approval of package designs and certain types of shipment to another organization having the necessary technical competence. National competent authorities also constitute the competent authorities referred to in any conventions or agreements on the transport of radioactive material to which the country adheres.

207.2. The competent authority should make the consignors, carriers, consignees and public aware of its identity and how it may be contacted. This may be accomplished by publishing details of the organizational identity (department, administration, office, etc.), with a description of the duties and activities of the organization in question as well as mailing address, telephone and facsimile numbers, email address, etc.

207.3. The primary source of competent authority identifications is the list of National Competent Authorities Responsible for Approvals and Authorizations in Respect of the Transport of Radioactive Material, which is maintained by the IAEA and is available on the IAEA Transport Safety web page <http://www-ns.iaea.org/tech:areas/radiation-safety/transport.asp>. Each country should ensure that the listed information is current and accurate. The IAEA requests verification of this information annually, and prompt responses by Member States will ensure the continued value of this list.

207.4. Full and proper implementation of the Transport Regulations requires that a competent authority be established by the government to regulate transport safety. Such a competent authority should be provided with sufficient powers and resources for effective regulation and enforcement, and should be independent of any government departments and agencies that are carrying out transport of radioactive material. The competent authority should also be independent of registrants, licensees and the designers and manufacturers of the transport systems. The effective separation of responsibilities between the functions of the competent authority and those of any other party should be made clear so that the regulators retain their independence of judgement and decision making as safety authorities.

207.5. The general functions of the competent authority include the following: the assessment of applications for package design approval; the issue of approval certificates and the authorization of shipments where applicable, subject to certain specified conditions; the conduct of periodic inspections to verify compliance with the conditions; and any necessary enforcement actions to ensure compliance with the Transport Regulations. An effective compliance assurance programme should, as a minimum, include measures related to review and assessment of package design, issue of approval certificates, and inspection and enforcement.

207.6. The powers of the inspectors of the competent authority should be well defined and consistency of enforcement should be maintained. The competent authority may need to provide guidance on how certain regulatory requirements are to be fulfilled for various transport activities.

207.7. The competent authority should encourage all parties to develop a safety culture that includes: individual and collective commitment to safety by workers, management and regulators; accountability of all individuals for protection and safety, including individuals at senior management level; and measures to encourage a questioning and learning attitude and to discourage complacency with respect to safety.

Compliance assurance

208.1. See paras 307.1–307.9.

Confinement system

209.1. The confinement system should be that part of a package necessary to maintain the fissile material in the configuration that was assumed in the

criticality safety assessment for an individual package (see para. 681). The confinement system could be (i) an inner receptacle with defined dimensions, (ii) an inner structure maintaining the outer dimension of a fuel assembly and any interstitial fixed poisons, or (iii) a complete package such as an irradiated nuclear fuel package with no inner container. The confinement system consists of specified packaging components and the package contents. Although the confinement system may have the same boundary as the containment system, this is not always the case since the confinement system maintains criticality control whereas the containment system prevents leakage of radioactive material. Each competent authority must concur that the confinement system defined in the criticality safety assessment is appropriate for the package design, for both damaged and undamaged configurations (see para. 681).

Containment system

213.1. The containment system can be the entire packaging but, more frequently, it makes up a portion of the packaging. For example, in a Type A package, the containment system may be considered to be the vial containing the radioactive contents. The vial, its enclosing lead pot shielding and fibreboard box make up the packaging. The containment system does not necessarily include the shielding. In the case of special form radioactive material and LDRM, the radioactive material may be part of the containment system.

213.2. The containment system of the package design should be explicitly defined, including the containment boundary of the system and, in particular, seals and fixation devices. The containment boundary system should consider features such as vent and drain ports that could present a leakage path from the containment system. For package systems that have double or concentric seals, the containment system seal should be defined. Secondary containers, such as bags, boxes and cans, that are used as product containers or to facilitate handling of the radioactive material should not be considered part of the containment system with respect to meeting the requirements of para. 659. The containment system should be composed of engineered features whose design is defined in the drawings of the packaging.

213.3. The leaktightness requirement for a containment system in a Type B(U), Type B(M) or Type C package depends on the radiotoxicity of the radioactive contents; for example, a Type B(U) or Type C package under accident conditions must have the release limited to a value of A_2 within a period of a week. This connection to the A_2 value means that for highly toxic radionuclides, such as plutonium and americium, the allowable volumetric leakage rate will be much

lower than for low enriched uranium. However, if fissile material is able to escape from the containment system under accident conditions, it must be demonstrated that the quantity that escapes is consistent with that assumed in the criticality safety assessment in applying para. 685(c).

Contamination

214.1. Contamination includes two types of radioactive material on surfaces or embedded in surfaces, namely, fixed contamination and non-fixed contamination. There is no definitive distinction between fixed and non-fixed contamination and various terms have been used to describe the distinction. For practical purposes, a distinction is made between contamination, which, during routine conditions of transport, remains in situ (i.e. fixed contamination) and therefore cannot give rise to hazards from ingestion, inhalation or spreading, and non-fixed contamination, which may contribute to these hazards. The only hazard from fixed contamination is that due to external radiation exposure, whereas the hazards from non-fixed contamination include the potential for internal exposure from inhalation and ingestion as well as external exposure due to contamination of the skin should it be released from the surface. Under accident conditions, and under certain use conditions such as weathering, fixed contamination may, however, become non-fixed contamination.

