IAEA

International Atomic Energy Agency

Safe Transport of Radioactive Material

Fourth Edition

VIENNA, 2006

TRAINING COURSE SERIES 1

IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards.

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety, and also general safety (i.e. all these areas of safety). The publication categories in the series are **Safety Fundamentals, Safety Requirements** and **Safety Guides**.

Safety standards are coded according to their coverage: nuclear safety (NS), radiation safety (RS), transport safety (TS), waste safety (WS) and general safety (GS).

Information on the IAEA's safety standards programme is available at the IAEA Internet site

http://www-ns.iaea.org/standards/

The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at P.O. Box 100, A-1400 Vienna, Austria.

All users of IAEA safety standards are invited to inform the IAEA of experience in their use (e.g. as a basis for national regulations, for safety reviews and for training courses) for the purpose of ensuring that they continue to meet users' needs. Information may be provided via the IAEA Internet site or by post, as above, or by e-mail to Official.Mail@iaea.org.

OTHER SAFETY RELATED PUBLICATIONS

The IAEA provides for the application of the standards and, under the terms of Articles III and VIII.C of its Statute, makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

Reports on safety and protection in nuclear activities are issued in other publications series, in particular the **Safety Reports Series**. Safety Reports provide practical examples and detailed methods that can be used in support of the safety standards. Other IAEA series of safety related publications are the **Provision for the Application of Safety Standards Series**, the **Radiological Assessment Reports Series** and the International Nuclear Safety Group's **INSAG Series**. The IAEA also issues reports on radiological accidents and other special publications.

Safety related publications are also issued in the **Technical Reports Series**, the **IAEA-TECDOC Series**, the **Training Course Series** and the **IAEA Services Series**, and as **Practical Radiation Safety Manuals** and **Practical Radiation Technical Manuals**. Security related publications are issued in the **IAEA Nuclear Security Series**.

TRAINING COURSE SERIES No. 1

Safe Transport of Radioactive Material

Fourth Edition

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2006

The originating Section of this publication in the IAEA was:

Radiation Safety Section
International Atomic Energy Agency
Wagramer Strasse 5
P.O. Box 100
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SAFE TRANSPORT OF RADIOACTIVE MATERIAL
IAEA, VIENNA, 2006
IAEA-TCS-01/04
ISSN 1018–5518

Printed by the IAEA in Austria
August 2006

FOREWORD

Since 1957, the International Atomic Energy Agency (IAEA) has exerted efforts towards developing and maintaining its Regulations for the Safe Transport of Radioactive Material. The IAEA's Transport Regulations are used worldwide as the basis for the safety requirements of relevant international organizations (including the United Nations Economic and Social Council, International Civil Aviation Organization, International Maritime Organization, UN Economic Commission for Europe, Universal Postal Union, and MERCOSUR/MERCOSUL) as well as the national transport regulations of many IAEA Member States. Indeed, Member States recognized at the IAEA General Conference in 1998 that "compliance with regulations which take account of the Agency's Transport Regulations is providing a high level of safety during the transport of radioactive materials".

Meeting its statutory obligation to foster the exchange and training of scientists and experts in the field of peaceful uses of atomic energy, the IAEA has developed a standardized approach to transport safety training as a means of helping Member States to implement the Transport Regulations. Under this approach, and compatible with a train-the-trainer concept, the IAEA provides training at the international level on the full requirements of its Transport Regulations to Member States' competent authorities responsible for regulating the safe transport of radioactive material in their respective countries. In turn, those that have been trained by the IAEA are expected to disseminate their knowledge at a national level on applicable aspects of the Transport Regulations.

This training manual is an anchor of the standardized approach to training: it contains all the topics presented in the sequential order recommended by the IAEA for the student to gain a thorough understanding of the body of knowledge that is needed to ensure that radioactive material — ranked as Class 7 in the United Nations' nomenclature for dangerous goods — is transported safely. The explanations in the text refer, where needed, to the appropriate requirements in the IAEA's Transport Regulations; additional useful information is also provided.

Thus, this training manual — in addition to the Transport Regulations and their supporting documents — is used by the IAEA as the basis for delivering all of its training courses on the safe transport of radioactive material. Enclosed with the training manual is a CD-ROM that contains the text of the manual as well as the visual aids that are used at the IAEA's training courses. The visual aids are presented in modules that are keyed to the chapters of the training manual.

IAEA training courses are mainly intended for national competent authorities for radioactive material, and address the full requirements of the Transport Regulations. However, training is also needed at courses not usually organized by the IAEA: for regulatory staff needing only certain aspects of the Transport Regulations (e.g. non-nuclear fuel cycle requirements) or for non-regulatory personnel (e.g. consignors and carriers, emergency first responders and drivers); visual aids for such courses are also available on the CD-ROM. Training courses for Member States' national purposes may be based on these other sets of visual aids, the contents of which need only be expanded to address applicable national requirements.

This edition of the training manual is based on the IAEA's Regulations for the Safe Transport of Radioactive Material (TS-R-1, 2005 Edition). It includes the updated training manual for the comprehensive training programme (duration 2 weeks), and two annexes –one relating to a new training manual for a short training programme for public authorities other than competent authorities (duration half day) and the other, a new training manual for a short training programme for cargo personnel including cargo handlers and vehicle crew (duration half day). This edition features exercises that have been included at the end of every chapter to help students gauge their own understanding of the topics addressed in each chapter. Prepared answers can be obtained by training course administrators from the IAEA on request.

The Secretariat wishes to express its gratitude to all experts who have contributed to the preparation of this manual.

Information about the IAEA's transport safety training programme may be obtained from:

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EDITORIAL NOTE

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1. INTRODUCTION

The transport of radioactive material embraces the carriage of radioisotopes for industrial, medical, and research uses, as well as the shipment of radioactive waste, and consignments of nuclear fuel cycle material. It has been estimated that, throughout the world, between eighteen and thirty-eight million package shipments of radioactive material take place each year [1].

The United Nations (UN) approved the statutes of the International Atomic Energy Agency (IAEA) in October 1956, and these statutes entered into force on 29 July 1957 [2]. The mandate given to the IAEA at its creation was to promote peaceful applications of atomic energy worldwide for humanity's benefit while, simultaneously, guarding against the spread of its destructive use [3].

One of the first tasks undertaken by the IAEA following its creation was the development of regulatory standards for ensuring the safe packaging and transport of radioactive material. Work on the safe transport of radioactive material was initiated at the IAEA in July 1959 when the United Nations Economic and Social Council requested that the IAEA be entrusted with the drafting of recommendations on the transport of radioactive substances [4]. The result of this effort was the publication of the IAEA's Regulations for the Safe Transport of Radioactive Materials[1], 1961 Edition, Safety Series No. 6 [5]. This first edition of the Regulations established basic prescriptions in terms of packaging standards and package make-up for the containment of radioactive material and for the prevention of criticality when the material is fissile [4].

Since the Regulations were first issued, the IAEA has diligently worked with its Member States and relevant international organizations to update the Regulations, taking advantage of experience in the application of the Regulations and of advances in technology and knowledge. Consequently, the IAEA has issued the following revisions to the Regulations:

1. 1964 Edition
2. 1967 Edition
3. 1973 Edition
4. 1973 Edition (As Amended 1979)
5. 1985 Edition (Supplemented 1986, 1888)
6. 1985 Edition (As Amended 1990) [6]
7. 1996 Edition
8. 1996 Edition (As Revised 2000)
9. 1996 Edition (As Amended 2003)
10. 2005 Edition

Throughout this document, when the IAEA's *Regulations for the Safe Transport of Radioactive Material* is being referred to, it is denoted by capitalizing the first letter in the word Regulations. This is to distinguish the IAEA Regulations from other national and international requirements, regulations and codes.

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[1] In issuing the 1985 Edition, the title of the Regulations was modified, changing the word to the singular "material" rather than the plural "materials" which had been used in previous editions. It was decided, during the 1985 review, to use the singular for radioactive material both in the title of the Regulations and throughout the regulatory provisions. Therefore, that practice is continued here.

The 1996 Edition of the Regulations was issued with a new nomenclature. It was identified as “IAEA Safety Standards Series, Requirements, No. ST-1,” [7] rather than “Safety Series No. 6”.

In 2000 a revised edition of ST-1 was issued. This 2000 edition was identified as “IAEA Safety Standards Series, Requirements, No. TS-R-1 (ST-1 Revised),” It was revised in 2003 and again in 2005. Henceforth in this training manual, unless otherwise noted, “the Regulations” meansTS-R-1 [8].

In approving the first revision to the Regulations in 1964, the IAEA’s Board of Governors authorized the Director General to apply the Regulations to IAEA operations. Member States and other relevant organizations were encouraged to use the Regulations as a basis for their respective national regulations for domestic and international transport [9]. As a result, the Regulations have been adopted worldwide by Member States and international regulatory bodies as the basis for relevant national and international regulations.

As one means of promoting safety in transport, as well as encouraging harmony in regulatory control, the IAEA has from time to time organized training courses with the co-operation of Member State Governments and organizations. These have been aimed at individuals from developing countries with appropriate responsibilities in the area of the transport regulations and their implementation. The programme started with individual training courses to specific Member States in the early 1980s and a regional training course for the sub-Andean countries in 1984. Beginning in 1987 (with a course held at Bristol, United Kingdom), formal regional and inter-regional training courses have been held about once per year. Thus far they have been held in Argentina, Australia, Belarus, Belgium, France, Germany, Lebanon, Lithuania, Syria, the United Kingdom, and the United States.

In order to encourage further training, the IAEA found it desirable to develop a basic course text on the safe transport of radioactive material. It was therefore decided that the lecture notes from the 1987 course held at Bristol would form the basis of this text, and that it would be focussed on the 1985 Edition of the Regulations [9]. The result was the IAEA’s Training Course Series No. 1 on the *Safe Transport of Radioactive Material*, which was updated to a second edition in 1991 [10]. To facilitate training, a Supplement to Training Course Series No. 1 on the *Safe Transport of Radioactive Material* was developed and issued in 1996 [11]. The current text is a further update of the training manual to make it consistent with the latest TS-R-1 Regulations [8], and to encompass the IAEA’s desire to structure its training courses in a modular format.

1.1. Objectives

The purpose of an IAEA regional or inter-regional training course is to provide guidance to regulatory and key industrial personnel on the Regulations and practices for the safe transport of radioactive material. The participants at such a course may be officials of national authorities or managers and technical staff from organizations undertaking or involved in the transport of radioactive material. In order to ensure proper regulatory and quality compliance, it is most appropriate if these persons have suitable background knowledge of the scientific principles that underlie the control of radiation hazards.

The objective of each IAEA training course is to ensure that the student thoroughly understands the philosophy, principles, and application of the provisions of the transport Regulations. Some practical reinforcement of this knowledge is afforded by means of exercises in appropriate chapters of this Training Course Series manual. In addition, during any course in which this material is used, efforts will be made by course organizers to further reinforce the training by arranging visits to the premises of suitable consignor and carrier organizations, as well as to package design and testing facilities.

The purpose of this training manual is to provide a rational method for convening a training course and to foster high quality training. This manual serves as a tool for instructors to use in presenting subjects pertaining to the Regulations in a logical and understandable manner. It also allows training course participants to become knowledgeable about the Regulations and how they should be applied. The document further provides a reference for students to use after the course to ensure their understanding of the requirements in the Regulations and how the regulatory requirements may be practically applied beyond the training course.

1.2. Course overview

The subject matter of the course focuses primarily on the transport Regulations of the International Atomic Energy Agency [8] and interweaves other requirements, supporting guides, and technical documents as necessary. Particular attention is accorded to:

(1) The Basic Safety Standards for Radiation Protection [12], and
(2) The advisory material for the Regulations [13].

Recognizing that the Regulations specify '**what**' is to be accomplished for a given requirement, the guidance document [13] presents the basics both on '**why**' the individual regulatory provisions exist, and on '**how**' to apply them. As such, it serves as a primary supplement to the Regulations.

Normally, the subject matter provided in this publication will be divided up and taught by expert specialists in each topical area. The lecturers will be drawn from the International Regulatory Community, National Competent Authorities, and from national organizations experienced in international and national transport. The lecturers may not necessarily teach directly from this text, but will use it to enhance their presentations and as a reference text book.

The exercises provided in this training course manual will usually be used during the course to enhance communication and understanding and to evaluate progress in learning. Other exercises may also be used if it is determined that they are more suitable for the specific participants. Practical exercises will be used as much as possible throughout the course to enhance the learning process.

Other practical inputs during the course will include visits to appropriate consignor and carrier organizations, or other transport-related facilities. These visits will be structured to include talks by staff, conducted tours of operational areas, and practical demonstrations of methods.

This training manual has three parts. Part I, comprising Chapters 1 to 4, serves as a comprehensive introduction for the training course.

Chapter 1 The remainder of this chapter discusses the structure of the IAEA and introduces some common uses of radioactive material. The IAEA's programme on the safe transport of radioactive material is then described, before the overview of the history, basic philosophy, and scope of the Transport Regulations are presented. Finally, Competent Authority responsibilities are introduced together with some of the IAEA's transport interfaces.

Chapters 2 & 3 These two chapters provide reviews of radioactivity and radiation, and radiation protection principles. Good comprehension of both of these topics is essential to the course.

Chapter 4 An entire chapter is devoted to a general introduction of the terminology used in the Regulations. This provides the course participant with some of the basic language of the subject. Ultimately, a complete understanding of terminology is essential to the proper use, and application of the Regulations. To obtain this complete understanding, the student should refer to Section II of TS-R-1.

Part II, comprising Chapters 5 to 15, provides a detailed discussion of the Regulations. The different chapters address topics vital to the proper implementation of the Regulations. These topics include:

Chapter 5 Basic safety concepts: This chapter provides a general overview of the safety concepts associated with materials and packages, which are the core of the regulatory philosophy.

Chapter 6 Activity limits and material restrictions: These parameters are the basis for the correct selection of package type and material classification.

Chapter 7 Selection of optimal package types for a given radioactive content: This chapter provides the details and distinctions of each package type including their limits and typical contents.

Chapter 8 Design and testing requirements and procedures for materials and packages: Material and package test procedures: The detailed requirements for each of the different types of material and package are covered along with a discussion of the design considerations. Examples of different packages are given. Each of the performance tests is presented along with some discussion of the facilities required to conduct them.

Chapter 9 Consignors responsibilities relating to the proper preparation of packages for shipment. Attention is paid to such items as radiation controls, marking and labelling, preparation of shipping documents, and contamination controls.

Chapter 10 Controls and communications: The focus of this chapter is on those actions that are required primarily of a consignor but also of the carrier. These ensure that hazards are properly controlled during transport and communicated during all phases of the shipment operations. Attention is paid to such items as radiation controls, placarding of conveyances, shipping documents, and contamination controls.

Chapter 11 Classification of LSA and SCO: This chapter helps the reader to classify LSA materials and SCOs appropriately. The user will be able to determine the correct package specifications and transport control requirements applicable to LSA materials and SCOs.

Chapter 12 Fissile material: The requirements which are imposed on packages and shipments of fissile material are presented here, noting that special care has been taken in the Regulations to ensure criticality safety for this material.

Chapter 13 Quality Assurance: The emphasis in this chapter is on those requirements which must be satisfied in terms of developing a Quality Assurance (QA) programme, and implementing that programme in a graded fashion.

Chapter 14 National Competent Authority: Chapter 13 focuses on the vital roles of the National Regulatory Body (or bodies). They are the organizations in each Member State responsible for promulgating, implementing, and administering the Regulations and/or providing necessary information to ensure that adequate guidance and training is available.

Chapter 15 Deals with additional regulatory constraints imposed by international modal organizations and agreements: The various modes (i.e., road, rail, water and air; as well as post) are discussed in detail, and the roles, responsibilities and agreements of the international organizations are covered.

Part III, comprising Chapters 16 to 19, deals with other relevant information. This material is not directly sequential and may be taught in more or less any order. Topics in this part include:

Chapter 16 International liability and insurance: The complex issues related to liability and insurance of radioactive material transport are summarized in this chapter. In particular, the distinctions between material that is covered by each protocol, and that which is not, are emphasized.

Chapter 17 Emergency planning and preparedness: Although the application of the Regulations leads to a high level of confidence in safe transport, accidents do occur. It is therefore necessary for all involved in these activities to have adequate emergency plans and to be properly prepared.

Chapter 18 Training: It has long been recognized that training of involved personnel is a keystone to both the successful implementation of the Regulations and good compliance with them. Therefore, training policies, programmes, requirements and records are discussed in this chapter.

Chapter 19 IAEA information services: The IAEA's vital role in providing information on the safe transport of radioactive material to Member States and international organizations is summarized here.

1.3. The International Atomic Energy Agency (IAEA)

Various events and activities, beginning in 1946, led to the creation of the IAEA by the UN in 1956, with the IAEA's programmes officially beginning in 1957 [2]. The key to the formation and subsequent functioning of the IAEA has been its Statute.

1.3.1. Statute

The development of the Statute [14] was undertaken during 1955 and 1956 by twelve of the future Member States of the IAEA. It was approved on 23 October 1956, during the

Conference on the Statute of the International Atomic Energy Agency, convened at the Headquarters of the UN. The Statute came into force on 29 July 1957, and it has been amended three times. The last amendments were made on 28 December 1989.

The objectives of the IAEA are clearly set forth in the Statute as follows:

"The Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose."

1.3.2. Mission and functions

The Statute also specifies the functions of the IAEA, by stating, in part, that it is authorized:

(1) To encourage and assist research on, and development and practical application of, atomic energy for peaceful uses throughout the world; and, if requested to do so, to act as an intermediary for the purposes of securing the performance of services or the supplying of materials, equipment, or facilities by one member of the Agency for another; and to perform any operation or service useful in research on, or development or practical application of, atomic energy for peaceful purposes;

(2) To make provision, in accordance with this Statute, for materials, services equipment and facilities to meet the needs of research on, and development and practical application of, atomic energy for peaceful purposes, including the production of electric power;

(3) To foster the exchange of scientific and technical information on peaceful uses of atomic energy;

(4) To encourage the exchange of training of scientists and experts in the field of peaceful uses of atomic energy;

(5) To establish and administer safeguards;

(6) To establish or adopt...standards of safety for protection of health and minimization of danger to life and property (including the standards for labour conditions), and to provide for the application of these standards to its own operations as well as to the operations making use of materials, services, equipment, facilities and information made available by the Agency or at its request or under its control or supervision; and to provide for the application of these standards, at the request of the parties, to the operations under any bilateral or multilateral arrangement, or, at the request of a State, to any of that State's activities in the field of atomic energy; and

(7) To acquire or establish any facilities, plant and equipment useful in carrying out its authorized functions.

1.3.3. Roles and responsibilities

The IAEA serves as the world's central intergovernmental forum for scientific and technical co-operation in the nuclear field. It also acts as the international inspectorate for the application of nuclear safeguards and verification measures covering civilian nuclear programmes. The IAEA is a specialized agency within the United Nations system. As such, the IAEA provides a wide range of IAEA products, services and programmes that incorporate the co-operative efforts and interests of the IAEA's Member States [15].

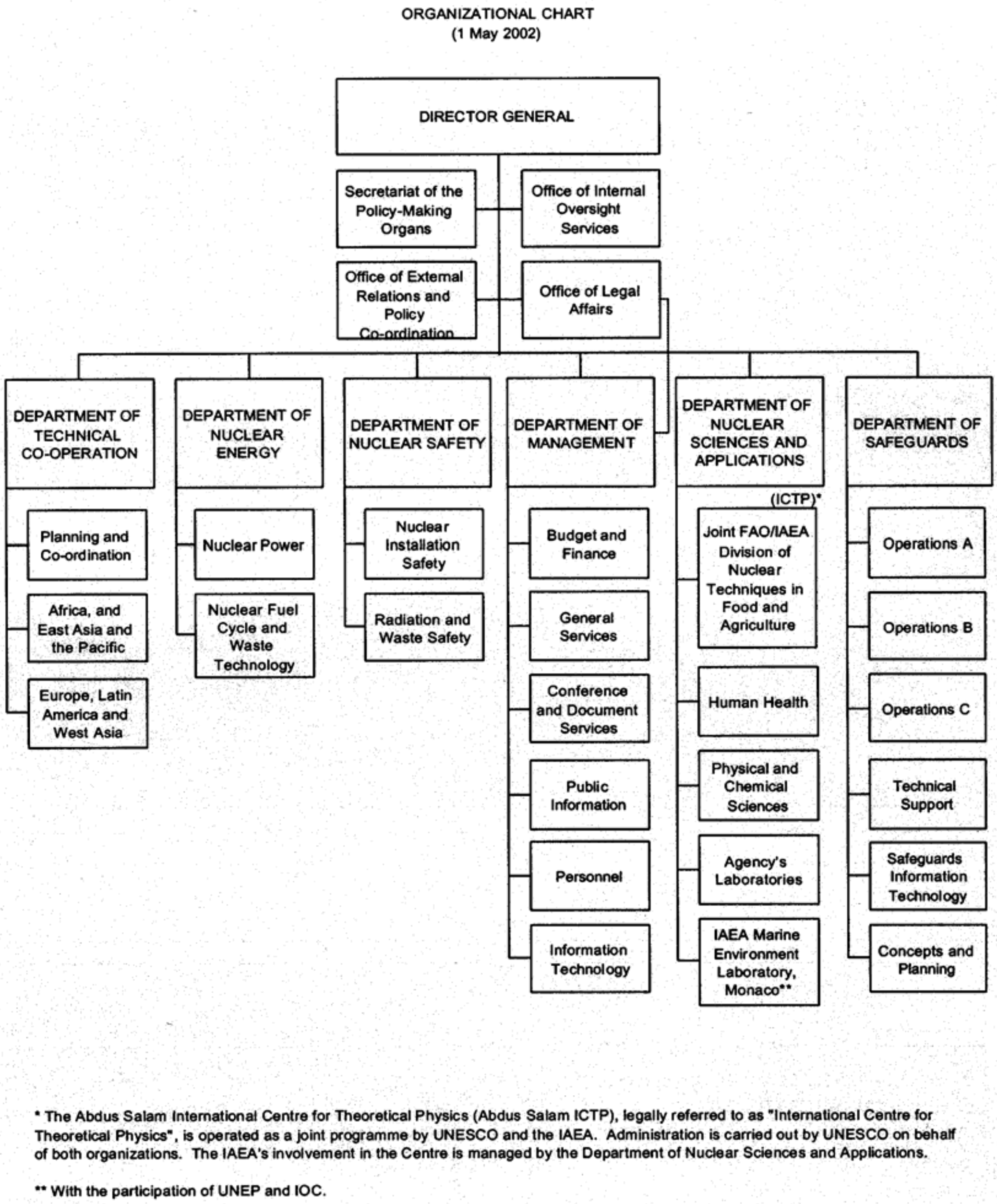

FIG. 1.1. IAEA organizational structure.

Considering the structure of the IAEA helps one to understand some of its varied roles and responsibilities. The IAEA currently has six Departments, each overseen by a Deputy Director General. Within each Department are a number of Divisions, and within the Divisions are Sections. Some Sections have specialized Units within them. As an example, the Transport Safety Unit is in the Radiation Safety Section, within the Division of Radiation and Waste Safety, which is in the Department of Nuclear Safety.

The current programmes of the IAEA can be classified under the following headings:

- Nuclear safeguards and verification;
- Nuclear radiation and waste safety;
- Nuclear power, fuel cycle and waste technology;
- Nuclear and radiation applications; and
- Technical assistance and co-operation.

1.3.3.1. Safeguards

In operation since the 1960's, the safeguards system of the IAEA is a central component of the world's commitment to control the spread of nuclear weapons. Under agreements that Member States conclude with the International Atomic Energy Agency, IAEA inspectors regularly visit nuclear facilities to verify records that State authorities keep on the whereabouts of nuclear material under their control, check IAEA-installed instruments and surveillance equipment, and confirm physical inventories of nuclear materials. These and other safeguards measures provide independent, international verification that governments are living up to their commitments to peaceful uses of nuclear technology.

1.3.3.2. Nuclear safety

Nuclear radiation and waste safety activities cover a large field from the development and publication of safety standards, guides and practices, to legally binding international safety conventions, to the very practical safety assessments of facilities by special review teams.

1.3.3.3. Nuclear energy

The IAEA's nuclear power programme assists Member States in nuclear power planning and implementation and in advanced reactor technology development. Assistance is provided to developing countries to assess the role of nuclear power in the future expansion of electricity supply systems. A significant emphasis is placed on the training and qualification of plant personnel.

The IAEA's programme on the nuclear fuel cycle covers such key areas as uranium supply and demand; light water reactor fuel performance at extended burnup; the reliability of spent fuel under long term storage; the management of spent fuel from research and test reactors; and the safe handling and storage of plutonium.

The radioactive waste technology programme focuses on the handling, processing and disposal and storage of radioactive waste; decontamination and decommissioning of nuclear installations; environmental restoration, quality assurance and management; waste management planning and infrastructure building; and technology transfer and exchange.

1.3.3.4. Nuclear sciences and applications

The promotion and development of the multiplicity of uses of radiation and radioisotopes is part of the function of the Department of Nuclear Sciences and Applications. Several of these are briefly discussed later in the section on uses of radioactive material. The main topic areas of usage include:

- Food and agriculture;
- Physical and chemical sciences;

- Industry and earth sciences; and
- Human health.

The IAEA plays a key role in co-ordinating the global project on the next step towards nuclear fusion energy, the ITER project.

1.3.3.5. Technical co-operation

Of particular interest is the fact that it is through the Department of Technical Co-operation that regional and inter-regional training courses are facilitated for developing Member States. More importantly, however, it is through this Department that the IAEA provides development assistance to Member States. Dr. Hans Blix, former Director General of the IAEA, has pointed out that:

> "*…over the course of more than three decades, IAEA's Technical Co-operation (TC) Programme has helped to build the foundations for effectively applying nuclear-related technologies in dozens of developing countries. The degree of sophistication of many nuclear applications has made this capacity building phase a complex process. It has entailed many stages of education and training, sharing of research, development and refinement of appropriate equipment and facilities, as well as international co-ordination of efforts*." [16]

In pursuit of the IAEA's focus on assisting developing Member States in the application of nuclear technologies to enhance the quality of life, the IAEA has delivered to them almost US$800 million in technical support. By 1996, 95 countries and territories had, or were participating, in TC projects in 49 principal areas, including:

- Building food security;
- Managing water resources;
- Promoting a sustainable environment;
- Enhancing the quality of health care; and
- Ensuring nuclear safety [16].

1.3.4. Services and information

Multiple services are provided by the IAEA to its Member States. These include the development of standards such as the Regulations [8], associated guidance documents, and other information products. All are provided through the IAEA's Division of Public Information and the Division of Conference and Document Services, both of which are under the Department of Management. The IAEA is the world's largest publisher of nuclear-related material. Not only does this include the aforementioned standards, but also many booklets, books, information circulars, fact sheets, periodicals, and proceedings as well as CD-ROMs, films and videos.

A large number of databases are maintained by the IAEA. Of particular note is the International Nuclear Information System (INIS), which contains well over two million bibliographic references to conventional and non-conventional nuclear literature, and offers various products and services.

In addition, the IAEA holds many dozens of meetings throughout the year as part of its mission regarding the dissemination of information. These vary from small consultants' meetings to major international symposia.

With the advent of the World Wide Web (www), the IAEA has taken significant steps to enhance and streamline communications. Many web pages and databases are available, as well as direct electronic communications with IAEA staff members. The IAEA's web pages are accessed tens of thousands of times monthly, and all IAEA programmes regularly publish information about their projects via the Internet. The IAEA's web site URL is http://www.iaea.org [15]. It is the best, up-to-date, single source of information about all that the IAEA is and does.

1.4. Uses of radioactive material

At this point, it is worth providing a brief overview of some of the everyday uses of radioactive material for those who are a little less familiar with the subject. Radioactive material is used in many more ways than most people realize to improve the quality of life. Whenever or wherever it is used, it is incumbent on qualified individuals and responsible organizations to ensure that the radioactive material is prepared, used, and disposed of in a safe manner. Each of these actions very frequently requires the transport of radioactive material. The following text and Fig. 1.2 provide a brief overview of some examples of these activities that require shipment of radioactive material or waste. Additional examples may be found in Reference [18].

FIG. 1.2. Some uses of radioactive material.

1.4.1. Food irradiation

The use of gamma rays and electron beams in irradiating foods to control disease-causing micro-organisms and to extend shelf life of food products is growing throughout the world [20]. For example, recent steps are leading to the expanded use of meat irradiation in the United States [19]. Food sterilization has been approved by 40 countries and is encouraged by the World Health Organization [20]. Typical radiation sources include ^{60}Co and ^{137}Cs, both of which are likely to be produced at one facility and transported to another facility for irradiation of the meat. It is noted [19] that one company with offices in the United States, Canada, and Puerto Rico provides contract sterilization sources and microbiological reduction services to manufacturers of food products in eleven separate facilities.

1.4.2. Health care product and consumer product irradiation

Gamma rays from sources such as ^{60}Co and ^{137}Cs are commonly used to irradiate health care and other consumer products. Such sterilization is focused on medical instruments, especially those that are likely to penetrate the protective skin barrier. The prevention of infection through this sterilisation technique complements the basic healing goal of medicine. About 180 facilities located in 47 countries worldwide provide sterile medical devices using gamma irradiation techniques [21].

1.4.3. Insect control

Radioisotopes are assisting in enhancing animal and food production. One method is the control of insects, including the control of screwworms, fruit flies, and the Tsetse fly [16]. The IAEA has worked for years to develop a method for controlling the Tsetse fly in areas such as Zanzibar [22], Nigeria, and Burkina Faso [16]. An evaluation of this work in 1996 showed that the Tsetse fly is no longer a problem on Ungaja, the main island of Zanzibar, Tanzania. The Tsetse fly causes the transmission of a parasitic disease, trypanosomiasis, which slowly destroys livestock herds, in sub-Saharan Africa. It also causes the spread of the human form of the disease, known as sleeping sickness. By irradiating male Tsetse flies in a controlled gamma ray environment, the male flies are made sterile, and the Tsetse fly population can be reduced to insignificant levels. The low-level exposures to gamma rays are provided by ^{60}Co and ^{137}Cs sources. These sources are produced in a laboratory and transported to the sites where the flies are exposed. In just two years of effort (1994 to 1996), the number of flies on Ungaja was reduced by two orders of magnitude. It is noted that by early 1997, the incidence of trypanosomiasis among a control group of cattle on the island had dropped to less than 0.1 percent. Previous surveys had shown that on average, 17-25 percent of the animals were infected with trypanosomiasis [22].

1.4.4. Nuclear applications in medicine

There are many applications of nuclear technology in the medical field, ranging from diagnostics, to treatment, to disease management [21]. Many of these use radionuclides produced from either reactors or cyclotrons. Examples include: ^{123}I for thyroid studies; ^{111}In for brain studies; ^{67}Ga for tumour studies; ^{99m}Tc for heart studies; ^{201}Tl for myocardial studies; ^{11}C for brain imaging; ^{81m}Kr for lung studies; ^{13}N for heart function studies; ^{15}O for oxygen studies; and ^{18}F for epilepsy. The safe transport of the radionuclides from the production sites to the hospitals, eventually followed by the safe transport of their residues and related wastes to disposal facilities, is vital to the success of nuclear medicine.

1.4.4.1. Diagnostic techniques

There are two distinct methods used in diagnostics [18, 21]. The first is to use the isotope as an *in vivo* tracer. Here, a carefully chosen radionuclide (commonly known as a radiopharmaceutical) is administered to a patient through inhalation, injection, or ingestion, to trace a specific physiological phenomenon. Detection is accomplished with special detectors such as a gamma camera placed outside the body. The radiopharmaceutical can be selected to seek out only desired tissues or organs. There are hundreds of radiopharmaceuticals used in this way. As an example, recurrent prostate cancer is identified by using an ^{111}In labelled antibody [23].

The second method is to use an *in vitro* technique. For example, blood can be taken from the body and studied using nuclear methods to assess exposures to infection by evaluating antibodies. It can also be used to provide detection of tumours by studying some two dozen tumour markers.

1.4.4.2. Treatment of disease

Radiation is widely used for the treatment of diseases such as hypothyroidism and cancer. The radiation is used to destroy the cancerous cells. A typical radionuclide used for this is ^{60}Co. In addition to teletherapy, where the radiation source has no physical contact with the tumour, the radiation source may be placed in immediate contact with the tumour, as in brachytherapy. Radiolabelled monoclonal antibodies may also be used to attach themselves to the specific tissue or cancer cell requiring treatment [18, 21].

1.4.4.3. Disease management

In addition to the sterilisation of medical equipment discussed earlier, nuclear medicine is also being used to reduce pain [21]. Radiotherapy is administered to patients to palliate the pain, thus replacing pain-killing drugs, which eventually lose their effectiveness. For example, physicians can administer a bone-seeking compound labelled with a high-LET radiation emitter, and the level of pain can be quickly lowered or totally eliminated [21]. A new method involves ^{153}Sm lexidronam, which is a therapeutic radiopharmaceutical used for the relief of pain in patients with confirmed osteoblastic metastatic skeletal lesions [24].

1.4.5. Nuclear applications in industry

Radioisotopes are used in a wide range of industrial applications [16]. One method includes using radioisotope thickness gauges in the manufacture of products such as steel and paper. In another application tracer experiments provide exact information on the condition of expensive processing equipment. Radioisotope sources are used for defining the exact position of tubes in manufacturing facilities. Gamma radiography is used on structures, castings, or welds where the use of X-rays is not feasible. Radioisotopic sources are also used as level indicators for feedstock supply hoppers. Moisture and density gauges use radioactive sources for analysis of soil water content and compaction. Radioisotopes are employed in smoke detectors, and as lasting, fail-safe light sources for emergency signs in aircraft and public buildings. Clearly, the variety of applications is enormous and growing annually.

1.4.6. Nuclear reactors

One of the major uses of radioactive material is in the generation of electricity in nuclear power reactors. By generating electricity with nuclear fission, the quality of life in many countries can be enhanced, the dependence on fossil fuels can be reduced, and the production of greenhouse gases can be reduced. Worldwide, nuclear power is contributing 17% of the world's supply of electricity, while 63% comes from the burning of fossil fuels [25]. Some countries have over 70% of their electricity generated from nuclear power plants. The nuclear fuel cycle which supports this generation requires the transport of radioactive material in many forms, including ores, uranium hexafluoride, fresh nuclear fuel, irradiated (or spent) nuclear fuel, and wastes.

Nuclear research reactors do not usually generate electricity, but are used for a variety of purposes including isotope production and teaching. They are also useful for a large variety of analytical methods including neutron activation analysis, neutron diffraction, neutron radiography, argon/argon geochronology, fission track geochronology, and boron neutron capture therapy.

Nuclear reactors have been used to power a variety of ocean-going vessels including merchant vessels, ice breakers, and naval ships. Nuclear power is particularly well suited to submarines because it allows these to operate submerged for long periods of time.

1.5. The IAEA's transport safety programme

1.5.1. Organization

The responsibility for the radioactive material transport safety programme has always resided within the organization at the IAEA concerned with radiation protection. As mentioned, that responsibility traces from the Director General of the IAEA to the Transport Safety Unit through the Department of Nuclear Safety and the Division of Radiation and Waste Safety [15]. This organizational structure, Figure 1.3 facilitates close co-ordination and communication with other safety-related working groups. The Radiation Safety Section includes the following Units:

- Regulatory infrastructure;
- Patient protection;
- Source safety and security;
- Transport safety; and
- Emergency preparedness & response.

Co-ordination on radiation safety is facilitated through the Radiation Safety Standards Committee (RASSC), which also resides within the Division of Radiation and Waste Safety.

1.5.2. Missions and functions

As part of the Department of Nuclear Safety, the Radiation and Waste Safety Division has a mission:

> *"...to promote radiation safety in the application of nuclear technologies. This includes the control of radiation doses to workers, to members of the public and to patients undergoing medical procedures involving radiation. It also covers the safety and security of radiation sources and radioactive material to prevent accidents or misuse, interventions in emergencies to prevent or mitigate the consequences of radiation accidents, the safe transport of radioactive material, the safe management of radioactive wastes and intervention in chronic exposure situations." [15].*

The Radiation Safety Section, has a mission [16], which recognizes that "all uses of radiation are potentially hazardous", so safety standards need to be developed and applied. The establishment of basic safety standards to cover all uses of radiation and of standards for the safe transport of radioactive material has been the responsibility of the Section since the early days of the IAEA. The Radiation Safety Section's goals include the development and maintenance

> *"...of a system of standards of protection that enable the beneficial uses of radiation to be developed while ensuring adequate protection of workers, the public and medical patients in normal operations and from accidents,"* and also *"to assist Member States in the implementation of these standards."*

The following functions from the Statute are key to the success of the IAEA's transport safety programme:

- Fostering the exchange of scientific and technical information;
- Encouraging the exchange of training of scientists and experts;

- Establishing and adopting standards of safety for protection of health, and minimization of danger to life and property (including the standards for labour conditions); and
- Providing for the application of these standards.

1.5.3. Roles and responsibilities

In response to the above functions in the Statute, the IAEA undertook a programme focussed on ensuring safety during the transport of radioactive material. The Transport Safety Unit has the role of developing the radiological basis for this safe transport of radioactive material. This enables the Unit to review and revise the Transport Regulations in order to keep them in line with the latest radiation protection principles, transport practices, and technological developments [15].

The Unit is responsible for continuously monitoring and reviewing the Regulations to ensure they are adequate and account for current needs and implementation experience. In view of this responsibility, it oversees the revision of not only the Regulations but also other associated IAEA-produced supportive documentation. Through this comprehensive review, continual interactions and co-ordination with the basic safety standards for radiation protection [12] are maintained. The Head of the Transport Safety Unit is also the Co-ordinator for the Transport Safety Standards Committee (TRANSSC).

TRANSSC is the top-level advisory group to the Director General for all activities undertaken by the IAEA relating to the transport of radioactive material. It is chaired by a designated representative from a Member State, and it generally meets in the first half of each year. TRANSSAC was formed in 1996 (and renamed to TRANSSC in 2000), but was preceded by a similar group, the Standing Advisory Group for the Safe Transport of Radioactive Material (SAGSTRAM). Through its meeting records, TRANSSC reports to the Director General its findings, conclusions and recommendations concerning the IAEA's Transport Safety Programme.

At the first meeting of TRANSSC, the concept of a Transport Safety Appraisal Service (TranSAS) was endorsed, and it was recommended that the IAEA take steps to offer this service to Member States. The broad goal of TranSAS is to improve implementation of the Regulations in Member States. Efforts are continuing to fully develop and implement the review team for those Member States in need of this service.

1.5.4. Interfaces with transport safety regulatory organizations

Many organizations have interfaces with radioactive material transport. These include all the United Nations regulatory bodies, as well as other international, governmental, industrial and public organizations. The interfaces between the IAEA and other regulatory bodies and agreements are summarized here, and described in more detail in Chapter 14. Several of these bodies are specialized UN agencies that fall under the umbrella of the Economic and Social Council (ECOSOC). Internationally, the responsibilities tend to be split according to the nature of the hazardous material, and according to the transport mode. Figure 1.4 provides a perspective of the worldwide transport of dangerous goods by all modes of transport. This figure also indicates how small the fraction of radioactive material shipments is in the overall picture.

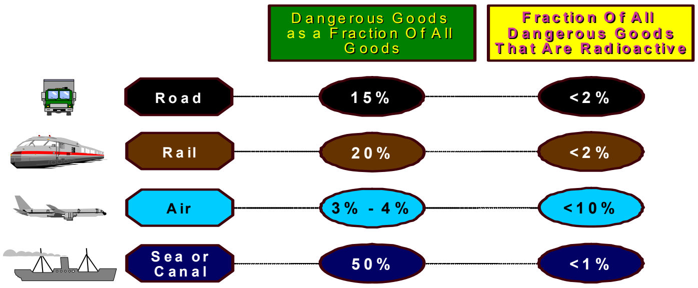

FIG. 1.3. Worldwide perspective of the transport of dangerous goods.

1.5.4.1. United Nations Economic and Social Council Committee of Experts (ECOSOC)

The development of recommendations on a broad international basis to assist national authorities in ensuring the safe transport of hazardous material by different modes of transport was initiated by the United Nations. Under the authority of the Economic and Social Council (ECOSOC), the Committee of Experts on the Transport of Dangerous Goods supervises the work.

The UN Committee of Experts issues Recommendations on the Safe Transport of Dangerous Goods. These Recommendations have been universally accepted as the basis for national and international regulations covering various modes of transport. The current "Recommendations of the Committee of Experts", commonly known in the transport world as the "Orange Book", were developed from an original version approved by the ECOSOC in 1957.

As early as 1959, the ECOSOC adopted a resolution entrusting the IAEA with the task of establishing recommendations for the safe transport of radioactive material. Therefore, the "Orange Book" and IAEA Safety Series No. 6 [6] have developed on a consistent basis, ensuring full compatibility between the treatment of radioactive material and other dangerous goods. On restructuring, the Orange Book will contain the body of the text of TS-R-1.

1.5.4.2. International Commission on Radiation Protection (ICRP)

Because of the vital importance of radioactivity and radiation in modern life and its potential impact on persons, property and the environment, the International Commission on

Radiation Protection (ICRP) has served as the global technical body in this field. It is tasked with the responsibility of ensuring that activities that utilize radiation or radioactive material are undertaken in a safe manner with respect to persons, property, and the environment. The ICRP issues periodic documents related to radiation protection, and the IAEA in turn considers and adopts the principles in these documents into its own safety-related publications.

Recent IAEA documents, which embody these actions, deal with radiation protection and safety of radiation sources [26] and basic safety standards for protection against ionizing radiation [12]. In turn, the principles set forth in these documents were considered in the development of TS-R-1, as is noted in paragraph 101 of TS-R-1.

1.5.4.3. International Maritime Organization (IMO)

Since its organization more than five decades ago, the International Maritime Organization (IMO)[2], which is a United Nations organization, has become recognized as the maritime community's forum for all matters affecting the safety of shipping. The transport of dangerous cargoes has been one of IMO's responsibilities since it came into being. The regulations, standards and recommendations that it has developed, are recognized, followed, and observed by ships of many nations.

1.5.4.4. International Civil Aviation Organization (ICAO)

The International Civil Aviation Organization (ICAO) is also a United Nations organization. It deals with all aspects of international civil aviation. ICAO develops standards and recommends practices covering all areas of civil aviation and these are produced as annexes to the Convention on International Civil Aviation. A set of Technical Instructions has been published that set out in detail the requirements for carrying dangerous goods by air. These Technical Instructions reflect the IAEA Regulations with regard to the carriage by air of radioactive material. A standard in the relevant annex requires States to ensure compliance with the Technical Instructions for all international air transport. There is also a recommendation for the Instructions to be used for domestic air transport.

1.5.4.5. International Air Transport Association (IATA)

IATA is a trade association representing airlines throughout the world. Its objectives are the promotion of safe, regular and economical air transport. In 1950, IATA set up a Restricted Articles Board (RAB) comprising experts acting on behalf of all member airlines to develop requirements for the transport of restricted articles by air. The requirements are now embodied in the Dangerous Goods Regulations, and these are generally consistent with the ICAO's Technical Instructions.

It is noted that close co-ordination exists between IAEA, ICAO, and IATA. Changes have been made in the IAEA's Regulations regarding packages to be transported by air at the request of ICAO and IATA. Liaison continues to assure accurate and timely implementation of the IAEA's Regulations.

1.5.4.6. Universal Postal Union (UPU)

The UPU was established in 1894 and is now a specialized agency of the United Nations, with its headquarters in Berne, Switzerland. The UPU Congress meets routinely to review and approve any changes to the Universal Postal Convention and the Detailed Regulations for Implementing the Convention.

Under the UPU Convention [27] and Detailed Regulations, a consignment of radioactive material in which the activity does not exceed one tenth of the activity limit allowed in an excepted package, may be accepted for international transport by post if certain requirements are met.

[2] Before 22 May 1982 the IMO was known as the Inter-Governmental Maritime Consultative Organization (IMCO).

1.5.4.7. Regional agreements for modal transport

The transport of dangerous goods by rail, road, and inland waterway modes is not covered by an international organization on a worldwide basis. Rather, these are covered by several regional agreements such as:

- The Regulations Concerning the International Carriage of Dangerous Goods by Rail (RID);
- The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR);
- The European Agreement concerning the International Carriage of Dangerous Goods on Inland Waterways (ADN); and
- The Regulations for the Transport of Dangerous Goods on the Rhine (ADNR).

These organizations were established in Europe because of the large economic potential, which is concentrated on a confined area, and is distributed over many states. In addition, there is the MERCOSUR/MERCOSUL agreement that affects road, rail, air and sea transport among certain South American countries. The exchange of economic goods, including radioactive material and other dangerous goods, requires many transport operations, as well as sound regulatory control of these operations.

1.6. IAEA Regulations for the Safe Transport of Radioactive Material

1.6.1. History and development

Although radioactive material has been used for more than a century, significant use for beneficial purposes only began in the later 1940s and early 1950s. At that time, since the utilization of this material was increasing dramatically, it was recognized that safe and effective transport arrangements were required in order to properly protect man and the environment.

To assure safety during the transport, handling, and storage of radioactive material, it was recognized early on that a very strict set of standards would be required. The need for international acceptance was recognized as being vital since transport is usually the only aspect of any nuclear-related activity in which the radioactive material itself may directly cross international borders. Even for transport within one country, international carriers or packagings may be involved.

Prior to 1959, the various national and international controls for transport safety were largely based on the United States Interstate Commerce Commission regulations. These were essentially aimed at facilitating the movement of radioactive ores and concentrates, as well as packages containing relatively small amounts of radionuclides for medical and industrial use. The rapid expansion of the nuclear industry required that these early regulations be further developed. Thus, one of the first activities undertaken by the IAEA after its formation was the development of methods for controlling and assuring safety during the transport of all kinds and quantities of radioactive material.

While it was expected that the basic principles underlying the Regulations would remain acceptable for a long period, it was also understood that feedback from experience, advances in technology, changes in the modal transport environments, and sociopolitical forces would result in improvements. This has proven true and five *comprehensive* revisions have subsequently been published: in 1964, 1967, 1973, 1985, and 1996.

The procedure used by the IAEA for the preparation of its Regulations is largely responsible for their extensive national and international application. Each stage of regulatory development involves the convening of panels. The panel members represent not only an extensive coverage of Member States and international transport organizations, but also personnel having experience in the various administrative and technical problems requiring solution. Based on proposals co-ordinated by the IAEA Secretariat, these panels prepare draft Regulations for comment by all Member States and all international organizations concerned. Then, following panel consideration of such comments, final drafts are prepared for approval by the IAEA's Board of Governors.

The process and its controls have changed in detail periodically over the years. In order to provide a structured approach, the Standing Advisory Group on the Safe Transport of Radioactive Material (SAGSTRAM) was established by the IAEA in 1978 to advise on the IAEA's transport programme and on the development and implementation of the Regulations. Recommendations concerning procedures and a schedule for a further comprehensive review of the Regulations and other supportive documents were made at SAGSTRAM meetings. As mentioned earlier, TRANSSAC was formed in 1996 (and renamed to TRANSSC in 2000) replacing the function of SAGSTRAM. This advisory body ultimately endorses the text for a revision to the Regulations, and recommends submission of that text to the IAEA Board of Governors for approval. Following approval by the Board, the transport secretariat responds to comments made by the Board, and then publishes a new edition of the Regulations in the official languages of the IAEA

The main body of the Regulations is structured topically in terms of:

- Introduction;
- Definitions;
- General Provisions;
- Activity Limits and Material Restrictions;
- Requirements and Controls for Transport;
- Requirements for Radioactive Material and for Packagings and Packages;
- Test Procedures;
- Approval and Administrative Requirements.

As such, a user desiring to transport a specified type of radioactive material consignment must study and assimilate requirements from all sections of the Regulations pertaining to that specific type of material although much of the information and requirements may not apply.

In response to an expressed need, a set of schedules listing the requirements to be met for the transport of specific types of consignments was developed and appended to the 1973 and 1973 (As Amended) Editions of the Regulations. Those schedules were intended to serve only as a practical aid to users. In endorsing the 1985 Edition of the transport Regulations, SAGSTRAM recommended that these schedules be published as a separate Safety Series document. Consequently, the "Schedules of Requirements for the Transport of Specified Types of Radioactive Material Consignments" was published separately from the Regulations in 1986 as Safety Series No. 80 [31].

Experience with the 1985 Edition of the Regulations and its companion set of Schedules by Member States showed that in future it would be better to revert back to having the Schedules as part of the same document. To that end, the 1996 Edition of the Regulations

[8] includes schedules of requirements following the main body of the regulatory requirements. It is noted in the foreword to TS-R-1 that "the **requirements to be met** for the transport of specified types of consignments are included in an **abbreviated form** as Schedules in this publication." The Preface to the Schedules in TS-R-1 emphasizes that they are included "as an **aid** to users of these Regulations," and that they "reproduce **some** of the provisions of these Regulations."[3] Thus, the Schedules are not the complete and binding set of regulatory requirements, but can be used as a basic aid or "guide to national authorities and international organizations that may wish to adapt these Regulations [8] in schedule form." It is essential to note that while the Schedules address requirements for transport in some detail, they simply refer to the package and testing requirements as described in the main body of the Regulations.

With time, as knowledge and experience has been gained, the details in the Regulations have become more defined, and more controls have been placed on the packaging and operational requirements. The focus has always been to ensure radiological and nuclear criticality safety while also striving to ensure that transport operations are feasible.

The need to continually work to keep the transport Regulations consistent with the radiation protection standards has caused changes to be made in almost every revision. For example, in the 1985 Edition, specific *General Principles for Radiation Protection* were added. Similarly, in the 1996 Edition, radionuclide-specific activity concentrations for exempt material, and activity limits for an exempt consignment were both added (replacing the simple definition of radioactive material that had existed previously). These changes were prompted by changes in basic radiation protection principles promulgated by the International Commission on Radiation Protection (ICRP), which then were implemented into the IAEA's basic radiation protection standards such as those in Reference [12].

1.6.2. Basic philosophy

Paragraph 101 of TS-R-1 specifically states that the Regulations:

> *"…establish standards of safety which provide an acceptable level of control of the radiation, criticality and thermal hazards to persons, property and the environment that are associated with the transport of radioactive material." This paragraph goes on to indicate that because the Regulations utilize the principles set forth in basic IAEA radiation protection documents, "compliance with these Regulations is deemed to satisfy the principles of the Basic Safety Standards in respect of transport."*

The Regulations are fundamentally based on the philosophy that radioactive material being transported should be adequately packaged to provide protection against the hazards of the material under all conditions of transport, including foreseeable accidents. The Regulations place the duty of providing adequate packaging upon the consignor of the material. This is accomplished by making safety a priority in the package design requirements. Through this fundamental philosophy, dependence on careful and proper actions by the carrier is minimized. However, this does not relieve the carrier from all responsibilities.

In addition, paragraph 105 of TS-R-1 indicates that "the safety of persons, who are either members of the public or workers, is assured when these Regulations are complied with," and that "confidence in this regard is achieved through *Quality Assurance* and

[3] Emphasis of bolded text added for benefit of this training manual.

Compliance Assurance programmes.” Thus, Quality Assurance and Compliance Assurance become key links in the safety chain established by the requirements in the Regulations.

In summary, the philosophy of the Regulations is that, as far as possible:

(1) Packages of radioactive material should be dealt with in the same way as other hazardous goods;

(2) Safety depends primarily upon the package and not on operational controls;

(3) The consignor should be responsible for ensuring safety during transport through proper characterization of the contents, proper packaging of those contents, and proper operational actions including adequate communications. Communications in this context include shipping papers, marking, placarding and labelling, transport indexes, criticality safety indexes, approval certificates, proper shipping names and UN numbers.

Again, this philosophy was developed so that the safety burden would be placed upon the proper preparation of consignments rather than actions required of carriers. The intent of the Regulations is that consignments of radioactive material can be transported with minimal special handling. Basic safety concepts associated with the Regulations are discussed further in Chapter 5.

Because of the robust nature of the packaging requirements in the Regulations, transport industry workers are expected to treat radioactive material consignments with care, but with no more care than that accorded to other dangerous goods.

Since the Regulations are, for administrative purposes, “model regulations” recommended by the IAEA to Member States and appropriate international organizations, they need to be practical with respect to what the various parties involved are required to do. This means that they must be structured to facilitate their conversion into the format and “language” used by the regulators in multiple countries and for various modes of transport.

In addition, the Regulations must be clear and concise, stating “what” has to be achieved. In other words, they are *performance based* rather than prescriptive. It was decided decades ago to formulate them in this fashion rather than specifying “how” to achieve the desired degree of protection in terms of detailed design specifications. The Regulations also do not generally explain “why” a given requirement is imposed or why it should be achieved.

1.6.3. Scope

The scope of the Regulations is clearly specified in paragraphs 106–109 of TS-R-1. These paragraphs define the range of applicability of the Regulations.

In summary, the Regulations apply to:

(1) The transport of radioactive material by all modes on land, water or in the air,

(2) Any transport which is incidental to the use of the radioactive material (paragraph 106 of TS-R-1).

In this context, transport comprises all operations and conditions associated with, and involved in, the movement of the radioactive material including the:

(1) Design of the package;
(2) Manufacture, maintenance, and repair of the packaging; and
(3) Preparation, consigning, loading, carriage (including in-transit storage), unloading and receipt at the final destination of loads of radioactive material and packages.

As already noted, the Regulations utilize a graded approach that is applied to the performance standards. This graded approach is characterized by three general performance levels that relate to the design of the package (paragraph 106 of TS-R-1):

(1) Routine conditions of transport (incident free);
(2) Normal conditions of transport (minor mishaps); and
(3) Accident conditions of transport.

In contrast, paragraph 107 of TS-R-1 specifies that the Regulations do *not* apply to five different types of material:

(1) Radioactive material that is an *integral part of the means of transport* (such as depleted uranium counterweights in aircraft);

(2) Radioactive material moved *within an establishment* that is subject to appropriate safety regulations in force in the establishment and where the movement does not involve public roads or railways;

(3) Radioactive material implanted *or incorporated into a person* or live animal for diagnosis or treatment (such as a cardiac pacemaker, or radionuclides injected into a person for medical purposes);

(4) Radioactive material in con*sumer products* that have received regulatory approval, following their sale to the end user (such as smoke detectors);

(5) *Natural material and ores* containing naturally occurring radionuclides that either are in their in their natural state, or have been processed only for purposes other than for extraction of the radionuclides, and that are not intended to be processed for use of these radionuclides provided that the activity concentration of the material does not exceed ten times the values specified (paragraphs 401–406 of TS-R-1); and

(6) Non-radioactive solid objects the surfaces of which do not carry radioactive contamination (paragraph 214).

There are two other areas related to the scope of the Regulations; one deals with *controls on shipments*, and the other deals with *subsidiary risks* of the contents of consignments.

Controls on shipments relating to routeing or physical protection, which may be imposed by various governmental agencies for purposes other than radiological safety are not specified in the Regulations (see paragraph 108 of TS-R-1). However, the Regulations note that such controls must not detract from the standards of safety for which the Regulations have been developed relative to the radiological hazards posed by the contents of the package.

Relative to *subsidiary risks*, the Regulations simply state (see paragraphs 109 and 507 of TS-R-1) that all “relevant transport regulations for dangerous goods of each of the countries” involved in the transport “shall apply in addition to” the Regulations.

1.6.4. Units

Prior to the 1985 Edition of the Regulations, the "conventional" system of units was used. For example, activity was specified in curies (Ci), and radiation levels in rems. Transition from the conventional system to the SI system of units occurred in the 1985 Edition of the Regulations. For example, activity is specified in becquerels (Bq), and radiation levels in sieverts (Sv). In the 1985 Edition, the SI units were controlling and the conventional units were shown in parentheses and generally were rounded down from the SI units. In the 1996 Edition of the Regulations, the only units used are those of the SI system.

1.7. Documents supporting the Regulations

The recognition of the need for more current information of both an explanatory and an advisory nature led the IAEA to publish a series of documents beginning in 1961 when it issued *Notes on Certain Aspects of the Regulations* [28].]. In addition, the IAEA issues a large number of other documents which indirectly support the Regulations. Key among those is the periodically updated Basic Safety Standards for Protection against Ionizing Radiation [12].

The current list of valid supporting documentation for the TS-R-1 Regulations is as follows:

- Advisory material (Safety Standards Series No. TS-G-1.1) [13];
- Emergency response guidance (Safety Standards Series No. TS-G-1.2) [32];
- Compliance Assurance guidance (Safety Series No. 112) [33]; and
- Quality Assurance guidance (Safety Series No. 113) [34].

As a result of a change in the form of documentation implemented by the IAEA in 1996, what had been Safety Series No. 6 (the Regulations) and Safety Series No. 80 [31] (the Schedules) were combined into a single document, now since 2000 denoted as Safety Standards Series, Requirements, No. TS-R-1 [8]. In parallel with the new regulatory development, the IAEA worked to combine Safety Series No. 7 [29] (the previous explanatory material) with Safety Series No. 37 [30] (the previous advisory material) into a new single supportive advisory document denoted as Safety Standards Series, No. TS-G-1.1 [13]. TS-G-1.1 provides specific insights, history and guidance on the regulatory requirements. It provides information on "why" and "how", whereas TS-R-1 specifies "what" must be satisfied in complying with the Regulations.

The primary purpose of TS-G-1.1 is to provide advice to users on proven and acceptable ways of achieving and demonstrating compliance with the Regulations. It is emphasized that the text is not to be construed as prescriptive. It offers guidance on ways of complying. It does not try to lay down the only way to comply with any specific provision. It is also emphasized that TS-G-1.1 is not a stand-alone document. It only has significance when used as a companion to the IAEA Safety Standards Series No. TS-R-1. To facilitate cross-referral between TS-G-1.1 and the Regulations, each paragraph of TS-G-1.1 is numbered correspondingly to the paragraph of the Regulations to which it most directly relates. To distinguish paragraphs of the advisory material in TS-G-1.1 from those of the Regulations for reference purposes, TS-G-1.1 paragraphs always have a numeral after the decimal point, even when only one subparagraph of text exists. Thus, for example, advice relating to paragraph 401 of the Regulations initially should be sought under paragraph 401.1 of TS-G-1.1. Similarly, integral paragraph numbers which are cited in the text of TS-R-1, either alone or accompanied by lower case letters in brackets, are intended to identify paragraphs of the Regulations.

In time, it is expected that the other Safety Series documents, especially SS112 [33] and SS113 [34], which support Quality and Compliance Assurance in transport, will be revised into Safety Standards Series documents.

In addition to the suite of Safety Series documents, the IAEA has published and will continue to publish other supportive documentation. This includes technical documents (i.e., TECDOCs). Recent examples include:

- Guidance on optimization of radiation protection in transport [35];
- Guidance on the safe transport of uranium hexafluoride [36];
- Guidance on the safe transport of reprocessed uranium [37];
- A manual on the safe production, transport, handling and storage of uranium hexafluoride [38];
- A report of papers presented at an IAEA transport of radioactive waste seminar [39];
- Guidelines for the safe design of shipping packages against brittle fracture [40];
- A directory of National Competent Authorities' certificates of compliance [41];
- A review of transport events [42].

1.8. Overview of competent authority responsibilities

No introduction to the Regulations would be complete without an overview of the Competent Authority's responsibilities. Firstly, the Regulations define a Competent Authority (paragraph 207 of TS-R-1) as:

> *"any national or international regulatory body or authority designated or otherwise recognized as such for any purpose in connection with these Regulations."*

The responsibilities of the Competent Authority fall into several main areas, under the following headings:

(1) Legislative activities; that is establishing regulations to bring the Regulations into effect in:
  - National Regulations
  - International Regulations.

(2) Implementation of regulatory activities, that is, assuring compliance with the requirements of the Regulations, with particular reference to:
  - Compliance Assurance programmes
  - Inspection and enforcement
  - Assessment and approval
  - Quality Assurance
  - Emergency planning and preparedness
  - Radiation protection.

(3) Administrative activities, including:
  - Issuance of certificates
  - ID marking
  - Receipt of notifications
  - Recording of incidents.

(4) Information-related activities, such as the preparation of guidance and policy documents, training, and the co-ordination of transport related research.

Chapter 13 of this training manual covers each of these in detail.

The Regulations stipulate that, in many cases “a particular action is prescribed, but the responsibility for carrying out the action is not specifically assigned...” (paragraph 103 of TS-R-1). It is therefore incumbent upon the Competent Authority in each Member State to assign responsibilities “according to the laws and customs” (see paragraph 103 of TS-R-1) of its state and appropriate international conventions into which its country has entered.

1.9. Interfaces between transport and other aspects of radioactive material

In addition to the regulation of the transport of radioactive material, there are a number of other facets and interfaces which have to be considered. The radioactive material may also be waste material subject to certain disposal criteria. It may be in a heavy package requiring a very large crane to load and unload it from the vehicle. It may be weapons-related material requiring accountability and physical protection from potential theft or sabotage. These auxiliary aspects are not the primary focus of this training manual, but need to be briefly mentioned here so that they are not forgotten.

1.9.1. Interfaces with waste management programmes and with facilities

It is noted that many IAEA Member States are placing increased importance on the decommissioning and dismantling of nuclear installations and the restoration of radioactively contaminated sites. Thus, the interfaces between transport and waste management activities are becoming a more significant issue [43].

Firstly, the waste forms to be packaged must comply with requirements for both transport and for the intermediate storage or final disposal site. These latter two requirements are often known as the Waste Acceptance Criteria (WAC). Receiving sites could provide storage, processing, and disposal. In general, the criteria used for categorizing wastes by waste management systems are not necessarily consistent with the criteria used for determining the parameters needed for transport. For example, waste management systems often categorize wastes as:

- Low-level waste;
- Medium- (or intermediate-) level waste; or
- High-level waste.

The waste intended for disposal, must also be prepared so that it is compatible with the packaging in which it will be transported. If this interface is not considered early in the waste management programme, then unnecessary re-packaging operations may have to be performed. An unnecessarily large number of shipments could result, and complex transport operational issues (e.g. oversize, or overweight) can occur. Any of these could result in increased risk or unnecessary exposure of workers and the public. Many other interface requirements are discussed in Ref. [44].

In addition to specific waste management issues, transport packages, conveyances, and even transport personnel must interface with the originating and destination facilities to ensure safety. The physical interfaces that must be addressed are many. For example, both facilities must have the capability to handle and, where relevant, maintain the transport packagings used in accordance with the package design’s Quality Assurance programme. Sometimes this requires fairly complicated equipment. Other examples relate to accessibility especially of overhead clearances, crane capacities, loading dock heights, and driveway turning radii.

1.9.2. Interfaces with other materials

Three interfaces with other hazardous material must be addressed during the transport of radioactive material. Firstly, the radioactive material may also have other hazardous properties such as flammability or toxicity. When such subsidiary hazards exist, they must be accounted for in the packaging and labelling for shipment (see paragraphs 109 and 507 of TS-R-1). Secondly, account must be taken of consignments that may consist of packages of both radioactive material and packages of other hazardous goods. Adherence to all of the relevant regulations pertaining to the combining of such loads is required (see paragraph 506 of TS-R-1). This means that consignors and carriers of radioactive material must be fully aware of the requirements for transport of other dangerous goods in order to facilitate full compliance with the Regulations. Thirdly, under certain conditions, the transport of other goods with a radioactive material consignment may be prohibited (see paragraph 505 of TS-R-1).

1.9.3. Interfaces with safeguards and physical protection functions

As discussed previously, one of the main roles of the IAEA is to ensure that the peaceful use commitments made under the Non-Proliferation of Nuclear Weapons Treaty (NPT) and similar regional treaties are kept [45]. Each Non-nuclear Weapon State that signs the NPT, or similar regional treaties, becomes subject to safeguards overview of its activities. This includes systems applicable to reactors and to the conversion, enrichment, fabrication, and reprocessing plants which supply and process the reactor fuel.

The IAEA's safeguards system consists of three major components:

(1) Accountancy, i.e. reporting by States on the whereabouts of the fissionable material under their control. This includes stocks of new and spent fuel, as well as information on the processing and reprocessing of nuclear material.
(2) Containment and surveillance techniques, such as seals, which provide proof that no material has disappeared, as well as film and TV-cameras, which record any action occurring in a particular area of a nuclear installation.
(3) Inspection by IAEA inspectors, who check instruments and seals installed, verify books, and confirm physical inventories of new or spent fuel.

Generally, the transport system, associated with the facilities at the origin and destination, will need to be operated using procedures and equipment that will satisfy safeguards requirements. The application of safeguards with the transport system will be a continuation of the current safeguards practices employed at the originating facility [44]. As materials requiring safeguards, or physical protection related actions, are moved into or out of facilities, safeguards monitoring and accountancy requirements come into force. This imposes interfaces on the transport systems involved. These interfaces must be addressed during shipment, and any actions undertaken for the purpose of safeguards cannot degrade the safety of the shipment (see, for example, paragraph 108 of TS-R-1). Often this will require safeguards inspectors monitoring the loading, closing and sealing of transportation packages at facilities.

REFERENCES FOR CHAPTER 1

[1] POPE, R.B., McCLURE, J.D., "Estimated annual worldwide shipments of radioactive material", Packaging and Transportation of Radioactive Materials, (Proc. Symp. Vienna, 1987), IAEA STI/PUB/718, IAEA, Vienna (1987) 459–468.
[2] INTERNATIONAL ATOMIC ENERGY AGENCY, International Atomic Energy Agency-IAEA Turns 40, Supplement to the IAEA Bulletin, Vienna (1997).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA and the UN-Partnerships for Development and Peace, IAEA, Vienna (1995).
[4] FAIRBAIRN, A., The development of the IAEA Regulations for the safe transport of radioactive materials, Atomic Energy Review, **11** 4 (1973) 843–889.
[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Materials, 1961 Edition, Safety Series No. 6, IAEA, Vienna (1961).
[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 1985 Edition (As Amended 1990), Safety Series No. 6, IAEA, Vienna (1990).
[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 1996 Edition, Safety Standards Series No. ST-1, IAEA, Vienna (1996).
[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Standards Series, Safety Requirements No. TS-R-1, IAEA, Vienna (2005).
[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 1985 Edition, Safety Series No. 6, IAEA, Vienna (1985).
[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Safe Transport of Radioactive Material, Training Course Series No. 1, 2nd Edition, IAEA, Vienna (1991).
[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Safe Transport of Radioactive Material, 2nd ed., Supplement to Training Course Series No. 1, IAEA, Vienna (1996).
[12] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Standards, Safety Series No. 115, IAEA, Vienna (1996).
[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1996 Edition), Safety Standards Series No. TS-G-1.1, IAEA, Vienna (2002).
[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Statute, IAEA, Vienna (1989).
[15] INTERNATIONAL ATOMIC ENERGY AGENCY, Profile of the IAEA, IAEA Web Site http://www.iaea.org/worldatom/About/, IAEA, Vienna (February 1998).
[16] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Technical Co-operation - A Partnership in Development, IAEA/PI/A52E, 97-01913, IAEA, Vienna (1997).
[17] INTERNATIONAL ATOMIC ENERGY AGENCY, More than just the FAX, IAEA Bulletin, 39/3/1997, IAEA, Vienna (September 1997) 44–45.
[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Isotopes in everyday life, IAEA/PI/A6E, IAEA, Vienna (1990).
[19] AMERICAN NUCLEAR SOCIETY, FDA announces approval of meat irradiation, Nuclear News **41** 1 (1998) 55–56.
[20] OSTERHOLM, M.T., Food safety and ionizing pasteurization, Nuclear News **41** 1 (1998) 26–27.
[21] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Techniques in Medicine, **FS/09 (Rev.1),** International Atomic Energy Agency Fact Sheet, IAEA, Vienna (1993).
[22] AMERICAN NUCLEAR SOCIETY, Tsetse fly eliminated on Zanzibar, Nuclear News **41** 1 (1998) 56–61.
[23] HENKIN, R. E., An overview of nuclear medicine in the United States, Nuclear News **41** 2 (1998) 30–34.
[24] Hladik, III, W.B., New radiopharmaceuticals used in nuclear medicine, Nuclear News **41** 2 (1998) 44.
[25] INTERNATIONAL ATOMIC ENERGY AGENCY, Sustainable Development, Nuclear Power, IAEA/PI/A/55E, IAEA, Vienna (1997).

[26] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and the Safety of Radiation Sources, Safety Series No. 120, IAEA, Vienna (1996).
[27] UNIVERSAL POSTAL UNION, Universal Postal Convention of Rio de Janeiro, UPU, Berne, Switzerland (1979).
[28] INTERNATIONAL ATOMIC ENERGY AGENCY, Notes on Certain Aspects of the Regulations, Safety Series No. 7, IAEA, Vienna (1961).
[29] INTERNATIONAL ATOMIC ENERGY AGENCY, Explanatory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, Material, 1985 Edition (As Amended 1990), Safety Series No. 7, IAEA, Vienna (1990).
[30] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, Material, Third Edition (As Amended 1990), Safety Series No. 37, IAEA, Vienna (1990).
[31] INTERNATIONAL ATOMIC ENERGY AGENCY, Schedules of Requirements for the Transport of Specified Types of Radioactive Material Consignments (As Amended 1990), Safety Series No. 80, IAEA, Vienna (1990).
[32] INTERNATIONAL ATOMIC ENERGY AGENCY, Emergency Response Planning and Preparedness for Transport Accidents Involving Radioactive Material, Safety Standards Series No. TS-G-1.2, IAEA, Vienna (2002).
[33] INTERNATIONAL ATOMIC ENERGY AGENCY, Compliance Assurance for the Safe Transport of Radioactive Material, Safety Series No. 112, IAEA, Vienna (1994).
[34] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance for the Safe Transport of Radioactive Material, Safety Series No. 113, IAEA, Vienna (1994).
[35] INTERNATIONAL ATOMIC ENERGY AGENCY, Discussion of and Guidance on the Optimization of Radiation Protection in the Transport of Radioactive Material, IAEA-TECDOC-374, Vienna (1986).
[36] INTERNATIONAL ATOMIC ENERGY AGENCY, Interim Guidance on the Safe Transport of Uranium Hexafluoride, IAEA-TECDOC-608, Vienna (1991).
[37] INTERNATIONAL ATOMIC ENERGY AGENCY, Interim Guidance on the Safe Transport of Reprocessed Uranium, IAEA-TECDOC-750, Vienna (1994).
[38] INTERNATIONAL ATOMIC ENERGY AGENCY, Manual on Safe Production, Transport, Handling and Storage of Uranium Hexafluoride, IAEA-TECDOC-771, Vienna (1994).
[39] INTERNATIONAL ATOMIC ENERGY AGENCY, Developments in the Transport of Radioactive Waste, IAEA-TECDOC-802, Vienna (1995).
[40] INTERNATIONAL ATOMIC ENERGY AGENCY, Guidelines for Safe Design of Shipping Packages against Brittle Fracture, IAEA-TECDOC-717, Vienna (1993).
[41] INTERNATIONAL ATOMIC ENERGY AGENCY, Directory of National Competent Authorities' Approval Certificates for Package Design, Special Form Material and Shipment of Radioactive Material, IAEA-TECDOC-903, Vienna (1996).
[42] INTERNATIONAL ATOMIC ENERGY AGENCY, Review of Events Occurring during the Transport of Radioactive Material for the period 1984–1993, IAEA-TECDOC-966, Vienna (1997).
[43] INTERNATIONAL ATOMIC ENERGY AGENCY, Radioactive Waste Management-1996 Annual Report, IAEA Web Site (http://www.iaea.or.at/worldatom/inforesource/annual/anrep96/rwm/html), IAEA, Vienna (February 1998).
[44] INTERNATIONAL ATOMIC ENERGY AGENCY, Interfaces between Transport and Geological Disposal Systems for High Level Radioactive Waste and Spent Nuclear Fuel, IAEA-TECDOC-764, Vienna (1994).
[45] INTERNATIONAL ATOMIC ENERGY AGENCY, The IAEA's Safeguards System-Ready for the 21st Century, IAEA/PI/A53E, 97-03433, IAEA, Vienna (1997).

EXERCISES FOR CHAPTER 1

The following are exercises to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 1.1. Basic Philosophy of the Regulations

REFERENCE SOURCES: Training Manual, Chapter 1.6.2, and TS-R-1, Section I.

DISCUSSION: The IAEA has published and periodically updates basic radiation protection standards including Safety Series No. 115 and related guidance such as the *Radiation Protection and the Safety of Radiation Sources*, Safety Series No. 120. During each review and revision process of the Agency's Transport Regulations, steps have been taken to ensure that the Transport Regulations are compatible with the basic radiation protection standards.

PROBLEM: In what manner do the Transport Regulations satisfy basic radiation protection standards?

ANSWER:

EXERCISE 1.2. Scope of the Regulations

REFERENCE SOURCES: Training Manual, Chapter 1.6.3, and TS-R-1, Section I

DISCUSSION: Many materials that exist in nature or are man-made may contain very small quantities of radioactive material that, for purposes of safety, are not subject to the transport Regulations.

PROBLEM:

a. To what types of material or activities do the Regulations **not** apply?

b. Do the Regulations impose any requirements for routeing or physical protection? If so, what are they?

ANSWER:

EXERCISE 1.3. Objective of the Regulations

REFERENCE SOURCES: TS-R-1 and TS-G-1.1

DISCUSSION: It is essential to understand that, according to the Regulations, safety is built into the package and does not depend on the means by which the package will be transported.

PROBLEM:

a. What is the objective of the Regulations?

b. How are the objectives achieved?

c. How are the requirements satisfied?

ANSWER:

EXERCISE 1.4. Using TS-R-1 and TS-G-1.1 to Understand Regulatory Requirements

REFERENCE SOURCES: TS-R-1 and TS-G-1.1

DISCUSSION: Many key topics discussed in the Regulations are listed in the index at the back of TS-R-1. For each topic, the index lists the numbers of the paragraphs that address the topic. Although, at this time, the student may not have been fully introduced to the requirements of the Regulations, this exercise is provided to introduce the student on how to use TS-R-1, the index in TS-R-1, and TS-G-1.1.

PROBLEM:

a. How can one quickly define and understand *all* regulatory requirements for a given topic?

b. How can one quickly define and understand *all* regulatory requirements for the topic ***empty packaging***?

ANSWER:

EXERCISE 1.5. Gaining Understanding of Regulatory Requirements

REFERENCE SOURCES: Training Manual, Chapter 1.7; TS-R-1; Sections I, II and III; and TS-G-1.1, Sections I, II and III; completion of Exercise 1.3.

DISCUSSION: The advisory document, TS-G-1.1, has been keyed topically to each paragraph in the eight Sections of TS-R-1. In addition, TS-R-1 contains an index (e.g. pages 215–220 of the English Edition of TS-R-1) that is liekwise keyed to relevant TS-R-1paragraph numbers (it does not provide references to text in the Schedules). A student of the Regulations can gain increased understanding of a specific topic of requirement by utilising these three key sources of information. To define quickly and *understand all regulatory requirements for a given topic*, it is suggested that the student:

a. Turn to the Index, and look for paragraph numbers in TS-R-1 where the topic of interest appears;

b. Study the requirements specified in those paragraphs; and

c. For further insight into why requirements are stated as they are and how one might satisfy the regulatory requirements, study the relevant paragraphs in TS-G-1.1.

Although, at this time, the student may not have been fully introduced to the requirements of the Regulations, this exercise is provided to introduce the student to the use of TS-R-1, the index in TS-R-1, and TS-G-1.1. This exercise should be used only after Exercise 1.4 has been completed and discussed in class.

PROBLEM::

a. Using TS-R-1 and TS-G-1.1, list those paragraphs in TS-R-1 that impose requirements about ***Compliance Assurance***.

b. What is meant by ***Compliance Assurance***, and where can information about it be found?

c. What are the principal objectives of a ***Compliance Assurance*** programme, and where can information about them be found?

d. What two measures should an effective ***Compliance Assurance*** programme contain, and where can additional information be found?

ANSWER:

2. REVIEW OF RADIOACTIVITY AND RADIATION

This chapter is included for completeness and for those persons entering radioactive material transport from other fields, such as the transport of other hazardous material. For students with a recognized basic training in radioactivity and radiation this chapter should not be considered compulsory.

2.1. Basic atomic and nuclear structure

2.1.1. Atoms and nuclei

The simplest unit into which matter can be broken down is the atom. Atoms may stand in isolation (e.g. noble gases), may form molecules (e.g. water or air) or combine in a special solid state (e.g. semiconductors). Atoms can be regarded as having two main parts. The first part is the central core, called the nucleus, where almost all of the mass of the atom resides. Orbiting the nucleus, a great distance away (on a nuclear scale), are very small lightweight negatively charged particles called electrons. The size of an atom is about 10^{-10} m (1/10000 μm).

The nucleus of the atom consists of a tightly bound group of particles of two types, protons and neutrons. Both these particles have about the same mass, but are different in that protons have a positive charge, whereas neutrons have no charge. The simplest possible atom consists of only one proton in the nucleus, surrounded by one electron. The proton and electron charges cancel each other and the atom, as a whole, is electrically neutral (see Figure 2.1).

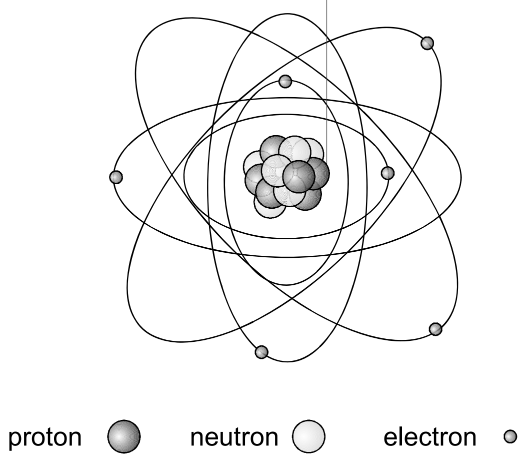

FIG. 2.1. Structure of an atom.

2.1.2. Elements

The number of protons in the nucleus of the atom determines the identity of that element. An atom with only one proton is an atom of the element hydrogen. There are approximately one hundred known elements, and these can all be seen in the Periodic Table of the Elements (Figure 2.2). A listing of some elements of interest is given in Table 2.1.

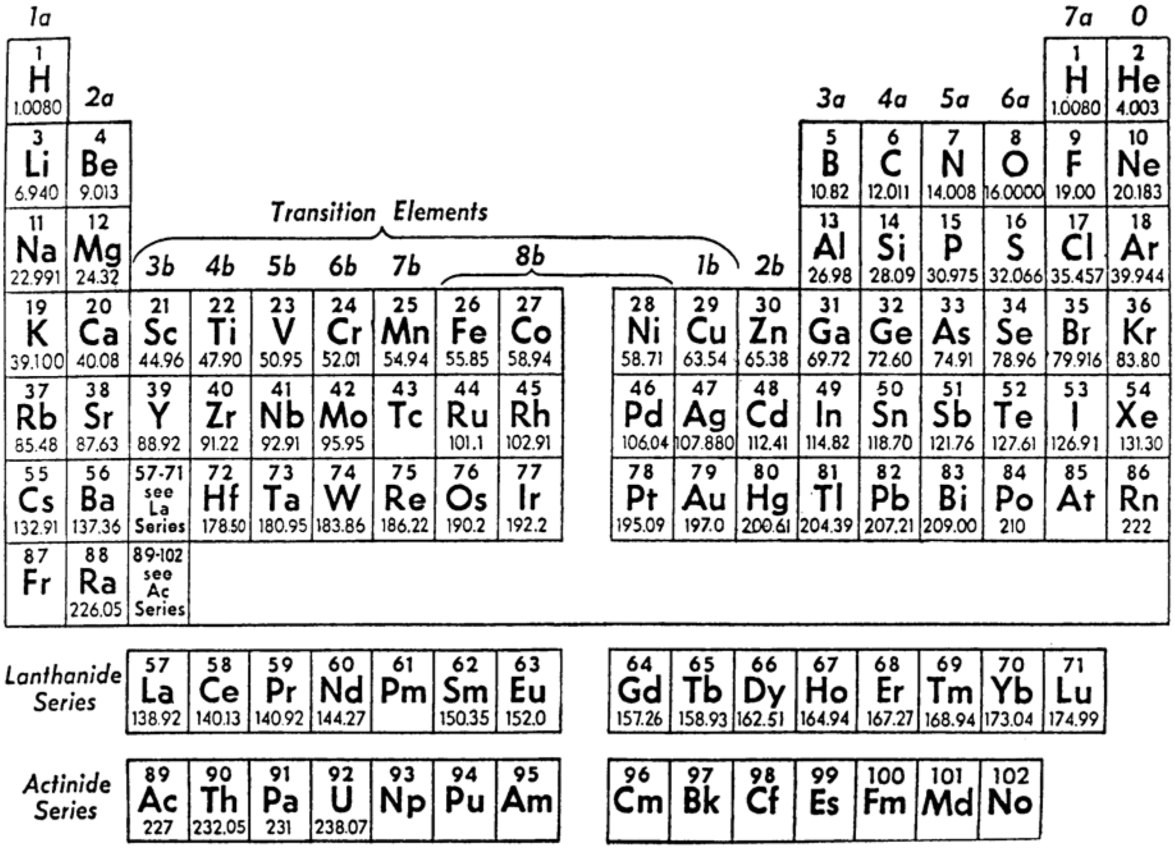

FIG. 2.2. Periodic table of the elements.

This list shows each element along with its symbol and atomic number. The atomic number is the number of protons in the nucleus. This is also the same as the number of electrons in the electrically neutral atom.

It is difficult to get a perspective on how small the nucleus is, and how most of an atom is actually the empty space between that nucleus and the electrons. A simple analogy could be to consider that if all the electrons were removed from all of the atoms in a human being, so that the nuclei could be brought together to touch each other, then it would be possible to get the nuclei of 8.3 million people into the volume of a single pinhead! However, because most of the mass is in the nuclei, this pinhead would weigh about 6×10^8 kg.

TABLE 2.1. SOME ELEMENTS OF INTEREST

Atomic number (Number of protons)	Element	Symbol
1	Hydrogen	H
2	Helium	He
6	Carbon	C
7	Nitrogen	N
8	Oxygen	O
11	Sodium	Na
14	Silicon	Si
15	Phosphorus	P
26	Iron	Fe
27	Cobalt	Co
38	Strontium	Sr
47	Silver	Ag
53	Iodine	I
55	Caesium	Cs
79	Gold	Au
82	Lead	Pb
88	Radium	Ra
92	Uranium	U
94	Plutonium	Pu

2.1.3. Isotopes

The number of neutrons may vary for a given element. Changing the number of neutrons does not essentially influence the chemical properties of the atom. But the mass of the atom changes as protons and neutrons are of roughly equal mass.

If a neutron is added to the nucleus of the simplest hydrogen atom (originally consisting of one proton and one orbiting electron), a different atom is formed. It has about twice the mass of the original atom, but is still hydrogen, as it still has only one proton. This is said to be an isotope of hydrogen, and happens to be given a special name, deuterium. If another neutron is added to the nucleus, another isotope of hydrogen, called tritium, is formed.

Some examples of isotopes are shown in Table 2.2.

2.1.4. Notation

A convention that is used to enable easy reference to each isotope is the following:

$$^{A}_{Z}X$$

where:

X is the element symbol,
Z is the number of protons (= atomic number), and
A is the sum of the number of protons and neutrons (called the mass number).

Some examples are: ${}^{3}_{1}H$, ${}^{12}_{6}C$, ${}^{60}_{27}Co$, ${}^{238}_{92}U$.

Due to the fact that the atomic number and symbol provide the same information, the former is often omitted, for example, ${}^{3}H$, ${}^{12}C$, ${}^{60}Co$, and ${}^{238}U$. In a commonly used alternative notation they are often represented as follows, H-3, C-12, Co-60, and U-238.

TABLE 2.2. SOME EXAMPLES OF ISOTOPES

Element	Number of protons	Number of neutrons	Mass Number
H (Hydrogen)	1	0	1
H-2 (Deuterium)	1	1	2
H-3 (Tritium)	1	2	3
Fe-54 (Iron)	26	28	54
Fe-56 (Iron)	26	30	56
Fe-57 (Iron)	26	31	57
Fe-58 (Iron)	26	32	58
U-235 (Uranium)	92	143	235
U-238 (Uranium)	92	146	238

2.1.5. Prefixes

In nuclear physics, it is often necessary to express very large and very small numbers. It is therefore important to become familiar with the prefixes that are listed in Table 2.3 (and in Annex II of TS-R-1).

TABLE 2.3. PREFIXES

Multiplying factor	Prefix	Symbol	Multiplying factor	Prefix	Symbol
10^{24}	yotta	Y	10^{-3}	milli	m
10^{21}	zetta	Z	10^{-6}	micro	μ
10^{18}	exa	E	10^{-9}	nano	n
10^{15}	peta	P	10^{-12}	pico	p
10^{12}	tera	T	10^{-15}	femto	f
10^{9}	giga	G	10^{-18}	atto	a
10^{6}	mega	M	10^{-21}	zepto	z
10^{3}	kilo	k	10^{-24}	yocto	y

2.2. Radioactivity

For any element there is a limited range in which the number of neutrons can be part of the nucleus and still be stable. If there are too few neutrons or too many neutrons in the nucleus, the atom is unstable. An unstable atom will try to become more stable by emitting energy in the form of radiation, and it is said to be radioactive.

Radioactivity can be simply defined as that process in which unstable atoms attempt to stabilize themselves by emitting radiation.

Using the previous example of hydrogen, when the nucleus consists of two neutrons and one proton (i.e. the isotope tritium), the atom is unstable and therefore radioactive. The combination of one proton and three neutrons is so unstable, that for all practical purposes it does not exist.

2.2.1. Chart of the nuclides

All of the existing known isotopes (stable and unstable) can be shown on a chart such as that in Figure 2.3. Each square represents one isotope (i.e. one combination of protons and neutrons). On the left is shown the number of protons in the isotope, and along the bottom, the number of neutrons is shown. A curved line of stable isotopes can be seen by the shaded squares on the chart. This is called the line of stability. The chart itself is called the Chart of the Nuclides and is published with useful information about each isotope in its own square.

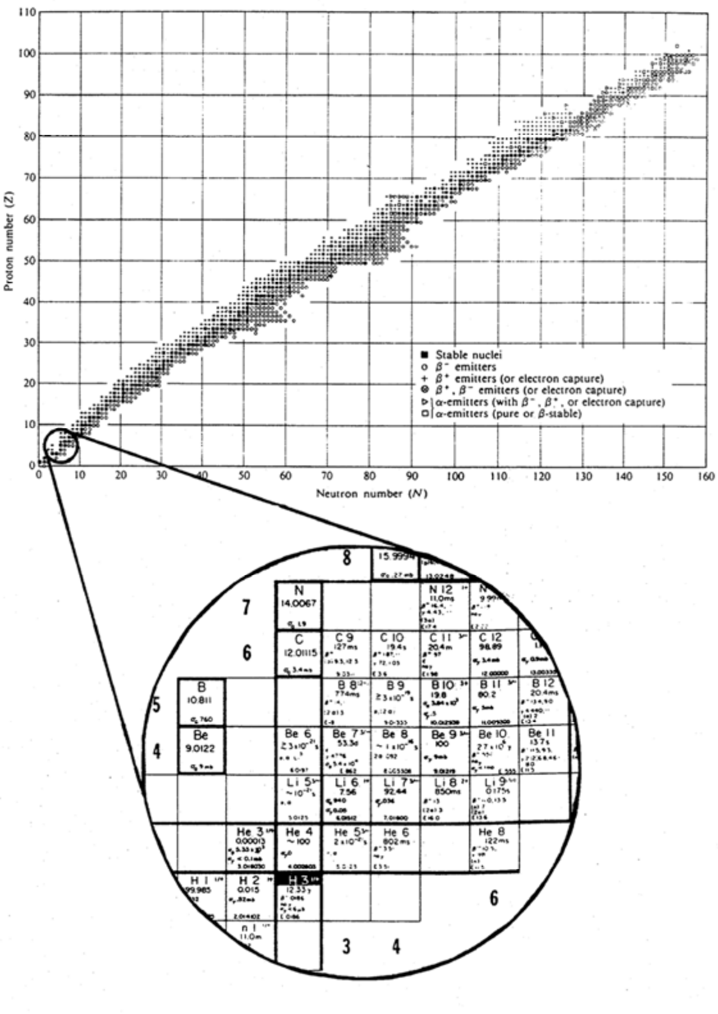

FIG. 2.3. Chart of the nuclides.

2.2.2. *Radioactive decay and half-life*

The further an isotope is distanced from the line of stability the more radioactive it is. When an unstable, radioactive atom emits radiation to become more stable, it is said to disintegrate or decay. Radioactive decay is an interesting process in that it has regular and predictable aspects as well as totally random aspects. When any one particular atom is going to decay is random and cannot be predicted. However, the time in which, on average, half of a certain (large) number of atoms of a particular isotope will decay is regular, known, and entirely predictable. This is somewhat analogous to the situation in which a large number of coins are placed in a tray all with the same side down. If they are thoroughly shaken up, half of the coins will have one side up and half will have the other side up on average. However, prior to shaking, it cannot be predicted which way up any particular coin will land.

Each kind of radioactive isotope has a specific known time in which half of the atoms will decay. This is called the half-life. Appendix II of TS-G-1.1 provides a listing of the half-lives of each of the radionuclides listed in Table I of TS-R-1. If the number of atoms of a particular radioactive isotope is plotted against time, a curve such as that shown in Figure 2.4 is obtained.

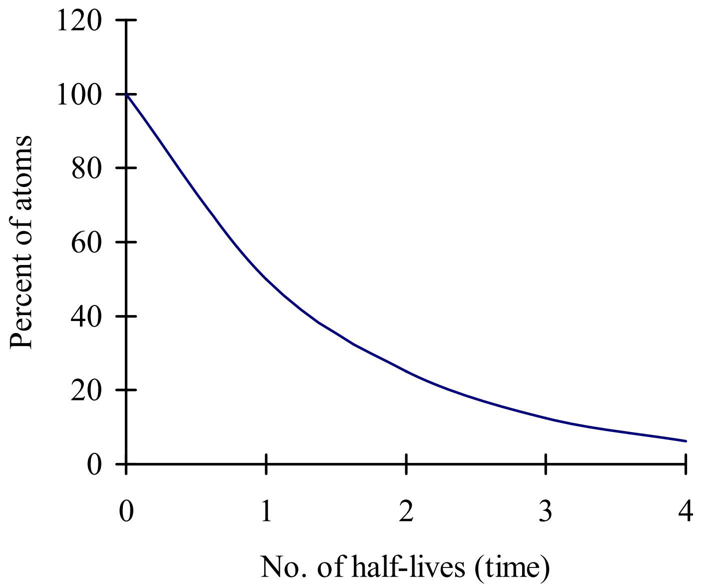

FIG. 2.4. Radioactive decay curve.

2.2.3. *Quantities and units*

There are special quantities to characterize radioactive material:

- The half-life is the time after which half of a given number of radioactive nuclei has decayed. The corresponding unit is usually given in years (y), days (d), hours (h), minutes (m) or in seconds (s).

- The activity of a radioactive material gives the number of decays per unit of time. The corresponding unit is the becquerel (Bq) (Figure 2.5). The conversion of activity into dose is treated in Chapter 3. One becquerel is equivalent to one atom decaying (or disintegrating) each second.

Due to the fact that some radioisotopes decay more rapidly than others, i.e. they have a shorter half-life, equal masses of different radioisotopes can have widely differing activities. The activity per unit mass is called the *specific activity*. The corresponding unit that is most commonly used is Bq/g. The specific activity for one kind of radionuclides is a constant. The specific activity of a mixture of radionuclides and inactive material depends on the mixing ratios. Table A.II-1 in TS-G-1.1. is a listing of many radioisotopes (also known as radionuclides) each given with its atomic number, half-life and specific activity.

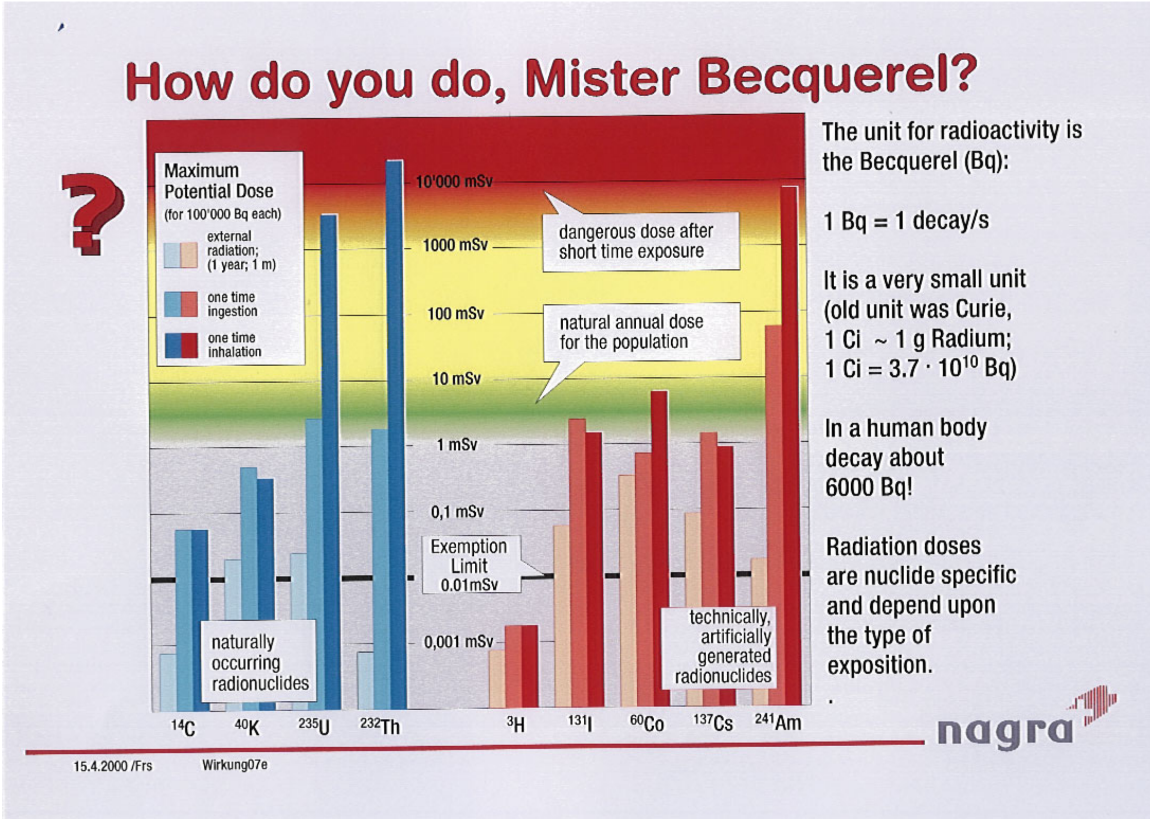

FIG. 2.5. The Becquerel.
(Credit: NAGRA, Switzerland)

2.3. Radiation

As already mentioned, an unstable nucleus will eventually become more stable by emitting particulate and/or electromagnetic radiation. The type of radiation emitted will depend on the type of instability. If a nucleus has too many neutrons for the number of protons (i.e. it is below the line of stability) it will tend to become more stable by essentially converting a neutron to a proton and emitting an electron. Electrons emitted from the nucleus are called *beta particles (β-radiation).* Typically, additional electromagnetic energy will also be emitted. Electromagnetic energy from the nucleus is called *gamma radiation (γ-radiation).*

If a nucleus has a large number of neutrons and protons, it is very heavy and will be located at the upper right end of the nuclide chart. If it has too many neutrons and protons it will be unstable, radioactive, and tend to become more stable by emitting a particle consisting of two neutrons and two protons. This particle is called an alpha particle (*α-radiation*).

It is also possible that some radioactive materials emit neutrons. If α-emitting radionuclides are mixed with material of light elements (e.g. Beryllium) the nuclear reactions of the α particles with light nuclei lead to the emission of neutrons (neutron-radiation). A frequently transported radioactive material exhibiting this phenomenon is uranium hexafluoride. Alpha particles from the uranium collide with fluorine nuclei and the reaction produces neutrons. These neutrons contribute significantly to the total dose resulting from exposures from the uranium hexafluoride. Fission will also lead to the emission of neutrons.

There are other processes in which nuclei can become unstable, and other processes by which they reach stability, but for our practical purpose alpha, beta, gamma and neutron radiations are the important processes.

2.3.1. Ionization

There are many other types of radiation energy to which humans are exposed. These include light, heat, radio waves, TV waves, ultra-violet, infrared, and microwave radiation. The major distinction between these and the radiations from the nuclei of atoms is that the latter can cause ionization.

Ionization of an atom occurs when an electron is removed from a neutral atom thereby leaving a positively charged ion (Figure 2.6). This process of ionization carries advantages and disadvantages. It is advantageous in that it enables the radiation to be detected, and it also enables the radiation to be shielded. However, the disadvantage is that the ionization of atoms in the human body causes harmful biological effects.

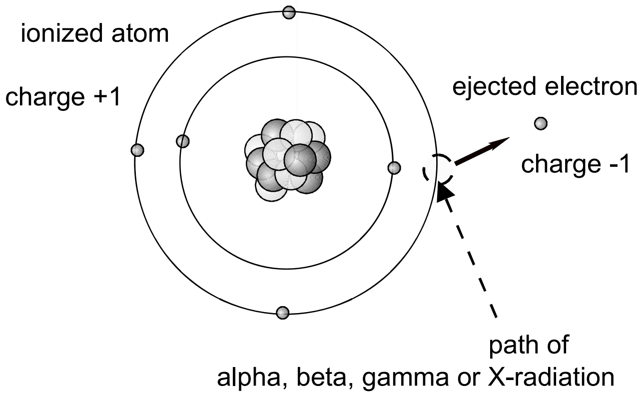

FIG. 2.6. The ionization process.

2.3.2. Alpha radiation

An alpha particle is actually the nucleus of a helium atom because it has two protons. Due to the fact that it is a heavy particle and that it has a charge of +2, an alpha particle will give up its energy within a very short distance mostly by causing ionization. The implications of this are that alpha radiation is not very penetrating. This in turn means that it can be easily shielded. In fact most alpha particles cannot penetrate the dead layer of cells on the skin surface and therefore do not present any hazard while the alpha emitting radionuclide is external to the body. However, if the material becomes ingested or inhaled into the body then the alpha particles can ionize atoms in living cells. The rate of ionization in this case is very high and significant cell damage can occur. Another implication of the lack of penetrating power is that it makes alpha radiation difficult to detect. Special instruments with very thin windows or even without windows are required.

In summary, then (Figure 2.7), alpha radiation:

- is not very penetrating, and can be shielded even by a sheet of paper,
- is a significant internal hazard, and
- is detected only by special instruments.

2.3.3 Beta radiation

Beta particles, because they are electrons, are very much smaller and lighter than alpha particles. They are subsequently more penetrating but will travel in zigzag paths through materials. Their rate of ionization is much less than that of alpha particles. The penetration range of beta particles depends on their energy and the density of the material they are passing through. An average energy beta particle will not penetrate a thin sheet of metal, and will only travel about 10 mm in tissue. Hence, beta-emitting radionuclides are a hazard to skin and eyes as well as a hazard if they are incorporated into the body. Ease of detection of beta radiation depends on the energy. However, all but the lowest energies can be detected fairly easily.

In summary, then (Figure 2.7), beta radiation:

- is more penetrating than alpha radiation, but can be shielded by a sheet of metal,
- is an external hazard to the skin and eyes,
- is an internal hazard, and
- detection is dependent on the energy of the radiation.

2.3.4. Gamma radiation

Gamma radiation is electromagnetic radiation similar to radar, radio, TV, microwave, light, ultra-violet, and infrared radiation. However, gamma radiation has higher energy, higher frequency, and shorter wavelength than these similar forms of radiation. It also causes ionization indirectly whereas the others do not ionize at all. X-rays can be generally regarded as lower energy gamma rays that are machine produced instead of coming from a radioactive atom.

Gamma radiation is very penetrating depending on the energy of the radiation. High-density material, or a large bulk of material, is required to shield gamma radiation. Consequently, it is relatively easy for gamma radiation to completely penetrate through the body.

In summary, then (Figure 2.7), gamma radiation:

- is very penetrating, but can be shielded by dense materials such as lead and steel,
- is an external and an internal hazard, and
- is easily detected at very low levels.

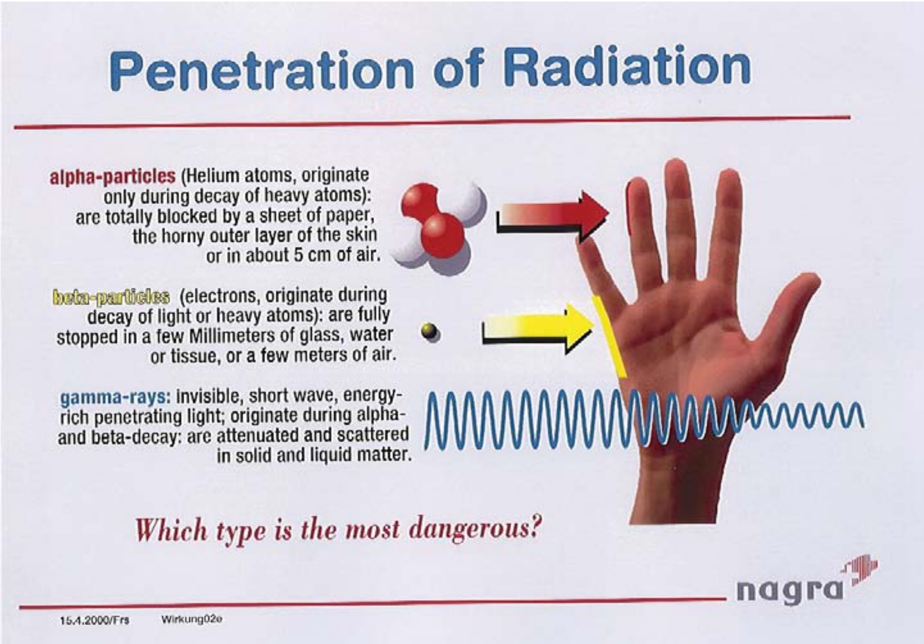

FIG. 2.7. The penetrating power of external radiation: alpha, beta and gamma.
(Credit: NAGRA Switzerland)

2.3.5 Neutron radiation

In addition to existing in the nucleus, it is possible to have free neutrons as a form of radiation. Neutrons are unique among the types of radiation, in that they only have interactions with other nuclei (nuclear reactions). These interactions can be:

- Elastic scattering. For example, if the neutron hits a hydrogen atom (even in water), the moving neutron and the proton at rest behave like billiard-balls. As the neutron and the proton have about the same mass, the neutron will be stopped completely in a central collision and the proton will carry away the full kinetic energy of the neutron. In non-central collisions the neutron and the proton share the kinetic energy. The neutron is slowed down.
- Inelastic scattering. A part of the kinetic energy of the neutron is absorbed by the target nucleus that in turn emits γ radiation.
- Neutron capture. The neutron is captured by a nucleus forming a new isotope of the nucleus it reacted with. This is called neutron activation, because the resulting nuclei are radioactive and emit a characteristic γ radiation.
- Other types of nuclear reactions are possible, including fission.

Neutrons are very penetrating and the ease with which they can be shielded and detected depends heavily on their energy. They can cause significant cell damage by indirect ionization and other processes as they pass through the body.

In summary then, neutron radiation:

- is very penetrating, but can be shielded by hydrogenous material for fast neutrons, and by cadmium or boron for slow thermal neutrons,
- is an external and internal hazard, and
- is detected only with special instruments.

2.4. Fission

When certain heavy isotopes such as U-235 or Pu-239 absorb neutrons, they can make the nucleus so unstable, that rather than emit radiation, the nucleus splits into two parts and emits neutrons and gamma radiation. This process is called fission. If some of the neutrons emitted can be used to cause further fission, then a chain reaction is initiated (Figure 2.8). This is the reaction used in nuclear reactors, where the energy from the fission in the chain reaction is converted to heat in the material that, in turn, heats up a coolant such as water. This is used to make steam, rotate a turbo-generator and generate electricity.

Another phenomenon is called spontaneous fission. Here a heavy nucleus splits spontaneously without being hit by a neutron. In this process neutrons are also released. One example of spontaneous fission is provided by the artificial neutron source californium-252. Spontaneous fission may also occur with uranium.

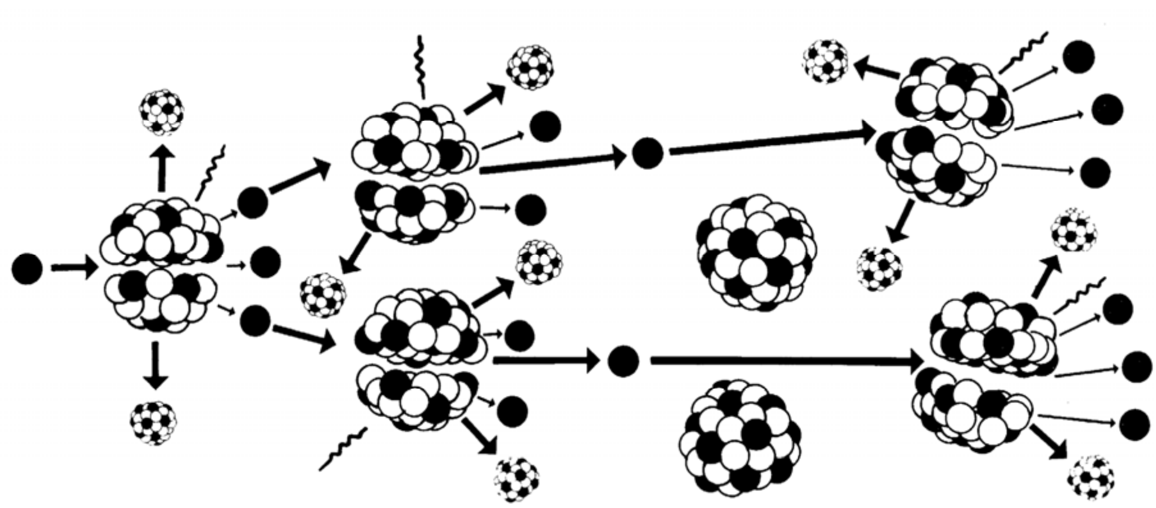

FIG. 2.8. The fission reaction.