214.2. Contamination below levels of 0.4 Bq/cm² for beta and gamma emitters and for low toxicity alpha emitters, or 0.04 Bq/cm² for all other alpha emitters, can give rise only to insignificant exposure through any of these pathways.

214.3. Any surface with levels of contamination lower than 0.4 Bq/cm² for beta and gamma emitters and for low toxicity alpha emitters, or 0.04 Bq/cm² for all other alpha emitters, is considered a non-contaminated surface in applying the Transport Regulations. For instance, a non-radioactive solid object with levels of surface contamination lower than the above levels is beyond the scope of the Transport Regulations and no requirement is applicable to its transport.

214.4. For checking levels of contamination, the measuring techniques referred to in para. 413.7 apply.

215.1. See paras 214.1–214.3.

216.1. See paras 214.1–214.3.

Criticality safety index

218.1. The criticality safety index (CSI) is a term defined for the first time in the 1996 Edition of the Transport Regulations. It is the main principle used for the criticality safety purpose of limiting accumulation of packages containing fissile material during transport and in-transit storage.

The CSI is a value obtained by dividing the number 50 by the value of N (see para. 686) or using the provisions of paras 674 and 675. The total CSI is required to be controlled in individual packages (see para. 526), consignments (see para. 525), conveyances, freight containers and overpacks (see paras 566(c) and 567) and in-transit storage (see paras 568 and 569). To facilitate such control, the CSI is required to be displayed on a label (see paras 541 and 542), which is specifically designed to indicate the presence of fissile material in the case of packages, overpacks or freight containers where contents consist of fissile material not excepted under the provisions of para. 417.

218.2. Fissile nuclide mass accumulation limits for packages and consignments are applied in the absence of CSI control only to special cases (see para. 417(c), (d) and (e)) where large safety margins have been judged adequate to prevent the potential for criticality.

Exclusive use

221.1. The special features of an ‘exclusive use’ shipment are, by definition, first, that a single consignor must make the shipment and must have, through arrangements with the carrier, sole use of the conveyance or large freight container, and second, that all initial, intermediate and final loading and unloading and shipment of the consignment are carried out only in strict accordance with directions from the consignor or consignee.

221.2. Since ordinary in-transit handling of the consignment under exclusive use will not occur, some of the requirements which apply to normal shipments can be relaxed. In view of the additional control which is exercised over exclusive use consignments, specific provisions have been made for them which allow:

- (a) Use of a lower integrity industrial package type for low specific activity (LSA) material;
- (b) Shipment of packages with radiation levels exceeding 2 mSv/h (but not more than 10 mSv/h) at the surface or a TI exceeding 10;

- (c) Increase by a factor of two in the total CSI for fissile material packages in a number of cases.

Many consignors find that it is advantageous to make the necessary arrangements with the carrier to provide transport under exclusive use so that the consignor can utilize one or more of the above provisions.

221.3. In the case of packaged LSA material, the Transport Regulations take into account the controlled loading and unloading conditions which result from transport under exclusive use. The additional controls imposed under exclusive use are to be in accordance with instructions prepared by the consignor or consignee (both of whom have full information on the load and its potential hazards), where so required by the Transport Regulations, allowing some reduction in packaging strength. Since uncontrolled handling of the packages does not occur under exclusive use, the conservatism which is embodied in the normal LSA packaging requirements regarding handling has been relaxed, but equivalent levels of safety are to be maintained.

221.4. Packages which may be handled during transport must necessarily have their allowable radiation levels limited to protect the workers handling them. The imposition of exclusive use conditions and the control of handling during transport help to ensure that proper radiation protection measures are taken. By imposing restrictions and placing a limit on the allowable radiation levels around the vehicle, the allowable radiation level of the package may be increased without significantly increasing the hazard.

221.5. Since exclusive use controls effectively prevent the unauthorized addition of radioactive material to a consignment and provide a high level of control over the consignment by the consignor, allowances have been made in the Transport Regulations to authorize more fissile material packages than for ordinary consignments.

221.6. For exclusive use of a conveyance or large freight container, the sole use requirement and the sole control requirement are the determining factors. Although a vehicle may be used to transport only radioactive material, this does not automatically qualify the consignment as exclusive use. In order to meet the definition of exclusive use, the entire consignment has to originate from or be controlled by a single consignor. This excludes the practice of a carrier collecting consignments from several consignors in a single vehicle. Even though the carrier is consolidating the multiple consignments on to one vehicle, it is not in exclusive use because more than one consignor is involved. However, this

does not preclude a properly qualified carrier or consignee who is consolidating shipments from more than one source from taking on the responsibilities of the consignor for these shipments and from being so designated.

221.7. Annex III in the Transport Regulations gives a list of shipments requiring exclusive use.

Fissile nuclides and fissile material

222.1. A fission chain is propagated by neutrons. Since a chain reaction depends on the behaviour of neutrons, fissile material is packaged and shipped under requirements designed to maintain subcriticality and thus provide criticality safety in transport.

222.2. Most radionuclides can be made to fission, but many can only be made to fission with difficulty and with the aid of special equipment and controlled conditions. The distinguishing characteristic of the fissile nuclides named in the definition is that they are capable of supporting a self-sustaining thermal neutron (neutron energies less than approximately 0.3 eV) chain reaction only by the accumulation of sufficient mass. No other action, mechanism or special condition is required. For example, Pu-238 is no longer listed in the definition because, although it can be made to support a fast neutron chain reaction under stringent laboratory conditions, in the form in which it is encountered in transport it does not have this property. Plutonium-238 cannot, under any circumstances, support a chain reaction carried by thermal neutrons. It is therefore 'fissionable' rather than 'fissile'.

222.3. As indicated in the above paragraph, the basis used to select the nuclides defined as fissile for the purposes of the Transport Regulations relies on the ease of accumulating sufficient mass for a potential criticality. Other nuclides that have the potential for criticality are discussed in Ref. [2] and subcritical mass limits are provided for isolated units of Np-237, Pu-238, Pu-240, Pu-242, Am-241, Am-242m, Am-243, Cm-243, Cm-244, Cm-245, Cm-247, Cf-249 and Cf-251. The predicted subcritical mass limits for these nuclides range from a few grams (Cf-251) to tens of kilograms. However, the lack of critical experimental data, the limited knowledge of the behaviour of these nuclides under different moderator and reflection conditions and the uncertainty in the cross-section data for many of these nuclides require that adequate attention (and associated subcritical margin) be provided to operations where sufficient quantities of these nuclides might be present (or produced by decay before or during transport). Advice of the competent authority should be sought on the need and means of performing a

criticality safety assessment as per the requirements of paras 673–686 whenever significant quantities of these nuclides are to be transported.

222.4. Fissile material means any material containing any of the fissile nuclides, excluding cases where, taking into account the physicochemical properties and the current transport practices, a criticality risk is judged not to be credible. For any package containing material defined as fissile material, paras 417 (classification), 418 and 673 have to be applied.

222.5. Packages containing less than 0.25 g of fissile nuclides would need to accumulate in very large numbers (several thousands) before there is even the theoretical possibility of criticality. Additionally, the probability of there being a sufficiently large number of ‘excluded’ packages as to influence the criticality safety of a consignment with fissile packages under CSI control has been judged not to be credible.

222.6. The major justification for excluding packages, each with a maximum fissile nuclide mass of 0.25 g, is that a shipment of several thousands of such packages containing essentially ‘pure’ (no additional neutron absorbing nuclides) fissile material has been assumed to be very unlikely. For instance, it is not envisaged as credible to transport several thousand UO_2 pellets, with an enrichment of 3.5% U-235 and containing around 0.25 g of U-235 per pellet, in individual packages with one pellet per package. Any indication of changed practices in the future needs to be observed and discussed. Packages with trace concentrations of fissile nuclides (e.g. wastes) are not a criticality safety problem, even in large quantities, if the mass limit per package is complied with.

222.7. Natural and depleted uranium that is unirradiated or irradiated in thermal reactors only are excluded from being defined as fissile material, but only if there is no other material with fissile nuclides in the package. The fissile nuclides in natural and depleted uranium could increase the neutron multiplication of a package carrying other material with fissile nuclides. Thus, when the package design or package contents are known to contain natural or depleted uranium, that natural or depleted uranium has to be accounted for in the safety assessment and in the approval requirements. This is often the case for modern light water reactor fuel which may contain axial end zones with natural or depleted uranium.

222.8. Separated from other fissile material, the likelihood of criticality for packages containing only natural or depleted uranium as part of the contents is not considered credible. For this reason, natural or depleted uranium is only defined as fissile when other fissile material is in the package.

222.9. Unpackaged natural and depleted uranium can be found in many shipments of slightly radioactive material. However, the likelihood of high purity natural or depleted uranium being transported in the same conveyance as fissile material in packages and for a criticality safety concern to occur by entering packages with fissile material, by being mixed with fissile material escaping from such packages, by being dispersed between such packages or by being placed in the vicinity of fissile material in packages, is not considered credible.

222.10. Irradiation of natural or depleted uranium could increase the probability for the material to sustain a neutron chain reaction. The restriction to irradiation in thermal reactors is intended to avoid this potential problem. Operators wishing to use para. 222 to exclude irradiated natural or depleted uranium from the definition of fissile material should ensure that any processing subsequent to irradiation will not have increased its reactivity. Production of plutonium during irradiation is greater at the surface of a fuel rod than in the centre. The surface layer will have a significantly higher plutonium concentration than the 'average' value throughout the fuel and can have criticality characteristics similar to those of low enriched uranium. If this surface layer has been separated from the bulk of the fuel, then material containing it (e.g. cladding residues) may not be suitable for exclusion under para. 222.