2.4.1. Criticality

When the chain reaction is self-sustaining at a constant rate, it is said to be critical. This means that on average one neutron resulting from each fission gives rise to one new fission. The rate of reaction depends on a number of conditions.

The main influences are:

(1) The mass of fissile material. The closer the fissile atoms are packed together, the greater the chance that a neutron hits a fissile nucleus on its way through the material.
(2) The shape of the fissile material. The most efficient shape is a sphere where the ratio of volume to surface area is optimal. That means that compared to all other shapes, the lowest number of neutrons can escape the surface to be lost to initiate further fissions.
(3) The surrounding material to the fissile mass. Having escaped the surface of the fissile material, neutrons may be reflected in the surrounding matter and re-enter the surface.

(4) Moderation of neutrons. The probability of fissioning a fissile nucleus depends on the energy of the neutron. The probability of fission increases if the neutrons become slower. Some material is especially efficient in slowing down (moderating) neutrons by scattering reactions with nuclei. Examples are water with its high content of hydrogen, heavy water where hydrogen is replaced by deuterium, or solid carbon.

(5) Neutron capture. Some materials capture free neutrons and form new nuclei. Those neutrons are lost to participation in further fission processes. Cadmium and boron are well known to capture slow neutrons, an important property used in reactor control systems. Another important example is the breeding of plutonium 239 by neutron capture in uranium 238 (see Figure 2.9).

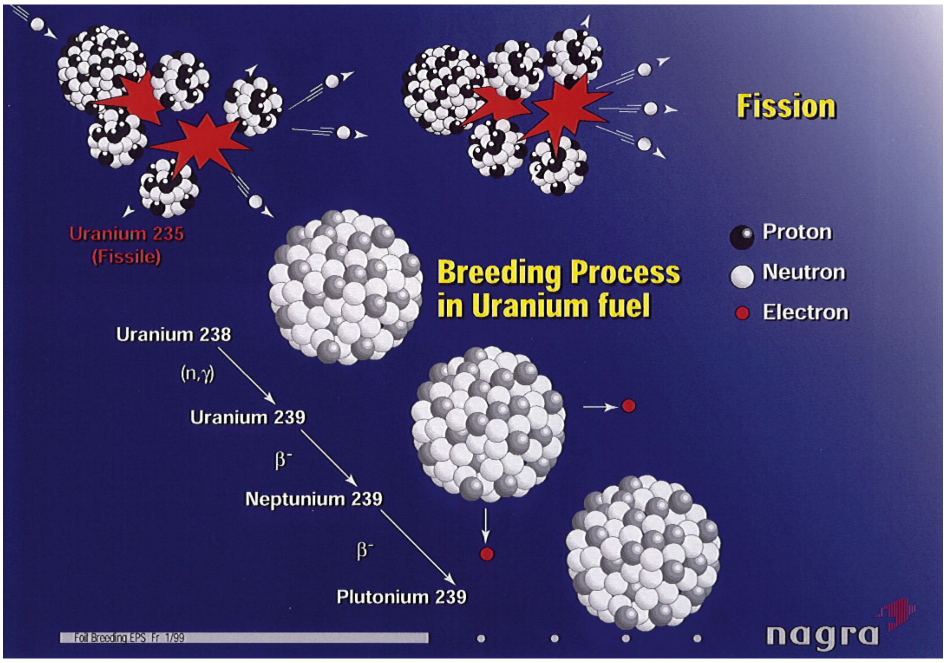

FIG. 2.9. Breeding process by neutron capture in uranium fuel.
(Credit: NAGRA Switzerland)

Taking the optimum values for all of these main influences leads to a minimum mass with which a chain reaction can occur. This is called the smallest critical mass. Unintentional criticality is always to be avoided. For this reason, strict controls are established to ensure that reactor fuel elements or other fissile material are not brought together in a way which could allow them to go critical. Sophisticated models are used and calculations are performed to guarantee that fissile material does not go critical during transport. This is also the case when evaluating the possible consequences during and following severe accidents. One decisive step is to limit the amount of fissile material taking into consideration the conditions that are encountered in transport. This is achieved by introducing the concept of a “Criticality Safety Index” (see para. 528 TS-R-1).

EXERCISES FOR CHAPTER 2

The following are exercises to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 2.1. Atoms

REFERENCE SOURCES: Training Manual, Chapter 2.1.

DISCUSSION: The origin of radiation is the atomic nucleus. For a better understanding it is helpful to know the structure of an atom.

PROBLEM:

a. What are the basic particles of an atom and what is their elementary charge?

b. What characterizes an element? Which naturally occurring element has the highest number of protons?

c. What are isotopes of an element? Give examples.

d. Give the notation for defining an atom.

ANSWER:

EXERCISE 2.2. Radioactivity

REFERENCE SOURCES: Training Manual, Chapters 2.2

DISCUSSION: Unstable nuclei emit particles or electromagnetic radiation. There are certain characteristics that are of practical significance.

PROBLEM:

a. Which types of radiation are known from the decay of unstable nuclei?

b. Where do neutrons come from?

ANSWER:

EXERCISE 2.3. Radiation

REFERENCE SOURCES: Training Manual, Chapter 2.3.

DISCUSSION: In considering the design of packages and the use of packagings for the transport of radioactive material, different radionuclides can produce different types of radiation. This exercise addresses two of these considerations.

PROBLEM:

a. There are essentially four types of radiation that must be considered in the packaging and transport of radioactive material. Name those that are penetrating and those which are less penetrating, and indicate one or more materials which are effective – in most cases – in shielding each type of radiation.

b. One of the types of radiation of concern has the ability to activate material through which it passes. Which type of radiation is this? What is the physical phenomenon occurring which allows this type of radiation to activate the material? Cite one example of *the use of radioactive material* where materials are commonly activated by exposure to this type of radiation.

ANSWER:

EXERCISE 2.4. Half-life, Activity, Specific activity, (Quantities and Units)

REFERENCE SOURCES: Training Manual, Chapter 2.2.

DISCUSSION: The decay of radionuclides is characterized by special quantities with corresponding units.

PROBLEM: Give the main quantities and units related to the radioactivity of material.

ANSWER:

EXERCISE 2.5. Fission

REFERENCE SOURCES: Training Manual, Chapter 2.4.

DISCUSSION: One of the nuclear transformations is fission. It is a certain property of some heavy nuclei.

PROBLEM:

a. Name the fissile nuclides that are relevant in transport (TS-R-1).

b. What influences criticality for a certain amount of fissile material?

ANSWER:

3. REVIEW OF RADIATION PROTECTION PRINCIPLES

Two very important documents in relation to radiation protection are the current recommendations of the International Commission on Radiological Protection (ICRP), and the International Basic Safety Standards for Protection against Ionizing Radiation and the Safety of Radiation Sources. Published in 1990, the latest ICRP recommendations are contained in ICRP 60 [1]. The Basic Safety Standards (BSS) were prepared jointly by the Food and Agriculture Organization of the United Nations, the IAEA, the International Labour Organization, the Nuclear Energy Agency of the Organization for Economic Co-operation and Development, the Pan American Health Organization and the World Health Organization. They were published in 1996 by the IAEA as Safety Series No. 115 (SS-115) [2]. The material presented in this chapter is consistent with the two documents. Paragraph 101 of the Transport Regulations TS-R-1 declares that the principles set out in both SS-115 and in IAEA Safety Series No. 120, “Radiation Protection and the Safety of Radiation Sources” [3], are fully utilized.

For students with a recognized basic training in radiation protection based on the BSS [2, 3] this chapter should not be considered compulsory.

3.1. Some quantities and units

3.1.1 Absorbed dose

When radiation strikes a material, it will deposit energy in that material through a variety of interactions (e.g. ionization). A measure of the amount of radiation that a material has received is the quantity called absorbed dose.

Absorbed dose, D, is the amount of energy deposited per unit of mass as a result of the interplay of ionizing radiation (this includes neutron radiation), and matter.

The unit of absorbed dose is the gray (Gy), which is equal to an energy deposition of 1 J/kg. However, because energy deposition varies for different materials, the material also needs to be specified, for example as “in an organ” or “0.1 Gy in tissue”.

One difficulty with the use of absorbed dose for radiation protection purposes is that the biological effect of an absorbed dose of one gray in tissue is dependent on the type and energy of the incident radiation. To overcome this difficulty a quantity called equivalent dose is used.

3.1.2. Radiation weighting factors and equivalent dose

To take account of the radiation quality of interest, a weighting factor called the radiation weighting factor, w_R is used. The equivalent dose in tissue, T, is given by the expression:

$$H_T = \sum_R w_R . D_{T,R}$$

where

$D_{T,R}$ is the absorbed dose averaged over the tissue or organ, T, due to radiation R.

Since w_R is dimensionless, the unit of equivalent dose is the same as that for the absorbed dose, namely J/kg, but to avoid confusion it has been given the special name sievert (Sv).

The value of the radiation weighting factor for a specified type and energy of radiation has been selected by the ICRP to be representative of values of the relative biological effectiveness of that radiation in inducing stochastic health effects at low doses. Cancer induction is an example of a stochastic effect, in that the probability of the effect is a function of the dose received. Some of the values of w_R are shown in Table 3.1.

TABLE 3.1. RADIATION WEIGHTING FACTORS

Type and energy range		w_R
Photons, all energies		1
Electrons, all energies		1
Neutrons, energy	<10 keV	5
	10 keV to 100 keV	10
	>100 keV to 2 MeV	20
	>2 MeV to 20 MeV	5
Alpha particles		20

where eV is the kinetic energy of the neutron. 1 eV = 1.6^{-19} Joule.

3.1.3. Tissue weighting factors and effective dose

There are circumstances where doses to individual organs can be assessed, (e.g. for the purpose of determining limits on the ingestion or inhalation of radioactive material). Thus a method is needed to combine the organ doses to give either an overall measure of the dose, or an assessment of the biological risk. To do this, tissue weighting factors, w_T, have been determined that take account of the relative radiosensitivity of different tissues (T). These factors are shown in Table 3.2.

TABLE 3.2. TISSUE WEIGHTING FACTORS

Tissue	w_T
Gonads	0.20
Red bone marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Oesophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surface	0.01
Remainder	0.05

The values in Table 3.2 have been developed from a reference population of equal numbers of both sexes and a wide range of ages. In the definition of effective dose, they apply to workers, to the whole population, and to either sex.

The reader's attention is called to the discussion in Chapter 2 of the becquerel and the need to understand the relationship between nuclear decay (*activity*) and radiation dose (*effective dose*). This was illustrated in Fig. 2.5, which assumed a distance of 1 m for external radiation and related all of the doses to an activity of 100,000 Bq. The figure also illustrates the widely varying range of radiotoxicity in both naturally occurring and man-made radionuclides.

3.1.4. Committed equivalent dose

The committed equivalent dose is a quantity that takes into account the time that a radionuclide will be resident in a person's body. When radioactive material is deposited inside the body, the various tissues of the body are committed to a certain dose. The magnitude of this dose is a function of many factors including the radionuclide, its half-life, and the metabolism of the element in the body. For the purpose of determining annual intake limits for *occupationally exposed adults*, the convention is adopted of assessing the total equivalent dose to an organ that will accrue in the 50 years following an intake of a radionuclide. The dose commitment assessed in this way is known as the committed equivalent dose, H_T (50). For *members of the public*, the time period is 70 years.

3.1.5. Committed effective dose

The summation of the committed equivalent dose in each significant organ or tissue multiplied by its weighting factor gives the committed effective dose.

$$E(50) = \sum_{T} w_T . H_T(50)$$

3.1.6. Collective equivalent dose and collective effective dose

In discussion of the effects of radiation on human populations, a number of collective quantities are useful. The collective equivalent dose, S_T, is the summation of the individual equivalent doses received by a group of people.

The collective effective dose, S, is similarly defined except that the effective dose is used in the summation. The unit of both of these quantities is person-sievert.

3.1.7. Collective effective dose commitment

A given source or practice may give rise to a collective effective dose rate which varies as a function of time. The collective effective dose commitment is the integral of this over time.

3.1.8. Radiation level

"Radiation level" is defined as *"dose rate"* in TS-R-1 paragraph 233. This gives no hint about which "dose" is meant, but some explanation is provided in paragraphs 233.1 through 233.6 in the Advisory Material TS-G-1.1.

One of the limiting quantities in radiation protection for the exposure of persons is *effective dose*. There is no technical instrument that has such a complicated response to radiation as living organs have in a human body. Therefore, it is necessary to find instruments that give an estimate of the *effective dose.* That means that the *effective dose* as such is no longer measured, but other quantities are measured instead. Suitable technical instruments can measure these so-called *operational quantities*.

The *operational quantities* taken for radiation protection are *ambient dose equivalent*, relating to strongly penetrating radiation (gamma or neutron radiation), or *directional dose equivalent*, relating to weakly penetrating radiation (alpha and beta radiation).

3.2. Background radiation levels

In order to have some perspective on the significance of certain radiation doses and dose rates, a scale of reference is needed. Giving the lower and upper ends of the dose rate range of interest, together with significant values from a regulatory viewpoint provides this scale. The lower end of the range is best provided by reference to both natural and man-made background radiation levels.

3.2.1. Natural background radiation

The 1993 report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [4] provides an accurate overview of natural background information.

All living organisms are continually exposed to ionizing radiation, which has always existed naturally. The sources of that exposure are cosmic rays that come from outer space and from the surface of the sun, terrestrial radionuclides that occur in the earth's crust, in building materials and in air, water and foods and in the human body itself. Some of the exposures are fairly constant and uniform for all individuals everywhere, for example, the dose from ingestion of potassium-40 in foods. Other exposures vary widely depending on location. Cosmic rays, for example, are more intense at higher altitudes, and concentrations of uranium and thorium in soils are elevated in localized areas. Exposures can also vary as a result of human activities and practices. In particular, the building materials of houses and the design and ventilation systems strongly influence indoor levels of the radioactive gas radon and its decay products, which contribute significantly to doses through inhalation.

The results are presented in Table 3.3. The exposure components have been added to provide an estimate of the global average exposure. The global average exposure does not pertain to any individual, since there are wide distributions of exposures from each source. The consequent effective doses combine in various ways in each location, depending on the specific concentration of radionuclides in the environment and in the body, the latitude and altitude of the location and many other factors.

The annual worldwide per capita effective dose is determined by adding the various components, as summarized in Table 3.3. The annual global per capita effective dose due to natural radiation sources is 2.4 mSv. However, the range of individual doses is wide. In any large population about 65% would be expected to have annual effective doses between 1 mSv and 3 mSv, about 25% of the population would have annual effective doses less than 1 mSv and 10% would have annual effective doses greater than 3 mSv.

TABLE 3.3. ANNUAL EFFECTIVE NATURAL BACKGROUND RADIATION DOSES

		Effective Dose (mSv/y)	
		Worldwide Average	Typical Range
External	Cosmic rays	0.4	0.3–1.0 [a]
	Terrestrial gamma rays	0.5	0.3–0.6 [b]
Internal	Inhalation (radon)	1.2	0.2–10 [c]
	Ingestion (potassium 40)	0.3	0.2–0.8 [d]
TOTAL		2.4	1–10

[a] Range from sea level to high ground elevation. [b] Depending on radionuclide composition of soil and building materials.
[c] Depending on indoor accumulation of radon gas. [d] Depending on radionuclide composition of foods and drinking water.

3.2.2. Man-made background radiation

In addition to natural background, people are exposed to various man-made radiation sources, or natural sources. By far the largest man-made contribution is the medical use of radiation in diagnosis. UNSCEAR lists the estimated average of radiation from this source, worldwide, to be about 0.3 mSv/y. In industrially developed nations, the range is 1–2 mSv/y. The contribution from fallout resulting from the atmospheric testing of nuclear weapons in the 1950's and 1960's is slowly decreasing and is now less than 5 μSv/y.

It is difficult to give a world average for other contributions to dosage. This is because although they can be significant, they are only applicable to a specific population. Included in this category are doses from air travel, radium-luminized watches, radiotherapy, natural gas, specific building materials, and occupational-related exposures. Nuclear power is estimated to contribute an average effective dose of 100 to 200μSv/y for the most highly exposed population near a facility. The limit of the occupational annual effective doses to exposed workers is 100 mSv in 5 years but not more than 50 mSv/y.

3.3. Biological effects

The upper end of the range of interest for dose and dose rate can best be illustrated by reference to those levels required to cause short term biological effects.

3.3.1. Short term biological effects

Biological effects of radiation vary greatly depending on such factors as the amount of exposure, rate of exposure, area of body irradiated, type of radiation and individual biological variability.

Relatively large doses of radiation are required to produce short-term biological effects. At high dose rates, the appropriate dose quantity is absorbed dose (Gy). The radiation weighting factors, w_R, given in Table 3.1 and the tissue weighting factors, w_T given in Table 3.2 are appropriate only for low doses.

If enough individual cells are damaged by ionizing radiation, then specific clinical symptoms will be evident. Most of these symptoms and effects can be classified as deterministic. A deterministic effect is one in which the *severity* of the effect is a function of the dose, and there is a threshold below which there is no clinically observable effect. Figure 3.1 illustrates this relationship. This curve shows that up to a certain dose the effect is negligible. As the dose increases, the effect increases up to a point where there is some maximum effect.

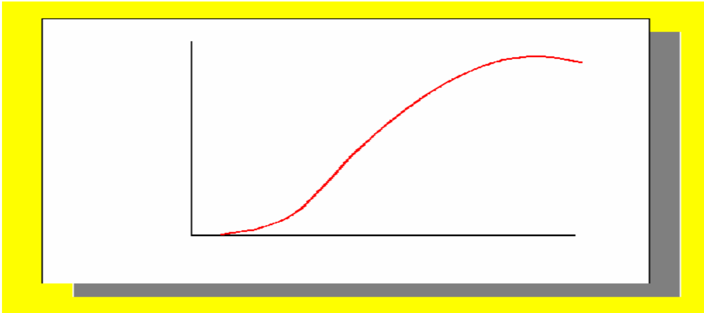

FIG. 3.1. Deterministic effects.

Radiation sickness is characterized by a group of symptoms that includes diarrhea and vomiting, nausea, lassitude, haemorrhaging, emaciation, infection and ultimately, death. The onset and severity of these symptoms is mainly a function of dose.

Table 3.4 gives a broad indication of the dose levels for certain short-term effects following *whole body* irradiation over a short period of time. If only part of the body is irradiated it would require much larger doses to produce the same effect.

TABLE 3.4. DOSES FOR ACUTE BIOLOGICAL EFFECTS

Effect	Dose (Gy)
No discernible effect	0.25
Blood changes, no illness	1.0
Radiation sickness, no deaths	2.0
Death to 50% of irradiated people	4.5
Death to 100% of irradiated people	10.0

3.3.2. Long term biological effects

The major long-term biological effects from smaller doses received over a longer period of time are the increased risks of cancer and severe hereditary effects in progeny.

3.3.2.1. Cancer

Cancer induction is a stochastic effect, in that the *probability* of the effect is a function of dose, perhaps with no threshold. The shape of the dose response function is uncertain. It is probably sigmoidal in shape, but is often conservatively assumed to be linear through the origin. This is illustrated in Figure 3.2.

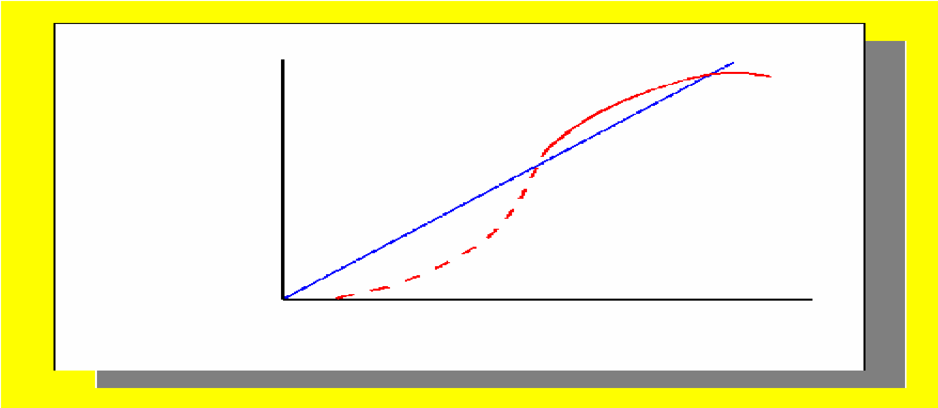

FIG. 3.2. Stochastic effects.

Some organs are more sensitive to cancer induction than others. The sensitivities for different organs are given by the tissue weighting factors. All radiation-induced cancers have some long latent period before they appear.

For doses over about 100 mSv or for high dose rates, the cancer fatality risk is reasonably well known from observations of the survivors of the atomic bomb attacks on Hiroshima and Nagasaki. International bodies such as ICRP and UNSCEAR quantify this risk at about 10 per 100 person-Sv.

At doses lower than this, or at low dose rates, the situation is much less clear. However, it seems that the risk is lower by about a factor of two. Most groups recommend using a value of five latent cancer fatalities per 100 person-Sv at doses less than 100 mSv. This means that if 10 000 people were exposed to a total dose of 10 mSv in a short period of time, five of them may die in years to come due to a cancer induced by that dose. However, in that population of 10 000, about 1 600 persons could eventually be expected to die from cancer induced by other mechanisms.

It should be recognized that opinion is increasing that the risk from low doses and dose rates is significantly lower than this 5% per person-Sv, and may in fact be zero.

3.3.2.2. Genetic effects

In epidemiology the hereditary effects of radiation in humans has not been detected with a statistically significant degree of confidence. Nevertheless, there can be no doubt about the existence of hereditary effects in humans. Risk estimation therefore rests on genetic experimentation with a wide range of organisms and on cellular studies, with limited support from the negative human findings. With this in mind, UNSCEAR estimates the risk of clinically important disorders appearing in first-generation offspring of exposed parents at $0.2–0.4 \times 10^{-2}$ per Sv in the reproductive segment of the population.

3.4. The system of radiation protection

The system of radiation protection is embodied in a set of radiation protection requirements contained in the Agency's Basic Safety Standards [2]. In turn, the Basic Safety Standards are based primarily on the recommendations of the ICRP.

3.4.1. Principles

For proposed and continuing practices, such as transport, the system of protection recommended by ICRP [1] is based on the general principles given below:

(1) Practices should produce sufficient benefit to offset the radiation harm that they may cause (*justification*):

(2) In relation to any particular source within a practice, the magnitude of the individual doses, the number of people exposed, and the likelihood of exposures where they are not certain to be received, should be kept as low as reasonably achievable (ALARA**)**, economic and social factors being taken into account. This procedure should be constrained by restrictions on the doses to individuals (dose constraints), or the risks to individuals in the case of potential exposures (risk constraints), so as to limit the disparity likely to result from the inherent economic and social judgements (the *optimization* of protection); and

(3) Individual exposure from all sources susceptible to control are subject to dose limits and some control of risk from potential exposures (*dose and risk limits*).

3.4.2. Justification

The Basic Safety Standards states that, “No practice or source within a practice should be authorized unless the practice produces sufficient benefit to the exposed individuals or to society to offset the radiation harm that it might cause; that is, unless the practice is justified, taking into account social, economic and other relevant factors.”

In the very few cases where decisions on the justification of transport operations are called for, the principle should be regarded in a general way. It would be sensible to state that all the merits and harm associated with the practice and the possible alternatives under consideration should be taken into account in reaching the decision.

3.4.3. Dose limits

The Basic Safety Standards states that, “The normal exposure of individuals shall be restricted so that neither the total effective dose nor the total equivalent dose to relevant organs or tissues, caused by the possible combination of exposures from authorized practices, exceeds any relevant dose limit specified in Schedule II, except in special circumstances provided for in Appendix I. Dose limits shall not apply to medical exposures from authorized practices.”

3.4.3.1. Individual dose limits

It is important to recognize that dose limits are the third part of the ICRP recommendations [1]. They are set so that any continued exposure just above the dose limits would result in additional risks that could be reasonably described as “unacceptable” in normal circumstances.

There are basically two requirements in setting the dose limits. The first is to keep doses below the threshold level for deterministic effects and the second is to keep the risk of stochastic effects at a tolerable level. The stochastic effects occur at considerably lower doses and are the basis for dose limitations. The dose limits recommended by ICRP [1] are summarized in Table 3.5.

TABLE 3.5. DOSE LIMITS

		Occupational	Public
Effective dose		20 mSv/y averaged over 5 consecutive years[a]	1 mSv in a year[b]
Effective dose in any single year		50 mSv	-
Annual equivalent dose:	Eye lens	150 mSv	15 mSv
	Skin	500 mSv	50 mSV
	Hands & feet	500 mSv	-

[a] Additional restrictions apply to the occupational exposure of pregnant women.

[b] In special circumstances, an effective dose of 5 mSv could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year.

The choice of a dose limit is not, and cannot be, a matter of science and scientific judgement alone. The final decision is essentially a political and economic one that needs to be made as part of the national regulatory process. The ICRP [1] and BSS-recommended limits [2] represent a professional judgement based on a complex and sophisticated multi-attribute analysis

3.4.3.2. Potential exposures and risk limits

Not all exposures occur as forecast. There may be accidental departures from planned operating procedures, or equipment may fail. Such events can be foreseen and their probability of occurrence estimated, but they cannot be predicted in detail. The ICRP recommends that the individual and collective harm resulting from an exposure that should not occur shall be included in the system of radiation protection. Ideally, dose limits should be supplemented by risk limits that take account of both the probability of incurring a dose and the harmful effects of that dose if it were to be received.

3.4.4. Optimization

ICRP states that “optimization of protection”, “keeping all exposures as low as reasonably achievable, economic and social factors being taken into account”, and “ALARA” are identical concepts within the ICRP system.

A wide range of techniques is available to optimize radiation protection. Some of these techniques are drawn from operational research, some from economics, and some from engineering. The techniques available include procedures based on cost-benefit analysis, which are discussed in detail in the ICRP report on optimization of protection. It is important to recognize that other techniques, some quantitative, others qualitative, may also be used in the optimization of radiation protection. IAEA-TECDOC-374 [5] contains a discussion of, and guidance on, the optimization of radiation protection in the transport of radioactive material. Clearly, in practice, and particularly in day to day operations, there will be little opportunity to undertake complex quantitative calculations to determine what is optimal, and professional judgements may need to be made on a qualitative and, sometimes, intuitive basis.

There are nevertheless a number of situations where the formal techniques such as cost-benefit analysis can provide a valuable aid to decision-making in radiation protection. Their application is most likely in circumstances where the decisions are complex and the expenditure potentially large.

3.4.5. Dose constraints

The Basic Safety Standards states, "Except for medical exposures, the optimization of the protection and safety measures associated with any particular source within a practice shall be subject to dose constraints that:

(a) do not exceed either the appropriate values established or agreed to by the Regulatory Authority for such a source or values which can cause the dose limits to be exceeded; and

(b) ensure, for any source (including radioactive waste management facilities) that can release radioactive substances to the environment that the cumulative effects of each annual release from the source be restricted so that the effective dose in any year to any member of the public, including people distant from the source and people of future generations, is unlikely to exceed any relevant dose limit, taking into account cumulative releases and the exposures expected to be delivered by all other relevant sources and practices under control."

The concept of a dose constraint sets an upper limit on the exposure of an individual to a single source. The dose constraint does not replace optimization; rather it sets a ceiling on the levels of individual dose to be considered in the optimization of protection for that source. Its purpose is three-fold:

(1) To ensure that the dose limit is not exceeded when exposures to all sources are summed,

(2) To further constrain individual inequalities when benefits and detriments are unevenly distributed among individuals, and

(3) To enable regulatory authorities to establish a dose constraint for a particular source based on a knowledge of good practice.

3.5. Control of the radiation hazard

One of the key principles of radiation protection is the minimization of personnel dose. The dose received is the product of the dose rate and the time exposed:

Dose = Dose Rate x Time

Therefore, dose from external radiation can be reduced by either reducing the dose rate, or by shielding, or by moving a greater distance from the source, or by reducing the time spent near the source.

3.5.1. Time

Reducing the time spent near the source of radiation will reduce the total dose that a person receives. This principle is applied in many situations in the transport of radioactive material.

3.5.2. Distance

Increasing distance from a source is a very good way of reducing the radiation dose rate and hence the total doses. For small sources emitting gamma rays, the inverse square law applies. Doubling the distance will reduce the dose rate to one quarter. Spacers in many packaging designs have the function of increasing distance to reduce the package surface dose rate.

3.5.3. Shielding

Placing shielding material between a source and the person will also reduce the dose rate. For gamma radiation, dense materials such as lead and steel are the most effective, and therefore, these materials are frequently used in packaging designs.

3.6. Control of the contamination hazard

It is important to have a clear concept of the distinction between radiation and contamination. Radiation is the particle or energy emitted from radioactive material (or generating devices such as X ray machines). Contamination is radioactive material where it is not wanted. Contamination can occur in many forms including powder, liquid, or gas.

3.6.1. Containment

Normally, radioactive material is placed or kept in some sort of containment. This may be anything from a glass vial, to the cladding on a fuel pin, to a special stainless-steel capsule. Contamination generally occurs when for some reason the containment is damaged or broken. Once contamination is outside of a controlled or contained environment it can spread very quickly and easily. Therefore, the basic method of control is by taking great care to keep the radioactive material in a known place.

3.6.2. External and internal personal contamination

Once contamination is in an uncontrolled environment, it may inadvertently come in contact with people. All the time it is external to the body, it is generally more of a nuisance than a hazard, but it still requires to be located and cleaned up. However, when contamination gets inside the body the hazard is much greater.

Once inside the body, the methods of time, distance and shielding cannot be applied to reduce the dose. Generally, the body is committed to a certain dose until the material is excreted or until it diminishes through radioactive decay. Therefore, it becomes very important to prevent radioactive material becoming incorporated into the body. Ways it could get inside include inhalation of dusts, gases or smoke, ingestion via the mouth from smoking, eating or drinking with contaminated hands, or incorporation through wounds, grazes or cuts.

3.6.3. Protective clothing

The general purpose of protective clothing is to prevent a person from becoming contaminated either externally or internally. The level of protection required will vary according to the level of the contamination hazard. Protective clothing can vary from a laboratory coat and gloves, to several layers of coveralls, with a complete positive pressure body suit and self-contained breathing apparatus.

3.6.4. Fixed and removable contamination

A distinction is often made between fixed and removable contamination without taking care to carefully define the terms. In radioactive material transport, removable, or non-fixed contamination as it is called in the Regulations, is contamination that can be removed from a surface during normal handling. Once contamination gets on a surface, all or part of it can become inpossible to remove. It is then called fixed contamination. Fixed contamination no longer presents a contamination hazard, but a radiation hazard.

For this reason, limits for fixed contamination are given in terms of a dose rate (mSv/h), whereas limits for non-fixed contamination are expressed in activity per unit area (Bq/cm^2).

3.7. Controlled areas

Restricting access to a particular area provides a basic method of implementing control over both radiation and contamination. This method is particularly useful in accident situations. For radiation, a controlled area keeps people remote from the source and hence controls the hazard by distance and time. For contamination, it keeps people remote from the loose radioactive material. If there is only one point where personnel are surveyed on entry and exit, then the radioactive material can be prevented from spreading outside of the area and hence is contained. Personnel can also be controlled to ensure that they have the necessary protective clothing on entry to the restricted area.

3.8. Radiation protection programmes

A radiation protection programme is a system of measures that primarily ensures the health and safety of workers and the public from radiation and radioactive material. Measures are also taken with the objective of minimizing environmental impact. The nature and extent of these measures is related to the magnitude and likelihood of radiation exposures. Paragraph 301 of TS-R-1 requires that a radiation protection programme must be established for all aspects of the transport of radioactive material. The radiation protection programme should include a training programme for the concerned personnel (paragraphs 303, 314–316). The Radiation Protection Programme should include a training programme for the concerned personnel (paragraphs 303, 314–316).

TS-R-1 and the BSS provide specific objectives of radiation protection programmes and guidance on how to achieve these objectives. The basic components of a typical radiation protection programme associated with the transport of radioactive material involve personnel dosimetry for workers handling the material and packages as well as dose rate and contamination surveys of packages, working areas, and conveyances. In addition to routine issues, consideration has to be given for non-routine and emergency radiological protection.

Record keeping is an important element of any radiation protection programme. Documented evidence shows that the program is achieving its objectives and also provides indications of trends and areas where further improvements are needed. Record documentation is essential to demonstrate compliance with regulatory requirements.

3.9. Non-compliance

Any instance of non-compliance with the Regulatory requirements identified during transport should be brought to the notice of the consignor by the carrier.

Any instance of non-compliance with the Regulatory requirements identified at receipt of the consignment should be brought to the notice of the consignor by the consignee.

The carrier, consignor or consignee, as appropriate should take immediate steps to mitigate the consequences of non-compliance, investigate its causes, circumstances and consequences' take appropriate actions to remedy the causes of the non-compliance and to prevent recurrence and communicate, as soon as practicable, to the competent authorities on the causes of non-compliance and on corrective and preventive actions taken (paragraph 313).

3.10. Basics of Q system

The current version of the Regulations, imposes three limits in relation to the activity of radionuclide contents. These three limits are:

(1) A_1 and A_2 in TBq (paragraphs 201 and 401(a) of TS-R-1) [6],
(2) Activity concentration for exempt material in Bq/g (paragraphs 240 and 401(b) of TS-R-1), and
(3) Activity limits for exempt consignments in Bq (paragraph 401(c) of TS-R-1).

The values of A_1 and A_2 specified in the Regulations come from what became known in the late 1970's as the Q-system. The development of the Q-system was initiated in support of the 1985 Edition of the Regulations (Safety Series No. 6) [7] to provide a justifiable dosimetric basis for the A_1 and A_2 values. It was extended to support the development of the 1996 Edition of the Regulations (ST-1, now TS-R-1 [6]).

The various limits prescribed in the Regulations to control the release of radioactivity from transport packages are based upon the activity contents limits for Type A packages. These limits are also used for several other purposes such as in specifying Type B and Type C package activity leakage limits, LSA materials, and excepted package contents limits.

Originally, radionuclides were classified into seven groups for transport purposes, each group having its Type A package content limits for special form radioactive material and for material in all other forms. Special form radioactive material was defined as that which was non-dispersible when subjected to specified tests. In the 1973 Edition of the Regulations the group classification system was developed into the A_1/A_2 system, where each nuclide had two Type A package contents limits, specified in curies. These were:

- A_1 when transported in special form, and
- A_2 when not in special form.

The Q-system developed for the 1985 Edition of the Regulations, and reassessed and modified for the 1996 edition of the Regulations [6], includes consideration of a broader range of specific exposure pathways than the earlier A_1/A_2 system. The Q-system considers a series of exposure routes for persons in the vicinity of a Type A package involved in a severe transport accident.

In the 1985 Edition of the Regulations, the reference dose (50 mSv) used in the derivation of A_1/A_2 values was linked to the annual dose limit for radiation workers. Although this link to the annual dose limit for workers is no longer valid for potential exposures, 50 mSv has been retained in the current Q-system assessment on the grounds that, historically, actual accidents involving Type A packages have led to very low exposures. In choosing a reference dose, it was agreed by the developers of the Q-system that it was also important to take into account the probability of an individual being exposed as the result of a transport accident. Such exposures may, in general, be considered as once in a lifetime exposures. Clearly, most individuals will never be exposed.

REFERENCES FOR CHAPTER 3

[1] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Recommendations of the International Commission on Radiological Protection, Publication No. 60, Pergamon Press, Oxford and New York (1990).
[2] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).
[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and the Safety of Radiation Sources, Safety Series No. 120, IAEA, Vienna (1997).
[4] UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION, Sources and Effects of Ionizing Radiation, UNSCEAR 1993 Report to the General Assembly, United Nations, New York (1993).
[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Discussion of and Guidance on the Optimization of Radiation Protection in the Transport of Radioactive Material, IAEA-TECDOC-374, IAEA, Vienna, (1986).
[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Standards Series, Safety Requirements No. TS-R-1, IAEA, Vienna (2005).
[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 1985 Edition (As Amended 1990), Safety Series No. 6, IAEA, Vienna (1990).

EXERCISES FOR CHAPTER 3

The following are exercises to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this Training Manual.

EXERCISE 3.1. Radiation Protection Quantities and Units

REFERENCE SOURCES: Training Manual, Chapter 3.1; TS-R-1, Sections I and III

DISCUSSION: The interaction of radiation with the human body is measured as the energy deposited. There are a number of modifying factors applied however, to correct such measurements to reflect the actual damage that may have been caused in human tissue.

PROBLEM: What are the main quantities and modifying factors in relation to radiation protection?

ANSWER:

EXERCISE 3.2. Background Radiation

REFERENCE SOURCES: Training Manual Chapter 3.2

DISCUSSION: It is important always to be aware of the contribution to radiation from natural and man-made sources

PROBLEM:

a. What are the sources of naturally occurring radiation, and how much dose results from it?

b. What is man-made radiation?

ANSWER:

EXERCISE 3.3. System of Radiation Protection

REFERENCE SOURCES: Training Manual, Chapter 3.4; TS-R-1 paragraphs 302 and 305, TS-G-1.1 paragraphs 302 and 305

DISCUSSION: The principles of radiation protection must be applied in the transport of radioactive material.

PROBLEM:

a. What are the main principles of radiation protection to be applied in transport?

b. What limits must be observed in transport?

ANSWER:

EXERCISE 3.4. Control of Radiation Hazards

REFERENCE SOURCES: Training Manual, Chapter 3.5

DISCUSSION: There are certain simple procedures by which doses may be reduced.

PROBLEM: What can be done to reduce the radiation absorbed by the human body?

ANSWER:

EXERCISE 3.5. Dose Limits

REFERENCE SOURCES: Training Manual, Chapter 3.4.4; TS-R-1, Sections I and III

DISCUSSION: Dose limits are recommended by the ICRP and by the basic safety standards of the IAEA. These are discussed briefly in Chapter 3.4.4 of the Training Manual. The Regulations (TS-R-1) specifically address how these dose limits are to be applied for transport.

PROBLEM:

a. Must the dose limits specified by the ICRP, and by the basic safety standards of the IAEA, be used by each Member State that implements the Regulations?

b. Who, at a national level, is responsible for satisfying the radiation protection requirements?

ANSWER:

EXERCISE 3.6. Radiation Protection Programme

REFERENCE SOURCES: Training Manual, Chapter 3.8; TS-R-1 Section III.

DISCUSSION: Chapter 3.8 of the Training Manual indicates that the Regulations require a radiation protection programme be established for the transport of radioactive material.

PROBLEM: Where, in TS-R-1, is the requirement established for a radiation protection programme?

a. Are the same nature and extent of measures in the programme required for all types of radioactive material transport?

b. How are occupational exposures controlled during transport of radioactive material?

ANSWER:

4. REGULATORY TERMINOLOGY

The purpose of this chapter is to systematically explain a selection of the terms necessary to provide a general understanding of the Radioactive Material Transport Regulations. The selection of terms explained in this chapter is not in the form of the regulatory definitions. The complete set of regulatory definitions is contained in Section II (paragraphs 201–248) of TS-R-1 [1].

4.1. Special form

Special form radioactive material (paragraph 239 of TS-R-1) is either an indispersible solid radioactive material or a sealed capsule containing radioactive material. The qualification test criteria for special form are very stringent. This means that the material has a very high degree of physical integrity so that if the material were released from the package in an accident, while there might be a high radiation hazard, it is unlikely that there would be any contamination hazard. Therefore, larger quantities can typically be shipped in any given package.

4.2. A_1 and A_2

A_1 and A_2 are quantities of radioactivity (paragraph 201 of TS-R-1), which are used in the Regulations to determine such things as the type of packaging necessary for a particular radioactive material shipment. A_1 applies to special form and A_2 applies to other than special form radioactive material. For example, A_1 is the maximum activity of special form material that is permitted in a type of package called a Type A package, and A_2 is the maximum activity of other than special form radioactive material that is permitted in a Type A package. A_1 and A_2 values have been determined for most common radionuclides and are listed in Table I of TS-R-1. Fractions and multiples of A_1 and A_2 are used in specific criteria throughout the Regulations.

4.3. Specific activity

The total quantity of radioactivity is an important parameter to know with respect to quantifying the hazards associated with a particular source. However, it does not tell the whole story. For example, 3×10^{20} Bq might seem to be a very large and hazardous source, but it is the total quantity of uranium in the world's oceans. It is a large quantity of radioactivity, but it is evenly distributed over an extremely large mass, or volume, of water. Specific activity is usually defined in terms of activity per unit mass. In the Regulations, an important parameter for comparing specific activity is A_2/g.

4.4. Exemptions

Exemptions are situations where the Regulations are not applicable. Most of these are common sense (paragraph 107 of TS-R-1), such as when the radioactive material is implanted into a person or animal, is incorporated into an approved consumer product, or is an integral part of the means of transport. The Regulations also do not apply to very low quantities of radioactive material in a consignment or very low concentrations of radioactivity that clearly represent insignificant hazards. Such material is not even defined as radioactive material (paragraph 236 of TS-R-1) in the Regulations. The basis and numerical values for these exemptions, which are the same as those in the BSS, are given in paragraphs 401–406 of TS-R-1. They are expressed in terms of specific activity (Bq/g) and total activity per consignment.

4.5. Excepted material

Excepted material is a very small quantity of radioactive material that would present insignificant hazards in the event that it was released. Excepted material is not specifically defined in the Regulations, but limits are placed upon the material and the packaging to allow shipment as an excepted package (paragraph 230(a) of TS-R-1). The basic limit for solid radioactive material contents of an excepted package is 10^{-3} A_1 or 10^{-3} A_2. Table III of TS-R-1 shows the detailed activity contents limits for excepted packages.

4.6. Low specific activity material

Low specific activity (LSA) material (paragraph 226 of TS-R-1) is radioactive material that by its nature has a low activity per unit mass (specific activity). LSA material is divided into three groups.

4.6.1. LSA-I

This material (paragraph 226(a) of TS-R-1) is intrinsically radiologically safe in that the radioactive concentration is such that a person cannot physically breathe or ingest enough of the material to give rise to significant doses. Generally, LSA-I comprises unirradiated natural or depleted Uranium and Thorium compounds and processing ores, other radionuclides with unlimited A_2 values, or material with a specific activity not exceeding 30 times the exempt concentration.

4.6.2. LSA-II

LSA-II material (paragraph 226(b) of TS-R-1) includes material for which the estimated average specific activity does not exceed 10^{-4} A_2/g for solids and gases and 10^{-5} A_2/g for liquids. The activity must be distributed throughout the material. For water with tritium, the concentration limit is 0.8 TBq/L.

4.6.3. LSA-III

LSA-III material (paragraph 226(c) of TS-R-1) comprises solids in which radioactive material is distributed throughout or is essentially uniformly distributed in a solid binding agent such as concrete or bitumen. It must be relatively insoluble with a leach rate of 0.1 A_2, or less, per week and a specific activity not exceeding 2×10^{-3} A_2/g.

4.7. Surface contaminated objects

A surface contaminated object (SCO) is a solid object which is not itself radioactive but which has radioactive material distributed on its surfaces. SCO is divided into two categories SCO-I (paragraph 241(a) of TS-R-1) and SCO-II (paragraph 241(b) of TS-R-1) that are differentiated by the levels of fixed and non-fixed contamination. SCO II has the higher allowed levels of contamination.

4.8. Fissile material

Fissile material (paragraph 222 of TS-R-1) is material that has the capability of undergoing nuclear fission, and thus requires additional package design considerations and controls to assure nuclear criticality safety during transport. The subject of nuclear criticality safety is considered in more detail in Chapter 11. Fissile Material, of this manual. In the

Regulations, fissile material is defined as ^{233}U, ^{235}U, ^{239}Pu, ^{241}Pu, or any combination of these radionuclides. Natural or depleted Uranium that is unirradiated or has only been irradiated in thermal reactors is not regarded as fissile material.

4.9. Fissile excepted

Certain quantities and configurations of fissile material cannot become critical under any circumstances. To allow for this, there are several exceptions to the fissile material requirements in the Regulations (paragraph 672 of TS-R-1). Generally, the exceptions are for small quantities. For example, less than 15 g per package (paragraph 672(a)(i) of TS-R-1), or for low concentrations or low enrichments. Only one type of exception is allowed per consignment. Fissile material and fissile exceptions are considered in more detail in Chapter 11 of this manual.

4.10. Consignment, consignor, consignee, carrier and conveyance

The consignment (paragraph 211 of TS-R-1) consists of the package(s) or load of radioactive material that is presented for transport. The consignor (paragraph 212 of TS-R-1) is the individual or organization that prepares a consignment for transport and the consignee (paragraph 210 of TS-R-1) is the corresponding agent that receives the consignment.

A carrier (paragraph 206 of TS-R-1) is an individual or organization that undertakes the carriage of radioactive material by any means of transport. Those who do this for hire or reward are known as common or contract carriers in some countries, while the rest are called private carriers. A conveyance (paragraph 217 of TS-R-1) is the means by which the package is transported, such as a vehicle (paragraph 247 of TS-R-1), vessel (paragraph 248 of TS-R-1), or aircraft (paragraphs 202 and 203 of TS-R-1).

4.11. Exclusive use

When the consignor or consignee has total control of a shipment, then the Regulations can generally be less restrictive. This leads to the concept of exclusive use consignments (paragraph 221 of TS-R-1). Exclusive use means that a single consignor has sole use of the conveyance (or large freight container), such that all loading and unloading is carried out in accordance with the directions of the consignor or consignee.

4.12. Packaging, containment and confinement

Packaging (paragraph 231 of TS-R-1) is the assembly of components necessary to enclose the radioactive material contents, and can include such things as absorbent materials, spacing structures, shielding material, service equipment, shock absorbing devices, handling and tie-down capability, and thermal insulation. Together, the packaging and radioactive contents make up the package (paragraph 230 of TS-R-1). A containment system (paragraph 213 of TS-R-1) is defined as that part of the packaging intended to retain the radioactive material during transport. A confinement system (paragraph 209 of TS-R-1) is the assembly of fissile material and packaging components intended to preserve criticality safety.

4.12.1. Excepted packages

Excepted packages may only contain limited quantities of radioactive material, which are so small that the potential radiological hazards that might pertain during transport are very low. There are no test requirements for excepted packages and therefore it must be assumed that in any form of accident the package may fail completely and that the contents may be dispersed. The radiation level at any point on the surface of an excepted package cannot exceed 5 μSv/h to ensure that any radiation dose to members of the public would be insignificant and that any sensitive photographic material in close proximity would not be damaged.

4.12.2. Industrial packages

Industrial packages are used to transport LSA and SCO material. There are three types of industrial packages (Type IP-1, Type IP-2, and Type IP-3) that are used for LSA and SCO shipments according to the schedule in Table IV of TS-R-1. The requirements that packages have to meet to be classified as industrial packages are not demanding. Many normal packages used in industry, such as steel drums or bins, could meet the requirements. Activity limits are fixed per conveyance as shown in Table V of TS-R-1.

4.12.3. Type A packages

Type A packages are intended to provide a safe and economical means of transporting a well defined, but significant, minor quantity of radioactive material. A total quantity of up to A_1 special form radioactive material, or up to A_2 if not special form, may be transported in a Type A package. They are required to maintain their integrity under the kind of abuse or mishandling which may be encountered in normal transport, for example: falling from vehicles, being dropped during manual handling, being exposed to the weather, being struck by a sharp object, or having other packages or cargo stacked on top. The specific tests required for Type A packages simulate such events.

4.12.4. Type B packages

The concept of a Type B package is that it should be capable of withstanding most accident conditions, without breach of its containment or an increase in radiation levels to a point that would endanger the general public and those involved in rescue or clean-up operations. In other words, the package could be safely recovered, but would not necessarily be capable of being reused.

While a Type B package is never required to withstand more than one accident, the design criteria imposed by the Regulations subjects the package to a series of mechanical and thermal tests with accumulative effects, each of which must cause the maximum damage. The requirements impose additional necessary design constraints over and above those imposed on packages that meet normal conditions of transport. The outcome of these constraints is to dictate greater structural integrity, more careful consideration of containment features, and the ability to protect from elevated temperatures.

For most modes of transport, a Type B package may contain any quantity of any type of radioactive material up to that allowed by its approval certificate. However, contents limits are applied if the package is transported by air. These limits are 3000 A_1 or 100,000 A_2 (whichever is lower) for special form material and 3000 A_2 for all other forms.

Type B packages may either be unilaterally approved (B(U)), or multilaterally approved (B(M)). Unilateral approval means that they are approved by the Competent Authority of the country of origin of the design only, while multilateral approval means that they are also approved by the Competent Authorities of the countries through, or into which, the consignment is to be transported.

4.12.5. Type C packages

In recognition of the fact that impact velocities from aircraft crashes can be significantly greater than those from surface modes of transport, the shipment of very large quantities of radioactive material by air requires the use of Type C packages. These are packages that must demonstrate the capability to withstand severe crush, puncture, and fire tests, as well as impact at the high speed of 90 metres/second. These features may all be encountered in a severe air accident.

4.12.6. Fissile packages

In addition to meeting the requirements pertaining to the radioactive properties of the material, if fissile material is being transported, the package must also be designed to ensure criticality safety under a variety of postulated conditions. Such packages require multilateral Competent Authority approval and they are given the additional designation as fissile packages.

4.12.7. Overpacks, freight containers, intermediate bulk containers and tanks

Each of these is used to facilitate the handling, stowage, and carriage of goods. An overpack is an enclosure such as a box, used by a single consignor to consolidate one or more packages so they may be treated as one. A freight container is an article of transport equipment that enables goods to be easily transferred between conveyances and from one mode of transport to another. An intermediate bulk container (IBC) is a portable packaging that has a capacity less than 3 m^3, which is designed for mechanical handling during transport, and meets the UN standards for IBCs. A tank has a fairly specific definition in the Regulations; however, most large containers that are envisioned when such a term is used with respect to transport will fit the definition.

4.13. Low dispersible radioactive material

Low dispersible radioactive material (LDM, see paragraph 225 of TS-R-1) is a solid material, which not only has limited dispersibility, but also has low solubility and a radiation level not exceeding 10 mSv/h at 3 metres from the unshielded material. These characteristics mean that large quantities of activity may be safely carried by air in Type B packages rather than using the Type C that would otherwise be necessary. Such material requires multilateral Competent Authority approval.

4.14. Transport index

The transport index (TI, see paragraph 243 of TS-R-1) is a number that is assigned to a package (or overpack, freight container, or conveyance), which is used to provide control over groups of packages for the purposes of minimizing radiation exposure risks.

4.15. Criticality safety index

The criticality safety index (CSI, see paragraph 218 of TS-R-1) is a number that is assigned to a package (or overpack, freight container, or conveyance) containing fissile material, which is used to provide control over the accumulation of groups of such packages for the purposes of preventing unintentional criticality.

4.16. Special arrangement

Special arrangements (paragraph 238 of TS-R-1) are those provisions that allow for the transport of consignments that do not satisfy all of the applicable regulations. These special arrangements must be approved by the affected Competent Authorities.

4.17. Competent authority

A Competent Authority (paragraph 207 of TS-R-1) is a national or international authority, which is designated or recognized as such. Practically, for most nations it is the government agency that regulates the transport of radioactive material. Amongst other things, Competent Authorities approve designs for special form radioactive material, LDM, fissile packages, and Type B and C packages. In addition, they approve special arrangements, certain shipments, and radiation protection programmes for special use vessels.

4.18. Quality assurance and compliance assurance

Quality Assurance (paragraph 232 of TS-R-1) and Compliance Assurance (paragraph 208 of TS-R-1) are systematic programmes aimed at ensuring that the standard of safety required by the Regulations is achieved in practice. Quality Assurance is applied by those involved in the transport of radioactive material, while Compliance Assurance is applied by a Competent Authority.

REFERENCE FOR CHAPTER 4

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Standards Series, Safety Requirements No. TS-R-1, IAEA, Vienna (2005).

EXERCISES FOR CHAPTER 4

The following are exercises to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 4.1. Definitions and their Use

REFERENCE SOURCES: Training Manual, Chapter 4; and TS-R-1, Sections II, IV; and TS-G-1.1

DISCUSSION: Each term defined in Section II of TS-R-1 is italicised throughout the remaining portion of the text where it is used in its defined form. In many cases, the use of these terms elsewhere in the Regulations can be found by referring to the index at the end of TS-R-1. In other cases, this may not be true.

PROBLEM: Chapter 4.3 of the Training Manual discusses the definition of *specific activity* that is contained in paragraph 240 of TS-R-1.

a. How is the definition of *specific activity* used in defining Low Specific Activity Material?

b. How is terminology equivalent to the definition of *specific activity* used in establishing exemptions for material (e.g. TS-R-1 paragraph 401 and Table 1)?

c. How is terminology equivalent to the definition of *specific activity* used in determining basic radionuclide values of mixtures of radionuclides (e.g. TS-R-1 paragraph 404)?

d. Where can values of *specific activity* for radionuclides be found (e.g. TS-G-1.1)?

ANSWER:

EXERCISE 4.2. Familiarization with Terminology

REFERENCE SOURCES: Training Manual, Chapter 4; and TS-R-1, Section II; and TS-G-1.1

DISCUSSION: The terms defined in Section II of TS-R-1 frequently utilise many specialised terms and key concepts. The purpose of this exercise is to encourage the student to study the terminology in depth, looking for key concepts and phrases.

PROBLEM:

a. In which definitions do each of the following terms appear?
   - "unirradiated natural uranium"
   - "indispersible"
   - "country of origin" and "through or into which"
   - "sole use, by a single consignor"

b. "Fissile material" is defined to include uranium-235. Is unirradiated natural uranium considered to be fissile material?

c. May a "cargo vessel" be considered as a "vehicle?"

d. What physical characteristics are assigned to the parameters "TI" and "CSI"?

ANSWER:

EXERCISE 4.3. Low Toxicity Alpha Emitters

REFERENCE SOURCES: Training Manual, Chapter 4; TS-R-1, Section II; and TS-G-1.1

DISCUSSION: The Regulations use, in defining contamination (paragraph 214), the phrase "low toxicity alpha emitters." In turn, the Regulations define this phrase (see paragraph 227) by listing a number of specific nuclides and then add the phrase "or alpha emitters with a half-life of less than 10 days."

PROBLEM: Using the information given in Appendixes I and II of TS-G-1.1 (first paragraph of AI.5.2 and Table AI-2, and Table AII.1), are there any standard radionuclides (as listed in Table I of TS-R-1) that are low toxicity alpha emitters?

ANSWER:

EXERCISE 4.4. Exclusive Use

REFERENCE SOURCES: Training Manual, Chapter 4; TS-R-1, Section II; and TS-G-1.1

DISCUSSION: The graded approach in the Regulations provides, in part, for greater control over shipment and in turn allows more flexibility in packaging and contents when such control is used. The greater control is provided through the specification of Exclusive Use.

PROBLEM: A vehicle is dedicated to the shipment of radioactive material packages by its owner/operator. No other commodities are carried in that vehicle. The owner/operator of that vehicle (i.e. the carrier) picks up packages from various suppliers (i.e. consignors) and delivers them to various users (i.e. consignees).

a. Are there any conditions under which the shipments in this vehicle can be made under exclusive use?

b. If the vehicle were to be used under exclusive use, what advantages would there be?

ANSWER:

EXERCISE 4.5. Packages

REFERENCE SOURCES: Training Manual, Chapter 4; TS-R-1; TS-G-1.1

DISCUSSION: Safety during transport is achieved by using packaging adequate for the radioactive contents.

PROBLEM:

a. What is the difference between a package and the packaging?

b. What are the types of packages?

ANSWER:

5. BASIC SAFETY CONCEPTS: MATERIALS AND PACKAGES

5.1. Basic safety concepts

As discussed in the first chapter, the core philosophy of the transport of radioactive material is that it should be performed safely. Safety can be achieved in a number of different ways. Some would argue that not transporting radioactive material at all is the only way to be assured of safety. However, this disregards the very significant benefits of using radioactive material and the ultimate need for properly treating and disposing of the existing material when it is no longer needed.

To properly understand the basic concepts for safely transporting packages containing radioactive material it is essential to always keep in mind a clear picture of the package components. These are shown in Figure 5.1

- ***Package*** **- The *packaging* with its *radioactive contents* as presented for transport**
- ***Packaging*** **- The assembly of components necessary to enclose the *radioactive contents* completely**

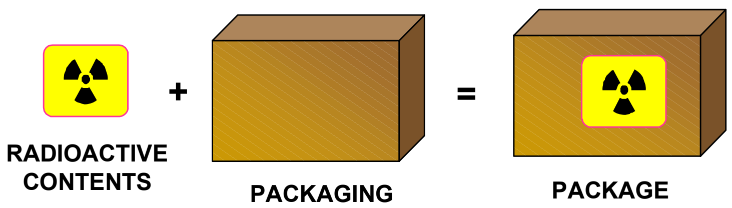

FIG. 5.1. Radioactive contents, packaging and package.

5.1.1. Inherent safety

While such aspects as administrative and procedural controls such as marking, labelling, notifications, and communications have their place, it is clearly best to have as much reliance on *inherent safety* as possible. This minimizes the human factor and the tendency to make mistakes. An example of inherent safety would be shipping the material in such a way that even if all the controls failed, and an individual ingested the material it would not have a detrimental effect. The difficulty is that radioactive material has a very large variety of properties and a very large range of specific activities. To incur a small dose the quantity of ingested material could range from a few milligrams to many kilograms. Because of this phenomenon, the accurate characterization of radioactive material type is a basic safety aspect of the IAEA TS-R-1 Transport Regulations, as will be seen later.

5.1.2. Passive safety

Once one can no longer rely on the inherent safety of the radioactive material itself, then the next best step is to use *passive safety*. An example of passive safety is packaging. If the quantity of radioactive material is such that it is not inherently safe, then it could be made part of a package that can withstand all the assaults to which it is likely to be exposed. It then does not matter how the radioactive material is treated during the transport process. The difficulty with this is that such a packaging may be extremely expensive compared to the value of the radioactive material content. It is also unreasonable to have a very tough packaging for material that might only be marginally hazardous.

This leads to the concept of a graded approach to packaging requirements. In other words, the package integrity is a function of the hazard associated with the radioactive material. The more hazardous the material, the tougher the packaging. Packaging 'toughness' is measured in its ability to withstand various conditions of transport. There are three basic conditions used in the IAEA Regulations with some variations within each condition (see para. 106 of TS-R-1):

- Routine conditions of transport (incident free);
- Normal conditions of transport (minor mishaps); and
- Accident conditions of transport.

Routine conditions of transport are those that are totally incident free, apart from the conventional stresses and strains resulting from the conveyance operation. Normal conditions of transport include the typical small incidents that a package might endure during shipment. These include such things as being rained upon, being dropped, and having other packages stacked on top.

The graded approach to packaging in the Regulations is illustrated pictorially in Figure 5.2. The packaging at the top of the figure is typical of that used for small limited quantities of radioactive material posing a minimal hazard. This package is designed to withstand only the routine conditions of transport. If the packaging fails, the consequences are insignificant because of the levels of radioactivity involved. The packaging in the centre of the figure is typical of that used for moderate quantities of radioactive material posing a small hazard. This package is designed to withstand both the routine, and the normal conditions of transport. If this packaging fails in an accident, there may a release of radiation, but they are unlikely to cause any measurable biological effects. The packaging at the bottom of the figure is typical of that used for more significant quantities of radioactive material, which would pose a large hazard if released. This package is designed to withstand not only the routine and normal conditions of transport, but also accident conditions of transport.

FIG. 5.2. Pictorial representation of the graded approach to packaging.

5.1.3. Active safety

Once all that is reasonably possible has been done with respect to inherent safety and passive safety, then the next level of safety is that associated with active controls. This generally requires the implementation of procedures of some sort. Included in this category would be labelling; marking and placarding; loading, stowage, storage, and segregation provisions; Quality and Compliance Assurance controls, and shipping documentation.

5.1.4. Summary of objectives of Transport Regulations

In summary, the objective of the Regulations is to protect persons, property and the environment from the effects of radiation during the transport of radioactive material (paragraph 104 of TS-R-1). In the words of the Regulations, this protection is achieved by requiring:

- Containment of the radioactive contents;
- Control of external radiation levels;
- Prevention of criticality; and
- Prevention of damage caused by heat.

In terms of this chapter, this can be thought of as applying the principles of inherent safety, passive safety, and active safety controls. The IAEA Regulations incorporate these principles by:

- Limiting the nature and activity of the radioactive material which may be transported in a package of a given design (see Section IV of TS-R-1);
- Specifying design criteria for each type of package (see Section VI of TS-R-1);
- Providing information on hazards by labels, marking, placards, and shipping papers (see Section V of TS-R-1);
- Applying simple rules of handling and stowage of the packages during transport and in-transit storage (see paragraphs 562–569 of TS-R-1).

5.2. Radioactive material

Following these basic safety concepts, it is important first to accurately characterize the radioactive material that is planned for shipment. The various possibilities were introduced in the previous chapter on terminology. The factors that need to be known in order to characterize the radioactive material include:

- the form (special form or not);
- the applicable A_1/A_2 value;
- the A_2/g value; and
- the nature of the material itself (e.g. instrument or article, surface contamination, combustibility, fissile properties, irradiated fuel, UF_6, and other dangerous properties).

The derivation of A_1/A_2 values and their application to material types are the subjects of Chapter 6.

Knowledge of the factors listed, along with the quantity of radioactive material that needs to be shipped, will largely characterize the material and determine the packaging needed. This process is discussed in the next few chapters.

Continuing with the basic safety theme, material that is exempt from the Regulations (see Section 4.3) clearly falls under the inherently safe criterion. The same can be said for material that can be shipped in excepted packagings. In addition, the nature of LSA-I is such that it would be very difficult to ingest or inhale sufficient quantities to cause a radiological problem. More hazardous material types however, need to progressively rely on the packaging for some aspects of safety.

5.3. Packages

The correlation between the three conditions of transport discussed earlier in 5.1.2. and the eight basic packaging types is an important aspect of the safety built into the Regulations. Table 5.1 just gives the broad overview.

TABLE 5.1. CONDITIONS OF TRANSPORT ASSOCIATED WITH DIFFERENT PACKAGES

Conditions of transport	Type of package
Routine	Excepted; Industrial Type IP-1, -2 and -3; Type A; Type B(U) and Type B(M); Type C
Normal	Industrial Type IP-2 and 3; Type A; Type B(U), and B(M); Type C
Accident	Type B(U) and Type B(M); Type C

Since packages are very much the key to the Regulations, information on them is found in several sections of TS-R-1. The contents limits and material restrictions for the different types of packages are defined in Section IV. The requirements for packagings and packages, including the tests needed as well as the pass criteria, are presented in a hierarchical fashion in Section VI of the Regulations. These build from the "General requirements for all packagings and packages” (TS-R-1 paragraphs 606–616) to “Requirements for packages containing fissile material” (TS-R-1 paragraphs 671–682). The specific procedures for all of the tests referred to in Section VI for the various types of package designs are specified in a similar fashion in Section VII of the Regulations.

Because of this method of presentation in the Regulations, it is sometimes difficult to gain a general overview of the requirements applicable for all of the packages. For this reason, information on packages is presented differently in this training manual. Following the general philosophical introduction given here, the package types, their limits, and typical contents are covered in Chapter 7. The requirements, design considerations, and examples of packages are given in the Chapter 8. In Chapter 8, the Figures 8.1 and 8.2 and the Tables 8.1, 8.2, 8.3 and 8.4, have been developed as a summary of much of these data. The figures and tables provide at a glance both the requirements needed for a particular package type as well as the package types for which a particular requirement is applicable. Because there is always more detail in the Regulations than can be provided in the table, the relevant paragraphs are given for reference. Tables 8.2, 8.3 and 8.4. provide a general and a detailed listing of the requirements for all package types from excepted packages to Type C packages. They also include a summary of the test procedures that apply. These three tables can be used to assist in understanding the hierarchical nature of requirements imposed on package designs following the basic philosophical principles discussed in this chapter. Finally, detailed information about the package tests, and how to perform them, is provided in Chapter 8.

It should be noted that the additional considerations for packages containing fissile material are covered separately in Chapter 11.

5.4. Optimization

Optimal practice in radioactive material transport involves seeking the best combination of material type and packaging, as well as considering other factors such as exclusive use and conveyance. Sometimes the radioactive material to be shipped can be characterized to meet more than one of the definitions of material given in the Regulations. In addition, there is often more than one packaging type that may be used. This is especially true if the radioactive material can be split into smaller lots.

Since the Regulations have been designed with the safety principles discussed above, the minimum allowable packaging and transport methods should be used. For example, there is nothing in the regulatory requirements to prevent shipping some radioactive material with an activity totalling 0.5 A_2 in a Type B(U) packaging. However, this is clearly excessive and expensive. The material could almost certainly be shipped more economically in a Type A packaging. Moreover, depending on a number of other factors, it might even be transportable in an industrial package as one of the LSA or SCO categories.

There are many advantages to be gained from optimally characterizing the radioactive material to be shipped and selecting the best packaging and transport options. This is the art of radioactive material transport. However, it can only be practised effectively when one has a complete knowledge of the Regulations.

EXERCISES FOR CHAPTER 5

The following are exercises to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 5.1. Satisfying the Regulations' Objectives

REFERENCE SOURCES: Training Manual, Chapter 5; and TS-R-1 Section I.

DISCUSSION: TS-R-1 sets forth the objective of the transport Regulations, documents four requirements used for achieving the objective, and lists three methods used in the Regulations that ensure that the requirements are satisfied.

PROBLEM: Using Section I of TS-R-1 and the discussion in Chapter 5 of the Training Manual answer the following questions.

a. What is the primary objective of the Regulations?

b. What are the four requirements used to satisfy this objective?

c. What are the three methods used to ensure that the requirements are satisfied?

ANSWER:

EXERCISE 5.2. Graded Approach to Package Integrity

REFERENCE SOURCES: Training Manual, Chapter 5; TS-R-1, Section I

DISCUSSION: Safety during transport of radioactive material lies in the integrity of the package after different situations.

PROBLEM:

a. What three severity levels in the performance standards do different packages have to withstand?

b. What severity levels are required from the different types of packages?

ANSWER:

6. ACTIVITY LIMITS AND MATERIAL RESTRICTIONS

The current version of the Regulations, TS-R-1 [1], imposes three limits in relation to the activity of radionuclide contents. These three limits are:

(1) A_1 and A_2 in TBq (paragraphs 201 and 401(a) of TS-R-1),
(2) Activity concentration for exempt material in Bq/g (paragraphs 240 and 401(b) of TS-R-1), and
(3) Activity limits for exempt consignments in Bq (paragraph 401(c) of TS-R-1).

Table I of TS-R-1 specifies these limits for commonly encountered radionuclides. The first two materials listed in that table (i.e. Actinium and Silver), and the activity limits for the seven commonly encountered radionuclides associated with those two materials, are shown in Table 6.1. The following sections address the manner in which these limits are derived.

TABLE 6.1. EXAMPLE OF BASIC RADIONUCLIDE VALUES

Radionuclide (atomic number)	A_1 (TBq)	A_2 (TBq)	Activity concentration for exempt material (Bq/g)	Activity limit for an exempt consignment (Bq)
Actinium (89)				
Ac-225[a]	8×10^{-1}	6×10^{-3}	1×10^{1}	1×10^{4}
Ac-227[a]	9×10^{-1}	9×10^{-5}	1×10^{-1}	1×10^{3}
Ac-228	6×10^{-1}	5×10^{-1}	1×10^{1}	1×10^{6}
Silver (47)				
Ag-105	2×10^{0}	2×10^{0}	1×10^{2}	1×10^{6}
Ag-108m[a]	7×10^{-1}	7×10^{-1}	1×10^{1}	1×10^{6}
Ag-110m[a]	4×10^{-1}	4×10^{-1}	1×10^{1}	1×10^{6}
Ag-111	2×10^{0}	6×10^{-1}	1×10^{3}	1×10^{6}

[a] A_1 and/or A_2 values include contributions from daughter nuclides with half-lives less than 10 days.

6.1. Derivation of A_1/A_2 limits

The values of A_1 and A_2 specified in the Regulations come from what became known in the late 1970's as the Q-system. The development of the Q-system was initiated in support of the 1985 Edition of the Regulations (Safety Series No. 6) [2] to provide a justifiable dosimetric basis for the A_1 and A_2 values. It was extended to support the development of the 1996 Edition of the Regulations (ST-1, now TS-R-1 [1]).

6.1.1. Background

The various limits prescribed in the Regulations to control the release of radioactivity from transport packages are based upon the activity contents limits for Type A packages.

These limits are also used for several other purposes such as in specifying Type B and Type C package activity leakage limits, LSA materials, and excepted package contents limits.

Type A packages are intended to provide economical transport for large numbers of small activity consignments, while at the same time achieving a high level of safety. The contents limits are set so as to ensure that the radiological consequences of severe damage to a Type A package are acceptable. Thus package design approval by the Competent Authority is not required, (except for packages containing fissile material). Activities in excess of the Type A package limits are covered in the Regulations by the requirements for Type B or Type C packages, which require Competent Authority approval. The design requirements for these packages result in a very low probability of significant activity release as a consequence of a very severe accident.

Originally, radionuclides were classified into seven groups for transport purposes, each group having its Type A package content limits for special form radioactive material and for material in all other forms. Special form radioactive material was defined as that which was non-dispersible when subjected to specified tests. In the 1973 Edition of the Regulations the group classification system was developed into the A_1/A_2 system, where each nuclide had two Type A package contents limits, specified in curies. These were:

- A_1 when transported in special form, and
- A_2 when not in special form.

The dosimetric basis of the A_1/A_2 system relied upon a number of somewhat pragmatic assumptions. A whole body dose limit of 3 rem (30 mSv) was assumed in the derivation of A_1. Although in calculating A_1 values, the exposure was limited to 3 R (~30 mGy) at a distance of 3 m in a period of 3 hours, an intake of $10^{-6} \times A_2$ was assumed in the derivation of A_2 as a result of a *median accident*. Such an intake leads to half the maximum permissible annual intake for a radiation worker. The *median accident* was defined arbitrarily as one which, for a Type A package, leads to a complete loss of shielding and to a release of 10^{-3} of the package contents in such a manner that 10^{-3} of this released material was subsequently taken in by a bystander.

The Q-system developed for the 1985 Edition of the Regulations, and reassessed and modified for the 1996 edition of the Regulations [1], includes consideration of a broader range of specific exposure pathways than the earlier A_1/A_2 system. However, it continued to use the same assumptions as those used in the original Q-system. Many of these are similar to those in the 1973 Edition of the Regulations, but in situations involving the intake of radioactive material, use was made of new data and concepts recently recommended by the ICRP [3, 4]. In particular, subjective assumptions were made regarding the extent of package damage and release of contents without reference to a *median accident*.

6.1.2. Basis of the Q-system

The Q-system considers a series of exposure routes for persons in the vicinity of a Type A package involved in a severe transport accident. The dosimetric routes are illustrated schematically in Fig. 6.1. These led to five contents limit values:

(1) Q_A for external photon dose,
(2) Q_B for external beta dose,
(3) Q_C for inhalation dose,
(4) Q_D for skin and ingestion dose due to contamination transfer,
(5) Q_E, for submersion dose.

Content limits for special form alpha and neutron emitters and tritium were considered separately. Type A package contents limits were determined for individual radionuclides. The A_1 value for special form material was the lesser of the two values Q_A and Q_B, while the A_2 value for non-special form radioactive material was the least of A_1 and the remaining Q values. Specific assumptions concerning the exposure pathways used in the derivation of individual Q values are discussed below, but all are based upon the following radiological criteria:

(1) The effective or committed effective dose to a person exposed near a transport package following an accident should not exceed a reference dose of 50 mSv;
(2) The dose or committed dose equivalent 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;
(3) A person is unlikely to remain at 1m from the damaged package for more than 30 minutes.

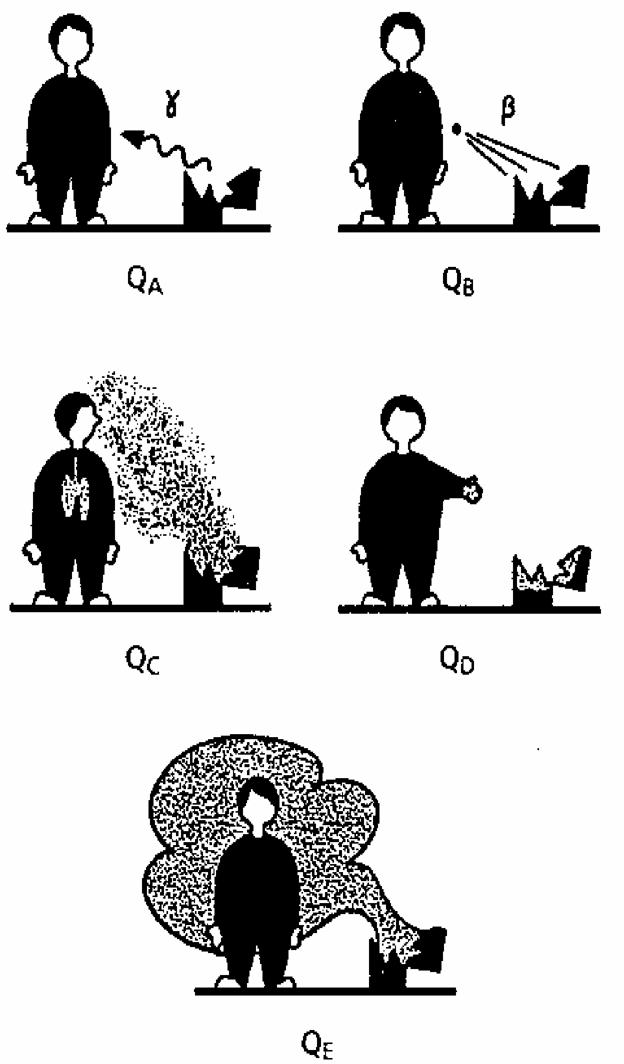

FIG. 6.1. Schematic representation of exposure pathways used in the Q-system.

In terms of the Basic Safety Standards (BSS) [5], the Q-system lies within the domain of *potential exposures*. A potential exposure is one that is not expected to be delivered with certainty, but may result either (a) from an accident at a source or (b) from an event or sequence of events of a probabilistic nature, including equipment failures and operating errors. For potential exposures, the dose limits set forth in the BSS are not relevant (see Schedule II, Table II-3 of the BSS [5]).

In the 1985 Edition of the Regulations, the reference dose (50 mSv) used in the derivation of A_1/A_2 values was linked to the annual dose limit for radiation workers. Although this link to the annual dose limit for workers is no longer valid for potential exposures, 50 mSv has been retained in the current Q-system assessment on the grounds that, historically, actual accidents involving Type A packages have led to very low exposures. In choosing a reference dose, it was agreed by the developers of the Q-system that it was also important to take into account the probability of an individual being exposed as the result of a transport accident. Such exposures may, in general, be considered as once in a lifetime exposures. Clearly, most individuals will never be exposed.

The exposure period of 30 minutes at a distance of 1 m is a cautious judgement of the incidental exposure of persons initially present at the scene of an accident, based on the assumption that subsequent recovery operations take place under health physics supervision and control. This is considered to be more realistic than the earlier assumption of exposure for 3 hours at a distance of 3 m. Coupled with the dose limits cited above, it leads to a limiting dose rate from the damaged Type A package for whole body photon irradiation of 100 mSv/h at 1 m.

6.1.3. Dosimetric models and assumptions

In this section, the dosimetric models and assumptions underlying the derivation of five principal Q values are briefly summarized. Further details can be obtained by referring to Appendix I of TS-G-1.1 [6].

6.1.3.1. Q_A — External dose due to photons

The Q_A value for a radionuclide is determined by consideration of the external radiation dose due to gamma or X-rays to the whole body of a person exposed near a damaged Type A package following an accident. The shielding of the package is assumed to be completely lost in the accident and the consequent dose rate at a distance of 1 m from the edge (or surface) of the unshielded radioactive material is limited to 100 mSv/h. It is further assumed that the damaged package may be treated effectively as a point source.

In the earlier Q-system, Q_A was calculated using the mean photon energy per disintegration taken from ICRP Publication 38 [7]. Furthermore, the conversion to effective dose per unit exposure free-in-air was approximated as 6.7 mSv/R from photon energies between 50 keV and 5 MeV.

In the revised Q-system, the Q_A values have been calculated using the complete X-ray and gamma emission spectrum for the radionuclides as given in ICRP Publication 38 [7]. The energy dependent relationship between effective dose and exposure free-in-air is that given in ICRP Publication 51 [8] for an isotropic radiation geometry.

6.1.3.2. Q_B — External dose due to beta emitters

The Q_B value is determined by consideration of the beta dose to the skin of a person exposed following an accident involving a Type A package containing special form radioactive material. As with Q_A the shielding of the transport package is again assumed to be completely lost in the accident. However, a residual shielding factor for beta emitters, which is associated with materials such as package debris was used. This concept assumed a very conservative shielding factor of 3 for beta emitters of maximum energy 2 MeV, and within the Q-system this practice is extended to include a range of shielding factors dependent on beta energy based on an absorber of approximately 150 mg/cm^2 thickness.

In the revised Q-system, Q_B is calculated using the complete beta spectra for the radionuclides of ICRP Publication 38 [7]. The spectral data for the nuclide of interest is used along with data from Cross [10, 11] on the skin dose rate per unit activity of a mono-energetic electron emitter. The self-shielding of the package is taken to be a smooth function of the maximum energy of the beta spectrum, as depicted in Figure 6.2.

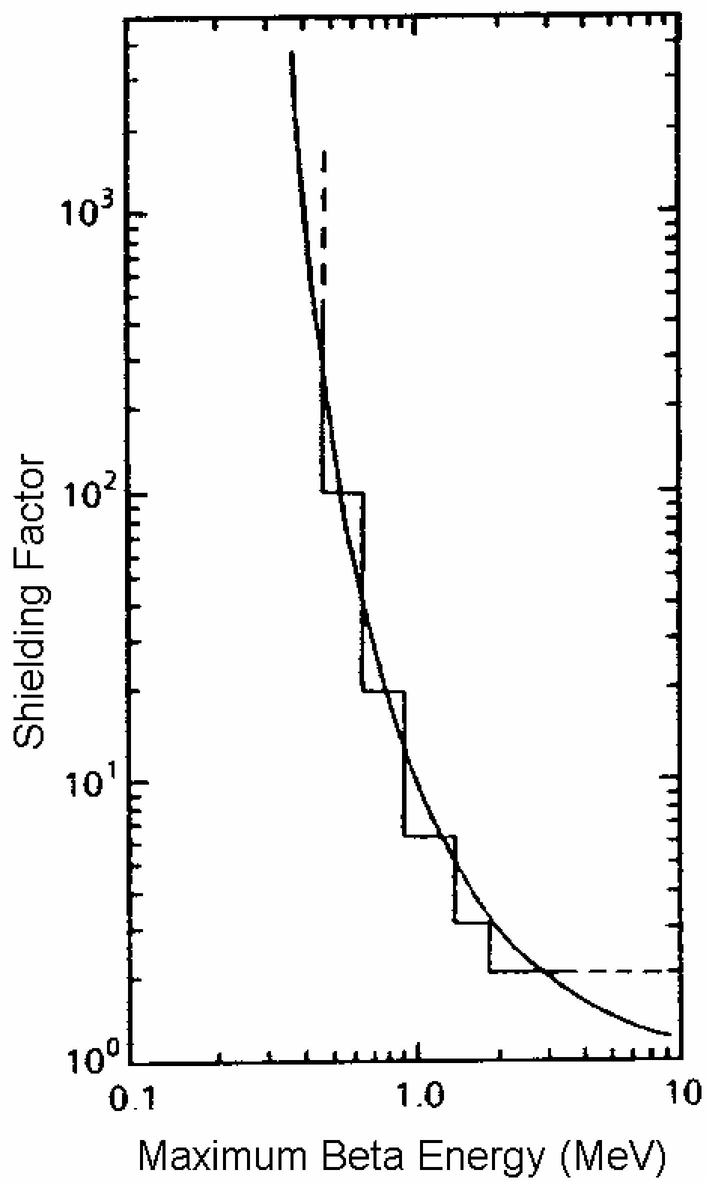

FIG. 6.2. Shielding factor as a function of beta energy.

Three additional factors were considered in the revised Q-system. Firstly, although the dose limit for the lens of the eye is lower than that for the skin, consideration of the depth doses in tissues for beta emitters indicates that the dose to the skin is always limiting for maximum beta energies up to approximately 4 MeV [12, 13, 14]. Thus, specific consideration of the dose to the lens of the eye was judged to be unnecessary.

Secondly, in accounting for conversion electrons in the determination of Q values, they were treated as mono-energetic beta particles, and weighted according to their yields. Thirdly, relative to the treatment of positron annihilation radiation, this was not included in the evaluation of the beta dose to the skin since it contributes only an additional few per cent to the local dose to the basal layer. However, the 0.51 MeV gamma rays are included in the photon energy per disintegration used in the derivation of Q_A.

6.1.3.3. Q_C — Internal dose via inhalation

The Q_C value relates to a radionuclide transported in a non-special form, where it has the potential to become airborne and inhaled in the event of an accident. It is determined by consideration of the inhalation dose to a person exposed to the activity released from a damaged Type A package following an accident. Compliance with the limiting doses cited earlier was ensured by restricting the intake of activity under accident conditions to the annual limit on intake (ALI) recommended by the ICRP [15].

Under the Q-system, a range of accident scenarios is considered, including that originally proposed for the derivation of Q_C. The accidents encompassed those occurring both indoors and out of doors and included the possible effects of fires. In the 1973 Edition of the Regulations, it was assumed that 10^{-3} of the package contents might escape as a result of a median accident and that 10^{-3} of this material might be taken into the body of a person involved in the accident. This resulted in a net intake factor of 10^{-6} of the package contents. Although this value has been retained within the Q-system, it is now recognized as representing a range of possible release fractions and a range of uptake factors. The model considers intake factors in terms of these two parameters independently.

The range of release fractions now recognized under the Q-system is 10^{-3}–10^{-2} of the package contents. This covers the range represented by the earlier assumption in the 1973 Edition of the Regulations, and also the range used in the original Q-system. Underlying this is the tacit assumption that the likelihood of a major accident, which could cause the escape of a large part of the contents of a Type A package, is small. This approach is borne out by the behaviour of Type A packages in severe accident environments [16, 17, 18].

For inhalation, it is the respirable aerosols released from the package which need to be taken into consideration. Data on the respirable aerosol fractions produced under accident conditions are generally sparse and are only available for a limited range of materials. For example, for uranium and plutonium specimens under enhanced oxidation rate conditions in air and carbon dioxide, respirable aerosol fractions up to approximately 1% have been reported [19]. However, below this level the aerosol fractions showed wide variations dependent on the temperatures and local atmospheric flow conditions. In the case of liquids, higher fractional releases are obviously possible. However, the multiple barriers provided by typical Type A packaging materials, potentially including absorbent material, a two-component containment system, and a lead shielding pot, remain an effective containment system even after severe impact or crushing accidents [18]. Indeed, in an example cited of an ^{131}I source, which was completely crushed in a highway accident, less than 2% of the package contents remained on the road after removal of the package debris [20].

Potentially the most severe accident environment for many Type A packages is the combination of severe mechanical damage accompanied by exposure to a fire. However, even in this situation the role of debris may be significant in retaining released activity. This is indicated by data from the 1979 Athens DC8 aircraft accident [17, 18]. Frequently, fires produce relatively large particles of material, which would tend to minimize any intake via inhalation, while at the same time providing a significant surface area for the absorption of volatile species and vaporized liquids. A further mollifying factor is the enhanced local dispersion associated with the convective air currents due to the fire, which would also tend to reduce intake via inhalation.

On the basis of considerations of the type outlined above, the release fraction in the range of 10^{-3}–10^{-2} was established, and was assumed to be appropriate for the determination of Type A package contents limits within the Regulations.

The range of uptake factors (i.e. the fraction of material released that is inhaled) now recognized under the Q-system is 10^{-4}–10^{-3}. This is based upon consideration of a range of possible accident situations, both indoors and out of doors. The original Q-system considered exposure within a storeroom or cargo-handling bay of 300 m^3 volume with four room air changes per hour. Assuming an adult breathing rate of 3.3×10^{-4} m^3/s, this resulted in an uptake factor of approximately 10^{-3} for a 30-minute exposure period. An alternative accident scenario might involve exposure in a transport vehicle of 50 m^3 volume with ten air changes per hour, as originally employed in the determination of the Type B package normal transport leakage limit in the 1985 Edition of the Regulations. Using the same breathing rate and exposure period as above, this led to an uptake factor of 2.4×10^{-3}, which is of the same order as the value obtained above.

For accidents occurring out of doors, the most conservative assumption for the atmospheric dispersion of released material is that of a ground level point source. Tabulated dilution factors for this situation at a downwind distance of 100 m range from 7×10^{-4} to 1.7×10^{-2} s/m^3 [21], corresponding to uptake factors in the range 2.3×10^{-7} to 5.6×10^{-6} for the adult breathing rate cited above. These values apply to short term releases and cover the range from highly unstable to highly stable weather conditions; the corresponding value for average conditions is 3.3×10^{-7}, which is towards the lower end of the range quoted above.

Extrapolation of the models used to evaluate the atmospheric dilution factors to shorter downwind distances is unreliable, but reducing the exposure distance by an order of magnitude to 10 m would increase the above uptake factors by about a factor of 30. This indicates that as the downwind distance approaches a few metres the uptake factors would approach the 10^{-4}–10^{-3} range used within the Q-system. However, under these circumstances other factors, which would tend to reduce the activity uptake, come into effect and may even become dominant. The additional turbulence to be expected in the presence of a fire has been mentioned earlier. Similar reductions in airborne concentrations can be anticipated as a result of turbulence originating from the flow of air around any vehicle involved in an accident or from the effects of nearby buildings. Thus, on balance, it can be seen that uptake factors in the range of 10^{-4}–10^{-3} appear reasonable for the determination of Type A package contents limits.

When this range in uptake factors is taken in conjunction with the range in release fractions discussed earlier, the overall intake factor for a Type A package becomes 10^{-6}. This is the same as that used in the original Q-system. However, it is emphasized that this value represents a combination of releases typically in the range up to 10^{-3}–10^{-2} of the package contents as a respirable aerosol, combined with an uptake factor of up to 10^{-4}–10^{-3} of the released material.

The ranges of release and uptake noted above are partially determined by the chemical form of the material and particle size of the aerosol. The chemical form consideration has a major influence on the dose per unit intake. The intake fraction derived above is consistent with the value used in the earlier Q-system. In calculating Q_C the most restrictive chemical form has been assumed and the effective dose coefficients, for an aerosol characterized by an aerosol median aerodynamic diameter (AMAD) of 1 micron, where applicable, are assumed [5, 7]. The 1 μm AMAD value used in the earlier Q-system is retained even though other AMAD values can give more conservative dose coefficients for some radionuclides.

For uranium, the Q_C values are presented in terms of the lung absorption types (formerly referred to as lung clearance classes) assigned for the major chemical forms of uranium. This more detailed evaluation of Q_C was undertaken because of sensitivity of the dose per unit intake to the absorption type and the fact that the chemical form of uranium in transport is generally known.

6.1.3.4. Q_D – Skin contamination and ingestion doses

The Q_D value for beta emitters is determined by consideration of the *beta dose to the skin* of a person contaminated with non-special form radioactive material as a consequence of handling a damaged Type A package.

The model used within the Q-system assumes that:

- 1% of the package contents are spread uniformly over an area of 1 m^2,
- handling of the debris is assumed to result in contamination of the hands to 10% of this level [22], and
- the exposed person is not wearing gloves but would recognize the possibility of contamination or wash his hands within a period of 5 hours.

Taken individually, these assumptions are somewhat arbitrary, but as a whole, they represent a reasonable basis for estimating the level of skin contamination that might arise under accident conditions. Values for Q_D were calculated using the beta spectra and discrete electron emissions for the radionuclides as tabulated by ICRP [7, 8]. The emission data for the nuclide of interest was used with data from Cross [23] on the skin dose rate for mono-energetic electrons emitted on the surface of the skin.

The models used in deriving the Q_D values for skin contamination were also employed to estimate the possible *uptake of activity via ingestion*. Assuming that a person may ingest all the contamination from 10^{-3} m^2 (10 cm^2) of skin over a 24 hour period [22], the resultant intake is $10^{-6} \times Q_D$, compared with that via inhalation of $10^{-6} \times Q_C$ derived earlier. Since the dose per unit intake via inhalation is generally of the same order or greater than that via ingestion [4], the inhalation pathway will normally be limiting for internal contamination due to beta emitters. Where this does not apply, almost without exception, Q_D is much smaller than Q_C, and explicit consideration of the ingestion pathway is unnecessary.

6.1.3.5. Q_E – Submersion dose due to gaseous isotopes

The Q_E value for gaseous isotopes, which do not become incorporated into the body, is determined by consideration of the submersion dose following their release in an accident. A rapid 100% release of the package contents into a storeroom or cargo-handling bay of dimensions $3 \times 10 \times 10$ m^3, with four air changes per hour, is assumed to provide the bounding case for this assessment. This leads to an initial airborne concentration of

$Q_E/300\ m^{-3}$, which falls exponentially with a decay constant of 4 h^{-1} as a result of ventilation over the subsequent 30 minute exposure period to give a mean concentration level of $1.44 \times 10^{-3} \times Q_E\ m^{-3}$. Over the same period the concentration leading to the dose limits cited earlier is 4000 × DAC (Bq/m^3), where the DAC was the derived air concentration recommended by the ICRP for 40 hours per week and 50 weeks per year occupational exposure in a 500 m^3 room. However, the use of the radiation protection quantity, DAC, is no longer deemed appropriate. Therefore the modified Q-system calculations use an effective dose coefficient for submersion in a semi-infinite cloud, from U.S.E.P.A. Federal Guidance Report No. 12 [24], as shown in Table 6.2.

TABLE 6.2. DOSE COEFFICIENTS h_{SUB} FOR SUBMERSION ($Sv \cdot Bq^{-1} \cdot s^{-1} \cdot m^3$)

Nuclide	h_{sub}	Nuclide	h_{sub}
Ar-37	0	Xe-122	2.19E-15
Ar-39	1.15E-16	Xe-123	2.82E-14
Ar-41	6.14E-14	Xe-127	1.12E-14
Ar-42	no value	Xe-131m	3.49E-16
Kr-81	2.44E-16	Xe-133	1.33E-15
Kr-85	2.40E-16	Xe-135	1.10E-14
Kr-85m	6.87E-15	Rn-218	3.40E-17
Kr-87	3.97E-14	Rn-219	2.46E-15
		Rn-220	1.72E-17
		Rn-222	1.77E-17

6.1.3.6. Special considerations

The dosimetric models described in the previous section apply to the vast majority of radionuclides of interest and may be used to determine their Q values, and the associated A_1 and A_2 values. However, in a limited number of cases the models are inappropriate or require modification. The special considerations that apply in such cases are discussed in this section.

The original Q-system assumed a maximum transport time of 50 days and thus radioactive decay products with half-lives less than 10 days were assumed to be in equilibrium with their longer lived parents. In such cases, the Q values were calculated for the parent and its progeny and the limiting value was used in determining A_1 and A_2 of the parent. In cases where a daughter radionuclide has a half-life either greater than 10 days or greater than that of the parent nuclide then such progeny, with the parent, were considered to be a mixture. The ten-day half-life criterion is retained in TS-R-1. Progeny radionuclide products with half-lives less than 10 days are assumed to be in secular equilibrium with the longer lived parent. However, the daughter's contribution to each Q value is summed with that of the parent. This provides a means of accounting for progeny with branching fractions less than one. For example, ^{137m}Ba is produced in 0.946 of the decays of its parent ^{137}Cs. In addition, if the parent's half-life is less than 10 days and the daughter's half-life is greater than 10 days, then the mixture rule is to be used by the consignor. For example, a package containing ^{47}Ca (4.53 d) is evaluated with its ^{47}Sc (3.351 d) daughter in transient equilibrium with the parent. A package containing ^{77}Ge (11.3 h) is evaluated by the consignor as a mixture of ^{77}Ge and its daughter ^{77}As (38.8 h).

In some cases, a long-lived daughter is produced by the decay of a short-lived parent. In these cases, the potential contribution of the daughter to the exposure cannot be assessed without knowledge of the transport time and the build up of progeny nuclides. It is, however, necessary to determine the transport time and the build up of progeny nuclides for the package in establishing the A_1/A_2 values using the mixture rule. As an example, consider ^{131m}Te (30 h) which decays to ^{131}Te (25 min) and which in turn decays to ^{131}I (8.04 d). The mixture rule should be applied by the consignor to this package with the ^{131}I activity derived based on the transport time and the build up of progeny nuclides. It should be noted that the above treatment of the decay chains, in some cases, differs from the BSS Table I of Schedule I. That table assumes that secular equilibrium exists for all chains. The decay chains for which the daughter's contribution is included in determining the Q value for the parent nuclide are listed in section AI.9 of Appendix I of TS-G-1.1 [6].

6.1.4. Alpha emitters

For alpha emitters it was not, in general, appropriate to calculate Q_A or Q_B values for special form material, owing to their relatively weak gamma and beta emissions. In the 1973 Edition of the Regulations an arbitrary upper limit for special form alpha sources of $10^3 \times A_2$ was introduced. There was no dosimetric justification for this procedure. In recognition of this, coupled with the good record in the transport of special form radioactive material, and the reduction in many Q_C values for alpha emitters resulting from the use of the latest ICRP recommendations [4], a tenfold increase in the arbitrary factor was used in the modified Q-system. Thus an additional Q value, $Q_F = 10^4 \times Q_C$, was defined for special form alpha emitters and is listed in the column headed Q_A where appropriate in the tabulation of Q values.

A radionuclide is defined as an alpha emitter for the purpose of the special form consideration if (a) in greater than 10^{-3} of its decays, it emits alpha particles; or (b) it decays to an alpha emitter. For example, ^{235}Np which decays by alpha emission in 1.4×10^{-5} of its decays is not an alpha emitter for the purpose of the special form consideration. Conversely, ^{212}Pb is an alpha emitter since its daughter ^{212}Bi undergoes alpha decay. Overall, the special form limits for alpha emitters have increased with increases in Q_C with the modified Q-system.

Finally, with respect to the ingestion of alpha emitters, arguments analogous to those used for beta emitters in the discussion on Q_D apply, and the inhalation rather than the ingestion pathway is always more restrictive. Hence the latter is not explicitly considered.

6.1.5. Neutron emitters

In the case of neutron emitters it was originally suggested under the Q-system that there were no known situations with (α,n) or (γ,n) sources or the spontaneous neutron emitter ^{252}Cf for which neutron dose would contribute significantly to the external or internal radiation pathways considered earlier [25]. However, neutron dose cannot be neglected in the case of ^{252}Cf sources. Data given in ICRP Publication 21 [26] for neutron and gamma emissions indicate a dose rate of 2.54×10^3 rem/h (25.4 Sv/h) at 1 m from a 1 g ^{252}Cf source.

Combined with the dose rate limit of 10 rem/h (0.1 Sv/h) at this distance cited earlier, this led to a Q_A value for ^{252}Cf of 0.095 TBq. The increase of a factor of about 2 in the radiation weighting factor for neutrons recommended by ICRP [26] gives a current value of 4.7×10^{-2} TBq for Q_A. This is more restrictive than the Q_F value of 28 TBq obtained based on the revised expression for special form alpha emitters. The neutron component dominates the external dose due to a ^{252}Cf source and similar considerations apply to the two other potential spontaneous fission sources ^{248}Cm and ^{254}Cf. The Q_A values for these radionuclides were evaluated assuming the same dose rate conversion factor per unit activity as for the ^{252}Cf source quoted above, with allowance for their respective neutron emission rates relative to that of this source.

6.1.6. Bremsstrahlung radiation

The A_1 and A_2 values tabulated in the 1973 Edition of the Regulations were subject to an upper cut-off limit of 1000 Ci (37 TBq) in order to protect against possible effects of bremsstrahlung radiation. Within the Q-system, this cut-off was retained at 40 TBq. It was recognized that this was an arbitrary cut-off and was not specifically associated with bremsstrahlung radiation or any other dosimetric consideration. It remains unchanged. A preliminary evaluation of bremsstrahlung, in a manner consistent with the assumptions of Q_A and Q_B, indicates that the 40 TBq figure is a reasonable value. However, explicit inclusion of bremsstrahlung within the Q-system might limit A_1 and A_2 for some nuclides to about 20 TBq, a factor of 2 lower. This analysis supports the use of an arbitrary cut-off.

6.1.7. Tritium and its compounds

During the development of the Q-system, it was considered that liquids containing tritium should be treated separately. The model used was a spill of a large quantity of tritiated water in a confined area followed by a fire. The A_2 value for tritiated liquids resulting from these assumptions was set in the 1985 Edition of the Regulations at 40 TBq, with an additional condition that the concentration should be smaller than 1 TBq/L. For the revised Q-system, no change was considered necessary.

6.1.8. Radon and its progeny

As noted earlier, the derivation of Q_E applies to noble gases, which are not incorporated into the body, and whose progeny are either a stable nuclide or another noble gas. In a few cases, this condition is not fulfilled and dosimetric routes other than external exposure due to submersion in a radioactive cloud must be considered [27]. The only case of practical importance within the context of the Regulations is that of ^{222}Ra, where the lung dose associated with the inhalation of the short lived radon progeny has received special consideration by the ICRP [28].

In the derivation of the Q values for ^{222}Ra, account is taken of the daughter radionuclides listed in Attachment A of Appendix I of TS-G-1.1. The corresponding Q_C value in the original Q-system was calculated to be 3.6 TBq. Allowing for a 100% release of radon, (rather than the 10^{-3}–10^{-2} aerosol release fraction incorporated in the Q_C model), this reduces to a Q_C value in the range 3.6×10^{-3} to 3.6×10^{-2} TBq. Treating ^{222}Ra plus its progeny as a noble gas resulted in a Q_E value of 4.2×10^{-3} TBq. This value is towards the lower end of the range of Q_C values. This is still the Type A package non-special form limit cited for ^{222}Ra in the tabulation of Q values. Radon dosimetry is continuing to be developed and these values may be revised in the future.

6.1.9. Assessment of low specific activity material having unlimited A_1 or A_2 values

The 1973 Edition of the Regulations recognized a category of radioactive material the specific activities of which are so low that it is inconceivable that an intake could occur which would give rise to a significant radiation hazard. These are called low specific activity (LSA) material. They were defined in terms of a model which assumed that it was most unlikely that a person would remain in a dusty atmosphere long enough to inhale more than 10 mg of material. Under these conditions, if the specific activity of the material is such that the mass intake is 10^{-6} A_2, then this material should not present a greater hazard during transport than the quantities of radioactivity transported in Type A packages.

This hypothetical model is retained within the Q-system. It leads to an LSA criterion limit of $10^{-4} \times Q_C$ g^{-1}. Thus, the Q values for those radionuclides whose specific activity is below this level are listed as "unlimited." In the cases where this criterion is satisfied, the effective dose equivalent associated with an intake of 10 mg of the nuclide is less than the dose criterion of 50 mSv. Natural uranium and thorium, depleted uranium and other material such as ^{238}U, ^{232}Th, and ^{235}U satisfy the above LSA criterion. Calculations using the latest dose coefficients listed in the BSS [5] and by ICRP [4] indicate that unirradiated uranium enriched to <20% also satisfies the same criterion, on the basis of the isotopic mixtures given in ASTM C996-90 [29]. A_1 and A_2 values for irradiated reprocessed uranium should be calculated based on the mixtures equation, taking into account uranium radionuclides and fission products.

The above excludes consideration of chemical toxicity for which a daily intake limit of 2.5 mg was recommended by ICRP [30].

A further consideration relevant to LSA material in the context of the skin contamination model used in the derivation of Q_D is the mass of material that might be retained on the skin for any significant period of time. The consensus view of the Special Working Group meeting on the modified Q-system was that, typically, 1-10 mg/cm^2 of dirt present on the hands would be readily discernible and would be removed promptly by wiping or washing, irrespective of the possible presence of radioactivity. It was agreed that the upper extreme of this range was appropriate as a cut-off for the mass of material retained on the skin and, in combination with the skin contamination model for Q_D, this resulted in an LSA limit of $10^{-5} \times Q_D$ g^{-1}. On this basis, Q_D values for radionuclides for which this criterion applies are also listed in the Regulations as "unlimited" in the tabulation of Q values.

6.1.10. Tabulation of Q values and selection of A_1 and A_2 limits

A full listing of Q values determined based on the models described above is given in Table AI.2 of Appendix I of TS-G-1.1. Also included are the corresponding Type A package A_1 and A_2 content limit values for special form and non-special form radioactive material, respectively. The Q values shown in that table have been rounded to two significant figures, and the A_1 and A_2 limiting values to one significant figure. In the latter case the arbitrary cut-off of 40 TBq has also been applied (i.e., the limiting values are not allowed to exceed 40 TBq except for those nuclides where the A_1 and A_2 limiting values are designated as "unlimited").

In general, the A_1 and A_2 limiting values under the modified Q-system lie within a factor of about 3 of the original Q-system values although there are a few radionuclides where the new A_1 and A_2 values are outside this range. A few tens of radionuclides have new A_1 values higher than previous values by factors ranging between 10 and 100. This is due primarily to the improved modelling for beta emitters. There are no new A_1 or A_2 values lower than the previous figures by more than a factor of 10. A few radionuclides previously listed are now excluded but two additional ones are included, namely both isomers of ^{150}Eu and ^{236}Np.

Examples of the Q-system values, and the selection of the Type A package A_1 and A_2 content limit values for special form and non-special form radioactive material, respectively are shown in Table 6.3. This abbreviated version of the full table from Appendix I of TS-G-1.1 is used here to illustrate how the A_1 and A_2 limiting values are derived from the various Q values.

TABLE 6.3. TYPE A PACKAGE CONTENTS LIMITS: Q_A, Q_B, Q_C, Q_D and Q_E VALUES AND LIMITS FOR SPECIAL FORM (A_1) AND NON-SPECIAL FORM (A_2) MATERIAL

Radionuclide	a - Q_F tabulated in place of Q_A	Q_A or Q_F (TBq)	Q_B (TBq)	Q_C (TBq)	Q_D or Q_E (TBq)	A_1 (TBq)	A_2 (TBq)
Actinium							
Ac-225		4.9e+00	8.5e-01	6.3e-03	3.0e-01	8e-01	6e-03
Ac-227	a	9.3e-01	1.3e+02	9.3e-05	3.7e+01	9e-01	9e-05
Ac-228		1.2e+00	5.6e-01	2.0e+00	5.2e-01	6e-01	5e-01
Silver							
Ag-105		2.0e+00	1.0e+03	6.3e+01	2.5e+01	2e+00	2e+00
Ag-108m		6.5e-01	5.9e+00	1.4e+00	6.0e+00	7e-01	7e-01
Ag-110m		4.2e-01	1.9e+01	4.2e+00	2.1e+00	4e-01	4e-01
Ag-111		4.1e+01	1.9e+00	2.9e+01	6.2e-01	2e+00	6e-01
Aluminium							
Al-26		4.3e-01	1.4e-01	2.8e+00	7.1e-01	1e-01	1e-01
Americium							
Am-241	a	1.3e+01	1.0e+03	1.3e-03	3.8e+02	1e+01	1e-03
Am-242m	a	1.4e+01	5.0e+01	1.4e-03	8.4e-01	1e+01	1e-03
Am-243		5.0e+00	2.6e+02	1.3e-03	4.1e-01	5e+00	1e-03

Remember that:

(1) The A_1 limiting value for special form material is determined as being the lesser of the two values Q_A and Q_B,
(2) The A_2 limiting value for non-special form radioactive materials is determined as being the least of A_1 and the remaining Q values.

Multiple situations therefore arise in defining the individual A_1 and A_2 limiting values as follows:

- The A_1 limit is defined by the external dose due to photons (Q_A). An example of this situation from Table 6.3 is ^{243}Am (i.e. Q_A = 5.0 e+00, and A_1 = 5.0 e+00, where no rounding was required).
- The A_1 limit is defined by the upper limit for alpha emitters where Q_F is substituted for Q_A. Examples of this situation from Table 6.3 are: ^{227}Ac, ^{241}Am, and ^{242m}Am (e.g. $Q_A = Q_F$ = 9.3 e-01 for ^{227}Ac, and A_1 = 9.0 e-01, where the Q_F value was rounded down).
- The A_1 limit is defined by the external dose due to beta emitters (Q_B). Examples of this situation from Table 6.3 are: ^{225}Ac, ^{228}Ac, and ^{111}Ag (e.g. Q_B = 8.5 e-01 for ^{225}Ac, and A_1 = 8.0 e-01, where the QB value was rounded down).
- The A_2 limit is defined by the internal dose via inhalation (Q_C). Examples of this situation from Table 6.3 are: ^{225}Ac, ^{227}Ac, ^{241}Am, ^{242m}Am, and ^{243}Am (e.g. Q_C = 6.3 e-03 for ^{225}Ac, and A_1 = 6.0 e-03, where the Q_C value was rounded down).
- The A_2 limit is defined by the skin contamination and ingestion doses (Q_D) or the submersion dose due to gaseous isotopes (Q_E). Examples of this situation from Table 6.3 are: ^{228}Ac and ^{111}Ag (e.g. Q_C = 5.2 e-01 for ^{228}Ac , and A_1 = 5.0 e-01, where the Q_C value was rounded down).

In all of the examples cited above, the Q value was taken as calculated or rounded down. There are cases where rounding up also occurred (e.g. see the selection of the A_1 limiting value for ^{111}Ag where Q_B = 1.9 e+00, and A_1 = 2.0 e+00, where the Q_B value was rounded up).

6.1.11. Consideration of physical and chemical properties

No consideration was given in the Q-system to the chemical form or chemical properties of the radionuclides. However, in the determination of Q_C values the most restrictive of the dose coefficients recommended by the ICRP were used. On balance, it was considered that only in the most extreme circumstances would the assumed intake factor of 10^{-6} be exceeded and that special modification of the Q_C model was unnecessary.

6.1.12. Multiple exposure pathways

Following the 1985 Edition of the Regulations, the application of the Q-system as described here treats the derivation of each Q value, and hence each potential exposure pathway, separately. In general, this will result in compliance with the dosimetric criteria defined earlier, provided that the doses incurred by persons exposed near a damaged package are dominated by one pathway. However, if two or more Q values closely approach each other this will not necessarily be the case. For example, in the case of a radionuclide transported as a special form radioactive material for which Q_A equals Q_B, the effective dose and skin dose to an exposed person could approach 50 mSv and 0.5 Sv, respectively. This consideration applies only to a relatively small number of radionuclides and, for this reason, the independent treatment of exposure pathways was retained within the Q-system.