222.11. The exclusion provisions of para. 222(a) and (b) also apply if a packaging contains unirradiated as well as irradiated (in thermal reactors only) natural and/or depleted uranium, e.g. as shielding material.

Freight container

223.1. The methods and systems employed in the trans-shipment of goods have undergone a transformation since about 1965; the freight container has largely taken the place of parcelled freight or general cargo which was formerly loaded individually. Packaged and unpackaged goods are loaded by the consignor into freight containers and are transported to the consignee without intermediate handling. In this manner, the risk of damage to packages is reduced; unpackaged goods are consolidated into conveniently handled units and transport economies are realized. In the case of large articles, such as contaminated structural parts from nuclear power stations, the container may perform the function of the packaging as allowed under para. 629.

223.2. Freight containers are typically designed and tested in accordance with the standards of the ISO [3]. They should be approved and maintained in accordance with the International Convention for Safe Containers (CSC) [4] in

order to facilitate international transport operations. If other freight containers are used, the competent authority should be consulted. It should be noted, however, that the testing prescribed in the CSC is not equivalent to that prescribed in ISO 1496-1 [3]. For this reason, the Transport Regulations require the design standard to be ISO.

223.3. In addition, special rules may be specified by modal transport organizations. As an example, the IMDG Code [5] contains the provisions for the transport by sea of dangerous goods, including radioactive material.

Low dispersible radioactive material

225.1. The concept of LDRM applies only to qualification for exemption from the requirements for Type C packages in the air transport mode.

225.2. LDRM has properties such that it will not give rise to significant potential releases or exposures. Even when subjected to high velocity impact and thermal environments, only a limited fraction of the material will become airborne. Potential radiation exposure from inhalation of airborne material by persons in the vicinity of an accident would be very limited.

225.3. The LDRM criteria are derived in consistency with other safety criteria in the Transport Regulations, as well as on the basis of established methods to demonstrate acceptable radiological consequences. The Transport Regulations require that the performance of LDRM be demonstrated without taking any credit for the Type B(U) or Type B(M) package in which it is transported.

225.4. LDRM may be the radioactive material itself, in the form of an indispersible solid, or a high integrity sealed capsule containing the radioactive material, in which the encapsulated material acts essentially as an indispersible solid. Powders and powder-like materials cannot qualify as LDRM.

Low specific activity material

226.1. The reason for the introduction of a category of LSA material into the Transport Regulations was the existence of certain solid materials, the specific activities of which are so low that it is highly unlikely that, under circumstances arising during transport, a sufficient mass of such materials could be taken into the body to give rise to a significant radiation hazard. Uranium and thorium ores and their physical or chemical concentrates are materials falling into this category. This concept was extended to include other solid materials on the basis

of a model which assumes that it is most unlikely that a person would remain in a dusty atmosphere long enough to inhale more than 10 mg of material. If the specific activity of the material is such that the mass intake is equivalent to the activity intake assumed to occur for a person involved in a median accident with a Type A package, namely $10^{-6}A_2$, then this material would not present a greater hazard during transport than that presented by a Type A package. This leads to an LSA material limit of $10^{-4}A_2/g$.

226.2. Consideration was given to the possibility of shipping solid objects without any packaging. The question arose for concrete blocks (with activity throughout the mass), for irradiated objects and for objects with fixed contamination. Under the condition that the specific activity is relatively low and the contamination remains in the object or fixed on the object's surface, the object can be dealt with as a package. For the sake of consistency and safety, the radiation limits at the surface of the unpackaged object should not exceed the limits for packaged material. Therefore, it was considered that above the limits of surface radiation levels for packages (2 mSv/h for non-exclusive use and 10 mSv/h for exclusive use), the object must be packaged in an industrial package which ensures shielding retention in routine transport. Similar arguments were made for establishing surface contamination levels for unpackaged surface contaminated objects (SCOs).

226.3. The preamble to the LSA definition does not include the unshielded radiation level limit on a dose rate of 10 mSv/h at 3 m (see para. 517) because it is a property of the quantity of material placed in a single package rather than a property of the material itself (although in the case of solid objects which cannot be divided, it is a property of the solid object).

Low toxicity alpha emitters

227.1. The identification of low toxicity alpha emitters is based on the specific activity of the radionuclide (or the radionuclide in its 'as shipped' state). For a nuclide with a very LSA, its intake cannot, because of its bulk, be reasonably expected to give rise to doses approaching the dose limit. The radionuclides U-235, U-238 and Th-232 have specific activities four to eight orders of magnitude lower than Pu-238 or Pu-239 (4×10^3 to 8×10^4 Bq/g as opposed to 2×10^9 to 6×10^{11} Bq/g). Although Th-228 and Th-230 have specific activities comparable to those of Pu-238 and Pu-239, they are only allowed as 'low toxicity alpha emitters' when contained in ores and physical and chemical concentrates, which inherently provides for the low activity concentration required.

Management system

228.1. The term ‘quality assurance’ has been in use in the Transport Regulations for many years. It was defined as a systematic programme of controls and inspections applied by any organization or body which is aimed at providing adequate confidence that the standard of safety prescribed in the Transport Regulations is achieved in practice.

228.2. In order to conform with internationally recognized standards dealing with quality management systems (e.g. ISO 9001:2008 [6]), the IAEA published IAEA Safety Standards Series No. GS-R-3, The Management System for Facilities and Activities [7]. These safety requirements are to be supported by guidance for specific activities such as transport. GS-R-3 defines ‘management system’ as a set of interrelated or interacting elements (system) for establishing policies and objectives and enabling the objectives to be achieved in an efficient and effective manner. All IAEA safety standards, including the Transport Regulations, have therefore replaced the term ‘quality assurance’ with ‘management system’.

228.3. In 2008, the IAEA issued a Safety Guide, IAEA Safety Standards Series No. TS-G-1.4, The Management System for the Transport of Radioactive Material [8], which provides additional guidance on how to comply with the requirements of the Transport Regulations for a management system.

Maximum normal operating pressure

229.1. The maximum normal operating pressure (MNOP) is the difference between the containment system maximum internal pressure and the mean sea level atmospheric pressure for the conditions specified below.

229.2. The environmental conditions to be applied to a package in determining the MNOP are the normal environmental conditions specified in paras 656 and 657 or, in the case of air transport, in para. 620. Other conditions to be applied in determining the MNOP are that the package is assumed to be unattended for a one year period and that it is subject to its maximum internal heat load.

229.3. A one year period exceeds the expected transit time for a package containing radioactive material; besides providing a substantial margin of safety in relation to routine conditions of transport, it also addresses the possibility of loss of a package in transit. The one year period is arbitrary, but has been agreed upon as a reasonable upper limit for a package to remain unaccounted

for in transit. Since the package is assumed to be unattended for one year, any physical or chemical changes to the packaging or its contents which are transient in nature and which could contribute to increasing the pressure in the containment system need to be taken into account. The transient conditions that should be considered include changes in heat dissipation capability, gas buildup due to radiolysis, corrosion, chemical reactions or release of gas from fuel pins or other encapsulations into the containment system. Some transient conditions may tend to reduce the MNOP, such as the reduction in pressure with time caused by a decrease in internal heat due to radioactive decay of the contents. These conditions may be taken into account if adequately justified.

Overpack

230.1. The carriage of a consignment from one consignor to one consignee may be facilitated by packing various packages or a single package, each of which fully complies with the requirements of the Transport Regulations, into one overpack, e.g. a box or bag. Specific design, test or approval requirements for the overpack are not necessary since it is the packaging which performs the protective function. The overpack is only a handling unit for convenience during transport. However, the interaction between the overpack and the packages should be taken into account, especially concerning the thermal behaviour of the packages during routine and normal conditions of transport.

230.2. A rigid enclosure or consolidation of packages for ease of handling in such a way that package labels remain visible for all packages need not be considered as an overpack unless advantage is taken by the consignor of the determination of the TI of the overpack by direct measurement of the radiation level.

Package

231.1. The terms ‘package’ and ‘packaging’ are used to distinguish the assembly of components for containing the radioactive material (packaging) from this assembly of components plus the contents (package).

231.2. As the package may be transported either with or without certain structural equipment, it may be necessary to evaluate both situations in determining packaging suitability and compliance.

231.3. If certain equipment is attached during transport for handling purposes, it also may be necessary to consider its effect in normal and accident conditions

of transport. In the case of Type B(U), Type B(M), Type C and packages designed to carry fissile material, the designer must reach agreement with the competent authority for certification.

231.4. A tank, freight container or intermediate bulk container with radioactive contents may be used as one of the types of package under the Transport Regulations, provided that it meets the prescribed design, test and any applicable approval requirements for that type of package. Alternatively, a tank, freight container or metal intermediate bulk container with radioactive contents may be used as a Type IP-2 or Type IP-3 industrial package if it meets the Type IP-1 requirements as well as other requirements which are specifically referenced in paras 627–630 of the Transport Regulations.

Packaging

232.1. Other safety functions in this definition (see paras 231.1 and 231.2) include shielding, criticality control, prevention of damage due to heat and the functioning of those features required to enable the package to comply with the performance criteria specified in the regulations for routine, normal and accident conditions of transport as applicable to the package type.

232.2. For design and compliance assurance purposes, a packaging may include any or all structural equipment required for handling or securing the package which is either permanently attached or assembled as an integral part of the packaging.

232.3. In order to determine which structural components should be considered part of the packaging, it is necessary to examine the use and purpose of such equipment with respect to transport safety. If, for safety purposes, a packaging can only be transported with certain structures, then it is normal to consider those structures to be part of the packaging. This does not mean that a trailer or transport vehicle should be considered part of the packaging in the case of dedicated transport. A conveyance should not be considered part of the packaging, even in the case of dedicated transport.