6.1.13. Summary of Q-system development for TS-R-1 A_1 and A_2 values

The Q-system summarized here, and discussed in more detail in Appendix I of TS-G-1.1 [6] represents an updating of the original A_1/A_2 system used in the 1985 Edition of the

Regulations for the determination of Type A package contents limits and other limits. It incorporates the latest recommendations of the ICRP [3] and by explicitly identifying the dosimetric considerations underlying the derivation of these limits, it provides a firm and defensible basis for the Regulations.

The Q-system now has the following features:

- The radiological criteria and exposure assumptions used in the 1985 Edition of the Regulations have been reviewed and retained.
- The effective dose quantity of the ICRP Publication 60 [3] has been adopted.
- The evaluation of the external dose from photons and beta particles has been rigorously revised.
- The evaluation of inhalation intakes is now in terms of the effective dose and is based on the dose coefficients from ICRP 61 and the Basic Safety Standards [4, 5].

6.2. A_1/A_2 ratios, mixtures, and unlisted radionuclides

One basic principle behind the activity limits in the Regulations is that, for some radionuclides, greater quantities can be transported in a Type A package design if it is special form, whereas for other radionuclides, the limit is the same irrespective of whether the material is special form or not. Examples can be seen from the data shown in Table 6.3 above.

Of the radionuclides listed in Table 6.3, those that have A_1 values that are greater than their A_2 values are shown in Table 6.4. The ratios of A_1/A_2 are shown, to indicate the increase in activity possible in a Type A package if the material is in special form. The increase ranges from very small for ^{228}Ac, to very large for ^{227}Ac, ^{241}Am, ^{242m}Am, and ^{243}Am.

There are four examples in Table 6.3 of radionuclides where there is no benefit, in terms of an increased quantity in a Type A package, from qualifying the material as special form; these are ^{105}Ag, ^{108m}Ag, ^{110m}Ag, and ^{26}Al. In these four cases, the A_1 and A_2 limiting values are equal.

TABLE 6.4. TYPICAL A_1/A_2 RATIOS FOR THE RADIONUCLIDES SHOWN IN TABLE 6.3

Radionuclide	A_1/A_2 Ratios
^{225}Ac	133
^{227}Ac	10 000
^{228}Ac	1.2
^{111}Ag	3.3
^{241}Am	10 000
^{242m}Am	10 000
^{243}Am	5 000

6.3. A_1/A_2 values for mixtures, unknown quantities and unlisted radionuclides

The A_1 and A_2 limiting values are listed for individual radionuclides. However, it is often necessary to prepare mixtures of radionuclides for transport. Methods are provided in the Regulations for defining the effective A_1 and A_2 limiting values for such mixtures. In addition, situations may exist where the specific radionuclides present in a mixture are known, but the individual activities of those radionuclides are unknown. Finally, cases may arise where a material contains one or more radionuclides not included in the table of limiting A_1 and A_2 limiting values provided in TS-R-1 [1]. The Regulations also provide for these latter two events. The following discusses all three of these concerns.

6.3.1. Mixtures of radionuclides

It is necessary to consider the package contents limits for mixtures of radionuclides, including the special case of mixed fission products. For mixtures whose identities and activities are known, the Regulations specify that the following must be satisfied if a mixture of these radionuclides is to be transported in a Type A package (see para. 414 of TS-R-1):

$$\sum_i \frac{B(i)}{A_1(i)} + \sum_j \frac{C(j)}{A_2(j)} \leq 1$$

where:

B(i) is the activity of radionuclide i as special form material,

A_1(i) is the A_1 value for radionuclide i,

C(j) is the activity of radionuclide j as other than special form material,

A_2(j) is the A_2 value for radionuclide j.

Alternatively, where the mixture comprises radionuclides whose identities and activities are known, then an A_1 or A_2 value for that mixture may be determined using the following equation (see paragraph 404 of TS-R-1):

$$X_m \text{ for mixture} = \frac{1}{\sum_i \frac{f(i)}{X(i)}}$$

where:

f(i) is the fraction of activity (or activity concentration) of radionuclide i in the mixture,

X(i) is the appropriate value of A_1 or A_2 (or the activity concentration for exempt material, or the activity limit for an exempt consignment) for the radionuclide,

X_m is the derived value of A_1 or A_2 (or the activity concentration for exempt material, or the activity limit for an exempt consignment) in the case of a mixture.

6.3.2. Known radionuclides, but unknown individual activities

The Regulations provide for the situation where the individual nuclides present in a mixture are known but the activities of each is not. Paragraph 405 of TS-R-1 indicates that, for this situation:

"…the radionuclides may be grouped and the lowest radionuclide value, as appropriate, for the radionuclides in each group may be used in applying the

formulas…. Groups may be based on the total alpha activity and the total beta/gamma activity when these are known, using the lowest radionuclide values for the alpha emitters or beta/gamma emitters, respectively."

This approach provides a conservative method, from the radiological protection perspective, for defining the A_1 or A_2 value for the mixture when the activities of individual nuclides are not known.

6.3.3. Unlisted radionuclides

The Regulations also provide for the situation where the contents of a package may have one or more radionuclides present which are not listed in Table I of TS-R-1. In this event, two alternatives are provided by the Regulations; either:

- A value for that radionuclide may be calculated, or
- Conservative default values may be used.

Relative to calculating the value, paragraph 402 of TS-R-1 indicates that the calculation:

"…shall require Competent Authority approval or, for international transport, multilateral approval. It is permissible to use an A_2 value calculated using a dose coefficient for the appropriate lung absorption type, as recommended by the International Commission on Radiological Protection, if the chemical forms of each radionuclide under both normal and accident conditions of transport are taken into consideration"

With respect to using conservative default values, those values are provided in Table II of TS-R-1, and are reproduced here as Table 6.5.

TABLE 6.5. BASIC RADIONUCLIDE VALUES FOR UNKNOWN RADIONUCLIDES OR MIXTURES

Radioactive contents	A_1 (TBq)	A_2 (TBq)	Activity concentration for exempt material (Bq/g)	Activity limits for exempt consignments (Bq)
Only beta or gamma emitting nuclides are known to be present	0.1	0.02	1×10^{1}	1×10^{4}
Only alpha emitting nuclides but no neutron emitters are known to be present	0.2	9×10^{-5}	1×10^{-1}	1×10^{3}
Neutron emitting nuclides are known to be present or no relevant data are available	0.001	9×10^{-5}	1×10^{-1}	1×10^{3}

6.4. Material types

The A_1 or A_2 limiting values described in 6.1 to 6.3 above are used throughout the Regulations to control a number of factors in the packaging and the transport of radioactive materials. One of the key uses of the A_1 or A_2 values is in specifying package contents limits for many of the types of packages, and also for defining acceptable release rates for some of the types of packages. These are covered in detail in the next chapter. A_2 is also used in the definition of LSA and low dispersible material. In addition, the Regulations establish exempt quantities, both for material and consignments. Both of these are briefly discussed below.

6.4.1. Exempt quantities for material and consignments

Prior to the 1996 Edition of the Regulations, an exempt quantity was defined independent of the radionuclide. This exempt quantity was established through the definition of radioactive material, such that any material having a specific activity greater than 70 Bq/g was defined as being radioactive material, and was then subject to the requirements of the Regulations. However, the need to establish radionuclide-specific exemption values was established by the experts involved in the deliberations leading to the 1996 Edition of the Regulations [1], and these exemption values (specified in terms of Bq/g) are now included as part of Table I of TS-R-1. Examples of these nuclide-specific limits are shown in the fourth column of Table 6.1 given earlier.

Whereas the previous exemption value was simply 70 Bq/g, the nuclide-specific exemption values are now specified as multiples of the factor ten. These values range from a low of 0.1 Bq/g (for ^{227}Ac); to highs of 1×10^5 Bq/g (for ^{41}Ca, ^{85}Kr, ^{33}P, ^{107}Pd), of 1×10^6 Bq/g (for ^{37}Ar, natural Rhenium, Tritium), and even 1×10^7 Bq/g (for ^{39}Ar). A majority of the nuclide-specific exemption values lie in the range of 1 to 100.

Prior to the 1996 Edition of the Regulations, there was no exempt quantity for a consignment. However, the need to have radionuclide-specific exemption values for consignments was also established by the experts involved in the deliberations leading to the 1996 Edition of the Regulations. These nuclide-specific exemptions for consignments (specified in terms of Bq) are provided as part of Table I of TS-R-1. Examples of these nuclide-specific consignment exemptions are given in the fifth column of Table 6.1. These values range from a low of 1×10^3 Bq to a high of 1×10^{10} Bq.

The wording of the definition of radioactive material (see paragraph 236 of TS-R-1) is critical. It indicates that *both* the activity concentration *and* the total activity in the consignment must exceed the values specified in Table I (or in paragraphs 401 to 406 of TS-R-1, as appropriate) for the material to be defined as radioactive and to be subject to the requirements of the Regulations. For example, consider a material containing a single nuclide, which has an activity concentration greater than the exemption value specified. If the total activity in the consignment is less than the consignment limit, then that material would not be a radioactive material, and the shipment would then not be subject to the requirements of the Regulations.

6.4.2. Use of A_2 values for LSA material

The A_2 values are used in defining LSA material (see paragraph 226 of TS-R-1). LSA-I uses, in one case, the unlimited A_2 values in its definition. LSA-II and LSA-III are defined in terms of specific activities:

- LSA-II must have a specific activity that is less than 10^{-4} A_2/g for solids and gases, and less than 10^{-5} A_2/g for liquids,
- LSA-III must have a specific activity that is less than 2×10^{-3} A_2/g for solids.

In addition, following the immersion test for LSA-III material, the amount of radioactivity released to the water cannot exceed 0.1 A_2.

6.4.3. Low dispersible material

The A_2 values are used in defining low dispersible material (see paragraphs 225 and 605 of TS-R-1). Specifically, following the enhanced thermal and impact tests specified in the Regulations, the amount of radioactivity that can be released as either gas or small particulates cannot exceed 100 A_2.

REFERENCES FOR CHAPTER 6

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Standards Series, Safety Requirements No. TS-R-1, IAEA, Vienna (2005).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 1985 Edition (As Amended 1990), Safety Series No. 6, IAEA, Vienna (1990).

[3] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Recommendations of the International Commission on Radiological Protection, Publication No. 60, Pergamon Press, Oxford and New York (1990).

[4] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Dose Coefficients for Intakes of Radionuclides by Workers, replacement of ICRP Publication No 61, Pergamon Press, Oxford and New York (1995).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1996 Edition), Safety Standards Series No. TS-G-1.1, IAEA, Vienna (2002).

[7] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Task Group on Dose Calculations - Energy and Intensity Data for Emissions Accompanying Radionuclide Transformations, Publication 38, Pergamon Press, Oxford and New York (1984).

[8] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Data for Use in Protection against External Radiation, ICRP Publication 51, Pergamon Press, Oxford and New York (1987).

[9] ECKERMAN, K. F., WESTFALL, R. J., RYMAN, J. C., CRISTY, M., Nuclear Decay Data Files of the Dosimetry Research Group, ORNL/TM-12350, Oak Ridge National Laboratory, Oak Ridge, TN (1993).

[10] CROSS, W.G., ING, H., FREEDMAN, N. O., WONG, P. J., Table of beta-ray dose distributions in an infinite water medium, Health Physics, 63, 2, Aug, (1992).

[11] CROSS, W.G., ING, H., FREEMAN, N. O., MAINVILLE, J., Tables of Beta-ray Dose Distributions in Water, Air, and Other Media, AECL-7617, Atomic Energy of Canada Ltd, Chalk River, Ontario (1982).

[12] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Recommendations of the International Commission on Radiological Protection, Publication 26, Pergamon Press, Oxford and New York (1977).

[13] CROSS, W.G., ING, H., FREEDMAN, N.O., MAINVILLE, J., Tables of Beta-Ray Dose Distributions in Water, Air and Other Media, Rep. AECL-2793, Atomic Energy of Canada Ltd, Chalk River, Ontario (1967).

[14] BAILEY, M.R., BETA: A Computer Program for Calculating Beta Dose Rates from Point and Plane Sources, Rep. RD/B/N2763, Central Electricity Generating Board, London (1973).

[15] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Limits for Intakes of Radionuclides by Workers, Publication 30, Parts 1-3, Pergamon Press, Oxford and New York (1980).
[16] LOHMANN, D.H., “Transport of radioactive materials: A review of damage to packages from the radiochemical centre during transport”, Packaging and Transportation of Radioactive Materials, PATRAM '80, (Proc. Symp. Berlin, 1980), Bundesanstalt für Materialprüfung, Berlin (1980), 818-825.
[17] HADJIANTONION, A., ARMIRIOTIS, J., ZANNOS, A., “The performance of Type A packaging under air crash and fire accident conditions”, ibid., pp. 826-832.
[18] TAYLOR, C.B.G., “Radioisotope packages in crush and fire”, ibid., pp. 1347-1354.
[19] STEWART, K., “Principal characteristics of radioactive contaminants which may appear in the atmosphere”, Progress in Nuclear Energy, Series 12, Health Physics, Volume 2, Pergamon Press, Oxford and New York (1969).
[20] WEHNER, G., “The importance of reportable events in public acceptance”, Packaging and Transportation of Radioactive Materials, PATRAM '83 (Proc. Symp. New Orleans, 1983), Oak Ridge National Lab., TN (1983).
[21] BRYANT, P.M., Methods of Estimation of the Dispersion of Windborne Material and Data to Assist in their Application, Rep. AHSB(RP)R42, United Kingdom Atomic Energy Authority, Berkeley (1964).
[22] DUNSTER, H.J., Maximum Permissible Levels of Skin Contamination, Rep. AHSB (RP)R78, United Kingdom Atomic Energy Authority, Harwell (1967).
[23] CROSS, W.G., FREEDMAN, N.O., WONG, P.Y., Beta ray dose distributions from skin contamination, Radiat. Prot. Dosim., 40 3 (1992) 149–168.
[24] UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, External Exposure to Radionuclides in Air, Water and Soil, Federal Guidance Report No. 12, EPA-402-R-93-081, USEPA, Washington DC (1993).
[25] MACDONALD, H.F., GOLDFINCH, E.P., “An alternative approach to the A_1/A_2 system for determining package contents limits and permitted releases of radioactivity from transport packages”, Packaging and Transportation of Radioactive Materials, PATRAM '80 (Proc. Symp. Berlin, 1980), Bundesanstalt für Materialprüfung, Berlin (1980) 48-56.
[26] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Data for Protection against Ionizing Radiation from External Sources: Supplement to ICRP Publication 15, Publication 21, Pergamon Press, Oxford and New York (1973).
[27] FAIRBAIRN, A., MORLEY, F., KOLB, W., ``The classification of radionuclides for transport purposes", The Safe Transport of Radioactive Materials (GIBSON, R., Ed.), Pergamon Press, Oxford and New York (1966) 44-46.
[28] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Limits for Inhalation of Radon Daughters by Workers, Publication 32, Pergamon Press, Oxford and New York (1981).
[29] AMERICAN SOCIETY FOR TESTING AND MATERIALS, Standard Specification for Uranium Hexafluoride Enriched to Less Than 5% U-235, ASTM C996-96, ASTM, West Coshohocken, PA (2002).
[30] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Recommendations of the International Commission on Radiological Protection (As Amended 1959 and Revised 1962), Publication 6, Pergamon Press, Oxford and New York (1964).

EXERCISES FOR CHAPTER 6

The following are exercises to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual

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EXERCISE 6.1. Radiological Exposure Pathways used in the Q-System

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REFERENCE SOURCES: Training Manual, Chapter 6; and TS-R-1, Sections II, IV, V, and the Index.

DISCUSSION: The Q-System is the basis for the activity limits A_1 and A_2 for individual radionuclides. It was originally developed in support of the deliberations leading to the 1985 Edition of the Regulations and was updated to support TS-R-1 the 1996 Edition of the Regulations. It provides a rationalized methodology for projecting radiological consequences of release from Type A packages under accident situations, and serves as the basis for Type A package contents limits (A_1 and A_2). The A_1 and A_2 values are used in many places in the Regulations to establish limits.

PROBLEM: In developing the Q-System:

a. What exposure pathways were considered?

b. How were the two A_1 and A_2 values selected from the five Q values?

ANSWER:

EXERCISE 6.2. Activity Limits

REFERENCE SOURCES: Training Manual, Chapter 6.1; TS-R-1, Sections II, IV and V; and TS-G-1.1, Appendix I.

DISCUSSION: The Regulations establish limits on package contents based on activities. Three such limits are clearly defined (Section IV of TS-R-1).

PROBLEM: Paragraph 201 of TS-R-1 indicates that A_1 is the maximum activity of special form radioactive material permitted in a Type A package; while A_2 is the maximum activity of radioactive material, other than special form radioactive material, permitted in a Type A package. The specific values of radionuclide limits are tabulated along with two other exemption limits.

a. Using the index of TS-R-1as a guide, what are the limits of activity specified in Section IV?

b. What other package activity limits are specified elsewhere in TS-R-1 (hint: consider limits on packages other than Type A)?

c. What are the other limits established using the A_1 and A_2 values?

d. Are there maximum activity values specified in TS-R-1 for Type B or Type C packages?

ANSWER:

7. SELECTION OF OPTIMAL PACKAGE TYPE

7.1. Introduction

Knowing the applicable A_1/A_2 value and the material type, is one part of the transport equation. The other part that it has to be closely co-ordinated with is the packaging. This chapter provides the specific details of the contents limits for each package type, then gives some examples of the contents that might be typically shipped in each packaging.

An overview of all package types is shown in Figure 7.1.

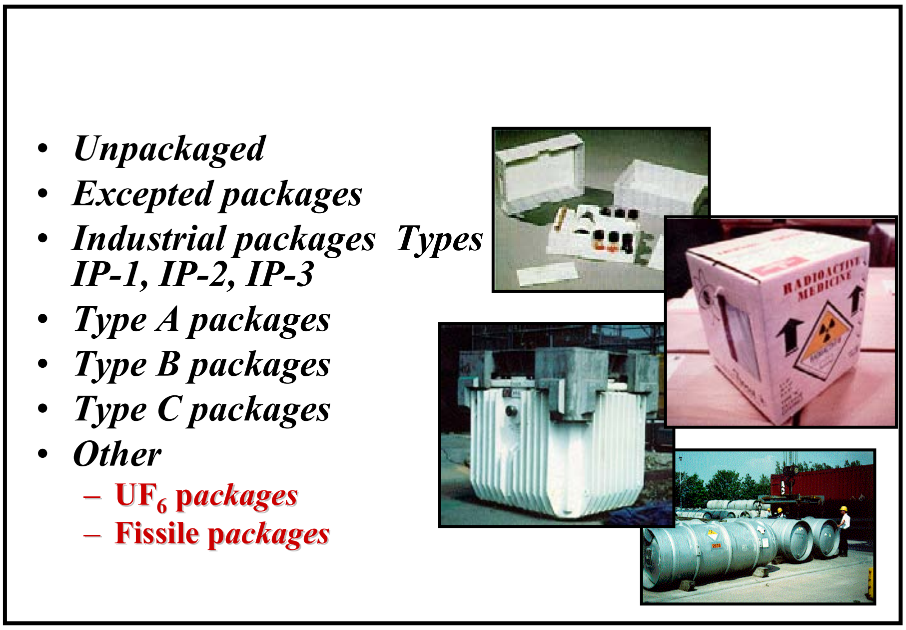

FIG. 7.1. Packages for transporting radioactive material.

7.2. Excepted packages

Excepted packages provide a means of shipping small quantities of radioactive material at relatively low cost but with a comparable standard of safety to that provided by Type A packages. This is achieved by severely limiting the contents. A typical excepted package is shown in Figure 7.2.

7.2.1. Contents limits

The activity limits for the shipment of radioactive material in an excepted package are provided in terms of multiples of A_1 or A_2 in Table III of TS-R-1. For convenience, this table is reproduced below as Table 7.1. Generally, the maximum quantity of material allowed in an excepted package for solid or gaseous contents is 10^{-3} of that permitted in a Type A. For liquids the maximum quantity is reduced to 10^{-4} of that allowed in a Type A package.

When the radioactive material is enclosed in or is included as a component of a manufactured article or an instrument, such as a gauge, smoke detector, electronic apparatus or similar device, allowance is made for the additional strength given by its structure. In which case the limits are increased. There are two sets of limits: one for the item and another for the package.

TABLE 7.1. ACTIVITY LIMITS FOR EXCEPTED PACKAGES

Physical state of contents	Instrument or article		Materials Package limits[a]
	Item limits[a]	Package limits[a]	
Solids			
special form	10^{-2} A_1	A_1	10^{-3} A_1
other forms	10^{-2} A_2	A_2	10^{-3} A_2
Liquids	10^{-3} A_2	10^{-1} A_2	10^{-4} A_2
Gases			
tritium	2×10^{-2} A_2	2×10^{-1} A_2	2×10^{-2} A_2
special form	10^{-3} A_1	10^{-2} A_1	10^{-3} A_1
other forms	10^{-3} A_2	10^{-2} A_2	10^{-3} A_2

[a] For mixtures of radionuclides, see paragraphs 404–406 of TS-R-1.

A manufactured article in which the sole radioactive material is natural uranium, depleted uranium, or natural thorium may be transported in any quantity in an excepted package. This is under the condition that the outer surface of the uranium or thorium is enclosed in an inactive sheath of metal or some other substantial material (see paragraphs 409 and 519 of TS-R-1).

All these provisions are subject to one or two over-riding constraints. The radiation level must be no greater than 5 μSv/h on the external surface of the package (TS-R-1 paragraph 516). In addition, when the radioactive material is in the form of an instrument or an article, the radiation level must be no greater than 0.1 mSv/h at any point 100 mm from the surface of the unpacked item (paragraph 517(a) of TS-R-1). If either of these limits is exceeded, then a Type A package must be used.

7.2.2 Types of contents

The typical contents of excepted packages include radiopharmaceuticals for medical purposes, which can often be in the form of liquid samples. As noted above, the quantity of activity in liquid form that can be carried is reduced by a factor of ten compared to solids.

Other typical contents may consist of immunoassay kits, small sealed check sources or activated samples from small to medium sized research reactors.

7.3. Industrial packages Type 1 (Type IP-1)

Industrial packages are used to transport certain low specific activity material and surface contaminated objects. Industrial package safety is assured more by the nature of the contents, than by the strength of the packaging.

7.3.1. Contents limits

Industrial packages Type 1 may contain (paragraph 524 and Table IV of TS-R-1):

- Solid LSA-I material,
- Liquid LSA-I material transported under exclusive use,
- SCO-I.

LSA-I material is one of the three categories of low specific activity (LSA) material. This material is considered to be intrinsically radiologically safe in that the radioactive concentration is such that a person cannot physically breathe in enough of the material to cause a problem. LSA-I is the least hazardous class and includes unirradiated natural or depleted uranium and thorium compounds and ores, and other radioactive material with unlimited A_2 values or with a specific activity which reaches only a very low level. LSA-I material is precisely defined in paragraph 226(a) of TS-R-1 and discussed in Chapters 4 and 5 of this manual.

SCO-I material is one of the two categories of surface contaminated objects (SCO). SCO are, by definition, objects that are not radioactive but have radioactive material distributed on their surfaces. SCO-I includes the objects that have the lowest levels of fixed and non-fixed contamination. SCO-I is precisely defined in paragraph 241(a) in TS-R-1 and also in Chapter 4.

The quantity of LSA-I material or SCO-I object, or collection of objects, in a single Type IP-1 package must be restricted so that the external unshielded radiation level at 3 m does not exceed 10 mSv/h (paragraph 521 of TS-R-1). (NOTE: This unshielded radiation level limit at 3 m is a generic limit that also applies to LSA-II, LSA III, SCO-1 and SCO II in individual Industrial packages types IP-II and IP-III.)

The total activity, for a single hold or compartment of an inland water craft, for carriage of SCO-I in Type IP-1, cannot exceed 10 A_2, and, for conveyances other than by inland waterway, 100 A_2 (paragraph 525 of TS-R-1).

7.3.2. Types of contents

7.3.2.1. Uranium and thorium ores and concentrates

Ores containing naturally occurring radionuclides (for example, uranium and thorium), and concentrates of such ores (for example "yellow cake" or sodium di-uranate) contain very low levels of radioactivity and are classified in the Regulations as LSA-I.

7.3.2.2. Uranium enriched to 20% or less

Uranium enriched to 20% or less has an A_2 value that is unlimited. Therefore, it can be classified as LSA-I in any form. This includes uranium dioxide (UO_2) powder, and ingots of metallic uranium. It also includes uranium hexafluoride (UF_6). Uranium hexafluoride is considered separately in 7.9 of this chapter, as packages containing UF_6 have very specific requirements.

7.3.2.3. *Very low level waste*

The decommissioning of nuclear facilities typically produces large volumes of very low level waste that can often be classified as LSA-I. In addition, large items associated with decommissioning of nuclear plants, such as building rubble, structural steelwork, pipes, machine tools and other scrap may also fall into the SCO-I category. Such items may have sufficiently low contamination levels to require no packaging.

7.3.2.4. *Unpackaged material*

Under the conditions prescribed in paragraph 523 of the Regulations, LSA-I material and SCO-I may be transported unpackaged.This is illustrated in Figure 7.2. One example of this is the shipment of uranium and thorium ores which may be transported without bagging or boxing in closed rail wagons or road vehicles

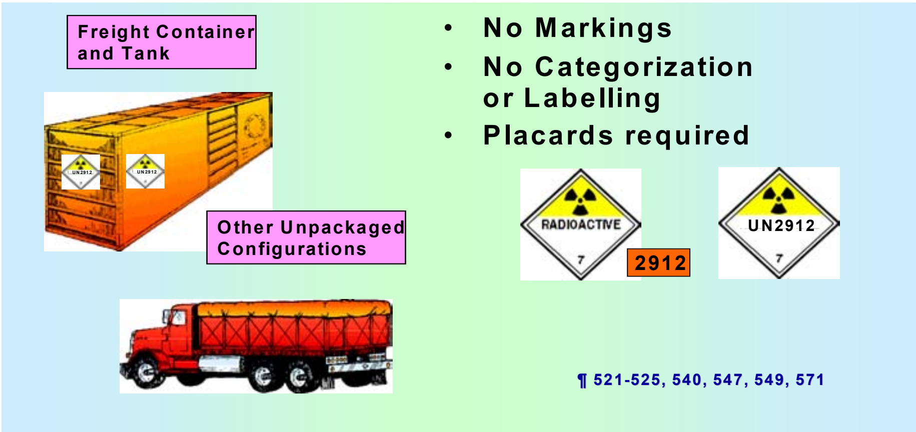

FIG. 7.2. Unpackaged LSA and SCO.

7.3.2.5. *Maintenance equipment*

SCO-I objects may include non-activated reactor maintenance equipment or other fuel cycle equipment which have come into contact with primary or secondary coolant or process waste resulting in fission product surface contamination. This equipment is not usually dedicated to a single reactor or fuel cycle facility and therefore has to be transported from one site to another.

7.4. Industrial packages Type 2 (Type IP-2)

Industrial packages Type 2 are also used to transport certain low specific activity material and surface contaminated objects.

7.4.1. Contents limits

Industrial packages Type 2 may contain (paragraph 524 and Table IV of TS-R-1):

- Liquid LSA-I material not transported under exclusive use,
- Solid LSA-II material,
- Liquid or gaseous LSA-II material transported under exclusive use,
- LSA-III material transported under exclusive use,
- SCO-II.

LSA-I, LSA-II and LSA-III are the three categories of low specific activity (LSA) material defined in paragraph 226 of TS-R-1 and discussed in Chapters 4 and 5 of this manual.

Remember that surface contaminated objects (SCO) are divided into two categories (SCO-I and SCO-II) which are differentiated by the levels of fixed and non-fixed contamination. SCO-II includes the objects that have the highest levels of fixed and non-fixed contamination among both categories. SCO-II is precisely defined in paragraph 241(b) of TS-R-1 and discussed in Chapter 4.

The quantity of LSA material or SCO-II in a single Industrial package Type 2 (Type IP-2) must be so restricted that the external radiation level at 3 m from the unshielded material does not exceed 10 mSv/h (paragraph 521 of TS-R-1). (NOTE: This unshielded radiation level at 3m is a generic limit that applies to all LSA-I, LSA-II, LSA-III, SCO-I and SCO-II materials when packed and shipped in individual Industrial packages types IP-I, IP-II and IP-III.)

A single package of non-combustible solid LSA-II or LSA-III material, if carried by air, must not contain an activity greater than 3000 A_2 (paragraph 412 of TS-R-1).

For a single hold or compartment of an inland watercraft, the total activity for carriage of non-combustible solid LSA-II and LSA-III materials cannot exceed 100 A_2. For liquid and gaseous LSA-II and combustible solid LSA-II and LSA-III materials, it cannot exceed 10 A_2. There is no limit for LSA-I material (paragraph 525 of TS-R-1).

For conveyances other than an inland watercraft, there is no limit for total activity for carriage of LSA-I material and non-combustible solid LSA-II and LSA-III materials. For carriage of combustible solid, liquid and gaseous LSA-II material, combustible solid LSA-III material, SCO-I and SCO-II, total activity is limited to 100 A_2 (paragraph 525 of TS-R-1).

7.4.2. Types of contents

7.4.2.1. Solid low level radioactive waste

Low-level radioactive wastes often contain small quantities of beta/gamma-emitting radionuclides and typically consist of contaminated items from hospitals, laboratories, nuclear power plants, fuel fabrication plants, and reprocessing plants.

Such waste may include rubber gloves and other items of protective clothing, paper, cardboard, tissues, plastic bags and sheeting, glass, scrap metal or broken apparatus. Most of this material will be contaminated rather than activated, although for some items the contamination may not reside on outer exposed (i.e. “accessible”, paragraph 241 of TS-R-1) surfaces. It should be noted that mixtures of surface contaminated and other radioactive objects could be considered for transport classification as LSA material.

The package contents can be loose within the drum, or possibly compacted so that more can be carried. However, if long term storage or disposal is required at the end of the journey, the contents are likely to be immobilized in a cement grout, bitumen, or polymer mix (i.e. “solid compact binding agent”, paragraph 226(c) of TS-R-1). This immobilizing medium will probably provide package containment in its own right without need for a sealed drum lid. Under some circumstances, where drums arrive from many sources, it may prove more effective from a storage or disposal point of view to “super-compact” complete drums into a much smaller volume. This may be done at the storage or disposal location, prior to grouting the whole package into a larger container for long term storage. In this case, the drums should be transported with the raw contents.

7.4.2.2. Liquid low level radioactive waste

In many countries, low-level radioactive wastes are not generally transported in a liquid state. They are treated at the site of origin to remove the bulk of the volume, and then solidified.

7.4.2.3. Ion exchange resins

Ion exchange resins, when either grouted with bitumen compounds, resin, or with cement, is another typical LSA-II or LSA-III material.

7.4.2.4. Maintenance equipment and nuclear facility decommissioning wastes

The equipment and decommissioning wastes, described earlier, can be classified as SCO-II, when the contamination level exceeds the values authorized for SCO-I. Clearly, they must also comply with the other requirements for SCO-II.

7.4.2.5. Fresh fuel assemblies

Uranium dioxide (UO_2), when enriched to less than 5% and coming from natural uranium, can be classified as LSA-II material. Therefore, UO_2 powder and fuel assemblies also fall into this category.

7.5. Industrial packages Type 3 (Type IP-3)

Industrial packages Type 3 are used to transport certain types of low specific activity material and surface contaminated objects.

7.5.1. Contents limits

Industrial packages Type 3 may contain (paragraph 524 and Table IV of TS-R-1):

- Liquid and gaseous LSA-II material not transported under exclusive use,
- LSA-III material not transported under exclusive use.

The quantity of LSA-II or LSA-III material in a single Industrial package Type 3 (Type IP-3) must be restricted so that the external radiation level at 3 m from the unshielded material does not exceed 10 mSv/h (paragraph 521 of TS-R-1). (NOTE: This unshielded radiation level at 3m is a generic limit that applies to all LSA-I, LSA-II, LSA-III, SCO-I and SCO-II materials when packed and shipped in individual Industrial packages types IP-I, IP-II and IP-III.)

A single package of non-combustible solid LSA-III material, if carried by air, cannot contain an activity greater than 3000 A_2 (paragraph 412 of TS-R-1).

For a single hold or compartment of an inland watercraft, the total activity for carriage of non-combustible solid LSA-III material may not exceed 100 A_2. For liquid and gaseous LSA-II and combustible solid LSA-III materials, the total activity cannot exceed 10 A_2 (paragraph 525 of TS-R-1).

For conveyances other than an inland watercraft, the total activity for carriage of non-combustible solid LSA-III material is not limited. For carriage of liquid and gaseous LSA-II material and combustible solid LSA-III material, the total activity is limited to 100 A_2 (paragraph 525 of TS-R-1).

7.5.2. Types of contents

The type of materials shipped in Type 3 industrial packages are essentially the same as those given previously for IP-2.

7.6. Type A packages

Type A packages are intended to provide a safe and economical means of transporting relatively small quantities of radioactive material. They are required to maintain their integrity under the kind of abuse or mishandling that may be encountered in normal transport. This includes events such as falling from vehicles, being dropped during manual handling, being exposed to rain, being struck by a sharp object (which may be the corner of another package), or having other packages or cargo stacked on top. Where the contents may be in either liquid or gaseous form, rather than solid, then higher standards are imposed because of the greater possibility of leakage or dispersal from the package.

It is assumed that a Type A package may be damaged in a severe accident and that a portion of the contents may be released. The Regulations, therefore, prescribe limits on the maximum amounts of radioactivity that can be transported in such packages.

The nature and form of a Type A package is dependent on the nature and form of the contents. In some cases, the package itself may be an integral part of the usage mechanism for the radioactive material itself.

7.6.1. Contents limits

The limits that apply to a Type A package come directly from the definition of A_1 and A_2. If the radioactive material is in special form, the limit is the applicable A_1 value, otherwise the limit is the applicable A_2 value.

7.6.2. Types of contents

7.6.2.1. Radioisotopes

Typical contents of Type A packages are radioisotopic sources. The movement of such radioisotopes is extensive. Within most industrialized countries for example, hundreds, and even thousands, of isotope packages are transported daily. Consignments can range from an individual package to several hundred packages. The majority is moved by road. Packages for export can be dispatched by air according to the half-life of the contents. In terms of the radioactivity of these isotopes, the contents can vary from a few kilo-becquerels for diagnostic medical use up to tens of giga-becquerels.

7.6.2.2. Technetium generators

The transport of technetium generators forms an important operation in its own right. These generators contain ^{99}Mo, which undergoes radioactive decay to produce the short-lived radionuclide ^{99m}Tc. Typically this is separated from the molybdenum at hospitals, attached to various chemicals and injected into patients to assist in the diagnosis of bone, liver, and brain cancers. The success of this technique has led to its use on a substantial scale worldwide so that regular supplies of the generators are required. Many hospitals will receive a generator each week.

7.6.2.3. Industrial sources

Industry relies on radioactive material in many ways. Hence, it is necessary to consider the transport of industrial sources, including those for non-destructive testing. The use of radiation in general industry has declined in recent years. Nevertheless, industry uses a wide range of radioisotopes for many applications. The varied nature of industrial applications requires the manufacturers to provide many different radioisotopes and forms.

Radioactive sources are used for industrial gauging, well logging, feedstock and tank level control, and for the calibration and operation of instruments. Sources are also used on a substantial scale for industrial radiography, mainly to test the effectiveness of welding or to detect imperfections in cast metal components. Some firms specialize in on-site radiography. The radioactive sources are transported to the site, removed from the transport container, used for inspection or testing purposes, and then returned to the container for transport back to the depot.

The transport and use of on-site radiography sources has led to a significant number of radiological accidents. For example, there have been several occasions where a radiographer has been exposed to high levels of radiation when the source was not properly returned to its container. Radiography sources are highly radioactive. Iridium–192, with an average source strength of a few hundred GBq, is used in the majority of cases. It should be noted that the larger radiography sources are transported in Type B packages.

7.7. Type B(U) and B(M) packages

As far as the contents limits and the types of contents are concerned, Type B(U) and Type B(M) packages can be considered together.

7.7.1. Contents limits

With one exception, the Regulations do not specify activity limits for Type B(U) and Type B(M) packages. The activity limits are generally established during design, and are included in the safety documentation supporting application for approval, which is submitted to the Competent Authority (see paragraph 415 of TS-R-1) requesting a certificate of approval. In other words, the contents limit is specific to a particular certified package design.

The exception concerns the carriage of radioactive material in Type B(U) and Type B(M) packages when transported by air (see paragraph 416 of TS-R-1). In this instance, there are two specific limits and one situation that allow variations from these limits. The two limits are:

- For special form radioactive material, the limit is either 3000 A_1 or 100 000 A_2, whichever is the lower; or,
- For all other radioactive material, the limit is 3000 A_2.

The situation that allows variation from these limits is when the radioactive material satisfies the requirements for low dispersible radioactive material (TS-R-1 paragraph 416(a)). In this event, the content limits are those authorized for the package design in the certificate of approval.

While the A_1 and A_2 values are not used directly to define the activity limits for Type B packages (with the exceptions given above), they are used to define the acceptable release limits. Therefore, they are involved in the design process. Under normal conditions of transport, the release limit is 10^{-6} A_2 per hour (see paragraph 656(a) of TS-R-1). The maximum allowable release under accident conditions of transport from a Type B package is A_2 in a period of one week (see paragraph 656(b)(ii)(ii) of TS-R-1). Release limits are discussed in the next chapters.

7.7.2. Types of contents

Type B(U) or Type B(M) packages are needed whenever the activity level exceeds the A_1 or A_2 levels. Therefore, a Type B(U) or Type B(M) package is required both for small quantities of alpha emitters which require virtually no shielding, as well as for large quantities of beta/gamma emitters which require significant radiation shielding.

The contents of typical Type B(U) and Type B(M) packages include:

- Bulk supplies of un-encapsulated medical or research radioisotopes such as ^{131}I, ^{3}H, ^{24}Na;
- Encapsulated sources such as ^{60}Co or ^{192}Ir for non-destructive testing or ^{60}Co for teletherapy;
- Unirradiated nuclear fuel involving highly enriched uranium, plutonium or mixed oxides;
- Irradiated nuclear fuel or research samples for post-irradiation examination.

The contents come in a multiplicity of forms, radionuclide composition, and radioactivity.

Another instance where a Type B(U) or a Type B(M) package must be used is the transport of LSA material or SCO when the external radiation level at 3 m from the unshielded material exceeds 10 mSv/h (paragraph 521 of TS-R-1). A typical example is provided by waste, such as ion exchange resin, which might comply with the criteria applicable to LSA material, but because of the quantity and dose rate, cannot be transported in an Industrial package.

As previously stated, the total activity in a conveyance, or in a hold or compartment of an inland watercraft, is limited when the LSA material or the SCO are transported as Type IP-1, 2 or 3. However, sometimes it is desirable to ship quantities of LSA or SCO that exceed these limits. To avoid dividing the cargo and multiplying the number of shipments, a Type B(U) or a Type B(M) package has to be used. One example of this might be waste contaminated with alpha emitting material that can be classified as LSA-II material. If the waste is made of plastic sheets or gloves, or tissues, it is combustible and instead of multiplying the number of shipments to comply with the 100 A_2 limit per conveyance, it might be advisable to use a Type B(U) package.

7.7.3. Lightweight Type B(U) and B(M) packages

Lightweight Type B(U) and Type B(M) packages are not specifically defined as a type of package in the Regulations. Nevertheless, some special testing requirements apply to such packages, and therefore, they need to be identified in this document. In essence, a lightweight Type B package (paragraph 656(b) of TS-R-1) is one which:

- has a mass not greater than 500 kg;
- an overall density not greater than 1000 kg/m^3 based on the external dimensions; and,
- radioactive contents greater than 1000 A_2 in other than special form.

Typical contents of a lightweight Type B(U) and Type B(M) packages are alpha emitters. These include for example, plutonium oxide powders and plutonium nitrate solutions.

7.7.4. Type B(U) packages containing very large quantities of activity

Earlier versions of the Regulations required an enhanced (200 m) immersion test for packages containing more than 37 PBq of irradiated nuclear fuel. This requirement was imposed to minimize the hazards associated with a spent fuel package being sunk on the continental shelf.

As a result of a number of studies the scope of the enhanced water immersion test has been extended in the 1996 Edition of the Regulations to cover any radioactive material transported in large quantity, not only irradiated fuel. Type B(U) packages designed to contain an activity greater than 10^5 A_2 are required to pass the enhanced immersion test discussed in Chapter 8. It should be noted that this test is also required for all Type C packages.

7.8. Type C packages

7.8.1. Contents limits

The 1996 Edition of the Regulations (TS-R-1) introduced a new, Type C, package specification. When adopted by Member States and the International Civil Aviation Organization (ICAO), this package type will apply to the transport of large quantities of radioactive material by air. As discussed above, the introduction of the Type C package places a content limit on Type B(U) and Type B(M) packages being transported by air. The content limits are expressed as:

- 3000 A_1 or 100 000 A_2 (whichever is lower) for material in special form; or
- 3000 A_2 for all other forms of radioactive material.

The choice of 3000 A_2 for non-special form was linked mainly to an older version of the Regulations that defined a large source as being 3000 A_1 or A_2. This quantity is retained in the Regulations as the threshold quantity for which shipment approval of Type B(M) packages is required. Also, a study undertaken in France suggested that at typical impact speeds for aircraft crashes the release fraction might be as high as 3×10^{-2} for a Type B(U) package. This release fraction in combination with the assumption that a release of 100 A_2 represents a significant hazard gave a further basis for the 3000 A_2 content limit. For special form radioactive material, the same content limit is used. However, there is recognition that the properties of the special form material may be impaired in an aircraft accident, so a cap of 100,000 A_2 has been placed on the content limit.

Variation from these limits is allowed with another new feature of TS-R-1, namely low dispersible radioactive material (LDM), as defined in paragraph 225 of TS-R-1. If the material is classed as LDM, it could be safely carried in large quantities by air in a Type B(U) or Type B(M) package.

As with Type B(U) and Type B(M) packages, the Regulations do not specify activity limits for Type C packages. The activity limits are generally established during design, and are included in the safety documentation supporting application for approval that is submitted to the Competent Authority (see paragraph 417 of TS-R-1) when requesting a certificate of approval.

In addition, the same release limits specified for Type B packages apply to Type C packages, both for the normal conditions of transport and the accident conditions of transport.

7.8.2. Types of contents

7.8.2.1. Plutonium and mixed oxide fuel

Plutonium, coming from the reprocessing of spent fuel, can be used to manufacture mixed oxide fuel assemblies. In this process, the mixed oxide will sequentially be in the form of powder, pellets, fuel pins, and fuel assemblies. According to the locations of the different processing plants, the mixed oxide will need to be transported. For instance, it may need to be shipped from a fuel pin fabrication plant to the place where the pins are assembled into a fuel assembly.

Plutonium and mixed oxides have a high activity in terms of A_2, so that 3000 A_2 will typically represent about one hundred grams of plutonium or two kilograms of mixed oxide. For reasons of physical protection, it could be best transporting these materials by air, especially if they have to be transported over a very long distance (for instance from one continent to another).

For these reasons, plutonium and mixed oxide fuel are candidates for transport in a Type C package.

7.8.2.2. Very large sources

Another candidate for transport in a Type C package is the very large source. Some sources have to be transported very rapidly due to their short half-life. Nevertheless, it must be recognized that 3000 A_2 represents a large amount of activity for this kind of material.

7.9. Packages containing uranium hexafluoride

Uranium hexafluoride (UF_6) is an important intermediate product in the manufacture of new reactor fuel from ore concentrates, and forms a very important part of international trade and transport. Uranium is converted into UF_6 to enable consequent enrichment.

Uranium hexafluoride is a compound of hexavalent uranium and fluorine. It is a white solid under ambient conditions. UF_6 is the process gas used by the gaseous diffusion plants to increase the concentration of the fissionable isotope ^{235}U in the mixture of ^{238}U, ^{235}U, and ^{234}U that is found in naturally occurring uranium ore. It is readily transformed into the gaseous state at a low temperature. It sublimes at 56.4°C at atmospheric pressure (0.101 MPa) and liquefies at 64°C at a pressure of 0.151 MPa. UF_6 is used for two reasons. Firstly, it can conveniently be used as a gas for processing, as a liquid for feeding and withdrawing, and as a solid for storage. Each of these states is achievable at relatively low temperatures and pressures. Secondly, because fluorine has only one natural isotope, all the isotopic separative capacity of the diffusion plant is used to enrich the concentration of the lighter uranium isotopes.

In addition to the radioactive and fissile properties, particular care must be taken with uranium hexafluoride because it is a material that has significant subsidiary hazards in addition to its radioactive and potentially fissile properties. The chemical and toxicity hazards of UF_6 when released to the atmosphere and reacted with water or water vapour are of greater concern from a packaging viewpoint than the radiological hazards. Similarly, the physical properties of the material are such that it has a low temperature triple point, as well as large fusion and liquid thermal expansion coefficients. This means that if the containment is submitted to a high temperature environment there may be a rupture hazard. Moreover, it should also be noted that uranium hexafluoride packagings are pressurized during loading and unloading operations even though they are not pressurized under normal transport conditions.

This means that packages containing uranium hexafluoride have additional criteria beyond those associated with the pure package type required by their radioactive and/or fissile nature. These are discussed in detail in the next chapter.

7.9.1. Content limits

The mass of uranium hexafluoride in a package must not exceed a value that would lead to an ullage smaller than 5%. The uranium hexafluoride must be in solid form and the internal pressure of the package must be below atmospheric pressure when presented for transport. These requirements are derived by reference, in paragraph 629 of TS-R-1, to the International Organization for Standardization (ISO) document [1] that deals with the packaging of UF_6 for transport.

It should be noted that when uranium is enriched in ^{235}U to more than 1% by mass, uranium hexafluoride must be transported in a package that complies with the requirements applicable to packages containing fissile material.

REFERENCE FOR CHAPTER 7

[1] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Packaging of Uranium Hexafluoride (UF_6) for Transport (ISO 7195:1993(E)), ISO, Geneva (1993).

EXERCISES FOR CHAPTER 7

The following are exercises to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 7.1. Defining Package Requirement Based on Activity of Contents

REFERENCE SOURCES: Training Manual, Chapters 4.2, 6, and 7; and TS-R-1, Sections II and IV.

DISCUSSION: One of the key requirements for defining the type of package needed is to determine the radionuclide-specific contents limits. This will assist in determining whether an excepted package, Type A package or Type B package is required. The requirement will depend upon the form of the material (e.g. special form or other than special form).

PROBLEM: Identify the packages required for:

a. 1 TBq of Cs-137 in special form

b. 1 TBq of Cs-137 in other than special form

c. An unknown mixture of radionuclides in special form with a total activity of 0.0005 TBq

d. An unknown mixture of radionuclides in other than special form with a total activity of 0.05 TBq

ANSWER:

EXERCISE 7.2. Defining Package Requirement Based on Activity of Contents

REFERENCE SOURCES: Training Manual, Chapters 4.2, 6, and 7; and TS-R-1, Sections II and IV.

DISCUSSION: One of the key requirements for defining the type of package needed is to determine the specific radionuclide content limits. This will assist in determining whether an excepted package, Type A package or Type B package, etc. is required. The requirement will depend upon the form of the material (e.g. special form or other than special form).

PROBLEM: Identify the types of packages required for

2 TBq of Gold (specific radioisotope unknown) in special form

8 TBq of Au-195 in special form

8 TBq of Au-195 in other than special form

0.2 TBq of mixed fission products in special form

ANSWER:

EXERCISE 7.3. Defining Package Requirement Based on Activity of Contents

REFERENCE SOURCES: Training Manual, Chapters 4.2, 6, and 7; and TS-R-1, Sections II and IV.

DISCUSSION: One of the key requirements for defining the type of package needed is to determine the specific radionuclide content limits. This will assist in determining whether an excepted package, Type A package or Type B package, etc. is required. The requirement will depend upon the form of the material also (e.g. special form or other than special form).

PROBLEM: A consignor plans to prepare a consignment consisting of a single package. The package is to contain Ac-227, Cm-246, Th-228, and W-181. The total activity in the package will be 2.0×10^{-4} TBq.

a. If the material is in other than special form, what type of package will be required to ship this material?

b. If the material is in special form, what type of package will be required to ship this material?

ANSWER:

EXERCISE 7.4. Defining Package Requirement Based on Activity of Contents

REFERENCE SOURCES: Training Manual, Chapters 4.2, 6, and 7; and TS-R-1, Sections II and IV.

DISCUSSION: One of the key requirements for defining the type of package needed is to determine the specific radionuclide content limits. This will assist in determining whether an excepted package, Type A package or Type B package, etc. is required. The requirement will depend upon the form of the material also (e.g. special form or other than special form).

PROBLEM: A consignor plans to prepare four consignments. Each consignment will use a single package. The individual packages contain:

a. 0.01TBq of Ni-63 as a metal alloy where the alloy *has not been tested* to demonstrate that it satisfies the requirements for special form.

b. 0.1 TBq of Ni-63 as a metal alloy where the alloy has been fabricated into a manufactured article as defined in paragraph 408, but *does not satisfy the requirements* for special form

c. 10 TBq of Ni-63 as a metal alloy where the alloy has *not been tested to demonstrate* that it satisfies the requirements for special form

d. 100 TBq of Ni-63 as a metal alloy where the alloy *has been tested to demonstrate* that it satisfies the requirement for special form.

What type of package is required for each of the contents specified?

ANSWER:

EXERCISE 7.5. Classifying a Material as LSA Material

REFERENCE SOURCES: Training Manual, Chapter 7; and TS-R-1, Sections II and V.

DISCUSSION: In preparing nuclear waste for transport, storage and disposal, care must be taken to ensure that the waste form and its container, prior to package and/or transport, fully satisfy the Regulatory requirements.

PROBLEM: A waste processor solidifies liquid radioactive material by mixing with concrete and casting into 1.8 m diameter × 1.8 m long steel cylinders. 3217 litres of solidifying material is used to provide a solid, uniformly mixed mass inside the steel cylinder.

a. The total mass of the loaded cylinder is 8570 kg.

b. The total activity in the cylinder exceeds the A_2 value for the nuclide mixture.

c. The radiation level (all gamma radiation) 3 m from the outside surface of the loaded steel cylinder is 10.5 mSv/h.

d. The activity measurements indicate that the specific activity of the solidified mixture is 8×10^{-5} A_2/g.

Does this loaded cylinder satisfy the requirements for LSA? What type of package will be required for transport?

ANSWER:

EXERCISE 7.6. Classifying a Material as LSA Material

REFERENCE SOURCES: Training Manual, Chapter 7; and TS-R-1, Sections II and V.

DISCUSSION: In preparing nuclear waste for transport, storage and disposal, care must be taken to ensure that the waste form and its container, prior to package and/or transport, fully satisfy the Regulatory requirements.

PROBLEM: A waste processor solidifies liquid radioactive material by mixing with concrete into a 1.8 m diameter × 1.8 m long steel cylinder. 3217 litres of solidifying material is used to provide a solid, uniformly mixed mass inside the steel cylinder.

- The total mass of the loaded cylinder is 8570 kg, and the mass of the contents (including the waste and the concrete) is 7710 kg.
- The radiation level 3 m from the outside surface of the solidified material (without the steel cylinder) is determined to be 6 mSv/h.
- An assay shows that the radioactive material in the cylinder is:
  - 2.40 TBq of Cs-137
  - 0.37 TBq of CS-134
  - 0.37 TBq of Sr-90

a. What is the A_2 value of the mixture in this second loaded (compare with Exercise 7.5) cylinder?

b. For this second loaded cylinder (compare with Exercise 7.5):
   - Is it an LSA material and, if so, what type of LSA?
   - What type of package is required?

ANSWER:

EXERCISE 7.7. Classifying Ores For Shipment

REFERENCE SOURCES: Training Manual, Chapter 7; and TS-R-1, Sections II and V.

DISCUSSION: In preparing radioactive ores (containing only naturally occurring radionuclides) for transport, consideration of the nature of the material has been taken into account in establishing packaging requirements. This follows the graded approach used in the Regulations for material classifications, and packaging and operational requirements

PROBLEM: A shipment consisting of 12,000 kg of unprocessed uranium ore is being prepared.

a. How is the material to be classified for transport?

b. How should the material be packaged for transport?

ANSWER:

8. TEST PROCEDURES: MATERIAL AND PACKAGES

The requirements for design and testing, and the test procedures for radioactive material, packaging and packages is a complex subject. When studying this chapter the student will need to frequently refer to both the TS-R-1 Regulations [1] and the TS-G-1.1 Advisory Material [2]. To attempt to simplify the material, the chapter will be treated in two main parts :

Part 1: Material and package *design and test requirements*, and,
Part 2: Material and package *test procedures*

PART 1: MATERIAL AND PACKAGE DESIGN AND TEST REQUIREMENTS

Material and package requirements in the Regulations are in the form of performance standards, rather than prescriptive specifications. This allows room for the production of many different designs as solutions to the various requirements. All these designs must fall somewhere within the categories specified in the Regulations. An overview of the material and package design and test requirements is shown in Figure 8.1.

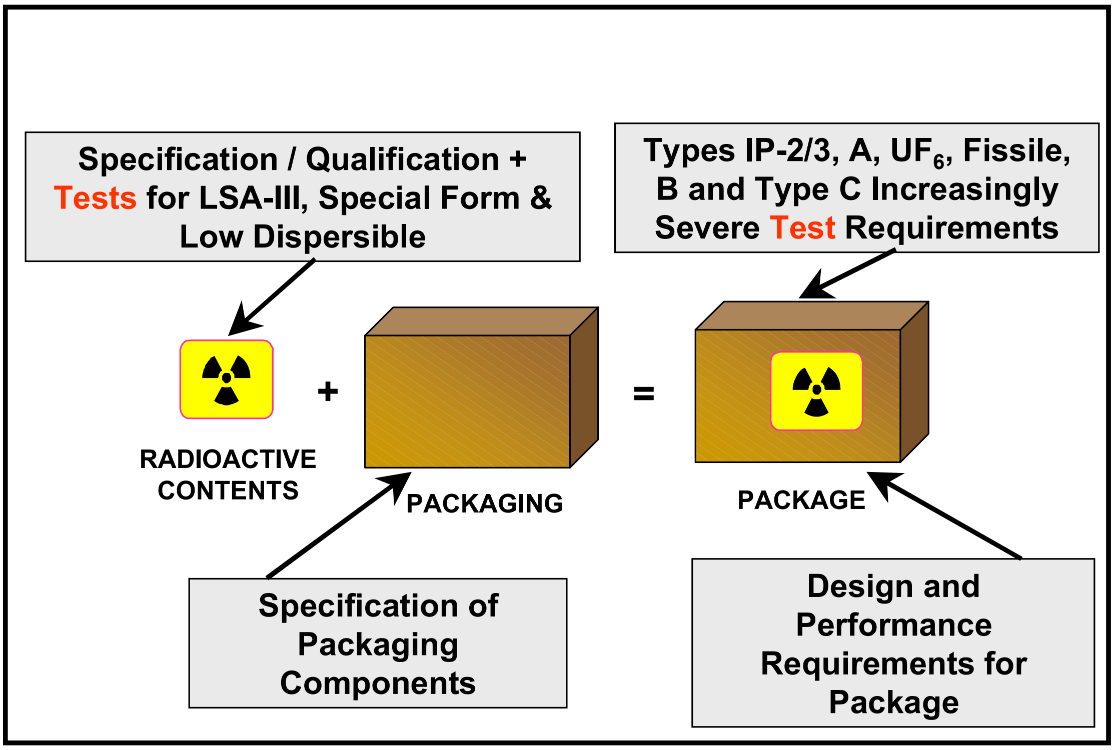

FIG. 8.1. Overview of radioactive material and package design and test requirements.

The purpose of this first part of Chapter 8 is to present the requirements for each material type and package category along with some of the design considerations. Examples of some common designs are also given. For the material and packages specifically requiring Competent Authority approval, some information is provided with respect to how this can be achieved. For material and packages where formal approval is not required, the consignor has to have quality assured documentary evidence of the compliance of the package design with all the applicable requirements. Figure 8.2 provides a broad overview of all the package types and divides them into the two main categories of those that do not require formal approval and those that do. This figure also illustrates the increasing complexity of the requirements and tests with the increasing hazard of the package contents.

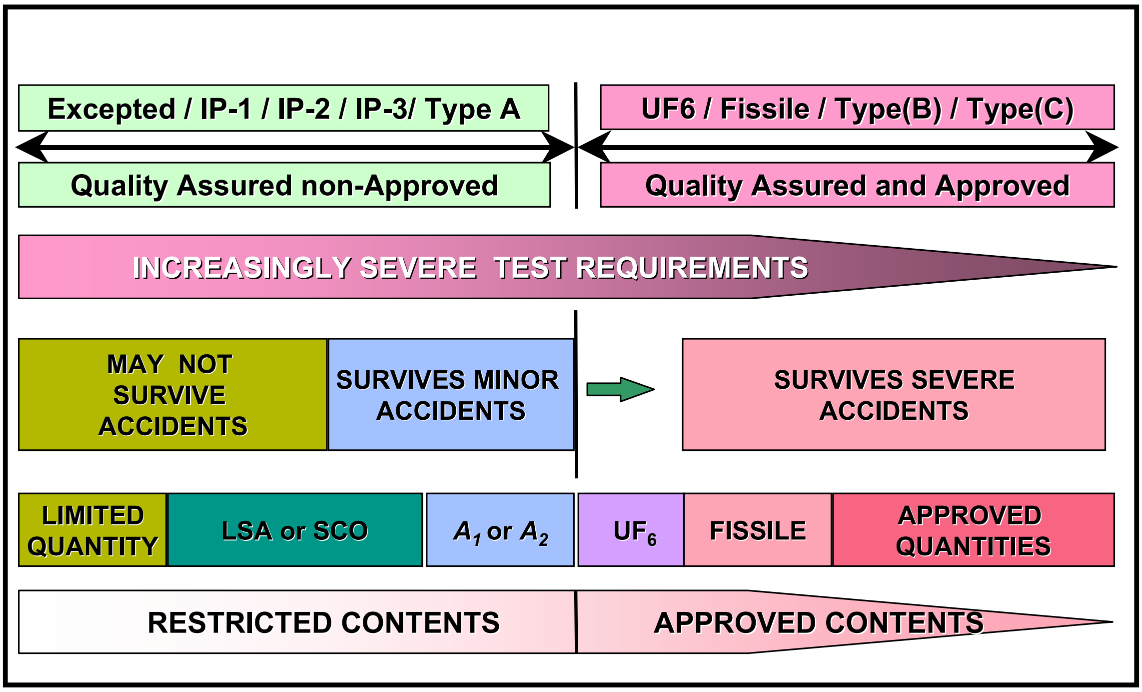

FIG. 8.2. Overview of package test requirements and range of approval.

It should be noted that this is a training text and therefore tries to provide easily understandable descriptions of the material and package requirements. Tables 8.1.to 8.4 provide useful summaries of the requirements and tests for each category of package. However, in order to understand the specific details and conditions relating to material and package requirements, the TS-R-1 Regulations must be referenced.

Table 8.1 shows the conditions of transport, (routine, normal and accident), that must be considered in designing the various types of package. Table 8.2 provides an overview of the general design requirements for all packages. Tables 8.3 and 8.4 sets out the test requirements for normal and accident conditions of transport respectively. The relevant paragraph numbers in the TS-R-1 Regulations are referenced in Tables 8.2, 8.3 and 8.4.

Packages containing fissile material are not considered in detail in this chapter, but are fully discussed in Chapter 11.

TABLE 8.1. TRANSPORT CONDITIONS TO BE CONSIDERED IN PACKAGE DESIGN

	Un-packaged	Excepted package	IP-1	IP-2	IP-3	Type A package	Type B packages	Type C packages
Routine (incident free)	x	x	x	x	x	x	x	x
Normal (minor mishaps)				x	x	x	x	x
Accident (severe accidents)								x

TABLE 8.2. GENERAL DESIGN REQUIREMENTS FOR ALL PACKAGE TYPES

	Excepted package	IP-1	IP-2	IP-3	Type A package	Type B packages	Type C packages
GENERAL REQUIREMENTS, PARAS 606–616							
Handling, lifting, vibration, acceleration, material compatibility	x	x	x	x	x	x	x
ADDITIONAL REQUIREMENTS BY AIR, PARAS 617–619							
Temperature and pressure							x

TABLE 8.3. PACKAGE TEST REQUIREMENTS FOR NORMAL CONDITIONS OF TRANSPORT, PARAS 719–724

	Excepted package	IP-1	IP-2	IP-3	Type A package	Type B package	Type C package
Drop test 0.3–1.2 m			x	x	x	x	x
Stacking			x	x	x	x	x
Water spray				x	x	x	x
Penetration:							
1.0 m				x	x	x	x
1.7 m					LIQ		

LIQ – applies to liquid contents

TABLE 8.4. PACKAGE TEST REQUIREMENTS FOR ACCIDENT CONDITIONS OF TRANSPORT, PARAS 726-737

	Excepted package	IP-1	IP-2	IP-3	Type A package	Type B package	Type C package
Drop test 9 m					LIQ	HHD	x
Penetration 1 m						x	
Crush test 9 m						LLD	x
Thermal test						x	
Water immersion 15 m						x	
Water immersion 200 m						LC	x
Puncture/tearing							x
Enhanced thermal test							x
Impact test							x
Water leakage test for criticality (paras 731–733)	All packages containing fissile material						

LIQ – Liquid contents
HHD – Heavy weight/High density packages
LLD – Lightweight/Low density packages
LC – Packages with large quantity contents (>10^5 A_2)

8.1. Material

All radioactive material needs to be properly specified prior to the optimal selection of the appropriate package. There are three categories of material that have very specific test requirements in the Regulations. These are LSA-III, special form, and low dispersible radioactive material (paragraphs 601–605 of TS-R-1).

8.1.1. LSA-III Material

The requirements for LSA-III are straightforward and are intended to provide assurance regarding its relative insolubility. LSA-III material has to be solid and there is a limit on the quantity of activity allowed to dissolve after being submerged in water for seven days. This means that the radioactive material has to be uniformly integrated within a solid matrix. There are a number of methods to achieve this integration if it is not an inherent characteristic of the material. These include solidification with resins, bitumen, or other proprietary materials.

8.1.2. Special form radioactive material

Special form radioactive material (paragraph 239 of TS-R-1) is defined as either (a) the radioactive material in the form of an indispersible solid, or (b) a sealed capsule containing the radioactive material, so that the encapsulated material is essentially as an indispersible solid. In many cases, substantially larger amounts of radioactivity can be transported in either an excepted (see Table III of TS-R-1) or a Type A package if the material is in special form (e.g. see Table 6.4 in Chapter 6 of this manual). This is allowed because it is unlikely to cause any type of contamination in an accident and has an A_1 value higher than its A_2 value.

There are three basic requirements related to special form material. The first is a requirement to have at least one dimension 5 mm or greater (paragraph 602 of TS-R-1). This is to provide some ease of handling and minimize the potential for the loss of a physically small but highly radioactive source.

The second requirement is to provide assurance that the radioactive material will not be released under any but extremely severe circumstances. To this end, the material must survive impact, percussion, bending, and thermal testing with virtually no leakage (paragraph 603 of TS-R-1). It is the resulting characteristics that provide the basis for differentiating between A_1 and A_2.

For special form material that is incorporated in a sealed capsule, it must also be made in such a way that destroying the capsule can be the only way to open it. (paragraph 604 of TS-R-1). This requirement would ensure a high degree of integrity of the special form radioactive material.

The design considerations for special form material generally revolve around very high integrity encapsulation for small masses of high specific activity material. As an example, this might result in an inert argon arc-welded, double-walled, stainless steel capsule containing pellets or discs of a solid isotopic source.

The special form radioactive material design, either as an indispersible solid or as a sealed capsule or sealed source, requires unilateral Competent Authority approval (paragraphs 802–804 of TS-R-1). Unilateral approval of a design of special form radioactive material means that the approval must be given by the Competent Authority of the country of origin of the design only. The requirements for the application for approval are provided in paragraph 803 of TS-R-1. The requirements for what is to be included in the approval certificate issued by the Competent Authority of the country of origin of the design, are provided in paragraph 804 of TS-R-1.

8.1.3. Low dispersible radioactive material

The main objective for this material is to assure a low probability of dispersion in the event of an aircraft accident. Therefore, to qualify as LDM there is a limit on the airborne release of gaseous and particulate radioactivity following the enhanced thermal test (800°C for 1 hour) and the high-speed (90 m/s) impact test. In addition, there is a limit on the solubility of the material following these tests. The total quantity of low dispersible radioactive material in a package cannot have a radiation level at 3 m from the unshielded material exceeding 10 mSv/h.

LDM was introduced with the 1996 Edition of the Regulations specifically to allow certain radioactive material to be shipped by air in Type B packages instead of in the new Type C package that otherwise might be required. Because of this recent introduction, and the multilateral approval required (paragraphs 803–804), no material has been qualified as LDM at the time of writing this manual.

8.2. Excepted packages

8.2.1. Requirements

The design of an excepted package must comply with the general requirements set forth in paragraphs 606–616 of TS-R-1. These refer to:

- Ease of handling and securing the package;
- Strength of lifting attachments;
- Lack of protruding features;
- Ease of decontamination;
- Design of the outer layer of the package to prevent collection of water;
- Avoidance of features that might reduce safety;
- Ability to withstand acceleration, and vibration;
- Physical and chemical compatibility of material;
- Protection of valves;
- Ability to handle ambient temperatures and pressures of normal conditions of transport;
- Taking account of any other hazardous properties of the radioactive contents.

In addition, if the package is going by air it must meet the requirements of paragraphs 617–619 of TS-R-1. These requirements cover:

- A maximum surface temperature;
- Ability to handle a wider range of ambient temperatures; and
- Ability to withstand an ambient pressure reduction.

No tests are required by the Regulations for excepted packages.

8.2.2. Design considerations

Because the Regulations do not call for any testing to demonstrate containment or shielding integrity, the design of excepted packages is not demanding. Almost any normal shipping package design could meet the requirements.

8.2.3. Examples

8.2.3.1. Radiopharmaceutical package

An example of an radiopharmaceutical excepted package is a cardboard and Styrofoam packaging containing small glass bottles filled with a liquid radioactive tracer, such as ^{125}I. These typically have an activity of a few MBq, and are intended for such tests as endocrinology function or in-vitro cancer diagnosis. Figure 8.3 shows a typical radiopharmaceutical excepted package.

FIG. 8.3. Excepted package containing radiopharmaceuticals.

8.2.3.2. Postal package

A common type of excepted package is the postal package. The limits of content for postal packages are reduced by a factor of ten compared to other modes of transport (see paragraph 579 of TS-R-1). Typical uses of postal packages include the sending of radiopharmaceuticals for medical purposes.

Attention is drawn to the fact that the relevant national Postal Authority may impose additional requirements that are not covered by the IAEA Regulations. Therefore, their advice should always be sought prior to the design and production of an excepted package for postal use.

8.2.3.3. Instruments and manufactured articles packages

Another type of excepted package can be one containing instruments or manufactured articles such as clocks and other consumer products, electronic tubes or experimental apparatus containing radioactive material as a component part (paragraph 517 of TS-R-1).

Included in this grouping would be aircraft counterweights made from depleted uranium coated with epoxy resin, as well as uranium shielding encased in metal for X or gamma ray radiography sources and medical devices. The inactive sheath, which should cover all readily accessible external surfaces, is required to absorb the alpha radiation and to reduce the beta radiation at the surface. Such sheaths may also protect the outer surface from abrasion, and reduce surface oxidation thereby minimising possible build-up of loose surface contamination. Although not a regulatory requirement, it is advisable to identify the contents of such packages so that they are not disposed of carelessly.

8.2.3.4. Empty packagings

Empty packagings which have previously contained radioactive material, and which represent a very limited radiological risk, may be transported as excepted packages (paragraph 520 of TS-R-1). This is allowed provided that:

- The package is in a well maintained condition and securely closed; and,
- The level of internal non-fixed contamination does not exceed 400 Bq/cm² for beta, gamma and low toxicity alpha emitters and 40 Bq/cm² for all other alpha emitters.

8.3. Industrial packages Type 1 (Type IP-1)

8.3.1. Requirements

Type IP-1 industrial packages have to meet the same general requirements (paragraph 621 of TS-R-1) as excepted packages discussed above in 8.2.1. If carried by air, they also have to meet the same additional requirements as excepted packages. Finally, an IP-1 package has to comply with the 10 cm smallest overall external dimension requirement (paragraph 634 of TS-R-1).

No tests are required by the Regulations for the Industrial packages Type 1 (Type IP-1).

8.3.2. Design considerations

Because the Regulations do not call for any testing to demonstrate containment or shielding integrity, the design of such packages is not demanding. Generally, anything sufficiently strong to hold the contents will suffice.

8.3.3. Examples

A common type of Industrial package Type 1 is a steel drum. Standard 100 L or 200 L drums, which are used in many industries, are used to transport uranium concentrates. These drums can also be used for the shipment of low level wastes that comply with the applicable requirements for LSA-I material.

Another common type of packaging might be a plywood box. This may have a plastic lining or could be steel banded for extra strength.

8.4. Industrial packages Type 2 (Type IP-2)

8.4.1. Requirements

8.4.1.1. General case

A Type 2 Industrial package has to meet all the requirements of an Industrial package Type 1 (Type IP-1) (paragraph 622 of TS-R-1).

In addition, Industrial package Type 2 designs have to be submitted to the *free drop* (paragraph 722 of TS-R-1) and the *stacking test* (paragraph 723 of TS-R-1) described in the next chapter. These tests are part of the normal conditions of transport tests. The criteria, which must be met by the package following the tests, are that the package will prevent:

- Loss or dispersal of the radioactive contents; and,
- Loss of shielding integrity that would result in more than a 20% increase in the radiation level at any external surface of the package.

8.4.1.2. Alternative requirements

The Regulations allow the alternative use of United Nations packagings, tank containers, tanks and intermediate bulk containers (IBC's), as well as the use of ISO freight containers (paragraphs 624–628 of TS-R-1). This is allowed provided that they fulfil additional requirements relating mainly to the loss or dispersal of radioactive contents, or to the loss of shielding integrity. These alternatives are summarized in Table 8.5.

The alternative requirements are considered as acceptable for two reasons. Firstly because the requirements and tests included in the United Nations Recommendations on the Transport of Dangerous Goods provide an equivalent level of safety. Secondly, (applicable to tanks and freight containers), because their extensive history of use has proved that they can provide safe handling and transport of LSA and SCO.

TABLE 8.5. THE USE OF SOME STANDARD PACKAGING AS ALTERNATIVES FOR IP-II OR IP-III

Package Substitution	IP equivalent	Conditions for Allowed Package Substitution
UN PG 1/II packages (para. 624)	IP-2	- Satisfies IP-1 requirements of para. 621 - General UN recommendations on packing for Packing Groups I or II
Tank container (para. 625)	IP-2 or IP-3	- Satisfies IP-1 requirements of para. 621 - Meets UN multi-modal tank transport requirements or equivalent - Minimum test pressure = 265 kPa - Retains shielding
Tanks (para. 626)	IP-2 or IP-3	- Satisfies IP-1 requirements of para. 621 - Limited to LSA-I or LSA-II liquids or gases as prescribed in Table IV - Excludes tank containers
Freight containers (para. 627)	IP-2 or IP-3	- Satisfies IP-1 requirements of para. 621 - Solid contents only - Prevent loss or dispersal of contents and loss of shielding
Interm. Bulk containers (IBCs) (para. 628)	IP-2 or IP-3	- Satisfies IP-1 requirements of para. 621 - Metal construction only - Conforms to UN design requirements for PG I or PG II IBC - Drop tests on most damaging orientation

8.4.2. Design considerations

The mere fact that these packages have to be submitted to the free drop test means that they have to have a certain minimal strength, which must be consistent with the mass of the package. However, such packages are not difficult to design. Generally, a package designed to withstand the free drop test can also easily withstand the stacking test.

8.4.3. Examples

8.4.3.1. Drums

A drum, filled with low level waste meeting the requirements of LSA-II material, may be transported as a package in its own right, or as a group of packages. Alternatively, for ease of handling, it can be transported inside an International Standards Organization (ISO) approved container. The use of an ISO container allows the option of declaring either the drums or the container as the packaging. Specifying the container as the package may provide some relaxation on the drum design, but may introduce other problems such as meeting the allowable quantities of fissile material in a package. Figure 8.4 shows a typical waste drum loading operation.

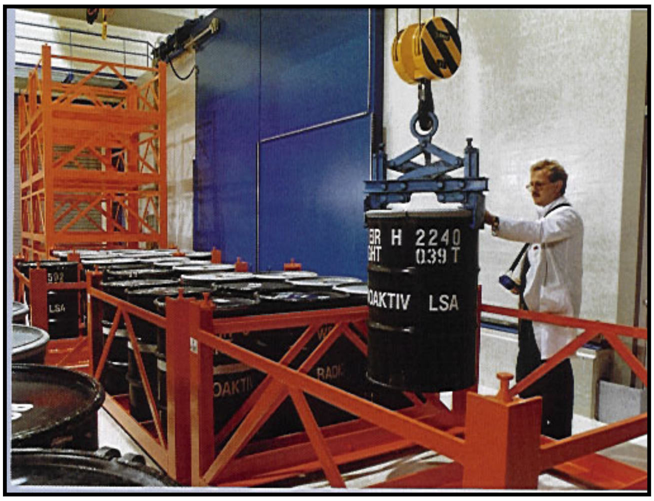

FIG. 8.4. Steel waste drum loading operation.

8.4.3.2. Concrete cylinders

Ion exchange resin mixed with either cement or a polymer resin is often poured into a reinforced concrete cylinder to be used for final disposal. This constitutes a typical Industrial package Type 2 that can be used for transport.

8.5. Industrial packages Type 3 (Type IP-3)

8.5.1. Requirements

8.5.1.1. General case

In addition to the general design requirements of paragraphs 606–616 of TS-R-1 (discussed in 8.2.1.), industrial packages Type 3 must also meet several requirements (paragraph 623 of TS-R-1) that are essentially the same as those required for Type A package designs (contained in paragraphs 634–647 of TS-R-1). In summary, paragraphs 634–645 of TS-R-1 refer to:

- The smallest dimension not to being less than 10 cm;
- The use of seals to indicate opening;
- Tie-downs not interfering with the package's ability to meet the requirements;
- The effect of specified ambient temperatures on packaging components and materials;
- Use of design and manufacturing standards;
- A containment system with a positive fastening device;
- Special form material potentially being part of the containment system;
- Separate unit containment systems also having separate positive fastening devices;
- Consideration of radiolytic decomposition;
- Ability to withstand reduced ambient pressure;
- Enclosures to retain any leakage from valves;
- Radiation shields designed to prevent unintentional release of components from the shield.

Industrial packages Type 3 have to be submitted (paragraph 646) to the tests designed to demonstrate ability to withstand normal conditions of transport. These are described in detail later in this Chapter, but include the water spray test (paragraph 721 of TS-R-1) preceding each of the free drop test (paragraph 722 of TS-R-1), the stacking test (paragraph 723 of TS-R-1), and the penetration test (paragraph 724 of TS-R-1). The criteria that must be met by the package design following these tests and that the package will prevent are:

- Loss or dispersal of the radioactive contents; and
- Loss of shielding integrity that would result in more than a 20% increase in the level of radiation at any external surface of the package.

As before, if being shipped by air the package must meet the requirements of paragraphs 617–619 of TS-R-1 (discussed in 8.2.1.).

Therefore, the requirements for a Type IP-3 carrying solid material are the same as those that apply to a Type A package carrying solid material.

Type IP-3 packages containing liquid radioactive material have to make allowance for ullage to address variations in temperature, for dynamic effects, and for filling effects (paragraph 647 of TS-R-1). However, the Type A package requirement of either absorbent material or a two-level containment system (paragraph 648 of TS-R-1) is not required for IP-3 packages designed for liquids.

8.5.1.2. Alternative requirements

The Regulations allow the use of some United Nations packagings under alternative requirements for Industrial Packages Type 3. (see paragraph 8.4.1.2. and Table 8.5 of this chapter). Figure 8.5 illustrates some typical Industrial Packages under the alternative requirements.

8.5.2. Design considerations

Since the requirements for Type IP-3 and Type A packages carrying solid radioactive material are the same, then many of the design considerations are similar. Often the material in the industrial package will have a lower specific activity and therefore, a Type IP-3 will be considerably bulkier.

8.5.3. Examples

Designers of Industrial package Type 3 frequently take advantage of the alternative that is allowed by the TS-R-1 Regulations. Consequently, a typical Type IP-3 is made of a 20 foot ISO container, with an internal stainless steel liner. The liner provides containment so that the internal part of the container can also be easily decontaminated. It is loaded with drums filled with Low Specific Activity (LSA) waste.

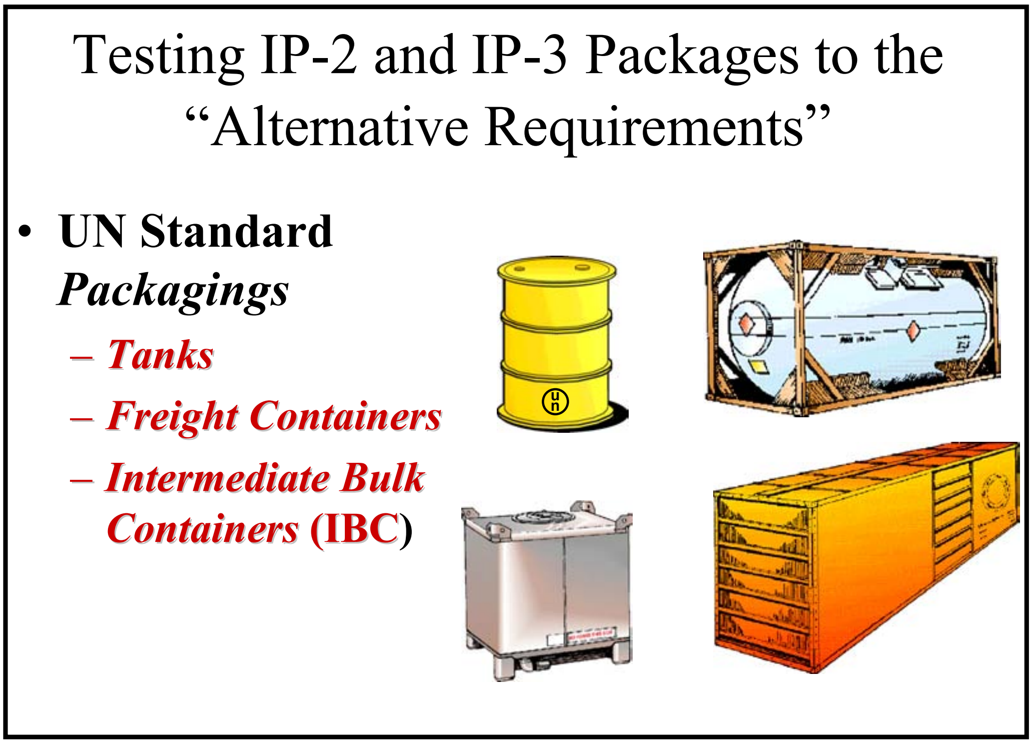

FIG. 8.5. UN Standard packagings as alternative Industrial Packages.

8.6. Type A packages — general

8.6.1. Requirements

The requirements for a Type A package designed to contain solid radioactive material contents (see paragraphs 633–647 of TS-R-1) are the same as those described above (8.5.1.1) for the general case of industrial packages Type 3. However, there are additional requirements for liquid (paragraph 648 of TS-R-1) and gaseous (paragraph 649 of TS-R-1) contents, and these are covered in paragraph 8.7 of this chapter.

8.6.2. Design considerations

8.6.2.1. Small, solid sample package

In order to illustrate the design process for Type A packages, consider a small sample of radioactive material. Assume that it is only a few grams, that it is not in special form, and that the activity of sample is less than the A_2 value for this combination of radionuclides.

Although the sample is solid, it is in a form where, under normal conditions of transport, some material could be detached and dispersed, if it is not contained. This dictates that a sealed container is required. The source is a reasonably strong gamma emitter and, therefore, some form of shielding is required. It can be assumed that the transport of this, or very similar sources, will be a fairly regular occurrence justifying the use of a re-usable, returnable container.

This information provides the basis for a Type A package design. The requirement for shielding probably dictates a lead or steel pot, substantial enough in its own right with a bolted, sealed closure to provide containment able to withstand the normal conditions of transport Regulatory tests (paragraphs 719–724 of TS-R-1). It must also be remembered that the package requires a security seal (paragraph 635 of TS-R-1) and labelling (paragraphs 541 to 544 of TS-R-1) appropriate to the contents. Finally by ensuring that all external dimensions are greater than the 100-mm minimum (paragraph 634 of TS-R-1), the design becomes a valid Type A package design.

For the case that the source is not of friable material, but rather a solid unbreakable object or sealed source, providing its own containment, no purpose-designed seal would be required for the pot. However, the security seal (paragraph 635 of TS-R-1) would still be needed and in practice, a weather seal would be necessary.

8.6.2.2. Non-returnable packaging

Sometimes the requirement that the empty packaging be returned is not applicable. This might be because the amount of lead shielding required is small and it becomes uneconomical to return empty packages to the consignor, or because it would be expensive to maintain the packages as required by the Regulations. Making the container non-returnable can change the form of the packaging dramatically. The containment feature can be switched from the pot itself to other components such as a thin tin plate or aluminium can. As the lead pot in this case may be quite thin and could suffer significant distortion under test conditions, it is usually surrounded with material, such as expanded polystyrene, within the can. This also prevents any significant increase in radiation levels on the package surface by maintaining the position of the source, as well as providing some support to the can itself, thus keeping distortion to a minimum. Tin cans such as these come with various closure types and may have lids that have been soldered, pressed or clamped. Where lids are pressed, or clamped, a thin synthetic rubber gasket provides the seal. It is common practice with these cans to package them inside cardboard cartons. This provides convenient surfaces for attaching labels, as well as providing some additional mechanical protection.

8.6.2.3. Spacing

Various package designs are available that allow distance between the source and the surface to reduce external dose rates. Sometimes shielding material is also used in combination with the distance. Where the inner packaging components are relatively light and unlikely to impose significant loads under test conditions, increased space may be provided inside a typical cardboard carton by using a cardboard spider or packaging material such as expanded polystyrene. The shape, size, and weight of the inner packaging components determine the best material to be used. Of prime consideration here is to ensure the minimum movement of the inner packaging, within the outer packaging, in order to comply with the Regulatory requirements regarding the minimal increase of the radiation dose rate on the surface (paragraph 646 of TS-R-1). Where the weight of the inner packaging is significant, and damage to inner and outer packaging could be anticipated during Regulatory tests, then such designs are usually composed of outer metal drums, with metal (steel) spacers inside to fix the inner packaging in position.

Consideration must also be given to the likely usage of such a space shielded package since this will determine whether a lightweight throw away design is practical, even if from the Regulatory point of view it is acceptable. For example, a package designed to contain a sealed source might be used for demonstration purposes. As such, it may be transported from place to place frequently, and will be used for storage between use. This package would have to have a very substantial, rugged and practical design, perhaps consisting of a steel drum with steel internals.

8.6.2.4. Multiple sources

In some instances, Type A packages may contain large numbers of individually packaged sources that, if considered in their own right, could be transported in excepted packages. However, when grouped together in sufficiently large numbers the sources would comprise sufficient activity to require transport in a Type A package.

8.6.2.5. Large Type A containers

Size and apparent structure is no guaranteed indication as to the type of radioactive material transport package. Indeed, Type A packages are not always small lightweight objects. Containers for neutron sources, for example, can be bulky objects with large amounts of paraffin wax, which provides the necessary neutron shielding. Similarly, when sources are excessively heavy, the packaging needs to be correspondingly strong and heavy to contain them.

8.6.2.6. Special form radioactive material contents

The use of radioactive material in special form, either as indispersible solids or as sealed sources, usually confers two additional benefits. Firstly, the material will probably be in a form that is easy to handle, greatly facilitating its production and use. For example, it is common practice for special form capsules to incorporate specific handling features as part of their construction. Secondly, the typical physical size and nature of special form radioactive material means that problems associated with tightly sealed containment vessels as part of the packaging are virtually eliminated since no gases, liquids, or solid particulate material will be available for release.

As an indispersible solid, the special form radioactive material requirements can be a property of the radioactive material itself. Conversely, a dispersible radioactive material may be absorbed or bonded to an inert solid in such a way that it acts as an indispersible solid (e.g. resin beads or metal foils).

Alternatively, dispersible material may be encapsulated in an inert material (e.g. a stainless steel capsule) in such that the only way of effectively opening the capsule would be to destroy it (paragraph 604 of TS-R-1). Sealed sources can come in any shape or size but are generally limited in practice to a cylinder, disc, or flat plate. A capsule may contain one or a number of sources all within the same containment structure. Packages may contain one or a number of sealed sources up to the limit established by the design of the package. In the case of a Type A package, this is the A_1 value.

Sealed sources may be supplied in packages designed for specific purposes such as industrial radiography or medical treatment. In these cases the package itself may also be the object used to carry out the work. For example, it may be fitted with a mechanism that allows safe and easy release of the source into the object to be radiographed, as well as remote withdrawal and storage back within the container.

8.6.3. Examples

Many examples of Type A packages have been described as part of the discussion on design. Type A packages are one of the most common, and come in an extensive array of shapes and sizes. This is shown pictorially in Figure 8.6. An actual common example is shown in Figure 8.7.

FIG. 8.6. Typical forms of Type A packages.

FIG. 8.7. A commonly used Type A package.

8.7. Type A packages — liquids or gases

8.7.1. Requirements

Type A packages designed to contain liquids or gases have to meet all of the requirements for Type A packages with solid contents described above in 8.6.1.and must satisfy additional requirements as discussed below.

8.7.1.1. Liquids

A Type A package designed to carry liquids must comply with the requirements of paragraphs 647 and 648 of TS-R-1. The first paragraph outlines the need for adequate ullage as discussed in 8.5.1.1. The second requires either:

- Sufficient absorbent material to absorb twice the volume of the liquid contents; or
- An inner and outer containment system designed to ensure the retention of the liquid contents even if the primary inner components leak.

Furthermore, a Type A package designed to carry liquids must be able to withstand a *9m-drop test* onto a flat unyielding surface and a *penetration test* from a height of 1.7 m (instead of 1 m). It must then satisfy the usual constraints with respect to loss of contents or shielding integrity.

8.7.1.2. Gases

The additional requirement for a Type A package carrying gases is the prevention of loss or dispersal of the radioactive contents if subject to the 9 m *drop test* and the 1.7 m *penetration test* (paragraph 649 of TS-R-1). An exception to this is made for tritium gas or for noble gases.

8.7.2. Design considerations

Clearly, the major additional design considerations for the liquids and gases are the enhanced drop and penetration tests. Generally, it is not difficult to allow for the ullage, and to build in the absorbent materials or double containment for liquids. In practice however, the consequence of the requirements is that most containers for liquid radioactive material contents are relatively small in volume.

8.7.3. Examples

Type A quantities of radioactive liquid samples are commonly transported in the type of container described as "non-returnable packaging" in 8.6.2.2. The sealed can provides a convenient way of providing a secondary containment barrier, to ensure retention of the liquid. A package design such as this usually can quite easily withstand the regulatory 9m-drop test and 1.7 m penetration test required for Type A packages carrying liquids.

8.8. Type B(U) and B(M) packages

8.8.1. Requirements for Type B(U) packages

The design of a Type B(U) package must comply with:

- The general requirements discussed in 8.2.1.1. (paragraphs 606–616 of TS-R-1);

- The requirements applicable to Type A packages designed to carry solids (paragraphs 634–647 of TS-R-1) discussed in 8.5.1.1.of this chapter;
- The requirements of paragraphs 617–619 of TS-R-1 if carried by air (covered in 8.2.1 of this chapter); and,
- The requirements specific to Type B(U) packages that are given in paragraphs 651–664 of TS-R-1. These are related to package pre-test and post-test quantified radiation level; containment, shielding, and thermal performance criteria; absence of pressure relief; and limitation of the maximum normal operating pressure (paragraph 228 of TS-R-1).

8.8.1.1. Normal conditions of transport

Type B(U) packages must be designed to withstand the normal conditions of transport tests, which are described in detail in the second part of this chapter. The criteria, which must be met by the package design following these tests, are that the package will:

- Restrict the loss of its radioactive contents to not more that 10^{-6} A_2 per hour (paragraph 656(a) of TS-R-1);
- Prevent loss of shielding integrity that would result in more than a 20% increase in the radiation level at any external surface of the package (paragraph 646(b) of TS-R-1).

These tests and pass criteria are equivalent to those which apply to Type A packages, except that the quantitative criteria given above is specified for the allowable release of activity for Type B(U) packages.

8.8.1.2. Accident conditions of transport

Type B(U) packages have to be designed to withstand the accident conditions of transport tests, which are described in detail in the second part of this chapter. These are tests that were conceived as producing damage to the package equivalent to that which would be produced in a very severe accident. This damage would be greater than that arising in the vast majority of incidents ever recorded (whether or not a package of radioactive material was involved). However, it should be remembered that the tests do not necessarily cover all conceivable accidents.

The tests include mechanical (paragraph 727 of TS-R-1), thermal (paragraph 728 of TS-R-1), and water immersion (paragraphs 729 and 730 of TS-R-1) tests. Two sequences have to be carried out. Two specimens may be used, one for each sequence, or one specimen may be used for both sequences (see paragraph 726 of TS-R-1):

- The mechanical tests followed by a thermal test; and,
- A water immersion test.

One mechanical test consists of a 9 m drop test onto a flat, horizontal, unyielding surface (paragraph 727(a) of TS-R-1). For lightweight Type B packages, this is replaced by a dynamic crush test caused by the drop of a 500 kg mass from 9 m onto the specimen (paragraph 727(c) of TS-R-1). The other mechanical test is a puncture resulting from a 1 m drop of the specimen onto a cylindrical bar (paragraph 727(b) of TS-R-1). Each mechanical test must be performed with the package in an orientation so as to result in the maximum damage to the package. In addition, they are to be performed in the most damaging order with respect to the subsequent thermal test.

The thermal test involves the exposure of the specimen for a period of 30 minutes to a fire with an average temperature of at least 800°C. The general water immersion test has to be performed with a head of water of 15 m. For packages with high activity contents the head of water must be 200 m.

In order for a package to pass (paragraph 656(b) of TS-R-1) the test series, it must:

- Restrict the accumulated loss of its radioactive contents, in a period of one week following the test procedure, to not more than A_2 (or 10 A_2 in the case of ^{85}Kr); and,
- Not allow the radiation level at 1 m from the package surface to exceed 10 mSv/h.

8.8.2. Requirements for Type B(M) packages

For a variety of reasons, it is sometimes necessary to transport significant quantities of radioactive material in packages which have been designed, manufactured and tested to criteria which do not exactly conform to those given in the Regulations for Type B(U) packages. This may be possible using a Type B(M) package, within a specific country or solely between specified countries, with the specific approval of the Competent Authorities of these countries (paragraph 204 of TS-R-1).

Type B(M) packages have to meet all the requirements for Type B(U) packages given above, except that different conditions may be assumed relating to: the ambient temperature; the solar insolation; the enhanced water immersion test for packages containing a very high activity; the presence of filters or pressure relief system (and intermittent venting); the maximum normal operating pressure; the presence of LDM; and the temperature on the outer surfaces of the package. Apart from these relaxations, the requirements for Type B(U) packages must be met as far as practicable (paragraphs 665 and 666 of TS-R-1).

8.8.3. Design considerations

8.8.3.1. General

The concept of a Type B(U) or Type B(M) package is that it should be capable of withstanding most accident conditions without breach of its containment or without an excessive increase in radiation levels. Therefore, the requirements for such a package are primarily:

- Provision to enable internal generated heat to escape;
- Containment of the radioactive material contents to a high and verifiable standard before and after the tests;
- Shielding to limit the external dose rate level, before and after the tests;
- Provisions to ensure criticality safety. The package must be sub-critical with the package conditions that result in the maximum neutron multiplication consistent with:
- Routine conditions of transport (incident free);
- Normal conditions of transport tests; and
- Normal conditions of transport test followed by the accident conditions of transport test.
- Mechanical integrity to ensure survival of the drop tests;
- Provisions to ensure survival of the packaging in the thermal test (fire test);
- Ability to avoid leakage from the water pressure of the 15 m immersion test; and,
- Ability to avoid rupture when exposed to the water pressure of the 200 m immersion test (for packages containing more than 10^5 A_2 of activity).

The contents of Type B packages come in a multiplicity of forms, radionuclide compositions, and activities. Clearly, the contents will dictate the package design. The use of the contents may also affect the design. Other design considerations, which are unrelated to the radiological safety of the consignment, include such things as excessive temperature build-up, operational interfaces with both facilities and conveyances, and maintenance.

Type B packages are designed to carry specific contents, and often are designed for carriage by specific transport modes. The Regulations specify the requirements, but do not emphasize that these requirements have to be taken into account at an early design stage and reviewed throughout the design process. The following discussion partly relates to the requirements of the Regulations but also gives advice on the best way to ensure that new package designs meet these requirements.

8.8.3.2. Design for the Regulations

Design must be carried out with the Regulations in mind. This means either having a design team specializing in transport packages or contracting specialists at an early design stage and at regular intervals. Although this may be fairly obvious, it is sometimes ignored and licensing staffs are asked to give approval for a design that falls short of the regulatory requirements. In extreme cases, packagings may sometimes be manufactured before regulatory considerations are taken into account.

8.8.3.3. Design for simplicity

Simplicity is desirable because the packagings must function over a long period with minimum operational controls. This is not a regulatory requirement but could certainly affect the ease with which the package design is approved. It is a good philosophy to design so those problems of approval are minimized. For example, stressed items should be designed so that stresses can be readily calculated. This saves effort in making a safety case. The same is true for the thermal design.

Only where a number of high-cost packagings are to be manufactured will the total project cost warrant “fine-tuning” development work to avoid over-designing the package.

8.8.3.4. Design for safety

The design should be as fail-safe as possible, considering the potential for human error. For example, safety features should be incorporated that make it unlikely for a package to be shipped without being appropriately sealed, or that an unsuspecting person can open the package and become exposed to radiation.

8.8.3.5. Design for operation

The design of any package should consider how the package is to be operated. Issues that should be addressed include:

- How the packaging will be loaded with its contents;
- How the packaging will be sealed;
- How contamination on the package surfaces will be minimized, and if such contamination should occur, how it will be removed to satisfy the requirements of the Regulations (paragraph 508 of TS-R-1);
- How the package will be handled within the facilities where it is intended to be used;
- How the package will be stowed on its conveyance;

- What steps are to be taken to minimize the likelihood of contamination of the conveyance and to ensure that any contamination that might occur will remain within the limits specified in paragraphs 512 and 513 of TS-R-1; and,
- How workers will be involved in these operations to ensure that their exposures to penetrating radiation and to contamination are kept low.

8.8.3.6. Design for Quality Assurance (QA)

The complete requirements for controlling the quality of manufacture and operation must be established at the design stage. Quality Assurance applies to all package designs, but usually the level of the QA programme is more comprehensive for packages requiring Competent Authority approval (i.e. the QA programme may follow the graded approach philosophy [3]).

The Regulations require that safety should be in the package design and not in the operational controls. QA operating procedures are required, but the package should be designed to have minimum special operating instructions. There should be nothing that can go wrong because of human error or unintentional actions.

Specifications for materials and manufacturing processes, and manufacturing tests such as those for radiation shielding, leak tightness, and operating temperature range must be written at the design stage. These specifications form an important part of the application for approval to the Competent Authority. They will be referred to either directly, or indirectly, in the certificate of approval.

The specifications should be written early in the design as they may affect fundamental features of the design, such as the need for the inclusion of double O-ring seals, for example.

The level of QA will depend on the particular package. Small packages made from commercially available items (e.g. drums) require minimum QA, except for assurance that the supplier has not changed the design of the component.

Package designs incorporating a sealing system require formal test procedures both at the stage of manufacture (paragraph 501 of TS-R-1) and before each shipment (paragraph 502 of TS-R-1). Larger packages are likely to have many features that require formal assurance. These include seals, closure studs, shielding, neutron absorbers, thermal insulation, shock absorbers, lifting, and tie-down points.

8.8.3.7. Design for pre-shipment inspection

Pre-shipment inspection and maintenance requirements (paragraph 502 of TS-R-1) should be taken into account during the design stages:

- Designing the package to facilitate verification of the sealing of its containment system;
- Satisfaction of external radiation level requirements (e.g. see paragraphs 526, 530–532, 572, 574, and 578 of TS-R-1);
- Satisfaction of temperature-related requirements (e.g. see paragraphs 617 and 652 of TS-R-1);
- Surface decontamination that may be required is especially important. For example, contaminated items are often extremely expensive to decontaminate and may lead to unnecessary exposure to personnel.

8.8.3.8. Design for maintenance

The design should take into account the effect of maintenance on approval certification. A repair may invalidate the approval (e.g. the use of studs in place of bolts). For items likely to require repair or replacement at maintenance (e.g. screw threads), approved repair procedures should be developed at the design stage.

8.8.3.9. Design for manufacture of packaging

If all the above specifications and procedures are developed during the design stage, fabrication should proceed smoothly under an adequate QA system. Manufacturing problems should be minimal because the potential problem areas will have been covered at the design stage.

8.8.4. Examples

These requirements result in Type B(U) or Type B(M) packages that come in an extensive array of shapes and sizes. This is shown pictorially in Figure 8.9. One common design used for shipping isotopes is shown in Figure 8.10. It is important to remember that the physical size of Type B packages provides no indication of the amount of radioactivity contained. Some small Type B packages may contain very large quantities of radioactivity. Some large Type B packages may contain relatively small quantities of radioactivity.

8.8.4.1. Fuel sample flasks

A fuel sample flask, or post-irradiation examination flask, is normally used to transport either a small number of intact fuel pins, fuel elements, or cut fuel specimens. Its purpose is to transport samples of fuel from a reactor to a laboratory for detailed metallurgical and chemical examination.

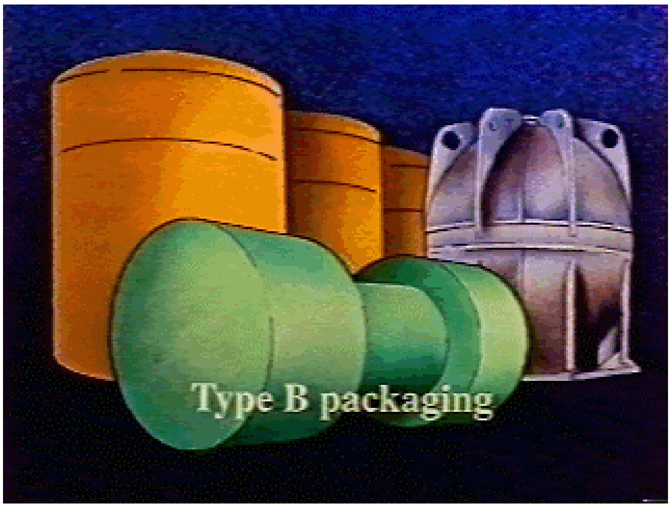

FIG. 8.8. Typical forms of Type B packages.

FIG. 8.9. Typical design of Type B(U) isotope package.

While the samples might be collected from the reactor site pond, and the flask loaded under water, they are quite often transported dry. This is because on arrival at the laboratory, the contents have to be transferred into a shielded cell for work on the fuel to be carried out Nevertheless, it may be necessary to transport the samples wet in order to limit their temperature. It is particularly important to avoid temperatures higher than those reached during operation in the reactor. This will prevent any metallurgical change in the structure of the sample between the reactor and the laboratory.

Transferring the samples into a hot cell can only be carried out from a flask that is equipped with a door. Generally, the door is an integral part of the flask and travels with it, but it is possible to design a flask in which the door travels separately from the flask. Other designs include a door that remains at the site for fitting to the flask when required, or is permanently fitted to the cell, or cave transfer port. While it may be a necessary feature of the fuel sample flask design, the door arrangement does introduce an area of potential structural weakness into the flask design. This is one good reason for having a detachable door that does not travel as part of the flask.

Fuel sample flasks tend to be designed for specific facilities. This in itself can dictate the form that a design will take. For example, where crane capacity within a building is limited, this may automatically mean that lead, rather than steel, has to be used as the shielding material in order to keep the weight down. This has the subsequent effect of dictating the consideration in the package design of the behaviour of the lead under the thermal accident test condition and may require an insulating thermal shield to protect the lead. However, the thermal shield may also need to be separable from the flask, because the combination of the two would be too heavy to handle within the facility. Many of these designs will not withstand the Regulatory drop tests without additional impact limiter panels. These are added to the outside of the package design so that both the flask itself and its thermal shield are afforded protection.

In facilities where weight handling is not a problem, the shielding material may be specified as steel, or a thick steel/lead combination. The presence of a door in the design is still a structurally weakening feature and this may result in a design requirement to provide impact limiters at each end of the flask for protection. Although there is not a threat of the radiation shield melting, the penetration seals may be threatened by the high temperatures resulting from the thermal test. This can be alleviated by providing thermal shields as part of the impact limiters.

As far as possible, it is desirable at all times to prevent the inside as well as the outside of the flask from becoming contaminated. This ensures that the contents are contained within a can or drum before loading into the flask. The leak-tightness of the can cannot normally be checked before shipment, because of the high radiation dose rate from the can. However, in practice, it provides a further containment barrier and keeps the flask contamination to a minimum.

8.8.4.2. Irradiated nuclear fuel and high level waste flasks

One of the major types of Type B packagings are those used for the transport of irradiated nuclear fuel. These flasks are discussed in detail in paragraph 8.9.3.1 of this chapter. In addition, during the discussion of LSA material, several types of waste packages were mentioned. Not all wastes can be qualified as LSA material. Some intermediate and high level wastes need to be transported in Type B packages rather than in industrial packages.

Typical Type B(U) irradiated nuclear fuel packages are shown in Figures 8.10. and 8.11.

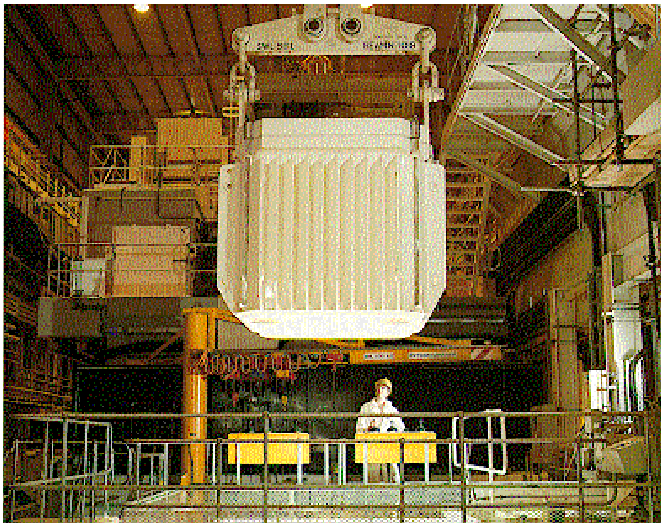

FIG. 8.10. Type B(U) irradiated Magnox nuclear fuel package.

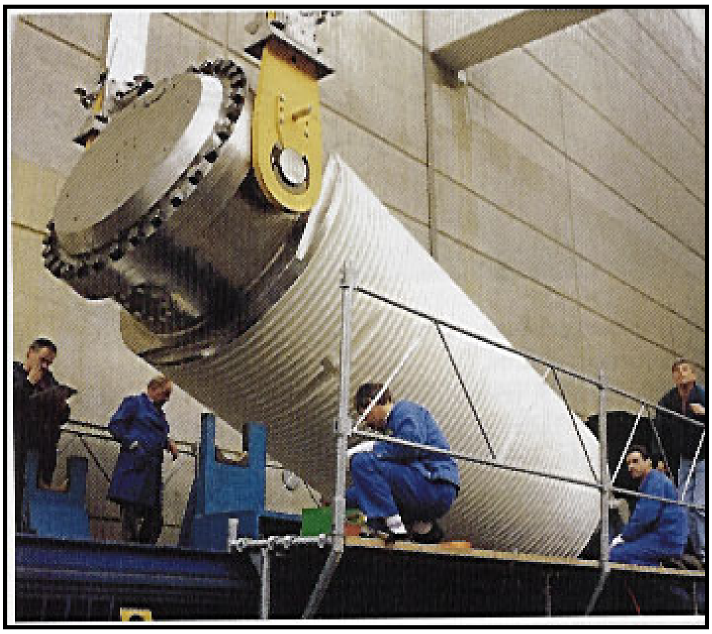

FIG. 8.11. Type B(U) irradiated LWR nuclear fuel package.

8.8.4.3. High enriched fissile material packages

Other, specialized Type B packages addressing fissile materials are those designed for the carriage of highly enriched products such as plutonium oxide powders. Here the emphasis is on high integrity seals, high integrity containment and high structural integrity. The quantity of material carried tends to be small; therefore, the sealed enclosures tend to be small in volume. In addition, users take great care to ensure that this material is transported with the highest degree of safety. A number of designs have been free-drop tested (in addition to the regulatory requirements) from heights of 300 m, 600 m and 1600 m with no dispersal of contents being recorded.

8.8.4.4. Transuranic waste packages

Type B packages have been designed for the transport of transuranic (TRU) wastes. These packages are different from irradiated nuclear fuel and high level waste packages because they generally are not required to have much, if any, gamma shielding. As such, they tend to be large, lighter weight packagings, and do not have the thick layers of steel, lead or depleted uranium. Since most of the radionuclides present in such wastes are alpha-emitters, the structure of the packagings required to resist the normal and accident conditions of transport are usually sufficient to provide all the shielding necessary to satisfy the external radiation level requirements of the Regulations.

8.8.5. Approvals

8.8.5.1. Unilateral and multilateral approval of package designs

Each Type B(U) package design requires unilateral approval (paragraphs 802 and 806 of TS-R-1), except that:

- A package design for fissile material requires multilateral approval; and,
- A Type B(U) package design for low dispersible radioactive material also requires multilateral approval.

Unilateral approval of a design, (paragraph 205 of TS-R-1), means that the approval must be given by the Competent Authority of the country of origin of the design only.

Each type B(M) package design, including those for fissile and those for low dispersible radioactive material requires multilateral approval (paragraphs 802 and 809 of TS-R-1).

Multilateral approval of a design (paragraph 204 of TS-R-1) means approval by the relevant Competent Authority both of the country of origin of the design, or shipment, and of each country through or into which the consignment is to be transported. The term “through or into” specifically excludes “over”. This means that the approval and notification requirements do not apply to a country over which radioactive material is carried in an aircraft, provided that there is no scheduled stop in that country.

8.8.5.2. Approval application contents

Each application for a Type B(U) or a Type B(M) package design approval to a Competent Authority needs to include (paragraph 807 of TS-R-1):

- A detailed description of the proposed radioactive contents with reference to their physical and chemical states and the nature of the radiation emitted.
- A detailed statement of the design, including complete engineering drawings and schedules of materials and methods of manufacture.
- A statement of the tests, which have been performed, and their results, or evidence based on calculation methods or other evidence that the design is adequate to meet the applicable requirements.
- The proposed operating and maintenance instructions for the use of the packaging.
- A specification of the materials of manufacture of the containment system, the samples to be taken, and the tests to be made, if the package is designed to have a maximum normal operating pressure in excess of 100 kPa gauge.
- Where the proposed radioactive contents are irradiated fuel, the applicant must state and justify any assumption in the safety analysis relating to the characteristics of the fuel and describe any pre-shipment measurement required.
- Any special stowage provisions necessary to ensure the safe dissipation of heat from the package considering the various modes of transport to be used and the type of conveyance or freight container.
- A reproducible illustration, not larger than 21 cm by 30 cm, showing the make-up of the package.
- A specification of the applicable Quality Assurance programme.

In addition to the previous required information, an application for approval of a Type B(M) package design has to include the following information (paragraph 810 of TS-R-1):

- A list of the requirements specified in paragraphs 637, 653, 654, and 657-664 of TS-R-1 with which the package does not conform. These are the conditions that relate to: the ambient temperature; the solar insolation; the enhanced water immersion test for packages containing a very high activity; the presence of filters or pressure relief system (and intermittent venting); the maximum normal operating pressure; and the temperature on the outer surfaces of the package;
- Any proposed supplementary operational controls to be applied during transport not regularly provided for in the TS-R-1 Regulations, but which are necessary to ensure the safety of the package or to compensate for the deficiencies listed in (1) above;
- A statement relative to any restrictions on the mode of transport and to any special loading, carriage, unloading or handling procedures; and,
- The range of ambient conditions (temperature, solar radiation) which will probably be encountered during transport and which have been taken into account in the design.

8.8.5.3. Approval certificate

Once it is satisfied that the package design meets the requirements, the Competent Authority establishes an approval certificate (paragraph 827 of TS-R-1). This states that the approved design meets the applicable requirements for Type B(U) or Type B(M) package, as applicable, and assigns a unique identification mark to that design.

Each approval certificate for package design that is issued by a Competent Authority must include the following information (paragraph 833 of TS-R-1):

- The type of certificate.
- The Competent Authority identification mark.
- The issue date and an expiry date.
- Any restriction on the modes of transport, if appropriate.
- A list of applicable national and international regulations, including which edition of the IAEA Regulations for the Safe Transport of Radioactive Material the design is to be approved.
- The following statement, “This certificate does not relieve the consignor from compliance with any requirement of the government of any country through or into which the package will be transported”.
- References to certificates for alternative radioactive contents, other Competent Authority validation, or additional technical data for information, as deemed appropriate by the Competent Authority.
- A statement authorizing shipment where shipment approval is required, if deemed appropriate.
- Identification of the packaging.
- A description of the packaging by a reference to the drawings or specification of the design. If deemed appropriate by the Competent Authority, a reproducible illustration, not larger than 21 cm by 30 cm, showing the make-up of the package should also be provided. This should be accompanied by a brief description of the packaging, including materials of manufacture, gross mass, general outside dimensions, and appearance.
- The specification of the design by reference to the drawings.
- A specification of the authorized radioactive material content, including any

restrictions on the radioactive contents which might not be obvious from the nature of the packaging. This includes the physical and chemical forms, the activities involved (including those of the various isotopes, if appropriate), amounts in grams (for fissile material), and whether the material is in special form or is low dispersible radioactive material.

Additionally, information required for packages containing fissile material includes:

- A detailed description of the authorized radioactive contents;
- The value of the criticality safety index;
- Reference to the documentation that demonstrates the criticality safety of the contents;
- Any special features, on the basis of which the absence of water from certain void spaces has been assumed in the criticality assessment;
- Any allowance for a change in neutron multiplication assumed in the criticality assessment as a result of actual irradiation experience;
- The ambient temperature range for which the package design has been approved.
- For Type B(M) packages, a statement specifying those prescriptions with which the package does not conform and any additional explanatory information which may be useful to other validating Competent Authorities.
- For packages containing more than 0.1 kg of uranium hexafluoride a statement specifying the applicable requirements prescribed in paragraph 632 and any amplifying information, which may be useful to other competent authorities.
- A detailed listing of any supplementary operational controls required for preparation, loading, carriage, unloading, and handling of the consignment, including any special stowage provisions for the safe dissipation of heat.
- Reference to information provided by the applicant relating to the use of the packaging or specific actions to be taken prior to shipment.
- A statement regarding the ambient conditions assumed for purposes of design if these are not in accordance with the standard ones given in the Regulations.
- A specification of the applicable Quality Assurance programme.
- Any emergency arrangements deemed necessary by the Competent Authority.
- If deemed appropriate by the Competent Authority, reference to the identity of the applicant and,
- Signature and identification of the certifying official.

8.9. Lightweight/low density Type B(U) and B(M) packages

8.9.1. Requirements

With one exception, the requirements which apply to lightweight/low density Type B(U) or Type B(M) packages are the same as those that apply to any Type B(U) or Type B(M) packages. While most Type B packages will be subject to the 9 m drop test, lightweight/low density Type B(U) and Type B(M) packages must be submitted to the crush test instead (paragraphs 656(b)(i) and 737(c) of TS-R-1). In this test, the specimen is subjected to a dynamic crush force by positioning the specimen on the target so as to suffer maximum damage by the drop of a 500 kg mass from 9 m onto the specimen as described later in this chapter.

8.9.2. Design considerations and approvals

The design considerations which apply to lightweight/low density Type B(U) or Type B(M) packages are the same as those that apply to any other Type B(U) or Type B(M) packages. Nevertheless, because of the crush test requirement, consideration has to be given to the external forces on the packaging. This might lead to the design having some sort of rigid framework. These packages are submitted to the same requirements as for other Type B packages.

8.9.3. Examples

Packages containing large amounts of alpha emitters are generally lightweight/low density packages because of the requirement for less shielding. This includes for example, plutonium oxide powders, and plutonium nitrate solutions, which are radioactive materials with high potential hazards.

8.10. Type B packages containing high quantities of radioactivity

8.10.1. Requirements

In addition to the requirements discussed earlier, a Type B package for radioactive contents with activity greater than 10^5 A_2 has to be designed so that if it were subjected to the enhanced water immersion test there would be no rupture of the containment system (paragraph 730 of TS-R-1). Originally, this requirement only applied to irradiated fuel with an activity greater than 37 PBq, but in TS-R-1 it was expanded to include all radioisotopes in large quantities.

For the enhanced water immersion test, the specimen must be immersed under a head of water of at least 200 m for a period of not less than one hour. For demonstration purposes, an external gauge pressure of a least 2 MPa is considered to meet these conditions. Again, this test is more fully discussed later in this chapter.

8.10.2. Design considerations and approvals

Clearly, to meet the additional water pressure more attention has to be paid to seals, closures, and valves to provide assurance of leak tightness. Except for the additional deep submersion test, these packages are designed to the same requirements as for other Type B packages.

8.10.3. Example

8.10.3.1. Wet/dry fuel flasks

Fuel flasks normally carry intact fuel pins and fuel elements. A typical fuel flask design is shown in Figure 8.12. Because of the activity associated with irradiated fuel, a large amount of gamma and neutron shielding is required to bring the radiation dose rate down to Regulatory levels. The type of shielding chosen is normally steel, although thick steel and lead, or cast iron may also be used.

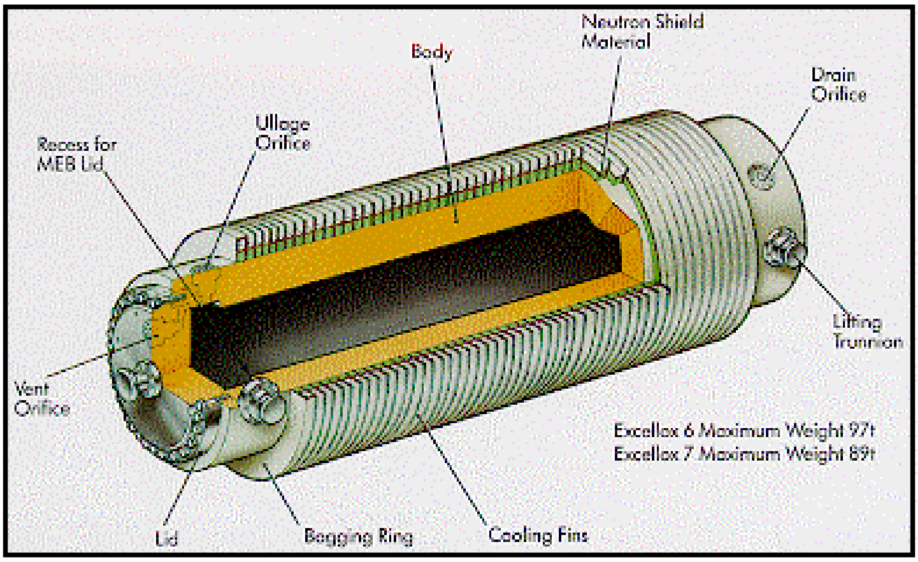

FIG. 8.12. Typical wet/dry irradiated fuel package design.

The loading of fuel into these flasks is normally carried out in a pond attached to irradiated nuclear fuel storage pools at reactor sites. Depending on the fuel type, the number of fuel pins carried, and the heat output from the pins, these flasks may be transported either full or drained of water. The presence of water provides some neutron shielding and enhances heat transfer from the fuel pins to the flask's walls, and hence to the environment and the fuel pins are kept cool. However, the presence of water in the container does impose extra loads on the flask body and lid under impact conditions.

On the other hand, although fuel flasks transported dry may be subjected to less onerous loading under impact conditions, they have to be equipped with a basket which provides efficient heat transfer. Otherwise, overheating of the fuel could result in cladding rupture, release of fission product gases, and possible oxidation of the fuel itself. An additional improvement over heat transfer is possible using helium as a coolant.

Helium has the added advantage that it counteracts the problem of radiolysis. Radiolysis is the breakdown of water molecules under the influence of strong gamma radiation into a potentially flammable or explosive mixture of hydrogen and oxygen. Even in containers where the water has been drained, some water is inevitably still present in the form of vapour, water droplets, or trapped free water. Vacuum drying can be employed to remove any water present thus negating the potential problem.

Because fuel flasks contain potentially releasable mixtures of fission product gases, volatile solid radionuclides and particular matter, an efficient and effective sealing system must be provided. This may take the form of a double O-ring seal. Such a seal also permits verification of the leak tightness of the container before shipment, by pressure testing the space between the seals.

One popular method of fabrication of fuel flasks is by forging steel into a monolithic flask body. An alternative cheaper method of fabrication is casting steel or spheroidal graphite cast iron into a monolithic flask body. For this second type of flask construction, great care is needed in controlling the production process and a very comprehensive Quality Assurance programme must be enforced. Yet another fabrication method includes the formation of large, concentric steel shells with interstitial layers of either lead, or depleted uranium, or both.

In many cases, it is also necessary to provide a neutron shield, usually on the outer portion of the package design. Frequently, impact-protecting devices are provided as part of the package design.

8.11. Type C packages

8.11.1. Requirements

Type C packages must generally meet the same requirements as Type B(U) packages up to, and including, the normal conditions of transport tests. However, some of the accident-simulating tests are more severe (paragraph 667 of TS-R-1).

Type C package designs are required to undergo the cumulative test sequences 1 and 2 outlined below and detailed later in this chapter. After the tests, they must be shown to retain their radioactive contents and shielding properties within defined limits. Like Type B(U) and Type B(M) packages, they must restrict loss of radioactive contents to no more than A_2 in a week (10 A_2 in a week for ^{85}Kr), and restrict the radiation level at 1 m from the package surface to not more than 10 mSv/h (paragraph 669(b) of TS-R-1).

Additionally, Type C package designs must be shown to meet the same containment and shielding criteria as those above when subjected to burial (paragraph 668 of TS-R-1) and must be shown not to rupture when immersed in water 200 meters deep (paragraph 670 of TS-R-1). The requirement to demonstrate the ability to withstand burial is done by calculation assuming the package to be undamaged and buried in dry soil at 38°C in a steady state condition. The burial test was introduced because packages involved in high-speed crashes may be covered by debris or buried in soil. If a package whose contents generate heat becomes buried, an increase in package temperature and internal pressure may result.

8.11.1.1. Sequence 1

This test sequence must be carried out in the given order on the same specimen:

- The specimen is subjected to the accident conditions of transport drop I (paragraphs 734(a) and 727(a) of TS-R-1), being dropped from 9 metres onto an effectively unyielding target so as to suffer maximum damage (the impact speed is 13.3 meters per second);
- The specimen is subjected to the accident conditions of transport dynamic crush test (drop III), by placing it on the same unyielding target, in the worst orientation, and dropping a 500 kg plate onto it from a height of 9 meters (paragraphs 734(a) and 727(b) of TS-R-1);
- The specimen is subjected to a puncture/tearing test being dropped from 3 metres onto a conical probe (paragraphs 734(a) and 735 of TS-R-1);
- The specimen is subjected to an engulfing 800°C thermal test for a period of <u>one hour</u> (paragraphs 734(a) and 736 of TS-R-1).

This test sequence recognizes that it is possible for a fire of long duration to occur following a low speed aircraft impact with subsequent crushing and puncture/tearing.

8.11.1.2. Sequence 2

This test may be carried out on a separate specimen from the first sequence. It requires that the specimen be subjected to an impact at a speed of 90 m/s onto an essentially unyielding target so as to suffer maximum damage (paragraphs 734(b) and 737 of TS-R-1).

A separate specimen may be used for this test. It is considered that exposure to long duration fires in the aftermath of a high-speed aircraft impact is highly unlikely. Because the fuel on board an aircraft is typically dispersed in a crash, it will not form pools to supply long lasting fires in a single location.

8.11.2. Design considerations

The tests for Type C packages are considerably more stringent than those applying to Type B(U) and Type B(M) packages and, for a given radioactive content, the package may be expected to be considerably more robust and heavier. The 90 m/s impact test is especially demanding.

8.11.3. Approvals

Each Type C package design requires unilateral approval, except that a package design for fissile material requires multilateral approval (paragraph 806 of TS-R-1).

The Competent Authority has to issue an approval certificate stating that the approved design meets the applicable requirements for Type C packages (paragraph 827 of TS-R-1) and assigns an identification mark to that design.

The contents of an application for approval and of an approval certificate of the design of a package issued by a Competent Authority must include the same information as for a Type B(U) or Type B(M) approval (see 8.8.5.2 and 8.8.5.3 of this chapter).

The provisions for Type C packages first came into effect for international air shipment when Member States and the International Civil Aviation Organization implemented them on 1 January 2001. As no transitional arrangements were foreseen, the new provisions had immediate effect. This means that since that date, package design approvals for Type B(U) and Type B(M) packages have to be amended to reflect the content limit for transport by air.

8.11.4. Examples

At the time of the publication of this document there are no known Type C approved package designs.

In the USA in the 1970's, packages were designed to carry plutonium dioxide (PuO_2) powder under the requirements of US Nuclear Regulatory Commission Guide NUREG 0360 [4]. This text requires, amongst other things, that the package withstand a 129 m/s impact and a one-hour fire (as compared with the 90 m/s impact required in TS-R-1). Obviously, these so-called PAT-1 and PAT-2 packages would be candidates for Type C approval.

An interesting and innovative design is the FS 81 packaging, which is under development in France. The packaging has been designed to accommodate one of the three following contents:

- One PWR mixed oxide (MOX) fuel assembly,
- Two BWR MOX assemblies, or
- Fuel rods in a canister.

To remain compatible with different operational and transport constraints and in view of the need to withstand the new regulatory tests, innovative principles have been introduced in this packaging design. One of the basic principles is to consider that a substantial part of the kinetic energy at the time of impact is absorbed by the containment components of the packaging and by the content itself. This leads to the concept of planned, controlled local plastic deformation of these different elements.

Therefore, a new containment concept excluding any mechanical assembly was used. A leak-tight welded capsule without any orifices provides the containment vessel. This cylindrical capsule is closed at each end by a hollow hemisphere. This containment vessel has no opening or closure arrangement. Welding onto one hemispherical end after the contents and the internals have been inserted makes closure. Mechanical cutting at the same end carries out opening.

The packaging body is designed to protect the containment vessel during the different mechanical and thermal regulatory tests. It contains a layer of efficient neutron absorbing resin that contributes primarily to shielding but also acts as fire protection. Special devices designed to absorb a large part of the kinetic energy during impact protect the two ends of the body. These devices absorb more than 50 % of the kinetic energy during an axial impact at more than 130 m/s. They also remain efficient during angled impacts. Their efficiency is still approximately 35 % at an impact angled at 19°.

The body consists of two almost identical parts that can be separated to provide access to the containment vessel during loading and unloading of the fuel assemblies. Two aluminium caps have been designed to protect both ends of the containment vessel, and “operate” at precise moments during impact.

Since the desire to transport different types of contents with the same packaging was one of the initial goals, only the internal arrangement is specific to the content transported. These internal arrangements are designed to prevent damage to the internal wall of the containment vessel from shocks imposed under normal and accident conditions of transport.

The package body is connected to an aluminium frame by means of an anti-vibration system to ensure fuel integrity with respect of its future use in the power reactor.

8.12. Packages containing uranium hexafluoride

Earlier versions of the Regulations did not specifically address uranium hexafluoride (UF_6), but dealt with its fissile and radiological considerations in the same manner as any other material. In 1984, the ship “Mont-Louis”, transporting 48Y cylinders from France to Russia, sank in the North Sea off the coast of Belgium. All the packages were recovered with no release of contents, and therefore with no chemical or radiological contamination. However, this led the international transport community to question the adequacy of the regulations relating to uranium hexafluoride. This accident highlighted the chemical hazard potential, especially when linked to the reaction of uranium hexafluoride with water or humid air. It also brought attention to the lack of a pressure relief system on the cylinders. This prompted the IAEA and the Member States to modify the existing regulations applying to the transport of UF_6.

The decision to write separate regulations in the 1996 Edition of the Transport Regulations for a specific material was not taken lightly. It represented a significant change in the philosophy in the Regulations, which had always been formulated to apply generally to all radioactive material. The impetus for the change was driven more by a desire to ensure physical and chemical toxicity safety in the event of an accident involving a fire, rather than concerns about radiological or criticality safety. This change reflects the importance of UF_6 within the fuel cycle, the very large quantities being shipped, and the peculiar physical and chemical properties of the material.

The new provisions (paragraphs 629–632 of TS-R-1) for packages containing UF_6 are restricted to package performance standards and administrative requirements. Otherwise, the Regulations draw on the International Organization for Standardization document ISO 7195:1993 (E) "Packaging of Uranium Hexafluoride (UF_6) for Transport" [5] for more detailed technical specifications.

Uranium hexafluoride is generally loaded under a pressure of 0.4 MPa and at a temperature of about 100°C, and under these conditions it is a liquid. The packages, therefore, also must comply with the requirements for pressurized equipment. Consequently, they are designed to resist a service pressure of 2 MPa (14 bar). The combination of these two sets of Regulations imposes stringent requirements. In particular, the packagings must be tested every five years to verify their resistance to a hydrostatic pressure of twice the service pressure.

The Revision Process dealt with a number of difficult items concerning UF_6. These included:

- Cylinder pressure test requirements (paragraphs 630(a) and 718 of TS-R-1),
- Drop test requirements (paragraphs 630(b) and 722 of TS-R-1),
- Thermal test requirements (paragraphs 630(c) and 728 of TS-R-1),
- Criticality safety (paragraph 677(b) of TS-R-1), and
- Need for Competent Authority design approval (paragraph 805 of TS-R-1).

Adopting the needed regulatory changes was simplified by the publication of the International Standards Organization's ISO 7195. This document provides the necessary detailed container design specifications and is directly incorporated by reference into TS-R-1.

8.12.1. Requirements

Uranium hexafluoride must be packaged and transported in accordance with ISO 7195 [5] (see paragraph 629 of TS-R-1). Packages designed to contain 0.1 kg or more of uranium hexafluoride must meet the regulatory requirements pertaining to the radioactive and fissile properties of the material.

In addition, packages containing 0.1 kg, or more of UF_6, must be designed to meet the following requirements (paragraphs 630 and 632 of TS-R-1):

- Withstand, without leakage and without unacceptable stress, an internal pressure of at least 1.4 MPa. However, cylinders withstanding less than 2.8 MPa require multilateral approval.
- Withstand, without loss or dispersal of the uranium hexafluoride, the drop test for normal conditions of transport, with graduated heights from 0.3 to 1.2 m depending on the package mass.

- Withstand, without rupture of the containment system, the thermal test of 800°C for 30 minutes if designed to contain less than 9000 kg of UF_6.
- Either meet the thermal test requirement or have multilateral approval if designed to contain 9000 kg or more of UF_6.
- If containing fissile UF_6, meet the test conditions applicable to fissile packages (i.e. the accident conditions of transport impact and thermal tests). These must be met with no contact between the valve and other normally non-contacting parts of the packaging, and no leakage from the valve. Other operational requirements must also be met before the designer can assume no in-leakage of water for the criticality safety analysis (paragraphs 671 and 673–682 of TS-R-1).

8.12.2. Design considerations

Designing UF_6 packages is complicated because they have to meet such a large variety of standards. These include those related to the radioactive nature of the contents, the possible fissile nature of the contents, as well as the uranium hexafluoride's unusual triple point at 64 C and material properties. The need for valves for filling and emptying the containers complicate the design since these are the weak points of any package design.

8.12.3. Approvals

With certain exceptions, the Regulations require that packages designed to contain 0.1 kg of UF_6 or more, must have at least unilateral Competent Authority design approval after 31 December 2003. If a UF_6 package design cannot withstand a test pressure of 2.8 MPa or cannot meet the thermal test criteria, it is required to have multilateral approval after 31 December 2000.

These provisions are represented in Table 8.6, which shows the approval criteria for uranium hexafluoride packages. The complexity of these requirements comes from a desire to address the areas of safety concern, while pragmatically recognizing the real world situation with respect to existing containers and older package designs.

8.12.4. Examples

There are many types of packages used for the transport of UF_6 throughout the world. Examples of these are described in the following sub-sections. Some typical UF6 packages are shown in Figure 8.13.

8.12.4.1. 48 Y cylinders

UF_6 coming from natural uranium is currently transported in a number of different types of packages (i.e. cylinders) and the so-called 48 Y cylinder is one of these. The 48Y cylinders are made with a cylindrical shell, which is 15.9 mm (5/8 inch) thick with ellipsoidal ends. At both ends, metal skirts complete the shell. The front end is fitted with a valve, to allow filling and emptying of the cylinder. The rear end is fitted with a plug.

These cylinders allow 12 500 kg of UF_6 to be shipped, with a total weight of the filled cylinder in the range of 15 000 kg. It is more or less obvious that those cylinders meet the requirements that apply to packages containing uranium hexafluoride, except for the fire test.

TABLE 8.6. DECISION CHART FOR EVALUATING AND CERTIFYING URANIUM HEXAFLUORIDE PACKAGE DESIGNS ACCORDING TO TS-R-1

Requirement	Satisfaction of Requirements for Certification or Competent Authority Approval				
	H(U)	H(M)	H(M)	H(M)	Special Arrangement
Mass of $UF_6 < 0.1$ kg	⇐⇐⇐⇐ None Required ⇒⇒⇒⇒⇒⇒				
0.1 kg ≤ Mass of UF_6 < 9,000 kg	x	x	x		x
9,000 kg ≤ Mass of UF_6				x	
Provisions of ISO 7195	x	x	As far as practicable	x	Any other combination
Para. 718 of TS-R-1 (without leakage and unacceptable stress) Test Pressure < 1.4 MPa					
1.4 MPa ≤ Test Pressure < 2.8 MPa		x			
2.8 MPa ≤ Test Pressure	x			x	
Para. 722 of TS-R-1 (without loss or dispersal of the UF_6) Normal Condition of Transport Drop Test	x	x		x	
Para. 728 of TS-R-1 (without rupture of the containment system) Accident Condition of Transport Thermal Test	x	x			
Para. 631 of TS-R-1 Not provided with pressure relief devices	x	x		x	
Controlling TS-R-1 paragraphs	629	629, 632(b)	632(a)	632(c)	

FIG. 8.13. Typical UF6 shipping cylinders.

A significant amount of research has been undertaken to study the problem of the fire test. Included in this is an IAEA Co-ordinated Research Programme (CRP) on the behaviour of UF_6 cylinders in thermal environments. At the time of writing the final conclusions have not been drawn.

Should the multi-national efforts show that the 48Y cylinders are not able to withstand the fire test, various solutions are available to enhance the thermal resistance of the cylinders. One would be to review the cylinder design with the purpose of making it more resistant to fire. This could lead to selecting upgraded steel for the shell, increasing its thickness, adding reinforcement rings, reviewing the valve design, and providing similar upgrades. All or part of these improvements would certainly render the new cylinder able to survive the regulatory fire test.

Another complex solution would be to fit the cylinder with an outer packaging system providing thermal insulation to protect the 48Y cylinder against the effect of fire. The 30B cylinders, which are used for the transport of enriched UF_6, are already equipped with such an outer packaging system. This outer packaging ensures compliance with the requirements applicable to packages containing fissile material. These include the 9 m drop test, and the 1 m drop test onto a punch, prior to the fire test.

Several other solutions might be considered including: specific transport frames; addition of two end covers to provide thermal insulation; or a cold point and thermal blankets. The optimization of such solutions is yet to be completed, including detailed dimensioning and selection of precise characteristics. The assessment must take into account not only the direct cost of the equipment, but also expense of its design and licensing. Obtaining a Competent Authority approval certificate for an "inexpensive" solution may require extensive testing, at an expense that may not be commensurate with the benefits expected. Finally, the evaluation must take into account a possible increase of the operational costs resulting from the preparation and transport of the cylinder, as well as inventory management and maintenance of this new equipment.

8.12.4.2. Sample bottles

To ship samples of UF_6, specialized cylinders have been designed. The basic designs originate from the USA and are named 1S and 2S cylinders which are allowed to carry 1.45 kg and 2.22 kg of UF_6 respectively.

Other designs have also been used successfully. For example, French designs of sampling cylinders for natural uranium, are based on a capacity of 1 L and are of cylindrical mono-block construction in an aluminium alloy.

PART 2: MATERIAL AND PACKAGE TEST PROCEDURES

8.13. Introduction to test procedures

Material and package testing provides quality assured evidence that a particular design meets the applicable Regulatory requirements. The procedures and facilities required for testing materials and light packages are quite modest and most reasonably sized establishments could perform this testing. For heavier packages, however, much more specialized, sophisticated and expensive equipment and facilities are required. Indeed, there are relatively few of these facilities around the world, and they are all in developed countries. A number of package test facilities are described in the "Directory of test facilities for radioactive materials transport packages" in the International Journal of Radioactive Materials Transport [6].

In addition to the brief discussion of testing in this chapter, TS-G-1.1 [2] provides more explanatory material relating to the rationale of the tests and their parameters. It also gives considerable advice and guidance on how to perform them.

The TS-R-1 Regulations [1] permit a completely flexible approach to the demonstration of compliance. Four separate methods or any combination of the four methods (paragraph 701 of TS-R-1) may be chosen, subject to the Competent Authority agreeing to the validity of the method or combination of methods chosen. The methods permitted are:

- Direct performance of physical tests with specimens representing the material (special form, LSA-III or LDM) or with prototypes or samples of the package carrying simulated contents;
- Comparison with previous satisfactory tests of a sufficiently similar nature;
- Performance of tests on models of appropriate scale, due allowance being made for test parameters which may need to be adjusted as a consequence of scaling; and/or
- Calculation or reasoned argument when the procedures involved are agreed to be reliable or conservative.

8.14. Overall procedure

The preparation that should be carried out before testing should involve early consultation with the Competent Authority concerned in order to establish the following points:

- That the test equipment to be employed, and arrangements for the tests to be witnessed are suitable. Some countries require testing to be carried out at a national test laboratory or other accredited facility.
- That the test specimens simulate all important features of the designs they represent. This will be particularly important where reduced scale models are proposed and will usually require full engineering drawings and specifications of the models to be submitted, as well as the package design itself. Important differences need to be highlighted and a justification submitted showing that these differences will not invalidate the tests, and
- That the proposed test programme, number of tests, number of specimens, drop sequences, drop attitudes, position of the specimen during the fire test, measurement methods, data handling etcetera need to be agreed before tests begin. However, the outcome of test work is inevitably uncertain, so some variation in the programme may be necessary as the tests proceed. Allowance should be made for this fact when preparing test specimens, scheduling tests, and reserving the use of test facilities. The Competent Authority may reserve the right to vary test programmes while they are in progress.

It should be noted that paragraph 717 of TS-R-1 defines the requirements for the drop target as a *"flat, horizontal surface of such a character that any increase in its resistance to displacement or deformation upon impact by the specimen would not significantly increase the damage to the specimen"*. The design of such a target is discussed later in this chapter.

Before testing, package specimens have to be inspected in order to identify and record faults, or damage, including:

- Divergence from the design,
- Defects in manufacture,

- Corrosion or other deterioration,
- Distortion of features (paragraph 713 of TS-R-1).

Paragraph 714 of TS-R-1 requires the specification of the containment system of a package prior to testing. The designer is free to choose to define the containment system. However, for package designs requiring Competent Authority approval, the Competent Authority will need this information and details of the proposed leak-testing methods to be employed. This is to assure that the required standards of leak-tightness are retained by the package after test. The onus is on the designer to prove the post-test leak-tightness of the package. Such testing methods must be sufficiently sensitive to ensure that the post-accident leak-tightness of the package is within the specified limits.

The designer will also need to establish what additional measurements are desirable during testing. The Regulatory tests are essentially simple "go/no-go tests". The design either passes or fails, and no specification on margin is given for pass or failure. It is often convenient for the designer to gather data during Regulatory testing concerning component behaviour and safety margins. These data can be used in future designs, or to correct existing design defects in the event of failure to reach the Regulatory requirements. Such additional measurements may include, for example, the use of strain gauges, accelerometers, thermocouples and, in the case of liquid filled packages, measurement of shock pressures.

Pre-test preparations must include sufficient measurements for determination of leak-tightness and shielding properties to enable the changes produced by testing to be accurately determined.

8.15. Material tests

8.15.1. Test for LSA-III material

This test is designed to provide assurance of the low solubility of the LSA-III material. The test involves immersing a representative sample of the material for 7 days in water at ambient temperature, with a specified initial pH and conductivity (paragraph 703 of TS-R-1). The free volume of the water remaining must be at least 10% of the volume of the solid test sample and the activity in the water must not exceed 0.1 A_2 (paragraph 601 of TS-R-1).

8.15.2. Tests for special form radioactive material

There are four tests for special form radioactive material, each of which has to be followed by a leaching assessment or volumetric leakage test. The four tests comprise the impact test, the percussion test, the bending test and the thermal test. A separate specimen may be used for each test. The purpose of the tests is to provide assurance that the radioactive material will not be released under any but the most severe circumstances.

It should be noted that certain sealed capsules may be excepted from the impact, percussion and thermal tests provided they are subjected to similar tests from ISO 2919 [7] (paragraph 709 of TS-R-1).

8.15.3. Impact test

The specimen must be dropped onto the target from a height of 9 m (paragraph 705 of TS-R-1).

8.15.3.1. Percussion test

The specimen must first be placed on a supported sheet of lead, which has an area larger than the specimen, and which has a specified hardness and maximum thickness. It is then struck by the flat face of a mild steel bar to cause an impact equivalent to that of a free drop of 1.4 kg through 1 m. The lower part of the bar must be 25 mm diameter and have 3 mm rounded edges. It must strike the specimen to cause maximum damage (paragraph 706 of TS-R-1).

8.15.3.2. Bending test

As might be expected this test is only applicable to long, slender sources (paragraph 707 of TS-R-1). The specimen is clamped horizontally so that half of its length protrudes from the clamp, in an orientation that will cause the maximum damage. The free end of the specimen is then subjected to the same impact as that specified in the percussion test.

8.15.3.3. Thermal test

The specimen is heated to 800°C for 10 minutes and then allowed to cool (paragraph 708 of TS-R-1).

8.15.3.4. Acceptance criteria, leaching and volumetric leakage methods

In addition to not breaking, shattering, or melting when subject to the above tests, a special form design must also meet certain leaching or leakage requirements following each of the tests. Generally, this means that the activity in the water after the leaching or leakage test must not exceed 2 kBq, although other criteria can apply to sealed sources (paragraph 603 of TS-R-1).

For indispersible solid material, the leaching assessment method must be used. For sealed capsules, either this or the volumetric leakage assessment may be performed.

The leaching assessment is made by immersing the specimen under conditions similar to that for LSA-III, then heating it to 50°C for 4 hours and determining the water activity. The specimen is kept for at least another 7 days in warm, humid air and the previous process repeated (paragraph 710 of TS-R-1).

The volumetric leakage test is similar, except that it does not require the initial 7-day soaking period (paragraph 711 of TS-R-1). Alternatively, ISO 9978 [8] may be used with leakage rates acceptable to the Competent Authority.

8.15.4. Leaching tests for LSA-III material and low dispersible radioactive material

The tests to assure the low probability of dispersal in the event of an aircraft accident involve subjecting the LDM specimen to the enhanced thermal test (800°C for 1 hour) discussed later in 8.7.2., and the high speed (90 m/s) impact test discussed in 8.7.3. (paragraph 712 of TS-R-1). A different specimen may be used in each test. The airborne release in gaseous and particulate forms must not exceed 100 A_2 (paragraph 605 of TS-R-1). After each test the specimen is subjected to the leaching test and the activity in the water must not exceed 100 A_2.

8.16. Tests for normal conditions of transport

8.16.1. Acceptance criteria

There are certain acceptance criteria associated with satisfactorily meeting the test requirements.

8.16.1.1. Industrial Type 2, Industrial Type 3, and Type A packages

The criteria that must be met for the subject package designs following exposure to the applicable normal conditions of transport tests, are that the package design will prevent:

- Loss or dispersal of the radioactive contents; and
- Loss of shielding integrity that would result in more than a 20% increase in the radiation levels at any external surface of the package.

8.16.1.2. Type B and Type C packages

The criteria for a Type B and a Type C package design are similar to those above, but in this case, a small rate of release is allowed. Following exposure to the normal conditions of transport tests, the package design must:

- Restrict the loss of its radioactive contents to not more that 10^{-6} A_2 per hour (paragraph 656(a) of TS-R-1); and
- Prevent loss of shielding integrity that would result in more than a 20% increase in the radiation level at any external surface of the package (paragraph 656(b) of TS-R-1).

The basis for the release rates, which were re-established during the Q-system deliberations for TS-R-1 are summarized below.

In the determination of the maximum allowable release rate for Type B packages under the conditions of normal transport in the 1973 Edition of the Regulations, the most adverse expected condition was judged to be represented by a worker spending 20% of his or her working time in an enclosed space in the conveyance of 50 m^3 volume, with ten air changes per hour. The space in the vehicle was considered to contain a Type B package leaking at a rate of r (Bq/h), and it was conservatively assumed that the resulting airborne activity concentration was in equilibrium at all times.

On this basis, the annual intake of activity via inhalation I_a for a person working 2000 hours per year with an average breathing rate of 1.25 m^3/h was evaluated. This intake was then equated with the historic maximum permissible quarterly dose for occupational exposure (30 mSv to whole body, gonads, and red bone marrow; 150 mSv to skin, thyroid, and bone; 80 mSV to other single organs). From the determination of A_2 values, this corresponded to an intake of $A_2 \times 10^{-6}$. This quantitatively established a value for r (i.e. the release rate limit) as:

$$r \leq A_2 \times 10^{-6} \text{ per hour.}$$

This assumes that all of the released material becomes airborne and can be inhaled. This may be a gross overestimate for many materials. There is additional conservatism in the assumption that equilibrium conditions are assumed to pertain at all times. These factors, together with the principle that leakage from Type B packages should be minimized, indicated that the exposure of transport workers would be only a small fraction of the ICRP limits for radiation workers [9]. In addition, this level of conservatism was considered adequate to cover the unlikely situation of several leaking packages contained in the same vehicle.

In the 1985 Edition of the Regulations, the maximum allowable release rates for Type B packages under normal transport conditions were unchanged, although some of the parameters used in the above derivation were updated.

The dose criterion of 50 mSv used in the Q-system is such that, under the BSS, the system lies within the domain of potential exposures. In determining the allowed routine release limits for Type B packages it was necessary to consider the most recent dose limits for workers of 20 mSv per year, averaged over 5 years [9]. The earlier models assumed an extremely pessimistic exposure model of 2000 hours per year. Retaining this value, together with exposure within a room of $30 \times 10 \times 10$ m^3, with 4 air changes per hour, and an adult breathing rate of 1.25 m^3/h, the permitted release rate, r, for an effective dose of 20 mSv was calculated. The assumed room size is larger than that assumed for an acute release under the Q-system. However, the assumed exposure time is very pessimistic. Exposure for 200 hours in a much more confined space of 300 m^3 would lead to exactly the same predicted effective dose. For incidental exposure out of doors for persons near a leaking Type B package the maximum inhalation dose would be significantly lower.

The limit of 10^{-6} A_2 per hour from a Type B package under normal conditions of transport (see paragraph 656(a) of TS-R-1) is thus justified, and was retained at the value used in early Editions of the Regulations. This value, as summarized above, was shown to be conservative. Experience has shown that it is rare for packages in routine transport to leak at rates anywhere near the permitted limit. Indeed, such leakage for packages carrying liquids would lead to very severe surface contamination in the vicinity of the seals and would be readily obvious from any radiological surveys during transit or on receipt by the consignee.

8.16.2. Water spray test

This test (paragraph 721 of TS-R-1) is intended for packages in which internal package space to reduce dose rates is provided by fibreboard components. It must be conducted using the same sample before each of other normal conditions of transport tests (paragraph 719 of TS-R-1): the free drop test, the stacking test, and the penetration test.

The water spray test (Figure 8.14.) simulates rainfall at a rate of approximately 50-mm per hour and is applied for at least one hour. The specimen is left to allow water to soak in to the maximum extent before the next test is carried out. This is normally two hours when all faces of the packages are soaked simultaneously. No soak time is required when all faces are soaked sequentially (paragraph 720 of TS-R-1).

If it is clear from the nature of the construction materials that the package is not vulnerable to this test, then the test may be omitted.

FIG. 8.14. Water spray test.

8.16.3. Free drop tests

These tests (paragraph 722 of TS-R-1) are designed to produce the kind of damage that is likely to be sustained by some packages during normal handling from minor drops and shocks.

In this test the specimen has to be dropped onto a flat, unyielding target. The height of the drop is graded according to the package mass as follows:

		package mass	<	5000 kg	=	1.2 m
5000 kg	≤	package mass	<	10000 kg	=	0.9 m
10000 kg	≤	package mass	<	15000 kg	=	0.6 m
15000 kg	≤	package mass			=	0.3 m

The package must be dropped in such a way that it will suffer the maximum damage. If there is any doubt, then the package will need to be dropped on all suspect features, including lids, closures and corners.

The free drop test, in the case of small packages where a 1.2 m drop height applies, is intended to simulate the kind of impact that would be suffered by a package falling from a vehicle tailgate or from a stacker truck. In many cases, packages would be expected to continue their journey after such minor mishaps.

Since heavier packages are less likely to be subjected to such large drops, (at least without undergoing close examination afterward), the drop height is scaled down with increased package weight.

Additional tests, on a separate specimen, apply to light fibreboard packages. Rectangular fibreboard or wood packages not exceeding a mass of 50 kg are subjected to a free drop onto each corner from a height of 0.3 m. In the same manner, cylindrical fibreboard packages not exceeding a mass of 100 kg must be subjected to a free drop onto each of the quarters of each rim from the same height of 0.3 m. These tests are intended to demonstrate the capability of such packages to resist the general rough handling to which they are particularly vulnerable.

8.16.4. Stacking test

In the stacking test (paragraph 723 of TS-R-1), the specimen is required to withstand for a period of 24 hours whichever is the greater of:

- The equivalent of 5 times the mass of the actual package; or
- The equivalent of thirteen kPa multiplied by the vertically projected area of the package.

This test (Figure 8.15) is intended to ensure that the effectiveness of containment and shielding is maintained when the package is submitted to the kind of damage that is likely to be sustained by having other packages stacked on top. The test is not required for packages whose shape effectively precludes stacking.

FIG. 8.15. Package stacking test.

8.16.5. Penetration test

A 6 kg metal bar with a 32 mm diameter having a hemispherical end is required to be dropped onto the package from a height of 1 m (paragraph 724 of TS-R-1). The direction and point of impact must be chosen to produce maximum potential damage to the containment system, and the test item must be placed on a rigid, flat horizontal surface.

This test (Figure 8.16) is intended to demonstrate the capability of the package to withstand the kind of puncture damage, which may arise in normal transport, from such causes as sharp objects falling on the package as well as from loading hooks.

FIG. 8.16. Penetration test for normal conditions of transport.

8.16.6. Additional tests for Type A packages containing liquids or gases

The tests described so far are relevant to packages with solid contents (including solid in powder form). They were based originally on the hypothesis that only a small fraction of the contents is likely to be released during a typical accident. Appendix I of TS-G-1.1 quotes the likely range of the release fraction over a range of severe accidents (but short of a major accident) to be 0.1% of the contents.

In the case of liquids and gases, the possible release fraction is clearly higher for a given accident severity level. Since it is inconvenient to have A_1 and A_2 values dependent on the physical form of the material, the approach adopted has been to require additional tests for packages designed for liquid or gaseous contents. Packages designed for such contents are thus required to undergo additional testing (using separate specimens from those of the earlier tests). These involve a free drop test from a height of 9 m and a penetration test from a height of 1.7 m. Type A packages designed for tritium or noble gases are excepted from these more stringent tests.

8.17. Tests for accident conditions of transport

8.17.1. Overview and basis

The accident conditions of transport tests are prescribed in terms that provide the engineering basis for the design. Since analysis is an acceptable method of qualifying designs (paragraph 701(d) of TS-R-1), the tests are prescribed in engineering terms that could serve as unambiguous, quantifiable input to these calculations. Recognition of the statistical nature of accidents is now implicit in the requirements. A major aim of the package tests is international acceptability, uniformity, and repeatability. The tests are designed so that the conditions can be readily reproduced in any country.

The accident conditions of transport tests consist of sequences of mechanical tests, a thermal test, and a submersion test.

The purpose of the mechanical tests and the subsequent thermal test is to impose on the package damage equivalent to that which would be observed if the package were involved in a severe accident. The order and type of tests are considered to correspond to the sequence of damage to the packaging in a real transport accident, i.e. mechanical impacts followed by thermal exposure. The test sequences also ensure mechanical damage to the package prior to the imposition of the thermal test. In this manner, the package is most liable to sustain maximum thermal damage.

The mechanical effects of an accident can be grouped into three categories: impact, puncture, and crush loads. Although the original figures for the test requirements were not derived directly from accident analyses at that time, subsequent risk and accident analyses have demonstrated that they represent a very severe transport accident.

The combination of a 9 m drop height, an unyielding target and the most damaging attitude (paragraph 727(a) of TS-R-1) produce a condition in which most of the drop energy is absorbed in the structure of the packaging. In real transport accidents, targets such as soil or vehicles yield, absorbing part of the impact energy and only high velocity impacts may create damage which approaches that equivalent to the test.

Thin walled package designs or designs with sandwich walls could be sensitive to puncture loads (paragraph 727(b) of TS-R-1) with respect to loss of containment integrity, loss of thermal insulation or damage to the confinement system. Even thick walled designs may have weak points such as closures of drain holes, or valves. Puncture loads could be expected in accidents, as impact surfaces are frequently not flat. In order to provide safety against these loads, the 1 m drop test onto a rigid bar was introduced. Again, the drop height and punch geometry parameters were more the result of engineering judgement than deductions from accident analyses.

The crush test (paragraph 727(c) of TS-R-1) applies specifically to lightweight packages with high potential hazards.

The thermal test (paragraph 728 of TS-R-1) provides an envelope of environments that encompasses most transport-related accidents involving fires. The Regulations specify a test condition based on a liquid hydrocarbon-air fire with a duration of 30 minutes. Other parameters relating to fire geometry and heat transfer characteristics are specified in order to define the heat input to the package.

Because of a transport accident near or on a river, lake, or sea, a package could be subjected to an external pressure from submersion under water. To simulate the equivalent damage from this low probability event, the Regulations require that a package be able to withstand external pressure resulting from submersion at reasonable depths. Engineering estimates indicated that water depth near most bridges, roadways or harbours would be less than 15 m (paragraph 729 of TS-R-1). Consequently, this was selected as the immersion test depth for packages. While immersion at depths greater than 15 m is possible, this value was selected to envelop the equivalent damage from most transport accidents. In addition, the potential consequences of a significant release would be greatest near a coast or in a shallow body of water. The eight-hour period is sufficiently long to allow the package to come to a steady state from rate dependent effects of immersion, such as flooding of exterior compartments.

It should be noted that an enhanced water immersion test to a depth of 200 m is necessary for packages containing radioactivity in excess of 10^5 A_2 (paragraph 730 of TS-R-1), with separate acceptance criteria as discussed in section 8.18 of this chapter.

8.17.2. Pass criteria

In order for a Type B package to pass the accident conditions of transport test series, it must (paragraph 669(b) of TS-R-1):

- Restrict the accumulated loss of its radioactive contents, in a period of one week following the test procedure, to not more than A_2 (or 10 A_2 in the case of ^{85}Kr); and
- Not allow the radiation level at 1 m from the package surface to exceed 10 mSv/h.

A discussion of the basis for the release criteria follows. Accidents of the severity simulated in the accident conditions of transport tests specified in the Regulations are unlikely to occur in a confined indoor space. Or, if they did occur indoors, the resulting conditions would be such as to necessitate immediate evacuation of all persons in the vicinity [10]. Hence, the exposure scenario of interest in this context is that of an accident occurring out of doors. The maximum allowable release in a period of one week from a Type B package is A_2, or 10 A_2 for ^{85}Kr, (see paragraph 656(b)(ii)(ii) of TS-R-1). In this situation, the radiological implications may be expressed as an equivalent dose limit by considering the exposure to a person remaining continuously downwind of the damaged package throughout the period of the release [11].

In practice, it is unlikely that any accidental release would persist for the full period of one week. In most situations emergency services personnel would attend the scene of an accident and take effective remedial actions to limit the release of activity within a period of a few hours. On this basis the maximum effective dose via inhalation to persons exposed in the range 50-200 m downwind from a damaged Type B package under average weather conditions is 1-10 mSv. This may increase by a factor of about 5 under generally less probable and persistent stable meteorological conditions [12]. Local containment and atmospheric turbulence effects close to the source of activity, plus possible plume rise effects if a fire were involved, will tend to minimize the spatial variation of doses beyond a few tens of metres from the source towards the lower end of the dose ranges cited above. Disregarding potential doses to persons within a few tens of metres of the source is considered justified by: (a) the conservative assumption of continuous exposure downwind of the source throughout the release period, and (b) the fact that emergency services personnel in this area should be working under health physics supervision and control.

A special provision in the case of ^{85}Kr was introduced in the 1973 Edition of the Regulations. This was retained in the 1985 Edition of the Regulations. It stems from consideration of the dosimetric consequences of a release of this radionuclide. The allowable release of 10 A_2 was originally derived on the basis of a comparison of the potential radiation dose to the whole body, or any critical organ, of persons exposed within about 20 m of a source of krypton-85 and other non-gaseous radionuclides. In particular, it was noted that the inhalation pathway model used in the derivation of A_2 values at the time was inappropriate for a rare gas that is not significantly incorporated into body tissues. This conclusion remains valid within the 1996 Edition of the Regulations. Currently, then, the Q-system provides an A_2 value for ^{85}Kr equal to the Q_E value for the submersion dose to the skin of persons exposed indoors following the rapid release of the contents of a Type A package in an accident. It has been demonstrated that even the allowable release of 10 A_2 for krypton-85 is conservative compared with the equivalent A_2 for other non-gaseous radionuclides.

After completion of the relevant tests, the integrity of containment and shielding must be demonstrated to the degree indicated above. Containment system integrity will normally be demonstrated by a direct leak-test with due allowance made, if necessary, for scaling. Other relevant test data, such as O-ring sealing capabilities, may be brought to bear on the problem of leak-tightness demonstration. The seal face distortions may, for example, be directly measured and compared with full-scale test data for which leak rate measurements have been determined.

Direct measurement of shielding system integrity by means of a radiation source applied before and after the test to the package cavity is the most obvious means of determining the extent to which shielding has degraded. However, it is rarely the most convenient method and in view of the considerable degree of shielding loss permitted by the Regulations, it is usually more practicable to measure the physical distortions of the shield. These, combined with calculations may often be sufficient to verify the integrity of the post-test shielding.

8.17.3. Mechanical test

The package must be subjected to two sequential drop tests from the three drops described below. The order must be chosen to produce the most damaging final effect with respect to the ensuing thermal test. The choice of the relevant pair of tests is determined by the characteristics of the package as follows:

- Packages having a mass not greater than 500 kg, and an overall density not greater than 1000 kg/m^3 (based on overall dimensions), and designed for contents exceeding 1000 A_2 in other than special form, must be subjected to drops II and III (paragraph 656(b)(i) of TS-R-1). These are the so-called lightweight Type B packages introduced earlier.
- Other packages must be subjected to drops I and II (paragraph 656(b)(ii) of TS-R-1).
- The three drops are defined below (paragraph 727 of TS-R-1) as:

Drop I — The specimen is dropped from a height of 9 m onto the unyielding target to suffer maximum damage.

Drop II — The specimen is dropped from a height of 1 m onto the top face of a rigidly mounted 150-mm diameter mild steel bar. The top face of the bar is flat and the edge is rounded to a radius not more than 6 mm. The bar should be at least 20 cm long.

Drop III — The specimen is subjected to a dynamic crush by first placing it upon an unyielding target, in the worst orientation. Then a 500 kg steel plate 1 m × 1 m square is allowed to fall upon it from a height of 9 m above the top of the package. The plate is required to fall in a horizontal attitude and suitable guidance may be necessary to achieve this.

Figure 8.17 shows a 9 m Drop I test and Figure 8.18 shows a Drop II penetration test.

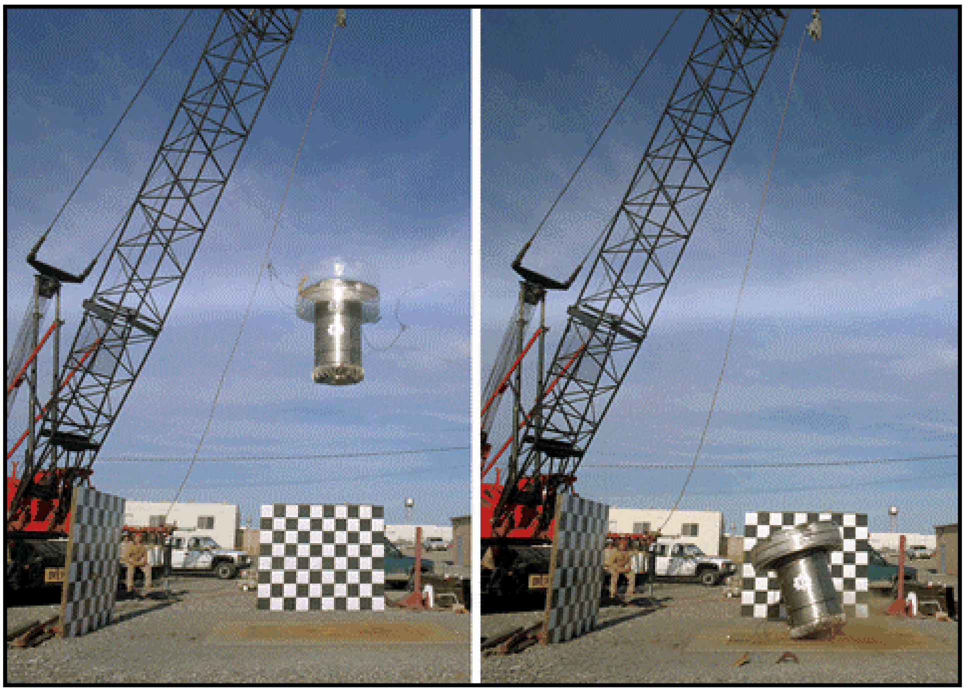

FIG. 8.17. A 9m drop test in progress.

The degree of safety provided by the 9 m drop test is smaller for light, low-density packages, than for heavy, high density packages, owing to the reduced impact energy and to the increased probability of impacting a relatively unyielding "target". Such packages may also be sensitive to crush loads. Accident analyses show that, for lightweight packages, the probability of dynamic crush loads in land transport accidents is higher than that of impact loads because lightweight packages are transported in larger numbers or together with other packages. Also, handling and stowage mishaps can lead to undue static or dynamic crush loads. This resulted in the inclusion of the crush test (drop III) in the 1985 Edition of the Regulations, which was carried through to TS-R-1.

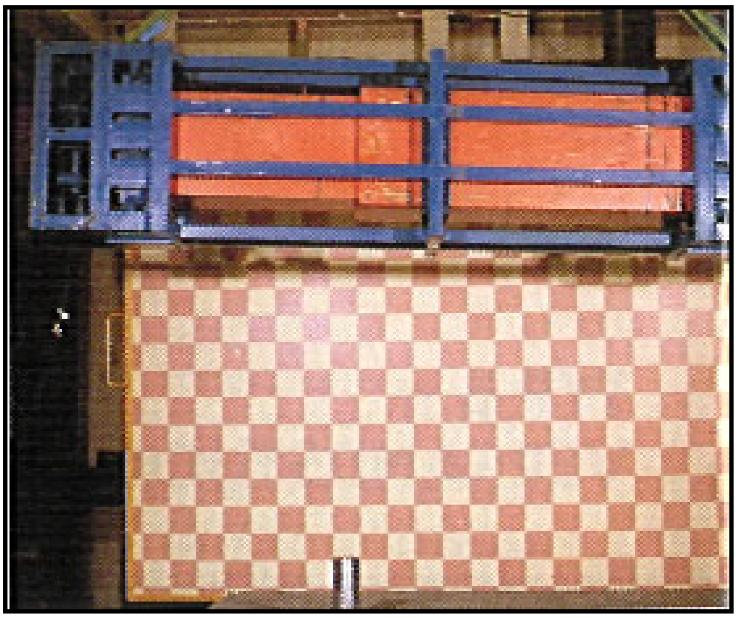

FIG. 8.18. Penetration test on an a Type B(U) fuel element package.

8.17.4. Thermal test

The thermal test is well defined in paragraph 728 of the TS-R-1 Regulations. It states that the specimen must be in thermal equilibrium under conditions of an ambient temperature of 38°C. It must be subject to certain solar insolation conditions as well as subject to the design level of the maximum rate of internal heat generation within the package from the radioactive contents. Alternatively, any of these parameters are allowed to have different values prior to and during test, providing due account is taken of them in the subsequent assessment of package response.

The thermal test consists of:

- Exposure of a specimen for a period of 30 minutes to a thermal environment that provides a heat flux at least equivalent to that of a hydrocarbon fuel/air fire. This must be in sufficiently calm ambient conditions to give a minimum average flame emissivity coefficient of 0.9 and an average temperature of at least 800°C. It must also fully engulf the specimen, with a surface absorptivity coefficient of 0.8 or that value which the package may be demonstrated to possess if exposed to the fire specified, followed by;
- Exposure of the specimen to an ambient temperature of 38°C, subject to the same conditions for a sufficient period to ensure that temperatures in the specimen are everywhere decreasing and/or approaching initial steady state conditions.

Alternatively, any of these parameters are allowed to have different values following cessation of heating, providing due account is taken of them in the subsequent assessment of package response.

During and following the test, the specimen may not be artificially cooled and any combustion of materials of the specimen must be permitted to proceed naturally.

A more complete discussion of this test can be found in TS-G-1.1. However, the test is such that it provides an envelope of environment that encompasses most transport-related accidents involving fires. The combination of the requirements for a fully engulfing fire, of the specified temperature, duration, and geometry result in a very demanding fire that is often difficult to achieve even during the test. For large packages, very still air conditions are needed to meet the requirements. Demonstration of compliance also may be achieved using analytical methods. Figure 8.19 shows a typical thermal test in progress.

FIG. 8.19. Thermal accident test in progress.

8.17.5. Immersion test

For this test (paragraph 729 of TS-R-1), the specimen must be immersed under a head of water of at least 15 m for a period of not less than eight hours in the position that will lead to maximum damage. Since the purpose of the test is to demonstrate the structural integrity of the package under external pressure, a pressure test or a calculation can be substituted for actual immersion.

The immersion test may be conducted on a separate specimen, because it is reasoned that the probability of its occurrence in conjunction with a mechanical and thermal accident combination is extremely low.

The eight-hour time period is sufficient to allow the package to come to a steady state from any rate-dependent effect of immersion, such as compartment flooding.

8.18. Enhanced water immersion test

This test (paragraph 730 of TS-R-1) is needed for Type B(U) and Type B(M) packages designed to contain quantities of radioactivity greater than 10^5 A_2, and Type C packages. It requires the immersion to a depth of 200 m for a duration of one hour. An external gauge pressure of at least 2 MPa is considered to meet the depth conditions. The methodology of test performance is similar to that for the 15-m immersion test. Again, typically only the likely weak points of the packaging such as valves and closures will need to be physically pressure tested.

The acceptance criterion differs from the other accident conditions of transport tests. Here, the acceptance criterion is that there would be no rupture of the containment system (paragraph 657 of TS-R-1) following exposure to water immersion to a depth of 200 m. This test is intended to ensure that a package containing a large quantity of radioactive material will be able to be recovered with its solid contents intact should it be lost on the continental shelf or in a lake or river. The acceptance requirement specified in terms of rupture of the containment system rather than in terms of a specified leak rate accomplishes this goal.

8.19. Type C tests

Many of the tests for Type C package designs are the same as those for Type B package designs and will not be discussed here again. Only the differences will be covered.

The acceptance criteria for Type C package designs are also the same as those for Type B package designs.

8.19.1. Puncture/tearing test

This test (paragraph 735 of TS-R-1) differs from the one which corresponds to drop II for Type B(U) package designs by the shape of the probe and the height of the drop. The probe is made of a mild steel cylinder of 20 cm diameter with the striking end forming the frustum of a cone 30 cm high and with a 2.5 cm diameter at the top. The probe has to be positioned to cause the maximum damage at the end of the 9 m drop and dynamic crush test.

Whether the package drops on the probe or the probe drops on the package is a function of the package mass. A package less than 250 kg must have a probe of mass 250 kg fall from a height of 3 m onto it, while a package of greater mass must drop the same height onto the probe. In each instance, the unyielding target is used as the base of the test.

8.19.2. Enhanced thermal test

The enhanced thermal test (paragraph 736 of TS-R-1) differs from the accident conditions of transport test by the fire duration. This is extended from thirty minutes to one hour. As for Type B(U) and Type B(M) package testing, the fire specification demands that the average flame temperature must be 800°C for the duration of the fire. This means that the peak temperatures (which are often reported in accounts of fires) may be much higher. In addition, the size of the pool of flammable liquid is specified to ensure that the specimen is fully engulfed, but not so large as to cause oxygen starvation around the specimen. Finally, the height at which the specimen is suspended above the surface of the flammable liquid must be maintained to ensure the maximum heat input into the package. Thus the fire specification is very severe and it is unlikely that a higher heat input to the package could be achieved in a real accident. The only difference in the performance of the enhanced thermal test is the need for the calm weather conditions to last longer, and a greater supply of fuel.

8.19.3. Impact test

The most severe test for a Type C package is the impact test (paragraph 737 of TS-R-1). It must be noticed that subjecting a package to an unyielding surface impact with a speed of 90 m/s in the most damaging orientation is a difficult test to perform. This impact speed corresponds to a free drop through a height of about 420 m, without taking into consideration air resistance. A greater drop height will be required to ensure the necessary 90 m/s impact speed is attained. Generally, guide wires will be needed to assure that the package impacts in the desired spot and with the correct orientation. Finally, the guided free fall will probably mean that friction must be accounted for, and an even greater release height will be needed to assure the speed at impact is correct. Techniques that utilize additional sources of energy to achieve speed and orientation reliability may also be used. These techniques include rocket sleds and cable pull-down facilities.

The impact speed of 90 m/s was derived from data collected for analysis by the Lawrence Livermore National Laboratory in the USA. Data on jet aircraft crashes were collected for the period 1952–1989. In total, over 700 accidents were recorded but of these 220 were deemed to be irrelevant because the incident happened during refurbishment or maintenance or were acts of sabotage. Of the relevant accidents, only 104 were sufficiently well documented to enable a calculation of the equivalent impact speed in terms of a velocity at which a specimen would hit an unyielding target. The equivalent impact velocity takes account of both the angle of impact (θ) and the hardness of the target (H_s).

$$\text{Equivalent speed} = \sin\theta \times H_s$$

Some representative values of H_S for different impact surfaces are as follows:

1.0 Theoretical unyielding target

0.89 Runways and concrete surfaces

0.78 Soft rock

0.67 Farmland

0.54 Water or swamp

It is acknowledged that Type B(U) and Type B(M) packages are designed to withstand nearly all conceivable accidents associated with surface mode transportation, but it is not feasible to protect against all possible accidents. Similarly, it was agreed that an appropriate level of protection would be achieved for Type C packages by specifying an impact speed of 90 m/s.

8.20. Test facilities

8.20.1. Facilities for testing normal conditions of transport

In their simplest forms, the drop tests for normal conditions of transport do not require large, expensive items of equipment, but can be performed fairly easily by most establishments.

For many packages, the water spray test will not be necessary. However, if the package has wood or fibreboard involved in its construction then the test must be performed. Some important considerations with respect to this test involve the need to have:

- A spray cone angle sufficient to envelop the whole specimen from a distance of about three metres;
- An accurate assessment of the spray rate, either by direct measurement, or by measurement of the water flow rate and calculation; and
- A means of support for the package and good drainage, so that the specimen does not sit in a pool of water.

Packages, which are light enough not to require special rigging or cranes for the drop tests, can be dropped from the appropriate height. A special target is not normally required for such packages. For heavy packages, the information that is provided in Chapter 8.8.2.1 of this manual concerning the accident conditions of transport tests is relevant.

For light packages, the stacking test requires no special equipment other than some heavy material with which to load the package. This may be a steel plate or a stiff board with bricks stacked on top. For heavy packages, a more sophisticated loading beam system. may need to be constructed.

The penetration test can be performed with a steel bar of the correct mass and end radius, and a piece of guide tubing of slightly larger diameter. The tubing is of such a length that when it is placed on the package, the steel bar can be held at the top at the correct height. Again, if there is any doubt as to the weakest part of the package for this test, it can be repeated several times, each at different locations.

8.20.2. Facilities for testing accident conditions of transport

8.20.2.1. Drop tests

Due to the large size and mass of most Type B and Type C packages, specialized equipment is usually needed for the drop tests. Consequently, there are relatively few places around the world where they are routinely performed. In particular, the drop tests require specialized targets, as well as heavy lifting rigs and special release mechanisms.

To have an “essentially unyielding target” for large packages requires a steel plate wet floated onto a homogeneous block of concrete or concrete and rock. The combined concrete and steel mass needs to be at least ten times the mass of any specimen to be dropped on it. The block should generally be cubic in form, at least 0.5 m larger on all sides than any sample package. The steel plate should be at least 40 mm thick with protruding fixed steel structures on its lower surface which are securely bolted to the main mass of the target to ensure tight contact with the concrete.

A crane of suitable capacity may most easily meet the lifting requirements. However, for packages that may require guidance to maintain a particular orientation, a purpose-built structure with hoisting capacity will be needed. If some form of guiding is used, it is important that the impact velocity be at least equal to that when the package or mass is under free fall. This approximates to 13.4 m/s for 9 m drops.

One of the most difficult requirements in terms of facilities and equipment is to be able to release very heavy packages in a particular orientation rapidly and without disturbance. This may be accomplished using various mechanisms. These can be mechanical, electromagnetic, pyrotechnic, motors or hydraulically operated release systems.

In addition to the drop testing equipment, a large array of instruments and recording equipment may be required. Deceleration and deformation measurements need transducers for deceleration, displacement, pressure, and strain linked to dynamic recording instrumentation.. Photographic recording will usually need to include high-speed film and videotape, as well as still photography and standard film.

8.20.2.2. Thermal tests

Conducting the thermal test required by the Regulations requires even more dedicated and specialized equipment than that needed for the drop tests. TS-G-1.1 provides forty paragraphs of advisory material relating to this test, which attest to the care needed to perform it properly.

8.20.2.3. Immersion tests

Many facilities will meet the immersion test requirements by the use of relatively simple pressure testing system. Often, only the critical part of the package will actually be tested. The remainder of the structure will be evaluated and proven by calculation and reasoned argument.

8.20.3. Facilities for the Type C impact test

As discussed earlier, this is a particularly difficult test. Facilities for guided free fall from heights of over 420 metres, rocket sleds or cable pull-down equipment are needed. Some systems capable of this testing exist [6], and because of the cost and complexity of such facilities, it is unlikely that others will be constructed without demonstrating larg e scale requirement for these packages.

8.21. Model testing

8.21.1. Reasons for model testing

There is a variety of reasons for performing scale model testing of packages, but most of them are related to cost. Prototypes of large, containers are very expensive to manufacture, and several may be needed to perform a suitable range of development and compliance tests. The cost of full-scale package testing is considerable. Not only may full-scale fabrication and testing of packages be expensive, this process may also take quite a long time. Finally, scale model testing enables a great deal more optimization of important package features, particularly with respect to package orientation and the resulting damage from drop test.

8.21.2. Replication, scalability and validity

Model testing is useful and valid for certain tests provided that appropriate scaling factors are used. In general, the use of models for the thermal test is not recommended, as the results are very difficult to validate. Similarly, it is difficult to extrapolate the results of scale model-testing involving seals and sealing surfaces to the responses expected on a full-sized package. However, experience has shown that the testing of scale models is very useful for predicting general structural behaviour during the mechanical tests. In the mechanical tests, similar conditions are relatively simple to create, provided the same materials and construction methods are used for the model as for the full-sized package. In some tests, such as the penetration test, it will also be necessary to scale the penetrating bar to produce accurate results.

Which detailed components should be included in the model will depend on the type of test being performed, but very often, certain peripheral features can be omitted.

In general, the scale drop ratio M (model dimension: prototype dimension) should not be less than 1:4. For such models, the effect of strain rate dependence on the mechanical properties will be negligibly small. A listing of the model prototype relationships is given in Table 8.7.

TABLE 8.7. MODEL/PROTOTYPE RELATIONSHIPS

PROPERTY	PROTOTYPE	MODEL
Linear dimensions	1	1/M
Mass	1	$1/M^3$
Acceleration	1	M
Inertia forces	1	$1/M^2$
Area	1	$1/M^2$
Stress	1	1
Strain	1	1
Deformation	1	1/M
Strain rate	1	M
Speed	1	1
Angular velocity	1	M
Time of impact	1	1/M
Elapsed time	1	1/M

Mechanical and model testing requires:

- Equal velocity and attitude of model and prototype;
- Equal friction and damping coefficient in model and prototype:
- Insignificant strain rate sensitivity;
- No significant gravity effects;
- Plastic flow deformation, rather than deformation due to fracture processes;
- The same target conditions applicable to the model and the prototype.

The conclusion that can be drawn is that, provided it is performed properly and with care, scale model testing is a useful method of developing and analyzing the effects of the mechanical tests on particular package designs relatively quickly and cheaply.

REFERENCES FOR CHAPTER 8

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Standards Series, Safety Requirements No. TS-R-1, IAEA, Vienna (2005).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1996 Edition), Safety Standards Series No. TS-G-1.1, IAEA, Vienna (2002).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance for the Safe Transport of Radioactive Material, Safety Series No. 113, IAEA, Vienna (1994).

[4] US NUCLEAR REGULATORY COMMISSION, "Qualification Criteria to Certify a Package for Air transport of Plutonium", NUREG/0360, USNRC, Washington DC (1978).

[5] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Packaging of Uranium Hexafluoride (UF6) for Transport, (ISO 7195: 1993(E), ISO, Geneva (1993).

[6] GOLDFINCH, E. P., "Directory of Test Facilities for Radioactive Materials Transport Packages", International Journal of Radioactive Materials Transport, Nuclear Technology Publishing, ISBN 1 870965 27 2, Volume 2 Nos. 4/5 1991, Kent, UK (1991).

[7] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Sealed Radioactive Sources – Classification (ISO 2919:1980(E)), ISO, Geneva (1980).

[8] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Radiation Protection – Sealed Radioactive Sources – Leakage Test Methods (ISO 9978:1992(E)), ISO, Geneva (1992).

[9] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Recommendations of the International Commission on Radiological Protection, Publication No. 60, Pergamon Press, Oxford and New York (1990).

[10] GOLDFINCH, E.P., MACDONALD, H.F., "Dosimetric aspects of permitted activity leakage rates for Type B packages for the transport of radioactive materials", Radiat. Prot. Dosim. **2** (1982) 75.

[11] MACDONALD, H.F., Radiological Limits in the Transport of Irradiated Nuclear Fuels, TPRD/B/0388/N84, Central Electricity Generating Board, Berkeley, UK (1984).

[12] MACDONALD, H.F. Individual and collective doses arising in the transport of irradiated nuclear fuels. Packaging and Transportation of Radioactive Materials, PATRAM '80 (Proc. Symp. Berlin, 1980), Bundesanstalt für Materialprüfung, Berlin (1980).

EXERCISES FOR CHAPTER 8

The following are exercises to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 8.1. Defining Design, Test and Certification Requirements – Special Form Material

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REFERENCE SOURCES: Training Manual, Chapter 8; and TS-R-1, Sections VI, VII and VIII.

DISCUSSION: The design requirements, test procedures and acceptance requirements for any of the specified material (i.e. special form material, low specific activity material, low dispersible material), and any package types can be found in the Regulations.

PROBLEM: Using TS-R-1 and TS-G-1.1 (and referring to appropriate Chapters of the Training Manual), *determine the paragraphs* which define:

a. What is special form radioactive material;

b. Why and how the characteristics of a material may be used to demonstrate that it is (or is not) a special form radioactive material;

c. The requirements for special form radioactive material;

d. The tests to qualify a material or capsule as special form radioactive material;

e. The approval requirements for special form radioactive material; and

f. The certification requirements for special form radioactive material.

[Hints: Only list the paragraph numbers for each item; and use the TS-R-1 index to look for the answers.]

ANSWER:

EXERCISE 8.2. Defining Design, Test and Certification Requirements – Type A Package for Solid Material

REFERENCE SOURCES: Training Manual, Chapter 8; and TS-R-1, Sections VI and VII.

DISCUSSION: The design requirements, test procedures and acceptance requirements for any of the specified materials (i.e. special form material, low specific activity material, low dispersible material), and package types can be found in the Regulations.

PROBLEM: A Type A package is being developed to transport 10,100 kg of low level solid waste. The waste is in granular form. Compliance with the regulatory requirements is to be demonstrated by testing. The packaging is to be fabricated of steel and will be cylindrical in shape.

a. What drop tests must be performed on the package?

b. What is the recommended shape and construction, and what is the recommended minimum mass of the target to be used for these tests?

c. During the drop test, what should the packaging contain?

d. What acceptance requirements must be satisfied following these tests and, for containment, how might this be demonstrated?

e. Must the package be exposed to a water spray test and, if so, for what time duration?

f. What other tests must be performed and which of these must be performed sequentially on the same test package?

ANSWER:

EXERCISE 8.3. Defining Design, Test and Certification Requirements – Type A package for Liquid Material

REFERENCE SOURCES: Training Manual, Chapters 7 and 8; and TS-R-1, Sections VI and VII.

DISCUSSION: The design requirements, test procedures and acceptance requirements for any of the specified materials (i.e. special form material, low specific activity material, low dispersible material), and package types can be found in the Regulations. Requirements may vary depending upon physical form of the contents (i.e. whether they are solid, liquid or gas).

PROBLEM: A Type A package is being developed to transport 6,000 kg of low level liquid waste. Compliance with the regulatory requirements is to be demonstrated by testing. The packaging is to be fabricated of steel and will be cylindrical in shape.

a. What drop tests must be performed on the package?

b. Compared to the design for solids discussed in Exercise 9.2, what additional features must be incorporated into this design to account for the presence of liquids?

ANSWER:

EXERCISE 8.4. Package Test Requirements

REFERENCE SOURCES: Training Manual, Chapter 8; and TS-R-1, Sections IV, VI and VII.

DISCUSSION: The test requirements that a package must be designed to satisfy, are dependent upon its physical parameters, the characteristics of its contents, and the activity of its contents.

PROBLEM: A package is to be designed with the following features:

a. Mass = 400 kg

b. Volume (based on external dimensions) = 1 m^3; and

c. Contents = 40 TBq of beta- and gamma-emitting nuclides, not in special form, whose specific identity is unknown.

What tests must be performed to demonstrate the ability of this package to withstand accident conditions of transport?

ANSWER:

EXERCISE 8.5. Defining Design, Test and Certification Requirements – Type B Packages

REFERENCE SOURCES: Training Manual, Chapter 8; TS-R-1, Sections VI, VII and VIII; and TS-G-1.1.

DISCUSSION: The design requirements, test procedures and acceptance requirements for any of the specified materials (i.e. special form material, low specific activity material, low dispersible material), and package types can be found in the Regulations. Elaboration on how these requirements may be satisfied is found in TS-G-1.1.

PROBLEM: A consignor wishes to make multiple shipments of 150,000 TBq of Co-60 in each consignment between country A and country B. The consignor determines that a vendor in country C has a package design available that is authorised to carry 60,000 TBq of Co-60, but the vendor only has two packagings manufactured to this design. The package was originally designed and certified to the 1973 Edition of the IAEA transport Regulations (Safety Series No. 6) as a Type B(U) package. The package has only been used in country C.

a. What arrangements must be made before these packagings can be loaded and shipped with the material from country A to country B?

b. Can the consignor, working with the owner of the package design, arrange to have a third package manufactured to this design to facilitate movement of 150,000 TBq in each consignment?

c. If the consignor desires to upgrade the certification of the package design to the 1996 Edition of the Regulations (TS-R-1), what additional tests (if any) must be performed on that design to demonstrate compliance with the requirements of TS-R-1?

d. In order to increase the shipping capacity using this design, does the consignor have any alternative to performing additional tests on the design in order to obtain certification to the 1996 Edition of the Regulations?

ANSWER:

EXERCISE 8.6. Defining Design, Test and Certification Requirements – Type C Package

REFERENCE SOURCES: Training Manual, Chapter 8; and TS-R-1, Sections VI and VII.

DISCUSSION: The design requirements, test procedures and acceptance requirements for any of the specified materials (i.e. special form material, low specific activity material, low dispersible material), and package types can be found in the Regulations. Requirements may vary depending upon physical form of the contents and the type of shipment planned.

PROBLEM: Tc-99m is to be transported by aircraft. The radioactive material is in a form that does not satisfy the requirements of paragraph 605.

a. What quantity of this material can be transported in a Type B package?

b. If the material were placed in a special form capsule, what quantity could be transported in a Type B package?

c. If a Type C package were designed for this material, is there any limit on the amount of material that can be carried in a single package?

d. The enhanced 200 m water immersion test is only required for Type B packages containing quantities of radioactive material in excess of 100,000 A_2. Above what activity must the Type C package be exposed to the enhanced 200 m water immersion test and why is this activity limit imposed?

e. For a Type C package, must it first be exposed to the tests in paragraphs 719–724 and 734 of TS-R-1, before being exposed to the burial test in paragraph 668 of TS-R-1)?

ANSWER:

EXERCISE 8.7. Defining Design, Test and Certification Requirements – Package for Uranium Hexafluoride

REFERENCE SOURCES: Training Manual, Chapter 8; and TS-R-1, Sections VI and VII.

DISCUSSION: The package design requirements, test procedures and acceptance requirements for any of the specified materials (including uranium hexafluoride) can be found in the Regulations. New requirements were added for uranium hexafluoride in the 1996 Edition of the Regulations.

PROBLEM: A cylinder is designed to contain 14 000 kg of depleted uranium hexafluoride.

a. The cylinder design satisfies all of the conditions of paragraphs 629–631of TS-R-1. What certification will be required, what type of code will be used in the approval certificate, and when must it be certified for use by a Competent Authority?

b. The cylinder design satisfies all of the conditions of paragraphs 629–631 of TS-R-1, but it has not been demonstrated that it can survive exposure to the thermal test without rupture of the containment system. What certification will be required, what type code will be used in the approval certificate, and when must it be certified for use by a Competent Authority?

c. Why were the additional requirements imposed for uranium hexafluoride packages in TS-R-1?

ANSWER:

EXERCISE 8.8. Pressure Requirements for Packages

REFERENCE SOURCES: Training Manual, Chapter 8; and TS-R-1, Section VI.

DISCUSSION: One of the requirements for IP-3, Type A, and Type B packages relates to demonstrating their ability to withstand reduced ambient pressure. If a package is to be transported by air, a different reduced ambient pressure requirement applies.

PROBLEM: Referring to the reduced ambient pressure requirements on packages:

a. What reduced pressure must be applied for surface transport of IP-3, Type A, and Type B packages, and where in the Regulations is this requirement found?

b. What reduced pressure must be applied for air transport of any package, and where in the Regulations is this requirement found?

c. What transport environments should be covered by each requirement?

ANSWER:

EXERCISE 8.9. Qualifying a Previously Loaded Package as an Empty Packaging

REFERENCE SOURCES: Training Manual, Chapter 8. and TS-R-1, Section V.

DISCUSSION: The specification of an *empty packaging* was introduced into the Regulations primarily to allow a robust package design to be shipped with fewer operational requirements and controls when shipped empty. However, certain requirements must be satisfied, including decontamination to adequate levels. This problem provides additional insight into this option for packaging.

PROBLEM: A Type B irradiated fuel flask is made of steel. It is used a number of times for shipping spent fuel and is loaded and unloaded underwater. After many uses, all irradiated fuel is removed from the flask and the inside of the flask is "vacuumed" of any debris. However, in order to keep personnel exposure low, no further actions are taken to clean contamination from the inside of the flask or to assess the level of contamination inside the flask. The flask is well maintained, and the outer surface is cleaned so that the radiation level on the external surface is 0.002 mSv/h. After sealing the lid of the flask, may it be shipped as an empty package? If not, why not? If so, what other requirements must be satisfied?

ANSWER:

EXERCISE 8.10. Advantages of Qualifying a Previously Loaded Package as an Empty Packaging

REFERENCE SOURCES: Training Manual, Chapter 8, Exercise 8.9; and TS-R-1, Section V.

DISCUSSION: Exercise 8.9 addresses the requirements that must be satisfied if a previously loaded Type B package is to be qualified as an empty packaging. There may be advantages and disadvantages in qualifying such an empty packaging as an excepted package.

PROBLEM: If the flask in Exercise 8.9 can be shown to satisfy requirements for an empty package as specified in TS-R-1, what operational advantages are to be gained by shipping this unloaded Type B package as an empty packaging? Are there any potential disadvantages in qualifying the packaging as an excepted package?

ANSWER:

9. REQUIREMENTS FOR TRANSPORT (CONSIGNOR'S RESPONSIBILITIES)

In preparing for the transport of radioactive material, it is important to follow the requirements established both in the IAEA Regulations and in other modal regulatory documents. This will ensure that proper safety controls are followed, and that adequate communication is provided to those involved in transport activities at all levels. The focus of this chapter is on those actions that are required primarily by a consignor to ensure hazards are properly controlled during shipment and communicated during all phases of the shipment operations. Attention is paid to such items as radiation controls, criticality controls, contamination controls, marking, labelling, placarding, shipping documents, and notifications.

Part of Section V of the Regulations deals with:

- The controls which are used in a consignment of radioactive material; and,
- The methods that are used to facilitate communications between the consignor, carrier, consignee and any others who may become involved in the transport, or storage in transit of the consignment.

Specifically, paragraphs 508–547 of TS-R-1 and other associated paragraphs are discussed in this chapter.

9.1. Controls

As discussed in Chapter 1, two of the four basic purposes of the Regulations are to protect persons, property, and the environment by guarding against:

(1) The hazard due to radiation emitted from the package, and,
(2) The possibility that a chain reaction (i.e. criticality) may be initiated in the material contained in the package.

The controls used in the Regulations to manage these hazards include the Transport Index, radiation dose rate limits, contamination limits, the Criticality Safety Index, activity limits, use of exclusive use shipments, as well as separation and segregation.

9.1.1. Radiation exposure controls

Table 9.1 provides a global summary of the radiation protection requirements both for workers and members of the public relative to transport of radioactive material. Multiple controls on radiation levels are imposed explicitly on material, packages, and conveyances by requirements established in Sections V and VI of the Regulations. In addition, requirements on radiation levels at distances 1 m from a package surface are implicitly established through the Transport Index.

TABLE 9.1. TRANSPORT OF RADIOACTIVE MATERIAL: RADIATION PROTECTION REQUIREMENTS

DOSE LIMITS AND RESTRICTIONS		ICRP 26 IAEA SS No. 9	REGULATIONS IAEA SS No. 6 1985 Ed. (AA 1990)	ICRP 60 IAEA SS No. 115 AR 10.1.1	REGULATIONS IAEA TS-R-1 2000 Edition
Workers	Effective dose E	≤ 50 msv/year		≤ 50 msv/year 100 msv averaged over 5 years Maximum = 5 msv (only one year)	
(Occupational exposure)	Equivalent dose H_T	Lens of the eye ≤ 150 msv/year Other ≤ 500 msv/year		Lens of the eye ≤ 150 msv/year Other ≤ 500 msv/year	
Members of the public	Effective dose E	≤ 5 msv/year		≤ 1 msv/year	
(Critical group)	Equivalent dose H_T	Lens of the eye ≤ 50 msv/year Other ≤ 50 msv/year		Lens of the eye ≤ 15 msv/year Other ≤ 50 msv/year	
Effective dose	Special work patterns shall not be required [1]	Not applicable	≤ 5 msv/year	Not applicable	≤ 1 mSv/year
Occupational Exposure	Dose assessment programme shall be conducted [2]	Not applicable	> 5 msv/year ≤ 15 msv/year	Not applicable	> 1 mSv/year ≤ 6 mSv/year
For transport workers	Individual monitoring shall be conducted.	Not applicable	> 15 msv/year ≤ 50 msv/year	Not applicable	> 6 mSv/year
Q SYSTEM	Effective dose, E, or Committed effect. dose, E(τ), τ = 50 years.	Not applicable	Exposed person ≤ 50 msv	Not applicable	Exposed pers. ≤ 50 mSv
	Equivalent dose, H_T, or committed equiv. Dose, $H_T(\tau)$, τ = 50 years.	Not applicable	Lens ≤ 150 msv Other ≤ 500 msv	Not applicable	Lens ≤ 150 mSv Other ≤ 500 mSv

[1] In addition, neither detailed monitoring nor dose assessment programmes nor individual record keeping shall be required.

[2] Dose assessment programme via work place monitoring or individual monitoring shall be conducted.

9.1.1.1. The Transport Index

Prior to the 1996 Edition of the Regulations, there was one control index; known as the Transport Index (TI), which provided controls both for radiation exposure and nuclear criticality. In the 1996 Edition of the Regulations (TS-R-1), this single index was divided into two separate indexes to enhance the control during packaging and transport, to assist in the prevention of misunderstanding, and to enhance communications. Thus, the TI now only provides control on radiation safety.

In general, the TI is determined through a two-step process (see paragraph 526 of TS-R-1) by:

(1) Measuring the maximum radiation level (RL_{1m}) in units of mSv/h at a distance of 1 m from the external surfaces of the package, overpack, freight container, or unpackaged LSA-I and SCO-I; and
(2) Multiplying the value deter Package limits[a] mined by 100.

The resulting number is the TI. In equation form this is simply:

$$TI \text{ (unit less)} = RL_{1m} \text{ (mSv/h)} \times 100$$

In addition, special steps are to be taken for specific types of material and packages, as follows:

(1) If the material under consideration is uranium and thorium ores or their concentrates, instead of making radiation level measurements, the maximum radiation level at any point 1 m from the external surface of the load may be taken from Table 9.2 (see paragraph 526(a) of TS-R-1).
(2) If the shipment is being made in tanks, freight containers and loads of unpackaged LSA-I and SCO-I, adjustments are needed because of the size of the load. The adjustment is made by multiplying the maximum radiation level 1 m from the surface by a factor which ranges from 1 to 10, depending upon the size. The multiplying factors are shown in Table VI of TS-R-1 (see paragraph 526(b) of TS-R-1).

TABLE 9.2. ALTERNATE RADIATION LEVELS AT 1 M FROM EXTERNAL SURFACES OF LOADS OF ORES AND CONCENTRATES

Material	Maximum radiation level for use in determining TI (mSv/h)
Ores and physical concentrates of uranium and thorium	0.4
Chemical concentrates of thorium	0.3
Chemical concentrates of uranium, other than uranium hexafluoride	0.02

When all of the above steps have been taken, the resulting TI value is rounded up to the first decimal place. However, if the TI value is 0.05 or less, it may be counted as zero (see paragraph 526(c) of TS-R-1).

Unless a consignment is under exclusive use, the TI for any package or overpack may not exceed 10 (paragraph 530 of TS-R-1). In addition, Table IX of TS-R-1 establishes a total TI limit for freight containers and conveyances, not under exclusive use, ranging from 50 for most cases to:

- 200 for cargo aircraft; large freight containers in holds, compartments or defined deck areas of a seagoing vessel; and for packages overpacks and small freight containers in or on a seagoing vessel; and
- No limit for large freight containers in or on a seagoing vessel.

9.1.1.2. Radiation exposure controls on materials

There are two types of material for which radiation exposure controls exist. One applies to instruments or articles prior to packaging for shipment in excepted packages. The other applies to LSA material or to an object or collection of objects being prepared for shipment as SCO in a single package. Table 9.3 summarizes these requirements.

TABLE 9.3. SUMMARY OF RADIATION LEVEL REQUIREMENTS FOR MATERIALS

TS-R-1 Para. No.	Material and condition to which radiation level limit requirement applies	Radiation level limit (mSv/h)
517(a)	Radiation level at 10 cm from any point on the external surface of any unpackaged instrument or article to be shipped in an excepted package	0.1
521	External radiation level at 3 m from the unshielded material categorized as LSA material, or the object or collection of objects categorized as SCO in a single package	10

It must be emphasized that, although all the requirements specified in the definition of LSA material or SCO (paragraphs 226 and 241 of TS-R-1, respectively) may be satisfied, unless the radiation exposure control requirements are also satisfied, they cannot be consigned in Industrial packages.

9.1.1.3. Radiation exposure controls on packages

The radiation exposure controls imposed by the Regulations on packages are summarized in Table 9.4. In addition to the requirements imposed by Section V of the Regulations, this table includes some radiation exposure controls imposed by Section VI of the Regulations on the package design.

With one exception, the radiation exposure controls on packages are imposed by explicit requirements in the Regulations; one is imposed implicitly. The implicit requirement is for radiation levels at 1 m from the external surfaces of packages when not transported under exclusive use. This requirement is established by relating the TI resulting from application of the requirements in paragraph 526 of TS-R-1 to the limit of TI not exceeding 10 as specified in paragraph 530 of TS-R-1.

Thus the radiation level at 1m from a package surface, when not being transported under exclusive use (paragraph 567 of TS-R-1), is limited to

$$RL_{1m} \text{ limit} = (10/100) \text{ mSv/h} = 0.1 \text{ mSv/h}$$

TABLE 9.4. SUMMARY OF RADIATION LEVEL REQUIREMENTS FOR PACKAGES

TS-R-1 para. No.	Package and condition to which radiation level limit requirement applies	Radiation level limit (mSv/h)
516	Radiation level at any point on the external surface of an excepted package	0.005
531	Radiation level at any point on any external surface of a package (when not transported under exclusive use by road or rail, or under both exclusive use and special arrangement by vessel or air)	2
532	Radiation level at any point on any external surface of a package (when transported under exclusive use)	10
572(a)	Radiation level on external surface of a package (when transported under exclusive use) by road or rail may only exceed 2 mSv/h, and must be kept below exclusive use limit if, and only if, (1) the vehicle is equipped with an enclosure, (2) the position of package in vehicle remains fixed during routine transport, and (3) there are no loading or unloading operations between beginning and end of the shipment	10
Table X, Footnote (a)	Radiation level on any external surface of a package when being transported under exclusive use in or on a vehicle may be transported by vessels provided they are not removed from the vehicle at any time while on board the vessel	10
574	Radiation level on any external surface of a package when being transported by a vessel: - Not under special arrangement - Under special arrangement	 2 2
578	Radiation level on any external surface of a package when being transported by air: - Not under special arrangement - Under special arrangement	 2 2
526 & 530	Radiation level 1 m from any external surface of a package not transported under exclusive use (established implicitly using TI)	0.1
646	Radiation level on any external surface of a Type A package following exposure to the normal conditions of transport tests	< 20% increase from design level
656	Radiation level 1 m from any external surface of a Type B package following exposure to accident-simulating tests	10

9.1.1.4. Radiation exposure controls on overpacks, conveyances and vehicles

The radiation exposure controls imposed by TS-R-1 on overpacks, conveyances and vehicles are summarized in Table 9.5.

TABLE 9.5. SUMMARY OF RADIATION LEVEL REQUIREMENTS FOR OVERPACKS, CONVEYANCES AND VEHICLES

TS-R-1 para. No.	Type of requirement	Radiation level limit (mSv/h)
531	Radiation level at any point on any external surface of an overpack (when not transported under exclusive use by road or rail, or under both exclusive use and special arrangement by vessel or air)	2
572(a)*	Radiation level at any point on the external surfaces of an overpack	10
513	Conveyances which have become contaminated must be decontaminated such that radiation levels at surfaces of conveyance from fixed contamination must be below limit	0.005
567(b) and 572(b)*	Radiation levels at any point on the external surface of the conveyance	2
567(b) and 572(c)*	Radiation levels at any point 2 m from the surfaces of the conveyance (for rail and road vehicles, the limit applies to the vertical planes projected from the outer edges of the vehicle)	0.1

* when transported under exclusive use

As with packages, one of the radiation exposure control requirements for overpacks is imposed implicitly. The implicit requirement is for radiation levels at 1 m from the external surfaces of overpacks when not transported under exclusive use. It is established implicitly by relating the TI resulting from application of the requirements in paragraph 526 of TS-R-1 to the limit of TI not exceeding 10 (paragraph 530 of TS-R-1).

When a consignment of radioactive material is assembled, many factors must be considered in defining allowable radiation levels. These include the form of the material, the type or types of packages, any use of overpacks, and the conveyance/vehicle to be used. Tables 9.1. through 9.4. provide a summary of these requirements.

9.1.2. Contamination limit controls

There are two fundamental controls on contamination:

(1) A lower limit (the definition of "contamination"), below which the presence of radioactive material on a surface is not deemed to be contamination; and
(2) Upper limits beyond which specific actions are required.

In both cases, consideration must also be given to whether the contamination is "fixed" (see paragraph 216 of TS-R-1), or "non-fixed" (see paragraph 215 of TS-R-1).

9.1.2.1. Lower limits on contamination

The lower limits on contamination (paragraph 214 of TS-R-1) are:

(1) 0.4 Bq/cm^2 for beta and gamma emitters and low toxicity alpha emitters,
(2) 0.04 Bq/cm^2 for all other alpha emitters.

9.1.2.2. Upper limits on non-fixed contamination

Generally, when determining non-fixed contamination levels, the contamination is averaged over any area of 300 cm^2 of any part of the surface of concern (e.g. see paragraph 508 of TS-R-1).

For packages, the non-fixed contamination on the external surfaces (paragraph 508 of TS-R-1) is required to be:

- As low as practicable;
- Limited to values not greater than ten times the lower limits, i.e. not greater than:
    - 4 Bq/cm^2 for beta and gamma emitters and low toxicity alpha emitters;
    - 0.4 Bq/cm^2 for all other alpha emitters.

In most cases, the same limits apply to the external and internal surfaces of overpacks, freight containers, tanks, intermediate bulk containers and conveyances (paragraph 509 of TS-R-1). If freight containers, tanks, intermediate bulk containers or conveyances are dedicated to the transport of unpackaged transport of radioactive material under exclusive use, the internal surfaces may be contaminated to higher levels as long as they remain dedicated to exclusive use (paragraph 514 of TS-R-1). Note that overpacks are not permitted to be employed for transport of unpackaged material.

Similarly, conveyances are limited to the same levels of non-fixed contamination as packages (paragraph 513 of TS-R-1). Should it be found that these limits have been exceeded, the conveyances must be decontaminated to acceptable limits as soon as possible. However, if the conveyance is dedicated to the transport of unpackaged radioactive material under exclusive use, the internal surfaces may be contaminated to higher levels as long as it remains dedicated to exclusive use (paragraph 514 of TS-R-1).

For an empty package to be shipped as an excepted package, the internal surfaces must not exceed 100 times the levels allowed for the external surfaces of packages (paragraph 520(c) of TS-R-1).

Additional limits for non-fixed contamination are used to define surface contaminated objects (SCOs) in paragraph 241 of TS-R-1.

9.1.2.3. Upper limit on fixed contamination

There is only one limit on fixed contamination, other than those specified in defining SCOs (see paragraph 241 of TS-R-1). This limit is that if any surface of a conveyance evidences a radiation level in excess of 5 μSv/h, it must be decontaminated to levels below this value as soon as possible (paragraph 513 of TS-R-1).

9.1.3. The Criticality Safety Index (CSI)

The CSI is determined only for fissile materials. Paragraphs 681 and 682 of the Regulations define the manner in which a consignor is to determine two separate values of a number "N". The first value of N is calculated for arrays of packages containing fissile material under normal conditions of transport, and the second value for arrays of packages containing fissile material under accident conditions of transport. The methodology for defining these two values of N is explained in Chapter 11 of this manual.

Once the two values of the number N are derived for the package (or packages) containing fissile material, the CSI is derived by dividing the number 50 by the smaller of the two values of N. In equation form this is simply:

$$\text{CSI (unit less)} = 50 / N_{min}$$

Unless a consignment is under exclusive use, the CSI for any package or overpack may not exceed 50 (see paragraphs 530 and 567 of TS-R-1).

The CSI for each consignment is determined by adding the CSIs of each of the packages in the consignment (paragraph 529 of TS-R-1).

Finally, Table X of TS-R-1 establishes a total vessel CSI limit for packages, overpacks and small freight containers. However, it allows an unlimited number of CSIs if the total sum of CSIs in any group is less than 50, and each group is separated from all other groups by 6 m. In the event that shipments are undertaken under exclusive use, higher limits apply (see Table X of TS-R-1).

9.1.4. Activity limit controls

There are multiple controls on the activity allowed in packages. The activity largely determines the type of package requirements to be used. In addition, there are activity limit controls on conveyances carrying LSA material or SCO (see paragraph 524 and Table V of TS-R-1). The conveyance limits are:

(1) 100 A_2 for non-combustible LSA-II and LSA-III solids in the hold or compartment of an inland water craft;

(2) 100 A_2 for combustible solid LSA-II and LSA-III, liquids and gases in the form of LSA-II and LSA-III, and SCOs when transported in any conveyance which is not an inland water craft; and,

(3) 10 A_2 for combustible solid LSA-II and LSA-III, liquids and gases in the form of LSA-II and LSA-III, and SCOs when transported in the hold or compartment of an inland watercraft.

Otherwise (i.e. for LSA-I, and for non-combustible LSA-II and LSA-III solids transported in any conveyance which is not an inland water craft), there is no activity limit.

9.1.5. Exclusive use shipments

Exclusive use is a means of enhancing safety by requiring that a consignment of radioactive material be transported through sole use, by a single consignor, on a conveyance or in a large freight container (paragraph 221 of TS-R-1). It applies to all activities relating to initial, intermediate and final loading and unloading, which must be undertaken in accordance with the directions of either the consignor or the consignee. Exclusive use allows relief from certain requirements, including:

(1) Decontaminating the internal surfaces of conveyances, freight containers, tanks and intermediate bulk containers (paragraph 514 of TS-R-1);

(2) Contamination requirements when transporting LSA-1 unpackaged (paragraph 523 of TS-R-1);

(3) The package or overpack TI limit of 10 (paragraphs 530 and 567 of TS-R-1);

(4) The package or overpack CSI limit of 50 (paragraphs 530 and 567 of TS-R-1);

(5) The package or overpack radiation level limit of 2 mSv/h (paragraph 531 of TS-R-1) subject to the additional controls in paragraph 572 of TS-R-1 for rail and road vehicles, in paragraph 574 of TS-R-1 for vessels, and in paragraph 576 of TS-R-1 for aircraft; and

(6) The TI limits for freight containers and conveyances (para. 566, Table X of TS-R-1).

9.1.6. Separation and segregation

Segregation of radioactive material consignments from occupied places (paragraph 562(a) of TS-R-1) is used to control radiation exposure of persons.

Segregation of radioactive material consignments from photographic film (paragraph 562(a) of TS-R-1) is used to protect the film from inadvertent exposure.

Segregation of radioactive material consignments from other dangerous goods is required (paragraph 562(b) of TS-R-1). This is in order to control inadvertent reactions between different types of dangerous goods and to comply with the dangerous goods requirements of each country involved in the shipment (paragraph 506 of TS-R-1).

Fissile material packages are controlled by a requirement that they be segregated into groups such that sum of the CSI in each group does not exceed 50, and each group must be separated by 6 m (paragraph 568 of TS-R-1). Some relief from this requirement is allowed for vessels under exclusive use (footnote c of Table X of TS-R-1).

9.2. Communications

The Regulations require that hazards posed by a consignment of radioactive material be communicated clearly to all parties concerned. In addition to facilitating radiation protection during all phases of the transport operations, some of these communications are vital for emergency responders. They are accurately informed of the potential hazards and emergency response procedures should an accident occur involving a shipment of radioactive material. This communication is accomplished by requiring:

(1) Markings on material and packagings;

(2) Labels on packages;

(3) Placarding of freight containers, tanks, and road and rail vehicles;

(4) Specification of the particulars of a consignment in shipping papers;

(5) Notifying Competent Authorities under certain conditions.

9.2.1. Markings

A number of different markings are required to be placed on material and packages.

9.2.1.1. Markings on material

The only material marking requirements apply to instruments and articles to be transported in excepted packages. Each instrument or article is required to bear the marking “RADIOACTIVE” (see paragraph 517(b) of TS-R-1).

9.2.1.2. Markings on packages

The package marking requirements are specified in paragraphs 518 and 534–540 of TS-R-1. The Regulations require that the markings be legible and durable. Some need to be marked such that they remain legible for many shipments, or even for the lifetime of the packaging, while others must remain legible only for the duration of a shipment.

The marking requirements, by type of consignment, are summarized in Section 8 of each schedule at the back of TS-R-1. In addition, paragraph 548 of TS-R-1 specifies that the responsibility for providing proper markings is with the consignor. In addition, the placement of labels on packages (see 9.2.2) must be accomplished in a manner that all markings remain visible (see paragraph 542 of TS-R-1).

Table 9.6 summarizes the marking requirements, and shows the duration expected for each marking. The markings are to be located on the outside of the package unless otherwise noted. To facilitate discussion of this table, each row has been numbered.

The marking requirements for transport by international post are noted in TS-R-1 (see Numbers 1b and 2c in Table 9.6). However, the markings for domestic post are not given since the requirements vary from country to country. The postal authority for the country in which a domestic shipment is to be shipped should be consulted for its requirements.

The following example is given to illustrate how the text of paragraphs 534 to 540 of TS-R-1 combined with the schedules of TS-R-1 and Table 9.6. in this chapter can be used to determine the marking requirements for a given consignment. It is assumed, for this example, that a 400 kg, Type B(U) package containing fissile material is to be transported. By reference to Table 9.6 and Schedule 11 of TS-R-1, the markings required are:

(1) The identification of the consignee, consignor, or both (No. 1 of Table 9.6);

(2) "UN 3328, RADIOACTIVE MATERIAL, TYPE B(U) PACKAGE, FISSILE" (No. 2a of Table 9.6);

(3) "Gross Mass = 400 kg" (No. 4 of Table 9.6);

(4) The identification mark allocated to that package's design by the Competent Authority (No. 8 of Table 9.6);

(5) A serial number unique to that packaging (No. 8 of Table 9.6);

(6) "TYPE B(U)" (No. 9 of Table 9.6);

(7) The trefoil embossed or stamped on the outermost fire-resistant and water-resistant receptacle (No. 11 of Table 9.6).

TABLE 9.6. SUMMARY OF PACKAGE MARKING REQUIREMENTS

No.	Type of package	Type of marking	Duration of marking	TS-R-1 para. no.
1a	All packages	The name of the consignor, consignee, or both	Shipment (may change between shipments for reusable packages)	534
1b	Excepted package by international post	The name and address of consignor with the request that the consignment be returned in the case of non-delivery (on the outside of the package); and The name and address of the consignor and the contents (indicated on the internal packaging)	Shipment	535 and 580
2a	All but excepted packages	"UN," followed by the UN Number, followed by the Proper Shipping Name[a]	Shipment, or possibly lifetime of packaging	535
2b	Excepted package not shipped by international post	"UN," followed by the UN Number[a]	Shipment, or possibly lifetime of packaging	535
2c	Excepted package shipped by international post	"RADIOACTIVE MATERIAL" QUANTITIES PERMITTED FOR MOVEMENT BY POST"	Shipment[b]	535 and 580
3	Excepted package containing material other than instruments or articles	"RADIOACTIVE" on an internal surface in such a manner to serve as a warning on opening the package	Shipment, or possibly lifetime of packaging	518(b)
4	All Packages	The package's permissible gross mass if greater than 50kg	Lifetime of packaging	536
5	All Industrial Packages	"TYPE IP-1," "TYPE IP-2," or "TYPE IP-3," as appropriate	Lifetime of packaging	537(a)
6	Type A Packages	"TYPE A"	Lifetime of packaging	537(b)
7	Industrial Type 2, Industrial Type 3, and Type A Packages	The VRI code of the country of origin of the design, and the name of manufacturers or other identification as specified by the Competent Authority	Lifetime of packaging	537(c)

No.	Type of package	Type of marking	Duration of marking	TS-R-1 para. no.
8	All packages approved by Competent Authorities	The identification mark assigned by the Competent Authority, and The unique serial number for each packaging	Lifetime of packaging	538(a) and 538(b)
9	Type B(U) and Type B(M)	"TYPE B(U), or "TYPE B(M)," as appropriate	Lifetime of packaging	538(c)
10	Type C	"TYPE C"	Lifetime of packaging	538(d)
11	Type B(U), Type B(M) and Type C	The trefoil symbol (Figure 1 of TS-R-1) embossed, stamped or other fire and water resistant method onto outermost receptacle	Lifetime of packaging	539
12	Receptacles or wrappings containing LSA-I material or SCO transported unpackaged, under exclusive use	"RADIOACTIVE LSA-I," or "RADIOACTIVE SCO-I," as appropriate	Shipment	540

[a] The UN Numbers and Proper Shipping Names can be found in Table VIII of TS-R-1.

[b] These words will be crossed out if the packaging is returned empty.

9.2.2. Labelling of packages and overpacks

The labelling of packages and overpacks is another important method for communicating the presence and potential hazard of radioactive materials. Prior to the 1996 Edition of the Regulations, three radioactive material labels were specified. However, in the TS-R-1, a fourth label was added. Each of the four labels is shown in Figures 2 through 5 of TS-R-1.

9.2.2.1. Labelling for radioactive contents

The labelling requirements for the radioactive nature of the contents of a package or overpack are based on the category assigned. These requirements are found in paragraphs 541-543 of TS-R-1.

Labelling requirements result from assigning a category to each package or overpack (see paragraph 533 of TS-R-1). The categories involve the use of either a I-White label (Figure 2 of TS-R-1), a II-Yellow label (Figure 3 of TS-R-1), or a III-Yellow label (Figure 4 of TS-R-1). The labelling requirements are summarized in Table 9.7.

As noted in paragraph 533 of TS-R-1, if the TI (i.e. a value which can be related to the radiation level at 1 m from the surface of the package or overpack) satisfies the condition for one category, but the surface radiation level satisfies the condition for another category, the package or overpack is assigned to the higher category.

TABLE 9.7. DEFINITION OF CATEGORIES FOR LABELLING OF PACKAGES FOR RADIATION PROTECTION

Transport Index (TI)	Maximum radiation level at 1 m from package surface[a] (mSv/h)	Maximum radiation level at any point on external surface of package (mSv/h)	Transport control requirement	Category
TI = 0[b]	$RL_{1m} = 0$	$0 < RL_S \leq 0.005$	None	I-White
0[b] < TI ≤ 1	$0 < RL_{1m} \leq 0.01$	$0.005 < RL_S \leq 0.5$	None	II-Yellow
1 < TI ≤ 10	$0.01 < RL_{1m} \leq 0.1$	$0.5 < RL_S \leq 2$	None	III-Yellow
10 < TI	$0.1 < RL_{1m}$	$2 < RL_S \leq 10$	Exclusive Use	III-Yellow

[a] Maximum level at 1 m determined using TI values and paragraphs 526–527 of TS-R-1.

[b] If the measured TI ≤ 0.05, the value quoted may be zero.

Each of these labels has a “7” at the bottom, which indicates the hazard class, i.e. “Radioactive, Class 7”.

In addition, whatever label applies to the package or overpack must have the contents and maximum activity of those contents noted. If the label is a II-Yellow or III-Yellow, it must also have the TI noted. The written communication of the contents, activity, and TI on the label should be accomplished by durable means that will not degrade during transport.