Radiation level

233.1. One of the limiting quantities in radiological protection with respect to the exposure of people is effective dose (the others being equivalent dose to the lens of the eye and to the skin (e.g. see Section II-8 of Ref. [1])). As protection quantities are not directly measurable quantities, operational quantities had to

be created which are measurable. These quantities are ‘ambient dose equivalent’ for strongly penetrating radiation and ‘directional dose equivalent’ for weakly penetrating radiation. The radiation level should be taken as the value of the operational quantity ‘ambient dose equivalent’ or ‘directional dose equivalent’, as appropriate.

233.2. In some cases, consideration should be given to the possibility of an increase in radiation level as a result of the buildup of daughter nuclides during transport. In such cases, a correction should be applied to represent the highest radiation level envisaged during the transport.

233.3. In mixed gamma and neutron fields, it may be necessary to make separate measurements. It should be ensured that the monitoring instrument being used is appropriate for the energy being emitted by the radionuclide and that the calibration of the instrument is still valid. In performing both the initial measurement and any check measurement, the uncertainties in calibration have to be taken into account.

233.4. For neutron dosimeters, there is, very often, a significant dependence of the reading on the neutron energy. The spectral distribution of the neutrons used for calibration and the spectral distribution of the neutrons to be measured may affect the accuracy of dose determination considerably. If the energy dependence of the instrument reading and the spectral distribution of the neutrons to be measured are known, a corresponding correction factor may be used.

233.5. The Transport Regulations require that, at the surfaces of packages and overpacks, specific radiation levels shall not be exceeded. In most cases, a measurement made with a hand instrument held against the surface of the package indicates the reading at some distance away because of the physical size of the detector volume. The instrument used for the measurement of the radiation level should, where practicable, be small in relation to the dimensions of the package or overpack. Instruments which are large relative to the physical size of the package or overpack should not be used because they might underestimate the radiation level. Where the distance from the source to the instrument is large in relation to the size of the detector volume (e.g. a factor of five), the effect is negligible and can be ignored; otherwise the values in Table 1 should be used to correct the measurement. For radiographic devices where the source to surface distance is generally kept to a minimum, the effect is usually not negligible, and an allowance should be made for the size of the detector volume.

TABLE 1. CORRECTION FACTORS FOR VARIOUS PACKAGE AND DETECTOR SIZES

Distance between detector centre and package surface (cm)	Half linear dimension of package (cm)	Correction factor ^a
1	>10	1.0
2	10–20	1.4
	>20	1.0
5	10–20	2.3
	20–50	1.6
	>50	1.0
10	10–20	4.0
	20–50	2.3
	50–100	1.4
	>100	1.0

^a The reading should be multiplied by the correction factor to obtain the actual radiation level at the surface of the package.

233.6. When monitoring finned flasks or other transport packages, care should be taken where narrow radiation beams may be encountered. A dose rate meter, with a detector area much larger than the cross-sectional area of the beam to be measured, will yield a proportionally reduced reading of dose rate because of averaging over the much larger detector area. An appropriate instrument should be chosen for the work.

Radioactive material

236.1. In previous editions of the Transport Regulations, a single exemption value of 70 Bq/g was used to define radioactive material for transport purposes. Following publication of the BSS [1], it was recognized that this value had no radiological basis. The radiological protection criteria defined in the BSS were therefore used to establish radionuclide specific exemption values for transport purposes (see para. 402.3).

236.2. The Transport Regulations are based on the assumption that a fissile material is always a radioactive material. However, the characteristics of a fissile material are based on completely different properties (fission probability and neutron multiplicity but not activity) than the characteristics of a radioactive material (activity, radiation type and energy). Whenever the specifications for classification of a material as radioactive are changed in the Transport Regulations, it is essential that the criticality potential be covered. The current limit for U-235 is judged to be sufficiently safe. A material with fissile nuclides other than those of U-235 could not have a potential for causing criticality while their activity concentrations and the total activities are below values specified in Table 2 of the Transport Regulations.

Shipment

237.1. In the context of the transport of radioactive material, the term ‘destination’ means the end point of a journey at which the package is, or is likely to be, opened, except during customs operations as described in para. 582.

Special arrangement

238.1. Special arrangement should be used only where it is impractical to ship under all the applicable requirements of the Transport Regulations. This type of shipment is intended for those situations where the normal requirements of the Transport Regulations cannot be met. For example, the disposal of old equipment containing radioactive material where there is no reasonable way to ship the radioactive material in an approved package. The hazard associated with repackaging and handling the radioactive material could outweigh the advantage of using an approved package, assuming a suitable package were available. The special arrangement provisions should compensate for not meeting all the normal requirements of the Transport Regulations by providing an equivalent level of safety. In keeping with the underlying philosophy of the Transport Regulations, reliance on administrative measures should be minimized in establishing the compensating measures.

Special form radioactive material

239.1. The Transport Regulations are based on the premise that the potential hazard associated with the transport of non-fissile radioactive material depends on four important parameters:

- (i) The dose per unit intake (by ingestion or inhalation) of the radionuclide;
- (ii) The total activity contained within the package;
- (iii) The physical form of the radionuclide;
- (iv) The potential external radiation levels.