9.2.2.2. Labelling for criticality safety

The labelling requirements for the fissile nature of the contents of a package to provide criticality safety are specified in paragraphs 541, 544 and 545 of TS-R-1. If the material is fissile, (unless it is in a fissile excepted package), a criticality safety label is required. This label (Figure 5 of TS-R-1) must be added in addition to the I-White, II-Yellow, or III-Yellow, as appropriate. The Criticality Safety Index is to be noted on the label. The written communication of the CSI on the label also has to be accomplished using a durable method that will not degrade during transport.

9.2.2.3. Placement of labels

The applicable label for radioactive contents (i.e. I-White, II-Yellow or III-Yellow) must be affixed to two opposite sides of the outside of a package or overpack. If a freight container or tank is used as a package (see paragraph 231 of TS-R-1), then the applicable label has to be affixed to all four sides.

Any labels which do not relate to the package contents must be removed or covered (paragraphs 520(d) and 541 of TS-R-1).

9.2.3. Placarding of freight containers, tanks, and rail and road vehicles

Placards may take three forms:

(1) The placard as depicted in Figure 6 of TS-R-1, which is similar to the II-Yellow or III-Yellow labels but is larger in dimension and does not include the red bars or allowances for specifying contents, activity or TI;

(2) The placard as depicted in Figure 7 of TS-R-1, which is a rectangular box with orange background upon which the appropriate UN number is to be displayed; and
(3) Enlarged versions of the appropriate labels as depicted in Figures 2-5, with dimensions as shown in Figure 6 of TS-R-1.

Any placard that does not relate to the contents of the freight container, tank, or conveyance must be removed (paragraph 546 of TS-R-1).

9.2.3.1. Placarding of freight containers

Each large freight container carrying radioactive material packages (other than excepted packages) must have one diamond-shaped placard as depicted in Figure 6 of TS-R-1 affixed to each of its side and end walls (paragraph 546 of TS-R-1).

For each freight container carrying LSA-I, SCO-I, or radioactive material under exclusive use having a single UN number, the appropriate UN number must be displayed in black digits not less than 65 mm in height. This may be either on the placard shown in Figure 6 of TS-R-1 with the UN number preceded by the letters "UN," or on the subsidiary placard shown in Figure 7 of TS-R-1. If the subsidiary placard shown in Figure 7 is used, it must be affixed immediately adjacent to the main, diamond-shaped placard. These placards must be affixed on all four sides of the freight container.

Paragraph 546 of TS-R-1 also allows enlarged labels, as appropriate to the contents (Figures 2-5 of TS-R-1) to be used on freight containers in place of the placards shown in Figures 6 and 7 of TS-R-1 (see paragraphs 546 and 541 of TS-R-1).

9.2.3.2. Placarding of tanks

Tanks carrying radioactive material have a similar requirement for a placard (as depicted in Figure 6 of TS-R-1) to be affixed to each of its side and end walls (paragraph 546 of TS-R-1).

For each tank carrying LSA-I, or radioactive material under exclusive use having a single UN number, the appropriate UN number must be displayed in black digits not less than 65 mm in height. Again this may be either on the label shown in Figure 6 of TS-R-1 with the UN number preceded by the letters "UN," or on the label shown in Figure 7 of TS-R-1.

If the label shown in Figure 7 of TS-R-1 is used, it must be affixed immediately adjacent to the main, diamond-shaped label. These labels must be affixed on all four sides of the tank. Note, although paragraph 546 of TS-R-1 implies SCO-I could be carried in a tank, that is not the intention of the Regulations.

9.2.3.3. Placarding of rail vehicles

A rail vehicle carrying packages, overpacks or freight containers labelled with I-White, II-Yellow, III-Yellow or the fissile material label (Figures 2–5 of TS-R-1) must have the diamond-shaped placard of Figure 6 of TS-R-1 on the two lateral walls of the vehicle. If the vehicle does not have walls, the placards may be affixed directly to the cargo-carrying unit as long as they are readily visible. If the vehicle is carrying placarded freight containers or tanks, then those placards will suffice (paragraphs 570–571 of TS-R-1).

9.2.3.4. Placarding of road vehicles

A road vehicle carrying packages, overpacks, or freight containers labelled with I-White, II-Yellow, III-Yellow or the fissile material label (Figures 20–5 of TS-R-1) must have the diamond-shaped placard of Figure 6 on the two lateral walls, and the rear wall of the vehicle. If the vehicle does not have walls, the placards may be affixed directly to the cargo-carrying unit as long as they are readily visible. If the vehicle is carrying placarded freight containers or tanks, then those placards will suffice (paragraph 570 of TS-R-1).

9.2.4. Communication documents

The consignor is required to provide transport documents that contain information as listed in paragraph 550 of TS-R-1, and a consignor's declaration as elaborated in paragraphs 551–554 of TS-R-1.

The purpose of the transport documents is to communicate clearly:

(1) What is being shipped, including:
- The proper shipping name,
- The UN Class number "7",
- The UN number,
- A listing of the radionuclides or description of mixtures of radionuclides involved

(2) A description of the physical and chemical form of the material, and
(3) The maximum activity or mass of fissile material;
(4) The category of the package;
(5) The TI (for II-Yellow and III-Yellow only);
(6) The CSI (for fissile material shipments);
(7) The identification mark for each applicable Competent Authority approval certificate;
(8) A detailed statement of the contents of packages in overpacks or freight containers;
(9) The statement "EXCLUSIVE USE SHIPMENT", if applicable; and
(10) The total activity in a consignment (in multiples of A_2) for consignments of LSA-II material, LSA-III material, SCO-I and SCO-II.

The purpose of the shipper's declaration specified in paragraph 551 of TS-R-1 is to establish, in written form, responsibility for the consignment. It must be signed and dated by the consignor.

The consignor is required to provide, in the transport documents, a statement regarding any actions required of the carrier (paragraph 555 of TS-R-1). This statement must be in appropriate languages, and must include:

(1) Loading, stowage, carriage, handling and unloading requirements;
(2) Mode or conveyance restrictions; and
(3) Appropriate emergency arrangements.

The consignor must possess a copy of each certificate appropriate to the consignment, the instructions for closing the package and preparations for shipment (paragraph 561 of TS-R-1). However, these certificates need not accompany the consignment (paragraph 556 of TS-R-1).

9.2.5. Notifications

Before the first shipment of a certified package, the consignor must ensure that copies of the applicable package design certificates are submitted to the Competent Authority of each country involved in the consignment. Acknowledgement of receipt of these certificates is not required (paragraph 557 of TS-R-1).

Certain shipments require notification of each Competent Authority of each country involved in those shipments. The notification must be made preferably at least 7 days in advance of the shipment. The shipments requiring such notification are (paragraph 558 of TS-R-1):

- Type C packages containing more than 3000 A_1 or 3000 A_2, as appropriate, or 1000 TBq, whichever is lower;
- Type B(U) packages containing more than 3000 A_1 or 3000 A_2, as appropriate, or 1000 TBq, whichever is lower;
- Type B(M) packages; and
- Shipments under special arrangement.

The particulars to be included in the notification are listed in paragraph 559 of TS-R-1.

EXERCISES FOR CHAPTER 9

The following are exercises to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 9.1. Controls and Additional Requirements on Numbers of Packages in a Consignment

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REFERENCE SOURCES: Training Manual, Chapters 8 and 9, and Exercise 7.4; and TS-R-1, Section V.

DISCUSSION: In addition to the safety provided by the package, controls are frequently placed on the number of packages that can be shipped in a consignment.

PROBLEM: A consignor plans to prepare a consignment consisting of a single package. The package will contain manufactured articles of a metal alloy of 0.1 TBq of Ni-63. The articles do not satisfy the requirements for special form [see also, Exercise 7.4(b).].

a. Can more than one article be shipped per package? If so, how many?

b. What additional requirements must be satisfied, if any?

ANSWER:

EXERCISE 9.2. Defining TI, CSI and Category of a Package

REFERENCE SOURCES: Training Manual, Chapters 10 and 11; and TS-R-1, Sections V and VI.

DISCUSSION: Controls are placed on the transport of packages through a number of mechanisms, including the transport index, the criticality safety index, and designation of category. The latter is then used to define the labelling requirements.

PROBLEM: For a Type B(U)F package, it is determined:

- Using the methods in paragraphs 671–682 of TS-R-1 an unlimited number of packages of this design is sub-critical;
- The maximum radiation level at 1 m from the surface of the package is 0.005 mSv/h; and
- The maximum surface radiation level is 0.02 mSv/h.

a. What is the Transport Index (TI) for the package?

b. What is the Criticality Safety Index (CSI) for the package?

c. What is the Category of the package?

ANSWER:

EXERCISE 9.3. Package Design Requirements and Shipment Controls

REFERENCE SOURCES: Training Manual, Chapters 8 and 9; and TS-R-1, Sections V and VI.

DISCUSSION: A number of parameters are frequently required to determine package design requirements and shipment controls. This exercise illustrates the types of parameters that must be considered.

PROBLEM: A consignment of four containers with a mixture of liquid radionuclides is presented for transport by road and inland waterway. The radionuclides in the liquid are not fissile, nor are they alpha emitters. It is determined that:

- The specific activity is 4×10^{-6} A_2/g;
- The radiation level at 3 m from the unshielded material in each container is 5 mSv/h;
- The contamination on the external surfaces of each container is less than 0.1 Bq/cm^2;
- The A_2 value for the mixture is 1.7 TBq;
- Each container holds 20 TBq; and
- The maximum radiation level at 1 m from the external surface of each package is 0.08 mSv/h.

a. What minimum package design requirements must each container satisfy?

b. What is the TI for each package?

c. What is the TI for the consignment?

ANSWER:

EXERCISE 9.4. Assigning Categories and Determining Consignment Constraints

REFERENCE SOURCES: Training Manual, Chapters 8 and 9; and TS-R-1, Sections V and VI.

DISCUSSION: The determination of TIs, categories and, ultimately, consignment constraints can become complex when different packages are proposed for a single consignment. Care must be taken to ensure that all requirements are satisfied.

PROBLEM: Three packages have the following characteristics:

Package 1**:** Is a Type B(M)F package; the value of N (for criticality) is determined according to paragraph 681 and has a value of 25; the maximum radiation level at 1 m from the surface of the package (RL_{1m}) is 0.01 mSv/h; and the maximum surface radiation level (RL_s) is 0.09 mSv/h.

Package 2: Is a Type B(U) package; RL_{1m} = 0.01 mSv/h; and RL_s = 0.04mSv/h.

Package 3: Is a Type B(M) package; RL_{1m} = 0.12 mSv/h; and RL_s = 2.25 mSv/h.

a. What is the TI for each package?

b. What is Criticality Safety Index for each package?

c. What is the Category of each package?

d. Can the three packages be combined into a single consignment and if so what requirements must be satisfied?

ANSWER:

EXERCISE 9.5. Marking, Labelling, and Placarding Requirements

REFERENCE SOURCES: Training Manual, Chapter 9; and TS-R-1, Section V.

DISCUSSION: The marking, labelling and placarding requirements for packages are dependent upon the package type, package mass, and contents.

PROBLEM: Assume that a Type B(U)F package has:

- A gross weight of 5000 kg,
- A radiation level on the surface of 5 mSv/h,
- A radiation level 1 m from its surface of 0.7 mSv/h,
- A CSI = 25,
- Contents which satisfy the description of "RADIOACTIVE MATERIAL," and
- To be transported on a road vehicle.

What are the marking, labelling and placarding requirements for this package, and where are these requirements found?

ANSWER:

EXERCISE 9.6. Package Contamination

REFERENCE SOURCES: Training Manual, Chapter 9; TS-R-1, Section V; and TS-G-1.1, Section V.

DISCUSSION: The Regulations specify limits on levels of contamination of packages, and require that these limits apply over 300 cm^2 of any part of the surface. Compliance with this requirement may require pragmatic judgement concerning how the measurements are made and interpreted.

PROBLEM: A package is being prepared for transport. It is checked for non-fixed contamination by taking a dry wipe of 300 cm^2 from the package surface with a piece of filter paper. The beta and gamma activity measured on the wipe is 900 Bq. Assuming that this value is as low as practicable, does the package comply with TS-R-1 requirements for shipment as:

a. An excepted package?, or

b. Other than an excepted package?

ANSWER:

EXERCISE 9.7. TI for a Freight Container

REFERENCE SOURCES: Training Manual, Chapter 9; and TS-R-1, Section V.

DISCUSSION: When the TI for a freight container loaded with LSA material packages is being determined by using the direct measurement method, care must be taken to apply all of the requirements in the Regulations.

PROBLEM: A consignment of non-fissile LSA material is prepared for shipment in a freight container. The freight container is 2 m wide, 2 m high and 4 m long. Radiation level measurements are taken at several points 1 m from the surface of the freight container. The maximum radiation level measured is 0.02 mSv/h. What is the TI of this consignment?

ANSWER:

EXERCISE 9.8. Assignment of TI for a Consignment of a Mixture of Radioactive Material Packages

REFERENCE SOURCES: Training Manual, Chapter 9; and TS-R-1, Section V.

DISCUSSION: none

PROBLEM: A consignor prepares 10 Type A non-fissile packages and 20 Type A fissile material packages for shipment. Each non-fissile Type A package has a TI of 0.5. Each fissile material Type A package has a CSI of 0.1, and a TI based on radiation level measurements of 0.05. The consignor places all 30 packages into a non-rigid overpack, measures a maximum radiation level at 1 m from the surface of the overpack of 0.031 mSv/h, and records on the shipping papers that the TI for the overpack TI_{op} = 3.1.

a. Should the TIs for the fissile material packages be recorded as 0.05?

b. Is this method of determining TI for the non-rigid overpack appropriate?

c. What is the CSI for this freight container?

ANSWER:

EXERCISE 9.9. Requirements for the Transport of a UF_6 Shipment

REFERENCE SOURCES: Training Manual, Chapters 6, 7, 8, 9; and TS-R-1, Section V.

DISCUSSION: Requirements from many sections of the Regulations must be used in determining packaging requirements and shipping controls for a consignment of a single commodity.

PROBLEM: A reprocessing facility must transport a 5kg sample of reprocessed uranium in the form of UF6. The UF6 has an enrichment of 0.85%, with the following constituents:

	Activity (Bq)
U-232	5.600E+05
U-234	2.300E+03
U-235	4.600E+05
U-236	4.900E+06
U-238	8.300E+06
MFP	2.000E+03

The package in which this material is contained is presented for transport with a surface radiation level of 60 μSv/h, and a reading at 1 m from the package surface of 12 μSv/h.

a. What is the A_2 value for this package?

b. What type of package is required?

c. What category label is required?

d. What is the applicable UN Number and Proper Shipping Name?

ANSWER:

10. CONTROL OF MATERIAL IN TRANSPORT (CONSIGNOR'S AND CARRIER'S RESPONSIBILITIES)

10.1. Consignor's responsibilities

As highlighted earlier, the IAEA TS-R-1 Regulations place the prime responsibility for actions to ensure safety in transport of radioactive material on the consignor. The safety measures specific to the radioactive hazard, for which the carrier is responsible, are thus minimized.

The process and procedures that a consignor must follow in order to properly prepare the radioactive material for shipment according to the Regulations is outlined here in a general sense. This outline is provided to facilitate the understanding of the Regulations for those people who are not normally involved in their practical application. It is not intended to be exhaustive or comprehensive. Each consignor preparing a shipment or a Competent Authority overseeing, inspecting or auditing such an activity will need to ensure that all international and applicable domestic regulatory requirements are satisfied. The first responsibility of the consignor is to optimize the shipment by proper characterization of the material and selection of the packaging type.

10.1.1. Material definition and package selection

There are multiple steps in the procedures to be followed. Basically, the procedure leads to proper package selection, which depends upon: (a) the form of the material to be shipped, (b) the radionuclides involved in the shipment, (c) the quantity of radionuclides involved, (d) the material type, and (e) the definition of the packaging requirements.

The use of proper packaging for the specific radioactive material to be transported is the key to achieving safety in the transport of radioactive material. In order to determine the packaging requirements, which will allow the correct package design to be selected, a prospective shipper must answer a number of questions, many of which are posed in the following sections.

10.1.1.1. Form of the radioactive material

Question: What is the form of the radionuclide or radionuclides being shipped?
Comment: If it is special form radioactive material, then the A_1 value will need to be determined; otherwise the A_2 value will need to be determined. As noted earlier in this manual, the A_1 and A_2 values are required for defining package requirements.

10.1.1.2. Radionuclides involved

Question: What radionuclide or combination of radionuclides are to be shipped?
Comment: This is clearly important in order to determine the appropriate A_1 or A_2 value. If the radionuclides are known, then the A_1 or A_2 values for the nuclides may be determined from Table I of TS-R-1. If the radionuclides are unknown, then the default values for A_1 or A_2 for the nuclides must be found using Table II of TS-R-1.

10.1.1.3. Quantity of radionuclides

Question: What quantity of the radionuclide is being shipped?
Comment: For a single radionuclide, or for a mixture of radionuclides whose activity was defined using Table II of TS-R-1, the activity being shipped will need to be compared with the A_1 or A_2 value found above in order to determine the packaging required. If there is a known mixture of nuclides involved, then the methods for defining the effective A_1 or A_2 value of the mixture to be used in performing this comparison are given in paragraphs 404 and 413 of TS-R-1.

10.1.1.4. Material type

There are a series of questions which must be addressed concerning the nature of the radioactive material to be transported. Specifically, more than just the form of the material must be evaluated. The following determinations need to be made:

Question: Can the material be considered as being incorporated in instruments or articles?
Comment: If the answer to this question is "yes," then it might be possible to transport it in an excepted package.

Question: Does the material meet the criteria for low specific activity material (i.e., LSA-I, LSA-II or LSA-III material) given in paragraph 226 of TS-R-1, or surface contaminated object (i.e., SCO-I or SCO-II) given in paragraph 241 of TS-R-1?
Comment: If the answer to this questions is "yes," then it may be possible to transport either unpackaged (see paragraph 523 of TS-R-1) or in industrial packages (see paragraph 524 of TS-R-1), but another requirement must first be satisfied, as set forth in the next question.

Question: Is the radiation level, 3 m from the unshielded material, object, or collection of objects less than 10 mSv/h?
Comment: The answer here must be "yes" in order to satisfy the requirement of paragraph 521 of TS-R-1 before the material, object or objects can be transported as LSA material or SCO.

Question: Is the material fissile, as defined in paragraph 222 of TS-R-1?
Comment: If it is fissile material, additional requirements in terms of packaging and controls must be satisfied.

Further questions may need to be asked, such as:

Questions:

- Is the material solid, liquid or gas (e.g. see paragraphs 226, 410, and 647–649 of TS-R-1)?
- Does it satisfy the low dispersible requirement for transport by air (e.g. see paragraph 416 of TS-R-1)?
- Is it uranium hexafluoride (e.g. see paragraphs 629–632 of TS-R-1)?
- Does it pose subsidiary hazards (e.g. see paragraphs 507 of TS-R-1)?
- Is it impacted by the conveyance activity limits of Table V, and paragraph 525 of TS-R-1?

Comment: Answers to questions such as these are needed not only to allow the proper package to be selected, but also to define specific communication requirements.

10.1.1.5. Package requirements

At this point there should be sufficient information available to determine the type of packaging required for the shipment.

If the quantity being shipped is small compared to the appropriate A_1 or A_2 value, then Table III of TS-R-1 may be consulted to determine if the material may be considered for shipment in an excepted package. Other criteria will also need to be met. In addition, if the quantity is very small (0.1 of the Table III limit), it may then be possible to transport the consignment by post (see paragraph 410 of TS-R-1) depending upon the regulations of the postal authorities in the country or countries where shipment is planned.

If the material meets the LSA material or SCO criteria, then it may be possible to transport it unpackaged or in an industrial package (IP-1, 2 or 3).

If the radioactive material does not satisfy all of the requirements for shipment in an excepted package, or as either LSA material or SCO, and the quantity of radiactivity in any one package is not greater than the A_1 or A_2 value (as applicable), then it must be shipped in a package designed to satisfy the requirements for a Type A package.

If the quantity of radioactivity of the material in any one package is greater than the appropriate A_1 or A_2 value (as applicable), then it must be shipped in a Type B package.

If the material is to be transported by air, and it is not a low dispersible radioactive material, it may require transport in a Type C package. (It is noted that this is a new requirement, which was imposed in 1996 by paragraph 416 of TS-R-1.)

In addition, if the material is uranium hexafluoride, and the quantity exceeds 0.1 kg, then it must be transported in a package the design of which has been specifically approved to contain uranium hexafluoride. (It is noted that this is a new requirement, which was imposed in 1996 by paragraphs 230 and 629–632 of TS-R-1.) Even if the quantity is less than 0.1 kg, other requirements still apply (paragraph 629 of TS-R-1).

Finally, if the material is fissile material, and is not fissile excepted (see paragraph 672 of TS-R-1), then the material must be transported in a package whose design has also been specifically approved for fissile material (see paragraph 230 of TS-R-1), where consideration has been given in the design to satisfying additional requirements as specified in paragraphs 671, and 673–682 of TS-R-1).

If a package design is already available for the radioactive material, a determination (by measurement or calculation) needs to be made as to whether the radiation levels on the outside of the package will satisfy the various requirements as summarized in Tables 9.2 to 9.5 in Chapter 9 of this document. If this is not the case, then the packaging will need to be changed or perhaps the material could be transported under special arrangement. If no suitable packaging is available, and shipment is not be undertaken under special arrangement, then a package will need to be designed, demonstrated to be in compliance with the standards of the regulations (see paragraphs 701–702 of TS-R-1), and constructed. In addition, it may also be necessary to have the design approved by the appropriate Competent Authority.

10.1.2. Use of the Schedules

Once this stage has been reached, enough information should now be available to the consignor to take advantage of the schedules which are included at the back of the Regulations. Each schedule provides some, but not all, of the requirements specified in the Regulations for a given type of consignment. Answering the questions given earlier, and determining the package type will lead the consignor to one particular schedule. The first item in each schedule is headed “MATERIALS” and therefore a check of this will confirm whether or not the correct schedule has been selected. Following the appropriate schedule, and referring to the TS-R-1 Regulations as necessary, will help to ensure that all the requirements of the Regulations are met.

The schedules will lead the consignor through the administrative requirements for each of several types of shipments. The detailed information given in each schedule includes:

- Materials,
- Packaging/Package,
- Maximum radiation levels,
- Contamination,
- Decontamination,
- Mixed contents,
- Loading and segregation,
- Labelling and marking,
- Placarding,
- Transport documents,
- Storage and dispatch,
- Carriage, and
- Other provisions.

There is some correspondence of the UN numbers to the schedules. Nevertheless, whereas there are 14 schedules, 25 UN numbers characterize more specifically the radioactive material to be transported.

10.1.3. Other administrative responsibilities

It is the consignor's responsibility to provide all of the following:

(1) Adequate packaging, as well as correct labelling and marking of the package and placarding of the conveyance (see paragraph 548 of TS-R-1). This includes correct determination of the Transport Index (TI), the Criticality Safety Index (CSI) and the correct UN number, in accordance with paragraphs 526–529 and Table VIII of TS-R-1.

(2) Transport documents that are completed correctly and are available as necessary (paragraph 555 of TS-R-1).

(3) A statement in the transport documents regarding any actions necessary on the part of the carrier, such as restrictions, routeing, or emergency actions.

(4) A formal declaration, signed and dated, that the contents of the consignment satisfy the relevant National and International Regulations, as appropriate to the modes of transport involved.

(5) Directions for the control of packages being transported under exclusive use.

(6) Advance notification of certain consignments to the Competent Authorities of each country through, or into which, the consignment is to be transported (paragraph 558 of TS-R-1).

(7) Competent Authority certificates to the carrier and Competent Authorities, as needed. However, the certificates do not have to accompany the consignment, but the consignor also needs to retain copies of them (paragraphs 557 and 558 of TS-R-1).

(8) Quality Assurance to ensure that the Regulatory requirements relative to the package and consignment are being met.

Consignors must also provide facilities for Competent Authority inspections of certain packagings during construction and use.

In addition, the consignor has other responsibilities if the radioactive contents have other hazardous properties. The consignor may also need to deal with liability or damage insurance and export requirements.

10.2. Carrier's responsibilities

10.2.1. Regulatory responsibilities

The special safety responsibilities of the carrier, as given in the Regulations, are mainly concerned with following the instructions given by the consignor. The consignor's directions may cover such topics as loading, storage, transport, handling, or unloading. These controls may include the segregation of radioactive consignments from persons and other dangerous goods, or the maintenance of exclusive use controls or special modal constraints. As an example of the latter, the segregation distances prescribed as a function of the external radiation dose rates of consignments are modal-specific because they must take into account the particular operational features of the mode concerned.

10.2.2. Practical responsibilities

In addition to the Regulatory requirements, there are a number of practical considerations which need to be taken into account when carrying radioactive material. The following paragraphs outline some of the more important ones.

10.2.2.1. Acceptance of consignments

Although most of the shipping responsibilities lie with the consignor, a responsible carrier will want to check a consignment carefully before accepting it. How rigorously this is done will depend on the relationship between the consignor and the carrier.

An example of the need for close co-operation between the consignor and the carrier lies in the matter of placarding.(Figures 10.1 and 10.2). It is the consignor's responsibility to ensure that the placarding requirements for containers and tanks are met. However, from a practical viewpoint, it is the carrier who most often does the placarding of the conveyance. The carrier will bear immediate responsibility in relation to inspections during transport.

Determining where to affix the placards

- Placement for road and rail vehicles
  - Rail *vehicle*: 2 external lateral walls
  - Road *vehicle*: 2 external lateral walls and external rear wall
  - In the case of *vehicles* without sides:
    - affix directly on cargo carrying unit (must be readily visible)
  - In the case of *vehicles* carrying physically large *tanks* or *freight containers*
    - Placard on *tank* or *freight container* sufficient

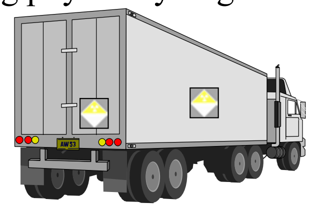
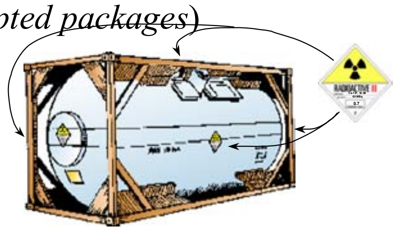


FIG. 10.1. Placarding for road and rail conveyances.

……determining where to affix the placards

- Placement for freight containers & tanks
  - Large *freight containers* carrying *packages* (other than *excepted packages*)
    - each side and each end wall
  - *Tanks*
    - each side and each end wall



- Subsidiary placard
  - When used, it shall be affixed immediately adjacent to the main placard

FIG. 10.2. Placarding for freight containers and tanks.

10.2.2.2. Documentation

The presence of the necessary documentation is a requirement. However, the carrier will wish to have copies not only on the vehicle with the consignment but also at some central control office. This makes it possible to determine what material is on what conveyance at any time.

A paperwork system for proving delivery also needs to be established. However, this can be linked to the main manifest scheme.

10.2.2.3. Personnel

The selection and training of good personnel is crucial in the successful running of a carrier's operation. Personnel involved in the service need to be screened for security purposes and for their attitude with respect to handling radioactive material. Clearly, the protection of the transport worker from undue radiological hazards and the commitment of the carrier to the philosophy of maintaining doses as low as reasonably achievable are of prime importance. In some cases this may involve providing personnel dosimetry to transport workers.

A vital part of this, and perhaps the most important part of a carrier's operation, is the initial and refresher training of all persons involved in the shipment and handling of the radioactive material. This is dealt with explicitly in paragraph 311 of TS-R-1.

10.2.2.4. Radiation protection programme

The application of a radiation protection programme is required. The nature and extent are related to the magnitude and likelihood of radiation exposures. It is only the carrier who is aware of the full scope of the operation in serving different consignors.

10.2.2.5. Vehicles

Many consignments travel by road, and therefore, the carrier's vehicles are an essential part of the system. Routine maintenance to ensure reliability is clearly an asset in carrying radioactive material. It is necessary that the vehicle can be secured and that the load is correctly stowed and secured on the vehicle.

Mobile telephones in vehicles help greatly in the routine tracking of material, and enable emergency assistance to be called quickly in an accident.

Drivers need special instructions on suitable parking of vehicles to minimize radiological and security risks.

Although routeing requirements are not imposed by the TS-R-1 Regulations, a carrier will carefully pre-plan the routes for all vehicles in order to have an efficient system of delivery as well as to avoid potential difficulties. Such things as hazardous driving areas, or road works and diversions may cause problems. Co-ordination with police and other officials will enable the carrier to be aware of such conditions.

10.2.2.6. Contamination of conveyances

If it is evident or suspected that a package is damaged or leaking, the Regulations require that access to the package be restricted and that a qualified person assesses the radiological situation. This would include an evaluation of the package, conveyance, adjacent areas, other material carried in the conveyance, as well as personnel. If necessary, a package leaking radioactive contents can be removed under supervision, and should not be forwarded until the situation is remedied (paragraphs 510 and 511 of TS-R-1).

Additionally, conveyances used routinely for carriage of radioactive material must be periodically checked for contamination (paragraph 510 of TS-R-1).

For these reasons, it is necessary for a carrier to have access to qualified health physics assistance. Sometimes this may be provided by the consignor or otherwise an independent contractor. This health physics support may also be linked to a dose monitoring system for the carrier's transport workers.

10.2.2.7. Accidents

Emergency response for transport accidents involving radioactive material is dealt with in more detail in Chapter 16. Suffice it to say here that the carrier plays a vital role in the system. If the conveyance has a mobile telephone, the carrier may be one of the first to know of the incident. Certainly, the carrier will be contacted as soon as possible and asked for a detailed listing of the radioactive material on that conveyance. Depending on national regulations the carrier may also have responsibility for any necessary clean up operations.

10.3. Stowage

10.3.1. General provisions

The basic requirement for the shipment of radioactive material consignments is that they should be securely stowed (paragraph 564 of TS-R-1). Generally, they can be stowed with other cargo with few exceptions (paragraph 565 of TS-R-1).

10.3.2. Transport Index Limits (TI) and Criticality Safety Index (CSI)

The number of packages to be stowed together may be limited for two reasons either because of radiation protection (TI), or because of criticality safety (CSI). Table IX and Table X of TS-R-1 shows the limits on the Transport Index and the Criticality Safety Index for freight containers and conveyances. These limits vary from a basic 50, up to 200 for certain conveyances or freight containers, to no limit for seagoing vessels loaded with large freight containers. The freight containers naturally have to meet the requirements for the limits of TI and CSI. The spacing of groups of packages may be required.

10.3.3. Segregation

10.3.3.1. Radiation control

There are three main criteria for the segregation of packages containing radioactive material during transport. The first is for radiation control purposes to minimize the dose to personnel and to undeveloped photographic film. For workers, segregation distances are based on a dose limit of 5 mSv per year. For members of the public, they are based on 1 mSv per year. For undeveloped photographic film, the dose limit is 0.1 mSv per consignment of film (paragraph 563 of TS-R-1).

In order to check these limits, hypothetical, but realistic models and assumptions must be used. Appendix III of TS-G-1.1 provides example calculations for establishing minimum segregation distance requirements. Often what happens in practice is that a carrier will make worst case assumptions using the maximum allowable dose rates on a maximum number of packages to try and show that for all of his routine shipments the dose limits will not be exceeded. Alternatively, the Modal Organizations establish tables of minimum segregation distances based on the Regulations. Nevertheless, the optimization requirement in radiation protection aims at keeping exposures to people as low as reasonably achievable, not just below the limits.

10.3.3.2. Dangerous goods

Consignments of radioactive material must be segregated from other dangerous goods in accordance with the various National and International Dangerous Goods Transport Regulations (paragraph 506 of TS-R-1).

10.4. Maximum radiation levels

Two basic dose rate limits apply to conveyances carrying radioactive material. The maximum allowed dose rate on the external surface is 2 mSv/h, and the maximum dose rate at 2 m from the external surface is 0.1 mSv/h (Figure 10.3). A summary of all applicable radiation levels is found in Tables 9.2 to 9.5 of Chapter 9 of this manual.

In the case of road vehicles, no person other than the driver and assistant is permitted in vehicles carrying packages, overpacks or freight containers bearing category II-YELLOW or III-YELLOW labels (paragraph 573 in TS-R-1).

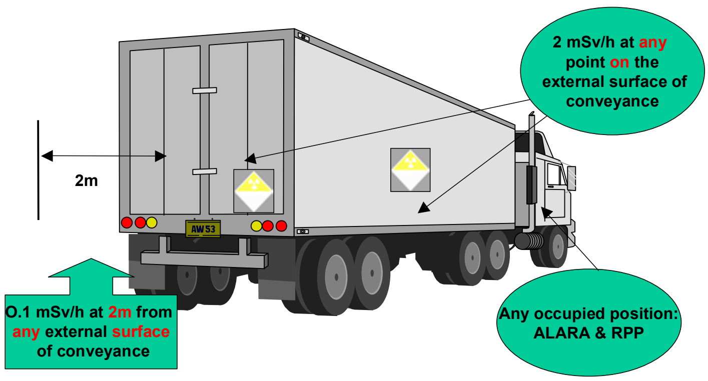


FIG. 10.3. Maximum radiation levels for conveyances.

10.5. Storage in transit

Similar segregation requirements are imposed on storage of packages in transit as during their transport. The dose limits are the same. In the case of packages containing fissile material, where the Criticality Safety Index for any one group of packages is 50 or above, a spacing of 6 m is required from other groups of packages (see Figure 10.4).

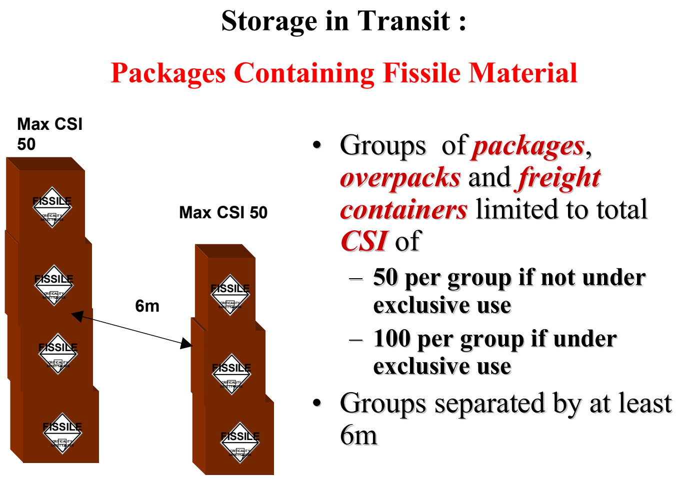


FIG. 10.4. Segregation of fissile packages during storage in transit.

10.6. Customs

Customs officials may inspect consignments of radioactive material provided that it is done in a suitable area and in the presence of qualified persons. Any opened package must be restored to its original condition before forwarding (paragraph 581 of TS-R-1).

10.7. Undeliverable packages

If neither the consignor nor consignee can be identified, then the package should be put in a safe location and the Competent Authority notified. This should be done as soon as possible with a request for instructions on further action (paragraph 582 of TS-R-1).

10.8. Physical protection

Physical security of radioactive material, especially of fissile material is an important and significant part of the whole transport area. Accordingly, it is fully addressed in other IAEA documents, and in particular in Chapter 6 of IAEA INFCIRC/225 [1] and the record of the Convention on the Physical Protection of Nuclear Material.

Physical protection is not covered in the IAEA Regulations on the Safe Transport of Radioactive Material and therefore is not discussed in detail in this text.

10.9. Use of agents

It is quite common to use freight forwarders, freight brokers, or contractors to carry out transport operations. This situation is not addressed explicitly in the TS-R-1 Regulations. If the service of agents is used, the responsibilities as given in Regulations stay with the persons mentioned there. It may be necessary to set up contracts between the consignor, the agent, and/or the carrier to fill any gap of responsibilities during transport. In this way compliance with the Regulations during the whole transport operation can be assured.

REFERENCE FOR CHAPTER 10

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Physical Protection of Nuclear Material, INFCIRC/225/Rev.4 (corrected), IAEA, Vienna (2001).

EXERCISES FOR CHAPTER 10

The following are exercises to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 10.1. Consignor's Responsibilities

REFERENCE SOURCES: Training Manual, Chapter 10; and TS-R-1, Sections II, III, V, and VIII.

DISCUSSION: In preparing a consignment for shipment, there are a number of responsibilities that a consignor must fulfill. The Schedules in TS-R-1 can assist the consignor in identifying many of these responsibilities.

PROBLEM: A consignor has a large quantity (in excess of 4,000 kg) of radioactive, non-fissile material that needs to be packaged and then transported by a road vehicle, under exclusive use. The radioactive material to be shipped has an unlimited A_2 value, and is in solid form. Using the relevant Schedules, determine:

a. How should this material be categorized?

b. What packaging requirements must be satisfied?

c. What radiation level requirements must be satisfied?

d. What marking, labelling and placarding requirements must be satisfied?

e. Can the packages of this material be loaded onto the road vehicle with packages containing other non-hazardous commodities?

ANSWER:

EXERCISE 10.2. Responsibilities for Problems in Transit

REFERENCE SOURCES: Training Manual, Chapter 10; and TS-R-1, Section V.

DISCUSSION: Problems such as: discovery of contamination on a package or conveyance; leaking packages; and undeliverable packages may occur during transit. These problems must be dealt with appropriately.

PROBLEM:

a. What must be done if a leaking package is discovered during transit?

b. What must be done if contamination on a package or conveyance is discovered during transit?

c. What must be done if the package is undeliverable?

ANSWER:

11. CLASSIFICATION OF LSA MATERIAL AND SCO

11.1. LSA and SCO

There are instances of transport of certain radioactive material in the classification of which the consignor may need assistance. For example, large volumes of low level radioactive waste, radioactive ores and contaminated objects arsing from maintenance operations can be transported in Industrial Packagings of type IP-1 or IP-2 or IP-3. The definitions of LSA I, II and III and of SCO I and II (see paragraphs 226 and 241 of TS-R-1) [1] and the explanations provided in the Advisory Material [2] would largely help in classifying the materials appropriately. Yet, difficulties may be experienced in appropriate classification of these materials as LSA or SCO. Some Competent Authorities have issued guidance material on this topic [3]. The following paragraphs provide certain explanations and examples, which though not exhaustive would be useful.

11.2. Classification of LSA Material into I, II and III

There are certain solid materials the specific activities of which are so low that it is highly unlikely that, under circumstances arising in 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 an 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 a low specific activity material limit of 10^{-4} A_2/g.

It is possible to ship solid objects without any packaging, for example, concrete blocks (with activity throughout the mass), irradiated objects and objects with fixed contamination. Under the condition that the specific activity is relatively low and remains in or fixed on the object's surface, the object can be looked upon and 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.

The limit on the radiation level from an unshielded LSA material, viz., 10 mSv/h at 3 m (see para. 521), 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).

The LSA material should be in such a form that an average specific activity can be meaningfully assigned to it. In the actual materials shipped as LSA, the degree of uniformity of the distribution would vary depending upon the LSA category. The degree of uniformity is specified for each LSA category (see, for example, para. 226(c)(i)).

11.2.1. LSA-I

LSA-I which may be described as very low specific activity materials may be shipped unpackaged, or they may be shipped in Industrial Packages Type 1 (Type IP-1) which are designed to minimal requirements (para. 621). According to para. 226(a)(i), LSA-I materials cannot consist of: concentrates of ores other than uranium or thorium concentrates (for example, radium ore concentrate cannot be LSA-I material), unless they meet para. 226(a)(iv). In the Regulations the LSA-I category takes into account:

- the clarification of the scope of the Regulations concerning ores other than uranium and thorium ores according to para. 107(e);
- fissile materials in quantities excepted from the package requirements for fissile material according to para. 672.

The definition of LSA-I was consequently modified to:

- include only those ores containing naturally occurring radionuclides which are intended to be processed for the use of these radionuclides (para. 226(a)(i));
- exclude fissile material in quantities not excepted under para. 672 (para. 226(a)(iii)); and
- radioactive material in which the activity is distributed throughout in concentrations up to 30 times the exemption level (para. 226(a)(iv)).

Materials containing radionuclides in concentrations above the exemption levels have to be regulated. It is reasonable that materials containing radionuclides up to 30 times the exemption level may be exempted from parts of the transport regulations and may be associated with the category of LSA-I materials.

Uranium enriched to 20% or less may be shipped as LSA-I material either in Type IP-1 packages or unpackaged in fissile excepted quantities. However, amounts exceeding fissile excepted quantities (see para. 672) will be subject to the requirements for packages containing fissile material, thus precluding transport of the material unpackaged, or in unapproved packages.

11.2.2. LSA-II

The materials expected to be transported as LSA-II could include nuclear reactor process wastes, which are not solidified, such as lower activity resins and filter sludge, absorbed liquids and other similar materials from reactor operations, and similar materials from other fuel cycle operations. In addition, LSA-II could include many items of activated equipment from the decommissioning of nuclear plants. Since LSA-II materials could be available for human intake after an accident, the specific activity limit is based upon an assumed uptake by an individual of 10 mg. Since the LSA-II materials are recognized as being clearly not uniformly distributed, the allowed specific activity is significantly lower than that of LSA-III. The factor of 20 lower allowed specific activity as compared with the limit for LSA-III compensates for localized concentration effects of the non-uniformly distributed material.

While some of the materials considered to be appropriate for inclusion in the LSA-III category would be regarded as essentially uniformly distributed (such as concentrated liquids in a concrete matrix), other materials such as solidified resins and cartridge filters are distributed throughout the matrix but are uniformly distributed to a lesser degree. The solidification of these materials as a monolithic solid, which is insoluble in water and non-flammable makes it highly unlikely that any significant portion of it will become available for intake into a human body. The recommended standard is intended to specify the lesser degree of activity distribution.

Some common examples of radioactive material which may qualify for classification into LSA-II are scintillation vials, hospital wastes such as contaminated cotton swab, injection vials, disposable syringes used in nuclear medicine and biological wastes and decommissioning wastes.

11.2.3. LSA-III

The provisions for LSA-III are intended principally to accommodate certain types of radioactive waste consignments with an average estimated specific activity exceeding the 10^{-4} A_2/g limit for LSA-II materials. The higher specific activity limit of 2×10^{-3} A_2/g for LSA-III materials is justified by:

- restricting such materials to solids which are in a non-readily dispersible form, therefore explicitly excluding powders as well as liquids or solutions;
- the need for a leaching test to demonstrate sufficient insolubility of the material when exposed to weather conditions like rainfall;
- the higher package standard Industrial Package Type 3 (Type IP-3) under non-exclusive use conditions, which is the same as Type A for solids; in the case of Industrial Package Type 2 (Type IP-2) (para. 523 of TS-R-1), the lack of the water spray test and the penetration test is compensated for by the leaching test and by operational controls under the exclusive use conditions, respectively.

The specific activity limit for LSA-II liquids of 10^{-5} A_2/g, which is a factor of 10 more restrictive than for solids, takes into account that the concentration of a liquid may increase during transport.

A solid compact binding agent, such as concrete, bitumen, etc., which is mixed with the LSA material, is not considered to be an external shielding material. In this case, the binding agent may decrease the surface radiation level and may be taken into account in determining the average specific activity. However, if radioactive material is surrounded by external shielding material, which itself is not radioactive, this external shielding material is not to be taken into account in determining the specific activity of the LSA material.

For LSA-II solids, and for LSA-III materials not incorporated into a solid compact binding agent, the activity should be distributed throughout the material. There is no requirement on how the activity is distributed throughout the material. It is, however, important to recognize that the concept of limiting the estimated specific activity fails to be meaningful if in a large volume the activity is clearly confined to a small percentage of that volume.

It is prudent to establish a method by which the significance of the estimated average activity, as determined, can be judged. There are several methods that would be suitable for this particular purpose.

A simple method for assessing the average activity is to divide the volume occupied by the LSA material into defined portions and then to assess and compare the specific activity of each of these portions. It is suggested that the differences in specific activity between portions of a factor of less than 10 would cause no concern. Judgment needs to be exercised in selecting the size of the portions to be assessed. The above method should not be used for volumes of material of less than 0.2 m^3. For a volume between 0.2 m^3 and 1.0 m^3, the volume should be divided into five, and for a volume greater than 1.0 m^3 into ten parts of approximately equivalent size.

For LSA-III materials consisting of radioactive material within a solid compact binding agent, the requirement is that they be essentially uniformly distributed in this agent. Since the requirement of 'essentially uniformly distributed' for LSA-III materials is qualitative, it is necessary to establish methods by which compliance with the requirement can be judged.

The following method is an example for LSA-III materials which are essentially uniformly distributed in a solid compact binding agent. The method is to divide the LSA material volume including the binding agent into a number of portions. At least ten portions should be selected, subject to the volume of each portion being no greater than 0.1 m^3. The specific activity of each volume should then be assessed (through measurements, calculations or combinations thereof). It is suggested that specific activity differences between the portions of less than a factor of three would cause no concern. The factor of three in this procedure is more constraining than the suggested factor of ten because the 'essentially uniformly distributed' requirement is intended to be more constraining than the 'distributed throughout' requirement.

11.3. Classification of SCO-I and II

There are two categories of surface contaminated objects (SCOs) in terms of their contamination level. This categorization defines the type of packaging to be used to transport these objects. SCO-I objects being of relatively level of contamination may be transported unpackaged or in an Industrial package (Type IP-1). The SCO-II objects which may be of a higher level of non-fixed contamination require the higher standard of containment afforded by Industrial package Type IP-2.

Objects in the category of surface contaminated objects include those parts of nuclear reactors or other fuel cycle equipment that have come into contact with primary or secondary coolant or process waste, resulting in contamination of their surface with mixed fission products. On the basis of the allowable contamination levels for beta and gamma emitters, an object with a surface area of 10 m^2 could have fixed contamination up to 4 GBq and non-fixed contamination up to 0.4 MBq. During routine transport this object can be shipped unpackaged under exclusive use, but it is necessary to secure the object (para. 523(a)) to ensure that there is no release of radioactive material from the conveyance. It is assumed that in the event of an accident involving an SCO-I object 20% of the surface of the SCO-I object is scraped and 20% of the fixed contamination from the scraped surface is freed. In addition, all of the non-fixed contamination is considered to be released. The total activity of the release would thus be 160 MBq for fixed contamination and 0.4 MBq for non-fixed contamination. Using an A_2 value of 0.02 TBq for mixed beta and gamma emitting fission products, the activity of the release equates to 8×10^{-3} A_2. It is considered that such an accident would only occur outside so that, consistent with the basic assumption of the Q system developed for Type A packages, an intake of 10^{-4} of the scraped radionuclides for a person in the vicinity of the accident is appropriate. This would result in a total intake of 0.8×10^{-6} A_2. Hence this provides a level of safety equivalent to that of Type A packages.

The model for an SCO-II object is similar to that for an SCO-I object, although there may be up to 20 times as much fixed contamination and 100 times as much non-fixed contamination. However, an Industrial package (IP-2) is required for the transport of SCO-II objects. The presence of this package will lead to a release fraction in an accident which approaches that for a Type A package. Using a release fraction of 10^{-2} results in a total release of beta and gamma emitting radionuclides of 32 MBq of fixed contamination and

8 MBq of non-fixed contamination, which equals 2×10^{-3} A_2. Applying the same intake factor as in the previous paragraph leads to an intake of 0.2×10^{-6} A_2, thereby providing a level of safety equivalent to that of Type A packages.

11.4. LSA or SCO?

Difficulties are experienced in practice while categorizing a material to be transported as LSA or SCO and further as LSA-I, II or III or SCO-I or II. Some examples are provided below.

11.4.1. Common LSA materials

The definition of LSA-I would enable easy classification of a material as one of that category. However, because of the complexity of the definition of LSA-II, some explanations would be called for. For example, waste from nuclear power plants such as evaporator bottoms, mechanical filters and filter media and absorbed liquids demolition rubble, which exceeds LSA-I limits, activated metals, organic liquids (liquid scintillation fluids, etc.), paints removed from contaminated surfaces and biological wastes would be generally LSA-II.

Compaction of material should not change the classification of the material. To ensure this, the mass of any container compacted with the material should not be taken into account in determining the average specific activity of the compacted material.

Compactable and non-compactable waste may be categorized either as LSA or SCO. It may generally be appropriate to categorize materials that absorb radioactivity such as towels, rags or tape as LSA. It would be generally appropriate to categorize contaminated objects such as used gloves, tools, hardware and glassware as SCO.

11.4.2. Contaminated LSA

Surface contaminated objects are by definition objects, which are themselves not radioactive but have radioactive materials distributed on their surfaces. The implication of this definition is that objects that are radioactive themselves (e.g. activated objects) and are also contaminated cannot be classified as SCOs. Such objects may, however, be regarded as LSA material insofar as the requirements specified in the LSA definition are complied with.

Objects, which are both activated or otherwise radioactive and contaminated, cannot be considered as surface contaminated objects (SCOs). However, such objects may qualify as LSA material since an object having activity throughout and also contamination distributed on its surfaces may be regarded as complying with the requirement that the activity be distributed throughout. For such objects to qualify as LSA material it is necessary to ascertain that the applicable limits on estimated average specific activity are complied with. In assessing the average specific activity, all radioactive material attributed to the object, i.e. both the distributed activity and the activity of the surface contaminations, needs to be included. As appropriate, additional requirements applicable to LSA material need to also be satisfied.

There are no limits on contamination for LSA materials. Therefore, an LSA material, which carries contamination, may still be treated as LSA provided it qualifies as LSA. Some special situations involving LSA and SCO are discussed here.

11.4.3. Collection of small, contaminated objects

Sometimes a collection of small, contaminated objects may be treated as LSA. Primarily, there is no doubt that non-radioactive objects whose surfaces are contaminated with radioactivity are SCOs, provided they meet the definition of SCO. For this purpose, when there is a collection of small, contaminated objects, the contamination on each small object need not be measured. It would be acceptable, if a representative sample of the small objects is assessed and the activity and the surface contamination on the entire collection is *estimated***.** In the absence of evidence to the contrary, uniform contamination over the surfaces of the collection may be assumed. If the estimate points to the objects being SCO-I or II, they should be transported as such otherwise, they may be considered for being classified as LSA-I or II or III. In determining the average specific activity or in measuring the radiation level from unshielded material, the mass of binding agents or grout may be considered, provided radioactive material is incorporated in the binding agent or grout. However, if the grout is used as a shielding material or used for structural support or encapsulating material, it cannot be considered in qualifying the radioactive material as LSA.

11.4.4. Activated metals or radioactive material solidified or absorbed

Activated metals or radioactive material, which is solidified or absorbed on non-radioactive material and decontamination wastes, which exceed LSA-I limits, may be categorized as LSA-II provided they qualify. Generally, activated metals are likely to be categorized as LSA-III. Their surfaces could be contaminated and they may be resistant to leaching. They should, however, be subjected to the leaching test.

11.5. Major considerations

With increasing varieties of radioactive materials and wastes, it would not be easy to provide an exhaustive list of examples of radioactive materials, which need to be classified as LSA or SCO. An assessment of the radiological hazard associated with the material and of the protection resulting from the classification would be important considerations. The above examples cover the major considerations required for properly classifying a radioactive material as LSA or SCO. It is not uncommon that in ambiguous situations one adopts a conservative approach in classifying such material. Experience would go a long way in making a proper classification.

REFERENCES FOR CHAPTER 11

[1] INTERNATIONAL ATOMIC ENERGY AGENCY Regulations for the Safe Transport of Radioactive Material, IAEA Safety Standards Series, Safety Requirements, TS-R-1 (2005).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1996 Edition), Safety Standard Series No. TS-G-1.1, IAEA, Vienna (2002).

[3] US NUCLEAR REGULATORY COMMISSION AND US DEARTMENT OF TRANSPORTATION, Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects, NUREG-1608, Washington DC (1997).

EXERCISES FOR CHAPTER 11

The following are exercises to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 11.1. Considerations for the classification of LSA / SCO

REFERENCE SOURCES: Training Manual, Chapter 11; and TS-R-1, Sections II, and IV.

DISCUSSION: It is important to classify a material as LSA or SCO properly so that the appropriate packaging is provided. The above discussion can assist the consignor in classifying a consignment properly as LSA or SCO.

PROBLEM:

A collection of concrete block weighing about 100 kg contain caesium-137 of total activity 0.8 TBq distributed uniformly throughout. The radiation level at one meter from the collection of blocks kept together is 10 mSv/h. Can the collection be classified as LSA ?

ANSWER:

EXERCISE 11.2. Classification into LSA and SCO

REFERENCE SOURCES: Training Manual, Chapter 11; and TS-R-1, Sections II, and IV.

DISCUSSION: Certain commonly transported materials could be classified either as LSA or as SCO. Though some examples are provided in this chapter, the consignor should use his judgement in arriving at the proper classification.

PROBLEM: Classify the following radioactive materials as LSA or SCO and provide brief explanations stating additional data required, if any, for proper categorization of the materials.

a. Bbags containing cotton swabs from a nuclear medicine facility
b. Activated metal
c. Liquid scintillation fluid used for measuring tritium activity
d. Activated metal pieces also carrying removable beta surface contamination of 3 Bq1/cm^2 on the accessible surface only
e. Biological waste collected from a nuclear medicine facility containing iodine 131 of activity 5 kBq/g with a radiation level less than 10 mSv per hour at one meter from the collection
f. Low activity ion exchange resins from nuclear reactors

ANSWER:

12. QUALITY ASSURANCE

12.1. Introduction to quality assurance

The importance attached to Quality Assurance (QA) was significantly increased by its high profile treatment in the 1985 IAEA Transport Regulations [1]. This treatment recognised the value of Quality Assurance in contributing positively to enhanced levels of safety in the transport of radioactive material. This importance was maintained in the 1996 Edition of the IAEA Transport Regulations (TS-R-1) [2]. Paragraph 306 of TS-R-1 was extended to cover s*pecial form material* and *low dispersible radioactive material*. The IAEA has published a separate Safety Practice document [3] to assist users of the Regulations in the further understanding and application of Quality Assurance to radioactive material transport activities.

When QA principles are applied to radioactive material transport operations, it becomes possible to have all relevant aspects of the transport operations clearly identified, controlled and documented. This is the key to demonstrate positive assurance that those operations are carried out safely, efficiently, and most importantly in compliance with the Regulations.

TS-R-1 not only defines QA but also indicates that QA programmes must be developed to cover the manufacture of the special form material, low dispersible radioactive material or package used to physically transport the radioactive material. Further, QA programmes must also be established for the design, testing, documentation, use, servicing and maintenance of the package, as well as shipment and in-transit storage operations. In an earlier edition of the Regulations, the 1973 Edition, the requirements for QA in transport did not address the manufacture of packages.

Quality Assurance is often described as embracing all activities and functions concerned with the attainment of quality. The transport Regulations define QA in paragraph 232 of TS-R-1 thus:

> *"Quality Assurance shall mean a systematic programme of controls and inspections applied by any organization or body involved in transport of radioactive material which is aimed at providing adequate confidence that the standard of safety prescribed in these Regulations is achieved in practice."*

ISO 8402:1995 [4] defined QA generally in a similar way:

> *"Quality Assurance: All the planned and systematic activities implemented within the quality system and demonstrated as needed to provide adequate confidence that an entity will fulfil requirements for quality".*

Essentially, QA is a formally prescribed management system that contributes to good and effective planned management of an activity (such as transport) and enables the following questions to be answered about that activity:

(1) Can we do it?
(2) Are we doing it properly?
(3) Did we do it properly?
(4) Can we show that we did it properly?
(5) Can we do it better?

In short, 'quality' is the ability of an item or service to meet the user's, owner's or regulator's requirements and 'assurance' is the demonstration that this has been done.

If quality is to be assured and a particular task done properly, then there are certain aspects with which everyone must be involved and clearly understand. These task-related aspects are listed below along with the formal requirements:

Everyone must	This requires:
1. Know what to do	Specifications, drawings, and schedules.
2. Know how to do it	Training, procedures, and instructions.
3. Be able to do it	Resources, materials, and equipment.
4. Know if it is done correctly	Measurements, and comparisons.
5. Be able to effect it	Feedback, involvement, and corrective action.
6. Want to do it	Motivation.
7. Record it	Records, certifications, and audits.

12.2. Development of a quality assurance programme

12.2.1. General

There may only be one QA programme covering all phases of radioactive material transport, but usually there are several separate QA programmes in effect during transport (see Figure 12.1.). For the purpose of this training manual, the development of a single typical QA programme will be considered. The starting point is the recognition by senior management that it is necessary to have such a programme. Only by such recognition and commitment on the part of management will it be possible for any QA programme to be successfully developed and maintained.

The development of the QA programme starts with the study and review of an organization's objectives and the way in which they are achieved. This involves ensuring that:

(1) The management system, structure, organization, and responsibilities are all prescribed;
(2) There are agreed, written specifications of the standard of work to be done;
(3) There are written procedures covering how the work will be done to the required standard;
(4) Adequate records of objective evidence are produced to demonstrate that the required standards have been achieved;
(5) Audits are carried out confirming that the procedures are being complied with, the QA system is creating the necessary objective evidence, and that faults and deviations in a system or product are investigated,
(6) Feedback arising from investigation of audit findings, deviations, and concessions is put to good use in improving the QA system and preventing further similar problems.

This might seem to be complicated, but it should not be, especially if the matter is approached in a common sense manner. Most successful organizations already have procedures (written or oral) covering the work that they do and the way that they do it. What the application of QA can do is to bring a positive and systematic sense of control and coherence to the management system, together with the ability to demonstrate that the specified requirements have been met.

When an organization has considered what its quality management or QA system is, or should be (by comparing it with a QA standard), it must ensure that the system is clearly understood and followed. This is done by putting the system in writing (sometimes called a Quality Manual), and issuing appropriate parts to management, employees, suppliers, and customers. In addition, all parts of the QA system are periodically checked to ensure that they are functioning properly, and in the desired manner. The Regulations now require QA programmes to be developed for transport, and it is most important that these are systematically fully documented. The documented QA programme, can be the whole or part of the prescribed QA system, depending on the size and structure of the organization involved. It should describe the methods and procedures used to achieve quality for all stages in the transport of radioactive material or for a package's life cycle.

12.2.2. Minimum requirements for a Quality Assurance Programme

The transport of radioactive material involves several phases, and is often carried out by different organizations. Indeed, one package movement alone may involve a designer, package manufacturer, test facility, consignor, shipping agents, carriers and a consignee. The life cycle of a radioactive material packaging is similar to many other items or pieces of equipment. It includes initial design feasibility work, design, regulatory testing, manufacture, use, servicing and maintenance, and disposal. For a package to be used in a compliant and safe manner throughout its life, QA needs to be applied appropriately, during all phases of the life cycle so that the design is not compromised later by subsequent misuse or incorrect maintenance operations.

With widely differing activities to carry out, a designer's QA management system will be significantly different to that of a carrier of radioactive material. Each of their QA management systems should however address some common QA criteria. Thus, when considering the transport of radioactive material, it can be seen from Table 12.1. that all QA management systems need to have certain elements (such as organization and document control) addressed and described in a QA programme document, but that some other elements do not always need to be featured. For example, in a carrier's QA system, design control or procurement controls are not usually relevant.

Irrespective of the size of the organization or the scale of its activities, there are certain minimum requirements that must be addressed in any QA programme. Table 12.1. gives some guidance on the applicability of various QA criteria to the different types of organizations and their QA programmes.

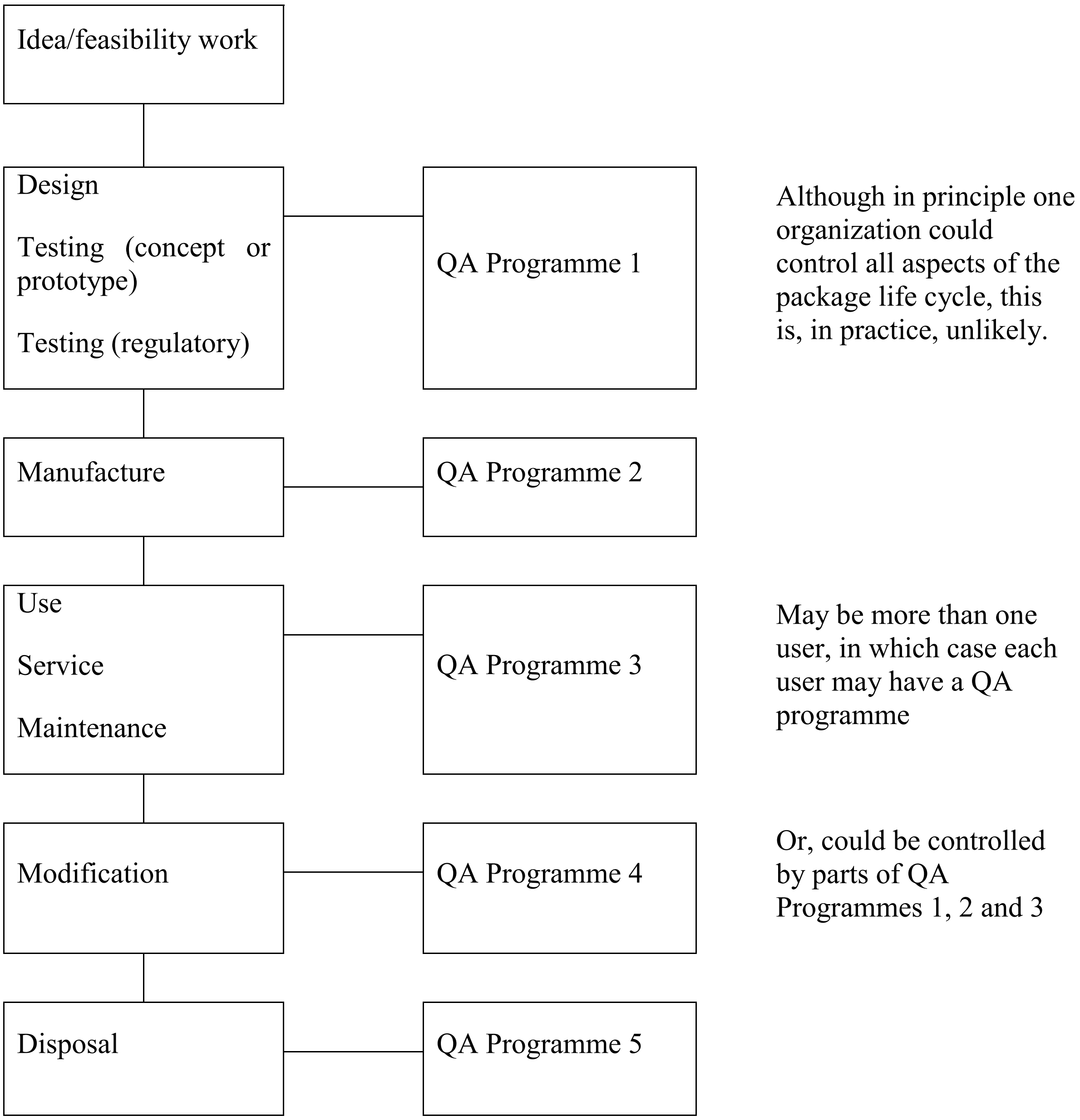


FIG. 12.1. Applications of QA programmes throughout the life of a package.

TABLE 12.1. COMPARATIVE ELEMENTS[a] OF A QA PROGRAMME

Quality Assurance element	Designers	Manufacturers	Users (Consignors/ Consignees)	Carriers
Quality Assurance programmes	x	x	x	x
Organization	x	x	x	x
Document control	x	x	x	x
Design control	x			
Procurement control	x	x	x	
Material control		x	x	
Process control		x	x	x
Inspection and test control		x	x	x
Non-conformance control	x	x	x	x
Corrective actions	x	x	x	x
Records	x	x	x	x
Staff and training	x	x	x	x
Servicing			x	x
Audits	x	x	x	x

[a] Care should be exercised in the interpretation and understanding of these elements. Reference should be made to the appropriate standard to ensure that all the requirements of the elements are clearly understood and included in the organization's QA programme.

12.2.3. Quality Assurance and the different phases of transport

Where an organization is involved in more than one activity, e.g. design and manufacture, or being both user and carrier, then the QA system should reflect that multiple involvement and address the appropriate QA criteria. The types of organization or criteria quoted in Table 12.1. above are merely a general guide, and not intended to be exhaustive. Other entities involved in the transport of radioactive material, such as test facilities, and shipping agents, should consider their activities, and possibly align themselves with one of the types mentioned.

It is recognized that one organization may well carry out more than one activity; for example radiopharmaceutical companies often engage in the tasks of design, manufacture, use, and carriage. Those four aspects are treated separately in order to discuss some of the applicable QA objectives.

12.3.2.1. Quality Assurance for package designers

The designer of a transport package needs to be able to demonstrate or assure the manufacturer, user, and certifying body that all necessary steps and design processes have been addressed during all phases of design. For example, the designer needs the means to assure that the final design specifications, drawings, and procedures have been produced taking account of regulatory requirements, design bases, codes, and standards. The designer also needs to demonstrate that any proposed changes, modifications or deviations from the accepted design are carefully considered, justified, controlled, documented and implemented in a quality assured manner, as well as being consistent with, or better than, the controls applied to the original design. If the designer is responsible for prototype manufacture and testing, the QA system needs to ensure that any prototype packages, including perhaps scale models, are specified correctly, made exactly as required, and are consistent with the production package's materials and fabrication methods.

The actual regulatory proof testing also needs to be accomplished in a quality assured way, using appropriate equipment and calibrated instruments working within their recognized capabilities and limits of accuracy. Only by controlling all design-related activities in this way can any subsequent manufacturer, user or certifying body have a reasonable assurance that the finished package complies with the designer's intent, and that any prototype package physically tested against the regulatory requirements is actually relative and traceable to the finished product.

12.2.3.2. Quality Assurance for package manufacturers

The manufacturer should also have a QA system that is capable of clearly demonstrating that the package has been manufactured strictly in accordance with the agreed specification prescribed by the designer or customer. Alternatively, where production has deviated from the agreed specification, it has been done in a controlled and authorized manner with appropriate reference to the designer or design authority, and with the necessary QA records being created. Manufacturing is perhaps the area where QA is most widely understood and has long been recognized as a valuable and ultimately an effective overall cost saver. Certainly under the 1973 Edition of the Regulations [5], manufacturing was the activity where QA was emphasised.

12.2.3.3. Quality Assurance for users (consignors and consignees)

Users of packages, who are very often the owners/consignors of packages containing radioactive material, have a multitude of tasks to perform in order to dispatch a package safely and in a compliant manner. Some of the actions taken by consignors are not normally associated with or considered by some to need QA, but upon reflection, they usually do. The average consignor has to ensure that the package used for the transport operation is the correct one and is appropriate for its intended contents. The consignor should also ensure that the package is in a fit state to transport the material. In the case of a reusable package, it should have been properly serviced and maintained. In the case of a new package, the user should ensure that it has been made and prepared for transport correctly.

The consignor very often prepares the material for loading into the package and carries out that operation. For some material, such as uranium hexafluoride or spent nuclear fuel, this must be done under carefully controlled conditions in accordance with detailed procedures. Even the preparation of a straightforward industrial gamma radiography unit requires careful and strict adherence to prescribed procedures to ensure radiological safety and compliance with the transport Regulations. The consignor is also responsible for appropriate monitoring of the package before dispatch as well as for correct labelling of the package or shipment, to assure safety during transport. The consignor has to prepare the necessary transport documents and be aware of the difference between various national Regulations when conducting international transport movements. If a separate carrier is to be used, the consignor should be satisfied that the carrier knows how to transport radioactive material safely and in compliance with the Regulations.

12.2.3.4. Quality Assurance for carriers

Independent carriers differ considerably in the type of work on which they engage, their business style, objectives, and to a certain extent, the type of operative they employ. Apart from a few nuclear transport specialists, most carriers handle a variety of goods including many different categories of dangerous goods. Nevertheless, in the case of radioactive material, the carrier has to ensure that the driver (in the case of road transport) is adequately trained, knows what the regulatory requirements are and how to comply with them. The carrier also must know what transport documents are required, what information they should contain, what action to take in the case of an emergency, and how the vehicle or container should be placarded or labelled. Segregation distances frequently need to be determined, and radiation exposures to people and undeveloped film need to be limited. In this manner, basic radiation protection principles are implemented.

With its roots in the manufacturing industry, QA is not necessarily familiar or understood in some carriers' circles. In recent times however, carriers are becoming “quality aware” and benefited from the application of QA to their logistical operations. The QA programme for a carrier can be relatively simple and straightforward. A QA programme is needed which:

(1) Defines and describes the management system;

(2) Helps recognize and identify the radioactive package to be transported;

(3) Enables all necessary safety and regulatory provisions for carriage to be identified and met;

(4) Lets the carrier know that all the necessary information has been provided by the consignor, including any special transport or handling requirements;

(5) Enables the carrier to know what emergency arrangements exist, and the actions required of the carrier as well as the driver in such arrangements;

(6) Lets the carrier know that the transport operation was accomplished in a controlled, safe and compliant manner, and enables clear demonstration of that to others, and

(7) Describes how the carrier monitors the system, by review and self-audit.

12.2.4. Documentation and Quality Assurance

A significant part of QA involves documentation and an example of a typical documentation structure is given in Figure 12.2. This shows a typical tiered document structure for a QA programme (or Quality Management system). The size and complexity of the organization involved will have considerable influence on its QA system and hence its documentation system. For example, a small, infrequent transporter of radioactive material may be able to condense or combine some of the tiers, or levels, to prescribe the QA system more accurately. Whereas a large, multi-divisional organization may need to have all the tiers/levels prescribed separately, with perhaps an additional tier/level added to assist with divisional management. Included in the documentation structure should be a system or procedure of controlling all relevant documents, including those constituent parts of the QA system itself. This ensures that documents including work instructions are prepared, reviewed, approved, issued, and changed in a timely and controlled manner.

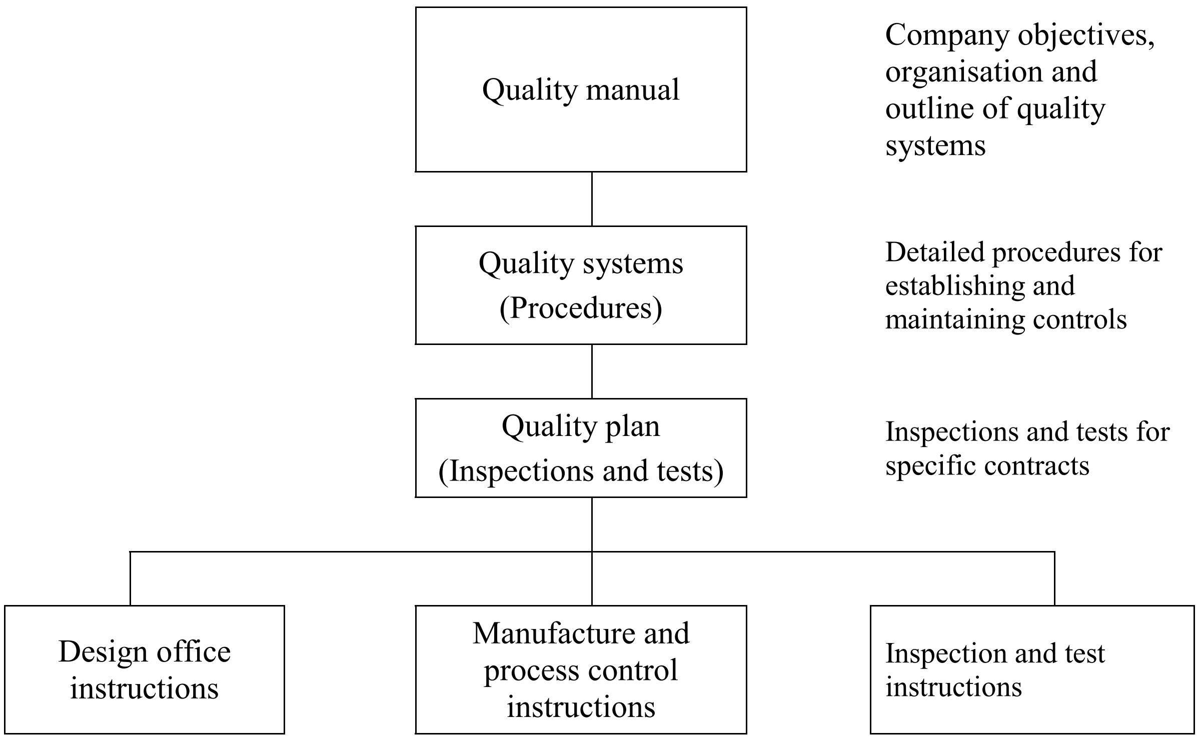


FIG. 12.2. A common Quality Management System documentation structure.

12.3. Quality assurance standards

There are a number of Quality Assurance standards in use around the world, all of which are aimed at establishing the fundamental requirements of a QA programme by referring to various QA elements or criteria. In the context of radioactive material transport, references [3], [6], [7], [8], and [9] are of particular interest. A cross-reference to some of these is given in Table 12.2. (IAEA TS-G-1.1, Appendix IV, and SS No. 112 are so similar in their treatment of the essential QA criteria that only TS-G-1.1 Appendix IV is featured in Table 12.2.)

TABLE 12.2. CROSS REFERENCE TO QUALITY ASSURANCE STANDARDS[a]

DESCRIPTION	IAEA-TS-G-1.1 APPENDIX IV	IAEA - SS No. 50-C/SG-Q (Basic requirement)	ISO 9001 (EN29001)	ASME NQA-1
Quality Assurance programme				
- Organization and structure of a QA programme	2.1	1	4.2	1
- Documentation of a QA programme	2.2	1	4.2	2
- Review and evaluation of the QA programme	2.3	9	4.1.3	2
Organization				
- Management Responsibility	3.1	1	4.1	2
- Contract Review	3.2	-	4.3	4S, 7S1
- Organizational Interfaces	3.3	1	4.1.2.1.	3
Document control	4	4	4.5	6
Design control	5	6	4.4	3
Procurement control	6	7	4.6	4, 7
- Purchaser supplied material	6.5	-	4.7	7, 8
Material control	7	5, 7	4.8, 4.12, 4.15	8, 12
Process control	8	5, 8	4.9, 4.15, 4.20	9
Inspection and test control	9	8	4.10	10, 11, 14
- Control of measuring and test equipment	9.4	8	4.11	12
Non-conformance control	10	3	4.12	15
Corrective actions	11	3	4.14	16
Records	12	4	4.16	17
Staff training	12	2	4.18	2
Servicing	14	5	4.19	12S1
Audits	15	10	4.17	18

[a] Care should be taken in the use of this table; in particular the wording of the elements differs between the standards.

When developing or amending a QA programme for the transport of radioactive material, the user should seek guidance and direction from the Competent Authority concerning acceptable standards. It is usually acceptable for a users QA programme to be designed to meet the requirements of more than one standard. Some organizations develop their QA programmes to meet a range of QA standards in order to obtain transport approvals more readily.

While the QA standards mentioned are structured differently and apparently have a variety of QA elements, the actual differences are not great. This is particularly true when the wording of the standards is compared, since one standard may well include more than one QA programme element within a main section whereas another standard will treat these elements separately.

12.4. Elements of a Quality Assurance Programme

Safety Standards Series No. TS-G-1.1 [6] Appendix IV and Safety Series No. 112 [3] are complementary to each other in their treatment of the essential elements of a QA programme. It is important to note that TS-G-1.1 Appendix IV is more prescriptive in terms of what is required from any particular QA programme element, whereas SS No. 112 offers advice and expands on what the individual QA elements mean and what is required in the context of radioactive material transport.

The various elements of a Quality Assurance programme as identified in Safety Series No. 112 are shown below together with some introductory comments.

Quality Assurance	The need for a properly structured and documented QA programme is established. The organization and structure of the QA programme is addressed as well as the need for the QA programme to be documented. The review and evaluation of the QA programme is also covered.
Organization	Management's responsibility in respect of the QA programme is established and the need for recognition and control of internal and external interfaces between groups involved in transport is covered. The review of contracts between different groups or organizations involved in transport activities is also addressed.
Document control	The need to control essential documents is identified with provisions made for their adequate preparation, review, and approval. Measures to control the release and distribution of documents as well as any changes to those documents are identified as a necessary part of the QA programme.
Design control	The requirement to control all relevant aspects of design is established. Design control is broken down into a number of different phases, and addresses such activities as design planning, design input and output, design verification and design change.
Procurement control	It is necessary to provide for suitable purchase control of all material and services, and measures are needed for the various aspects of procurement control such as supplier evaluation and selection, purchasing data, purchasing verification. Items supplied by the customer or end user that are incorporated into the final product also require appropriate control within the QA programme.
Material control	The importance of identifying and controlling all materials, equipment, and packages used throughout the transport cycle is established. The need to maintain and control traceability and prevent damage or deterioration of items is also a requirement.
Process control	The need for all processes to be effectively controlled by appropriate measures must be applied as an essential part of the QA programme. The requirements of process control related to transport operations and special processes are identified and developed.

Inspection and test control	Clear requirements relating to all phases of inspection work and testing are laid down. Programmes of inspection, test programmes, calibration and control of measuring and test equipment are all addressed in terms of developing appropriate measures within the QA programme.
Non-conformance control	The necessity of establishing measures to identify and control all non-conforming items is recognized. Various aspects of non-conformance control are highlighted; covering for example segregation, repair, rework, reclassification, justification, and final disposition of the non-conforming item.
Corrective action	Sufficiently comprehensive procedures need to be established to control all corrective actions. The full analysis of problems and the investigation of root causes are encouraged before the determination and implementation of corrective actions.
Records	The requirement to create and maintain pertinent records and documentation is established. The type and form of quality record is mentioned as well as the retention periods for such records.
Staff training	The need for appropriately trained personnel as well as the provision of pertinent training is confirmed. Measures to identify and document the necessary training, certification, refresher training, and records are addressed.
Servicing	The requirement for documented measures to be developed and implemented which cover pertinent servicing activities is clearly established.
Audits	The necessity of an appropriately comprehensive audit programme is confirmed. The scope and scheduling of audits is addressed as well as the various phases of an audit from start to finish.

12.5. Graded approach

Both TS-R-1 and SS No. 112 introduce the principle of a graded approach to the application of Quality Assurance in the transport of radioactive material. Essentially when developing a QA programme, the complexity of the transport package, its components, or the actual transport operation should be taken into account along with the relative hazard of the contents. This is to enable measures commensurate with the necessary safety of the transport operation to be developed in a manner that is neither too onerous, nor too lax.

The Appendix in SS No. 112 identifies three grades (1, 2, and 3, in descending order of importance), that can be used in developing a graded approach within the QA programme. Definitions and guidance describing what constitutes a “Grade 1”, “Grade 2”, or “Grade 3” item are given in the Appendix, together with examples of grading applied to package types.

12.6. Conclusions

The appropriate and informed application of QA to the transport of radioactive material makes for greater safety. When a task is carried out in a quality assured manner the whole process employed by the company or organization involved has been developed systematically. By applying QA to radioactive material transport, the cycle of transport of a package can be examined and carefully managed by those carrying out the tasks so that it is accomplished a safe and compliant manner. By the creation of appropriate QA records, safety and compliance can be demonstrated to third parties. This is becoming even more important with heightened public and environmentalist awareness.

When QA is fully understood or appreciated in a company, its QA programme will reflect that understanding by being a 'living management system' working and adapting to that company's needs and objectives as well as the requirements of the company's customers or regulators. For example, when a package develops a previously unknown or unexpected defect in service, the user’s QA programme should assist in:

(1) The early detection of the defect (by providing meaningful and effective in-service handling instructions, inspection and testing);
(2) The determination of the most appropriate corrective action to rectify the particular defect;
(3) The review of the appropriate aspects of design, manufacture, use, testing, servicing and maintenance to see what changes, if any, are necessary to identify and prevent similar occurrences;
(4) The implementation of any changes necessary in a controlled and recorded manner.

Some other examples of non-conformity, which could be easily prevented by the implementation of an effective QA programme, include:

(1) Failure to properly package a radioactive material;
(2) Poor condition of packaging due to lack of maintenance;
(3) Packages presented for transport in a radiological hazardous condition, especially in the case of radiography exposure devices and source changers;
(4) Failure to properly prepare, label or document packages;
(5) Failure to placard a vehicle properly;
(6) Improper removal of placards and labels from vehicles;
(7) Packages insecurely stowed or improperly handled; resulting in lost and/or damaged packages;
(8) Packages improperly stowed, inhibiting adequate heat dissipation;
(9) Improper application of exclusive use shipment controls;
(10) Failure to comply with special arrangement conditions.
(11)

In most cases, as stated earlier, radioactive material transport often involves a number of different people or organizations, and a wide variety of different activities and equipment. In addition to the transport Regulations, QA can be considered a common denominator in these matters as shown in Figure 12.2. It is not often that one QA programme will cover all aspects of transport. More often, it will be several QA programmes linked together (with clearly defined interfaces) which give the necessary assurances.

Figure 12.1. is an example of the application of QA throughout the life cycle of a package or generation of packages. There could be more than one organization involved in the design and testing phases. There may be several manufacturers as well as several organizations using, servicing, maintaining, and modifying the packages.

By the application of QA measures and techniques to all phases of radioactive material package life, each of these phases is brought under more demonstrable and positive management control. With transport safety and regulatory compliance being a clearly established management goal, the transport operation can be achieved in a systematically controlled and assured manner.

REFERENCES FOR CHAPTER 12

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 1985 Edition, Safety Series No. 6, IAEA, Vienna (1985).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Standards Series, Safety Requirements No. TS-R-1, IAEA, Vienna (2005).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance for the Safe Transport of Radioactive Material, Safety Series No. 112, IAEA, Vienna (1994).

[4] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Quality management and Quality Assurance - Vocabulary, ISO 8402 1994, ISO, Geneva (1994).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 1973 Edition, Safety Series No. 6, IAEA, Vienna (1973).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1996 Edition), Safety Standard Series No. TS-G-1.1, IAEA, Vienna (2002).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance for Safety in Nuclear Power Plants and other Nuclear Installations, Safety Series No. 50-C/SG-Q, IAEA, Vienna (1996).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Systems - Model for Quality Assurance in design, development, production, installation and servicing, ISO 9001:1994, ISO, Geneva (1994).

[9] AMERICAN NATIONAL STANDARDS INSTITUTE, Quality Assurance Program Requirements for Nuclear Facilities, ANSI/ASME NQA-1-1989, ANSI, New York (1989).

EXERCISE FOR CHAPTER 12

The following exercise is to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 12.1. Responsibilities and Functions in Quality Assurance and Compliance Assurance

REFERENCE SOURCES: Training Manual, Chapter 12; and TS-R-1, Sections I, II, III, and VIII.

DISCUSSION: Quality Assurance (QA) and Compliance Assurance (CA) play key roles in ensuring safety through proper application of the regulatory requirements. Paragraph 105 of TS-R-1 states that confidence in regard to safety "is achieved through Quality Assurance and Compliance Assurance programmes."

PROBLEM:

a. In radioactive material packaging and transport, who is responsible for QA?

b. In radioactive material packaging and transport, who is responsible for CA?

c. TS-R-1 specifies that a consignor or user must be prepared to demonstrate to a Competent Authority that two primary QA-related functions have been satisfied and are subject to monitoring by the Competent Authority. What are they?

d. What are the means for discharging the C A responsibilities?

e. What role does QA play in applications for Competent Authority approvals of materials and package design?

f. What role does QA play in allowing the continued use of packages designed to earlier versions of the Regulations?

g. What should a Competent Authority include in approval certificates with respect to QA?

ANSWER:

13. FISSILE MATERIAL:

REGULATORY REQUIREMENTS AND OPERATIONAL ASPECTS

13.1. Introduction

Fissile material has a number of special characteristics that need to be addressed for transport. Because of this, it is treated differently in the Regulations and is given a separate chapter in this manual. Readers from countries that do not have nuclear fuel cycle activities may have normally little to do with fissile material. However, it is important to remember that fissile material may be transported *through* countries while in transit to its final destination. Some knowledge about these special characteristics is advisable, at least for reference. The requirements for fissile material are contained in paragraphs 671–682 of the TS-R-1 Regulations. Appendix VII of TS-G-1.1 advisory material addresses criticality safety assessments in more detail.

13.1.1. Criticality

13.1.1.1. Fission

As explained in Chapter 2, when a neutron is absorbed by the nucleus of certain heavy isotopes, such as uranium-235 or plutonium-239, the resulting compound nucleus may split in two. This process is known as fission, and is shown diagrammatically in Figure 13.1. The two smaller nuclei that are formed initially fly apart, giving up energy to their surroundings as heat. Fission also produces gamma radiation and more neutrons, typically two or three. The latter can take part in further fissions, setting up a chain reaction as in Figure 13.2. When this reaches a self-sustaining level, criticality has been achieved. If the rate of fissioning, the neutron population, and the reactor power are constant, the reactor is said to be *exactly critical.*

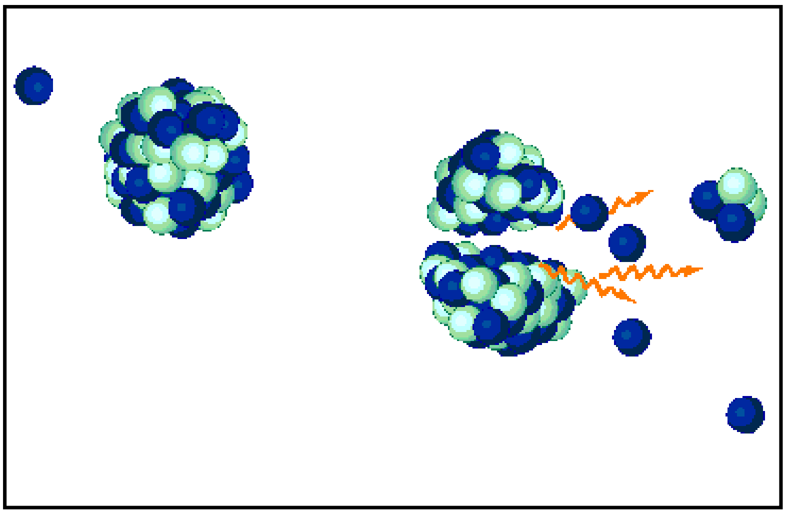


FIG. 13.1. Fission.

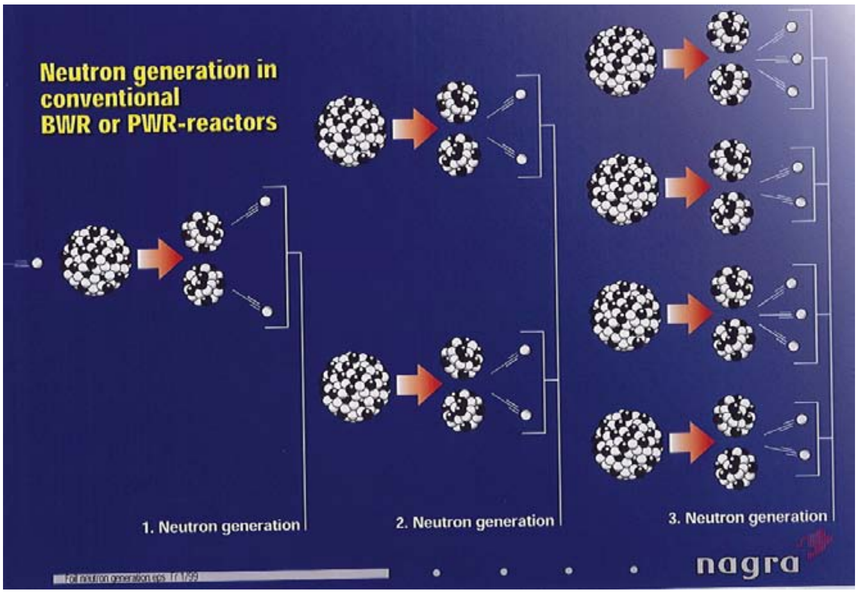


FIG. 13.2. Chain fission reaction.
(Credit: NAGRA, Switzerland

In this chapter, the analogy between the concepts essential to the prevention of accidental criticality and the conditions in an operating nuclear reactor will be used, where appropriate, as a means of explanation. The physical processes are the same in the two cases. The emphasis in a reactor is to conserve neutrons and to promote criticality. This is safe because conditions are strictly controlled. Personnel and the environment are adequately protected by the reactor's heavy containment and shielding. On the other hand, the uncontrolled releases of energy and radiation that would result from accidental criticality in transport could cause injury and damage. Such an eventuality is unacceptable. As will be explained, the regulatory requirements are designed to exclude accidental criticality during transport.

13.1.1.2. Minimum critical mass

There are essentially three significant reactions for a neutron in fissile material. Firstly, it can be absorbed by a fissile nucleus and cause fission. Secondly, it can be absorbed by a nucleus in a non-fission capture. Thirdly, it can cross the outer boundary of the system and escape. In the latter two cases, the neutron is lost to the fission chain. The competing effects of neutrons, causing fission, being absorbed, or escaping from a finite system lead to the fact that a certain minimum mass is needed for criticality to occur. Consider that the quantity of material in a finite reacting system is increased, simply by adding to its size, without changing its composition or its shape. As the size of a geometric figure increases, the ratio of its surface area to its volume decreases. For example, if the volume of a sphere is doubled, its surface area increases by only about 60%. Consequently, the number of neutrons escaping, relative to the number causing fission, falls. Reducing the volume has the opposite effect. It is, therefore, possible to have a system of such a size that the relative chances of fission, absorption without fission and escape are balanced, so that it is just critical. This is the *critical size*, and the mass present is called the *critical mass*. Below the *critical size*, the proportion of escaping neutrons is too high to support a self-sustaining chain reaction. The system is *sub-critical*. Above it, a neutron chain reaction could be divergent with power increasing. The system is *super-critical*.

13.1.1.3. Shape and reflection

As the occurrence of criticality depends on the proportion of neutrons leaking out of the system, the critical mass depends on the shape or compactness of the system, and whether escaping neutrons are reflected back into it. The most compact geometric shape, i.e. that having the minimum ratio of surface area to volume, is a sphere. Therefore, a sphere is the shape that has the smallest critical mass. A cylinder, in which the height and diameter are equal, has a slightly greater critical mass. Other, less compact shapes have even higher values. Figure 13.3 shows this effect diagrammatically for cylinders from the most compact to an infinitely long critical cylinder.

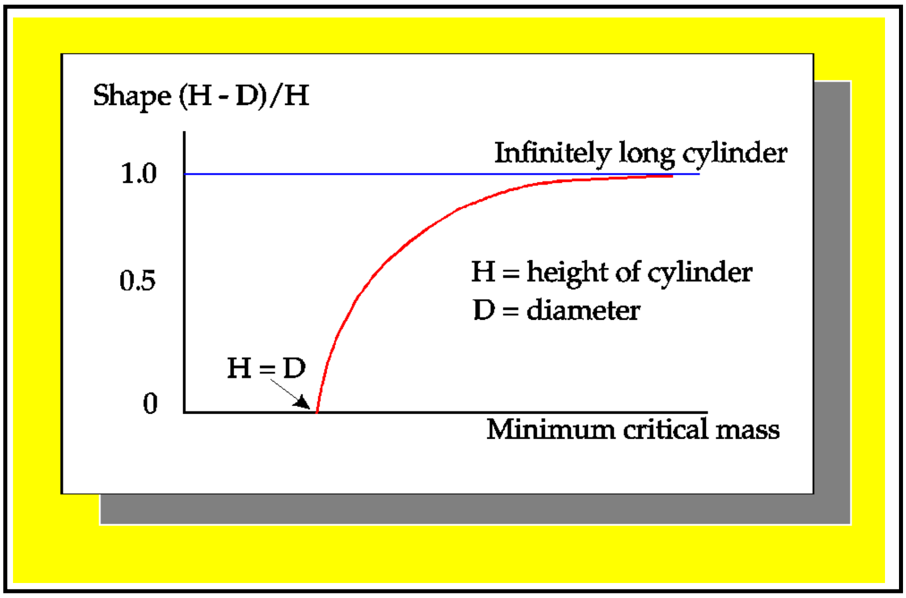


FIG. 13.3. Effect of shape of cylinder.

The material surrounding fissile material is capable of scattering neutrons back into the fissile material. The effectiveness of such reflecting material depends on its properties, e.g. neutron absorption, neutron moderation, how closely the material is fitted, and its thickness. Because reflection depends on scattering, no reflector is able to return all escaping neutrons. Many power reactors have essentially cylindrical cores with thick reflectors. Water, or any other material containing hydrogen nuclei, makes a good reflector. Because of its neutronic properties and natural abundance, water has special significance in transport criticality safety. Other materials can be encountered in transport that could conceivably act as powerful but unintentional reflectors. Examples include packaged merchandise, bulk timber, oil, and foodstuffs, and structures made of concrete or brick.

13.1.1.4. Moderation of neutrons

Neutrons are released from fission with substantial kinetic energy. Collisions between neutrons and the nuclei of the surrounding material can cause the neutrons to lose energy and slow down. This process is known as moderation. The process of moderation is very significant for criticality. The amount of energy lost in a collision depends on the mass of the nucleus involved. If this is large, as for example in the case of a uranium nucleus, the neutron may bounce off after colliding, with little energy loss. Just like a ball bouncing off a wall.

Very light nuclei are much more affected by colliding with a neutron, which subsequently tend to lose more energy in the collision.

The lightest nucleus of all, that of a hydrogen atom (a proton) has a mass nearly the same as that of a neutron. A single collision between a neutron and a proton can cause the neutron to lose almost all of its energy. This is similar to a billiard ball collision. On average, a neutron will lose half its energy in a collision with a hydrogen nucleus. Thus hydrogen is said to be a good moderator.

Eventually, if it is not absorbed, the speed of a neutron will reach equilibrium with the nuclei of the surrounding material after repeated collisions. Its speed is then in a range appropriate to the temperature of the material in which it resides. It is said to be a thermal neutron.

Fissile nuclei are those which can fission after absorbing neutrons of any energy, but especially thermal neutrons. Because the probability of initiating a fission in a fissile nucleus is very high for a collision with a thermal neutron, critical mass is often at its lowest in a well-moderated, thermal system. A nucleus is said to be fissionable if it is only able to undergo fission after absorbing a neutron of significant energy. There is an energy threshold, below which fission cannot take place. This process is used in fast breeder reactors. Fissionable material cannot reach criticality under normal circumstances even in accidents.

This effect can be well illustrated for the case of a fissile isotope, first dry, and then dissolved in water at progressively increasing dilution. Figure 13.4.shows how the critical mass falls from several kilograms of unmoderated metal to less than half a kilogram at optimum moderation. The extent of moderation is expressed as the ratio of the number of hydrogen atoms, H, in the solution to the number of fissile isotope atoms, X, in the solution (the H/X ratio). The scales of the graph must be logarithmic to cover the ranges of values needed. Optimum moderation occurs at an H/X ratio of about 500. At a value of somewhat less than 1500, the critical mass goes off to infinity. This is called the infinite sea concentration, since even a sea of the solution of infinite extent will not be critical.

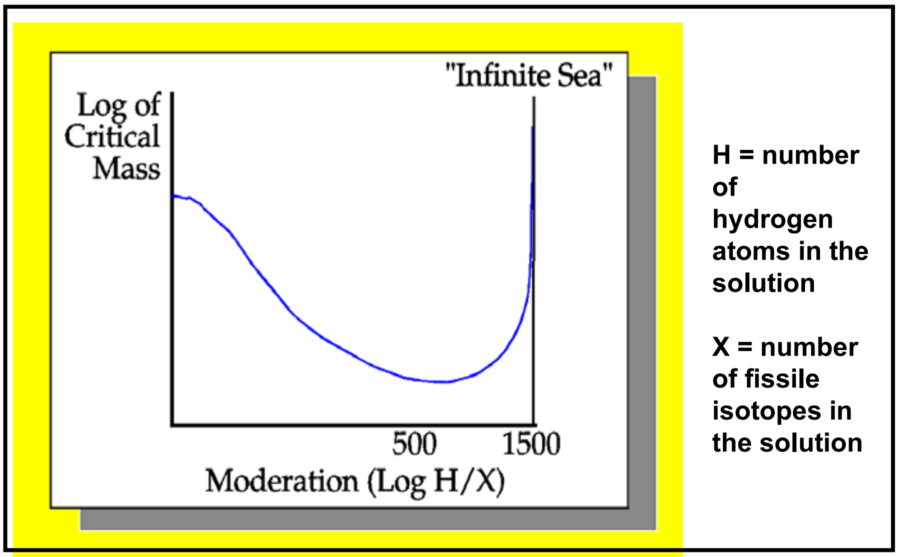


FIG. 13.4. The effect of moderation and the infinite sea.

Moderation is a very important factor in reactor design. Thermal reactors are usually moderated by water (e.g. Light Water Reactors), heavy water (e.g. Canadian “CANDU” type reactors), or graphite (e.g. Advanced Gas Reactors). They are designed to maintain criticality largely due to controlling the thermal neutrons.

Moderation has a vital influence on criticality safety. As will be explained, specially stringent requirements are imposed by the Regulations concerning the assumptions made concerning the possible leakage of water into or out of all void spaces in a package.

13.1.1.5. Absorption of neutrons

A neutron may be lost to a reacting system as a result of being absorbed by a nucleus in a non-fission capture. Almost all nuclides are able to absorb neutrons, without the occurrence of fission. However, there are some nuclides, such as isotopes of lithium, boron, cadmium or gadolinium, which absorb neutrons very strongly under suitable conditions. These are so-called neutron poisons. The power at which a reactor is operating can be altered, or the reactor completely shut down, by moving control rods containing neutron absorbers into or out of the core. This is shown in Figure 13.5. To increase the power, control rods are moved out. The consequent divergence of the chain reaction causes the neutron population to rise. When the necessary neutron population has been achieved, the control rods can be restored to a position that will maintain criticality and the desired power level.

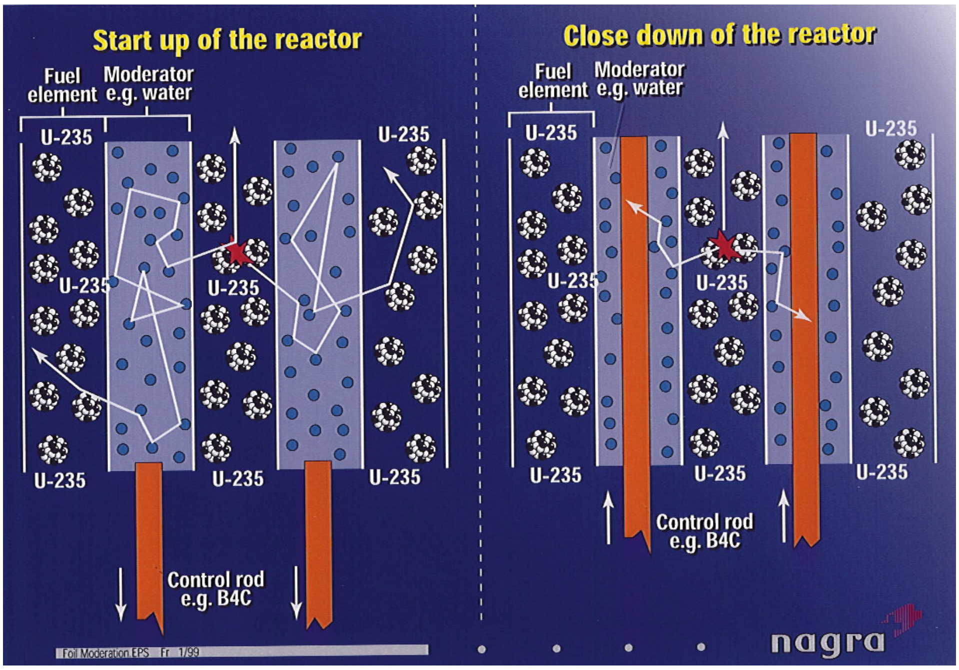


FIG. 13.5. Absorption of neutrons by reactor control rods.
(Credit: NAGRA, Switzerland)

Neutron poisons are often incorporated into the packaging used for fissile material as a means of criticality control. The Regulations incorporate specific Quality Assurance provisions, requiring tests to verify the presence and distribution of such poisons before shipment.

13.1.2. Definitions for fissile material

13.1.2.1. Confinement system

In order to help explain criticality safety considerations "confinement system" is defined in paragraph 209 of TS-R-1:

"Confinement system shall mean the assembly of fissile material and packaging components specified by the designer and agreed to by the Competent Authority as intended to preserve criticality safety."

13.1.2.2. Criticality safety index

"Criticality safety index" is defined in paragraph 218 of TS-R-1:

"Criticality safety index (CSI) assigned to a package, overpack or freight container containing fissile material shall mean a number which is used to provide control over the accumulation of packages, overpacks or freight containers containing fissile material."

How the (CSI) is used for control of nuclear criticality safety in transport and in storage in transit is described later.

13.1.2.3. Fissile material

Fissile material is defined in paragraph 222 of TS-R-1 as follows:

"Fissile material shall mean uranium-233, uranium-235, plutonium-239, plutonium-241, or any combination of these radionuclides. Excepted from this definition is:

(1) Natural uranium and depleted uranium which is unirradiated,

(2) Natural uranium or depleted uranium which has been irradiated in thermal reactors only."

This is a limited definition, devised especially for transport safety purposes. In conventional terminology, the definition is all-inclusive and a fissile nuclide is any one that can undergo fission after absorbing a thermal neutron.

There are a number of fissile nuclides higher than uranium in the Periodic Table of the Elements. The transport safety definition of fissile material, however, restricts itself to those nuclides that could present a significant criticality hazard in terms of the quantities transported. Other, relatively rare, nuclides are not included because they are likely to be transported only in very small quantities. It is likely that they would also be very securely packed because of their other properties.

The definition excludes natural and depleted uranium, even if they have been used as thermal reactor fuel. Although these materials are generically fissile, their minimum critical masses are very large (multi-ton quantities). Criticality is only possible in special lattice configurations with moderators like graphite and heavy water, which are exceptionally poor neutron absorbers. Criticality in a transport situation for natural or depleted uranium is considered to be of very low probability and of no concern.

Natural and depleted uranium, which has been irradiated in other than a thermal reactor, are retained in the definition. This is to avoid any possible misunderstanding about the status of natural uranium discharged from a breeder reactor. This could contain significant amounts of fissile plutonium isotopes due to neutron absorption by uranium-238.

13.1.2.4. Unirradiated uranium

Unirradiated uranium is defined in paragraph 245 of TS-R-1 as:

"Unirradiated uranium shall mean uranium containing not more than 2×10^3 Bq of plutonium per gram of uranium-235 and not more than 9×10^6 Bq of fission products per gram of uranium-235 and not more than 5×10^{-3} g of uranium-236 per gram of uranium-235."

This definition recognizes that uranium is always likely to contain a trace amount of plutonium, due to absorption of neutrons in uranium-238. The amount permitted is negligible for criticality. It is also sufficiently small to exclude uranium that has been irradiated in a reactor to a significant extent.

13.1.2.5. Uranium — natural, depleted, enriched

The definition in paragraph 246 of TS-R-1 is:

"Natural uranium shall mean chemically separated uranium containing the naturally occurring distribution of uranium isotopes (approximately 99.28% uranium-238, and 0.72% uranium-235 by mass). Depleted uranium shall mean uranium containing a lesser mass percentage of uranium-235 than in natural uranium. Enriched uranium shall mean uranium containing a greater mass percentage of uranium-235 than 0.72%. In all cases, a very small mass percentage of uranium-234 is present."

13.1.3. Examples of consignments of fissile material

Common shipments of fissile material include fresh and irradiated reactor fuel, intermediate fuel cycle compounds, (e.g. uranium hexafluoride), and nuclear plant wastes containing fissile material. Fresh reactor fuel may be transported in the form of fabricated pellets, fuel pins or complete fuel element assemblies.

13.1.3.1. Unirradiated power reactor fuel

Fresh fuel for power reactors mostly consists of slightly enriched uranium oxide. A mixture of uranium oxide and plutonium oxide, commonly known as mixed oxide (MOX), is also used. The fuel component of a typical pressurized water reactor (PWR) fuel assembly consists of a square lattice of around 220 to 250 pins containing uranium oxide, enriched to about 3–5% in U-235. A mixed uranium and plutonium oxide fuel (MOX) may replace the uranium oxide. The whole fuel assembly may be around 4 m long. An example of a light water reactor fuel element being loaded is shown in Figure 13.6.

Since they are very costly items, fresh fuel assemblies are packaged with special concern to avoid damage during transport, and are sealed against the intrusion of dust and moisture. However, the packaging used is relatively lightly constructed. The largest 4 metre long assemblies are typically carried in pairs. They are packed together and firmly supported at regular intervals along the length. Unless they contain plutonium, packages of fresh fuel do not need to incorporate radiation shielding, and are normally constructed to meet Type A package standards but with the additional requirements for packages containing fissile material, i.e. Type A(F) packages.

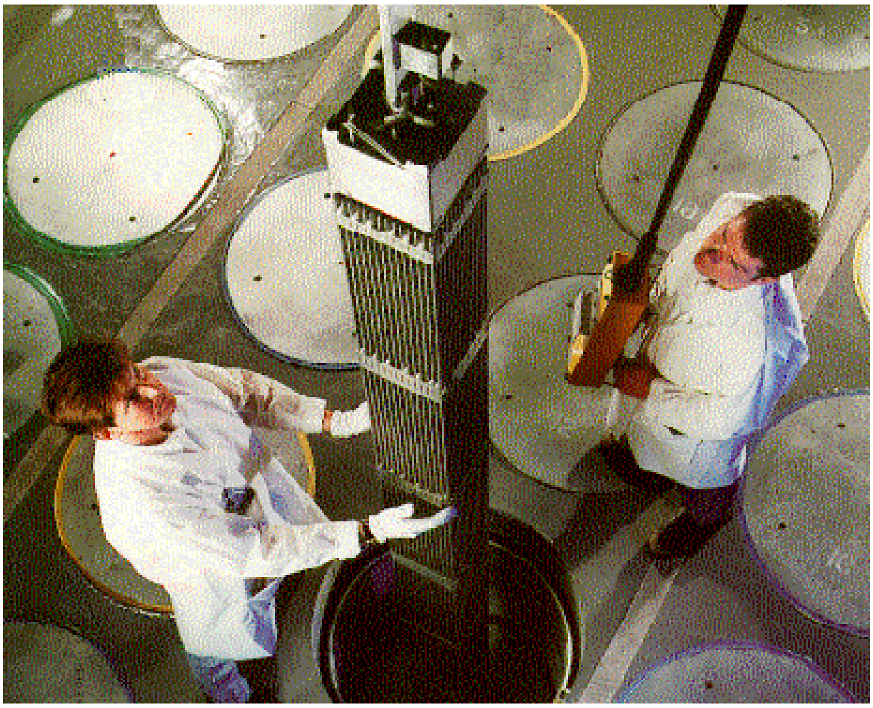


FIG. 13.6. Typical LWR fuel element assembly.

13.1.3.2. Research reactor fuel

Research reactor fuel typically consists of thin plates of highly enriched uranium metal intimately mixed and clad with aluminum. Elements are often made up from parallel plates arranged in an approximately square cross-section of about 10 centimetre square cross section. Another common type of research reactor fuel element is a clad rod about 60 centimetres long and 4 centimetres in diameter. These contain a zirconium hydride-uranium mixture at various enrichments.

13.1.3.3. Spent, irradiated nuclear fuel

Because of its high activity content and heat output, irradiated nuclear fuel must be transported in Type B packages with the additional requirements for packages containing fissile material. (i.e. Type B(U)F or B(M)F packages).

These packages, usually referred to as casks or flasks, are of heavy steel or cast iron construction, incorporate thick gamma and neutron shielding, and are provided with elaborate sealing arrangements. Several fuel assemblies are often packed closely together in one package, to economize on the overall size of the package, which is costly to construct, to certify, and to ship. Neutron-absorbing partitions separate adjacent assemblies. In some designs, water is present during shipment to provide a heat transfer medium to assist heat removal.

13.1.3.4. Uranium hexafluoride

Uranium hexafluoride (UF_6) is transported at low enrichment in cylindrical gas bottles. Typical ones in wide use are the so-called 30B cylinders for enriched UF_6, which hold about 2.5 tons. The 48Y cylinders used for (UF_6) of natural isotopic abundance hold about 13 tons and are of no criticality concern.

UF_6 is an unusual substance. At normal temperatures, it is a solid with significant vapour pressure. If heated in the package, it will liquefy under pressure at about 60°C. If heated in air, it will convert to a gas directly by sublimation from the solid at about 56°C without melting.

Uranium hexafluoride reacts vigorously with water, forming uranyl fluoride solution. The existence of a small opening in the containment however, would not necessarily lead to flooding on immersion. This is because the high viscosity intermediate hydration products can act as an effective sealing compound.

To provide protection against fire, 30B UF_6 gas bottles are packed in thermally protective outer packagings. For criticality safety, it is of great concern that UF_6 should neither escape from the package nor should the interior of the gas bottle become hydrated. In either case, the fissile contents of a 30B cylinder could be sufficient for criticality to occur. Further need to avoid leakage is based on the extending corrosive, poisonous nature of UF_6.

13.1.3.5. Waste

Nuclear plant waste is likely to be of very variable composition and therefore any such wastes containing fissile material have to be very carefully analyzed and quantified before consignment. To date, the worldwide shipment of nuclear wastes has been a limited activity because there are only a small number of final or intermediate waste repositories. However the start of the 21st century should see an increase in such shipments as new repositories are developed. The transport of radioactive wastes will then become a significantly larger activity. As is already the case a fraction of these shipments will involve fissile containing wastes.

13.2. Requirements for packages containing fissile material

13.2.1. General principles

The requirements for packages containing fissile material are set out in paragraphs 671 and 673 to 682 of TS-R-1.

The regulatory requirements are based on the following general principles as given in paragraph 671 of TS-R-1:

"Fissile material shall be transported so as to:

(a) Maintain sub-criticality during normal and accident conditions of transport; in particular, the following contingencies shall be considered:

- *(i) Water leaking into or out of packages,*
- *(ii) The loss of efficiency of built-in neutron absorbers or moderators,*
- *(iii) Rearrangement of the contents either within the package or as a result of loss from the package,*

(iv) *Reduction of spaces within or between packages,*
(v) *Packages becoming immersed in water or buried in snow,*
(vi) *Temperature changes, and*

(b) *Meet the requirements:*

(i) *Of paragraph 634 for packages containing fissile material,*
(ii) *Prescribed elsewhere in these regulations which pertain to the radioactive properties of the material,*
(iii) *Specified in paragraphs 673–682, unless excepted by paragraph 672."*

As is the case for the radioactive hazard, criticality safety is required to be assured primarily through the use of adequate packaging. Responsibility for providing this rests on the consignor. Controls applied in transport, under the joint responsibility of the consignor and the carrier, are also essential for safety.

Sub-criticality must be maintained under conditions that are likely to be encountered both during normal and accident conditions of transport. The Regulations require this and the test requirements are specified accordingly.

All of the foregoing contingencies in (a) above are foreseeable conditions of special importance for criticality safety. The designer of a package and the Competent Authority, who review it for certification and approval, must take them fully into account.

The Regulations require the sub-criticality of each individual package and consignment to be ensured. They also provide safety measures against possible hazard due to the chance accumulation of different consignments in transport or storage in transit. The designer of a package is required to carry out an assessment of the criticality of an array of similar packages. The Criticality Safety Index (CSI) has to be derived from this assessment. The CSI is used in transport and storage in transit to control criticality. Independently, the transport index TI is used to control radiation exposure. The restrictions imposed by CSI and TI have to be met independently and simultaneously.

A minimum overall external dimension of 10 cm of a package is required in paragraph 634 of TS-R-1.

Packages containing fissile material must still comply with the regulatory requirements appropriate to their radioactive nature, quantity, and form. Fissile material consignments will fall into one of the categories of material classifiable as LSA-I (only for fissile excepted material according to paragraph 672 of TS-R-1), LSA-II, LSA-III, SCO-I, or SCO-II or of quantities requiring to be shipped in Type A, Type B or Type C packages. They must be packaged and transported according to the requirements for the appropriate package category, as well as the specific additional requirements for fissile material.

13.2.2. Exceptions from the requirements for packages containing fissile material

Paragraph 672 of TS-R-1 specifies categories of fissile material that are excepted from the requirements for packages containing fissile material as well as the other requirements of TS-R-1 that apply to fissile material. These involve quantities and conditions which are such as to ensure that criticality in transport is incredible even assuming the chance accumulation of consignments and the destruction of packaging in an accident.

13.2.2.1. Mass limit per consignment

Paragraph 672(a) of TS-R-1 excepts a mass of fissile material not exceeding a limit per consignment such that:

$$\frac{mass\ of\ uranium-235(g)}{X}+\frac{mass\ of\ other\ fissile\ material(g)}{Y}<1$$

where X and Y values are as given in Table 13.1. and in TS-R-1 Table XII.

TABLE 13.1. CONSIGNMENT MASS LIMITS

Fissile material	Fissile material mass (g) mixed with substances having an average hydrogen density	
	Less than or equal to water	Greater than water
Uranium-235 (X)	400	290
Other fissile material (Y)	250	180

In addition to the consignment limit, one of the following conditions must be met per consignment:

(1) Each individual package contains not more than 15 grams of fissile material; for unpackaged material, this applies for the whole consignment on the conveyance.

(2) The fissile material is a homogeneous hydrogenous solution or mixture where the ratio of fissile nuclides to hydrogen is less than 5% by mass.

(3) There is not more than 5 grams of fissile material in any 10-litre volume of material.

Beryllium or deuterium is only allowed in quantities not exceeding 0.1% of the fissile material mass.

The conditions of paragraph 672(a)(i) of TS-R-1 effectively limit both the mass of material that could be present in transport and its initial maximum density. It should be noted that 15 grams of uranium-233 or of plutonium, in unspecified form, would, in any case require Type B packaging under the Regulations because it would be greater than, an A_2 quantity.

Paragraph 672(a)(ii) of TS-R-1 excepts certain homogeneous hydrogenous solutions or mixtures. Both aqueous and organic solvents are admissible. The basis of this exception is that when the ratio of fissile material to hydrogen decreases sufficiently, the critical mass becomes infinite. This concentration is the infinite sea concentration discussed in Section 13.1.1.4.

Two factors of safety are built into the exception to allow for uncertainties. Firstly, the theoretical infinite sea concentration is more than halved. Secondly, to allow for the possibility of the fissile material becoming concentrated by some mechanism such as precipitation, its total mass is limited to the approximate minimum critical mass in water at the optimum concentration.

Paragraph 672(a)(iii) of TS-R-1 applies a concentration limit of 5 grams in a volume of 10 liters. The packaging must be strong enough to maintain this condition under routine transport conditions. Such an initially low concentration makes it inconceivable that criticality could occur in any foreseeable accident, regardless of the size of an individual package, or taking into account the possible accumulation of packages.

13.2.2.2. Uranium up to 1% enrichment

According to paragraph 672(b) of TS-R-1 uranium of 1% maximum enrichment, if homogeneously distributed with limits on the amount of uranium-233 and plutonium, is excepted from the requirements for packages containing fissile material. There is an additional proviso that metal, oxide or carbide forms of uranium-235 shall not form a lattice. The safety basis of this exception is that criticality is possible only in a lattice, below 1% enrichment, in a normal water-moderated system. The proviso concerning metal oxide or carbide forms is to exclude reactor fuel, either in the form of fuel elements or fuel pellets.

13.2.2.3. Uranyl nitrate solution up to 2% enrichment

Paragraph 672(c) of TS-R-1 excepts any volume of uranyl nitrate solution up to 2% enrichment in U-235, (again with limits on uranium-233 and plutonium), provided that the N to U atomic ratio is a least 2. This is based on experimental evidence that the critical mass in solutions limited in this way would be infinite. In the event of concentration of the uranium due to precipitation, the quantity of uranium needed for criticality at 2% enrichment, even assuming optimum moderation by water, would be so large that accidental criticality in transport can be ruled out.

13.2.2.4. Up to 1 kg of plutonium isotopes

Paragraph 672(d) of TS-R-1 excepts a mixture of plutonium isotopes, up to 1 kg provided that not more than 20% consists of plutonium-239 and plutonium-241, or any combination of these nuclides. It should be noted that such considerations require Type B or Type C packaging for all plutonium isotopes in masses of significance for criticality safety.

13.2.3. Methods of criticality safety assessment

Content specifications for assessment of packages containing fissile material are given in paragraphs 673 and 674 of TS-R-1. These effectively require the determination of maximum neutron multiplication under certain conditions of transport and the regulatory package tests. In determining neutron multiplication factors, either values of parameters influencing this are known (conservatively considering the related uncertainties) or the parameters are imposed to give maximum multiplication.

Packages for unirradiated and irradiated reactor fuel provide an interesting contrast as regards criticality safety. With unirradiated fuel, the relatively lightly constructed packages may deform appreciably in an accident. The situation of most concern for criticality is likely to be a closely assembled array of packages, all damaged in an accident.

In a calculation, this could be modelled as a regular lattice of assemblies, at various spacings, with some structural material intervening. On the basis that the packages could be damaged and fall into a river or lake, water would be assumed to be present between the assemblies and all around them, acting both as a moderator and a reflector.

The packages used for irradiated reactor fuel assemblies, have such thick walls that the contents of individual packages are virtually neutronically isolated. The prime safety concern is to ensure that each cask is individually sub-critical. Given this, an array of any number of such packages would typically be safely sub-critical.

Criticality safety assessment is a highly specialized subject. This sub-section will attempt to give no more than a brief overview of how it is done. The first prerequisite is a competent and appropriate evaluation of the resistance of the package to the prescribed tests. Quite often, because of the diverse areas of expert knowledge involved, this necessitates consultation between the criticality safety assessor and one or more engineers or scientists specializing in the testing technology. Appropriately conservative models must be established to represent the condition of the packaging and contents during routine transport, after tests representing normal conditions of transport, and after tests representing the effects of accidents. Close collaboration is needed between the specialists concerned because effects, which might seem trivial otherwise, could be important in the context of criticality safety. Furthermore, the contingencies laid down in paragraph 671 of TS-R-1 as discussed in 13.2.1 must be taken fully into account.

Having established conservative models for the conditions of the 'undamaged' and the 'damaged' package, the degree of criticality must be evaluated. This could be done by actual experiment, but it is rarely practical to do so. Comparison with suitable experimental information obtained for another purpose is sometimes a viable possibility. The methods of calculation used must have been validated for the purpose, usually in comparison with appropriate benchmark experimental data. The parameter used as the index of criticality is the effective neutron multiplication factor, k_{eff}. This is a number that gives a measure of the tendency for the neutron population in a finite system to increase, decline or remain constant. It takes into account the neutrons absorbed without causing fission, those that escape from the system, as well as those reflected back to it. Theoretically, if its value is 1, the system is exactly critical. If the value is less than 1, it is sub-critical; if the value is more than 1, it is super-critical. However, when using k_{eff} to establish sub-criticality for compliance with the Regulations, the criticality specialist must ensure that it is sufficiently sub-critical. This is necessary to allow for errors in the code and the nuclear data used, as well as for uncertainties about modelling of the package and its behavior. It is also usual to incorporate an arbitrary margin of sub-criticality.

Among the methods of calculation that have been used in connection with transport, the most successful as regards its ability to take close account of the geometry and configuration of packages and their surroundings is the Monte Carlo technique. For this method, a mathematical representation of the package is set up on a computer. The fissile contents, the materials of construction and any additional moderators or reflectors are incorporated by including data on the possible reactions of their constituent nuclei with neutrons. The model system can be as detailed and closely conforming to reality as the investigator desires. When run, the code effectively tracks individual neutrons successively through the mathematical system, using random numbers to decide the path taken, the reactions that occur and their outcome. Depending on the code, the computer and the complexities of the system, it is possible to track many neutrons quite economically. The overall result can be a value of k_{eff}, with an indication of its associated uncertainty.

Conditions for neutron multiplication assessment of irradiated nuclear fuel are given in paragraph 674 of TS-R-1. The criticality hazard of spent reactor fuel will, most often, decline with increasing irradiation time. This is because the fissile constituent diminishes with burnup, whereas neutron absorbing fission products accumulate. However, there can be exceptions, because some fuel may incorporate burnable neutron poisons to improve the performance during irradiation. The Regulations allow the actual condition of the irradiated material to be used, but only if it is known with sufficient certainty. Otherwise, the most restrictive conditions for safety must be assumed. If the maximum neutron multiplication during the irradiation history of a fuel element is not used, a conservative assessment has to be carried out with a measurement prior to the shipment to confirm the conservatism of the assumed isotopic composition.

13.2.4. Special package design and test requirements

The additional specific requirements for fissile packages are set out in paragraphs 675 and 676 of the Regulations.

Paragraph 675 of TS-R-1 is intended to ensure adequate resistance to normal conditions of transport as regards characteristics that could affect the neutron multiplication factor by interaction with other packages of the allowable minimum size. The prohibition of the entry of a cube of 10 cm concerns packages designed with built-in spacing to reduce neutron interaction with other packages. If a small package were to intrude into this spacing, the control could be invalid.

Paragraph 676 of TS-R-1 is a clear statement that the package has to be designed for a temperature range of -40^{0}C to +38^{0}C unless otherwise is specified in the Competent Authority certificate of approval. This clearly covers the actual range of ambient temperatures that might be encountered.

13.2.5. Assessment of an individual package in isolation

The sensitivity of neutron multiplication of fissile material to water moderation has been discussed. Paragraph 677 of TS-R-1 gives the requirements regarding whether in-leakage or out-leakage of water of a package has to be considered to assure that the package remains sub-critical. Normal and accident conditions of transport have to be taken into account. Special attention is paid to the construction and safety features of uranium hexafluoride cylinders.

The presence of water need not be considered in void spaces where they are protected by multiple high standard water barriers that remain watertight if the package is subjected to the tests in paragraph 682(b) of TS-R-1. However, according to the transitional arrangements allowed in TS-R-1 for packages designed and approved in accordance with the requirements of the 1985 Edition (As Amended 1990) of the IAEA Regulations, the presence of water may be excepted from the void space taking into account the other features multilaterally approved. Such packages may continue in use according to the transitional arrangements of paragraph 817 of TS-R-1. Special attention must be given to those designs for which modifications after 31 December 2003 to the package could significantly affect safety. Such packages have to meet the full requirements of TS-R-1.

Paragraph 678 of TS-R-1 considers criticality safety in relation to the confinement system. Reflection of 20 cm of water is used since this thickness is close to infinite as far as neutrons are concerned.

A package containing fissile material must be shown (paragraph 679 of TS-R-1) to be sub-critical under routine condition of transport, normal condition of transport (the type A tests), and accident condition of transport (the type B tests), as defined in the Regulations. Water in-leakage, out-leakage, and reflection have all to be considered.

If a package containing fissile material above the limit of “fissile excepted” is transported by air, paragraph 680 of TS-R-1 has to be considered. This essentially requires sub-criticality after the air accident Type C tests without water in-leakage.

13.2.6. Assessment of package arrays

Paragraphs 681 and 682 of TS-R-1 require that an array of packages must be sub-critical. The conditions are defined for the calculation of the number, N, which is used in the determination of the criticality safety index (CSI). The designer of a package must show that a closely packed array of identical packages would be sub-critical if surrounded by a water reflector 20 cm thick. In the case of normal conditions of transport, 5 times N, with nothing intervening, must be sub-critical. For accident conditions of transport as given in paragraph 682 of TS-R-1, 2 times N must be sub-critical. An optimum amount of hydrogenous moderator between packages and fissile material escaping from packages has to be considered in the safety assessment.

These requirements apply even if only one package is likely to be constructed to the design. This is because they enable the contribution that such a package might make to a chance accumulation of different consignments and designs to be assessed.

13.3. Controls in transport and storage in transit

13.3.1. Pre-shipment checks

Pre-shipment checks are required before the first shipment because of their potential importance to safety. The effectiveness of shielding and containment, and the presence and distribution of neutron poisons, must be checked for any package containing fissile material (paragraph 671 of TS-R-1).

Compliance checks are required before each shipment to ensure that all requirements specified in the Competent Authority certificate of approval have been satisfied. For irradiated nuclear fuel, measurements may be required to confirm the assumed isotopic composition (paragraph 674 of TS-R-1). For packages containing uranium hexafluoride, tests to demonstrate the closure of each package are necessary (paragraph 677 of TS-R-1).

13.3.2. Determination of Criticality Safety Index (CSI)

The rules for determining criticality safety index (CSI) are set out in paragraphs 528 and 529 of TS-R-1.

The criticality safety index is defined to give control on nuclear criticality during transport and storage in transit. It is related to the potential contribution to criticality that the package or other item might represent. It acts as a control through the limits applied to CSI. Its value is derived from the formula:

$$CSI = 50/N$$

N is obtained as described in 13.2.6. using the smaller of the two numbers N determined according to paragraphs 681 and 682 of TS-R-1. Should N be effectively infinite, the CSI can be taken to be zero.

The criticality safety index of a package or overpack must not exceed 50 (paragraph 530 of TS-R-1), except for consignments under exclusive use.

The criticality safety index of an overpack or freight container or a consignment is the sum of the CSI of all the packages of the consignment (paragraph 529 of TS-R-1).

13.3.3. Categories of packages, marking, labels and placards

13.3.3.1. Package category

The package category is determined according to the requirements given for the radiation level. The CSI is not involved.

13.3.3.2. Marking

The requirements for marking of packages of fissile material, again are the same as for other radioactive material according to the radioactive nature and form of the contents. As the "UN numbers" and the corresponding shipping name have to be marked on the outside of a packaging, the term "FISSILE" will appear. Otherwise, the distinguishing mark specific to fissile packages is the letter "F" incorporated in the Competent Authority identification.

13.3.3.3. Labelling

The normal labelling requirements apply to fissile packages. The TI is specified on Category II and III-YELLOW labels. In case of fissile material, the weight of the material in units of grams (g), or multiples thereof, may be given instead of Bq.

Each package containing fissile material other than fissile excepted shall bear an additional label with "FISSILE", a "7" and the corresponding "Criticality Safety Index" on it, according to the description given in paragraphs 544 and 545 of TS-R-1.

The TIs and the CSIs have to be considered independently when stowing packages in freight containers or conveyances. The same applies when stowing packages, freight containers, overpacks or tanks on board vessels. The limiting value of 50 given for each index must not be exceeded.

13.3.3.4. Other hazardous properties

Packages, which have contents with additional hazardous properties (e.g. uranium hexafluoride or uranium nitrate), must be additionally labelled as required by the relevant dangerous goods transport regulations.

13.3.3.5. Placarding

Conventional placarding requirements apply to fissile packages. If, for example, the contents of a freight container consist entirely of packages containing such material or mixed-oxide fuel assemblies in type B(U) packages, and the shipment is under exclusive use, then paragraph 547 of TS-R-1 would require the appropriate United Nations Number, namely 3328, to be displayed. Similarly, for enriched UF_6 the appropriate number would be 2977.

13.3.4. Transport documents

Consignments of fissile material are subject to the generic requirements of paragraphs 550 to 562 of TS-R-1. There are only a few additional requirements arising uniquely from their fissile contents. The proper shipping name, as required by paragraph 550(a) of TS-R-1, must be the appropriate entry from Table VIII of TS-R-1. Instead of giving the activity of the radioactive material, the mass in units of grams, or multiples thereof, may be used for fissile material. The CSI for the consignment has to be given in addition to the TI.

13.3.5. Limits on CSI during transport and storage in transit

A consignment that has a criticality safety index that is greater than 50 can only be transported under exclusive use (paragraph 567 of TS-R-1).

Packages, overpacks and freight containers containing fissile material may be stored in transit in a storage area as long as the CSI of any group does not exceed 50. Packages, overpacks and freight containers must be stored in groups, with a minimum spacing of 6 metres between each group. (paragraph 568 of TS-R-1).

The CSI limits for transport may exceed 50 in certain cases as stated in Table X of TS-R-1. In these special cases, the requirement has to be applied to stow packages, overpacks or freight containers in groups where CSI does not exceed 50. The minimum spacing shall also be 6 metres between groups. (paragraph 569 of TS-R-1). There are certain exceptions to this grouping rule in the case of seagoing vessels. (See footnote (c) in Table X of TS-R-1).

13.3.5.1. Road, rail, air and inland waterway

The limit is 50 for the total sum of the CSIs in a large freight container, a road or rail vehicle, an aircraft, and an inland waterway vessel. This means that the number of packages of fissile material permitted to be transported together is limited, at the maximum, to N (see 13.2.6).

13.3.5.2. Sea

The limit of 50 for the total sum of the CSIs applies to each hold, compartment, and defined deck area. In addition, there is a limit of 200 for the whole vessel, unless all the consignments are also confined within large freight containers. If there are more than 50 CSI on a vessel, then, as stated before, no more than 50 CSIs can be in one group and the groups must be separated by at least 6 m.

13.3.5.3. Exclusive use

The limiting CSIs per container and freight container are generally increased from 50 to 100 when transported under "exclusive use" except for small freight containers or passenger aircraft. This relaxation relies on the extra safeguard against mistakes in stowage, because there is only one consignor who provides instructions for intermediate loading or unloading. Shipments taking advantage of the CSI limit of 100 are also subject to multilateral Competent Authority shipment approval. Under this relaxation however, a distance of 6 metres must be maintained between the groups. (See TS-R-1 paragraph 569).

13.4. Approvals and administrative requirements

13.4.1. Competent Authority approval

Every package design for non-excepted fissile material requires multilateral Competent Authority approval (paragraph 802 (a)(iv) of TS-R-1).

In addition, Competent Authority approval is required for shipments under exclusive use where the sum of the CSIs of the packages in a large freight container or a conveyance exceeds 50 (paragraph 820(c) of TS-R-1). Shipments of sea-going vessels are excluded provided the sum of the CSI does not exceed 50 for any hold, compartment or defined deck area as prescribed in Table X and the requirement that a distance of 6 m between groups of packages or overpacks is met.

Shipments of packages containing fissile material under special arrangement also require multilateral Competent Authority approval.

13.4.2. Information on approval certificates

As required by paragraph 833(m) of TS-R-1, additional information must be provided in the Competent Authority certificate of approval of package design, in respect of packages for fissile material. This information includes:

(1) A detailed description of the authorized radioactive contents;
(2) The value of the criticality safety index;
(3) Reference to the documentation that demonstrates the criticality safety of the contents;
(4) Any special features, on the basis of which the absence of water from certain void spaces has been assumed in the criticality assessment;
(5) Any allowance (based on paragraph 674(b) of TS-R-1) for a change in neutron multiplication assumed in the criticality assessment as the result of actual irradiation experience; and
(6) The ambient temperature range for which the package design has been approved.

13.5. Physical protection and safeguards

13.5.1. Physical protection

Security measures may be needed to protect fissile material consignments against malicious interference, sabotage, and theft. How these are applied, and the allocation of responsibilities for them, will depend on the national arrangements in the country concerned. The consignor, the carrier, and the local and national authorities are all likely to be involved.

Many features of physical protection precautions are closely akin to those for safety. For example, arrangements for providing communication in case of emergencies could be allied with those for accidents. It is very important that physical protection measures should not detract in any way from the essential regulatory safety requirements as stated explicitly in paragraph 108 of TS-R-1.

The IAEA has issued comprehensive recommendations for physical protection in transport, which include categories of consignment based on the level of perceived hazards. The scale of precautions is graded according to these. Organizational structures, protective measures, and response arrangements are all covered.

13.5.2. Safeguards

Safeguards control of nuclear material requires appropriate measures for licensing, verification of dispatch, and receipt of consignments, transport documentation, sealing of packages and inspection. Details of these specialized activities and the organizational structures necessary to support them, are given in the document "IAEA Safeguards, Guidelines for States Systems of Accounting for and Control of Nuclear Materials" [1].

REFERENCE FOR CHAPTER 13

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Guidelines for States' Systems of Accounting for and Control of Nuclear Materials, IAEA/SG/INF/2, ISBN 92-0-179180-1, IAEA, Vienna (1980).

EXERCISES FOR CHAPTER 13

The following are exercises to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE NO. 13.1. Confinement System for Fissile Material

REFERENCE SOURCES: Training Manual – Chapter 13, TS-R-1 Section VI

DISCUSSION: The Regulations define a confinement system and a containment system. These two definitions serve different purposes.

PROBLEM: A radioactive material package is designed to carry a fissile material whose contents will have radioactivity well in excess of an A_2 value. The primary components of the packaging include:

- A cylindrical shell of steel, with a welded, closed bottom end, and a flanged top end with a sealing surface and a set of threaded bolt holes;
- A matching cylindrical-shaped steel lid with bolt holes and an O-ring groove;
- An O-ring;
- A set of bolts for closing the lid on the packaging body;
- A recessed valve for draining water from the package after loading and for checking pressure prior to shipment;
- Externally attached radiation shielding material;
- A basket with neutron poisons for positioning the fissile contents within the package; and
- Lifting and tie-down attachments.

The contents for which the package is designed are in special form capsules; the designers consider the capability of the capsules in assessing the performance of the containment system. Which of the components listed are most likely to be considered part of:

a. A confinement system?

b. A containment system?

ANSWER:

EXERCISE 13.2. Determination and Use of CSI

REFERENCE SOURCES: Training Manual – Chapter 13, TS-R-1 Sections V and VI

DISCUSSION: The Regulations impose stringent requirements for assessing criticality safety for packages of fissile material. The following exercise provides an example of the calculation of a CSI and how this CSI is used to determine shipping requirements. In determining a value "N" for calculating the CSI, k_{eff} is often used. As noted in 13.2.3 of the Training Manual, the criticality specialist must ensure that the value of k_{eff} is significantly below 1. A rule of thumb is that, statistically, the value of k_{eff} should not exceed 0.95 (i.e., k_{eff} + 3F < 0.95).

PROBLEM: Forty (40) packages of fissile material are to be assembled into a freight container as a single consignment. Each package has the following criticality characteristics:

For normal conditions of transport, criticality assessments of various arrays to the requirements of TS-R-1 show that:

Array	*Number of Packages*	**k_{eff} + 3F**
8 × 8 × 5	320	0.945
9 × 9 × 4	324	0.935
9 × 9 × 5	405	0.955

For accident conditions of transport, criticality assessments of various arrays to the requirements of TS-R-1 show that:

Array	*Number of Packages*	**k_{eff} + 3F**
4 × 4 × 3	48	0.947
5 × 5 × 2	50	0.920
4 × 4 × 4	64	0.955
5 × 5 × 3	75	0.960

EXERCISE 13.2. Determination and Use of CSI

a. What is the appropriate value of N to use in calculating CSI?

b. What is the value of CSI for each package?

c. Must the label shown in Figure 5 of TS-R-1 be placed on each package, and if so, what CSI is to be shown on the label?

d. Must the label, as shown in Figure 5 of TS-R-1, be placed on the freight container and, if so, what CSI is to be shown on that label?

e. Can this consignment be transported normally without using exclusive use?

14. NATIONAL COMPETENT AUTHORITY

14.1. The role of the national competent authority

This chapter explains the role of the Competent Authority as an essential agency in implementing the Regulations and in assuring compliance with them. Its aim is to inform both regulators, who have to make a direct contribution to the work of the Competent Authority, and users of transport, who need to establish an effective relationship with their national Competent Authority.

Information on the responsibilities of the Competent Authority exists in the Transport Regulations [1], in Safety Standards Series No. TS-G-1.1 [2], and No. TS-G-1.2 [3]. The IAEA's main publication specifically relevant to the topic of Competent Authority is Safety Series No. 112 [4], entitled "Compliance Assurance for the Safe Transport of Radioactive Material."

14.1.1. Need for the Competent Authority

Experience in other fields has shown that, when regulating safety, certain requirements are so important that compliance with them must be independently verified. The body responsible for verification must be authoritative; that is, it must have the backing of law with appropriate powers of enforcement. It must be competent, having the necessary resources and expertise to carry out its functions properly. Above all, it must be independent of the users; it should never be both 'advocate' and 'judge'.

To the public, all safety requirements relating to the transport of radioactive material are likely to seem so important as to need independent verification. In the Regulations, certain responsibilities, such as the approval and certification of Type B package design, are specifically assigned to the Competent Authority. However, as has been said, there is also a general assumption underlying the whole of the Regulations, that the Competent Authority will assure compliance on all points.

14.1.2. Identity of the Competent Authority

The establishment of the national Competent Authority is a matter for the government of the country concerned. How the function is set up and organized will depend on the national regulatory and institutional framework. The Regulations define 'Competent Authority', only in the general terms of paragraph 207 of Safety Standards Series TS-R-1 as:

> *"Competent Authority shall mean any national or international regulatory body or authority designated or otherwise recognized as such for any purpose in connection with these Regulations."*

In some countries, the legally designated Competent Authority is the appropriate government minister or government department. The executive functions, however, are assigned to one or several bodies. These can include branches of government departments, national institutes, and officially appointed agents. As will be explained later, it is unnecessary for the Competent Authority to have all the technical resources required by the functions of its title in its organization. Any such task can be delegated elsewhere, on the responsibility of the Competent Authority.

Functions may be allocated to bring together work in specialized fields, such as radiation protection. There may also be different authorities for the different transport modes. This aspect has a special significance where a country is party to an international convention. The Competent Authority's responsibilities then derive from the convention. Some functions of the Competent Authority may be linked to other compliance responsibilities, for example, licensing controls exercised over the nuclear power industry.

Figure 14.1 shows schematically how a "Competent Authority for the transport of radioactive material" may in fact be shared among Competent Authorities responsible for:

- modal dangerous goods transport regulations,
- radiation protection regulations, and
- nuclear plant regulation.

This is a common situation, for example, in countries with nuclear power plants. It works efficiently provided each of the components and sub components understands clearly both their own function and also the function of the others. Interfaces are particularly important and must be sharply defined and respected. For the user, the most important facts are the contact point for advice on a given function, and the address to which to send approval applications, and notifications of shipments. A basic duty of the Competent Authority is to make users aware of its identity and how it can be contacted.

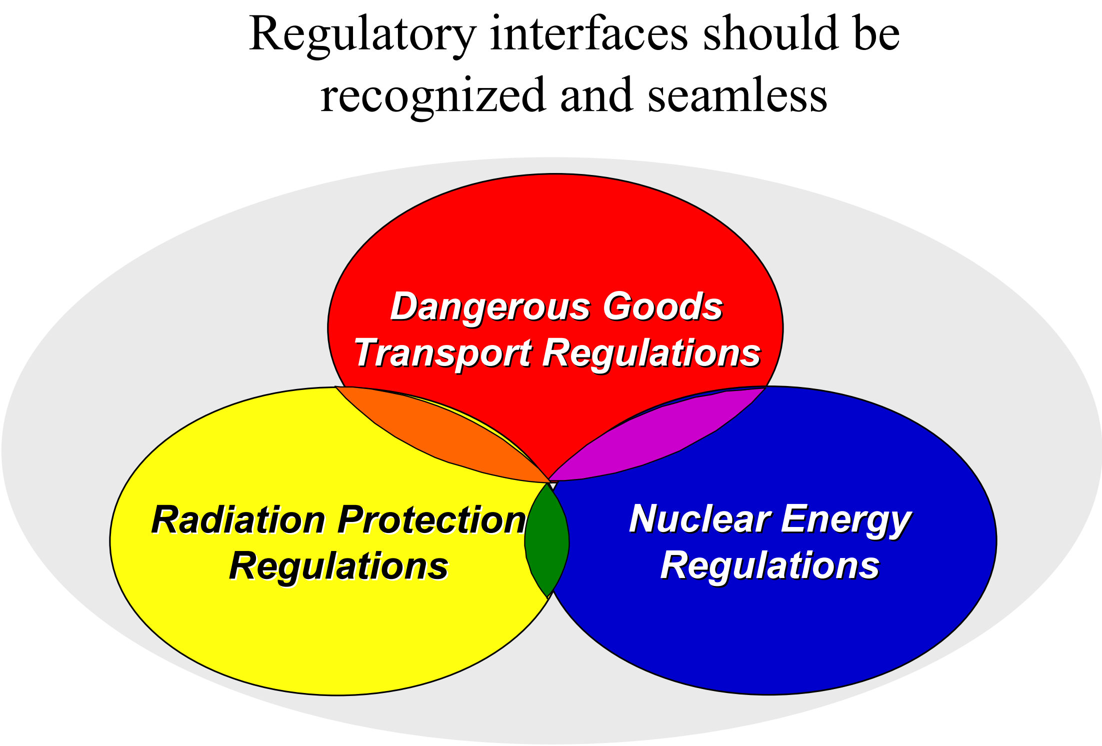


FIG. 14.1. Typical "Competent Authority" interfaces.

Each year the IAEA publishes a list entitled “National Competent Authorities Responsible for Approvals and Authorizations in respect of the Transport of Radioactive Material”. In 133 Member States there are around one hundred and forty designated authorities, including national radiation institutes, atomic energy commissions and university faculties. As the list is updated annually, it is a primary source to consult on the identity of a particular Competent Authority.

For simplicity, the term ‘Competent Authority’ is used in this chapter as if it denoted a single entity.

14.1.3. Duties of the Competent Authority

The duties of the Competent Authority fall into several main areas, under the following headings:

(1) Legislative activities to bring into effect:
- National Regulations;
- International Regulations;

(2) Implementation of regulatory activities to assure compliance with the requirements of the Regulations:
- Compliance Assurance programmes;
- Inspection and enforcement;
- Assessment and approval;
- Transitional arrangements;
- Quality Assurance;
- Emergency planning and preparedness;
- Radiation protection;

(3) Administrative activities, including:
- Issuing certificates;
- ID marking;
- Receipt of notifications;
- Recording of incidents; and

(4) Information-related activities, e.g. the preparation of guidance and policy documents, training, and the co-ordination of transport-related research.

Each of these duties is discussed later in this chapter, and more detailed information is to be found in Safety Series No. 112 [3].

14.1.4. Technical resources

In order to be truly independent of transport users, the Competent Authority must have adequate technical resources. Just what range of expertise should be available depends on the kinds of shipment expected to take place in the country concerned. A very significant factor is whether packages are to be designed in the country or not. If Type B(U) package designs originate in a country, a substantial responsibility is placed on the Competent Authority of that country, because the unilateral principle of the Regulations means that approvals by the Competent Authority of the country of origin should be acceptable everywhere else in the world. The technical ability of the Competent Authority is vital in this case, not only to ensure domestic safety, but also to avoid potential risks in other countries. Even if the only packages designed internally are Type A or Industrial packages, the Competent Authority will need to have sufficient technical resources to carry out Compliance Assurance checks of the work involved. This is also true with regard to Compliance Assurance relating to manufacture, including the case where packages are constructed in a country to designs originating abroad.

As a minimum, the Competent Authority needs the capability to be able to carry out radiation protection, Compliance Assurance, and enforcement activities to the extent necessary to be able to deal with shipments of excepted packages, radioisotopes, technetium generators, industrial sources and low-level wastes. This would imply, in the first place, the ability to make appropriate Regulations with provisions for segregation suitable for the transport modes concerned. The control of exposure to workers and keeping necessary records, would be matters for attention. A special problem could be Compliance Assurance in respect of Type B(U) packages bought in from other countries, such as those used for gamma radiography purposes. The continued use and maintenance of such equipment needs significant Competent Authority vigilance especially with respect to the user's Quality Assurance programmes.

In countries where there are specialized transport needs, for example shipments taking place associated with the nuclear industry, the Competent Authority will need a wider range of expertise. The following areas of technology could be included:

- Radiation safety;
- Mechanical engineering;
- Materials science;
- Structural analysis;
- Thermal analysis;
- Criticality safety;
- Emergency planning and preparedness;
- Transport operations;
- Risk assessment;
- Quality Assurance and quality control; and
- Inspection and enforcement.

An assessment undertaken in connection with the transport of spent nuclear fuel or high-level nuclear waste could well involve all of these areas of technology. As has already been pointed out, it is not necessary for all such areas of expertise to be available in one single organization. The Competent Authority may choose to delegate any of its functions elsewhere, or may make use of consultants if deemed fit. There is no need for the Competent Authority to be self-sufficient in all areas.

14.2. Regulations

14.2.1. National regulations

The Competent Authority is responsible for providing the national regulations, which implement the IAEA Regulations [1], and for up-dating them when necessary.

The national regulations must fully and accurately reflect the requirements of the IAEA Regulations. This is necessary to ensure harmony with other countries’ regulations. In addition, the national regulations must suitably extend the IAEA’s Regulations to cover all national needs, and all practical operational requirements relating to the modes involved.

Some countries give effect to the Regulations simply by incorporating the text of them into their national regulations. Alternatively, citing them in national regulations can enact the Regulations. The effect of these measures is multi-modal and will need to be supplemented to cover modal requirements. National regulations will often be mode-specific, catering for the individual conditions of transport in a specific mode. Figure 14.2 provides a model example for mode specific national dangerous good transport regulation.

Another significant factor is the existence of conventions in international modal transport. Information on the relevant conventions is given in Chapter 14. If a country is party to international convention, national regulations will invariably bring into force the applicable international regulations, for example, the International Maritime Dangerous Goods Code of IMO. Having ratified a convention nationally means that the Competent Authority is responsible for ensuring that the provisions of the applicable international modal regulations are fully and accurately implemented. There must be no national deviations from the provisions unless these are allowable under the convention. Exceptions and variations may need to be formally notified to the International Regulatory Body that administers the convention. They also need to be published for the information of other participating countries.

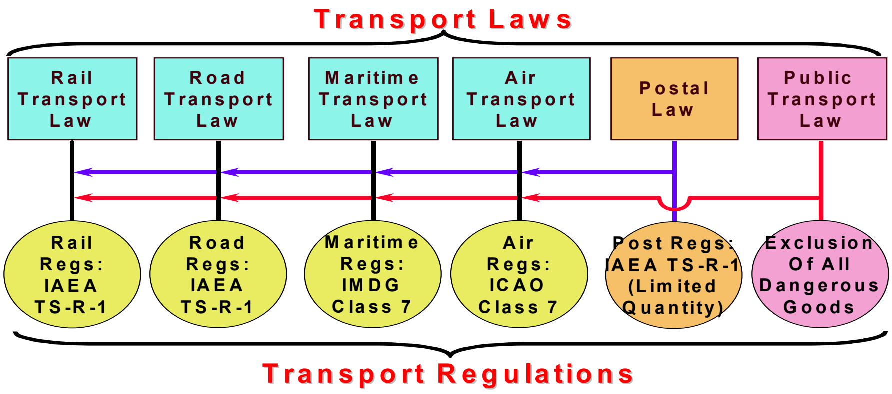


FIG. 14.2. Model example for the regulation of dangerous goods transport.

14.2.2. International regulations

The Competent Authority has responsibilities in relation to both the IAEA Regulations and the regulations of any international modal organization, which its country has agreed to ratify, by signing a convention, or by some other formal process. In principle, the nature of the Competent Authority's duties is much the same in both cases. For the IAEA Regulations, it means organising national input to regulatory reviews and related studies. For the international modal regulations, the task is to organize the national input to meetings dealing with up-dating and revising the regulations.

In general, the organization of a national input to IAEA reviews or other regulatory revisions involves administrative action possibly supplemented by technical contributions.

The administrative actions usually comprise the following:

(1) Receiving communications from IAEA, and distributing them to interested parties nationally;

(2) Calling for national views on existing regulatory provisions and proposals for change;
(3) Arranging meetings to discuss these matters; and, as a result
(4) Co-ordinating a national view on them that can be fed back to the IAEA.

It is of great assistance to IAEA advisory groups working on regulatory reviews to have comments from Member States that are clear, properly organized, fully supported by explanations and, most of all, self-consistent. This is an important responsibility. It often happens that individual organizations within a country have differing views on a given regulatory provision. If these differences cannot be resolved by discussions between the parties concerned through correspondence, or at meetings organized by the Competent Authority, then it is the responsibility of the Competent Authority to make the final decision so that a single co-ordinated national view is presented to the IAEA.

Technical contributions may also be required in regulatory reviews. An example is the provision of information to the IAEA on the national working of the Regulations. This can come from incident records or from experience in enforcement. For example, details of infringements of regulatory provisions and their consequences can be information useful to the IAEA. Valuable feedback can also come from transport data compiled by the Competent Authority concerning the IAEA's transport information collection and data compilation. It is also necessary to undertake surveys of radiation exposure in transport from time to time and feed the results of this back to the IAEA. Finally it is necessary to arrange for national representation at International Regulatory meetings.

14.3. Implementation

14.3.1. Compliance Assurance

14.3.1.1. Scope

The IAEA Regulations ensure safety in the transport of radioactive material by laying down detailed requirements, which are appropriate to the degree of hazard represented by the material, taking into account its form and the quantity being carried. As discussed, a basic philosophy is that protection should be afforded as far as possible by the use of adequate packaging. This is consistent with the approach adopted for dangerous goods in general in the recommendations of the UN Committee of Experts (see Chapter 14).

Based on this principle, the Regulations provide a complete system of safety requirements covering packaging design, the fabrication and makeup of packaging and contents, the preparation of packages for transport, the carriage of consignments and their receipt at the final destination. Emergency measures to respond effectively to accidents, as well as comprehensive provisions for Quality Assurance and Compliance Assurance, are also required.

14.3.1.2. Responsibilities for Compliance Assurance

To help ensure that safety is achieved in practice, the Regulations assign responsibility for compliance with certain requirements to the consignor, the carrier, and the Competent Authority.

A fuller description of the respective responsibilities of the consignor and the carrier is given in Chapter 10. However, as an illustration for the purpose of compliance, they would be collectively responsible for ensuring that:

(1) Sound packages are used, fully complying with applicable requirements for the nature and quantity of the contents, the design and construction of the packaging and terms of any relevant approval certificate;
(2) All required pre-shipment measures are taken;
(3) The transport documents are accurate and complete;
(4) Labelling, marking and placarding are properly effected;
(5) Packages are properly handled, stowed, and segregated;
(6) Radiation and contamination levels are within any applicable limits, as regards packages and vehicles;
(7) Any necessary instructions and schedules relating to emergency response arrangements are available and known to those concerned; and,
(8) Quality Assurance programmes, covering all the above items, exist as required by the Regulations, and are fully operational.

The responsibility for assuring compliance with the Regulations rests with the Competent Authority, this is assigned in para. 311 of Safety Standards Series No. TS-R-1. Compliance Assurance is defined in paragraph 208 of Safety Standards Series No. TS-R-1 as:

> *"A systematic programme of measures applied by a Competent Authority which is aimed at ensuring that the provisions of the Regulations are met in practice."*

While the Competent Authority has an overall responsibility for assuring compliance in regard to each and all of the above-listed items, its responsibilities go much further than this. There is a tacit assumption underlying the whole of the provisions of the Regulations that the national Competent Authority will provide the necessary support for all of the regulatory safety requirements and will ensure that they are properly carried out within the country concerned.

In the first place, the Competent Authority must establish a legal framework and national regulations to bring the IAEA Regulations into effect. Then it must see that the technical and administrative infrastructure exists to enable users to comply with them. As a further step, it must create the Compliance Assurance and enforcement procedures that are prescribed by the Regulations and necessary to ensure that they are fully implemented in practice.

The responsibility to develop and maintain a Compliance Assurance programme places a significant burden on Competent Authorities. Some may have been carrying out such duties as inspections or package assessments as part of their current Regulatory function. But only a fraction will have comprehensive Compliance Assurance programmes in operation. If a Competent Authority is to respond to the Regulatory requirement in paragraph 311 of TS-R-1 [1], then it must develop and maintain an appropriate and effective Compliance Assurance programme. Total assurance of compliance is clearly impractical and virtually impossible to achieve, and, therefore reasonable assurance of compliance becomes the goal. In order for a Competent Authority to provide reasonable assurance it must:

(1) Create a legal environment, in which it can work and be effective;
(2) Organize itself so as to be independent and of an appropriate size and expertise for the radioactive material transport for which it has responsibility;
(3) Issue or revise regulations appropriate to the activities for which it is responsible;
(4) Develop its own Compliance Assurance programme and work to it; and
(5) Produce evidence that Compliance Assurance is being achieved.

It is important to realize that while the Regulations assign certain direct responsibilities for compliance and a responsibility for a Compliance Assurance programme to the Competent Authority, there remains a clear responsibility on those organizations actually transporting to comply with the Regulations.

14.3.1.3. Compliance Assurance programmes

Compliance Assurance programmes may be relatively simple and straightforward or progressively complex and wide-ranging, depending on the size and variety of the industry for which the Competent Authority has responsibility. A simple Compliance Assurance programme for a country in which the radioactive material industry only involves medical isotope transport needs to take account of:

- Import/re-export operations;
- Internal transport operations;
- Package Type A and occasional Type B;
- Low volume of movements.

A more complex Compliance Assurance programme will be needed for a country in which the radioactive material industry involves all types of radioactive material movements.

Such a programme would need to take account of:

- Import/re-export operations;
- All modes of transport;
- All package types and associated certifications;
- Medical isotope use, industrial radiography, research, civil construction, food irradiation, nuclear fuel production and reprocessing;
- Package design, manufacture and use;
- High volume of movements.

However, three elements should be present in any Compliance Assurance programme. These are:

(1) Review and assessment activities, including the issue of approval certificates;
(2) Inspection and enforcement;
(3) Emergency response.

Each of these can be expanded to match the complexity and variety of a particular Competent Authority's responsibilities.

14.3.1.4. Methods of assurance, inspections, and enforcement

Assurance of Regulatory compliance and associated inspections can be carried out in a variety of ways, depending on the size and complexity of the radioactive material transport industry in the country. Some examples of these are listed below, and illustrated in Figures 14.3. to 14.12.

(1) Issue of Competent Authority approvals;
(2) Assessment of package designs;
(3) Assessment and approval of Quality Assurance programmes;
(4) Witnessing/inspection of testing arrangements;

(5) Observance of manufacture;
(6) Examination of maintenance and servicing arrangements;
(7) Inspection/observation of transport operations;
(8) Inspection /observation of emergency arrangements;
(9) Distribution of information (communication with industry);
(10) Application of enforcement measures, such as:
   - Written notices,
   - Suspensions,
   - Prosecutions;
(11) Interdepartmental liaison/co-operation;
(12) Review of regulations (national and international);
(13) Review of the Competent Authority's Compliance Assurance programme.

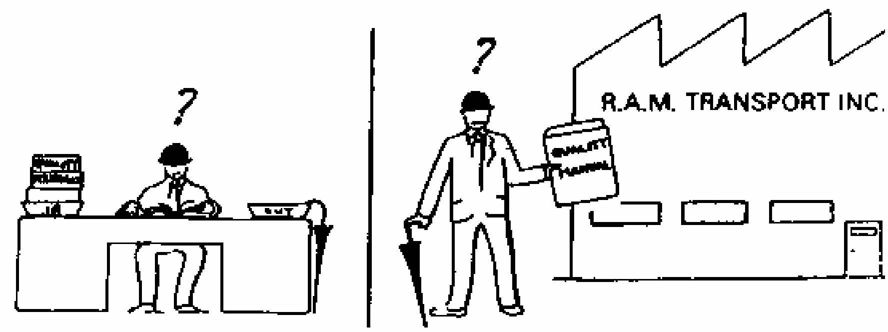


FIG. 14.3. Assessment and approval of Q.A. programmes.

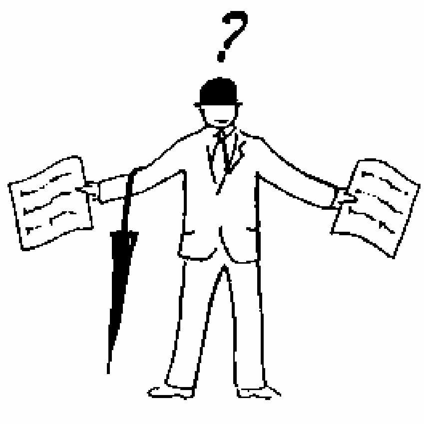


FIG. 14.4. Comparison of package design with IAEA Regulations.

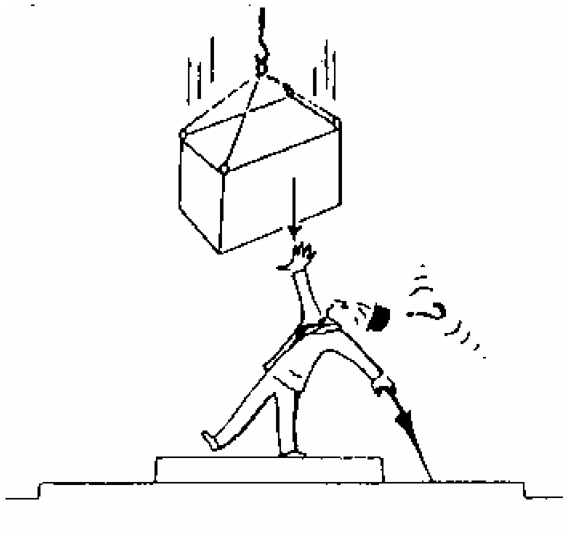


FIG. 14.5. Witnessing and inspection of regulatory proof testing arrangements.

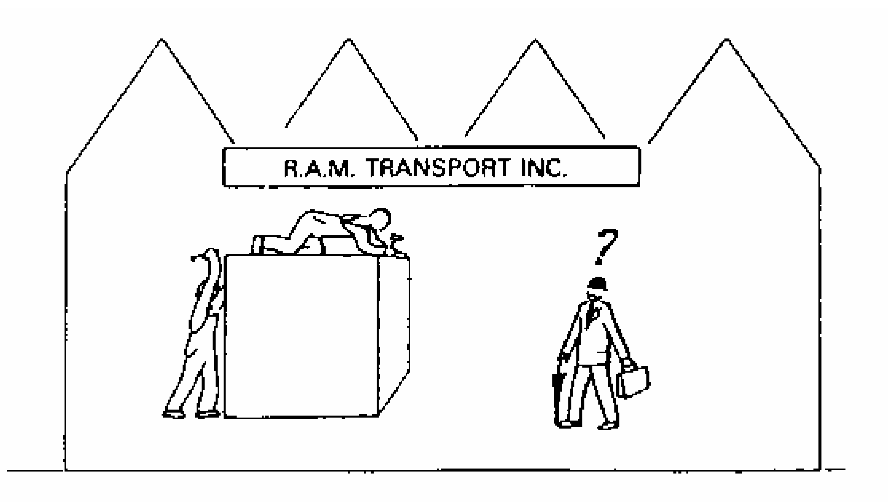


FIG. 14.6. Observance of manufacture.

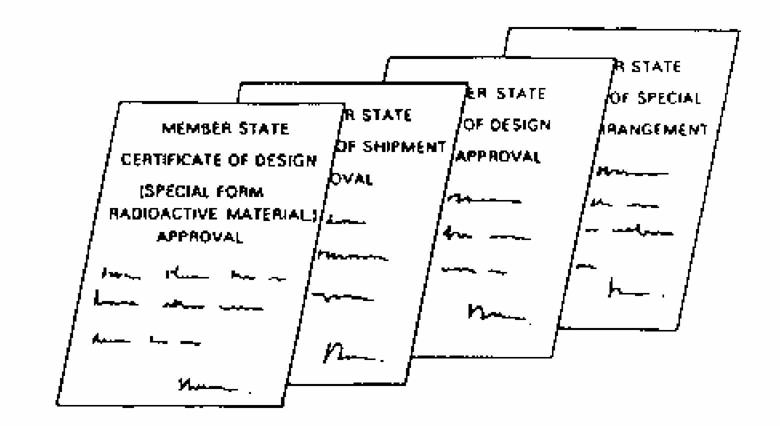


FIG. 14.7. Issuance of Competent Authority certification (when appropriate).

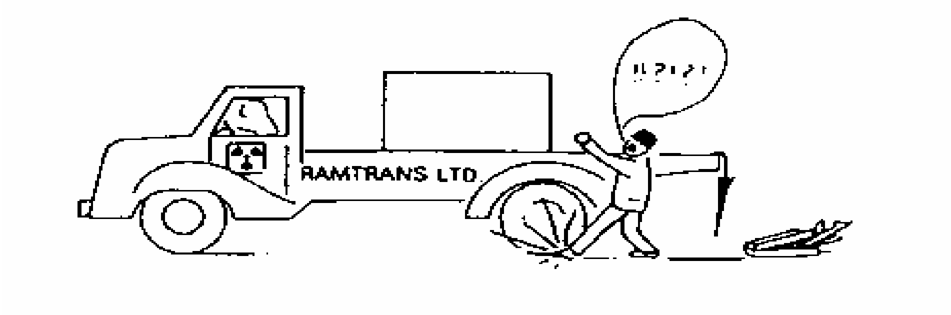


FIG. 14.8. Inspection and observation of transport operations.

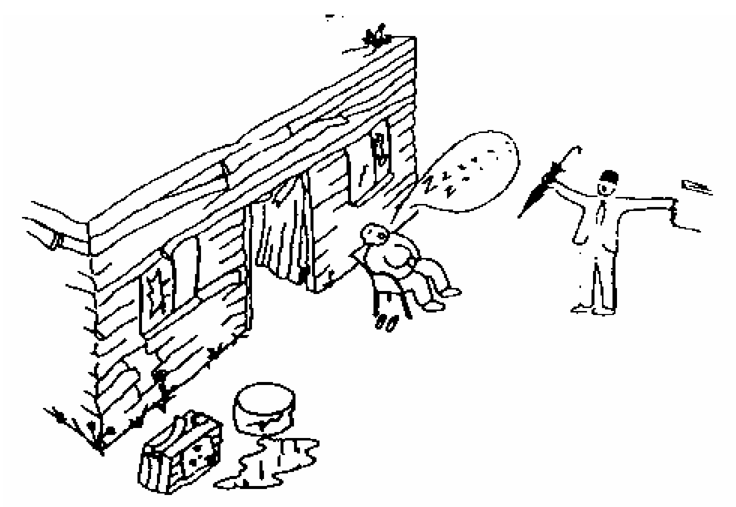


FIG. 14.9. Examination of maintenance and servicing arrangements.

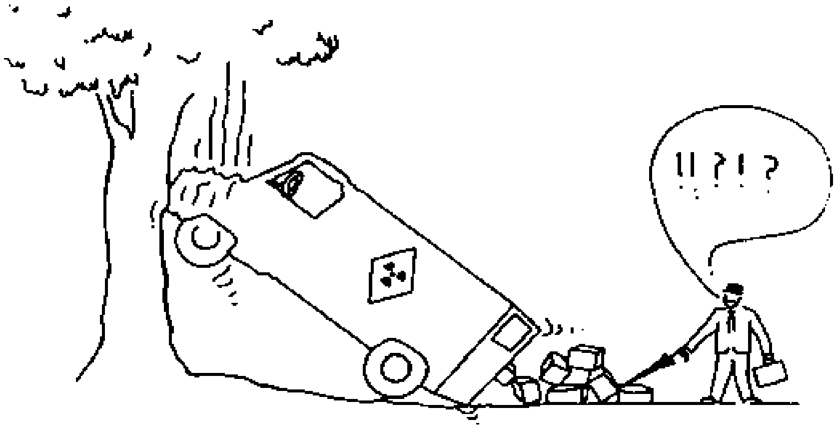


FIG. 14.10. Emergency arrangements.

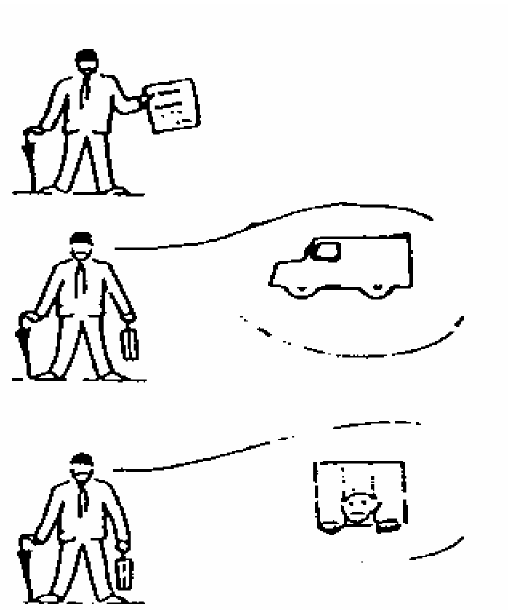


FIG. 14.11. Application of enforcement measures.

FIG. 14.12. Review of Competent Authority's Compliance Assurance.

Inspection and enforcement activities are essential components of any Competent Authority's Compliance Assurance programme. The national legal and institutional framework will determine how they are carried out in any country. General advice on inspection and enforcement practice is given in Section IV of TS-G-1.1. It is essential to have effective sanctions and remedies to apply in cases where inspection reveals non-compliance or violations in respect of regulatory requirements. The Competent Authority may be concerned to distinguish between inadvertent non-compliance, which can be addressed by corrective, advisory reactions, and culpable negligence or deliberate disregard of required actions. There should be a possibility of remedial action, which is supported by formal warnings, and backed up by penalties severe enough to be an effective deterrent.

14.3.2. Approvals

14.3.2.1. Scope

The Regulations distinguish between cases where the transport of radioactive material can be made without Competent Authority approval and cases where some kind of approval is required (see paragraphs 801 and 802 of TS-R-1 [1]). Assessment and subsequent approval by the national Competent Authority is required in the following cases:

(1) Designs for:

- Special form radioactive material;
- Low dispersible radioactive material;
- Packages containing 0.1 kg or more of uranium hexafluoride;
- All packages containing fissile material (unless excepted by para. 672 of TS-R-1[1]);
- Type B(U) packages and Type B(M) packages; and
- Type C packages;

(2) Special arrangements;
(3) Certain shipments;
(4) Radiation protection programmes for special use vessels;
(5) Calculation of radionuclide values not listed in Table 1 of TS-R-1[1].

Multilateral approvals are required under certain circumstances and these may be given effect by validation of an approval certificate issued by the Competent Authority of the country of origin of the design or shipment (see para. 834 of TS-R-1 [1]).

14.3.2.2. Assessment

Applications

For a Competent Authority to issue an appropriate approval, it must first receive an application for approval against which a safety or compliance assessment can be carried out. Such an application should contain sufficient technical and other information to enable the Competent Authority to conduct a satisfactory assessment and determine whether all the regulatory requirements are met.

However, before the submission of an application for approval, it is often desirable that there be consultation between the applicant and the Competent Authority. This is advantageous to both parties. It promotes good mutual understanding, which is essential in such an advanced technological area and is also likely to save both parties time and money.

The applicant, by being made aware in advance of the Competent Authority's needs for information, can more easily avoid omitting essential facts and data from the safety evidence presented for approval. Compensating for these at a later stage can be costly and cause delays.

The Competent Authority can profit from early consultation because its assessment task will be much simpler if the approval application is complete, to the point, and presented in a preferred format. Advance information of applications helps management of the assessment workload, saving time and costs to the Competent Authority organization, which may be under-resourced and overworked. The Competent Authority can learn from applicants and this is more likely if there is a good dialogue between them. Ideally, the intending applicant should inform the Competent Authority, in advance about the proposed design or operation. Information should include the:

(1) Nature and quantity of contents;
(2) Category of approval to be sought;
(3) Main design features, construction materials, and dimensions;
(4) Sealing arrangements;
(5) Radiation and thermal shielding methods;
(6) Criticality safety control method;
(7) Test programme envisaged;
(8) Intended use of scale modelling; and
(9) Intended use of calculations to show compliance.

Consultations

Prior discussions can take into account material properties, for example, brittle fracture. It can be useful to make known intentions concerning manufacture and Quality Assurance in some cases. It is very desirable, for example, to establish the acceptability, at an early stage, of a certain material as a neutron absorber for criticality control. Suppose the Competent Authority were unable to accept methods envisaged to ensure the composition, and hence the efficacy of the material, this might invalidate some of the basic parameters of the design. It might be found that the package cavity was insufficiently dimensioned to accommodate both the intended contents and the minimum thickness of the neutron absorber required.

An important subject for consultation is the test programme. As regards mechanical tests, there must be agreement about the acceptability of the test facility, the number and nature of the tests proposed and the drop attitudes. The drop target must be adequate in relation to the size of specimen. If a fire test is to be carried out, the parameters of this should be agreed. The instrumentation provided to observe and record significant test data must be fit for its purpose. If the applicant does not possess an adequate test facility, the Competent Authority may be able to advise on the availability of suitable facilities.

Consultation will need to continue during the test programme. It is essential for the Competent Authority to be able to witness significant tests. Sometimes it may be desirable to invite representatives of foreign Competent Authorities to attend these tests, if it is known that multilateral approval will be needed. Based on interim test results, it may be necessary to modify the test programme and this too should be agreed upon.

Documentation

To aid intending applicants, some Competent Authorities provide guidance material on the preparation of design safety documentation. A comprehensive listing of the aspects that may be covered is provided in Annex II of SS No.112. [4]). The main topics are:

Part I	General Information
Part II	Administrative Information
Part III	Specification of Radioactive Contents
Part IV	Specification of Packaging
Part V	Package Analyses and Tests
Part VI	Shipment
Part VII	Special Arrangement Transport Operation
Part VIII	Special Form Radioactive Material, and
Part IX	Quality Assurance

The details in each of the above parts can be presented as a series of questions, each based on a relevant requirement of the Regulations, which the applicant has to answer. In the simplest cases, the applicant has only to compile a set of answers and the result may constitute an acceptable design safety approval application, ready for submission.

Irrespective of whatever prior consultation has taken place, at the appropriate time the applicant must submit an application for approval to the Competent Authority. The documentation presented must include all the items detailed in the relevant paragraphs of Section VIII of the Regulations [1]. For a package design, a design safety report may be provided. This should comprise all necessary design specifications, including drawings, material schedules and construction methods. Evidence of compliance with the respective regulatory requirements can be based on test details and results, calculations, and comparisons with other approved designs and reasoned arguments. As applicable, evidence will be needed of: structural integrity; leaktightness; adequacy of radiation and thermal shielding; ability to dissipate generated heat, and safety from accidental criticality. The results of the appropriate regulatory tests must be taken into account. Operating, handling, storage, and maintenance arrangements should all be discussed as necessary. Full information on Quality Assurance programmes covering all the foregoing should be provided. This includes the design work itself, the preparation of the safety evidence (especially regarding tests and the test specimens), the control of quality in manufacture, deviations from design features, preparations for shipment, as well as maintenance, repairs and reconditioning.

Application for approval of shipment, including special arrangements, must include details more related to the actual operations proposed. The relevant requirements of the Regulations [1] can be found in paragraphs 820 to 825. Besides the necessary details of the consignment, including the contents and packages in each component package, the intended modes of transport, the types of conveyance and the proposed route must be considered. Any special precautions to compensate for particular features of the consignment must be described. Moreover, it may be necessary, for multilateral approval applications, to take proper account of the transport conditions particular to the country concerned, (e.g. the climate). In the case of shipments under special arrangements, it may be necessary to require risk assessments to be carried out for the operations and the routes proposed.

Management and staffing

On receiving the application, the first task of the Competent Authority should be to record and acknowledge receipt of the application, and to allocate it a suitable reference. This may be related to the identification mark that will ultimately be given to the design or operation, if it is approved. The next concern should be to check the completeness of the information included, as far as this can be ascertained on first inspection.

Some Competent Authorities may, for internal management purposes, assign each application, as soon as it is raised, to an individual officer who will be responsible for co-ordinating the assessment work by the various specialists involved. This officer will act as the contact for technical liaison with the applicant, throughout the review. With prior consultation, the project officer will already be familiar with the design details when the application arrives and will have witnessed tests in connection with it, or arranged for others to do so.

An important organizational aspect for the Competent Authority is the scheduling of assessment work. The necessity for careful scheduling increases with the number and complexity of the applications for approval. The contributions made by specialists to the overall assessment must be co-ordinated effectively in order to make best use of resources.

It is desirable to reduce the overall duration of an assessment when possible. Lengthy assessments delay the implementation of designs, may disrupt manufacturing arrangements, and cause extra costs for applicants. Larger projects, which depend on transport for their realisation, may be impaired. The Competent Authority's staff will inevitably come under pressure, and in the case of undue delays, the validity of the assessment may be endangered. Efficient Competent Authorities will be conscious of the need for effective management of assessment work.

Evaluation

One action invariably taken in the course of the assessment will be to check all input data used in tests or calculations for conformity to the design specification. Ideally, independent assessment should involve a complete check of every item in the safety case, using independently prepared input data and independent methods of appraisal throughout. This is often not possible. The regulatory tests are prescriptive in nature. Therefore, if there has been adequate prior consultation, the Competent Authority will have been a party to agreeing the equipment and procedures to be used, and in witnessing them as necessary, and viewing the results. There may be just one preferred method of calculation having the necessary extent of validation to be used confidently to establish safety in a given area. The Competent Authority can, of course, repeat certain calculations or carry out independent ones where the means exist. In some cases, the applicant may be requested to carry out further calculations. One objective of this would be to test the sensitivity of the results to variations in input data.

As far as possible, the Competent Authority will want to standardize the assessment procedure, particularly for similar designs. There will also inevitably, and desirably, be an ad-hoc element in almost every assessment. Indeed, it is often the non-standard features and the unexpected findings that can be the critical aspects of an assessment. They can lead to advances in knowledge and techniques. Finally, after all the systematic checking, it is the experience of the Competent Authority assessment staff, developed by the study of many comparable cases, which enables any deficiencies in a design to be identified, and which contributes to the effectiveness of the assessment.

14.3.2.2. Transitional arrangements

The question of how and when to phase out materials, packagings and packages used or approved under previous editions of the IAEA Regulations always requires detailed attention from both users and Competent Authorities alike. Paragraphs 815 to 818 of TS-R-1 [1], set out the rules to be applied concerning these “Transitional Arrangements”.

These rules recognise the large capital investment incorporated into the design, manufacture and use of re-usable packagings in the transport of radioactive material. Similar sizeable investment applies to much special form radioactive material. Because of these long term investments, generous time scales are allowed to provide an ordered transition from the old requirements to the new.

However all new requirements set out in the Regulations concerning Quality Assurance as well as all new activity limits and material restrictions are intended to apply immediately the new edition of the Regulations is applicable.

14.3.3. Quality Assurance

It is expected that Competent Authorities will need to make increasing use of Quality Assurance and Quality Assurance techniques to assure compliance with the Regulations. The requirement in paragraph 306 of TS-R-1, which effectively states that Quality Assurance programmes shall be established for all packages and all aspects of transport, has considerable significance. Where approval for package design and use is needed, the Competent Authority is required by paragraph 306 to consider the appropriate Quality Assurance programmes.

It is clear that Quality Assurance has an important part to play in assisting the Competent Authority to achieve full Compliance Assurance in as much as:

(1) It is, or can be, a common denominator in the transport of radioactive material;
(2) All aspects of radioactive material transport need suitable Quality Assurance programmes;
(3) It is a management tool or management control system;
(4) It can be used to demonstrate compliance;
(5) It can assist in self-correction or self-improvement;
(6) Its techniques can be used by the Competent Authority; and,
(7) Its application and use can promote public confidence in radioactive material transport operations.

A Competent Authority can maximize on the Quality Assurance practised by the industry in support of its own Compliance Assurance efforts. As applications for approvals are received, reference to quality programmes can be taken up, examined, and verified. This may involve one relatively straightforward Quality Assurance programme or more complex interacting programmes where design, testing, manufacture, use, servicing and maintenance are carried out by different organizations, each with their own separate Quality Assurance arrangements, (see Fig. 12.2. of Chapter 12). Matters can be further complicated by one organization’s singular Quality Assurance programme applying to the design, testing or manufacture, for a whole range of packages but with individual quality plans only applicable to each separate package design or type. The Competent Authority can confirm the adequacy of the Quality Assurance arrangements by not only examining the actual written programmes and plans, but also by auditing the arrangements to verify their correct functioning. Only when satisfactory Quality Assurance arrangements are confirmed, can the Competent Authority issue a full approval certificate that must specify the Quality Assurance programmes concerned. Obviously, the interest in Quality Assurance does not finish with the issue of a certificate, but further action can be taken to ensure that the packages concerned continue to comply with the approved specification. It is considered most important that the original design and its approval not be compromised in subsequent use. Thus, the Competent Authority can further examine Quality Assurance applied to all post manufacturing transport operations such as servicing, maintenance, modification, and use.

14.3.4. Emergency planning

Emergency planning and preparedness is covered in depth in Chapter 16. This present chapter only serves to introduce the Competent Authority’s responsibilities and activities in that field. The responsibility of the national Competent Authority for emergency planning and preparedness has two main aspects. Firstly, the Competent Authority has a responsibility to ensure that appropriate national emergency arrangements for dealing with radioactive material transport accidents exist and are maintained. Secondly, the Competent Authority must ensure that consignors and carriers have adequate contingency arrangements to respond to accidents and incidents involving their own consignments.

The scope and nature of the national emergency arrangements will depend largely on the legal and institutional framework of the country. The question of appointing a ‘lead agency’ to co-ordinate emergency response activities, will be a matter for the Competent Authority. A significant factor will be the arrangements for responding to transport accidents in general, and to transport accidents involving dangerous goods other than radioactive material. National emergency response planning benefits from simplicity and consistency, irrespective of the hazards. To have integrated national plans for all hazardous materials, including radioactive material, enables resources to be more effectively utilized and experience to be accumulated beneficially. This aspect is highlighted in Safety Standards Series No. TS-G-1.2 [3].

The Competent Authority should ensure that, whatever other arrangements exist, expert advice on dealing with the hazards of accidents involving radioactive material can always be made available at the scene with minimum delay. This is essential if non-specialist emergency services, such as the police, fire and ambulance personnel, are to function confidently and effectively whenever a radioactive hazard is suspected.

The Competent Authority will need to take into account the influence of modal considerations. Air and water-borne emergencies can have significantly different characteristics from those by road and rail. One factor is the much greater likelihood of international implications. Especially, sea and inland waterway modes may give rise to the need for bilateral and multi-lateral agreements between neighbouring countries, for mutual actions and for co-operation in sharing information and facilities.

The Competent Authority will need to ensure reporting and recording of all accidents and incidents, as well as ensuring that information is provided to the IAEA's database EVTRAM (see Chapter 18).

14.3.5. Radiation protection

14.3.5.1. Radiation protection requirements in TS-R-1

There is now a clear requirement in paragraph 301 of TS-R-1 for radiation protection programmes (RPP) to be established for the transport of radioactive material. While the responsibility for the transport related radiation protection programme rests with the organization carrying out the transport activity, the Competent Authority also has certain responsibilities. The Competent Authority's responsibility for radiation protection mainly concerns ensuring compliance with the general requirements of paragraphs 301–305 and 311 of the TS-R-1 Regulations concerning control of exposure to the public and transport workers. The Competent Authority must also arrange for periodic assessments of radiation doses to persons due to the transport of radioactive material.

Suitable advice on the objectives, scope, and application of radiation protection programmes is given in Section 3 of the advisory material TS-G-1.1 [2].

The transport of radioactive material is only one of the possible sources of radiation exposure to which persons are subjected in the course of their lives. Because the science of radiation protection is particularly specialized, the national institute responsible for radiation protection will often act as the relevant Competent Authority for transport purposes. Alternatively, the transport Competent Authorities may have sufficient resources to directly manage their radiation protection responsibilities. Where there is more than one authority involved in radiation protection, the interfaces and respective responsibilities must be clearly established to ensure a consistent and comprehensive approach.

Actions that are the direct responsibility of the Competent Authority include:

- Monitoring the optimization of radiation protection in transport;
- Establishing segregation procedures;
- Conducting periodic surveys;
- Ensuring that there are radiation protection programmes, including for the approval of programmes for special use vessels; and
- Providing instructions for dealing with undeliverable packages.

14.3.5.2. Optimization

Optimization is of concern not only to users, but also to regulators. This is because the requirement of paragraph 302 of the Regulations to keep exposures “as low as reasonably achievable” (ALARA), must be enshrined in national regulations. The implementation aspect is, however, of considerable importance because with the currently prevailing state of knowledge and practical experience, it is not possible to lay down specific prescriptions in regulations. In the event of a prosecution for failure to comply with an 'in-principle' regulatory prescription, the Competent Authority would be involved in establishing the technical case, probably on a more or less ad-hoc basis. The Compliance Assurance activity of the Competent Authority will consist in helping users to identify activities where it is desirable to improve practice. Such activities are likely to address such topics as the high volume of traffic or particular handling problems. The transport of technetium generators may be a possible candidate. In any particular case, the involvement of the Competent Authority should be advisory and exploratory in the first instance. Enforcement activities may need to be applied, but only as a last resort. The IAEA’s publication IAEA-TECDOC-374 [5] entitled “Discussion of and Guidance on the Optimization of Radiation Protection in the Transport of Radioactive Material” should be consulted for further information.

14.3.5.3. Segregation procedures

Paragraph 303 of TS-R-1 requires segregation procedures to limit possible doses to workers and to the public. This is a regulatory process, but is referred to here, as it is a practical aspect of implementation involving an extension of the provisions of the Regulations. For sea and air modes, the recommendations of IMO and ICAO are paramount, and should serve as the basis of the domestic rules. For surface transport modes, there may be pertinent international provisions, such as those of ADR, RID, ADN and ADNR (see Chapter 14) for countries in and around Europe. Segregation provisions will have to be made for transit storage as well as for handling at points of trans-shipment, at seaports and airports. The segregation provisions should take due account of national and local conditions, including the nature and volumes of radioactive material in transit, and the prevailing national customs and practice. The provisions should be subject to periodic review to ensure continued satisfactory implementation of the Regulations. Methods of deriving segregation provisions, with examples, are given in Appendix III of Safety Standards Series No. TS-G-1.1. Briefly, these rely on assumed maximum exposure times for workers and the public, that are calculated from estimated total travel times. Factors associated with the likelihood of encountering consignments of radioactive material are also included.

14.3.5.4. Periodic surveys

Paragraph 304 of the Regulations requires a Competent Authority to make periodic assessments to evaluate doses to workers and the public from transport. How this function should best be carried out depends on the circumstances. In some cases, measurements by Competent Authority personnel may be a suitable contribution. This could be the case in intensive, short-term studies undertaken at a specific site, such as an air or seaport. Such surveys could serve to provide sample values of doses to guide the control of certain areas of activity as well as to help assess overall exposures. Surveys that are more comprehensive may be based on data obtained from users, taken either from routine measurements, or because of special requests. The necessary extent of co-operation between the Competent Authority and users may be based on voluntary participation. It may also be useful for a Competent Authority to have legal power to require reporting if voluntary responses are not obtainable. As paragraph 304 of the Regulations makes clear, the results of surveys of exposures should be used to verify that the provisions of the IAEA's Basic Safety Standards for Radiation Protection are being met. The Competent Authority should consider making them available to the IAEA, both as evidence for the benefit of regulatory review panels and as a contribution to the database EXTRAM (see Chapter 18).

In paragraph A-304.2 of Safety Standards Series No.TS-G-1.1 [2] it is recommended that information on doses to workers and the public is collected at an appropriate frequency. Previous advice in earlier editions of the advisory material, (Safety Series No. 37), suggested that 5 years was a suitable frequency for such reviews. More frequent reviews should be undertaken if circumstances warrant, for example, if there have been significant changes in transport patterns or when a new technology involving radioactive material may have had a significant impact on transport.

14.3.5.5. Radiation protection programmes

As mentioned above the Competent Authority's involvement in Radiation Protection Programmes is primarily to ensure that they are developed and followed by those organizations involved in the shipment of radioactive material. Simply, where there is only one body responsible for all radiation protection matters, and that body is also the Competent Authority, it will be a relatively straightforward matter for it to ensure that suitable RPP's are developed and implemented. Where there is more than one authority with responsibility for radiation protection, the Competent Authority will need to review the activities and responsibilities of those organizations and ensure that the requirements of RPPs for transport are recognized and addressed. It will also have to develop and maintain suitable arrangements for the assessment and approval of RPPs when necessary.

The approval of RPPs for special use vessels is a highly specialized function. Relatively few countries are concerned with controlling such vessels. Those ships that are currently operating are mainly employed in the shipment of large quantities of spent nuclear fuel. Paragraph 575.2 of TS-G-1.1 [2] gives further advice on the type of information to be included in RPPs for special use vessels.

14.3.5.6. Instructions for dealing with undeliverable packages

Occasionally a package will be found to be undeliverable for various reasons, such as lost identity, illegible labelling, lost documentation, or damage in transport (usually involving international movements). Through its Compliance Assurance programme, the Competent Authority should make industry aware that such undeliverable packages are to be reported as soon as practicable. This will usually be after, but sometimes while, all reasonable efforts are being made to identify the original consignor or owner of the package.

The carrier's Quality Assurance programme and or radiation protection programme should identify and quarantine an undeliverable package and notify the incident to the Competent Authority. The Competent Authority will need to ensure that a responsible organization for the undeliverable package is identified and all best endeavours are made to trace the original consignor. In the event that the originating organization cannot be determined, the package will have to be examined in a place of safety so that its contents and final destination can be decided. The way in which such undeliverable packages will be managed inevitably depends on the infrastructure of the country concerned and the instructions issued by the Competent Authority. One fundamental principle however, should be clearly established, namely that anyone discovering such a package should be encouraged, in the interest of safety, to report its existence, condition and location without delay.

14.4. Administration

14.4.1. Issuance of certificates

The issuance of Competent Authority approval certificates is essentially an administrative function following an appropriate technical assessment. Paragraphs 827 to 833 of the TS-R-1 Regulations [1] have been carefully drafted to include all the necessary details and to ensure they are presented in a uniform, consistent manner. The actual format of certificates used in a given country will depend, to some extent, on the legislative system and the regulations in place there. However, the technical and administrative information included should always closely conform to that prescribed in the Regulations. The Competent Authority approval certificate is an important element in assuring safety.

If the details given in approval certificates are not adequate and consistent between those of the different Competent Authorities involved, there will be a serious risk of safety being compromised. Particular care must be taken when describing or specifying the actual contents of packages covered by such certificates. Therefore, technical provisions should be drawn up by the Competent Authority's technical staff, usually under the control of the officer having overall responsibility for the assessment.

As an administrative input to certificates, duration of validity should be appropriately assigned. Records should be carefully maintained as an essential contribution to Compliance Assurance. They also help ensure correct scheduling of significant actions such as re-inspection of packages after prolonged use. There should also be appropriate inputs to the IAEA's PACKTRAM database (see Chapter 18).

14.4.2. ID marking

An important administrative task is to allocate approval identification marks (paragraph 828(b) of TS-R-1) These should be assigned exactly according to the provisions of paragraphs 828 and 829 of the TS-R-1 Regulations [1]. It should be noted that a list of national VRI codes appears in Table IV of TS-G-1.1. Figures 14.12 and 14.13 show the make up of package identification marks and type codes respectively.

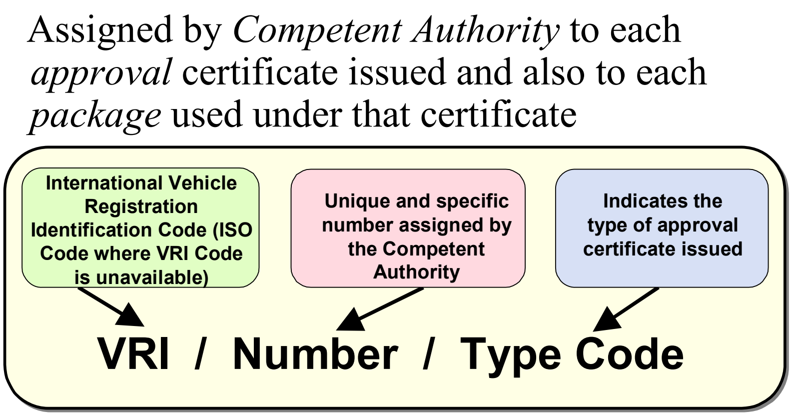


FIG. 14.13. Competent Authority identification marks.

Code	Type of Approval Certificate Issued
AF	*Type A package design* for *fissile material*
B(U)	*Type B(U) package design* [B(U)F if *fissile material*]
B(M)	*Type B(M) package design* [B(M)F if *fissile material*]
C	*Type C package design* (CF if for *fissile material*)
IF	*Industrial package design* for *fissile material*
S	*Special form radioactive material*
LD	*Low dispersible radioactive material*
T	*Shipment*
X	*Special Arrangement*

FIG. 14.14. Package type codes.

14.4.3. Receipt of notifications

Another aspect of administration is the receipt of notifications of shipments and copies of certificates. Besides being useful in the case of possible accidents, these documents also provide information on consignments of packages that have high activity contents, and those containing fissile material.

14.4.4. Recording of incidents

Notification of incidents in transport should be required by national regulations, and receiving and recording these is another Competent Authority administrative duty. This is another important source of information on transport events in a country. Input should be provided to the IAEA's EVTRAM database (see Chapter 18).

14.5. Information

14.5.1. Regulatory guidance

The national Competent Authority has special responsibility to provide information to the IAEA. This information serves as the basis for establishing, justifying, or changing Regulatory standards and provides general background knowledge on Regulatory applications for the mutual benefit of all Member States. The Competent Authority must also be a national source of information for various groups on the principles of the Regulations as well as on their use and interpretation. This implies that the Competent Authority must have considerable knowledge, not only of the Regulations, but also those of the relevant modal authorities.

14.5.2. Policy guidance to government and response to public concerns

As the Competent Authority will be acting for the government of its country, it will inevitably be required to give advice on matters relating to the safe transport of radioactive material. Depending on the structure of the Member State, the Competent Authority may well be responsible in determining certain policy matters, or simply advising ministers and/or other government bodies on such policy.

The Competent Authority should be prepared to give advice on the safety standards to government ministers, elected representatives, other government departments, local authorities, industry and the public. This can be in reply to requests for information or in response to perceived public concern. This is a field of considerable importance and activity in some countries and is likely to become increasingly important in many more countries.

14.5.3. Training

There is a need to provide training facilities and courses to instruct personnel concerned on the transport of radioactive material. This training can be provided directly by the Competent Authority or by specialized organizations with the necessary resources. When training courses are not provided directly by the Competent Authority, it is nevertheless valuable for all concerned to have the support and relevant participation of expert Competent Authority personnel. Such courses should be open to anyone in need of learning. Persons who customarily take advantage of these courses are consignor's personnel (particularly those responsible for preparing and despatching consignments and who have to sign the consignor's certificates), carrier personnel (drivers, and freight forwarding staff), emergency service officers (fire, police and ambulance personnel), customs officers and the Competent Authority's own staff. In addition to nationally organized courses, many organizations in developed countries will run their own internal courses on safe transport of radioactive material.

14.5.4. Co-ordination of research

The Competent Authority should help national research workers take advantage of opportunities to benefit from research activities elsewhere and to collaborate with other workers. The IAEA's co-ordinated research programmes, supported by the REDTRAM database (see Chapter 18), provide a means to encourage international collaboration in research.

14.5.5. Physical protection and safeguards

Consignments must be adequately protected from interference, whether unintentional or malicious, and also against theft and sabotage. This is a specialized concern, and the relevant authorities, which may include the civil police forces, need to decide where a threat exists and what action, if any, is required. The Competent Authority's role is to advise, as necessary, on the safety aspects. In this context, paragraph 108 of the TS-R-1 Regulations [1] points out that controls for physical protection must not be allowed to detract from the standards of safety. More information on physical protection, and safeguards, is given in IAEA-TECDOC-413 [6]. The IAEA has sponsored a convention on physical protection that includes transport.

14.5.6. Third party liability

This subject is fully discussed in Chapter 15. The Competent Authority may have an advisory role on safety in relation to the international conventions on liability, for the benefit of other governmental authorities or of insurers.

14.6. Addressing delay / denial of shipments

Because of difficulties encountered in the interfacing between various regulatory authorities including port authorities, customs officials, etc. it is possible that carriage of packages containing radioactive material may be denied or delayed. Extended storage of radioactive cargo in the public domain should, however, be minimized from radiological safety point of view. In addition, many of the sources have a short half-life and many of them are used for healthcare applications. At the same time, it is important that all the relevant regulatory requirements should be complied with. Close interaction is, therefore, necessary among all the relevant regulatory authorities. A mechanism should be established through which it is ensured by all the concerned authorities that the appropriate regulatory requirements are duly met. Such a mechanism would improve compliance and also minimize the number of instances avoidable delay or denial of shipments.

REFERENCES FOR CHAPTER 14

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Standards Series, Safety Requirements No. TS-R-1, IAEA, Vienna (2005).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1996 Edition), Safety Standards Series No. TS-G-1.1, IAEA, Vienna (2002).

[3] [INTERNATIONAL ATOMIC ENERGY AGENCY, Emergency Response Planning and Preparedness for Transport Accidents Involving Radioactive Material, Safety Standards Series No. TS-G-1.2, IAEA, Vienna (2002).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Compliance Assurance for the Transport of Radioactive Material, Safety Series No. 112, IAEA, Vienna (1994).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Discussion of and Guidance on the Optimization of Radiation Protection in the Transport of Radioactive Material, IAEA-TECDOC-374, IAEA, Vienna (1986).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Competent Authority Regulatory Control of the Transport of Radioactive Material, IAEA-TECDOC-413, IAEA Vienna (1987).

EXERCISES FOR CHAPTER 14

The following are exercises to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 14.1. Competent Authority Approvals

REFERENCE SOURCES: Training Manual, Chapter 14; TS-R-1, Sections II, VIII; and TS-G-1.1, Sections II and VIII.

DISCUSSION: Certain types of material, shipments, package designs, etc. require Competent Authority approval.

PROBLEM:

a. What types of material require Competent Authority approval? Is each approval required to be unilateral or multilateral, and where are these requirements found?

b. What types of shipments require Competent Authority approval? Is each approval required to be unilateral or multilateral, and where are these requirements found?

c. What types of package designs require Competent Authority approval? Is each approval required to be unilateral or multilateral, and where are these requirements found?

d. What additional actions or activities require Competent Authority approval? Is each approval required to be unilateral or multilateral, and where are these requirements found?

e. Why do only a few specific types of material require Competent Authority approval? Why do some of these specific types require multilateral approval while others require unilateral approval?

ANSWER:

EXERCISE 14.2. Competent Authority Identification

REFERENCE SOURCES: Training Manual, Chapter 14; and SS-113.

DISCUSSION: The Competent Authority is the key national or international regulatory body or authority designated or otherwise recognized in connection with the enforcement of the Regulations for radioactive material packages and transport activities under their jurisdiction.

PROBLEM:

a. How can one identify the Competent Authority in a given country?

b. Does each country have only one Competent Authority?

c. What are the primary responsibilities and functions of a Competent Authority as defined in Safety Series No. 112?

d. Safety Series No. 112 lists 12 features of a Competent Authority's Compliance Assurance programme. What are they? (Hint: See Annex I of Safety Series No. 112)

ANSWER:

EXERCISE 14.3. Transitional Arrangements for Old Package Designs

REFERENCE SOURCES: Training Manual, Chapters 8 and 14; and TS-R-1, Section VIII.

DISCUSSION: The Regulations address the subject of old package designs and how they can and cannot be used after new editions of the Regulations come into force. In some cases, old designs may continue to be used depending upon:

- The edition of the Regulations to which they have been designed,
- Whether those designs have been changed in a manner which affects safety,
- The date of manufacture of the packagings to that design, and
- The date of use of that packaging.

PROBLEM: A Type B package design was certified to the 1973 Edition of the Regulations. The Quality Assurance programme for that design has been upgraded to comply with the requirements of paragraph 306 of TS-R-1. Two packagings were manufactured to these designs in the late 1970's.

a. Can these two packagings continue to be used and, if so, what additional constraints are placed upon their use?

b. Can additional packagings be manufactured to this package design and used during the first decade of the 21st century?

ANSWER:

EXERCISE 14.4. Transitional Arrangements for Old Package Designs

REFERENCE SOURCES: Training Manual, Chapters 8 and 14; and TS-R-1, Section VIII.

DISCUSSION: The Regulations address the subject of old package designs and how they can and cannot be used after new editions of the Regulations come into force. In some cases, old designs may continue to be used depending upon

- The edition of the Regulations to which they have been designed
- Whether those designs have been changed in a manner that affects safety
- The date of manufacture of the packagings to that design, and
- The date of use of that packaging.

PROBLEM: A Type B package design was certified to the 1985 (As Amended 1990) Edition of the Regulations. The Quality Assurance programme for that design has been upgraded to comply with the requirements of paragraph 306 of TS-R-1. Two packagings were manufactured to these designs in the early 1990's.

a. Can these two packagings continue to be used and, if so, what additional constraints are placed upon their use?

b. Can additional packagings be manufactured to this package design and used during the first decade of the 21st century?

ANSWER:

15. ADDITIONAL REGULATORY CONSTRAINTS FOR TRANSPORT

15.1. Introduction

In addition to the IAEA, there are a number of bodies and agreements that have important roles in the transport of dangerous goods. Several of the bodies are specialized UN agencies that fall under the umbrella of the Economic and Social Council (ECOSOC). Internationally, the responsibilities tend to be split according to the mode of transport.

The International Maritime Organization (IMO) has a large responsibility with respect to the International Maritime Dangerous Goods Code (IMDG Code) which covers the transport of hazardous material by sea.

The International Civil Aviation Organization (ICAO) produces standards and recommended practices for the transport of dangerous goods by air. The International Air Transport Association (IATA) has incorporated these into a set of industry-related requirements.

The transport of radioactive material through the post falls under the concern of the Universal Postal Union (UPU).

In Europe, inland transport is regulated by various agreements. Rail and road transport of dangerous goods is covered by the Regulations concerning the International Carriage of Dangerous Goods by Rail (RID) and the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR). A European Agreement concerning the International Carriage of Dangerous Goods on Inland Waterways (ADN) is being developed and there are specialized regulations for the Rhine (ADNR).

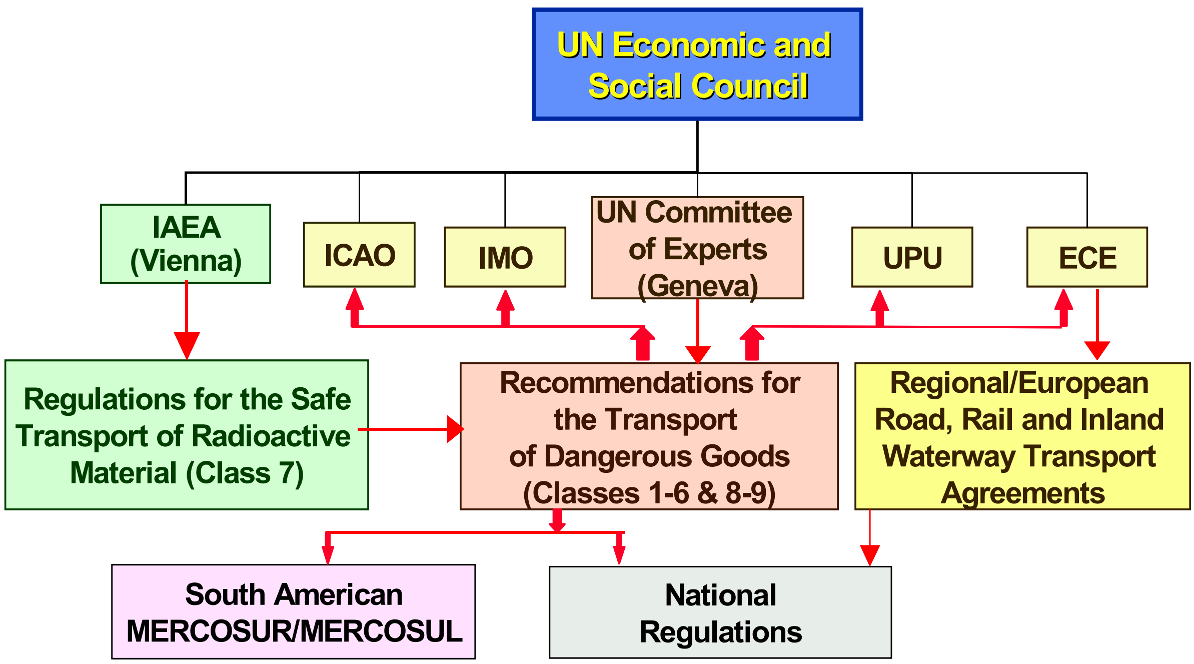


FIG. 15.1. The main international modal organizations and their inter-relationships.

In South America, MERCOSUR/MERCOSUL member countries use this agreement to regulate the transport of dangerous goods by road, rail, air, and sea.

15.2. United Nations Economic and Social Council Committee of Experts on the Transport of Dangerous Goods (UN-ECOSOC)

The United Nations initiated the development of recommendations on a broad international basis to assist national authorities in ensuring the safe transport of hazardous material by different modes of transport. Under the authority of the Economic and Social Council (ECOSOC), the Committee of Experts on the Transport of Dangerous Goods supervises the work.

The UN Committee of Experts issues Recommendations on the Transport of Dangerous Goods [1]. These Recommendations have been universally accepted as the basis for national and international regulations covering various modes of transport. The current "Recommendations of the Committee of Experts", known in the transport world as the "Orange Book", were developed from an original version approved by the ECOSOC in 1957.

Two of the main achievements of the Committee of Experts have been the establishment of a classification system for dangerous goods and the adoption of a corresponding set of labelling standards. For this purpose, dangerous goods are divided into nine classes:

Class 1 -	Explosives
Class 2 -	Gases: compressed, liquified, or dissolved under pressure
Class 3 -	Flammable liquids
Class 4.1 –	Flammable solids
Class 4.2 –	Substances liable to spontaneous combustion
Class 4.3 –	Substances which, in contact with water, emit flammable gases
Class 5.1 -	Oxidizing substances
Class 5.2 –	Organic peroxides
Class 6.1 -	Poisonous (toxic) substances
Class 6.2 –	Infectious substances
Class 7 -	**Radioactive materials**
Class 8 -	Corrosives
Class 9 -	Miscellaneous dangerous substances.

This classification system has been adopted by all international organizations concerned with the transport of dangerous goods. Figure 15.2 shows the labels used in this classification system.

FIG. 15.2. International dangerous goods labels.

As early as 1959, the ECOSOC adopted a resolution entrusting the IAEA with the task of establishing recommendations for the safe transport of radioactive material. The “Orange Book” and IAEA Safety Series No. 6 therefore, have developed on a consistent basis. This has ensured full compatibility between the treatment of radioactive material and other dangerous goods. In particular, there is agreement on the basic principle of ensuring safety through the packaging employed and placing responsibility for the provision of adequate packaging on the consignor. Up to 1996, the Orange Book was presented under the form of Recommendations laid down in various chapters. In 1997, it was published under the form of “Model Regulations” annexed to basic recommendations. The aim of this reformatting was to guarantee an improved uniformity between all legal instruments regulating the transport of dangerous goods at the national or international level, and to facilitate the development of suitable legislation in developing countries. In its old format, the “Orange Book” dealt with radioactive material mainly by referring to the IAEA Regulations. IAEA and the UN Committee of Experts are now co-operating in order to include all relevant provisions of IAEA TS-R-1 into the UN “Model Regulations on the Transport of Dangerous Goods”, on the basis of the revised format of the Orange Book.

In addition to the general recommendations of the United Nations and a number of agreements, the competent bodies for the different modes of transport have established regulations and recommendations related to the transport of dangerous goods, including radioactive material. In some cases, observance of the requirements is mandatory for the relevant mode. In all cases, the IAEA Transport Regulations have been incorporated as the requirements for the transport of radioactive material. They are, where appropriate, expanded to include specifications of segregation distances between packages and persons or photographic films.

Representatives of the organizations responsible for preparing these international agreements and regulations have taken part in all the detailed discussions leading to the establishment and updating of the IAEA transport Regulations. This has undoubtedly facilitated the incorporation of uniform requirements. Although international regulations for the different modes of transport may undergo major reviews at different times, all efforts have been made to ensure simultaneous entry into force of various amendments applying to all these regulations. In addition, the future harmonisation of the format of all the regulations based on the UN Model Regulations is expected to facilitate co-ordination and to eventually eliminate any temporary disparities. Fig. 15.3 shows the incorporation process of the IAEA Regulations into the various modal organizations.

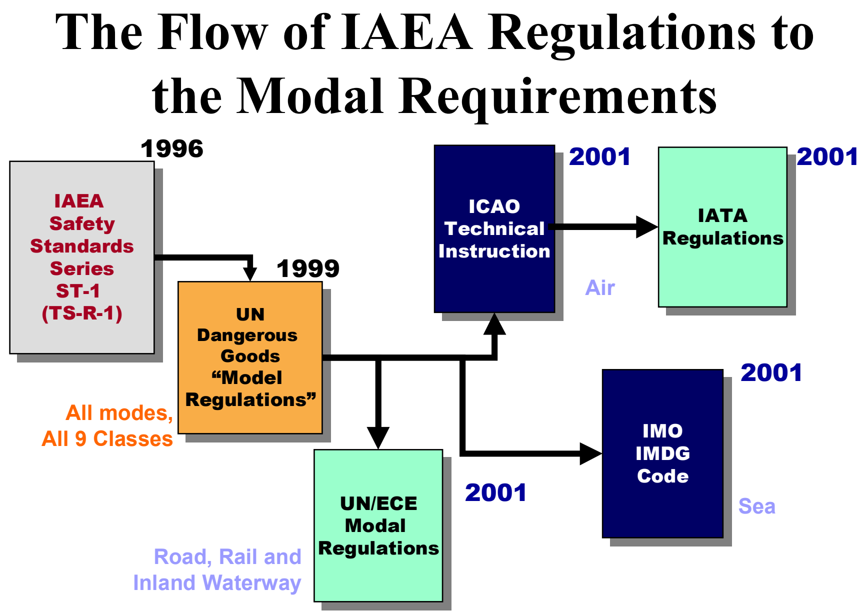


FIG. 15.3. Process of incorporating the requirements of the IAEA Transport Regulations into the Modal Regulations.

15.3. Transport by sea — International Maritime Organization (IMO)

15.3.1. Introduction

15.3.1.1. Foundation and purpose

The International Maritime Organization (IMO) is a United Nations specialized agency, dealing with all aspects of international maritime affairs. The Convention establishing the IMO was adopted on 6 March 1948 by the United Nations Maritime Conference in Geneva. This Convention entered into force on 17 March 1958. The new Organization was inaugurated on 6 January 1959 when the assembly held its first session. The name of the Organization was changed to the International Maritime Organization in May 1982.

The purposes of the Organization are “to provide machinery for co-operation among Governments in the field of governmental regulation and practices relating to technical matters of all kinds affecting shipping engaged in international trade; encourage and facilitate the general adoption of the highest practicable standards in matters concerning maritime safety, efficiency of navigation and prevention and control of marine pollution from ships”. The Organization is also empowered to deal with administrative and legal matters related to these purposes.

15.3.1.2. Members

IMO has 155 Member States and two Associate Members, as of 1 March 1998. The Organization is based in London, and is the only United Nations specialized agency to have its headquarters in the United Kingdom.

15.3.1.3. Structure

The governing body of IMO is the Assembly, which meets once every two years. Between sessions of the Assembly, a Council, consisting of 32 Member States elected by the Assembly, acts as the IMO's governing body. There are also five committees and a number of subcommittees in which most of the Organization's work is carried out.

The Maritime Safety Committee (MSC) is the most senior of the committees that carry out the Organization's technical work. It has a number of subcommittees including one dealing with dangerous goods.

The Marine Environment Protection Committee (MEPC) is responsible for co-ordinating the Organization's activities in the prevention and control of pollution of the marine environment from ships.

The Legal Committee (LEG) was originally established to deal with the legal problems arising from the Torrey Canyon accident of 1967, but it was subsequently made a permanent committee. It is responsible for considering any legal matters within the scope of the Organization.

The Technical Co-operation Committee (TC) is responsible for co-ordinating the work of the Organization in the provision of technical assistance, in particular to the developing countries. The importance of technical assistance in IMO's work is shown by the fact that it is the first Organization in the United Nations system formally to recognize a Technical Co-operation Committee in its Convention.

The Facilitation Committee (FAL) is responsible for IMO's activities and functions relating to facilitating international maritime traffic. These are aimed at reducing the formalities and simplifying the documentation required of ships when entering or leaving ports or other terminals.

All the committees and subcommittees of IMO are open to participation by all Member States on an equal basis.

15.3.2. IMO regulations concerning the transport of dangerous cargoes

It is estimated that more than 50% of packaged goods and bulk cargoes transported by sea today can be regarded as dangerous, hazardous, or harmful to the environment according to IMO criteria. The cargoes concerned include products that are transported in bulk, such as solid or liquid chemicals and wastes, as well as gases and products relating to the oil industry.

Over the last four decades, IMO has become recognised as the maritime community's forum for all matters affecting the safety of shipping. The transport of dangerous cargoes has been one of IMO's responsibilities since it came into being and a number of relevant regulations and recommendations have been developed. Several useful IMO publications related to dangerous, hazardous, and harmful cargoes are listed in the references.

15.3.2.1. International Convention for the Safety of Life at Sea (SOLAS), 1974

The SOLAS Convention [2] is generally regarded as the most important of all international treaties concerning the safety of merchant ships. The first version was adopted in 1914, the second in 1929 and the third in 1948.

The 1960 SOLAS Convention was the first major task for IMO after its creation and it represented a considerable step forward in modernizing regulations and in keeping pace with technical developments in the shipping industry. Chapter VII of the revised 1960 SOLAS Convention, which entered into force in May 1965, dealt exclusively with the carriage of dangerous goods. With a few exceptions, SOLAS 1960 applied to all ships engaged on international voyages with gross tonnage of 500 tons or more. This was later amended to include cargo ships of less than 500 tons gross tonnage. The 1974 SOLAS Convention has been ratified by 137 countries, the combined merchant fleets of which constitute approximately 98% of the gross tonnage of the world's merchant fleet.

Regulation 1 of Chapter VII prohibits the carriage of dangerous goods by sea except when they are carried in accordance with the provisions of the SOLAS Convention. It also requires each Contracting Government to issue, or cause to be issued, detailed instructions on safe packing and stowage of dangerous goods which must include the precautions necessary in relation to other cargo. In a footnote, reference is made to the more detailed provisions of the International Maritime Dangerous Goods (IMDG) Code [3].

Regulation 2 divides dangerous goods into nine classes. The other six regulations deal with: the packing; identification; marking, labelling and placarding of dangerous goods; shipping documentation; stowage and segregation requirements; the carriage of explosives on board passenger ships; and the reporting of incidents involving dangerous goods.

It should be noted that Chapter VII contains mandatory requirements and thereby provides the necessary legal basis for International and National Regulations for the Transport of Dangerous Goods by Sea.

15.3.2.2. International Maritime Dangerous Goods (IMDG) Code

The fourth IMO Assembly adopted the IMDG Code [3] in 1965. This was the result of the SOLAS Conference recommending that IMO, in co-operation with the United Nations Committee of Experts on the Transport of Dangerous Goods, should pursue its studies on a uniform international code for the carriage of dangerous goods by sea. It was envisioned that this would supplement the SOLAS regulations and cover such matters as packing, container traffic, and stowage, with particular reference to the segregation of incompatible substances, especially with respect to classification, description, and labelling.

Although designed primarily for mariners, the provisions of the IMDG Code affect a number of industries as well as storage, handling and transport services from manufacturers to consumers. Chemical and packaging manufacturers, packers, shippers, forwarders, carriers and terminal operators are guided by its provisions on classification, terminology, identification, packing and packagings, marking, labelling and placarding, documentation and marine pollution aspects. Its provisions guide feeder services, such as road, rail, harbour, and inland watercraft. Port authorities, terminal, and warehousing companies consult the IMDG Code to segregate and separate dangerous cargoes in loading, discharge, and storage areas. Although the Code only applies to ships covered by the SOLAS Convention, IMO considers it highly desirable that all ships should observe its provisions.

Since its introduction in 1965, the IMDG Code has undergone many changes, both in appearance and in content to keep pace with the ever-changing needs of industry. The Maritime Safety Committee alone may adopt amendments that do not affect the principles upon which the Code is based. Thus, IMO can respond to transport developments in a reasonable time frame.

Amendments to the IMDG Code originate from two sources: (1) proposals submitted directly to IMO by Member States, and (2) amendments required to take account of changes to the United Nations Recommendations on the Transport of Dangerous Goods. The Committee of Experts makes amendments to the provisions of the United Nations Recommendations on a two-yearly cycle. Approximately two years after their adoption by the Committee, the authorities responsible for regulating the various transport modes adopt them. In that way a basic set of requirements applicable to all modes of transport is established and implemented, thus ensuring that difficulties are not encountered at inter-modal interfaces.

As a result of an Assembly resolution adopted by the IMO in November 1991, amendments to the United Nations recommendations are incorporated into the IMDG Code to ensure that it remains harmonized with the requirements of the other transport modes. The latest amendment harmonizes the Code with the tenth revised edition of the United Nations Recommendations on the Transport of Dangerous Goods. This Amendment will enter into force on 1 January 1999, with a six-month transitional period permitted until 1 July 1999.