239.2. The Transport Regulations acknowledge that radioactive material in an indispersible form or sealed in a strong metallic capsule presents a minimal contamination hazard, although the direct radiation hazard still exists. Material protected in this way from the risk of dispersion during accident conditions is designated as special form radioactive material. Radioactive material which itself is dispersible may be adsorbed, absorbed or bonded to an inert solid in such a manner that it acts as an indispersible solid, e.g. metal foils. (See paras 603.1–603.4, 604.1 and 604.2.)

239.3. Unless the radioactive contents of a package are in special form, the quantity of radioactive material that can be carried in an excepted or Type A package will be limited to A_2 or multiples thereof. For example, a Type A package is limited to A_2 and the contents of excepted packages are limited to values ranging from A_2 to as low as $10^{-4}A_2$, or $10^{-5}A_2$ if transported by post, depending upon whether the material is solid, liquid or gas and whether or not it is incorporated into an instrument or article. However, if the material is in special form, the package limits change from A_2 to A_1 or appropriate multiples thereof. Depending on the radionuclide(s) involved, the A_1 values differ from the A_2 values by factors ranging from 1 to 10 000 (see Table 2 of the Transport Regulations). The capability to ship an increased quantity in a package if it is in special form applies only to Type A and excepted packages.

Specific activity

240.1. The definition of specific activity in practice covers two different situations. The first, the definition of the specific activity of a radionuclide, is similar to the ICRU definition of specific activity of an element. The second, the definition of the specific activity of a material for the Transport Regulations, is more precisely a mass activity concentration. Thus, the definition of specific activity is given for both cases and depends upon its specific application in the requirements of the Transport Regulations. The term ‘activity concentration’ is also used in some paragraphs of the Transport Regulations (e.g. see para. 402 and the associated Table 2 of the Transport Regulations).

240.2. The half-life and the specific activity of each individual radionuclide given in Table 2 of the Transport Regulations are shown in Table II.1 of

Appendix II. These values of specific activity were calculated using the following equation:

$$\begin{aligned}\text{Specific activity (Bq/g)} &= \frac{(\text{Avogadro's number}) \times \lambda}{(\text{Atomic mass})} \\ &= \frac{4.17 \times 10^{23}}{A \times T_{1/2}}\end{aligned}$$

where

A is the atomic mass of the radionuclide;

$T_{1/2}$ is the half-life in s of the radionuclide;

λ is the decay constant in s^{-1} of the radionuclide = $\ln 2/T_{1/2}$.

240.3. The specific activity of any radionuclide not listed in Table II.1 of Appendix II can be calculated using the equation shown in para. 240.2.

240.4. The specific activity of uranium, for various levels of enrichment, is shown in Table II.3 of Appendix II.

240.5. In determining the specific activity of a material in which radionuclides are distributed, the entire mass of that material or a subset thereof (i.e. the mass of radionuclides and the mass of any other material) needs to be included in the mass component. The different interpretations of specific activity in the definition of LSA material (para. 226) and in Table II.1 should be noted.

Tank

242.1. The lower capacity limit on tank volume of 450 L is included to achieve harmonization with the current United Nations Recommendations [9].

242.2. Paragraph 242 includes solid contents in tanks where such contents are placed in the tank in liquid or gaseous form and subsequently solidified prior to transport (e.g. uranium hexafluoride).

Through or into

243.1. The definition of multilateral approval is limited to countries “through or into which the consignment is transported” and specifically excludes countries

over which an aircraft may carry the consignment provided that the aircraft has no scheduled stops in that country.

Transport index

244.1. The TI performs many functions in the Transport Regulations, including providing the basis for the carrier to segregate radioactive material from persons, undeveloped film and other radioactive material consignments, and to limit the level of radiation exposure to members of the public and to transport workers during transport and in-transit storage.

244.2. In the 1996 Edition of the Transport Regulations, the TI no longer makes any contribution to the criticality safety accumulation control of packages containing fissile material. Accumulation control for criticality safety is now provided by a separate CSI (see paras 218.1–218.3). Although the previous approach of a single control value for radiological protection and criticality safety provided for simple operational application, the current use of a separate TI and CSI removes significant limitations on segregation in the transport and storage in transit of packages not containing fissile material. The reason for retaining the designation of TI is that the vast majority of radioactive consignments are not carrying fissile material and, therefore, a new name for the ‘radioactive only’ TI could have created confusion because of the need to introduce and explain two new names. Care should be taken not to confuse the use of the TI value and to consider the CSI value as the only control for accumulation of packages for criticality safety.

244.3. See paras 523.5–524.1.

Unirradiated thorium

245.1. The term ‘unirradiated thorium’ in the definition of LSA material is intended to exclude any thorium which has been irradiated in a nuclear reactor so as to transform some of the Th-232 into U-233, a fissile material. The definition could have prohibited the presence of any U-233, but naturally occurring thorium may contain trace amounts of U-233. The limit of 10^{-7} g of U-233 per gram of Th-232 is intended to prohibit any irradiated thorium while recognizing the presence of trace amounts of U-233 in natural thorium.