The IMDG Code is published in three volumes. Volume I contains Parts 1 (general provisions, definitions and training), 2 (classification), 4 (packing and tank provisions), 5 (consignment procedures), 6 (construction and testing of packagings, intermediate bulk containers (IBCs), large packagings, portable tanks and road tank vehicles), and 7 (provisions concerning transport operations). Volume 2 contains Part 3 (dangerous goods list and limited quantities exceptions). The Supplement contains the details of procedures for packing of dangerous goods or actions to take in the event of an emergency or accident involving personnel who handle goods at sea:

- Emergency Procedures for Ships Carrying Dangerous Goods, Group Emergency Schedules (EmS);
- Medical First Aid Guide for Use in Accidents Involving Dangerous Goods (MFAG);
- Reporting Procedures, General Principles for Ship Reporting Systems and Ship Reporting Requirements including Guidelines for Reporting Incidents involving Dangerous Goods, Harmful Substances and/or Marine Pollutants;
- Guidelines for Packing of Cargo Transport Units (CTUs);
- Safe Use of Pesticides in Ships;
- International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel; Plutonium and High-Level Radioactive Wastes in Flasks on Board Ships (INF Code); and
- An Appendix containing Resolutions and Circulars referred to in the IMDG Code and its Supplement.

The requirements for each class of dangerous goods is preceded by an introduction that describes the properties, characteristics, and definitions of the goods and gives detailed advice on handling and transport. Stowage and segregation provisions are also detailed. The class introductions give information concerning procedures that should be followed during loading and unloading.

Each substance, material or article that is listed in the IMDG Code is referred to by a proper shipping name (correct technical name) together with a four-digit UN Number assigned to the goods by the United Nations Committee of Experts on the Transport of Dangerous Goods. Each package containing dangerous goods should be durably marked with the proper shipping name of the contents, and, when assigned, the corresponding UN Number preceded by the letters “UN”.

A distinctive mark, label, placard, or sign identifies each class or category of goods. Where appropriate, each individual schedule (page) in the Code refers to the required label and, if applicable, the marine pollutant mark and elevated temperature or fumigation warning signs.

The other headings used in the individual schedules include properties or descriptions (such as state and appearance), special observations, packing, stowage, segregation and the marine pollution aspects. The schedule also indicates the label or labels/placards and, if applicable, the MARINE POLLUTANT and other signs required on the package or cargo transport unit.

The provisions for **class 7 - radioactive materials** are based upon the requirements of the International Atomic Energy Agency’s (IAEA) Regulations for the Safe Transport of Radioactive Material (TS-R-1). They offer guidance to those involved in handling and transport of radioactive material in ports and on ships without necessarily consulting the IAEA’s Transport Regulations. However, references to the IAEA Regulations have been included in the class 7 IMDG Code texts. A typical ship loading Class 7 material is shown in Figure 15.4.

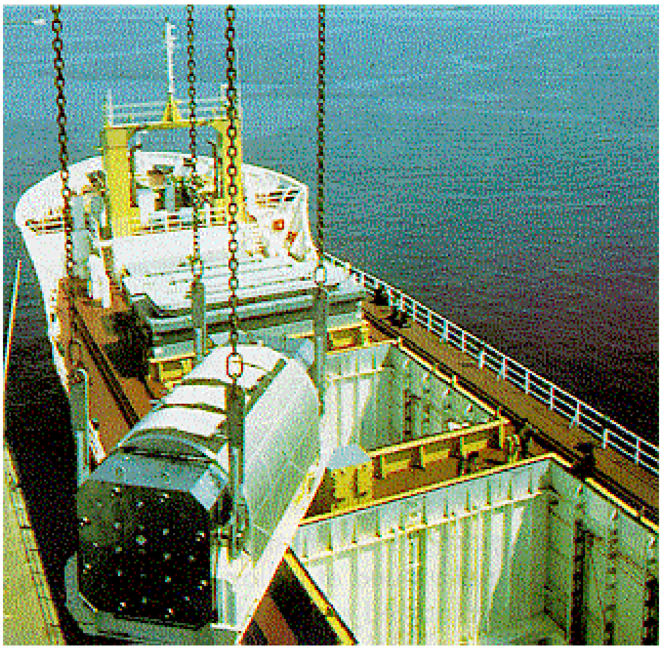


FIG. 15.4. Ship loading Class 7 package.

Packing, labelling, and placarding, stowage, segregation, and other requirements vary according to the radioactivity of the material. Radioactive material is divided into three categories, depending upon radiation levels, category I (white) being the least dangerous. The labels for categories II and III (yellow) are printed in yellow and white for additional emphasis. For Class 7, a special placard has been developed.

IMO Member Governments are periodically requested to provide information on the current status of implementation of the IMDG Code, its Annexes and Supplements. In addition, they are requested to provide the names, addresses, telephone, telex and fax numbers of the offices of Competent Authorities and other appointed bodies within their administration which deal with questions related to the carriage of dangerous cargoes.

Some 51 States, whose combined merchant fleets total 80% of the world's gross tonnage, have currently informed the IMO that they are applying the IMDG Code (Table 15.1). It is appropriate, however, to assume that most of the 137 Contracting States to the 1974 SOLAS Convention are effectively implementing the provisions of the IMD Code. The legal system of each country determines in detail whether the IMDG Code becomes mandatory or whether it is applied as a recommendation. At the time of writing, the possible mandatory application of the IMDG Code, by amending Chapter VII of the SOLAS Convention is under discussion.

15.3.2.4. Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes in Flasks on Board Ships (INF Code)

The lack of specific requirements in the SOLAS Convention and the IMDG Code, and the increase in the maritime transport of irradiated nuclear fuel, plutonium, and high-level radioactive wastes were the driving forces that led to the development of the INF Code. The United Nations Conference on Environment and Development (UNCED) encouraged the IMO and the IAEA to work together to complete consideration of a code on the carriage of irradiated nuclear fuel in flasks on board ships. Consequently, a joint IMO/IAEA/UNEP Working Group on the Safe Carriage of INF and other Nuclear Materials by Sea was established in 1992. This group prepared the draft INF Code, which was subsequently approved by the relevant committees and finally adopted by the IMO in November 1993 [9].

In adopting the resolution, the Assembly urged Member States to implement the INF Code at the earliest opportunity and concluded that it should be kept under review and amended, as necessary. The Code, which applies to all ships, regardless of size, engaged in the carriage of irradiated nuclear fuel, plutonium, and high-level radioactive wastes in flasks, principally covers matters of such ship's design, construction, and equipment.

In November 1997, the INF Code was further amended with respect to how irradiated nuclear fuel, plutonium and high-level radioactive wastes in flasks should be carried. Under the amendments to the Code, ships transporting INF Code materials should carry a shipboard emergency plan, which should include:

- Procedures to be followed in reporting an incident involving INF Code material;
- A list of authorities or persons to be contacted in the event of an incident;
- Descriptions of actions to be taken immediately to prevent, reduce or control the release of INF Code material; and
- Procedures, and points of contact on the ship for co-ordinating action with local and national authorities.

The INF Code amendments also cover notification of an incident involving INF Code material. The amendments state that the reporting requirements for incidents involving dangerous goods should apply both to the loss of INF Code cargo overboard and to any incident involving release, or probable release of INF Code material. A report should also be made in the event of damage, failure, or breakdown of a ship carrying INF Code material.

The mandatory application of the INF Code is under consideration by the relevant IMO bodies. The Maritime Safety Committee in June 1997 agreed that the INF Code should be made mandatory by drafting the necessary amendments to Chapter VII of the SOLAS Convention.

15.3.3. Technical assistance

IMO's technical assistance programme has grown considerably in recent years and is now one of the Organization's most important activities. Although many developing countries have financial difficulties, probably the most important problem they face is the shortage of experienced and expert personnel. Although this is true for many maritime activities, it is particularly true in complex areas such as the transport of dangerous, hazardous and harmful cargoes.

The improvement of maritime training has been one of IMO's priorities since its inception. IMO tackles the subject in two ways. Firstly, it adopts international standards and regulations in conventions, codes, and recommendations that are designed to be implemented at the national, regional or international level. Secondly, it provides practical assistance and advice to countries, particularly developing countries, for the improvement of training programmes. Few sectors of industry have seen such rapid progress as has been made in raising safety standards in the transport of dangerous goods. Nevertheless, much work remains to be done.

15.3.3.1. The World Maritime University

The opening of the World Maritime University (WMU) in July 1983 has led to major improvements in the implementation (see Table 15.1) of IMO's safety standards. The purpose of the University, which is based in Malmö, Sweden, is to provide advanced training for senior experts and administrators. In particular, WMU focuses on those from developing countries in various fields of maritime activities, including the safe transport of dangerous, hazardous and harmful cargoes by sea. Training of this type is often lacking in developing countries. The University is fully supported by IMO Member States and the maritime community as a whole.

The University offers two-year degree courses on general maritime administration and environment protection, maritime safety administration, maritime education, and training, port management, and shipping management.

15.3.3.2. The IMO model course programme

The model course programme was developed out of suggestions from a number of IMO Member Governments, following the adoption of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978. Assisted by the Government of Norway, IMO has designed a series of courses to help implement this Convention and, further, to facilitate access to the knowledge and skills demanded by an increasingly sophisticated maritime technology. The courses are flexible in application.

Maritime Institutes and their teaching staff can use them in organizing and introducing new courses or in enhancing, updating or supplementing existing training material.

The aim of this programme is to make available to developing countries a number of model training courses in order to enhance current maritime training programmes or to develop additional, specialized maritime training. The maritime courses reflect the requirements of the IMO international conventions governing ship safety and the prevention of pollution and therefore, will contribute to the establishment of minimum global standards of training.

Many other model training courses will relate to "state of the art" maritime activities and will contribute to the increasing professional knowledge and expertise of ship operators ashore and afloat.

The development of a real and effective minimum standard of maritime training throughout the world will enhance ship operational safety and provide a much safer and cleaner environment. Such a development will also enable maritime standards to be improved periodically on a worldwide basis in a much more effective way.

TABLE 15.1. INTERNATIONAL MARITIME DANGEROUS GOODS (IMDG) CODE IMPLEMENTATION BY IMO MEMBER COUNTRIES

No.	Member country	Date of implementation	Gross tonnage	Percentage of world's tonnage
1	Algeria	–	935,812	0.20
2	Argentina	1981	715,747	0.15
3	Australia	20.03.68	3,012,177	0.63
4	Bahamas	1976	22,915,349	4.82
5	Belgium	20.07.73	233,390	0.05
6	Brazil	4.10.72	5,282,869	1.11
7	Bulgaria	1.01.83	1,294,941	0.27
8	Canada	1982	2,489,520	0.52
9	Chile	24.10.78	720,987	0.15
10	China	1.10.82	15,826,688	3.33
11	Denmark	1.02.72	5,798,908	1.22
12	Ecuador	–	269,640	0.06
13	Finland	1.01.81	1,403,711	0.29
14	France	8.08.68	4,347,617	0.91
15	Gambia	12.06.91	2,512	0.00
16	Germany	7.04.72	5,696,088	1.20
17	Greece	4.02.74	30,141,758	6.34
18	Iceland	20.09.82	174,508	0.04
19	India	4.11.78	6,485,374	1.36
20	Iran, Islamic Republic of	–	3,803,342	0.80
21	Ireland	1968	190,311	0.04
22	Israel	11.11.72	645,683	0.14
23	Italy	1968	6,818,178	1.43
24	Japan	1.10.79	22,101,606	4.64
25	Liberia	1.03.79	57,647,708	12.11
26	Malaysia	–	2,727,572	0.57
27	Morocco	1958	362,151	0.08
28	Netherlands	1.01.74	4,396,246	0.92
29	New Zealand	9.02.79	251,205	0.05
30	Norway	1971	22,387,936	4.70
31	Pakistan	1.09.73	374,949	0.08
32	Panama	March 1986	64,170,219	13.49
33	Papua New Guinea	–	46,528	0.01

34	Peru	1.01.70	321,460	0.07
35	Philippines	5.01.81	9,413,228	1.98
36	Poland	9.01.74	2,609,678	0.55
37	Portugal	1986	883,905	0.19
38	Republic of Korea	1.07.79	7,004,199	1.47
39	Russian Federation	1.01.69	14,503,871	3.47
40	Saudi Arabia	March 1985	1,064,052	0.22
41	Singapore	14.06.81	11,894,846	2.50
42	South Africa	21.11.75	330,725	0.07
43	Spain	27.11.88	1,560,101	0.33
44	Sweden	1.08.81	2,796,519	0.59
45	Switzerland	1.02.73	336,174	0.07
46	Thailand	–	1,373,501	0.29
47	United Kingdom	29.12.78	4,433,128	0.93
48	United States	10.11.80	13,655,438	2.87
49	Uruguay	25.04.85	125,053	0.03
50	Vanuatu	28.10.82	1,998,017	0.42
	Associate member			
51	Hong Kong, China	29.12.78	7,703,410	1.62
				79.38

15.4. Transport by air

Two organizations play a role in the regulation of hazardous materials transported by air. These are the International Civil Aviation Organization and the International Air Transport Association.

15.4.1. International Civil Aviation Organization (ICAO)

15.4.1.1. Organization

The International Civil Aviation Organization (ICAO) is a United Nations Agency that deals with all aspects of international civil aviation. The Organization was set up in 1944 as a result of an agreement on a Convention on International Civil Aviation. The meetings that produced the Convention were held in Chicago, USA, and therefore the Convention is known as the Chicago Convention. The headquarters of ICAO is in Montreal, Canada, and there are seven regional offices, each of which is related to an appropriate group of Member States. The membership of ICAO comprises those countries (states) which have air operators involved in international civil aviation. At the time of writing this involves 185 Member States. The overall body responsible for ICAO is the Assembly, which has members from all states. Below that is the Council, which deals with all day-to-day affairs and which has members from a representative selection of states. One of the main groups reporting to the Council is the Air Navigation Commission. The Commission is responsible for dealing with all matters affecting aircraft safety.

ICAO develops standards and recommends practices covering all areas of civil aviation and these are produced as annexes to the Convention. The development of these standards and recommended practices is carried out by groups of people who have expertise in the subject under discussion. These groups are usually called panels and they report to the Air Navigation Commission. Once a panel has developed an annex, it is sent formally to states to agree or disagree with all or any part of it. States are required to notify a disagreement within a set period of time. Failure to respond by the state is taken as an agreement.

Once an annex is adopted, dates are agreed within ICAO as to when it will come into effect and when it will become applicable. The effective date is the earliest date from which it can be introduced and the applicable date is the latest date for introduction. Member States of ICAO are bound by the Convention to incorporate annexes into national legislation or file "differences". The differences are listed in the annex to show where national legislation in a state requires something different to that agreed as the standard by an annex. It is through the incorporation of annex material into national legislation that worldwide compatibility on civil aviation is achieved.

15.4.1.2. Technical Instructions for the Safe Transport of Dangerous Goods by Air

For nearly thirty years, the air transport industry, through its trade association, has developed and obtained some measure of international acceptance of regulations for the transport of dangerous goods by air. Such regulations, however, do not carry the force of policy control by Member States required to ensure full international acceptance and compliance. For this reason, the ICAO Air Navigation Commission established a Dangerous Goods Panel of Experts for the development of appropriate "Standards and Recommended Practices", together with supporting "Technical Instructions".

It was agreed that the work of the panel should be based on the recommendations of the UN Committee of Experts on the Transport of Dangerous Goods and the IAEA Transport Regulations, taking into account the IATA Restricted Articles Regulations. The result of this work was that in 1981 ICAO adopted a new annex dealing with the safe transport of dangerous goods by air. The effective and applicable dates for this annex were 1st of January 1983 and 1st of January 1984. In addition to the annex, a set of Technical Instructions [10] was published which detailed the requirements for carrying dangerous goods by air. These Technical Instructions reflect the IAEA Regulations in regard to the carriage of radioactive material by air. A standard in the annex requires states to ensure compliance with the Technical Instructions for all international air transport and there is a recommendation that the Instructions be used for domestic air transport. States are also required to have inspection and enforcement procedures.

The Dangerous Goods Panel is now responsible for ensuring the Annex and the Technical Instructions for the Safe Transport of Dangerous Goods by Air are kept up-to-date. There are regular meetings of the Panel to do this, at which proposals for change are discussed. These proposals are made by Panel members and are usually in response to problems encountered in using the Technical Instructions. The Panel also receive the reports of the UN Committee of Experts showing the changes to the Recommendations on the Transport of Dangerous Goods. From them, they produce the amendments necessary to the Instructions to keep them in line with the UN Recommendations. Amendments to the IAEA Regulations are also incorporated as changes to the Instructions, to ensure that the requirements for radioactive material remain compatible in all the modes of transport and between domestic and international transport.

The Technical Instructions contain, among other things, a list of dangerous goods, including radioactive material, which is based on that of the UN. They also provide for classifying goods according to the UN system and give quantity limitations for each item, together with requirements for packing, marking, labelling, and documentation. In some instances the transport of dangerous goods is strictly forbidden or controlled by specific approval given by the appropriate National Competent Authorities. For radioactive materials, the Technical Instructions are consistent with the IAEA Regulations. They contain tables indicating the minimum distances, corresponding to specified total sums of transport indices, from the surface of packages to the inner floors of passenger cabins and flight decks, irrespective of the duration of transport. They also provide minimum distances from the surface of packages to undeveloped photographic film, for various flight times. Packages for which the total sum of the transport indices is greater than 50 must be carried as a full load. Figure 15.5. shows Class 7 packages being loaded onto an aircraft.

FIG. 15.5. Packages being loaded onto an aircraft.

15.4.2. The International Air Transport Association (IATA)

The International Air Transport Association, IATA, is the trade association representing scheduled airline carriers worldwide. It includes both passenger and cargo carriers. Founded in 1945 under a Special Act of Incorporation of the Canadian Parliament, its objectives include the promotion of safe, regular and economical air transport. It currently comprises over 250 member airlines operating under the flags of over 100 nations. IATA is based in Geneva, Montreal, London, and Singapore.

In 1950, IATA recognized the need for an international standard for the transportation of dangerous goods by air. In consequence, a Restricted Articles Board (RAB) comprising experts acting on behalf of all member airlines was instituted with the goal of developing requirements for the transport of restricted articles by air. Restricted articles later became known as dangerous goods. Unless countries objected, these requirements became binding to IATA member airlines.

One of the main tasks assigned to the RAB was to develop and continuously review the IATA Restricted Articles Regulations (RAR). The first edition of RAR was issued for worldwide use in 1956 and updated editions were issued on a regular basis until 1983. At this point IATA recognized that in order to ensure enforcement of standards for the safe carriage of dangerous goods, government action was required. In consequence, IATA worked closely with the ICAO in developing the ICAO Technical Instructions for the Safe Transportation of

Dangerous Goods. However, IATA recognized that Dangerous Goods Regulations are complex. They saw the need for a "field manual" of the Technical Instructions that would be easily understandable and applicable to all sectors of the air transport industry. Hence, the RAR was re-titled the Dangerous Goods Regulations (DGR) [11]. It reproduced, with a number of additions (e.g. specific format for the Shipper's Declaration and explanatory notes), the provisions contained in the Technical Instructions. The DGR is updated by an IATA Dangerous Goods Board (DGB) and published annually, whilst the Technical Instructions is published every two years. The DGR acknowledges that it is developed from the Technical Instructions and recognizes that those Instructions are the legal source material for the transport of dangerous goods by air. The DGR is consistent with the Technical Instructions.

It should be noted that close co-ordination exists between IAEA, ICAO, and IATA. This ensures that changes to Regulations concerning radioactive material to be transported by air are included in the current editions of the ICAO Technical Instructions, the IATA Dangerous Goods Regulations and the IAEA's TS-R-1 as appropriate.

15.5. Transport by post - Universal Postal Union (UPU)

The Universal Postal Convention establishing the Universal Postal Union (UPU) was adopted by an international conference held in Berne in 1874. The UPU is now a specialized agency of the United Nations, with its headquarters in Berne, Switzerland. Any member of the United Nations may accede to the Union, and sovereign countries, which do not belong to the UN, may also request admission to the UPU.

Member countries are considered as forming "a single postal territory for the reciprocal exchange of letter-post items". The Acts of the UPU, affecting practically the entire population of the world, now binds 189 countries.

The UPU Congress meets at intervals of not more than five years to consider and approve among other things, any changes to the Acts. Urgent changes needed to be introduced in the Detailed Regulations for Implementing the Convention may be adopted in the interval between Congresses pending approval by one of the UPU's bodies in charge of operational questions: the Postal Operations Council.

One of the main Acts of the Universal Postal Union is the Convention and its Detailed Regulations. It deals with technical issues pertaining to postal operations, including the conditions of acceptance and marking of items containing radioactive materials. The issue of radioactive materials transported by post is also dealt with in the Postal Parcels Agreement.

Under the UPU Convention and Detailed Regulations (article RE 2402), the contents and make-up of items containing radioactive materials must comply with the Regulations of the International Atomic Energy Agency providing special exemptions for certain categories of items. One exemption is as follows: a consignment of radioactive material in which the activity of the contents does not exceed one tenth of the limits prescribed in Table IV of TS-R-1.

A consignment that conforms to these requirements may be accepted for international movement by post, subject to the following additional requirements:

(1) Prior consent from the Competent Authorities of the country of origin;

(2) It shall be dispatched by the quickest route, normally by air;

(3) The outside packing of items containing radioactive materials shall be plainly and durably marked by the sender with the words *"Matières radioactives. Quantités admises au transport par la poste"* (RADIOACTIVE MATERIAL. QUANTITIES PERMITTED FOR MOVEMENT BY POST); these words shall be officially crossed out if the packaging is returned empty to the place of origin. It shall also bear, in addition to the name and address of the sender, a request in bold letters for the return of the items in the event of non-delivery;

(4) The sender shall give his name and address and the contents of the item on the inner wrapping; and

(5) Administrations may designate special post offices for the posting of items containing radioactive materials.

The regulations of the International Atomic Energy applying to consignments to be transported by mail are published by the UPU in the Official Compendium of Information of general interest concerning the implementation of the Postal Parcels Agreement.

15.6. European regional agreements for inland transport

The transport of dangerous goods by road, rail, and inland waterway modes is not covered by an international organization on a worldwide basis. Rather, these are covered by regional organizations such as the United Nations Economic Commission for Europe.

In Europe, a large economic potential is concentrated in a confined area, but distributed over many states. The exchange of economic goods, including radioactive material and other dangerous goods, requires many transport operations.

15.6.1. International Regulations Concerning the Carriage of Dangerous Goods by Rail (RID)

The European railway system was extensively developed in the late nineteenth century and many national laws were enacted, covering the transport of passengers and goods. However, it was soon realized that disparities between national laws could impede international transport. In 1893 a first step towards harmonization in this area was achieved with the adoption of the Convention concerning the International Carriage by Rail (COTIF). As Member States, the parties to this Convention constitute the Intergovernmental Organisation for International Carriage by Rail (OTIF).

The Convention has two Appendices:

- Appendix A: "Uniform Rules concerning the Contract for International Carriage of Passengers and Luggage by Rail (CIV)";
- Appendix B: "Uniform Rules concerning the Contract for International Carriage of Goods by Rail (CIM)".

Pursuant to the CIM, the railway system of the Member States must accept for transport any goods, except defined classes of dangerous goods, that are submitted by a consignor, provided that a certain number of conditions are met. Dangerous goods may also be accepted for transport, if the conditions specified in Annex I to the CIM are met. This annex, which is entitled: "Regulations concerning the International Carriage of Dangerous

Goods by Rail" [13], is usually referred to as the RID, which is an abbreviation of its title in French. The RID is published in French and German by the Office Central des Transports Internationaux par Chemins de Fer (OTIF), with headquarters in Berne, Switzerland.

The dangerous goods covered by the RID are classified in accordance with the UN system, and the IAEA Regulations have been adopted to apply to the transport of radioactive material (Class 7). A typical class 7 rail transport is shown in Figure 15.6.

FIG. 15.6. Typical Class 7 rail shipment.

A system has been established for introducing amendments during intervals between major revisions of the RID. Under this system, a Committee of Experts makes decisions on proposals sent by Member States to amend RID provisions. The Central Office notifies amendments agreed by the Committee to the Member States. Unless one-third of the Member States have objected within four months from the date of such notification, the decision come into force for all Member States on the first day of the twelfth month following the month of the notification.

15.6.2. European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR)

Within the UN system, regional Economic Commissions have been set up under the Economic and Social Council to study the economic problems of different regions. They are to recommend co-operative approaches in coping with such problems. Various specialized committees assist these Commissions in the discharge of their responsibilities.

Shortly after 1945, the Economic Commission for Europe (ECE) established an Inland Transport Committee (ITC) to consider international transport matters in Europe. Within the ITC, a Working Party deals with the international transport of dangerous goods. Based on the ITC's work and recommendations, the ECE in 1957 adopted the European Agreement Concerning the International Carriage of Dangerous Goods by Road [14]. This is usually referred to as the ADR, which is an abbreviation of its title in French. This agreement entered into force in January 1968. It has been updated at frequent intervals since then.

The IAEA Regulations have been adopted to apply to the transport of substances in Class 7 (radioactive material) under the ADR.

The procedure for amending the annexes to the ADR is similar to that used for the RID. In order to maintain compatibility between the RID and the ADR, joint meetings of the RID Safety Committee and the ITC Working Party are held to consider questions that are common to both modes of transport. Agreed amendments are then circulated to the Contracting Parties and if five of them are not opposed to the proposed amendments within a three-month period, the amendments become effective after a further period of three months. They can also become effective on another agreed date in order to allow the simultaneous entry into force of similar amendments to other international agreements concerning the carriage of dangerous goods.

It should be noted that the process of introducing the IAEA Regulations, which were specifically developed for the transport of radioactive material (Class 7), into the existing codes for the transport of all kinds of dangerous goods, is not easy. It can cause points of confusion and conflict in a number of areas. The following are a few examples.

- Definitions of IAEA Safety Series No. TS-R-1 may differ in some parts from the definitions of the general codes, e.g. full load, container, and size of packages.
- Some definitions are only used in the provisions for Class 7 and are unknown in the provisions for the other classes, e.g. exclusive use, transport index, low specific activity material.
- The IAEA requirements are complete only from the radiological point of view, but for codes like RID and ADR which regulate the transport of all kinds of dangerous goods, requirements for radioactive material with subsidiary risks must also be provided.
- For radiation protection purposes, transport workers are classified either as occupationally exposed workers or as members of the public. This is unique to the field of radioactive material transport and can be confusing.
- The transition times during which packages of older designs may be used can be different in RID and ADR than in the IAEA Regulations (TS-R-1).

A typical road vehicle transporting Class 7 material is shown in Figure 15.7.

FIG. 15.7. Road vehicle loaded with Class 7 package.

15.6.3. European Provision concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN and ADNR)

The Inland Transport Committee of the Economic Commission for Europe has also developed European Provisions concerning the International Carriage of Dangerous Goods by Inland Waterways, usually referred to as ADN [15]. Again, these provisions have adopted the UN classification system for dangerous goods and the IAEA Transport Regulations as the requirements for radioactive material.

For the Rhine, the Central Commission for Navigation on the Rhine (CCNR) has promulgated the Regulations Concerning the Carriage of Dangerous Goods on the Rhine. This is known as the ADNR [16].

15.7. Regional agreements in South America

15.7.1. The South American Common Market

For many years, Argentina and Brazil recognised the need for close co-operation to help economic development. However, formal agreement was long delayed because of problems with large foreign debts. Therefore, it was not until 1986 that the Act for the Argentine-Brazilian Integration was finally signed. In the late 1980's, first Uruguay then Paraguay negotiated integration with the result that in March 1991, Argentina, Brazil, Uruguay, and Paraguay signed the Asunción Treaty. This formally created the South American Common Market known as MERCOSUR/MERCOSUL (from the Spanish MERcado COmun del SUR, and the Portugese MERcardo COmun do SUL). After a transition period, the Common Market entered into force in the four states on 1 January 1995.

The MERCOSUR/MERCOSUL is a Common Market for regional integration, with the objective of economic development of the member states. The Common Market includes:

- Free trade of goods and services between Member States and the adoption of a common commercial policy between them and with other States and regional agreements;
- Elimination of customs duties and fees on commercial transactions between Member States and the establishment of a common external tax;
- Co-ordination of macro-economic and specific policies between Member States; and
- Harmonization of legislation in pertinent areas.

The South American Common Market is a block which has about 12 million square kilometres, 200 million inhabitants, an Internal Gross Product near US$100 billion and an average per capita income of about US$3400.

15.7.2. MERCOSUR/MERCOSUL Agreement of Partial Reach to Facilitate the Transport of Dangerous Goods

In the framework of this Common Market, regulations were developed which cover broad aspects of common areas of interest. For transport purposes, the "MERCOSUR/MERCOSUL Agreement of Partial Reach to Facilitate the Transport of Dangerous Goods" [17] is relevant. This Agreement was signed in Montevideo (Uruguay) on 30 December 1994. It is a binding instrument, published in Portuguese and Spanish, that regulates the transport of dangerous goods by road, rail, air, and sea between the MERCOSUR/MERCOSUL Member States. The Agreement was qualified as "of Partial

Reach” because its application is limited to the four countries of the MERCOSUR/MERCOSUL group. The Agreement does not apply to the rest of the Latin America countries which form part of the “Latin America Integration Association”, ALADI.

The MERCOSUR/MERCOSUL Agreement consists of the following three main parts:

(1) The Agreement proper,
(2) Annex I: “Functional Standards for Land Transport”, and
(3) Annex II: “Technical Standards for Land Transport”.

15.7.2.1. The MERCOSUR/MERCOSUL Agreement

The Agreement (Figure 15.8) establishes:

- That its objective is to harmonize the regulations for the transport of dangerous goods within the MERCOSUR/MERCOSUL countries;
- That its scope is to regulate the Transport of Dangerous Goods between the Member States;
- General requirements; and
- Detail requirements.

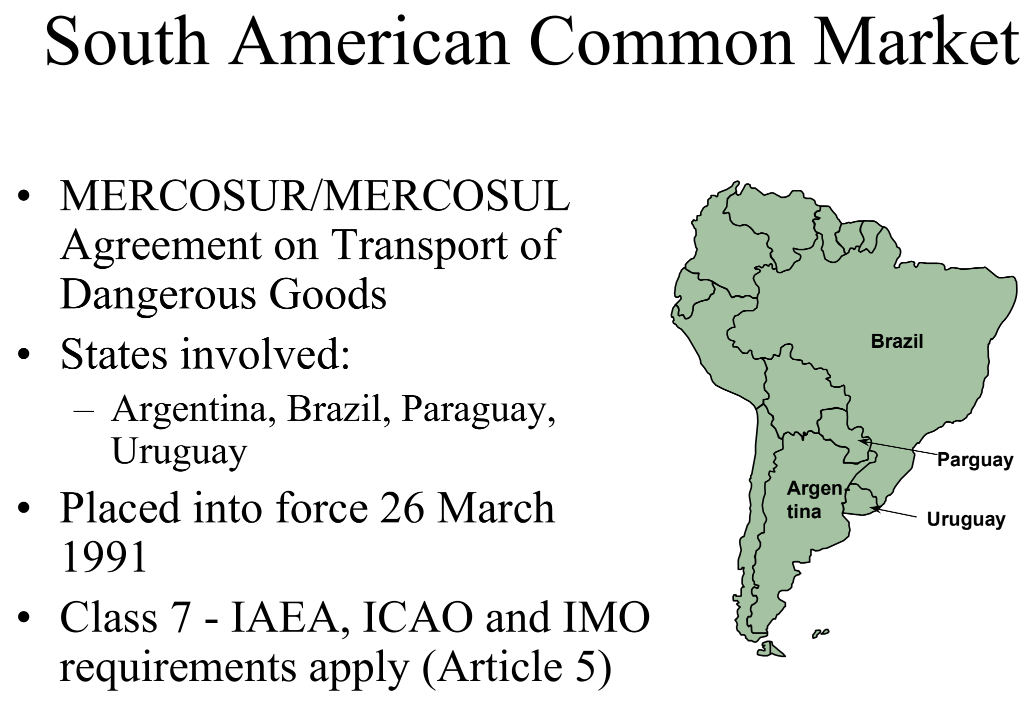


FIG. 15.8. Mercosur/Mercosul Agreement.

For Class 1 (explosives) and for Class 7 material (radioactive material) and hazardous wastes, the requirements of the Agreement and the specific regulations established by the Competent Authorities of each Member State apply. These are derived from the Seventh Revised Edition of the UN Recommendations of the Committee of Experts on Transport of Dangerous Goods of December 1990. With respect to the transport of radioactive material, both the requirements of the Agreement, and the specific requirements of each MERCOSUR/MERCOSUL Member State, are consistent with the IAEA’s Regulations for the Safe Transport of Radioactive Material. These requirements are applied in each country through the corresponding Competent Authority for Class 7 material. Additionally, shipments of dangerous goods transported by air and by sea must comply with the requirements of the ICAO and the IMO respectively, and the MERCOSUR/MERCOSUL countries must accept such shipments.

15.7.2.2. Annex I

Annex I, entitled "Functional Standards for Land Transport" includes ninety-two articles and two appendices. Its main body includes standards related to vehicles as well as to other operational and administrative requirements. These include: loading, unloading, carriage, handling, stowage, in-transit storage and segregation; routeing and parking; vehicle decontamination; emergency procedures; vehicle licensing; shipping documentation; duties, obligations and responsibilities of vehicle manufacturers; consignors, carriers, consignees and contracting parties; regulatory control; as well as breaches and penalties. Appendix I.1 includes a list of the correspondent Competent Authorities of each Member State with respect to Classes 1 and 7 and hazardous wastes. Appendix I.2 includes the Training Programme for road vehicle drivers involved in the transport of dangerous goods and the conditions for driver training license.

15.7.2.3. Annex II

Annex II, entitled "Technical Standards for Land Transport" includes nine chapters and four appendices. Chapters I and IV establish the classification, definition and list of dangerous goods in accordance with the UN Recommendations. Chapter II establishes general standards for vehicle and equipment used in the transport of dangerous goods by road and rail. Chapter III establishes specific standards applicable to emergency provisions in abnormal conditions of transport, decontamination, and notification of appropriate Competent Authorities. Chapter V establishes the proper shipping names and descriptions for dangerous goods in accordance with the UN Recommendations. Chapter VI establishes quantity limits for exempt material from the requirements of the transport of dangerous goods, except for Class 7 in which case the requirements are in accordance with the IAEA Regulations. Chapter VII includes requirements on marking, labelling, and placarding of packages containing dangerous goods as well as vehicles transporting such goods. Again, for Class 7 the requirements are in accordance with the IAEA Regulations. Chapter VIII establishes the package performance requirements based on the UN Recommendations, with Class 7 packaging and package requirements conforming to the IAEA Regulations. For the transport of UF_6 (radioactive material with other dangerous risks), it is specified that the packaging shall also comply with ANSI N14.1-1982 or an equivalent standard. Chapter IX includes requirements related to Intermediate Bulk Containers (IBC's). Finally, there are Appendices that specify the requirements related to Class 1, Class 6, Class 4 and Class 5 materials respectively.

REFERENCES FOR CHAPTER 15

[1] UNITED NATIONS COMMITTEE OF EXPERTS ON THE TRANSPORT OF DANGEROUS GOODS, Recommendations on the Transport of Dangerous Goods, United Nations, New York (19XX).

[2] INTERNATIONAL MARITIME ORGANIZATION, International Convention for the Safety of Life at Sea (SOLAS) - (Consolidated Edition), IMO-110E, IMO, London (1997).

[3] INTERNATIONAL MARITIME ORGANIZATION, International Maritime Dangerous Goods (IMDG) Code, IMO-200E, IMO, London (2000).

[4] INTERNATIONAL CIVIL AVIATION ORGANIZATION, Technical Instructions for the Safe Transport of Dangerous Goods by Air, 1995-1996 Ed., DOC 9284-AN/905, ICAO, Montreal and Chicago (1995).
[5] INTERNATIONAL AIR TRANSPORT ASSOCIATION, Dangerous Goods Regulations, 39th Ed., IATA, Montreal and Geneva (1998).
[6] UNIVERSAL POSTAL UNION, Universal Postal Convention of Rio de Janeiro, UPU, Berne (1979).
[7] OFFICE CENTRAL DES TRANSPORTS INTERNATIONAUX PAR CHEMINS DE FER, Regulations concerning the International Carriage of Dangerous Goods by Rail (RID), 1993 Ed., OTIF, Geneva (1973).
[8] UNITED NATIONS ECONOMC COMMISSION FOR EUROPE, European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) and Protocol of Signature, UNECE, Geneva (1957).
[9] UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE, European Agreement Concerning the International Carriage of Dangerous Goods on Inland Waterways (ADN), UNECE, Geneva (1990).
[10] CENTRAL COMMISSION FOR THE NAVIGATION OF THE RHINE, Règlement pour le transport de matières dangéreuses sur le Rhin (ADNR), MD1, CCNR, Strasbourg (2001).
[11] MERCOSUR/MERCOSUL Agreement of Partial Reach to Facilitate the Transport of Dangerous Goods - Signed by the Governments of Argentina, Brazil, Paraguay and Uruguay in Montevideo, 30 December 1994.

EXERCISE FOR CHAPTER 15

The following exercise is to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 15.1. Additional Regulatory Requirements for Class 7 Transport

REFERENCE: Training Manual, Chapter 15

DISCUSSION: None

PROBLEM:

a. How do the IAEA's Transport Regulations affect the requirements of modal international organizations?

b. What is the impact of the requirements of the modal international organizations on Member States? Hint: differentiate between international and regional requirements.

ANSWER:

16. INTERNATIONAL LIABILITY AND INSURANCE

Two issues, which commonly face consignors, carriers, and consignees of shipments of radioactive nuclear material are: (a) liability, and (b) insurance to cover such liability. This chapter addresses these two issues from an international perspective.

16.1. Introduction

Anyone involved in the cross–border shipment of radioactive material must be cognizant of the potential third party liability for nuclear damage arising from an incident involving such nuclear material.

Third-party liability for nuclear damage involves both national legislation and international Conventions. It is not always easy to know which legal prescriptions are to be applied in a given case. Nonetheless, for the shipper and other persons involved in transport it is important that, as far as possible, they understand the potential nature and scope of their liability. Such knowledge will enable them to procure the appropriate type and amount of insurance cover.

Since it is not possible to give an exhaustive overview of all the legal regulations that might be applicable to the national and international transport of radioactive material in this document, this chapter will concentrate on the nuclear liability Conventions.

16.2. Background

The present international liability regime is based on two instruments: the Vienna Convention on Civil Liability for Nuclear Damage of 1963 [1] and the Paris Convention on Third Party Liability in the Field of Nuclear Energy of 1960 [2]. They are linked by the Joint Protocol that was adopted in 1988. The Vienna Convention is an instrument of a universal nature adopted under the auspices of the IAEA. There are now 31 States party to it. The Paris Convention, which is a regional instrument concluded within the framework of the OECD, has 14 parties. In 1963, it was enhanced by the Brussels Supplementary Convention.

16.3. Paris and Vienna Conventions

The two Conventions, which are based on the civil law concept, establish a special regime of third party liability for nuclear damage.

16.3.1. Liability

The operator of a nuclear installation is absolutely (without fault) and exclusively liable for nuclear damage caused by a nuclear incident occurring in that installation or involving nuclear material in the course of carriage to, or from, that installation. This approach simplifies procedures for obtaining redress.

16.3.2. Scope of application

The regime applies to nuclear installations defined in the Conventions, e.g. civil, land based nuclear reactors, reprocessing and storage facilities, as well as to nuclear material sent from or to such installations.

16.3.3. Nuclear material/substances

A distinction must be made between the various types of consignments such as: uranium ores and concentrates, uranium hexafluoride; unirradiated nuclear fuel; low level radioactive waste; radioisotopes, and irradiated nuclear fuel. This is needed in order to establish whether the nuclear liability Conventions are applicable, or whether other regulations of civil law may apply. The nuclear liability Conventions are in principle applicable only to the transport of nuclear fuel, spent fuel, enriched uranium hexafluoride, and low level waste from nuclear installations. The following material falls outside the scope of the Conventions:

(1) Radioisotopes which have reached the final stage of fabrication so as to be usable for any industrial, commercial, agricultural, medical or scientific purpose. The Paris Convention only excludes such radioisotopes that have left the nuclear installation;

(2) Natural uranium and depleted uranium; and

(3) Radioactive waste not originating from a nuclear installation.

In addition, both Conventions permit the exclusion of small quantities of these materials from the application of the Conventions (under the Conventions, the IAEA Board of Governors and the OECD Steering Committee have the appropriate authority to this effect). The quantities that have been specified for exclusion are such that, from a scientific point of view, it is unlikely that they would ever cause a catastrophic nuclear incident.

16.3.4. Financial limits

Liability is limited in amount. Under the Vienna Convention, it may be limited to not less than US$ 5 million, but an upper ceiling is not fixed. The US dollar referred to in this Convention is a unit of account equivalent to the value of the US dollar in terms of gold on 29 April 1963, that is to say US $35 per one troy ounce of fine gold.

The Paris Convention sets a maximum liability of 15 million Special Drawing Rights (SDRs) provided that the Installation State (State of the liable operator) may provide for a greater or lesser amount but not below 5 million SDRs taking into account the availability of insurance coverage.

The Brussels Supplementary Convention (i.e. the Convention of 31 January 1963 Supplementary to the Paris Convention of 29 July 1960, as amended by the Additional Protocol of 28 January 1964 and by the Protocol of 16 November 1982) is an accessory to the Paris Convention. It establishes additional funding beyond the amount available under the Paris Convention up to a total of 300 million SDRs, consisting of contributions by the Installation State and contracting parties. Compensation is structured into three tiers, as follows:

(1) The first tier is provided by the operator's insurance or other financial security according to the Paris Convention, with a minimum amount of 5 million SDRs;

(2) The second tier is provided by the Government of the Contracting State of the operator, up to a maximum of 175 million SDRs; and

(3) The third tier is provided by the Contracting States, giving additional compensation of 125 million SDRs.

It should be borne in mind that any interest and costs awarded by a court, in action for compensation under the Conventions, have to be paid by the operator over and above the aforementioned liability limits. Both Conventions impose on the operator of a nuclear installation the obligation to cover his liability by insurance or other financial security.

16.3.5. Insurance

The operator must maintain insurance or other financial security for an amount corresponding to his liability. If such security is insufficient, the Installation State is obliged to make up the difference to the limit of the operator's liability.

16.3.6. Time limits

Liability is limited in time. Compensation rights expire under both Conventions if an action is not brought within ten years from the date of the nuclear incident. Longer periods are permissible if, under the law of the Installation State, the liability of the operator is covered by financial security. National law may establish a shorter time limit, but not less than two years (the Paris Convention) or three years (the Vienna Convention) from the date the claimant knew or ought to have known of the damage and the operator liable. In the case of damage caused by a nuclear incident involving nuclear material/substances which at the time of the incident have been stolen, lost, jettisoned, or abandoned and have not yet been recovered, the period of 10 years is computed from the date of that nuclear incident. However, in no case may the period exceed 20 years from the date of the theft, loss, jettison, or abandonment.

16.3.7. Territorial scope

The Vienna Convention is silent on its territorial scope of application. It has been interpreted only to apply to damage suffered in Contracting Parties and on or over the high seas. The Paris Convention specifically states (Article 2) that it does not apply to damage suffered in non-Contracting States. The Contracting Party of the liable operator may however, extend in its national legislation the application of the Convention to such damage and incidents. The NEA Steering Committee and the IAEA Standing Committee have recommended that the Conventions should apply to nuclear damage suffered in the territory of a contracting State or on the high seas (Vienna Convention). They apply on the high seas on board a ship registered in the territory of a contracting state (Paris Convention) even if the nuclear incident occurred in the territory of a non-Contracting State.

16.3.8. Jurisdiction

Jurisdiction over actions lies exclusively with the courts of the Contracting Party in whose territory the nuclear incident occurred.

16.3.9. Exoneration

Under the Conventions, no liability attaches to an operator for nuclear damage caused by a nuclear incident directly due to an act of armed conflict, hostilities, civil war or insurrection. The same applies to nuclear damage caused by a nuclear incident, which is directly the result of a grave natural disaster of an exceptional character, unless a contracting party has otherwise provided.

16.3.10. Liability during transport

16.3.10.1. Liability of consigning organizations

Generally, the operator dispatching nuclear material is deemed liable until the material is taken in charge by the recipient operator, unless otherwise agreed between them by a contract in writing. More specifically, the operator is liable for nuclear damage upon proof that it has been caused by a nuclear incident involving nuclear material/substances coming from or originating in his installation and occurring:

- before liability has been assumed in a written contract by the operator of another nuclear installation;
- in the absence of such express terms, before the operator of another nuclear installation has taken charge of the nuclear substances; or
- where nuclear material/substances are intended to be used in a nuclear reactor with which a means of transport is equipped for use as a source of power, before the person duly authorized to operate such reactor has taken charge of the nuclear material/substances; but
- where the nuclear substances have been sent to a person within the territory of a non-contracting state, before they have been unloaded from the means of transport by which they have arrived in the territory of that non-contracting state.

16.3.10.2. Liability of consignee organization

The receiving operator is the liable person when the incident occurs:

- after liability has been assumed in a written contract from the operator of another nuclear installation;
- in the absence of such express terms, after the operator has taken charge of the nuclear substances; or
- after he has taken charge of the nuclear material/substances from a person operating a nuclear reactor with which a means of transport is equipped for use as a source of power; but
- where the nuclear material/substances have, with the written consent of the operator, been sent from a person within the territory of a non-contracting state, after they have been loaded on the means of transport by which they are to be carried from the territory of that state.

Both Conventions allow Contracting States to designate the carrier of nuclear material as an operator instead of the sending (consignor) or receiving (consignee) operators. In which case, the carrier will be considered, for the purposes of the two Conventions, as an operator.

16.3.11. Liability during storage in transit

It is not unusual that during transport nuclear material/substances are temporarily stored. When the storage does not take place in an existing nuclear installation the rules concerning transport apply. If, incidental to transport, nuclear material/substances are temporarily stored in a nuclear installation and a nuclear incident occurs that involves such nuclear material/substances, the sending or receiving operator is liable.

16.3.12. Liability during carriage of nuclear material/substances belonging to more than one operator

It is possible that several consignments of nuclear substances will accumulate, e.g. in a warehouse or sea-going vessel. There will be an operator liable up to a limited amount for each individual consignment. In the event of a nuclear incident involving these nuclear substances during the course of carriage, there will be no cumulation of the various liability limits. However, the total liability will be fixed at the highest amount that is in force for one of those transports, and no operator will be obliged to pay more than the amount applicable to him.

16.3.13. Damage to the means of transport

The operator is not liable for damage to the means of transport conveying the nuclear material/substances unless a Contracting Party has otherwise provided. However, the inclusion of damage to the means of transport should not result in reducing the liability of the operator with respect to other damage to an amount less than 5 million units of account.

16.3.14. Certificates

Both Conventions provide that an operator must supply the carrier with a certificate issued by the operator's insurer. The certificate must provide the name and address of the operator, the details of the insurance, an indication of the nuclear substances involved, the relevant carriage, and a statement by the Competent Authority that the person named is an operator within the meaning of the Conventions. This certificate is provided, in part, to facilitate the transport of nuclear substances between countries, including the transit of such shipments through countries.

In case of a nuclear incident, the identity of the liable operator may thus be immediately determined by reference to the transport certificate.

16.4. Other International Agreements

16.4.1. Linking the Paris and the Vienna Conventions

Until 1988, the Vienna and Paris Conventions each operated in isolation. There was no single global and uniform third-party liability regime. Thus, for example, since parties to one Convention were non-contracting States to the other Convention, the Paris Convention would not have applied (as a general rule) to nuclear damage suffered or a nuclear incident occurring in the territory of a party to the Vienna Convention, and vice versa. The parallel operation of the Conventions raised a potential problem of the conflict of law in transport cases due to the possibility of their simultaneous application, e.g. both Conventions could apply to the same nuclear incident on or over the high seas.

In 1988, a combined effort by the IAEA and OECD/NEA resulted in the adoption of the Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention. It linked the two Conventions into one expanded regime. Parties to the Joint Protocol are treated as though they were Parties to both Conventions. Between parties to the Joint Protocol, specified operative articles of both Conventions, i.e. Articles I to XV of the Vienna Convention and Articles 1 to 14 of the Paris Convention, are applied "in the same manner" as between parties to each Convention. Also, in order to avoid conflict of jurisdiction, the Joint Protocol contains a choice of law rule to determine which of the

Conventions should apply to the exclusion of the other in respect of the same accident. According to this rule, the applicable Convention is that to which the Installation State of the operator liable is party. The Joint Protocol does not change material rules of the two Conventions. As of 1 January 1999, there are 20 parties to the Protocol.

16.4.2. Brussels Convention

At the time the Conventions were drafted it was realized that there were international agreements in the field of transport dealing with third party liability for damage to the means of transport, international agreements dealing with collisions involving a means of transport, and international agreements dealing with bills of lading. In order to avoid the possibility of conflicting provisions, the nuclear liability Conventions were written so that they do not affect such agreements. Therefore, a person suffering damage caused by a nuclear incident in the course of transport may have two rights of action. One of these may be against the operator of the nuclear installation, and another against the carrier following these international agreements in the field of transport.

As mentioned above, the two-fold liability, which might arise from the simultaneous application of international agreements in the field of transport and the nuclear liability Conventions, has caused problems for insurers. In the past, insurers have been requested to cover this twofold liability for very high amounts. It even happened on occasion that unlimited liability cover was solicited. The reason for this is that, in some special cases a carrier might not be entitled to limit his liability in accordance with international agreements in the field of transport. This caused difficulties for insurers who were not prepared to grant cover for those very high cumulative amounts.

The need to overcome these problems prompted the conclusion, on 17 December 1971, in Brussels, of the Convention Relating to Civil Liability in the field of Maritime Carriage of Nuclear Material. It came into effect on 15 July 1975. Currently, ten countries are party to the Convention, which means that although a good start has been made, the problems highlighted above are still far from being fully solved. The Convention gives the principles of nuclear law, as laid down in the Vienna and Paris Conventions, precedence over the liability rules of the various Conventions with respect to international sea transport. The intent was that it would put an end to the two-fold liability.

Article 1 of that Convention provides that:

"Any person who by virtue of an international Convention or national law applicable in the field of maritime transport might be held liable for damage caused by a nuclear incident shall be exonerated from such liability:

(a) If the operator of a nuclear installation is liable for such damage under either the Paris or the Vienna Convention; or
(b) If the operator of a nuclear installation is liable for such damage by virtue of a national law governing the liability for such damage, provided that such law is in all respects as favourable to persons who may suffer damage as either the Paris or the Vienna Convention."

However, Article 4 of the 1971 Brussels Convention stipulates explicitly:

"The present Convention shall supersede any international Conventions in the field of maritime transport which, at the date on which the present Convention is opened for signature, are in force or open for signature, ratification or accession but only to the

extent that such Conventions would be in conflict with it; however, nothing in this Article shall affect the obligations of the Contracting Parties to the present Convention to non-Contracting States arising under such international Conventions".

This means that a maritime carrier may be held liable for nuclear damage before the court of a non-Contracting State by virtue of a maritime Convention, when the country in question is party to it, or by virtue of the national maritime law of that country. However, if ordered by a court to pay compensation, the carrier has the right of recovery from the operator of the nuclear installation in accordance with Articles 2 and 6(d) of the Paris Convention and Article IX (2) of the Vienna Convention. By virtue of the Paris Convention any person, regardless of nationality or domicile, has this right of recovery while, under the Vienna Convention, that the right may only be exercised by persons who have the nationality of a Contracting Party.

The desire to make the scope of operation of the 1971 Brussels Convention as wide as possible was the reason for including the provision in paragraph (b) of Article 1. It has the effect of giving precedence to national law governing nuclear liability, on the condition that that law is in all respects as favourable to persons suffering damage as the nuclear Conventions are. At the time of the adoption of the Brussels Convention, some States were of the opinion that, in practice, this provision cannot be easily enforced as it would be difficult to determine whether national law would be just as favourable for the injured parties as the respective Conventions.

16.5. Revision of the Vienna Convention

Following the Chernobyl accident, the IAEA initiated, as high priority, a review aimed at strengthening the existing civil liability regime, including the revision of the 1963 Vienna Convention, and also developing a comprehensive international liability regime. In the latter context, consideration was given to establishing a mechanism of supplementary compensation through some form of State involvement.

In 1990, the IAEA Standing Committee on Liability for Nuclear Damage was established to deal with all aspects of international nuclear liability. Intensive negotiations resulted in the elaboration of a draft protocol amending the Vienna Convention and a draft Convention providing for supplementary compensation. At its session in June 1997, the IAEA Board of Governors, having considered the report of the Standing Committee, authorized the Director General to convene a diplomatic conference for the adoption of those instruments.

The conference took place in Vienna 8-12 September 1997; 81 States participated, 4 international and 3 non-governmental organizations attended as observers. It adopted by an overwhelming majority two instruments: the Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage [4] and the Convention on Supplementary Compensation for Nuclear Damage [5]. As of 1 January 1999, the Protocol had been signed by 14 States and ratified by one State; the Convention has been signed by 13 States.

The two instruments consolidate recent developments in the legal, technical and economic aspects of nuclear liability. They provide for higher standards and clarity in the liability regime that is in the interests of both potential victims of nuclear accidents and of operators. At the same time, the recognized principles of nuclear liability, such as no-fault liability and channeling, are preserved.

The main provisions of the two instruments are described in the following sections.

16.5.1. Protocol to Amend the Vienna Convention

(1) The Protocol explicitly extends the coverage of the 1963 Vienna Convention to nuclear damage wherever suffered. However, an exception is allowed in respect of nuclear damage suffered in a non-Contracting State, including its maritime zones, if such a State has a nuclear installation on its territory or in its maritime zones and does not afford reciprocal benefits.

(2) The Vienna Convention defines nuclear damage in a general way. The Protocol provides for further harmonization by expressly including some additional types of nuclear damage, e.g. the costs of measures of reinstatement of impaired environment, certain loss of income resulting from a significant impairment of the environment and costs of preventive measures and further damage caused by such measures. The law of the competent court determines the extent of recovery for such damage.

(3) The new definition of nuclear damage led to a change in the definition of nuclear incident. It has been expanded to include, in respect of preventive measures which may have to be taken, any occurrence which creates "a grave and imminent threat" of causing nuclear damage. Also, some new definitions such as "measures of reinstatement", "preventive measures" and "reasonable measures" have been developed.

(4) Since the minimum liability limit set in the Vienna Convention (US$5 million in terms of gold on 29 April 1963) was deemed insufficient to provide adequate compensation in the event of a major incident, the Protocol increases this limit to not less than 300 million SDR's (currently this amounts to approximately US$400 million). This amount may be assigned to the operator entirely, or divided between the operator and the Installation State.

(5) Those States that have difficulty in immediately implementing the increased liability amount may phase-in this amount during a fixed period of time. For a maximum of 15 years from the date of the entry into force of the Protocol, the operator's liability may be limited to not less than 100 million SDRs.

(6) Where the operator's liability is unlimited, the Installation State may establish a limit of financial security required of the operator to an amount of 300 million SDRs or greater.

(7) In order to ensure that the operator's liability is always covered by financial security, the liability amounts fixed by the Installation State of the liable operator would apply regardless of the place of the nuclear incident.

(8) The Protocol provides for a partial modification of the time period during which claims for nuclear damage may be submitted. A thirty-year period is set for claims for loss of life and personal injury, the ten-year period would remain for all other types of nuclear damage.

(9) The Protocol extends coverage of the Convention to the means of transport on which the nuclear material was located at the time of the nuclear incident. However, compensation for such damage should not reduce the liability of the operator in respect of other damage to an amount less than either 150 million SDRs, or any higher amount established by the legislation of a Contracting Party, or an interim phasing-in amount.

(10) The Protocol contains a substantial addition to the rules regarding jurisdiction over actions for compensation. A new clause provides that in the case of incidents within the Exclusive Economic Zone of a Contracting Party or if such a zone has not been established, in an area not exceeding the limits of an Exclusive Economic Zone if one had been established, jurisdiction over actions concerning nuclear damage shall lie with the courts of that Party. A clause is added that the provision should not be

interpreted as permitting the exercise of jurisdiction in a manner contrary to the international law of the sea, including the 1982 United Nations Convention on the Law of the Sea.

16.5.2. Convention on Supplementary Compensation

The Convention on Supplementary Compensation for Nuclear Damage (CSC) is a free-standing instrument aimed at establishing a worldwide liability regime for nuclear damage that may be adhered to by all States irrespective of whether they are party to the Vienna Convention or the Paris Convention. Its purpose is to supplement the compensation of nuclear damage available under the national legislation of States Parties implementing the two basic Conventions or under national legislation which is consistent with the liability rules set out in the Annexe of the CSC (which are equivalent to those in the basic Conventions).

(1) The Annexe, which is an integral part of the Convention, allows adherence to it by States not Party to the Vienna Convention or Paris Convention. Contracting Parties of the CSC who are not Party to these Conventions would be obliged to bring their national legislation on compensation for nuclear damage in line with the liability provisions laid down in the Annexe. These provisions are equivalent to those contained in the two Conventions.

(2) The Annexe also contains a "grandfather" clause, which allows a State whose nuclear liability legislation is based on the principle of "economic channeling" and which meets certain requirements specified in the clause, to participate in the CSC without changing its legislation.

(3) The CSC applies to nuclear damage as defined in the Protocol to Amend the Vienna Convention, for which an operator of a nuclear installation used for peaceful purposes situated in the territory of a Contracting Party to the CSC is liable under either of the two basic Conventions or under national legislation as mentioned above. The Convention does not apply to nuclear damage in the territory of non-Contracting Parties.

(4) Supplementary compensation is provided by States Parties in addition to the national compensation amount of at least 300 million SDRs which should be made available by the liable operator and, where appropriate, by the Installation State. States Parties that are in a difficult economic situation may make use of a phasing-in mechanism similar to that in the revised Vienna Convention. In particular, the national compensation amount may be reduced to an amount of at least 150 million SDRs for a maximum of 10 years from the date of the opening of the CSC for signature in respect of a nuclear incident occurring within that period.

(5) The contribution of a Contracting Party is calculated on the basis of its installed nuclear capacity of nuclear reactors (1 unit for each MW of thermal power) and its United Nations rate of assessment. The latter part of the supplementary fund constitutes 10% of the part calculated on the basis of installed nuclear capacity. Contracting Parties that are on the minimum United Nations rate of assessment with no nuclear reactors are not required to contribute.

(6) In order to avoid a situation where one or more Contracting Parties having a large nuclear power capacity would have to provide an excessively large portion of the supplementary funds, especially during the initial period with a limited number of participants, a percentage limitation ("cap") for the contribution of an individual Contracting Party is included in the calculation. The cap amounts to the United Nations rate of assessment expressed as a percentage plus 8 percentage points. The cap will start to phase-out when the total installed nuclear capacity reaches the level of 625,000 units. The cap is not, however, applicable to the Installation State.

(7) The supplementary funds are allocated as follows:

(a) 50% of the funds are devoted for the compensation of nuclear damage in or outside the Installation State; and
(b) 50% of the funds are devoted exclusively for the compensation of trans-boundary damage to the extent it has not been compensated from the former amount.

(8) In the event that an Installation State avails itself of the phasing-in provision described in sub-paragraph (d), the allocation of supplementary funds will be adjusted. In particular: the amounts of compensation for both domestic and trans-boundary damage ((a) above) will be reduced by the percentage by which the national compensation amount is less than 300 million SDRs and the amounts reserved for the compensation of trans-boundary damage only ((b) above) will be increased by the same percentage. On the other hand, if the national compensation amount is 600 million SDRs or greater, then all supplementary funds will be used to compensate nuclear damage in and outside the Installation State.

(9) The CSC will enter into force when 5 States with a minimum of 400,000 units of the total installed nuclear capacity adhere to it. There is a requirement that in order to be a Party, a State having on its territory a nuclear installation as defined in the 1994 Convention on Nuclear Safety, must be a Contracting State to that Convention.

(10) The CSC contains a jurisdiction clause similar to that in the Protocol regarding nuclear incidents occurring in an Exclusive Economic Zone.

REFERENCES FOR CHAPTER 16

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Vienna Convention on Civil Liability for Nuclear Damage, INFCIRC/500, IAEA, Vienna (1996).
[2] NUCLEAR ENERGY AGENCY OF THE OECD, Convention on Third Party Liability in the Field of Nuclear Damage, OECD/NEA, Paris (29 July 1960).
[3] NUCLEAR ENERGY AGENCY OF THE OECD, Nuclear Liability: A Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention, 1988, IAEA & OECD/NEA, Vienna (1989).
[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage, INFCIRC/566, IAEA, Vienna (1998).
[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Convention on Supplementary Compensation for Nuclear Damage, INFCIRC/567, IAEA, Vienna (1997).

EXERCISE FOR CHAPTER 16

The following exercise is to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 16.1. Insurance coverage

REFERENCE SOURCES: Training Manual, Chapter 15.

DISCUSSION: The Training Manual discusses liability and insurance coverage for radioactive material packaging and transport activities.

PROBLEM: Various Conventions have been implemented to cover liability and insurance. These are discussed in Chapter 15. The Training Manual also notes that there are situations that are not covered by insurance. What are these situations?

ANSWER:

17. EMERGENCY PLANNING AND PREPAREDNESS

17.1. Introduction

The TS-R-1 Regulations [1] have a requirement for the provision of emergency response capability for transport accidents or incidents involving radioactive material. All approval certificates issued by the Competent Authority are similarly required to include the emergency arrangements deemed necessary by the Competent Authority. The emergency arrangements would normally be provided by the relevant national organization.

In order to provide assistance to those who are responsible for ensuring safety in establishing and developing emergency response plans, the IAEA published Safety Series No. 87 in 1988 [2]. This material has since been updated to fully reflect the requirements in TS-R-1 and is published as IAEA Safety Guide, TS-G-1.2, entitled “Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material” [3].

TS-G-1.2 is neither a collection of rules nor a list of approved steps and actions. However, it does provide guidance on the various aspects and philosophies of emergency planning and preparedness, along with a consideration of the problems that might be encountered in a transport accident involving radioactive material. The guide is intended for use in preparing national emergency plans and procedures, taking into account the specific governmental and legislative structures.

The purpose of this chapter is to provide a general introduction and overview to emergency response planning and preparedness as detailed in TS-G-1.2.

17.2. Overview of Safety Guide TS-G-1.2

After a general introduction in Section I, TS-G-1.2 provides a review of the Regulations in Section II. Section III is a brief chapter that describes the responsibilities of the various entities that could be involved in the emergency response plan. Section IV provides an overview of the items to be considered in preparing the national plan.

The heart of TS-G-1.2 is Section V, which outlines the response to transport accidents and addresses the need for training, exercises, reviewing of plans and public information. Half of the publication consists of the appendices, which reproduce the markings, labels, placards, and documents associated with radioactive material. These appendices also provide examples of response to transport accidents, as well as examples of some emergency response guides and procedures.

17.3. Emergency response planning

17.3.1. Need for emergency response planning

Until now, there have been no reported transport accidents with serious radiological consequences. However, in spite of all the measures taken to ensure the safe transport of radioactive material, there is still a possibility that such accidents may take place. An accident resulting in a significant release of radioactive material or loss of shielding could have considerable consequences. These consequences can be controlled or mitigated by proper emergency response actions.

17.3.2. Type of emergency response planning

The type of emergency planning and preparedness that is needed for responding to transport accidents involving radioactive material is similar to that required for responding to transport accidents involving non-radioactive hazardous material, such as flammables, explosives, poisonous gases and toxic chemicals. Many of these non-radioactive hazardous materials pose greater threats to public health and safety than do most radioactive material. Responses to an accident can be initiated properly once it is determined what hazard is involved. Therefore, emergency response organizations and personnel need to be provided with training to recognize the various hazards, and with emergency response plans and procedures to respond to these hazards. They must have the basic knowledge, skills, and equipment to deal effectively with the wide range of possible consequences of hazardous material accidents.

Emergency plans need to be developed by responsible authorities for responding to transport accidents involving packages containing radioactive material. Ideally a main national plan would be developed and all provincial, state, and local plans would be based on the main national emergency plan. Consignors and carriers would also have their specific emergency plans and preparedness procedures.

The main national plan needs to be flexible to cope with a wide variety of accidents. However, the plan should at least cover:

- The planning basis;
- Responsibilities, capabilities, and duties of the organizations involved;
- Procedures for alerting and notifying key organizations and persons;
- Methods for warning and advising the public;
- Intervention levels for exposure and contamination;
- Protective measures;
- Procedures for response actions;
- Resources, and medical and public health support;
- Procedures for training, exercises and updating plans; and,
- Public information.

17.3.3. Basis of emergency response planning

To determine the basis for emergency plans, the responsible authorities can conduct an assessment of the transport systems used for radioactive material in their country and generally determine what types of shipments pass through these systems and the main routes used. Using statistical data concerning traffic accidents, such as that collected in Ref. [4], consideration can be given to identifying those areas where accidents are more frequent and locations in which the possible accidents might have higher impact. The planning basis can then be defined taking into account the potential consequences of transport accidents.

The type of emergency plan needed for response to radioactive material accidents is very similar in structure to the plan needed for responding to other dangerous goods transport accidents. Thus many of the same organizations are involved. Therefore, it is preferable, wherever possible, to integrate the emergency plan for radioactive material with plans for responding to hazardous material accidents in general. This is done by developing a master plan with national or regional alerting centres for all types of transport accidents involving hazardous material. Such a system would be activated more frequently than would separate arrangements for each hazardous material, and the experience gained would strengthen the reliability and effectiveness of the response system.

Emergency plans for dealing with accidents involving radioactive material should conform as closely as possible to existing capabilities and procedures for dealing with other transport accidents. The first line of response action will be provided by such organizations as the police, fire fighting, or military organizations. The carrier's employees, or members of the public who may be directly involved and are initially on the scene of an accident, will most likely call the police. The carrier's employees (the crew of the vehicle) should be given advance instructions on procedures to be followed in the case of an accident and in notifying the police and/or other organizations defined in the emergency plans.

Clear step-by-step procedures should be prepared to implement the emergency plan in a graded response (e.g. local, state, and provincial responses) as required by the severity of the accident and its consequences. This response could range from simple confirmation that there is no radiological hazard, with minimal involvement of expert responders, to situations where large-scale remedial measures may be required and need to be brought to bear at the accident site with major involvement of experts. Pre-established radiation exposure and contamination levels should be defined as intervention levels. When these intervention levels are exceeded, certain protective measures are required. A major consideration is that transport accidents may occur in any location, including remote areas where access may be difficult and in populated areas where control of access by the public may be required. Response plans may have to be implemented on difficult terrain and under adverse weather conditions.

17.3.4. Creation of national emergency response network

A transport emergency involving radioactive material may occur any where at any time. Though packages carrying radioactive material are designed to withstand normal and, as appropriate for the radioactive contents, even accident conditions of transport it is essential that response action is initiated without any delay because an emergency may occur in the public domain. The concerned national emergency response authority should, therefore, create a network of emergency response centers. Each center should be equipped with adequate number of all necessary emergency response tool kits and of trained response personnel. The number and distribution of response centers should be so determined that the response team can reach any location within the jurisdiction of a center within a short time. All the emergency response centers should have communication links among themselves and also with a centralized emergency communication unit. The emergency response action plan accompanying a consignment should provide the contact details of the centralized emergency communication unit so that in the event of an emergency involving a radioactive consignment, information about the incident can be communicated to the unit who in turn can flash the message to the emergency response center nearest to the scene of the emergency. The emergency response network would be effective only if the centralized unit and the individual centers are manned around the clock.

Further detailed guidance on emergency planning and preparedness is provided in TS-G-1.2. In addition, IAEA-TECDOC-953 [5] provides a practical systematic method for developing integrated user, local and national emergency response capabilities.

17.4. Consequences of transport accidents

Clearly the nature, characteristics and effects of accidents involving radioactive material depend on many factors. These include the type of package, the physical and chemical form of the material, its radiotoxicity, the amount of radioactive material contents, the mode of transport, and the severity of the accident as it affects the integrity of the package. Consequences range from a low radiological hazard with a high probability of occurrence, such as might result from an LSA shipment, to a high radiological hazard with a low probability of occurrence, which might involve a Type B package.

TS-G-1.2 provides a description of the potential consequences of accidents involving different types of packages as well as the significance of whether the material is dispersible or non-dispersible. The hazards associated with such accidents may include radiation, contamination from other than special form material, criticality from fissile material, and other dangerous properties of the material.

17.5. Response to transport accidents

TS-G-1.2 divides the emergency response to transport accidents into three phases: the initial phase; the accident control phase, and the post-emergency phase (Figure 17.1) However, it acknowledges the fact that in any actual accident, many of the response actions described in the section on the accident control phase may be commenced in the initial phase. The type of personnel at the accident scene and the promptness of their actions perhaps best characterize the three phases. The actions described are related to land based transport accidents with a modifying discussion of air and sea modes later. The planning and preparedness arrangements for road transport are generally applicable to rail transport. However, railways often carry spent fuel and have their own internal communications network.

Phase of emergency	Action to take
Initial phase	Emergency first response
Accident control phase	Radiation protection
Post-emergency phase	Clean-up

FIG. 17.1. The three emergency response phases.

There are different types of responders involved in the emergency response to a transport accident. Interactions between them, as well as step-by-step procedures of actions to be taken are described in IAEA TECDOC-1162 [14].

17.5.1. Initial phase

During the initial phase, the only responsible people at the accident scene will be the emergency first response personnel such as police, fire and medical first aid or ambulance personnel. Such people should be trained to recognize an incident involving radioactive material and to perform their normal limited functions in the radiological environment. Taking into account the fundamental principles of radiological protection and the knowledge of the accident condition, saving lives and fighting fires have much higher priority over anything else.

The key sequence for this initial phase should be as follows:

- First aid and lifesaving rescue;
- Inform and notify that radioactive material is present;
- Restrict access for radiation and contamination control; and
- Stop or suppress any fires

It is essential to emphasize the importance of some basic steps such as personnel safety, simple radiological control, and getting expert assistance to the scene. At the same time, it should be recognized that the first responder's role is limited.

17.5.2. Accident control phase

The accident control phase (Figure 17.2) will usually begin with the arrival on the scene of qualified radiological personnel. As part of the emergency planning process, prior arrangements should have been made to contact properly qualified or experienced and equipped persons or teams from governmental authorities, nuclear establishments, or other organizations where radiological protection services exist. These persons or teams should be able to perform the radiation monitoring necessary, assess the real hazard, and provide advice to the person in overall charge of the accident scene.

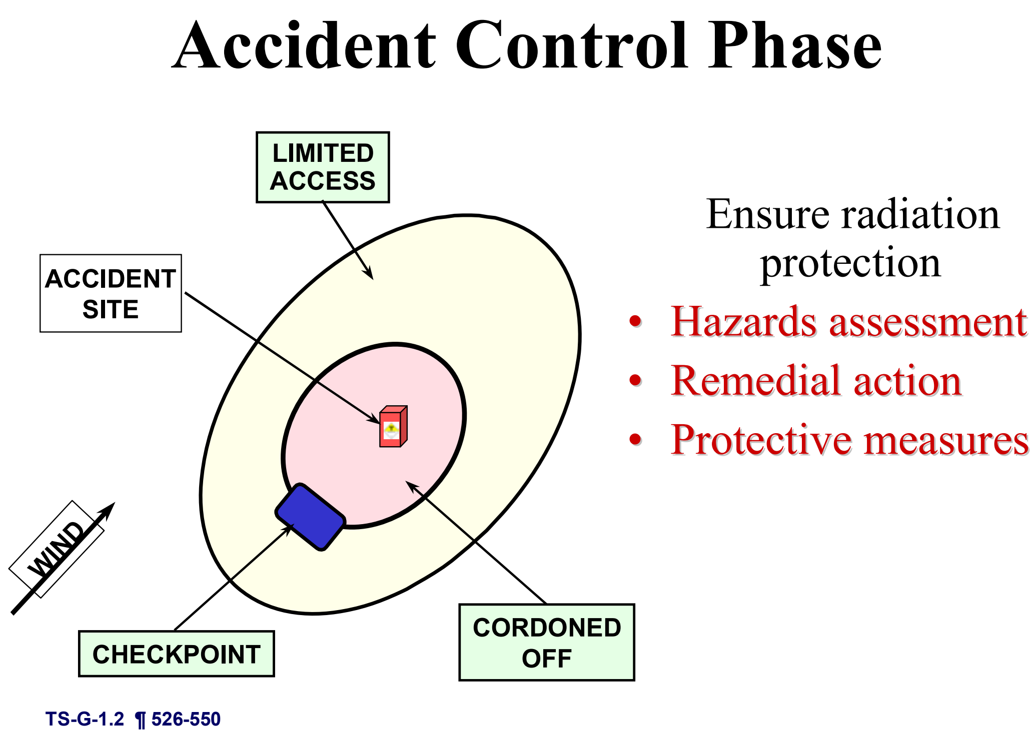


FIG. 17.2. The accident control phase.

At this stage, the immediate needs have been taken care of, and a proper radiological assessment can be made. In addition, appropriate controls and protective measures can be taken under expert guidance.

TS-G-1.2 provides details of such measures as:

- Control of access;
- Protective actions within a cordoned off area;
- Personal protective measures;
- Sheltering or evacuation;
- Decontamination of persons;
- Control of food and water supplies;
- Protection of the local drainage system.

17.5.3. Post-emergency phase

When it is clear that no further hazard exists in the accident area, and that all of the necessary protective measures have been, or are still being taken, then the emergency can be declared terminated by the local responsible authorities. This is when the post-emergency phase or clean-up phase begins. As part of the emergency planning efforts, arrangements should have been made with appropriate agencies that have suitable expertise and equipment for a large scale clean-up, if necessary.

Decontamination and restoration of the area to its original condition are the major goals of this phase of the incident. Additionally, some food and water control that may have been initiated in the second phase may also need to be continued.

17.5.4. Transport modes other than road

There are special considerations for accidents involving transport modes other than road. When the radioactive material accident involves water transport, then there is a much greater potential for spread of contamination and the location of radioactive debris may be difficult. However, the International Maritime Organisation (IMO) Emergency Response Schedules may provide helpful guidance. It should be noted that vessels subject to the IMO INF Code have a requirement for a shipboard emergency plan.

With air transport accidents, more remote areas may be involved and debris may be scattered over a large area. Because air transport is most frequently used for shipments of short half-life isotopes, radiopharmaceuticals and similar limited hazard materials are likely to be involved.

17.6. Responsibilities for emergency planning and preparedness

The responsibilities for dealing with a transport accident are generally divided among several organizations and persons. The severity of the accident in terms of its consequences typically determines the level of governmental response and involvement. The governmental responsibilities and responses are dependent on the legal framework of a country and, therefore, may vary between different countries. However, for developing and coordinating governmental response plans for transport accidents involving radioactive material, designation within a country of a “Lead Agency” to provide a focal point is useful.

In principle, prime responsibility rests with the consignor, who needs to ensure that before undertaking the transport of radioactive material, carriers are fully aware of the procedures to be followed in the event of an accident. When an accident occurs, several public organizations and their personnel have the general responsibility to act to mitigate the consequences of the accident. In most transport accident situations, this response consists of the FIRST actions detailed earlier. Also, specialized organizations trained to deal with radioactive material may have to be called in to assess the accident and implement protective measures used to contain, control or eliminate any radiological hazard. The degree of involvement of the various organizations may vary during the progress of the operation.

A key to any emergency response is an efficient notification and communications system. Establishment of regional alerting centres for any kind of accident is recommended in TS-G-1.2. In several incidents, communication has been identified as a significant problem in post-incident reviews and analysis.

The general emergency planning and preparedness responsibilities of consignors and carriers, government and radiological monitoring teams are outlined in the rest of Section VI of TS-G-1.2.

17.7. Training, drills, exercises and plan review

Training programmes for all personnel included in the emergency plan need to be developed and implemented. Training should be provided for first response personnel, technical experts, and representatives of appropriate authorities. Routine refresher training is similarly needed to maintain proficiency.

Due to the fact that there are very few transport accidents involving radioactive material, the knowledge and skills required for responding to such an event are not used very often. Therefore, drills and exercises are vital to develop, test, and maintain expertise.

In addition, exercises test the effectiveness of the plan and highlight any inadequacies or deficiencies. For this reason, and to allow for normal changes, the emergency plan should be reviewed and revised routinely. The best time is usually once a year after an exercise and its critique. Exercises and drill should be regarded as opportunities to "Test the Plan, and Train the People" (TTP)[2] rather than for testing the people.

17.8. Public information

Since there is considerable public sensitivity surrounding the transport of radioactive material, a significant amount of effort should be put into the plan regarding the dissemination of information. Section VIII of TS-G-1.2 provides some helpful principles on this topic.

17.9. International notification and assistance

17.9.1. Introduction

Largely as a result of the Chernobyl nuclear reactor accident, two new Conventions were adopted by the IAEA General Conference on September 23, 1986. The first of these is the Convention on Early Notification of a Nuclear Accident and the second is the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency [6]. The first Convention came into force on October 27, 1986 and the second on February 26th, 1987. Both of these Conventions are applicable to incidents involving radioactive material in transport even though the probability of their application in an incident is small.

A transport accident involving a source that is transported across or is suspected of having been transported across a national border can potentially become a trans-national emergency. Guidance about the responsibility regarding notification in such cases is available in Reference [15].

In order to meet its responsibilities under the Early Notification and Assistance Conventions, the IAEA established in 1986 a 24-hour Warning Point and operation focal point in its Secretariat, the Emergency Response Centre (ERC), to which States and relevant international organizations can promptly and effectively direct notification and/or warning messages or event reports, requests for emergency assistance and requests for information. Guidance is available in Reference [16], which was first published in 2000 and is updated every two years.

17.9.2. Convention on Early Notification of a Nuclear Accident

This Convention applies to accidents "from which a release of radioactive material occurs or is likely to occur and which has resulted or may result in an international trans-boundary release that could be of radiological safety significance for another state". Included in the list of facilities and activities are:

(1) The transport and storage of nuclear fuels or radioactive wastes; and,
(2) The transport of radioisotopes for agricultural, industrial, medical, and related scientific and research purposes.

The major provision in the Convention is that in the event of an applicable accident, the state will notify directly or through the IAEA other states that are, or may be, physically affected by the release. The notification will include the following information as available:

(1) The time, exact location where appropriate, and the nature of the nuclear accident;
(2) The facility or activity involved;
(3) The assumed or established cause and the foreseeable development of the nuclear accident relevant to the trans-boundary release of the radioactive material;
(4) The general characteristics of the radioactive release, including, as far as is practicable and appropriate, the nature, probable physical and chemical form and the quantity, composition and effective height of the radioactive release;
(5) Information on current and forecast meteorological and hydrological conditions necessary for forecasting the trans-boundary release of the radioactive material;
(6) The results of environmental monitoring relevant to the trans-boundary release of the radioactive material;
(7) The off-site protective measures taken or planned; and,
(8) The predicted behaviour of the radioactive release.

17.9.3. Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency

As its title implies, the general provisions of this Convention are “to facilitate prompt assistance in the event of a nuclear accident or radiological emergency to minimize its consequences and to protect life, property and the environment from the effects of radioactive releases”.

If a state needs assistance in the event of a nuclear accident or radiological emergency, whether or not such accident or emergency originates within its territory, jurisdiction or control, it may call for such assistance from any other state, either directly or through the IAEA, and from the IAEA, or, where appropriate, from other international intergovernmental organizations.

A state requesting assistance has to specify the scope and type of assistance required and, where practicable, provide the assisting state with such information as may be necessary for them to determine the extent to which it is able to meet the request. Any State may request assistance relating to medical treatment or temporary relocation into the territory of another state, for persons involved in a nuclear accident or radiological emergency.

The IAEA will respond to any State's request for assistance in the event of a nuclear accident or radiological emergency by:

(1) Making available appropriate resources allocated for this purpose;
(2) Transmitting promptly the request to other states and international organizations which, according to the IAEA's information, may possess the necessary resources; and,
(3) If so requested by the applying state, co-ordinating the assistance at the international level, which may thus become available.

The Convention discusses the issues of the international assistance in detail, including:

(1) Direction and control of the assistance;
(2) Competent Authorities and points of contact;
(3) Functions of the IAEA;
(4) Confidentiality and public statements;
(5) Reimbursement of costs;
(6) Privileges, immunities and facilities for assisting personnel; and,
(7) Claims and compensation.

These are addressed and resolved in what may be regarded as a friendly, common sense manner.

17.10. A review of selected nuclear transport event case histories

17.10.1. Introduction

Appendix II of TS-G-1.2 contains the details of three actual transport accidents and associated emergency response actions. In addition, a hypothetical situation involving uranium hexafluoride is discussed.

This current chapter includes a brief review of information on several selected case histories of transport events. While these case histories do not generally include details of the emergency response actions, they are very useful in assessing the effect of transport accidents on packages and can yield lessons that can be of value to shippers as well as carriers in reducing the frequency of recurrences. In addition, they provide information that may be used to set up scenarios for local drills and exercises for responding to emergencies that involve radioactive material. A list of references from which more detailed information can be gathered is provided at the end of this chapter.

17.10.2. Case history No. 1 – Boston, Massachusetts, 23 February 1968 [7]

This event, widely publicised at the time, later became known as the “frozen pig” incident. It involved the air shipment of a 540 kg lead/steel “pig” from warm California to frigid Boston, Massachusetts in mid-winter. The “pig” had been loaded underwater by its shipper with a sealed irradiation canister of quartz ampoules containing mixed irradiation samples. After arrival at Boston, the “pig” was transferred to storage outdoors within a delivery vehicle where it sat for several days. Later, leakage was observed from the drain spigot, which was then surveyed and found to be contaminated.

It was later determined that some water, which had not been drained from the cask cavity, had frozen and displaced the drain spigot and also ruptured the canister and ampoules. Upon thawing, the contaminated water was released into the delivery vehicle, where it contaminated other cargo. An extensive clean-up and survey effort then ensued to track down and remove any spread of contamination, which generally remained confined to the delivery vehicle itself.

This incident served as an early reminder of the importance of procedural quality control requirements in preparation of packages for shipment. In addition, it served as an example of local involvement, and of consignee and local authorities working together to deal with a contamination problem during transport.

17.10.3. Case history No. 2 – Buenos Aires, Argentina, 24 June 1975 [11]

A large-scale fire occurred at about 7.30 a.m. on the 24 June 1975 in a dock used to store dangerous goods in transit at the port of Buenos Aires, Argentina. The fire involved a Type B(U) package Model F79, containing a ^{60}Co source with an activity of about 74 TBq. This package was erroneously stored (administrative error) in a place for goods in transit instead of being speedily dispatched.

Personnel, who immediately notified the fire brigade, detected the fire because it was spreading quickly. The two-story warehouse (340 m x 30 m x 10 m) involved in the fire was built of masonry with a stone roof. The extent of the fire was about 50 m x 30 m x 10 m. The fire involved paper and rubber bobbins, a lorry parked on the first floor and packages containing spare engines on the second floor. The package containing the cobalt source was near the lorry.

Two hours after the fire began, the main roof stone collapsed, falling on the package with the cobalt source. The customs authority notified the office of the External Users of the Competent Authority, Comision Nacional de Energia Atomica (CNEA) at about 11:30 a.m. (four hours after the fire began). Forty minutes later the CNEA emergency group arrived at the scene of the accident. From this point, and until total control of the event had been gained (about thirty-five hours after the fire began), the CNEA emergency action team monitored the radiation dose rates and controlled access in the area. To minimize overheating of the contents of the package during the fire, a water jet was maintained over its external surface.

When the fire ended, the CNEA emergency group put up warning signs around the Type B(U) package. Then, the fire brigade removed the debris to permit the documentation of the event and to begin recovery.

Finally, the Type B(U) package was recovered and carried to Ezeiza Atomic Center, CNEA. The fire protection packaging was removed in a hot cell and the drawer, the fastenings of the source and the external containment of the source were inspected by CNEA personnel. This inspection showed that the container and shielding systems of the package were not damaged and there was no contamination.

As a result of this accident, two important conclusions were drawn:

(1) A brief analysis shows that in this case the event sequence was fire followed by impact, which is the reverse of the TS-R-1 test sequence of impact followed by fire. Thus, this accident demonstrates with a high level of reliability that Type B packages also withstand the reverse event sequence of fire followed by impact.

(2) The fire protection casing withstood the fire and adequately protected the package. On the other hand, some parts of the package which are not safety-related and found outside the fire protection casing, such as supports, base sheet and external surface paint, were damaged.

17.10.4. Case history No. 3 – Houston, Texas, 27 January 1988

An improperly blocked and braced radiography camera fell from a camper truck and was struck by a car. The camera became lodged beneath a following car and was dragged for several blocks. The hazardous materials response team responded to the accident and retrieved the package. Upon notification and subsequent arrival, the shipper discovered that the 1.8 TBq ^{192}Ir source was missing. Because they were unfamiliar with the package, the Emergency Response Team had not recognized that the radioactive source was not in the package. Eventually the shipper retrieved the source after it had been lying alongside the highway for about six hours. The individual performing the recovery received about 6.4 mSv. It was discovered that the camera had a small tear along a welded seam approximately 4 cm long and 1 mm wide. One of several violations associated with this consignment involved modifications that had been made to the Type B package design without receiving Competent Authority approval.

This incident is instructive in that scraping and tearing, a type of mechanism not specifically covered by the Regulations, damaged the package. It also highlights the fact that emergency responders should be aware that not all consignments are made in accordance with the Regulations.

17.10.5. Case history No. 4 – Toronto, Ontario, Canada, 26 March 1989

This accident involved a package of 816 MBq of ^{201}Tl that was crushed under the wheels of a forklift in an air cargo terminal at Pearson International Airport. The contents escaped and contaminated the floor of the cargo terminal and the forklift wheel. The driver's gloves became contaminated when an attempt was made to move the package. The radioactive label was only noticed at this time.

The accident caused considerable disruption to activity in the cargo terminal. The area was cordoned off and emergency response personnel from the shipper were called in to assess the situation and clean up the radioactive material. Due to the nature of the terminal floor (rough concrete with oil and grease), it was decided, as a temporary measure, to allow the remaining contamination to decay under a lead plate in the area cordoned-off. This allowed terminal activity to resume. The forklift wheel, as well as the contaminated gloves, were removed and stored. The terminal owner, despite the negligible hazard, later removed portions of the floor. There was no significant radiological risk to the public or to the transport workers.

This accident illustrates the importance of training transport employees in the correct response to accidents involving radioactive cargo and the disruptive effect of accidents with even small activities of radioactive material.

17.10.6. Case history No. 5 – Montreal, Quebec, Canada, 23 May 1989 [12]

A shipment of nine 48Y cylinders containing uranium hexafluoride (UF_6) residue was involved in an accident at sea on a journey from Europe to Canada via the ports of Rotterdam in The Netherlands, and Montreal in Canada. During a mid-Atlantic storm, three UF_6

cylinders, which were inadequately secured inside a 12 m closed freight container mounted on the deck of the ship, broke loose and damaged the freight container and two other neighbouring freight containers. Valves were broken from two of the cylinders. The radioactive material residue escaped and contaminated the deck of the ship, other equipment and cargo in the neighbouring freight containers. A section of the dock area was also contaminated when the freight containers were unloaded in the Port of Montreal. Over three weeks, the deck of the ship, UF_6 cylinders, freight containers, and cargo were progressively decontaminated to acceptable levels. The dock area was the last to be completed. Some of the damaged freight containers had to be scrapped. There was no significant radiological risk to the public, or to transport workers.

The accident was caused by the improper stowage of the UF_6 cylinders within the 12 m freight containers. Each of the nine UF_6 cylinders had been tied using four half-inch polypropylene lines. The lines were attached horizontally to strapping on the interior walls of the freight container. During the storm, some of the lines snapped and allowed three of the cylinders to roll freely within one freight container. During the uncontrolled movement, two valves and their protective covers were broken off. The cylinders were able to puncture the sides of the freight container and the two other neighbouring freight containers. The event received wide press coverage.

The accident prompted a change in the preparation for transport procedures of the shipping company. Port authorities also modified and improved their emergency response procedures.

17.10.7. Case history No. 6 – Springfield, Massachusetts, 16 December 1991 [13]

At 3:15 a.m. a tractor trailer carrying 12 Type A Fissile containers each containing two unirradiated fuel assemblies collided with a passenger vehicle travelling the wrong way down the interstate highway. The front axle of the truck separated from the truck during the impact with the concrete roadside barrier, but the cargo remained intact on the truck during the collision. Following the accident, a fire started in the engine compartment. Lack of suitable survey equipment, misunderstanding about the level of hazard, and poor communication led to the decision to allow the fire to burn itself out. The fire engulfed the tractor and then the trailer, burning the wooden outer containers and their hold-down straps. During the fire, eight containers fell off the trailer from a height of about 2 m and sustained minor damage.

Localized regions near the tyres had flame temperatures around 1000°C. The rest of the containers were exposed to temperatures of about 700°C. The fuel assemblies inside the containers were distorted to the configuration of the metal containers. In addition, some of the clad tubes had swollen due to the increase in pressure within the fuel rod as a result of the elevated temperatures during the accident. There was no release of radioactive material from the containers and the radiation levels near the containers did not exceed background levels.

It should be noted that the initial engine fire could have been easily extinguished with no radiological hazard to anyone involved. If this had been done then there would have been no damage to the fuel packages and the magnitude of the incident would have been much smaller. This incident emphasizes the importance of having teams well prepared for radiological emergency response.

17.10.8. Case history No. 7 – Propane truck collision with bridge column and fire white plains, New York, 27 July, 1994

[As a comparative study a case history of an accident involving a non-radioactive chemical is discussed here.]

About 12:30 a.m. on July 27, 1994, a tractor cargo-tank semitrailer loaded with 9,200 gallons of propane (a liquefied petroleum gas) and operated by Suburban Paraco Corporation was traveling east on Interstate 287 in White Plains, New York. The truck drifted across the left lane onto the left shoulder and struck the guardrail; the tank hit a column of the Grant Avenue overpass. The tractor and the semitrailer separated, and the front head of the tank fractured, releasing the propane, which vaporized into gas. The resulting vapor cloud expanded until it found a source of ignition. When it ignited, according to an eyewitness, a fireball rose 200 or 300 feet (about 90 m) in the air. The tank was propelled northward about 300 feet (about 90 m) and landed on a frame house, engulfing it in flames. The driver was killed, 23 people were injured, and an area with a radius of approximately 400 feet (about 120 m) was engulfed by fire.

The National Transportation Safety Board determines that the probable causes of this accident were the reduction in the alertness of the driver (consistent with falling asleep) caused by his failure to properly schedule and obtain rest, and the failure of Paraco Gas Corporation, Inc., to exercise adequate oversight of its driver's hours of service. Contributing to the accident was the design of the highway geometries and appurtenances, which did not accommodate an errant heavy vehicle. Contributing to the severity of the accident was the vulnerability of the bridge to collision from high-speed heavy vehicles.

In this accident investigation, the Safety Board identified the following safety issues:

(1) Truck driver fatigue
(2) Carrier's oversight of the driver's work/rest cycles
(3) Countermeasures for single-vehicle roadway departures (SVRDS)
(4) Compatibility of highway design and the operating characteristics of heavy vehicles and bridge vulnerability
(5) Cargo tank integrity.

As a result of its investigation, the Safety Board issued five safety recommendations to the Federal Highway Administration, one to the Research and Special Programs Administration, one to the New York State Department of Transportation, one to the American Association of State Highway and Transportation Officials, one to the American Association of Motor Vehicle Administrators, one to the American Trucking Association, and two to Paraco Gas Corporation, Inc. The Safety Board also reiterated three recommendations to the Federal Highway Administration.

RECOMMENDATIONS

As a result of its investigation of this accident, the National Transportation Safety Board makes the following recommendations:

— to the Federal Highway Administration:

Require that highway geometric design and traffic operations of the National Highway System be based on heavy-truck operating characteristics. (Class II,Priority Action) (H-95-32)

Conduct research with cargo tanks (80,000 pounds ≈ 36,360 kg) to evaluate the safety performance of roadside barriers and highway geometries, such as embankanent sideslopes and ditches, and change the standards accordingly. (Class II, Priority Action) (H-95-33)

Require any Federal-aid project involving bridges to use the 1994 Load and *Resistance Factor Design* guidelines for the protection of structures and the design of piers. (Class II, Priority Action) (H-95-34)

Cooperate with the Research and Special Programs Administration in studying methods and developing standards to improve the crashworthiness of front heads on cargo tanks used to transport liquefied flammable gases and potentially lethal nonflammable compressed gases. (Class II, Priority Action) (H-95-35)

Cooperate with the American Association of Motor Vehicle Administrators and the American Trucking Association to review and augment the commercial drivers license manual and test materials to include information on the role of fatigue in commercial vehicle accidents and methods to identify and address fatigue. (Class II, Priority Action) (H-95-36)

— to the Research and Special Programs Administration:

In cooperation with the Federal Highway Administration, study methods and develop standards to improve the crashworthiness of front heads on cargo tanks used to transport liquefied flammable gases and potentially lethal nonflammable compressed gases. (Class II, Priority Action) (H-95-37)

— to the New York State Department of Transportation:

When Interstate 287 is redesigned, design the geometrics and safety appurtenances for the vehicle characteristics of heavy trucks. (Class II, Priority Action) (H-95-38)

— to the American Association of State Highway and Transportation Officials:

Add a cargo tank to the design vehicles in the AASHTO A Policy on Geometric Design of Highways and Streets. (Class II, Priority Action) (H-95-39)

— to the American Association of Motor Vehicle Administrators:

In cooperation with the Federal Highway Administration and the American Trucking Association review and augment the commercial drivers license manual and test materials to include information on the role of fatigue in commercial vehicle accidents and methods to identify and address fatigue. (Class II, Priority Action) (H-95-40)

— to the American Trucking Association:

Cooperate with the American Association of Motor Vehicle Administrators and the Federal Highway Administration to review and augment the commercial drivers license manual and test materials to include information on the role of fatigue in commercial vehicle accidents and methods to identify and address fatigue. (Class II, Priority Action) (H-95-41)

— to Paraco Gas Corporation, Inc.:

Develop and implement driver scheduling, oversight, and monitoring practices that ensure that drivers obtain adequate rest in accordance with Federal hour-of-service requirements. (Class II, Priority Action) (H-95-42)

(a) Institute a written policy to ensure that all company drivers comply with the Federal Regulations (49 *CFR* 16) requiring the use of seatbeits whenever the vehicle is in motion; (b) ensure that all drivers are made aware of this requirement. and (c) monitor seatbelt use periodically. (Class II, Priority Action) (11-95-43)

Also, the National Transportation Safety Board reiterates the following safety recommendations to the Federal Highway Administration: H-94-5

Request States to identify and assess bridges that are vulnerable to collapse from a high-speed heavy-vehicle collision with their bridge columns and develop and implement countermeasures to protect the structures. H-95-3

Examine truckdriver pay compensation to determine if there is any effect on hours-of-service violations, accidents, or fatigue. H-95-5

Develop and disseminate, in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee, a training and education module to inform truckdrivers of the hazards of driving while fatigued**.** It should include information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss, such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience.

Source: http://www.ntsb.gov/publictn/1995/HAR9502.htm

REFERENCES FOR CHAPTER 17

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Standards Series, Safety Requirements No. TS-R-1, IAEA, Vienna (2005).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Emergency Response Planning and Preparedness for Transport Accidents Involving Radioactive Material, Safety Series No. 87, IAEA, Vienna (1988).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Emergency Response Planning and Preparedness for Transport Accidents Involving Radioactive Material, Safety Standards Series No. TS-G-1.2, IAEA, Vienna (2002).

[4] EMERSON, E.L., MCCLURE, J.D., Radioactive Materials (RAM) Transportation Accident/Incident Data Analysis Program, SAND82-2156, TTC-0385, Sandia National Laboratories, Albuquerque, NM, (1983).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Method for the Development of Emergency Response Preparedness for Nuclear and Radiological Accidents, IAEA-TECDOC-953, Vienna (1997).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, “Generic procedures for assessment and response during a radiological emergency” IAEA-TECDOC-1162, IAEA, Vienna (2002).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Convention on Early Notification of a Nuclear Accident and Convention of Assistance in the Case of a Nuclear Accident or Radiological Emergency, IAEA, Vienna

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, “Preparedness and Response for a Nuclear or Radiological Emergency”, Safety Standards Series No., GS-R-2, IAEA, Vienna (2202).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, “Emergency Notification and Assistance. Technical Operations Manual” EPR-ENATOM (2000). IAEA, Vienna (2000).

[10] GRELLA, A.W., Accident Experience with Type B Packaging in the United States of America, IAEA-SM-167/19, IAEA, Vienna (1971).

[11] RODRIGUEZ, C.E., PUNTARULO, L.J., CANIBANO, J.A., “Accidents involving radioactive material in transit stored at port depots: operational and regulatory aspects”, PATRAM ’86 (Proc. Symp. Davos, 1986), IAEA-SM-286/54 (1986) Vol. 1, 501–509.

[12] JOHNSTON, G.B., Report on Sea Accident and Montreal Contamination Incident involving UF6 Cylinders – May 23, 1989. Unpublished report in the files of the Atomic Energy Control Board, Ottawa, Canada (1989).

[13] U.S. NUCLEAR REGULATORY COMMISSION, Emergency Response to a Highway Accident in Springfield, Massachussetts, on December 16, 1991, NUREG-1658, USNRC, Washington, DC (1992).

EXERCISE FOR CHAPTER 17

The following exercise is to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 17.1. Emergency Planning and Preparedness

REFERENCE SOURCES: Training Manual, Chapter 17; and TS-R-1, Section III, V, and VIII.

DISCUSSION: Accidents will happen, and when they do the consignors, carriers, consignees, Competent Authorities, and even local and regional law enforcement and emergency responders must all be prepared to respond properly.

PROBLEM:

a. What specifically does TS-R-1 require with respect to emergency planning and preparedness?

b. As noted in this chapter, TS-G-1-2 identifies phases that can be used to structure an appropriate early response to an emergency. What are they?

c. What are the four prime actions first responders must take when responding to the initial phase of a transport accident involving radioactive material?

ANSWER:

18. TRAINING

18.1. IAEA Training policy

18.1.1. Introduction

Training policy, training philosophy, and training practices for the safe transport of radioactive material must be consistent with those for other aspects of IAEA activities and follow a systematic approach. In particular, the NUSS Safety Guide (Revision 1, 1790) "Staffing of Nuclear Power Plants and the Recruitment, Training and Authorization of Operating Personnel" [1] and the Guidebook on "Nuclear Power Plant Personnel Training and Its Evaluation" [2], provide detail on what a systematic approach involves. However, it is essentially a series of clearly identified stages for the analysis, design, development, implementation and evaluation of both initial and continuing training. With this method, there is assurance that job competence requirements for all groups of personnel, from policy makers and senior managers to practitioners and hands-on persons, are established and achieved. Competency can be considered in the three areas of knowledge, skills, and attitudes (termed the cognitive, psychomotor, and affective domains by educationalists) all of which are important when identifying training in any topic.

18.1.2. Competence

Only competent persons should be employed in positions involving radioactive material transport, particularly those that relate to safety. These positions and their associated duties and responsibilities should be clearly indicated in the descriptions of the consignor's, the carrier's and the consignee's organizations. It will be appropriate for others such as the Competent Authority employees, independent inspectors, and emergency responders to have their duties and responsibilities also specified to enable their training to be determined.

Member States, in general, recognize three categories of duties and responsibilities relating to the safe transport of radioactive material. Personnel can be grouped into (a) policy makers, and senior managers, (b) managers and similar responsible persons, and (c) practitioners and hands-on persons.

Within each group, there is a requirement for an individual to become appropriately qualified by means of:

- Basic educational level (e.g. academic qualifications);
- Previous experience;
- Training and continuing training;
- Medical fitness, if appropriate; and
- Authorization, when so required.

This chapter concentrates on training and continuing training. The responsibility of ensuring that individuals are appropriately qualified, and remain so, rests with the Competent Authority, the consignor's, the carrier's or the consignee's organization. In some Member States, a formal authorization issued by the Competent Authority may be required before a person is assigned to a designated position.

18.1.3. Training requirements

A series of requirements for training and continuing training should be prepared for each of the positions in the Competent Authority, the consignor's, the carrier's or the consignee's organizations. This is particularly important for those positions related to safety. Requirements will vary according to the level of responsibility and level of competence needed by each individual position. Job training requirements should be prepared by persons having specific competence in the safe transport of radioactive material and experience in training activities. It is the responsibility of the senior manager in each organization to ensure that for each position:

(1) The appropriate qualification requirements are established;
(2) The training needs are analyzed, and an overall training programme is developed;
(3) The proficiency of the trainee at the various stages of the training is reviewed and verified;
(4) The effectiveness of the training is reviewed and verified;
(5) The competence acquired is not lost after the final qualification; and
(6) The competence of the person occupying the subject position is periodically checked, and continuing training is provided on a regular basis.

18.2. Training system

18.2.1. Preparing a training programme

Ideally for each group of personnel identified in 18.1.2., a separate initial and continuing training programme should be defined and implemented. A job-specific training and qualification programme should be developed to provide and enhance the knowledge, skills, and attitudes necessary to perform the assigned tasks and functions under all conditions.

The training programme for most individuals should include on-the-job training to ensure that they obtain the required job-related knowledge and skills in the actual work environment. Formal on-the-job training provides hands-on experience and allows the trainee to become familiar with routine work while being trained. However, on-the-job training is not just working in the position under the supervision of a qualified individual, but it involves the use of learning objectives, qualification guidelines, and trainee assessment. This training should be conducted and evaluated in the work environment by qualified, designated individuals.

A performance-based training programme founded on an analysis of the responsibilities and tasks of a job should be designed, developed, implemented, and subsequently evaluated for each major work group. The programme design should include:

(1) The identification of all tasks for each work group;
(2) The analysis of these tasks in terms of the knowledge, skills, and attitudes required to perform the tasks adequately;
(3) Written learning objectives;
(4) The definition of basic educational and experience requirements, and selection of trainees;
(5) The training programme's specifications;
(6) The development of current training material and equipment;
(7) The structured organization of the planning, schedules, classroom instruction, laboratory exercises, special workshops and on-the-job training;
(8) Verification of the learning results; and
(9) Validation and improvement of the training programme.

18.2.2. Analysis

The first step is to conduct job and task analysis for all positions and then to identify training needs. The analysis identifies required knowledge, skills, and attitudes and the results are used to ensure that personnel are competent to perform all known predictable tasks and to avoid improper actions. If this analysis is undertaken within an organization where the potential trainees have already been selected and are actually in their posts, the training may have to be more rigorous than if the trainees are selected after a thorough job and task analysis has been undertaken.

18.2.3. Design

The second step is to establish the goals or purposes of each training programme in terms of general training aims. These will be statements as to what a particular training period must achieve. Examples of training aims are given in sections 18.7.2, 3, and 4 of this chapter. Further information on how the general aims will be met during the training period are then determined as learning objectives. Ideally, an objective will state what a trainee will be able to do under defined conditions, and to what standard, by the end of the training period. Accordingly, objectives must be capable of being observed and measured. Examples of such objectives are also given in 18.7.2, 3, and 4.

18.2.4. Development

From the aims and objectives of the training programme, the timetable for a module or course can be developed. The programme is broken down into training sessions, each of which will have its own aims and objectives. In fact, it is likely that the training programme objectives will be converted into training session aims that, in turn, will have their own objectives. These will state the anticipated performance, conditions, and standards, and they will all be observable and measurable. At this stage, the method of training will be chosen, as will the medium in which to conduct the training. Detail on the training activities and materials, including resources required, student handouts, and assessment questions would be developed in this phase.

18.2.5. Implementation

There are some training methods that are widely used.

(1) Classroom instruction is the most widely adopted training setting. Its effectiveness is enhanced by the use of training media such as written material, transparencies, audio, video, and computing devices and scale models.

(2) On-the-job training should be conducted according to the prescribed guidelines by job incumbents who have been trained to deliver this form of training. Progress should be monitored and assessment carried out by an independent assessor.

(3) Laboratory or workshop training is needed to ensure safe working practices. Mock-ups and models should be provided to train activities that have to be carried out quickly and skilfully and that cannot be practised with genuine equipment. Training mock-ups should be full scale to the extent possible.

(4) Open learning and self-study training can be undertaken at home and at the work place. In all cases, the trainees require support from a designated expert.

In general, the training should consist of periods of formal training in the classroom intermixed with intervals of laboratory or workshop training as well as practical training.

In some Member States central training facilities are available, and have proved to be beneficial. The use of foreign training facilities may involve the additional requirement for the trainees to know a particular foreign language and may also imply different National Regulations and practices.

The Agency provides comprehensive training courses and is able to provide some assistance with the organization of national training courses. These comprise classroom instruction with participative exercises and technical visits. A typical schedule for a comprehensive training course mainly intended for competent authorities is shown in Appendix A. This manual forms the basis for the lectures at such a course.

Even if off-site training facilities are to be used, a training expert or unit should still be a part of the Competent Authority, the consignor's, the carrier's, or the consignee's organizations. This expert or unit should:

(1) Advise the Senior Manager on questions related to training;
(2) Co-ordinate training activities on-site;
(3) Ensure proper liaison with the off-site training facilities; and
(4) Collect the appropriate evidence of the satisfactory completion of the training and continuing training of the individual persons.

The existence of full-time training staff does not relieve an organization's line management from their responsibility to ensure that their staff are adequately trained and qualified. Each supervisor should recognize and provide for the training needs of subordinates. The responsibilities and the authority of training personnel, as distinct from those of line management, should be clearly defined and understood.

Personnel at an on-site training unit should be properly trained, in particular about policies of the organization, regulatory requirements, and Quality Assurance (QA) practices.

The on-site or off-site training instructors should have sufficient technical knowledge in their assigned areas of responsibility. This means that they should be technically competent and have credibility with the trainees and other personnel within the organization. In addition, the instructors should be familiar with the basics of adult education and have adequate instructional skills. They should also be given the time necessary to maintain their technical and instructional competence through work experience and continuing training.

Training progress should be assessed and documented. Assessments of trainee performance can include:

(1) Written examinations;
(2) Oral questioning; and
(3) Performance demonstrations.