Unirradiated uranium

246.1. The term ‘unirradiated uranium’ is intended to exclude any uranium which has been irradiated in a nuclear reactor so as to transform some of the U-238 into Pu-239 and some of the U-235 into fission products. The definition could have prohibited the presence of any plutonium or fission products, but naturally occurring uranium may contain trace amounts of plutonium and fission products. In the 1985 Edition of the Transport Regulations, the limits of 10^{-6} g of plutonium per gram of U-235 and 9 MBq of fission products per gram of U-235 were intended to prohibit any irradiated uranium while recognizing the presence of trace amounts of plutonium and fission products in natural uranium.

246.2. The presence of U-236 is a more satisfactory indicator of exposure to a neutron flux and 5×10^{-3} g of U-236 per gram of U-235 has been chosen as representing the consensus view of ASTM Committee C-26 in specification C-996 for enriched commercial grade uranium. This value is incorporated into the 1996 Edition of the Transport Regulations and reflects the possibility of trace contamination by irradiated uranium, but ensures that the material may still be treated as unirradiated. This specification represents the composition with the maximum value for uranium radionuclides for which the A_2 value for uranium hexafluoride can be demonstrated as being unlimited. The difference in A_2 for uranium dioxide is considered to be insignificant [10].

REFERENCES TO SECTION II

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- [8] INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for the Safe Transport of Radioactive Material, IAEA Safety Standards Series No. TS-G-1.4, IAEA, Vienna (2008).
- [9] UNITED NATIONS, Recommendations on the Transport of Dangerous Goods, Model Regulations, Seventeenth Revised Edition (ST/SG/AC.10/1/Rev.17), UN, New York and Geneva (2011).
- [10] INTERNATIONAL ATOMIC ENERGY AGENCY, Interim Guidance for the Safe Transport of Reprocessed Uranium, IAEA-TECDOC-750, IAEA, Vienna (1994).

Section III

GENERAL PROVISIONS

RADIATION PROTECTION

301.1. Optimization of protection and safety requires that both normal and potential exposures be taken into account. Normal exposures are exposures that are expected to be received under routine and normal transport conditions as defined in para. 106 of the Transport Regulations. Potential exposures are exposures that are not expected to be delivered with certainty but that may result from an accident or from an event or sequence of events of a probabilistic nature, including equipment failures and operating errors. In the case of normal exposures, optimization requires that the expected magnitude of individual doses and the number of people exposed be taken into account. In addition, in the case of potential exposures, the likelihood of occurrence of accidents or events or sequences of events is also taken into account. Optimization should be documented in the radiation protection programmes (RPPs). (See also Refs [1–3].)

301.2. The BSS [4] define radiological protection requirements for practices (activities that increase the overall exposure to radiation) and for interventions (activities that decrease the overall exposure by influencing the existing causes of exposure). The system of radiological protection for practices as set out in the BSS (Section 2, Principal Requirements) is summarized as follows:

No practice is to be adopted unless it produces a positive net benefit (justification of a practice).

All exposures are to be kept as low as reasonably achievable, economic and social factors being taken into account (optimization of protection).

Total individual exposure is to be subject to dose limits or, in the case of potential exposures, to the control of risk (individual dose and risk limits).

301.3. In practical radiological protection, there has in the past existed, and continues to exist, a need to establish standards associated with quantities other than the basic dose limits. Standards of this type are normally known as secondary or derived limits. When such limits are related to the primary limits

of dose by a defined model, they are referred to as derived limits. Derived limits have been used in the Transport Regulations.

301.4. Setting dose constraints is part of optimization [4, 5]. The constraints alluded to in the BSS should be related to transport and should take into account the cumulative effects of exposures from other sources relevant to planned working situations. In the case of workers devoted only to transport activities, it will be reasonable to set constraints for transport of radioactive material. In other cases, it may be appropriate for individual users to include dose constraints in their RPP, in which case lower constraints would normally be expected to be set than for transport activity alone since, by definition in the BSS, “the dose constraint for each source is intended to ensure that the sum of doses to the representative person from all controlled sources remains within the dose limit”. (For further information, see Ref. [4].)

301.5. Examples of derived limits in the Transport Regulations include the maximum activity limits A_1 and A_2 , maximum levels for non-fixed contamination, radiation levels at the surfaces of packages and in their proximity, and segregation distances associated with the TI. The Transport Regulations require assessment and measurement to ensure that standards are being complied with.

301.6. It should be a task of the competent authority to ensure that all transport activities are conducted under a general framework of optimization of protection and safety.

302.1. The objectives of the RPP for the transport of radioactive material are:

- To provide for adequate consideration of radiation protection measures in transport;
- To ensure that the system of radiological protection is adequately applied;
- To enhance a safety culture in the transport of radioactive material;
- To provide practical measures to meet these objectives.

The RPP should include, to the extent appropriate, the following elements:

- (a) Scope of the programme (see paras 302.2–302.4);
- (b) Roles and responsibilities for the implementation of the programme (see para. 302.5);
- (c) Dose assessment and optimization (see para. 303);
- (d) Surface contamination assessment (see paras 508, 513 and 514);
- (e) Segregation and other protective measures (see paras 562.1–562.14);