A combination of written and oral techniques has been found to be the most appropriate for knowledge and performance demonstrations. Assessment should not be regarded as a one-time activity. In some Member States, reassessment of individuals at regular intervals is undertaken by their instructors and their immediate supervisors.

18.2.6. Evaluation

Each training programme as well as the associated training facilities and materials should be periodically evaluated by a formal review and be modified if necessary. This evaluation should cover the adequacy and effectiveness of the training, with due consideration of the actual performance of persons in their jobs. It should also examine training needs, training programmes, and training facilities, and factors due to changes to regulations, changes in the organization, and lessons learned elsewhere in the transport industry. Such an evaluation should be undertaken by persons other than those directly responsible for the training. The evaluation may include an external audit.

18.3. Training programmes

18.3.1. General

All new employees starting with an organization should be introduced to their work environment in a systematic and consistent manner. General employee training programmes should give new employees a basic understanding of their responsibilities and safe work practices.

All persons likely to be occupationally exposed to ionizing radiation, and not only the radiation protection staff, should receive suitable training covering radiation risks and the technical and administrative means to prevent undue exposure and to implement the ALARA principle.

18.3.2. Training for supervisory personnel

In addition to the training described above, it is recognized that senior managers and responsible persons may require additional technical knowledge and skills as well as additional and also supervisory skills and attitudes.

Managers and supervisors should master their own technical field through basic training and long experience with the safe transport of radioactive material. This involves a thorough understanding of the relevant standards, rules, and regulations. Managers should also have good overall knowledge of the Regulations controlling the Transport of Dangerous Goods. Those having responsible positions as emergency responders should be specially trained for their emergency duties.

Since the persons in this category are being trained for leading positions in an organization, it is important that they promote the need for safety in all routine activities. This is best done by example.

The organization should also have a management development programme to ensure that an adequate number of qualified persons are available to fill any management position, in case such a need were to suddenly arise. Training of managers and supervisors, and of their potential successors, should include courses and seminars on management and supervisory skills.

18.3.3. Training for emergencies

General training should be provided for all personnel who have assignments during an emergency. Supplementary training should be provided to those personnel who must perform specialist duties required in the event of an accident.

Training for accident response and management should cover:

(1) Lessons learned from past accidents;
(2) Standards and regulations;
(3) Information on evaluated safety margins;
(4) Accident management measures; and
(5) The principal results of any probabilistic safety assessment that shows the importance of preventing damage or severe accidents.

18.3.4. Continuing training

Continuing training is that training necessary to maintain and enhance the competence of staff in terms of their knowledge, skills, and attitudes. It can also include training to improve the career development potential of selected individuals. Continuing training must be regarded therefore, as an integral part of the operations of an organization concerned with the Safe Transport of Radioactive Material. Continuing training based on a systematic approach is essential to ensure that the levels of qualification and competence are maintained, and upgraded when necessary.

Continuing training should be performed on a regular basis. The programme should involve all those personnel whose functions relate to safety, and should reflect the special needs of each category of trainees.

All personnel should have continuing training in the performance of their duties during an emergency. Similarly, persons occupationally exposed to ionizing radiation should receive periodic training in radiation protection.

Practitioners should undergo formal continuing training on a regular basis and the time needed for this should be taken into account when work schedules are established. In particular, refresher training should be provided for situations that do not occur frequently such as accidents.

The continuous training programme should also include:

(1) An update on equipment, packaging and packages;
(2) Procedure changes or modifications;
(3) Operating experience gained in-house;
(4) The transport industry as a whole; and
(5) Trends in job performance by category of trainees.

18.4. Experience requirements

18.4.1. General

Some guidance is given here on the previous experience required of candidates before being assigned to the various positions in an organization. Only general guidance can be given, because of the large variety of valid experience possible. The suggestions given in the following text are derived from data on average experience levels in countries that have significant activity involving transport of radioactive material.

Successful performance in subordinate positions is an acceptable component of required experience for head positions. The policy makers, senior managers, managers and responsible persons require a variety of experiences in positions of increasing responsibility. The prerequisite experience for these positions must include demonstration of leadership.

On-the-job training does not always correspond to practical experience. Its equivalence to practical experience, in terms of duration and of effectiveness for the qualification of a person should be assessed case by case.

18.4.2. Managers

Policy makers and senior managers should have experience in several of the important areas of activity such as operations, maintenance, or technical support. This experience may usually be gained in 10 to 15 years. They should also have appropriate management experience.

Managers and responsible persons should have experience in their respective fields of activity in order to develop specific competence and management capacity. This experience may usually be gained in 5 to 8 years, with a minimum of 2 to 3 years within a relevant organization.

Supervisors should have experience in a packaging, transport, or regulatory organization in order to develop teamwork and leadership experience. This experience may usually be gained in 4 to 6 years, with a minimum of 2 to 3 years within an organization transporting radioactive material.

The head of a radiation protection group should have experience at comparable facilities. Sufficient experience may usually be gained in 4 to 6 years at similar facilities.

18.4.3. Practitioners and hands-on persons

The senior members of this category should have operational experience with a relevant organization. Sufficient experience may be gained in 3 to 4 years, of which a minimum of 2 years are spent with an organization transporting radioactive material.

Other practitioners should have experience relevant to their duties and responsibilities.

18.5. Authorization

18.5.1. General

In some Member States, certain persons within the Competent Authority, the consignor's, the carrier's or the consignee's organizations, have to be authorized or certified before they are allowed to perform their duties. In these circumstances, procedures must be established for authorization, and training must be designed and organized to meet the procedures.

These procedures should provide for an assessment of the capabilities of persons to be authorized. These capabilities should include a thorough knowledge of the practices, rules and regulations, and hence training in these aspects must be provided.

Persons occupying these types of positions should hold a formal authorization issued by the Competent Authority. In some Member States, a proposal detailing the necessary qualifications and the functions to be performed by authorized personnel is submitted to the Competent Authority for approval. Training to satisfy those qualifications may be needed.

In the following text, the term “authorization” will be used to indicate both the authorization by the person’s organization and also the formal authorization issued by the Competent Authority. In some Member States, the Competent Authority requires documented evidence of the qualifications of other personnel, not normally authorized by them, whose duties have a significant, though not direct, bearing on safety.

It is the responsibility of the organization to ensure that all on-site and off-site personnel are appropriately qualified regardless of any formal authorization issued by other bodies.

The organization has the responsibility for establishing qualification criteria for its own personnel and for contractor personnel. This is particularly true for those who perform activities relating to safety. Assurance is required that contractor personnel meet the qualification criteria prior to active involvement in transportation or a support activity. Training may be necessary to provide such assurance.

18.5.2. Basis for authorization

Authorization should be based on a careful evaluation of the individual's qualifications including education, experience, training, and personal attributes. The level of the required knowledge and capability should be appropriate to the duties of the position.

18.5.3. Re-authorization

If the authorized individual moves to a different position in the same organization or to a different organization, for which an authorization is also required, that person should satisfy the specific qualification requirements and receive additional training, if necessary, before being authorized to assume the new position.

Consideration should be given to the need for periodic re-authorization as well as for re-authorization of individuals who are to resume authorized duties after an extended period of absence. An authorization is generally subject to a periodic review (2-3 years) of the competence of the authorized person. This authorization may be withdrawn, or not extended, if the required conditions are no longer met.

18.6. Records

Each organization should maintain adequate records of individual training plans of the performance of the individual trainees and of the authorizations issued. Records should be collected and kept according to the applicable QA requirements.

The main purposes of these records are:

(1) To provide evidence to the Competent Authority of the appropriate qualifications of all persons whose duties have a bearing on safety;
(2) To provide evidence for the basis for authorizations; and
(3) To provide documentation of use in the review of the training programme that will enable necessary corrective actions to be taken.

18.7. Assistance available from the IAEA

18.7.1. Areas of responsibility

As outlined in 18.1.2., Member States recognize three broad areas of duty and responsibility in the field of radioactive material transport into which personnel can be grouped. For each group, training programmes should be developed and implemented in the manner described:

(1) Competent Authority;
(2) Consignor/Consignee;
(3) Carriers' managers and Freight forwarders;
(4) Cargo handlers;
(5) Drivers of road vehicles;
(6) Public Functionaries; and
(7) Emergency Response Personnel.

The IAEA is able to provide some assistance toward training programmes comprising of classroom training and on-job training as identified in 18.2.5. For each of the three groups of personnel, overall training programme aims and objectives that are more detailed (by which the aims will be met) must be drawn up. Some typical examples of these at each of the three levels are given below.

18.7.2. Training programme aims and objectives for policy makers and senior managers

Typical training aims and objectives for policy makers and senior managers are given below.

18.7.2.1. Aim

To provide guidance to senior managers and policy makers as regulators, licensing personnel, consignors, carriers, forwarding agents, consignees and emergency service personnel on the regulations and practices for the safe transport of radioactive material.

18.7.2.2. Objectives

By the end of the training programme, the senior manager or policy maker should be able to:

(1) Describe a model of the atom and explain the process of radioactivity;

(2) State the quantities and units used in radiation protection and outline radiation protection principles;

(3) Define the terms used in IAEA TS-R-1 [3];

(4) Outline the types of radioactive material transported throughout the world;

(5) Explain the requirements of the IAEA Regulations for the Safe Transport of Radioactive Material;

(6) Explain the particular considerations necessary for the shipment of fissile material

(7) Explain the role of a National Competent Authority;

(8) Describe the agencies and agreements concerned with the transport of dangerous goods, and state how they relate to IAEA TS-R-1;

(9) Characterize international liability and insurance regarding radioactive material in transit;

(10) Outline the processes and procedures necessary to prepare radioactive material for transport;

(11) Describe the roles of the consignor and carrier in the control of radioactive material during transport;

(12) Explain the procedures necessary to transport a package under special arrangements;

(13) Describe the different types of package used for transporting radioactive material;

(14) Outline the tests and pass criteria specified by TS-R-1;

(15) Outline the role of Quality Assurance and in the safe transport of radioactive material;

(16) Outline the role of and need for Compliance Assurance in the safe transport of radioactive material;

(17) Outline the data collected by the IAEA on the transport of radioactive material;

(18) Outline the guidance given by IAEA in relation to emergency planning and preparedness;

(19) Describe the important components of a good training programme for personnel involved in radioactive material transport.

18.7.3. Training programme aims and objectives for managers and responsible persons

Typical training aims and objectives for managers employed by a carrier are given below.

18.7.3.1. Aim

To provide the manager with knowledge, skills and attitudes necessary to correctly interpret and apply those aspects of the Transport Regulations applicable to the loading, storage, shipping, handling, and unloading of radioactive material.

18.7.3.2. Objectives

By the end of the training programme, the manager should be able to:

(1) Ensure correct and safe execution of all aspects of the transport of radioactive material;
(2) Ensure that a package is stowed and segregated in accordance with applicable national and international regulatory requirements;
(3) Correctly select a vehicle and handling equipment;
(4) Describe the basic principles of radiation protection;
(5) Explain the quantities and units of activity and dose;
(6) Ensure availability and proper functioning of radiation monitoring instruments;
(7) Monitor and assess vehicle surface contamination;
(8) Monitor and assess dose rates at defined distances from the vehicle;
(9) Issue the appropriate personal dosimeter to drivers and cargo handlers;
(10) Interpret dose records for individual employees of the organization, and take appropriate action with regard to that individual's immediate future employment;

(11) Select employees with appropriate competence and ensure that competence is maintained via education, experience and training;
(12) Organize employee training in normal and accident conditions of transport;
(13) Take appropriate action if the organization's staff become involved in an accident;
(14) Instruct staff on the optimum method of delivering the radioactive material;
(15) Choose the correct vehicle placards and plates;
(16) Verify adequacy and completeness of transport documents.

18.7.4. Training programme aims and objectives for drivers of road vehicles

Typical training aims and objectives for drivers of road vehicles are given below:

18.7.4.1. Aim

To provide drivers of vehicles carrying radioactive material with the knowledge and skills necessary to take appropriate action in normal and accident conditions of transport.

18.7.4.2. Objectives

By the end of the training programme, the driver should be able to:

(1) Drive the vehicle safely;
(2) Check that the vehicle and stowage of load comply with national regulations;
(3) Recognize the significance of transporting radioactive material;
(4) State the basic principles of radiation protection;
(5) Quote the quantities and units of activity and dose;
(6) Make simple measurements of dose rate using the instruments provided by the carrier;
(7) Appreciate that there are international and national regulations for the safe transport of radioactive material, and that the latter may differ in different countries;
(8) State the relevant sections of the national regulations for the safe transport of radioactive material;
(9) Describe the driver's particular responsibilities in transporting the radioactive material, and relate these to the responsibilities of the carrier;
(10) Correctly interpret the information on labelling and marking;
(11) Take appropriate actions if involved in an accident.

18.7.5. Training courses available

Training courses for policy makers and senior managers – generally from the competent authority - are organized by the IAEA in the form of inter-regional or regional training courses through its Department of Technical Co-operation. Typical aims and objectives are identified in paragraph 18.7.2. of this chapter. The text of this manual is suitable for participants at such courses. Visual aids to support the presentations, which are consistent with the text of this manual, are available from the IAEA. A model timetable for a three-week course at this level is given in Appendix A, but this should be adapted to meet particular requirements. The advantage of the IAEA holding courses at this level is that consistency is achieved throughout the world. In addition, any modifications to the IAEA Regulations can be introduced into these training programmes with immediate effect.

Training for managers and responsible persons, particularly of companies involved in the actual transport of radioactive material, should be organized and run on a national basis, provided that competent teachers are available. If competent teachers are not available, the IAEA, upon request, may provide assistance for the Member State. Typical aims and objectives are identified in paragraph 18.7.3 of this chapter. Selected chapters from the text of this manual are suitable for trainees undertaking these courses. However, for specific aspects, additional text that is more detailed may be necessary. The IAEA may be able to assist with the procurement of visual aids to support training at this level.

Training for practitioners and hands-on persons such as drivers should be organized and run on a national basis. The number of persons to undergo training at this level is potentially very large. Typical aims and objectives are identified in paragraph 18.7.4. of this chapter, but these will need to be adapted to specific national or regional requirements. A selected chapter or paragraphs from the text of this manual are suitable for trainees undertaking these courses, although considerably more detailed text will be necessary. The IAEA may be able to assist in enabling Member States to collaborate in the sharing of training materials (such as texts and visual aids) to optimize resources for this level of training.

REFERENCES FOR CHAPTER 18

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Staffing of Nuclear Power Plants and the Recruitment, Training and Authorization of Operating Personnel, Safety Series No. 50-SG-1 Rev. 1, IAEA, Vienna (1991).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Power Plant Personnel Training and Its Evaluation, A Guidebook, Technical Reports Series No. 380, IAEA, Vienna (1996).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Standards Series, Safety Requirements No. TS-R-1, IAEA, Vienna (2005).

EXERCISE FOR CHAPTER 18

The following exercise is to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 18.1. Training

REFERENCE SOURCES: Training Manual, Chapter 18; Safety Series No. 112

DISCUSSION: Training is one of the areas for which the Competent Authority bears responsibility. This does not mean that the Competent Authority as such should provide training. The Competent Authority must ensure that there are national training programmes that address training requirements relevant to the extent that radioactive material is used and transported in the country.

PROBLEM:

a. Who should be trained on the safe transport of radioactive material?

b. Who can provide such training?

c. Why should training be provided?

d. Who is responsible for providing the training?

e. What is meant by the IAEA's standardized approach to transport safety training?

ANSWER:

19. SERVICES PROVIDED BY THE IAEA

Being in a unique position to facilitate information exchange, the former Standing Advisory Group on the Safe Transport of Radioactive Material (SAGSTRAM)[4] asked the IAEA in the mid-1980s to initiate data collection activities, establish a training programme and provide general information publications.

19.1. Data collection

The advantages of data collection are:

- The efficacy of the Regulations can be monitored;
- Data on radiation exposure can be made available to the IAEA and to other organizations such as the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR);
- Necessary input can be provided for the review and revision process for the Transport Regulations;
- Trends in transport conditions can be established;
- Factual information may be made available to help allay public concerns;
- Necessary input can be provided for risk analysis studies;
- Lessons-learned can be made available to help avoid similar occurrences;
- Authorities can obtain information helpful for allocating resources.

The main disadvantages of data collection are:

- The effort and resources which are required on the part of the IAEA, Member States and other international organizations are significant;
- There are potential difficulties over commercial sensitivity.

Because data collection work is critically dependent on available staff resources, SAGSTRAM provided specific guidance on the relative priorities between each database and the extent of information to be gathered within each database. The five databases being maintained are:

- National Competent Authorities (NCAL);
- Competent Authority Package Approval Certificates (PACKTRAM);
- Events in the Transport of Radioactive Material (EVTRAM);
- Shipments of Radioactive Material (SHIPTRAM);
- Radiation Exposure from Radioactive Material Transport (EXTRAM).

19.1.1. Regulations development and maintenance

The main objective of the IAEA's work programme in transport safety is to develop the radiological basis for the safe transport of radioactive material. The purpose of this is to review and, where necessary, revise the Transport Regulations in order to keep them in line with the latest radiation protection principles, transport practices and technological developments, and to monitor their application.

Part of the activity being carried out within this work programme is the collection of data that could provide the experiential documentation needed for the further development of regulations. Four databases are discussed.

[4] SAGSTRAM role has since been replaced by the Transport Safety Standards Committee (TRANSSC).

19.1.1.1. EVTRAM database

EVTRAM is the acronym for the database on events that occur during the transport of radioactive material. It was established on the recommendation made at the sixth meeting of SAGSTRAM in November 1987. This was done with the idea that the data prepared by the national Competent Authorities would be used by the IAEA as a source of information to help determine the effectiveness of the Regulations. Also, sharing summarized information would allow full use to be made of any lessons learned as a result of an accident or incident (referred to as events).

Consultant services were engaged in 1988 to develop the structure of the EVTRAM database together with a Transport Event Data Form to be used by Member States for collecting and reporting the data. It was decided that data should be collected for events that occurred from 1 January 1984 onwards. For various reasons (including lack of resources), it was only possible to obtain reports from some Member States on a limited number of transport events. Although the data collected could hardly be described as being sufficient basis for establishing trends and drawing conclusions it was nevertheless decided to publish a demonstration report. The purpose of this report was to demonstrate the type of analyses and cross-tabulations that could be made using the data obtained. The report also showed that Member States' concerns about the confidentiality of commercial information could be respected. This first report was published in 1997 as IAEA-TECDOC-966 "Review of events occurring during the transport of radioactive material for the period 1984-1993; A report on the IAEA's EVTRAM database" [1]. It was hoped that by providing this initial feedback on how the IAEA treated Member States' data, other Member States would be encouraged to provide data regularly to the IAEA.

The transport event data form comprises several parts:

- General notes on the form. These include: definitions, what to consider as reportable events, guidelines for completing the form, and explanations of some specific questions.
- The first part of the form asks for data about the event.
- The second part of the form asks for data about the packages involved in the event. One of these to be completed for each type of package and material involved in the event being reported. It is possible to have multiple package forms for any one event.
- A list of codes to designate geographic and political areas (needed for some entries in the first part of the form).
- An event severity scale that is being used for radioactive material transport.

In designing the form (and the structure of the database) it was considered important to circulate to Member States a stable form that is not changed too often. Thus, the form was developed to accommodate all the data that was considered necessary to know about any given event. Although at first none of the reports will contain the complete information about an event, it is hoped that this will improve with time. As responders to transport events become aware about the information that needs to be reported to the IAEA, they will be more alert in recording the details about the circumstances of an event. Eventually the database will contain increasingly more complete reports about transport events. Therefore better data will be available on which to base realistic analyses, trends, and conclusions. With the improved scope of reporting, it will not be necessary to upgrade the database structure nor the report form. Therefore, there is little intent to modify the transport event data form.

Each Member State designates a contact point that is responsible for co-ordinating its participation in the EVTRAM database. That contact point then sends the completed forms to the IAEA annually. Since it is only necessary to report events in which the safety functions of a package have been disturbed, it is not expected that the number of reports that need to be prepared will be high. Experience has shown for example, that Member States with nuclear energy programmes only have a few events to report in a year. For its part, the IAEA will be preparing reports that summarize and analyze the data received approximately every three to five years. An improved reporting base will ensure that these reports contain meaningful analyses that meet the objectives for which the database was established.

The terminology used within the EVTRAM database is consistent with the definitions in the Transport Regulations. Where these were not available, the following explanations are used [2]:

- Normal transport - A shipment that occurs without unusual delay, loss of, or damage to the package, or an accident involving the conveyance.
- Transport event - These comprise transport accidents and incidents when:
  - A shipment of radioactive material in transport is mislaid or misdirected;
  - A package or conveyance is damaged;
  - The contents of a package, or a package itself is lost or destroyed.
- Transport accident - An event during transport that leads to, or could lead to, abnormal radiation exposure conditions.
- Transport incident - All other transport events.

Guidelines being followed regarding the scope of events to be reported to the IAEA are:

- Events that happen between the time that the package is presented for transport and the time it is accepted by the consignee should be included. If an event takes place after the package has been loaded onto the vehicle, it should be included. Any events that happen during in-transit storage and handling are also to be included. Events involving transport within a facility, for reasons other than shipping off premises, are not to be included. Any event that happens during the preparation of the package for shipment is not to be included. If on opening the package, discrepancies are found in the form of missing components, or leaking vials, for example, these are to be included in the database.
- Events that were originally reported to be a problem but on investigation nothing was found to be in error, are regarded as non-events and are not included. For example, occasionally a package is reported to be leaking but closer examination indicates that the liquid is rainwater and there is nothing wrong with the package. This would not be included. On the other hand, if the outer surface of the package is cardboard and it was wet when it should not have been, it is possible that this should be included. Events with packages classified as excepted packages and carrying excepted quantities of material should not normally be included in the database. This is because the minimum hazard with this quantity of material in these packages and the lack of controls on their use and handling (particularly with smoke detectors) means that routine inclusion of them in the database could unduly influence statistical analyses. An exception is made when the Member State making the submission believes that it is a matter of interest to other Member States.

- If radiographic devices and gauges such as density measuring gauges are involved in events when being transported to and from the job site on public roads these should be included.
- The results of any radiation dose surveys undertaken by Member States as required in the Transport Regulations would not be included unless they resulted in an incident report.

The severity scale being used in the EVTRAM database was developed in the mid-1980's to provide technical information for further data analysis and correlation. Concerns have been expressed that the severity scale being used under the International Nuclear Event System [3] could be used instead. The latter is widely accepted as a tool for communicating to the public the consequences of an event occurring at a nuclear installation. Using INES classifications would show the consequences of transport events relative to those of events at nuclear installations, and therefore could be useful for addressing public concerns about transport events. The results of ongoing research being undertaken at other institutes and under the sponsorship of other international organizations will be considered in the further development of EVTRAM.

19.1.1.2. EXTRAM database

An assessment of the radiological impact of the transport of radioactive material was undertaken in October 1985 [4] at the first meeting of the Technical Committee on the Radiological Impact of the Transport of Radioactive Material. On that occasion, radiation exposure data from fourteen countries was collected and analyzed. The findings of this meeting were published in 1986 [5].

The overall conclusion was that while exposures due to transport of radioactive material were low, there was inadequate information on which to base a full assessment, particularly in relation to accidents and incidents. A subsequent technical committee agreed with this conclusion and stressed the need to consider the views of the international and regional organizations that compile data where transport information could be useful input. For example, UNSCEAR reviews and compiles information on radiation exposures from all sources, and their transport data is at present very limited. The technical committee agreed that it was essential to provide adequate information to maintain public confidence and that comparisons with radiation exposures from other activities would be helpful in this respect. The committee recommended that this should be a longer term objective and that the immediate aim should be to establish systems requiring a basic level of information and to develop the requirements once the systems are in place.

EXTRAM is the acronym for the database on radiation exposure resulting from radioactive material transport. At the recommendation of SAGSTRAM, the Secretariat established this database in 1989 by inviting Member States to provide the following information for the calendar year 1990:

(1) The main sources of radiation exposure for workers during transport, and
(2) An estimate of the collective dose due to all transport operations for members of the public.

The few responses received showed that there was no uniform understanding of the information being requested by the IAEA, and therefore no report was prepared on the results obtained.

Because of the requirements in paragraphs 301 and 304 of TS-R-1, a Technical Committee that met in October 1997 [6] recommended that efforts to develop the EXTRAM database be pursued further. It was suggested that relevant data should focus on those transport workers who are not otherwise engaged in transport or in other duties at fixed facilities. However, to the extent that data may be available and obtainable for fixed facility transport workers, an attempt to collect the data was recommended. Radiography workers and, to a similar extent, portable gauge users are special cases of transport worker because their exposures during transport are inextricably linked to their normal duties. Additionally, the radiography camera or portable gauge is often the transport package. Because of the significant activity of the sources in the devices, particular attention should be given to the exposure of the individuals who use them. It was also found important to determine exposure to the public from all phases of the transport of radioactive material.

Each Member State should determine the method for collection and evaluation of exposure data. It may involve an extensive gathering of exposure information or the use of sampling techniques from which valid conclusions can be drawn. The Member State will then analyze the national data, summarize the conclusions, and provide these to the IAEA. The role of the IAEA is to prepare an international report based on the Member States' contributions (ensuring that concerns regarding confidentiality are respected), make this report available to appropriate international organizations such as UNSCEAR, and to ensure that the information is used in preparing future editions of the Transport Regulations.

It is intended that the data below be collected for one calendar year. The following are regarded as essential:

(1) Annual dose to the maximum-exposed transportation worker;
(2) Annual dose to the maximum-exposed member of the public;
(3) Identification of the critical group of transportation workers by types of packages handled, such as:
  - Radiopharmaceuticals,
  - Radiography or portable gauges,
  - Spent fuel and high-level waste,
  - Low-level waste,
  - Uranium or uranium compounds;
(4) Identification of the critical group of the public by age and residence, such as:
  - Adult, teen, child, infant, or foetus,
  - Urban, suburban, or rural;
(5) Identification of the mode of transport causing maximum exposures;
(6) Identification of measured and calculated doses;
(7) Description of techniques used to measure or calculate doses; and
(8) Description of the main source of exposure.

The following additional data are regarded as optional:

(1) Estimate of the number of workers and members of the public exposed;
(2) Estimate of the collective doses to workers and members of the public by mode of transport;
(3) Estimate of the size of the critical groups; and
(4) Estimate of the collective dose to the critical groups.

Assuming that significant data are received, the IAEA will collate Member States' contributions and prepare an appropriate report. The results obtained will influence the further development of the EXTRAM database.

19.1.1.3. SHIPTRAM database

In the 1980's, the IAEA made the first attempt to develop a system for the collection, storage, and retrieval of information on the worldwide volume of traffic for all types of radioactive material by all modes of transport. Forms were sent to the IAEA's Member States requesting summary information based on the best data available to, or collected by, the Competent Authorities over an initial one-year reporting period. It was felt that this would be a reasonable compromise between the desirability of receiving exact data on a continuing basis and the necessity of having adequate and representative worldwide data. Further, it was planned that these data would be compiled and electronically stored in the IAEA for future use and reference by both the IAEA and Member States.

The data initially sought, for domestic and for export shipments were:

(1) For each classification of package:
   a. The mode of shipment,
   b. The number of packages,
   c. The transport indexes,
   d. The total distance of transport;
(2) The total number of packages by label; and
(3) A detailed summary of the number of movements, and the distance shipped, for each mode for certain package contents.

As data began arriving at the IAEA, it was noted that most data were not internally consistent. Other problems were identified that made it clear that computerization would not be possible. Nevertheless, by December 1984 the information had been analyzed and extrapolated with the help of consultants' services, and it was possible to publish a report in the following year [7]. This report is still often been cited as a source of shipping data.

Discussions at the Technical Committee meeting in 1988 resulted in a revised form to collect shipment data. Another attempt was made, but this time only for the nuclear fuel cycle and only for the calendar year 1990. Again, only a few Member States were able to provide the requested data and inconsistencies in reporting were observed. The low response rate meant that it was only possible to prepare an administrative report on the subject.

In 1997, the Technical Committee Meeting on transport safety databases considered that the purposes for collecting shipment data are:

(1) To provide reliable and understandable information to the public and international organizations on the increasing number of radioactive material shipments. Numbers are viewed as being particularly useful in aiding public understanding of transportation activities;
(2) To assess the relative accuracy of Member State shipment estimates; and
(3) To provide data on Member State shipments for use by international organizations in monitoring radioactive material shipments.

Risk assessments are not an objective of the IAEA's data collection activities. However, Member States may wish to collect such data (e.g. distance, exposure, routes and associated population densities along those routes) in addition to that requested by the IAEA in order to perform such assessments.

Member States differ in the relative ease by which data can be collected. Some have either compulsory or voluntary data collection systems that provide detailed data on virtually all shipments within the State, while others have no systems in place, and must devise approaches to collect shipment data. One that might be considered, particularly in those Member States with a large number of shipments, is the use of statistical sampling. However, there is concern that the use of different sampling techniques may unduly affect the compilation of summary data. So Member States are requested to provide a description of the sampling techniques used, together with the data collected. Depending on the outcome of results obtained in the next data collection period, and subject to the availability of resources, the IAEA may develop guidance on sampling techniques to be used for collecting radioactive material shipment data.

It is intended that data will be collected for fuel cycle and non-fuel cycle shipments. However, the non-fuel data may prove more difficult for some Member States to provide.

The collection of shipment data for excepted packages is not required because of the limited impact from the shipment of these packages and the difficulty in obtaining this information from some Member States. Member States who collect this information and wish to provide it to the IAEA may do so at their discretion, but Member States are under no obligation to do so.

With regard to the non-fuel data, transport of portable devices such as gauges and radiography devices, should be included.

For fuel cycle and non-fuel cycle shipments, the following types of information are recommended for collection:

(1) Number of shipments;
(2) Package Type. This is considered the parameter of most interest to the Member States;
(3) Mode. The use of a single, primary mode designation for all shipments, including multi-modal shipments has been suggested. It is recognized that this is not precise, but attempting to track the various modes has been considered to be too ambitious for SHIPTRAM at this time; and
(4) Transport Index. This may be the most difficult parameter for which to provide data. However, this data would enable some evaluation of occupational and public exposures occurring during transport operations.

The following types of information are considered to be of lower priority than the above-mentoned items; they are not recommended for collection at this time (Member States may provide this information to IAEA if they choose to, but are under no obligation to do so):

- Radionuclide;
- Distance;
- Activity and mass; and
- Category of material (e.g. LSA/SCO, fissile).

A survey was undertaken in 1996 to determine what transport data Member States considered the IAEA should collect, and what transport data Member States would be able to provide. The results of that survey were considered in selecting the data items to be collected for SHIPTRAM. These were then categorized into four tables:

- Table 1. Number of Packages Shipped by Package Type;
- Table 2. Number of Packages Shipped by Mode;
- Table 3. Number of Shipments by Package Type; and
- Table 4. Number of Shipments by Mode.

As in the other transport safety databases, the definitions are those in the Transport Regulations:

- Carrier (paragraph 206) — Shall mean any person, organization, or government undertaking the carriage of radioactive material by any means of transport. The term includes both carriers for hire or reward (known as common or contract carriers in some countries) and carriers on own account (known as private carriers in some countries);
- Consignee (paragraph 210) — Shall mean any person, organization, or government that receives a consignment and is named as consignee in the transport documents; (see paragraph 550);
- Consignment (paragraph 211) — Shall mean any package or packages, or load of radioactive material, presented by a consignor for transport;
- Consignor (paragraph 212) — Shall mean any person, organization, or government that prepares a consignment for transport, and is named as consignor in the transport documents; (see paragraph 550);
- Package (paragraph 230) — Shall mean the packaging with its radioactive contents as presented for transport;
- Shipment (paragraph 237) — Shall mean the specific movement of a consignment from origin to destination; and
- Vehicle (paragraph 247) — Shall mean a road vehicle (including an articulated vehicle, i.e. a tractor and semi-trailer combination) or railroad car or railway wagon. Each trailer shall be considered as a separate vehicle.

In addition, for the purpose of this database, “shipment” refers to the packages listed on a single shipping document. The following examples of shipments demonstrate the need to understand the terms being used in the transport Regulations:

- One shipment involving one package in one consignment being transported from one consignor to one consignee;
- One shipment involving one consignment with x packages being transported on one vehicle from one consignor to one consignee;
- One shipment involving one consignment with y packages being transported on more than one vehicle from one consignor to one consignee;
- Z shipments involving z consignments with yy packages being transported from one consignor on one vehicle and destined for more than one consignee;
- Xx shipments involving xx consignments with yy packages being transported on one vehicle from more than one consignor to more than one consignee;
- One shipment involving one package (e.g. a radiographic source) being used by one consignor at three sites;
- One shipment involving one consignor/consignee consolidating packages (e.g. waste collection or consolidation processing service) from more than one user.

Further work is needed to address these items before actual data collection is undertaken.

19.1.2. Implementation of the Regulations

Another objective of the IAEA’s work programme for radioactive material transport is to monitor the application of the Transport Regulations by Member States and other international organizations. The IAEA provides information services to assist Member States implement its Transport Regulations.

19.1.2.1. List of National Competent Authorities

Since 1967 the IAEA has been publishing a list containing the identity and postal and telegraphic addresses of the designated National Competent Authority for radioactive material transport (para. 207 TS-R-1), among its Member States. In Member States where the Competent Authority functions are distributed among two or more organizations, information is also provided on the functional responsibilities of the organizations listed. The list is updated and published annually in the form of a booklet. List No. 33 was distributed in 2002 [8]. Copies are sent on publication free of charge to the offices listed therein, to the IAEA's Member States, and to other registered interested parties.

For data verification purposes, information for the list is only accepted from either the National Competent Authority or the respective foreign ministry.

This list has proven to be useful particularly in the light of the Competent Authority's role in implementing international transport regulations (TS-R-1 para. 311).

19.1.2.2. Directory of Package Approval Certificates (PACKTRAM)

The IAEA's Transport Regulations prescribe various requirements for the authorization of packages and shipments in respect of both national and international movement of radioactive material. These authorizations are issued by the relevant Competent Authority of the country concerned in the form of approval certificates of any of the following types:

(1) Special form radioactive material;
(2) Low dispersible radioactive material;
(3) Special arrangement;
(4) Shipment; and
(5) Package design.

At the request of SAGSTRAM, the IAEA established a programme to maintain a file of those certificates for packages and shipments that are either transported internationally or used outside the country of origin. The data were published in the "Directory of National Competent Authorities Approval Certificates for Package, Shipments, Special Arrangements and Special Form Radioactive Material" in 1986 and 1987 [9]. Data for those publications were processed on the IAEA's mainframe computer.

In the late 1980's, the services of a consultant were engaged to rewrite the computer program for use on a personal computer to allow contributing Member States and the IAEA more flexibility in data processing and reporting. The system program for the PACKTRAM database (distributed free of charge) is a 424 kbyte executable file for which complete documentation is available in the form of a user guide [10].

The PACKTRAM database contains administrative and technical data on valid and recently expired approval certificates. Between 1,300 and 1,600 records are carried at any given time. Member States update their entries annually, some doing so by using the standard data input forms, while a growing number provide data in electronic form either on data diskettes, through electronic mail or by file transfer protocol. The IAEA verifies data submitted by Member States and archives the records before preparing an annual report [11]. The report is distributed to the National Competent Authorities worldwide, as well as users of the database and other interested parties. It has proven to be a useful tool for compliance assurance, being a handy reference for safety regulators and customs and port officials.

Shippers consult the annual report for information on designs currently in use for transporting various types and quantities of radioactive material.

The data collected for the PACKTRAM database is as shown in the data input form. The annual report shows the data rearranged into various tables. Tables 1 to 4 of the annual report present administrative data including issue and expiry dates, package identification, package serial numbers, modes for which the package/shipment is approved and the edition of the IAEA's Transport Regulations on which the approval was based. The technical information on package mass, authorized contents, and detailed and general description for all packages reported in the database are in Table 5. Table 6 lists the certificates reported by each participating Member State with a note to indicate when the data was last updated. Appendix I lists the Vehicle Registration Identification country codes being used to form the Competent Authority identification marks. (All records in the database are based on these identification marks.) Appendix II lists the addresses of the Competent Authorities who provide information to the PACKTRAM database, or who have signified their intent to do so. Appendix III provides statistics on the certificates being reported in the current report. A copy of the data input form is reproduced in Appendix IV.

19.2. Training and public information

19.2.1. IAEA Training

Since 1994, the IAEA has been annually offering training on the philosophy and provisions contained in its Transport Regulations. This is a means of helping Member States to establish or improve national regulatory infrastructure for radioactive material transport. The IAEA's Department of Technical Co-operation and Department of Nuclear Safety together with the designated institute at the host Member State jointly organize the training courses. The methods of instruction include lectures, practical exercises, open panel discussions, and technical visits.

Nominations are submitted through the Ministry of Foreign Affairs, the National Atomic Energy Authority or the Office of the United Nations Development Programme. Participants are officials of National Competent Authorities or managers or technical staff from organizations undertaking the transport of radioactive material. It is expected that the participants will use the training provided by the IAEA in carrying out their regulatory or operational functions.

As the training courses are taught based on the IAEA's Transport Regulations, all IAEA publications regarding radioactive material transport are provided to course participants. These include the Transport Regulations with the supporting documents, the safety practices, the training manual with visual aids, and other publications available in electronic form. Together, all these publications comprise the IAEA's standardized training material for radioactive material courses. The training material is available to Member States for use in their national training programs.

The IAEA offers two types of training course:

(1) Comprehensive training on the complex and elaborate transport safety programme associated with the nuclear fuel cycle, operation of a nuclear reactor or waste management operations (lasting about two weeks); and,
(2) Condensed training focusing on requirements relating to the safe transport of non-fuel cycle radioactive material (one-week).

It is expected that participants at the IAEA's training courses will, in turn, pass the knowledge gained to others in their own country as part of the "train the trainers" strategy.

19.2.2. Training material for national training programmes

In addition to the comprehensive and the condensed courses, the IAEA has developed visual aids for use by Member States at the national level. These visual aids have been specifically developed for use in:

- A 3-day course for carriers;
- A 1 or 2-day course for emergency responders;
- A half-day course for cargo handlers;
- A half-day course for Public authorities (Other than Competent Authorities); and
- A 1-day seminar to introduce new regulations to existing users.

Each of these sets of visual illustrates to varying degrees the chapters of this Training Manual. The 3-day course is primarily intended to provide detailed instruction for carriers or for small consigning organizations. The one- or two-day course is designed primarily for emergency responders, i.e. persons indirectly involved with the transport of radioactive material. These could include police officers, fire service personnel, ambulance crews, and customs officers. The one-day seminar is designed to introduce the latest transport regulations to established existing users at all levels.

19.2.3. Public information

The IAEA has developed a colour video film describing its work programme, and presenting some basic information on the principles for transporting radioactive material safely.

19.3. Transport Safety Appraisal Service (TranSAS)

The Agency recently established a service by which Member States can request an appraisal of their regulatory infrastructure for safety in the transport of radioactive material. The service is carried out by a team of independent experts who, using an Agency-prepared checklist, review national regulations for compliance with international requirements, co-ordination among relevant national regulatory offices, the extent of use of radioactive material in the country and the transport scenario resulting therefrom, and practices in actual transport operations. The service concludes with a report that summarizes the findings by citing good practices that have been observed, and suggests items for improvement, when applicable. It is the prerogative of the Member State involved to de-restrict the distribution of a TranSAS report, and to carry out improvements suggested by the TranSAS.

19.4. Computer tools

The former edition of the IAEA's Transport Regulations (Safety Series Nos. 6, 7, 37 and 80) were available in a computer programme called HyperTrans! The software was structured using text (or graphics) windows or nodes connected by links. These links connected texts or keywords in the four IAEA documents. The user jumped from the text in the regulatory document to the advisory or explanatory material by clicking on the links; it was possible to create reader's notes and printing the results of text searches.

The current edition of the Transport Regulations will likewise be available electronically in SafeTRAM, a programme that will link keywords not only within the transport safety publications, but also with the Basic Safety Standards [12].

REFERENCES FOR CHAPTER 19

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Review of Events Occurring During the Transport of Radioactive Material for the Period 1984–1993; A Report on the IAEA's EVTRAM Database, IAEA-TECDOC-966, IAEA, Vienna (1997).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Chairman's Report of the Technical Committee Meeting on the Assessment of the Radiological Impact of the Transport of Radioactive Material, TC-556.2, 11–15 April 1988, IAEA (1988).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY and NUCLEAR ENERGY AGENCY/OECD, INES: The International Nuclear Event Scale, User's Manual, Revised and Extended Edition 1992, IAEA/INES/92/01, IAEA/OECD/NEA Vienna (1992).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Chairman's Report of the Technical Committee Meeting on the Assessment of the Radiological Impact of the Transport of Radioactive Material, TC-556, 21–25 October 1985, IAEA, Vienna (1985).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Assessment of the Radiological Impact of the Transport of Radioactive Material, IAEA-TECDOC-398, IAEA, Vienna (1986).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Chairman's Report of the Technical Committee Meeting on the Transport Safety Databases, TCM-1048, 20–24 October 1997, IAEA, Vienna (1997).

[7] POPE, R.B., "Estimated Annual Worldwide Shipments of Radioactive Material", Packaging and Transportation of Radioactive Materials, PATRAM '86, (Proc. Symp. Davos, 1986), IAEA-SM-286/6, IAEA, Vienna (1987) 459.

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, National Competent Authorities Responsible for Approvals and Authorizations in respect of the Transport of Radioactive Material, NCAL-33, IAEA, Vienna (2002).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Directory of National Competent Authorities Approval Certificates for Package, Shipments, Special Arrangements and Special Form Radioactive Material, IAEA-TECDOC-389, Vienna (1986), IAEA-TECDOC-442 (1987).

[10] INTERNATIONAL ATOMIC ENEGRY AGENCY, The PACKTRAM Database on National Competent Authorities' Approval Certificates for Package Design, Special Form Material and Shipment of Radioactive Material, User's Guide for Compiled System Program, IAEA/CMS/07, IAEA, Vienna (1995).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Directory of National Competent Authorities' Approval Certificates for Package Design, Special Form Material and Shipment of Radioactive Material, (updated annually since 1989) 2002 Edition, IAEA-TECDOC-1302, Vienna (1997).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, STI/PUB/996, IAEA, Vienna (1996).

EXERCISE FOR CHAPTER 19

The following exercise is to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE 19.1. Information Services Provided by the IAEA

REFERENCE SOURCES: Training Manual, Chapter 18

DISCUSSION: In addition to training, the IAEA provides information services to help Member States in implementing the Transport Regulations.

PROBLEM:

Give an outline of the information services that the IAEA provides to help Member States use the Transport Regulations.

ANSWER:

TYPICAL PROGRAMME FOR A COMPREHENSIVE TRAINING COURSE ON THE SAFE TRANSPORT OF RADIOACTIVE MATERIAL

Day / Time	Week One	Week Two
MONDAY 0900-1030	Course opening and administrative arrangements	Review of homework assignment
Morning break		
11:00-1230	Module 1. Introduction	Module 11: Classification of LSA material and SCO
Mid-day break		
1330-1500		Module 12. Quality assurance
Afternoon break		
1530-1700	Module 2. Review of radioactivity and radiation Module 3. Review of radiation protection principles	Module 13. Fissile material
TUESDAY 0900-1030	IAEA transport safety video film	Module 14. National competent authority
Morning break		
1100-1230	Module 4. Regulatory terminology	
Mid-day break		
1330-1500	Module 5. Basic safety concepts – materials and packages	
Afternoon break		
1530-1700		
WEDNESDAY 0900-1030	Module 6. Activity limits and material restrictions	Module 15. Additional regulatory constraints for transport
Morning break		
1100-1230		Module 16. International liability and insurance
Mid-day break		
1330-1500	Module 7. Selection of optimal package type	Module 17. Emergency planning and preparedness
Afternoon break		
1530-1700		
THURSDAY 0900-1030	Module 8. Test procedures – material and packages	
Morning break		
1100-1230		
Mid-day break		
1330-1500	Module 9. Requirements for transport (consignor's responsibilities)	Desktop exercises
Afternoon break		
1530-1700		
FRIDAY 0900-1030	Module 10. Control of material in transport (consignor's and carrier's responsibilities)	Module 18. Training
Morning break		
1100-1230		
Mid-day break		
1330-1500		Module 19. Information services provided by the IAEA
Afternoon break		
1530-1700		Closing Ceremonies

Note: Each module comprises a lecture and practical component; the time allotted for a module is bound by solid lines and may extend over scheduled breaks.

ANNEX A

TRAINING MANUAL FOR PUBLIC AUTHORITIES

A1. BASICS OF RADIOACTIVITY AND THE SIGNIFICANCE OF TRANSPORTING RADIOACTIVE MATERIAL

A1.1. Basic atomic and nuclear structure

A1.1.1. Atoms and nuclei

The simplest unit into which matter can be broken down is the atom. Atoms may stand in isolation (e.g. noble gases) or may combine, for example, to form molecules like water or air. Atoms can be regarded as having two main parts. The first part is the central core, called the nucleus. Orbiting the nucleus are very small lightweight negatively charged particles called electrons.

The nucleus of the atom consists of a tightly bound group of particles of two types, protons and neutrons. Protons are positively charged (to compensate for the negatively charged electrons) and the neutrons have no charge (are neutral). The overall charge of any atom is zero. (Figure A1.1).

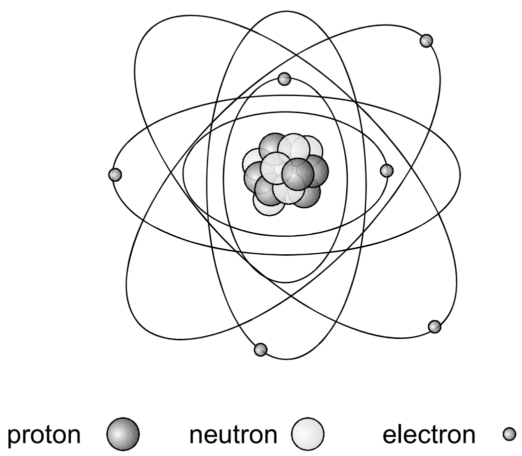


FIG. A1.1. Structure of an atom.

A1.1.2. Protons and neutrons

The hydrogen atom has 1 proton in the nucleus and 1 electron orbiting; the helium atom has 2 protons and 2 neutrons in the nucleus and 2 electrons orbiting; the carbon nucleus has 6 protons and 6 neutrons while 6 electrons are in the orbit.

A1.1.3. Isotopes

The number of neutrons may vary even in a given element. Changing the number of neutrons does not essentially influence the chemical properties of the atom. For example, if a neutron is added to the nucleus of the simplest hydrogen atom (originally consisting of one proton and one orbiting electron), a different structure is formed, but it is still hydrogen, as it still has only one proton. This is said to be an isotope of hydrogen. If another neutron is added to the nucleus, another isotope of hydrogen is formed. Some examples of isotopes are shown in Table A1.1. Uranium, among naturally occurring elements, has the highest number of protons.

Isotopes are commonly denoted by indicating the total number of protons and neutrons in the nucleus (the mass number), e.g. ^{3}H, ^{12}C, ^{60}Co, and ^{238}U.

TABLE A1.1 SOME EXAMPLES OF ISOTOPES

Element	Number of protons	Number of neutrons	Mass Number
^{3}H (Hydrogen)	1	2	3
^{60}Co (Cobalt)	27	33	60
^{99}Mo (Molybdenum)	42	57	99
^{131}I (Iodine)	53	78	131
^{137}Cs (Caesium)	55	82	137
^{238}U (Uranium)	92	146	238

A1.2. Radioactivity

If a nucleus contains too few or too many neutrons, it is unstable. An unstable nucleus will try to become more stable by emitting energy in the form of radiation, and it is said to be radioactive. Radioactivity can be simply defined as the process in which unstable nuclei attempt to reach a stable state by emitting radiation. This radiation is harnessed for its many beneficial applications in medicine, industry, etc., which are discussed in a later section.

A1.2.2. Radioactive decay and half-life

When an unstable, radioactive nucleus emits radiation to become more stable, it is described as disintegration or decay. The time in which, on average, half of a certain (large) number of nuclei of a particular isotope will decay is characteristic for that particular isotope and is called its half-life. Isotopes with short half-lives such as ^{131}I and ^{99}Tc find application in nuclear medicine where a small quantity of the isotope is administered to the patient either orally or intravenously for accurate diagnosis of a variety of diseases. Isotopes with large half-lives, such as ^{60}Co, are used for treatment of cancer and sterilization of medical products and food.

A1.3. Radiation

An unstable nucleus will eventually become more stable by emitting particulate and/or electromagnetic radiation. Radiation emitted by unstable nuclei can be alpha radiation (α particles), beta radiation (β particles), gamma radiation (γ) and neutrons.

A1.3.1. Ionization

Radiation can cause ionization of another atom. Ionization is the process by which an electron is removed from a neutral atom thereby leaving a positively charged ion (Figure A1.2). This property of ionization is used for detection of radiation. It also enables the radiation to be shielded.

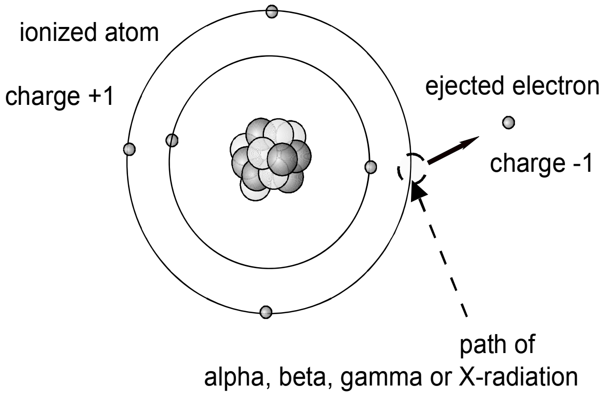


FIG. A1.2. The ionization process.

A1.3.2. Alpha radiation

Alpha particles consist of two neutrons and two protons. An alpha particle will give up its energy within a very short distance mostly by causing ionization. Alpha radiation is not very penetrating. It can be easily shielded. In fact most alpha particles cannot penetrate the dead layer of cells on the skin surface and therefore do not present any hazard while the alpha emitting radionuclide is external to the body. However, if the material becomes ingested or inhaled into the body then the alpha particles can ionize atoms in living cells. Special instruments are used for detection of alpha radiation. Alpha emitters are used as static eliminators in industrial processes where an electric-charge-free environment is essential for production efficiency.

A1.3.3. Beta radiation

Beta particles are identical to electrons. They are very much smaller and lighter than alpha particles. They are consequently more penetrating. Their rate of ionization is much less than that of alpha particles. The penetration range of beta particles depends on their energy and the density of the material they are passing through. A beta particle of average energy will not penetrate a thin sheet of metal, and will travel about 10 mm in tissue. Hence, beta-emitting radionuclides can be a hazard to skin and eyes and also if they are incorporated into the body. Ease of detection of beta radiation depends on the energy. Beta sources are used in nuclear medicine, agriculture research and industrial manufacturing (e.g. thickness gauging of polyester films).

A1.3.4. Gamma radiation

Gamma radiation is electromagnetic radiation similar to radar, radio, TV, microwave, light, ultra-violet, and infrared radiation but has higher energy, higher frequency, and shorter wavelength. It also causes ionization indirectly. Gamma radiation is very penetrating, but can be shielded by dense materials such as lead and steel. It is an external and an internal hazard, and is easily detected at very low levels. Gamma sources are widely used (e.g. cancer treatment, industrial radiography for non-destructive testing, sterilization of medical products and food).

A1.4. Some units of relevance to radiation protection

Some of the units which would be useful for the present purpose are explained below.

A1.4.1. Activity

The activity of a radioactive material is the number of disintegrations per unit of time. The corresponding unit is the becquerel (Bq). In the past, the unit of activity was the Curie. This term may be still in use in some countries.

A1.4.2. Dose

When radiation interacts with matter, it will deposit energy in matter. The amount of radiation that is absorbed in a material is called the dose.

The unit of dose is Sievert (Sv). It may also be expressed in sub-units such as milliSievert (mSv) and microSievert (µSv). Another term for dose which was in common use is rem and its sub-units are millirem and microrem.

Normally, when radiation levels are measured using portable radiation monitors, the measured values are expressed as dose-rates or dose per unit time, e.g. mSv/h. If a radiation monitor reads the radiation level at a location as 2 mSv/h, it simply means that if an individual spends one hour at the spot he/she would receive a total dose of 2 mSv. If the person spends only 30 minutes at the spot, the dose received would be just 1 mSv. Since the dose-rates typically encountered in the transport environment are very low, the commonly used unit of dose rate is µSv/h. Radiation monitors are calibrated in µSv/h and multiples thereof.

A1.5. Background radiation levels

All living organisms are continually exposed to ionizing radiation, which has always existed naturally. The sources of that exposure are cosmic rays that come from outer space and from the surface of the sun, naturally occurring radioactive material in the earth's crust, in building materials (e.g. ceramic tiles, concrete, marble) and in air (e.g. basements of buildings), water and foods (e.g. milk) and in the human body itself. Some of the exposures are fairly constant and uniform for all individuals everywhere, for example, the dose from ingestion of potassium-40 in foods. Other exposures vary widely depending on location. Cosmic rays, for example, are more intense at higher altitudes, and concentrations of uranium and thorium in soils are elevated in localized areas. Exposures can also vary as a result of human activities and practices. In particular, the building materials of houses and the design and ventilation systems strongly influence indoor levels of the radioactive gas radon and its decay products, which contribute significantly to doses through inhalation. The natural background radiation level varies from place to place on the earth. The average dose one receives from natural background radiation is estimated to be around 2.4 mSv in a year.

A1.6. Uses of radioactive material

Radioactive materials are used in medicine, industry, research and production of electricity around the world each day. These products must be properly and safely shipped from the point of manufacture (supplier's licensed facility) to the point of use (customer's licensed facility).

At this point, it is worth providing a brief overview of some of the everyday uses of radioactive material for those who are a little less familiar with the subject. Radioactive material is used in many more ways than most people realize to improve the quality of life. Whenever or wherever it is used, it is incumbent on qualified individuals and responsible organizations to ensure that the radioactive material is prepared, used, handled, transported and disposed of in a safe manner. The following text and Fig. A1.3 provide a brief overview of some examples of these activities that require shipment of radioactive material or waste.

FIG. A1.3. Some uses of radioactive material.

A1.6.1. Health care product and consumer product irradiation

Gamma rays from cobalt 60 (^{60}Co) are commonly used to irradiate health care and consumer products. This includes surgeon's gloves, gowns, sutures, syringes, catheters, etc. In fact, about 45% of all medical disposables are sterilized using gamma radiation from ^{60}Co. Consumer products such as bandages, cosmetics, hygiene products and solutions are also sterilized by ^{60}Co. The prevention of infection through this sterilization technique complements the basic healing goal of medicine. About 200 facilities located in more than 50 countries worldwide provide sterile medical devices using gamma irradiation techniques [1]. Radioactive materials (typically ^{137}Cs) are also used for blood irradiation (for patients with deficient immune systems so as to preclude rejection of graft).

A1.6.2. Nuclear applications in medicine

There are many applications of nuclear technology in the medical field, ranging from diagnostics, to treatment, to disease management [1]. Many of these use radionuclides are produced in either nuclear reactors or cyclotrons. Examples include use of specific radioactive material for diagnostic studies in specific organs/tissues ^{123}I (thyroid), ^{111}In (brain); ^{67}Ga (Hodgin's disease, hepatoma, bronchogenic carcinoma, etc.); ^{99m}Tc (heart); ^{201}Tl (myocardial tissue); ^{11}C (brain); ^{81m}Kr (lung); ^{13}N (heart); and ^{18}F for epilepsy. The safe transport of the radionuclides from the production sites to the hospitals, eventually followed by the safe transport of their residues and related wastes to disposal facilities, is vital to the success of nuclear medicine.

Several tens of thousands of nuclear medicine procedures are conducted every day all over the world. For example, in the United States alone an estimated 16 million nuclear medicine imaging and therapeutic procedures are performed each year. Of these, 40–50% are cardiac exams and 35–40% are cancer related. Nuclear medicine, being a powerful tool deployed by the medical profession the world over, is increasingly being used in several countries because of the benefits that accrue to patients. There are nearly 100 different nuclear medicine imaging procedures available today. Unlike other tests/procedures, etc., nuclear medicine provides information about the function of virtually every major organ system within the body. Children commonly undergo nuclear medicine procedures to evaluate bone pain, injuries, infection, or kidney and bladder function. Common nuclear medicine applications include diagnosis and treatment of hyperthyroidism (Graves' Disease), cardiac stress tests to analyze heart function, bone scans for orthopedic injuries, lung scans for blood clots, and liver and gall bladder procedures to diagnose abnormal function or blockages.

A1.6.2.1. Diagnostic techniques

There are two distinct methods used in diagnostics [1, 2]. The first is to use the isotope as an *in vivo* tracer. Here, a carefully chosen radionuclide (commonly known as a radiopharmaceutical) is administered to a patient through inhalation, injection, or ingestion, to trace a specific physiological phenomenon. Detection is accomplished with special detectors such as a gamma camera placed outside the body. The radiopharmaceutical can be selected to seek out only desired tissues or organs. There are hundreds of radiopharmaceuticals used in this way. As an example, recurrent prostate cancer is identified by using an ^{111}In labelled antibody [3].

The second method is to use an *in vitro* technique. For example, blood can be taken from the body and studied using nuclear methods to assess exposures to infection by evaluating antibodies. It can also be used to provide detection of tumours by studying some two dozen tumour markers.

A1.6.2.2. Treatment of disease

Radiation is widely used for the treatment of diseases such as hypothyroidism and cancer. Cobalt 60 is the primary isotope used in cancer therapy. In addition to teletherapy, where the radiation source has no physical contact with the tumour, the radiation source may be placed in immediate contact with the tumour, as in brachytherapy. There are other applications which target the specific tissue or cancer cell thereby minimizing the risk to surrounding tissue and cells[1, 2].

A1.6.2.3. Disease management

In addition to the sterilization of medical equipment discussed earlier, nuclear medicine is also being used to reduce pain [1]. Radiotherapy is administered to patients to palliate the pain, thus replacing pain-killing drugs, which eventually lose their effectiveness. For example, physicians can administer a bone-seeking compound labelled with a radiation emitter, and the level of pain can be quickly lowered or totally eliminated [1].

A1.6.3. Food irradiation

The use of gamma rays and electron beams in irradiating foods to control disease-causing micro-organisms and to extend shelf life of food products is growing throughout the world [4]. Food sterilization has been approved by 40 countries and is encouraged by the

World Health Organization [4]. The radiation source that is commonly used for this purpose is ^{60}Co, which is produced at one facility and transported to another facility for irradiation of the product.

A1.6.4. Insect control

Radioisotopes are assisting in enhancing animal and food production. One method is the control of insects, including the control of screwworms, fruit flies, and the Tsetse fly [5]. The Tsetse fly causes the transmission of a parasitic disease, trypanosomiasis, which slowly destroys livestock herds, in sub-Saharan Africa. It also causes the spread of the human form of the disease, known as sleeping sickness. By irradiating male Tsetse flies in a controlled gamma ray environment, the male flies are made sterile, and the Tsetse fly population can be reduced to insignificant levels. The low-level exposures to gamma rays are provided by ^{60}Co and ^{137}Cs sources.

A1.6.5 Nuclear applications in industry

Radioisotopes are used in a wide range of industrial applications [5]. Examples include gamma radiography of structures, castings, or welds where the use of X-rays is not feasible, using radioisotope thickness gauges in the manufacture of products such as steel and paper; in tracer experiments to provide exact information on the condition of expensive processing equipment; in defining the exact position of tubes in manufacturing facilities. Radioisotopes are also used as level indicators for feedstock supply hoppers. Moisture and density gauges use radioactive sources for analysis of soil water content and compaction. Radioisotopes are used in smoke detectors, and as lasting, fail-safe light sources for emergency signs in aircraft and public buildings. Clearly, the variety of applications is enormous and growing annually.

A1.6.6 Nuclear reactors

One of the major uses of radioactive material is in the generation of electricity in nuclear power reactors. The nuclear power industry, now generates electricity in 32 countries contributing 17% of the world's supply of electricity, while 63% comes from the burning of fossil fuels [6]. Some countries have over 75% of their electricity generated from nuclear power plants. The nuclear fuel cycle, which supports this generation requires the transport of radioactive material in many forms, including ores, uranium hexafluoride, fresh nuclear fuel, irradiated (or spent) nuclear fuel, and wastes.

Specific types of power reactors produce cobalt 60 and research reactors are used for production of radioisotopes used in nuclear medicine. Nuclear reactors have been used to power a variety of ocean-going vessels including merchant vessels, ice breakers, and naval ships. Nuclear power will continue to play a significant role in meeting the world's increasing need for safe, clean, affordable and secure electricity.

The nuclear fuel cycle begins with conventional mining of the ore which is processed and converted into a product containing natural uranium, which is commonly known as yellow cake. This is shipped in conventional 200 litre drums and standard ISO containers. Certain types of reactors cannot be operated on natural uranium so the content of the isotope of uranium called U-235, is increased by a process known as enrichment. Upon enrichment, the material is transported in the form of uranium hexafluoride (UF6) to fuel fabrication facility. The fabricated fuel assemblies are then transported to the reactor where they are used to produce electricity. Up to this stage the material is only mildly radioactive, and is transported via commercial transport companies. The fuel stays in the reactor about 3 to 5 years after which the spent fuel has to be replaced. The spent fuel is radioactive and is stored in a water pond to allow decay of some of the heat and radiation. The spent fuel may be sent to be reprocessed or stored in a dedicated storage.

A1.6.7. Importance of effective and efficient transport

Radioisotopes used in nuclear medicine having very short half-lives need to be rushed to the waiting patients. Cobalt 60 being an important source used for teletherapy and sterilization of medical products and food has to be transported from the supplier to the user. The radioactive materials used in nuclear power industry have to be carried from one facility to another for efficient production of reliable and clean energy. All the concerned organizations, viz., the manufacturer, the carrier, the handler and the customer play key roles in facilitating the transport of radioactive material for the various safe applications. Radioactive material has been transported for more than 40 years without any serious accident. The regulatory requirements for the manufacture, transportation and handling ensure safety and security.

REFERENCES FOR CHAPTER A1

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Techniques in Medicine, FS/09 (Rev.1), International Atomic Energy Agency Fact Sheet, IAEA, Vienna (1993).
[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Isotopes in everyday life, IAEA/PI/A6E, IAEA, Vienna (1990).
[3] HENKIN, R.E., An overview of nuclear medicine in the United States, Nuclear News, 41, 2, 30–34, (1998).
[4] OSTERHOLM, M.T., Food safety and ionizing pasteurization, Nuclear News 41, 1 (1998) 26–27.
[5] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Technical Co-operation - A Partnership in Development, IAEA/PI/A52E, 97-01913, IAEA, Vienna (1997).
[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Sustainable Development, Nuclear Power, IAEA/PI/A/55E, IAEA, Vienna (1997).

EXERCISES FOR CHAPTER A1

The following exercise is to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE A1.1. Atoms

REFERENCE SOURCES: Training Manual, Chapter A1.1.

DISCUSSION: The origin of radiation is the atomic nucleus. For a better understanding it is helpful to know the structure of an atom.

PROBLEM:

a. What are the basic particles of an atom and what is their elementary charge?

b. What characterizes an element? Which naturally occurring element has the highest number of protons?

c. What are isotopes of an element?

d. Give the notation for defining an atom.

ANSWER:

EXERCISE A1.2. Background radiation

REFERENCE SOURCES: Training Manual, Chapters A1.5

DISCUSSION: There is natural background radiation everywhere and present always. This background radiation has been there for ages.

PROBLEM:

a. List three radioactive elements which contribute to natural background radiation.

b. List some of the sources of natural background radiation.

ANSWER:

EXERCISE A1.3. Radiation

REFERENCE SOURCES: Training Manual, Chapter A1.3.

DISCUSSION: In considering the design of packages and the use of packagings for the transport of radioactive material, different radionuclides can produce different types of radiation. This exercise addresses two of these considerations.

PROBLEM:

a. There are essentially four types of radiation that must be considered in the packaging and transport of radioactive material. Give an example each of more penetrating and less penetrating radiation. Indicate one or more materials which are effective in shielding each type of radiation.

b. One of the types of radiation of concern has the ability to activate material through which it passes. Which type of radiation is this? What is the physical phenomenon occurring which allows this type of radiation to activate the material?

ANSWER:

EXERCISE A1.4. Half-life, Activity, Specific activity, (Quantities and Units)

REFERENCE SOURCES: Training Manual, Chapter A1.2.

DISCUSSION: The decay of radioactive materials is described in terms of quantities, such as, activity and half-life with corresponding units.

PROBLEM: Give the main quantities and units related to the radioactivity of material and radiation dose.

ANSWER:

EXERCISE A1.5. Uses of Radioactive Material

REFERENCE SOURCES: Training Manual, Chapter A1.6

DISCUSSION: Radioactive materials find many applications in medicine, industry and research.

PROBLEM:

a. Give an outline of the applications of radioactive material in medicine and industry.

b. If a package containing the following radioactive material being forwarded in accordance with the regulatory requirements is not permitted to be transported or received at a port, what are the possible consequences?

i) Cobalt 60 teletherapy source

ii) Cobalt 60 source used in a sterilization facility

iii) A consignment of radionuclides used in nuclear medicine

iv) A consignment of uranium fuel to be used for power production in a nuclear reactor.

ANSWER:

A2. SAFETY OF TRANSPORT OF RADIOACTIVE MATERIAL

A2.1. Control of the radiation hazard

The Regulations for the Safe Transport of Radioactive Material [1] form the basis of the various national and international modal regulations, which are currently in force. The objective of the Regulations is to protect persons, property and the environment from the effects of radiation during the transport of radioactive material.

The dose from external radiation can be reduced by one or all of the following methods:

- reducing the time spent near the source
- increasing the greater distance from the source of radiation
- interposing shielding between the source of radiation and the exposed person(s).

A2.1.1. Time

The dose received is the product of the dose rate and the time exposed:

Dose = Dose Rate x Time

Reducing the time spent near the source of radiation will reduce the total dose that a person receives. This principle is applied in many situations in the transport of radioactive material.

A2.1.2. Distance

Increasing distance from a source will reduce the dose rate and hence the total dose. If the size of the source of radiation is small compared to the distance at which dose is measured, the 'inverse square law' applies: that is, doubling the distance will reduce the dose rate to one quarter. Spacers in many packaging designs have the function of increasing distance to reduce the package surface dose rate.

A2.1.3. Shielding

Placing shielding material between a source and the person will also reduce the dose rate. For gamma radiation, dense materials such as lead and steel are the most effective, and therefore, these materials are frequently used in package designs.

A2.2. Explanation of Terms used in the Regulations

A2.2.1 Radioactive material

Radiation is present in the environment and many commonly encountered materials are radioactive. It would be cumbersome to apply the regulations to all materials that are radioactive. Hence, materials whose activity (Bq) and also specific activity (Bq/g) do not exceed certain threshold values are exempt from the regulations.

A2.2.2. Special form radioactive material

Special form radioactive material is either an indispersible solid radioactive material or a sealed capsule containing radioactive material. The qualification test criteria for special form are very stringent. This means that the material has a very high degree of physical integrity so that if the material were released from the package in an accident, it is unlikely that there would be any contamination hazard. Therefore, larger quantities can typically be shipped in any given package. Cobalt 60 sources used in medical applications are generally special form radioactive materials.

A2.2.3. Consignment, consignor, consignee, carrier and conveyance

The consignment consists of the package(s) or load of radioactive material that is presented for transport. The consignor is the individual or organization that prepares a consignment for transport and the consignee is the corresponding agent that receives the consignment.

A carrier is an individual or organization that undertakes the carriage of radioactive material by any means of transport. A conveyance is the means by which the package is transported, such as a vehicle, vessel, or aircraft.

A2.2.4. Exclusive use

When the consignor has total control of a shipment, this leads to the concept of exclusive use consignments. Exclusive use means that a single consignor has sole use of the conveyance (or large freight container), such that all loading and unloading is carried out in accordance with the directions of the consignor or consignee.

A2.2.5. Packaging and package

Packaging is the assembly of components necessary to enclose the radioactive material contents during transport. It includes absorbent materials, spacing structures, shielding material, service equipment, shock absorbing devices, handling and tie-down capability, and thermal insulation. Together, the packaging and radioactive contents make up the package.

A2.2.6. Transport index

The transport index (TI) is a number that is a measure of the dose-rate on the exterior of a package or overpack or freight container. TI is used for controlling accumulation of packages for the purposes of minimizing exposure to radiation.

A2.2.7. Competent authority

A competent authority is a national or international authority, which is designated or recognized as such. Practically, for most nations it is the government agency that regulates the transport of radioactive material. Amongst other things, competent authorities approve designs for special form radioactive material, certain packages and shipments.

A2.2.8. Quality assurance and compliance assurance

Quality assurance and compliance assurance are systematic programmes aimed at ensuring that the standard of safety required by the regulations is achieved in practice. Quality assurance is applied by those involved in the transport of radioactive material, while compliance assurance is applied by a competent authority.

A2.2.9. Control of the contamination hazard

It is important to have a clear concept of the distinction between radiation and contamination. Radiation is the particle or energy emitted from radioactive material (or generating devices such as X-ray machines). Contamination means presence of radioactive material in excess of prescribed limits. Radioactive material is placed in the containment system within a package.

A2.2.10. Radiation protection programmes

A radiation protection programme is a system of measures that primarily ensures the health and safety of workers and the public from radiation and radioactive material. The Regulations require that a radiation protection programme be established for all aspects of the transport of radioactive material. The radiation protection programme should include a training programme for the concerned personnel. Record keeping is an important element of any radiation protection programme.

A2.3. Types of Packages used for transport of radioactive material

Radioactive materials are transported in appropriate packages as described here (Figure A2.1). Some radioactive material may be transported unpackaged.

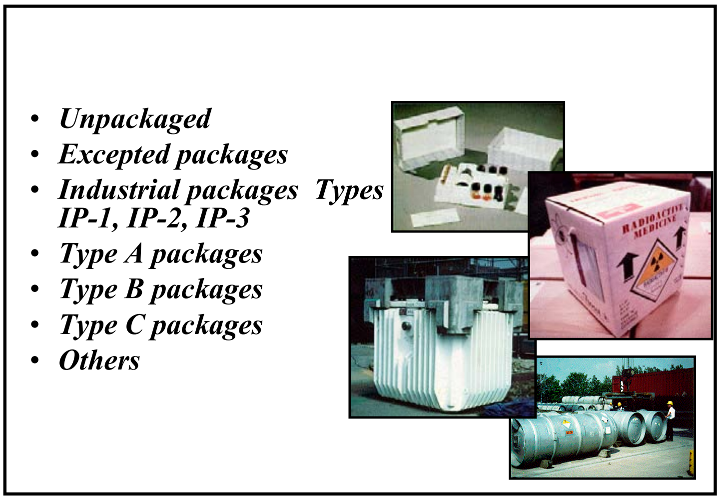


FIG. A2.1. Packages for transporting radioactive material.

A2.3.1. Unpackaged consignment

Under the conditions prescribed in the regulations, LSA-I material and SCO-I may be transported unpackaged. This is illustrated in Figure A2.2. One example of this is the shipment of uranium and thorium ores which may be transported without bagging or boxing in closed rail wagons or road vehicles

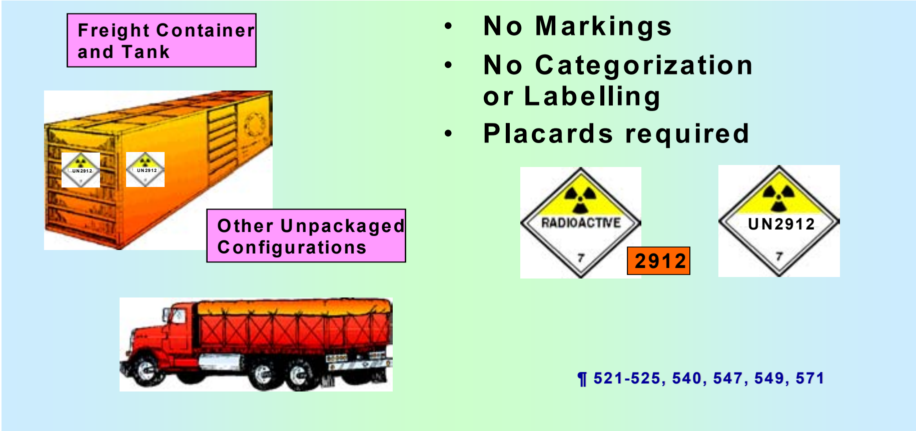


FIG. A2.2. Unpackaged LSA and SCO.

A2.3.2. Excepted packages

Excepted packages contain limited quantities of radioactive material, which are so small that the potential radiological hazards that might pertain during transport are very low. Hence there are no test requirements for excepted packages. The radiation level at any point on the surface of an excepted package would be so low that radiation dose to members of the public would be insignificant and that any sensitive photographic material in close proximity would not be damaged.

A2.3.3. Industrial packages Types 1,2 and 3 (Type IP-1, IP-2 and 3)

Industrial packages are used to transport low specific activity (LSA) materials and Surface contaminated objects (SCO). These materials are intrinsically safe. There are three types of industrial packages (Type IP-1, Type IP-2, and Type IP-3) that are used for LSA and SCO shipments. Many normal packages used in industry, such as steel drums or bins, could meet many of the requirements. Activity limits per conveyance are prescribed in the Regulations.

A2.3.4. Type A packages

Type A packages are intended to provide a safe and economical means of transporting relatively small quantities of radioactive material. They are required to maintain their integrity under the kind of abuse or mishandling that may be encountered in normal transport. This includes events such as falling from vehicles, being dropped during manual handling, being exposed to rain, being struck by a sharp object (which may be the corner of another package), or having other packages or cargo stacked on top. Where the contents may be in either liquid or gaseous form, rather than solid, then higher standards are imposed because of the greater possibility of leakage or dispersal from the package.

It is assumed that a Type A package may be damaged in a severe accident and that a portion of the contents may be released. The Regulations, therefore, prescribe limits on the maximum amounts of radioactivity that can be transported in such packages. Type A packages are designed to the performance standards prescribed in the Regulations, which include tests simulating normal conditions of transport. Typical contents of Type A packages are radioisotopes used in nuclear medicine (e.g. iodine 131, molybdenum 99, etc.) and industrial gauging (e.g. cobalt 60, caesium 137, americium-beryllium, etc.). The movement of such radioisotopes is extensive. Within most industrialized countries for example, thousands, of Type A packages are transported daily.

A2.3.5. Type B(U) and B(M) packages

As far as the contents limits and the types of contents are concerned, Type B(U) and Type B(M) packages can be considered together. These packages are designed to withstand severe accident conditions of transport. Regulations prescribe stringent design and test requirements to be satisfied by these packages.

The concept of a Type B package is that it should be capable of withstanding most accident conditions, without breach of its containment or a significant increase in radiation levels. The Regulations subject the package to a series of mechanical and thermal tests with accumulative effects, each of which must cause the maximum damage. The requirements impose additional necessary design constraints over and above those imposed on packages that meet normal conditions of transport. The outcome of these constraints is to dictate greater structural integrity, more careful consideration of containment features, and the ability to withstand high temperatures.

Common examples of radioactive material transported in Type B(U)/(M) packages are cobalt 60 sources used in cancer therapy and for sterilization of medical products.

A2.4. Test requirements

As stated earlier, the packages used for transport of radioactive material are required to be designed to meet the appropriate regulatory standards. These standards include tests simulating normal and accident conditions of transport. The tests stimulating normal conditions of transport are:

Water Spray test (heavy rain);
Free drop test (dropping of package during handling);
Stacking test (stacking loads about 5 times the weight of the package);
Penetration test (impact of sharp objects on the package).

The regulatory tests which simulate accident conditions of transport are:

Mechanical tests (Dropping the package on a hard surface or a heavy object on the package through 9 m followed by dropping the package on a sharp rod);

Thermal test (Fire accident);

Water immersion test (fall of package in deep water).

The packages used for transport of radioactive material are designed to withstand the prescribed tests and demonstrated to be of safe design.

REFERENCES FOR CHAPTER A2

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Standards Series, No. TS-R-1, IAEA, Vienna (2005).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

EXERCISES FOR CHAPTER A2

The following exercise is to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE A2.1. Types of packages prescribed in Regulations.

REFERENCE SOURCES: Training Manual, Chapter A2.3

DISCUSSION: Radioactive material is transported in different types of packages depending upon the nature of the radioactive content.

PROBLEM:

List the types of package used for transport of radioactive material.

ANSWER:

EXERCISE A2.2. Tests simulating normal conditions of transport

REFERENCE SOURCES: Training Manual, Chapter A2.4

DISCUSSION:

PROBLEM:

How is it demonstrated that a package is designed to withstand normal conditions of transport?

ANSWER:

EXERCISE A2.3. Tests simulating accident conditions of transport

REFERENCE SOURCES: Training Manual, Chapter A2.4

DISCUSSION:

PROBLEM:

How is it demonstrated that a package is designed to withstand accident conditions of transport?

ANSWER:

A3. REGULATIONS FOR THE SAFE TRANSPORT OF RADIOACTIVE MATERIAL

A3.1. National regulations

Transport of radioactive material is governed by national regulations of each State. The Member States of IAEA have adopted the IAEA Regulations within the frame work of the local laws. These national regulations specify the requirements relating to the type of the package, labeling and marking and documentation to be provided by the consignor and the responsibilities of the consignor and the carrier. The consignors, carriers and the public authorities concerned with transport of cargo ensure that the shipments are made in compliance with the applicable national regulations. It would be of great help if all public authorities who have an interface with movement of radioactive cargo are familiar with the applicable sections of the national regulations for the safe transport of radioactive material. It should be borne in mind that there could be some differences between the national regulations and the international regulations for the safe transport of radioactive material. These differences may occur because of the legal system specific to each state and also because of the procedure involved in amending regulations.

A3.2. Interfaces with transport safety regulatory organizations

Many organizations have interfaces with radioactive material transport. These include all the United Nations regulatory bodies, as well as other international, governmental, industrial and public organizations. The interfaces between the IAEA and other regulatory bodies and agreements are summarized here. Figure A3.1. provides a perspective of the worldwide transport of dangerous goods by all modes of transport. This figure also indicates how small the fraction of radioactive material shipments is in the overall picture.

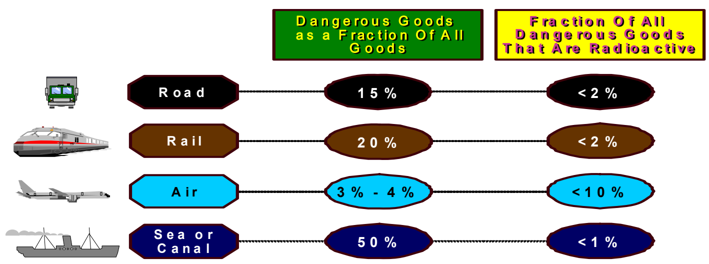


FIG. A3.1. Worldwide perspective of the transport of dangerous goods.

A3.2.1. International Commission on Radiation Protection (ICRP) and the International Atomic Energy Agency (IAEA)

The International Commission on Radiation Protection (ICRP) has served as the global technical body in the field of radiation protection. It is tasked with the responsibility of ensuring that activities that utilize radiation or radioactive material are undertaken in a safe manner with respect to persons, property, and the environment. The ICRP issues periodic documents related to radiation protection, and the IAEA in turn considers and adopts the principles in these documents into its own safety-related publications.

A3.2.2. International Maritime Organization (IMO)

The International Maritime Organization (IMO), which is a United Nations agency. The transport of dangerous cargoes has been one of the areas of interest of the IMO. The regulations, standards and recommendations (IMDG Code) that it has developed, are recognized, followed, and observed by ships of many nations.

A3.2.3. International Civil Aviation Organization (ICAO)

The International Civil Aviation Organization (ICAO) is also a United Nations agency. ICAO develops standards and recommends practices covering all areas of civil aviation. A set of Technical Instructions has been published that set out in detail the requirements for carrying dangerous goods by air. These Technical Instructions reflect the IAEA Regulations with regard to the carriage by air of radioactive material.

A3.2.4. International Air Transport Association (IATA)

IATA is an association representing airlines throughout the world. Its objectives are the promotion of safe, regular and economical air transport. IATA has developed their Dangerous Goods Regulations, which are generally consistent with the ICAO's Technical Instructions and hence the IAEA Regulations. Close co-ordination exists between IAEA, ICAO, and IATA. Changes have been made in the IAEA's Regulations regarding packages to be transported by air at the request of ICAO and IATA. Liaison continues to assure accurate and timely implementation of the IAEA's Regulations.

A3.2.5. Universal Postal Union (UPU)

The UPU is a specialized agency of the United Nations. Under the UPU Convention and Detailed Regulations, a consignment of radioactive material in which the activity does not exceed one tenth of the activity limit allowed in an excepted package, may be accepted for international transport by post if certain requirements are met.

A3.2.6. Regional agreements for modal transport

The transport of dangerous goods by rail, road, and inland waterway modes is not covered by an international organization on a worldwide basis. Rather, these are covered by several regional agreements such as:

- The Regulations Concerning the International Carriage of Dangerous Goods by Rail (RID);
- The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR);
- The European Agreement concerning the International Carriage of Dangerous Goods on Inland Waterways (ADN); and
- The Regulations for the Transport of Dangerous Goods on the Rhine (ADNR).

These organizations were established in Europe because of the large economic potential, which is concentrated on a confined area, and is distributed over many states. In addition, there is the MERCOSUR/MERCOSUL agreement that affects road, rail, air and sea transport among certain South American countries. The exchange of economic goods, including radioactive material and other dangerous goods, requires many transport operations, as well as sound regulatory control of these operations.

A3.3. Design safety and administrative measures

The basic requirements of the regulations for the safe transport of radioactive material focus on design safety and administrative measures. Selecting the package of appropriate design achieves the desired design safety.

Prior to shipping the package, the consignor measures the radiation and contamination levels and the temperature on the external surface of the package to assure that the regulatory limits are not exceeded. The package are marked and labelled. The UN number appropriate to the radioactive content should be inscribed on the package and included in the transport documents. For example, the UN number of a radiopharmaceutial used in nuclear medicine is 2915. Typically the UN number of a Type B(U) package containing a cobalt 60 source used for teletherapy or sterilization of medical products is 2916. The transport documents include a declaration signed by the consignor certifying that the package meets all the applicable regulatory requirements and specific instructions to the carrier regarding routine operations and emergency instructions.

The number of packages stacked in a storage area or transported in a vehicle or in an aircraft or in a defined deck of a vessel area is so restricted that the sum of the transport indexes of the packages does not exceed the specified limits. The limits are stipulated in the regulations.

A3.4. Role of regulatory authorities

There may be several Public Authorities who may be concerned with transport of radioactive material, for example, the regulatory authority for licensing the use of radioactive material, the Competent Authority for enforcing the national regulations transport of radioactive material, customs authorities, port authorities, civil aviation authorities, etc.

Assurance of compliance with the regulatory requirements is the responsibility of the Competent Authority. Any instance of non-compliance with the Regulatory requirements identified during transport should be brought to the notice of the Competent Authority.

A3.5. Emergency situations

In an emergency situation involving a package containing radioactive material, the officials on the scene of accident should observe certain basic precautions:

- Do not panic;
- Rescue the injured;
- If there is fire, fight fire;
- Try to remove packages containing radioactive material from the fire zone;
- After fire is put out, allow the packages to cool before approaching them;
- Measure the radiation level around the package;
- If the package is visibly damaged, cordon a few metres around it;

- Place a placard about the cordon;
- Note down the details of the consignment as read from labels affixed on the exterior of the package;
- Inform the consignor and the consignee;
- Act as directed by a radiation protection expert.

A3.6. Safe and unhindered transport of radioactive material

Because of the many useful applications of radioactive material in medicine, industry and research, transport of such material is an essential activity of the modern world. It is important that radioactive materials are transported safely. Sometimes transport of radioactive material may be hindered due to lack of knowledge of (a) the standards of safety incorporated in the Regulations and (b) the need for the movement of these materials. A Radiation Protection Programme should be established by the Public Authorities for ensuring that their representatives can perform their duties and at the same time ensure smooth and safe transport of radioactive cargo.

A3.7. Conclusion

Radioactive material is like any of the other dangerous goods and hence has to be treated as such. Radioactive materials are used for a multitude of beneficial daily applications round the world (e.g. nuclear medicine, cancer treatment, industrial radiography, nucleonic gauging, sterilization of medical products and food, etc.). They have to be transported from the supplier to the user. The packages are designed to meet stringent standards of safety. It is safe to handle them. As a matter of regulatory requirement, packages are packed, marked, labelled and declared in the transport documents appropriately. Familiarity, on the part of the public authorities, with the regulatory requirements and the simple safety precautions outlined in this training course manual would contribute to safe and unhindered movement of radioactive materials.

EXERCISES FOR CHAPTER A3

The following exercise is to be used in connection with this chapter. It is suggested that the student write her/his answers in the space provided, and compare her/his work with the solutions as discussed by the instructor in class. In all cases, the student is encouraged to cite the relevant references when answering the questions. This includes quoting the paragraphs, sections, figures and tables in the TS-R-1 Regulations; as well as other documents such as TS-G-1.1 and this training manual.

EXERCISE A3.1. Regulations for transport of radioactive material

REFERENCE SOURCES: Training Manual, Chapter A3.3

DISCUSSION: Transport of radioactive material is governed by national and international regulations. Criteria for ensuring safe transport of material are clearly laid out in the regulations.

PROBLEM:
List three international regulations governing transport of dangerous goods including radioactive material.

ANSWER:

EXERCISE A3.2. Design safety and administrative measures

REFERENCE SOURCES: Training Manual, Chapter A3.3

DISCUSSION:

PROBLEM:
List of six important measures which should be taken by the consignor prior to forwarding a package containing a cobalt 60 source to a sterilization plant.

ANSWER:

EXERCISE A3.3. Competent authority for transport of radioactive material

REFERENCE SOURCES: Training Manual, Chapter A3.4

DISCUSSION: Every country appoints a Competent Authority which is responsible for implementing the regulations for safe transport of radioactive material

PROBLEM:

Has your country adopted the IAEA Regulations for the Safe Transport of radioactive Material ?

Which edition of the IAEA Regulations have been adopted by your country?

Who is the Competent Authority responsible for radiation protection in your country?

Who is the Competent Authority responsible for transport of radioactive material in your country?

Who are the public authorities who would be concerned in the regulation of import, export and transit of radioactive consignments in your country?

ANSWER:

TYPICAL TRAINING PROGRAMME SCHEDULE: SAFETY OF TRANSPORT OF RADIOACTIVE MATERIAL FOR PUBLIC AUTHORITIES

Target audience: Sea/Air port authorities, customs, national security and other government officials

0900–0930	Module A1
0930–0945	Discussion
0945–1030	Module A2
1030–1100	discussion
1100–1115	Break
1115–1130	Module A3
1130–1145	Discussion
1145–1215	Question & Answer

ANNEX B

TRAINING MANUAL FOR CARGO PERSONNEL

B1. THE SIGNIFICANCE OF TRANSPORTING RADIOACTIVE MATERIAL

Radioactive materials need to be transported from one place to another because these materials are used in medicine, industry, research and production of electricity. The materials have to be transported from the licensed supplier's facility to the licensed user's institution. The user may for the purpose of the authorized use, have to transport the radioactive material from one place to another. When the radiation from the material becomes weak, the material cannot be used any longer. Then the materials are transported to the authorized radioactive waste disposal facilities for safe disposal. Some of the peaceful applications of radioactive material are briefly described below.

B1.1. Uses of radioactive material

Radioactive materials are used in medicine, industry, research and production of electricity around the world each day. These materials must be properly and safely shipped from the point of manufacture (supplier's licensed facility) to the point of use (customer's licensed facility).

At this point, it is worth providing a brief overview of some of the everyday uses of radioactive material for those who are a little less familiar with the subject. Radioactive material is used in many more ways than most people realize to improve our quality of life. Whenever or wherever it is used, it is incumbent on qualified individuals and responsible organizations to ensure that the radioactive material is prepared, used, handled, transported and disposed of in a safe manner. The following text and Fig. B1.1 provide a brief overview of some examples of those activities that require shipment of radioactive material or waste.

FIG. B1.1. Some uses of radioactive material.

B1.1.1. Health care product and consumer product irradiation

Gamma rays from cobalt-60, (^{60}Co) are commonly used to irradiate health care and consumer products. This includes surgeon's gloves, gowns, sutures, syringes, catheters, etc. In fact, about 45% of all medical disposables are sterilized using gamma radiation from ^{60}Co.

Consumer products such as bandages, cosmetics, hygiene products and solutions are also sterilized by ^{60}Co. The prevention of infection through this sterilization technique complements the basic healing goal of medicine. About 200 facilities located in more than 50 countries worldwide provide sterile medical devices using gamma irradiation techniques [1]. Radioactive materials (typically ^{137}Cs) are also used for blood irradiation (for patients with deficient immune systems so as to preclude rejection of graft).

B1.1.2. Nuclear applications in medicine

There are many applications of nuclear technology in the medical field, ranging from diagnostics, to treatment, to disease management [1]. Many of these use radionuclides which are produced in either nuclear reactors or cyclotrons. Examples include use of specific radioactive material for diagnostic studies in specific organs / tissues ^{123}I (thyroid), ^{111}In (brain); ^{67}Ga (Hodgkin's disease, hepatoma, bronchogenic carcinoma, etc); ^{99m}Tc (heart); ^{201}Tl (myocardial tissue); ^{11}C (brain); ^{81m}Kr (lung); ^{13}N (heart); and ^{18}F for epilepsy. The safe transport of the radionuclides from the production sites to the hospitals, eventually followed by the safe transport of their residues and related wastes to disposal facilities, is vital to the success of nuclear medicine.

Several tens of thousands of nuclear medicine procedures are conducted every day all over the world. For example, in the United States alone an estimated 16 million nuclear medicine imaging and therapeutic procedures are performed each year. Of these, 40-50% are cardiac exams and 35-40% are cancer related. Nuclear medicine, being a powerful tool deployed by the medical profession the world over, is increasingly being used in several countries because of the benefits that accrue to patients. There are nearly 100 different nuclear medicine imaging procedures available today. Unlike other tests/procedures, etc., nuclear medicine provides information about the function of virtually every major organ system within the body. Children commonly undergo nuclear medicine procedures to evaluate bone pain, injuries, infection, or kidney and bladder function. Common nuclear medicine applications include diagnosis and treatment of hyperthyroidism (Graves' Disease), cardiac stress tests to analyze heart function, bone scans for orthopedic injuries, lung scans for blood clots, and liver and gall bladder procedures to diagnose abnormal function or blockages.

Radiation is widely used for the treatment of diseases such as hypothyroidism and cancer. Cobalt 60 is the primary isotope used in cancer therapy. In addition to teletherapy, where the radiation source has no physical contact with the tumour, the radiation source may be placed in immediate contact with the tumour, as in brachytherapy. There are other applications which target the specific tissue or cancer cell thereby minimizing the risk to surrounding tissue and cells [1, 2].

In addition to the sterilisation of medical equipment discussed earlier, nuclear medicine is also being used to reduce pain [1]. Radiotherapy is administered to patients to palliate the pain, thus replacing pain-killing drugs, which eventually lose their effectiveness. For example, physicians can administer a bone-seeking compound labelled with a radiation emitter, and the level of pain can be quickly lowered or totally eliminated [1].

B1.1.3. Food irradiation

The use of gamma rays and electron beams in irradiating foods to control disease-causing micro-organisms and to extend shelf life of food products is growing throughout the world [3]. Food sterilization has been approved by 40 countries and is encouraged by the World Health Organization [3]. The radiation source that is commonly used for this purpose is ^{60}Co, which is produced at one facility and transported to another facility for irradiation of the product.

B1.1.4. Insect control

Radioisotopes are assisting in enhancing animal and food production. One method is the control of insects, including the control of screwworms, fruit flies, and the Tsetse fly [4]. The Tsetse fly causes the transmission of a parasitic disease, trypanosomiasis, which slowly destroys livestock herds, in sub-Saharan Africa. It also causes the spread of the human form of the disease, known as sleeping sickness. By irradiating male Tsetse flies in a controlled gamma ray environment, the male flies are made sterile, and the Tsetse fly population can be reduced to insignificant levels. The low-level exposures to gamma rays are provided by ^{60}Co and ^{137}Cs sources.

B1.1.5 Nuclear applications in industry

Radioisotopes are used in a wide range of industrial applications [4]. Examples include gamma radiography of structures, castings, or welds where the use of X-rays is not feasible, using radioisotope thickness gauges in the manufacture of products such as steel and paper; in tracer experiments to provide exact information on the condition of expensive processing equipment; in defining the exact position of tubes in manufacturing facilities. Radioisotopes are also used as level indicators for feedstock supply hoppers. Moisture and density gauges use radioactive sources for analysis of soil water content and compaction. Radioisotopes are used in smoke detectors, and as lasting, fail-safe light sources for emergency signs in aircraft and public buildings. Clearly, the variety of applications is enormous and growing annually.

B1.2. Nuclear reactors

One of the major uses of radioactive material is in the generation of electricity in nuclear power reactors. The nuclear power industry, now generates electricity in 32 countries contributing 17% of the world's supply of electricity, while 63% comes from the burning of fossil fuels [5]. Some countries have over 75% of their electricity generated from nuclear power plants. The nuclear fuel cycle, which supports this generation requires the transport of radioactive material in many forms, including ores, uranium hexafluoride, fresh nuclear fuel, irradiated (or spent) nuclear fuel, and wastes.

Specific types of power reactors produce cobalt 60 and research reactors are used for production of radioisotopes used in nuclear medicine. Nuclear reactors have been used to power a variety of ocean-going vessels including merchant vessels, ice breakers, and naval ships. Nuclear power will continue to play a significant role in meeting the world's increasing need for safe, clean, affordable and secure electricity.

The nuclear fuel cycle begins with conventional mining of the ore which is processed and converted into a product containing natural uranium, which is commonly known as yellow cake. This is shipped in conventional 200 litre drums and standard ISO containers. Certain types of reactors cannot be operated on natural uranium so the content of the isotope of uranium called U-235, is increased by a process known as enrichment. Upon enrichment, the material is transported in the form of uranium hexafluoride (UF6) to fuel fabrication facility. The fabricated fuel assemblies are then transported to the reactor where they are used to produce electricity. Up to this stage the material is only mildly radioactive, and is transported via commercial transport companies. The fuel stays in the reactor about 3 to 5 years after which the spent fuel has to be replaced. The spent fuel is radioactive and is stored in a water pond to allow decay of some of the heat and radiation. The spent fuel may be sent to be reprocessed or stored in a dedicated storage.

B1.3. Importance of effective and efficient transport

Radioisotopes used in nuclear medicine having very short half-lives need to be rushed to the waiting patients. Cobalt 60 being an important source used for teletherapy and sterilization of medical products and food has to be transported from the supplier to the user. The radioactive materials used in nuclear power industry have to be carried from one facility to another for efficient production of reliable and clean energy. All the concerned organizations, viz., the manufacturer, the carrier, the handler and the customer play key roles in facilitating the transport of radioactive material for the various safe applications. Radioactive material has been transported for more than 40 years without any serious accident. The regulatory requirements for the manufacture, transportation and handling ensure safety and security.

REFERENCES FOR CHAPTER B1

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Techniques in Medicine, FS/09 (Rev.1), International Atomic Energy Agency Fact Sheet, IAEA, Vienna (1993).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Isotopes in everyday life, IAEA/PI/A6E, IAEA, Vienna (1990).

[3] OSTERHOLM, M.T., Food safety and ionizing pasteurization, Nuclear News 41 1 (1998) 26–27.

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Technical Co-operation - A Partnership in Development, IAEA/PI/A52E, 97-01913, IAEA, Vienna (1997).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Sustainable Development, Nuclear Power, IAEA/PI/A/55E, IAEA, Vienna (1997).

EXERCISE FOR CHAPTER B1

EXERCISE B1.1. Need for transporting radioactive material

REFERENCE SOURCES: Training Manual Chapter B1.1

DISCUSSION: Radioactive Materials find many applications in medicine, industry and research.

PROBLEM: Give three examples of the need for transporting radioactive material.

ANSWER:

B2. THE BASIC PRINCIPLES OF RADIATION PROTECTION AND QUANTITIES AND UNITS FOR ACTIVITY AND DOSE

The radiation protection standards on which the current Transport Regulations [1] and international practice are founded are prescribed in the IAEA Basic Safety Standards (BSS). The BSS was prepared jointly by the Food and Agriculture Organization of the United Nations, the IAEA, the International Labour Organization, the Nuclear Energy Agency of the Organization for Economic Co-operation and Development, the Pan American Health Organization and the World Health Organization. They were published in 1996 by the IAEA as Safety Series No. 115 (SS-115) [2].

B2.1. Basic atomic and nuclear structure

B2.1.1. Atoms and nuclei

The simplest unit into which matter can be broken down is the atom. Atoms may stand in isolation (e.g. noble gases), or may combine, for example, to form molecules like water or air. Atoms can be regarded as having two main parts. The first part is the central core, called the nucleus. Orbiting the nucleus are very small lightweight negatively charged particles called electrons.

The nucleus of the atom consists of a tightly bound group of particles of two types, protons and neutrons. Protons are positively charged (to compensate for the negatively charged electrons) and neutrons have no charge (are neutral). The overall charge of any atom is zero (Figure B2.1).

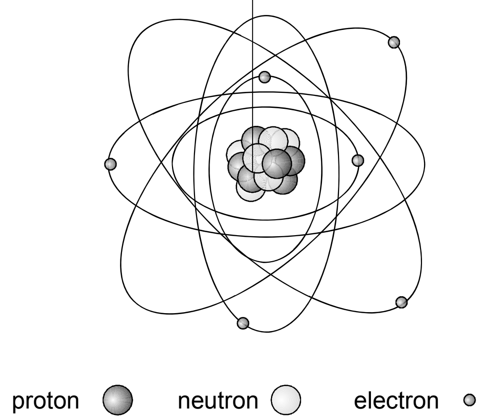


FIG. B2.1. Structure of an atom.

B2.1.2. Protons and neutrons

The hydrogen atom has 1 proton in the nucleus and 1 electron orbiting; the helium atom has 2 protons and 2 neutrons in the nucleus and 2 electrons orbiting; the carbon nucleus has 6 protons and 6 neutrons while 6 electrons are in the orbit.

B2.1.3. Isotopes

The number of neutrons may vary even in a given element. Changing the number of neutrons does not essentially influence the chemical properties of the atom. For example, if a neutron is added to the nucleus of the simplest hydrogen atom (originally consisting of one proton and one orbiting electron), a different structure is formed, but it is still hydrogen, as it still has only one proton. This is said to be an isotope of hydrogen. If another neutron is added to the nucleus, another isotope of hydrogen is formed. Some examples of isotopes are shown in Table B2.2. Uranium, among naturally occurring elements, has the highest number of protons.

Isotopes are commonly denoted by indicating the total number of protons and neutrons in the nucleus (the mass number), ^{3}H, ^{12}C, ^{60}Co, and ^{238}U.

TABLE B2.2. SOME EXAMPLES OF ISOTOPES

Element	Number of protons	Number of neutrons	Mass Number
^{3}H (Hydrogen)	1	2	3
^{60}Co (Cobalt)	27	33	60
^{99}Mo (Molybdenum)	42	57	99
^{131}I (Iodine)	53	78	131
^{137}Cs (Caesium)	55	82	137
^{238}U (Uranium)	92	146	238

B2.2. Radioactivity

If a nucleus contains too few or too many neutrons, it is unstable. An unstable nucleus will try to become more stable by emitting energy in the form of radiation, and it is said to be radioactive. Radioactivity can be simply defined as the process by which unstable nuclei attempt to reach a stable state by emitting radiation. This radiation is harnessed for its many beneficial applications in medicine, industry, etc., which are discussed in another section.

B2.2.2. Radioactive decay and half-life

When an unstable, radioactive nucleus emits radiation to become more stable, it is said to disintegrate or decay. The time in which, on average, half of a certain (large) number of nuclei of a particular isotope will decay is characteristic for that particular isotope and is called its half-life. Isotopes with short half-lives such as ^{131}I and ^{99}Tc find application in nuclear medicine where a small quantity of the isotope is administered to the patient either orally or intravenously for accurate diagnosis of a variety of diseases. Isotopes with large half-lives such as ^{60}Co are used for treatment of cancer and sterilization of medical products and food.

B2.3. Radiation

An unstable nucleus will eventually become more stable by emitting particulate and/or electromagnetic radiation. Radiation emitted by unstable nuclei can be alpha radiation (α particles), beta radiation (β particles), gamma radiation (γ) and neutrons.

B2.3.1. Ionization

Radiation can cause ionization of another atom. Ionization is the process by which an electron is removed from a neutral atom thereby leaving a positively charged ion (Figure B2.2). This property of ionization is used for detection of radiation. It also enables the radiation to be shielded.

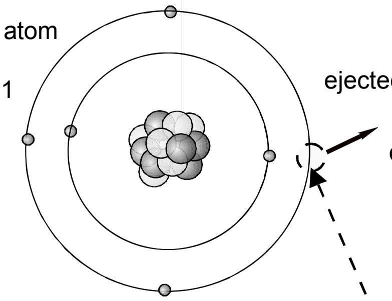


FIG. B2.2. The ionization process.

B2.3.2. Alpha radiation

Alpha particles consist of two neutrons and two protons. An alpha particle will give up its energy within a very short distance mostly by causing ionization. Alpha radiation is not very penetrating. It can be easily shielded. In fact most alpha particles cannot penetrate the dead layer of cells on the skin surface and therefore do not present any hazard while the alpha emitting radionuclide is external to the body. However, if the material becomes ingested or inhaled into the body then the alpha particles can ionize atoms in living cells. Special instruments are used for detection of alpha radiation. Alpha emitters are used as static eliminators in industrial processes where an electric-charge-free environment is essential for production efficiency.

B2.3.3. Beta radiation

Beta particles are identical to electrons. They are very much smaller and lighter than alpha particles. They are consequently more penetrating. Their rate of ionization is much less than that of alpha particles. The penetration range of beta particles depends on their energy and the density of the material they are passing through. A beta particle of average energy will not penetrate a thin sheet of metal, and will travel about 10 mm in tissue. Hence, beta-emitting radionuclides can be a hazard to skin and eyes and also if they are incorporated into the body. Ease of detection of beta radiation depends on the energy. Beta sources are used in nuclear medicine, agriculture research and industrial manufacturing (e.g. thickness gauging of polyester films).

B2.3.4. Gamma radiation

Gamma radiation is electromagnetic radiation similar to radar, radio, TV, microwave, light, ultra-violet, and infrared radiation but has higher energy, higher frequency, and shorter wavelength. It also causes ionization indirectly. Gamma radiation is very penetrating, but can be shielded by dense materials such as lead and steel. It is an external and an internal hazard, and is easily detected at very low levels. Gamma sources are widely used (e.g. cancer treatment, industrial radiography for non-destructive testing, sterilization of medical products and food).

B2.4. Some units of relevance to radiation protection

Some of the units which would be useful for the present purpose are explained below.

B2.4.1. Activity

The activity of a radioactive material is the number of disintegrations per unit of time. The corresponding unit is the becquerel (Bq). In the past, the unit of activity was the Curie. This term may be still in use in some countries.

B2.4.2. Dose

When radiation interacts with matter, it will deposit energy in matter. The amount of radiation that is absorbed in a material is called the dose.

The unit of dose is Sievert (Sv). It may also be expressed in sub-units such as milliSievert (mSv) and microSievert (μSv). Another term for dose which was in common use is rem and its sub-units are millirem and microrem.

Normally, when radiation levels are measured using portable radiation monitors, the measured values are expressed as dose-rates or dose per unit time, e.g. mSv/h. If a radiation monitor reads the radiation level at a location as 2 mSv/h, it simply means that if an individual spends one hour at the spot he/she would receive a total dose of 2 mSv. If the person spends only 30 minutes at the spot, the dose received would be just 1 mSv. Since the dose-rates typically encountered in the transport environment are very low, the commonly used unit of dose rate is μSv/h. Radiation monitors are calibrated in μSv/h and multiples thereof.

B2.5. Background radiation levels

All living organisms are continually exposed to ionizing radiation, which has always existed naturally. The sources of that exposure are cosmic rays that come from outer space and from the surface of the sun, terrestrial radioactive materials that occur in the earth's crust, in building materials (e.g. ceramic tiles, concrete, marble) and in air (e.g. basements of buildings), water and foods (e.g. milk) and in the human body itself. Some of the exposures are fairly constant and uniform for all individuals everywhere, for example, the dose from ingestion of potassium-40 in foods. Other exposures vary widely depending on location. Cosmic rays, for example, are more intense at higher altitudes, and concentrations of uranium and thorium in soils are elevated in localized areas. Exposures can also vary as a result of human activities and practices. In particular, the building materials of houses and the design and ventilation systems strongly influence indoor levels of the radioactive gas radon and its decay products, which contribute significantly to doses through inhalation.

B2.6. Control of the radiation hazard

The Regulations for the Safe Transport of Radioactive Material form the basis of the various national and international modal regulations, which are currently in force. The objective of the Regulations is to protect persons, property and the environment from the effects of radiation during the transport of radioactive material. The dose received is the product of the dose rate and the time exposed:

The dose from external radiation can be reduced by one or all of the following methods:

- reducing the time spent near the source
- increasing the greater distance from the source of radiation
- interposing shielding between the source of radiation and the exposed person(s).

B2.6.1. Time

The dose received is the product of the dose rate and the time exposed:

Dose = Dose Rate x Time

Reducing the time spent near the source of radiation will reduce the total dose that a person receives. This principle is applied in many situations in the transport of radioactive material.

B2.6.2. Distance

Increasing distance from a source will reduce the dose rate and hence the total dose. If the size of the source of radiation is small compared to the distance at which dose is measured, the 'inverse square law' applies: that is, doubling the distance will reduce the dose rate to one quarter. Spacers in many packaging designs have the function of increasing distance to reduce the package surface dose rate.

B2.6.3. Shielding

Placing shielding material between a source and the person will also reduce the dose rate. For gamma radiation, dense materials such as lead and steel are the most effective, and therefore, these materials are frequently used in package designs.

B2.7. Control of the contamination hazard

It is important to have a clear concept of the distinction between radiation and contamination. Radiation is the particle or energy emitted from radioactive material (or generating devices such as X-ray machines). Contamination means presence of radioactive material in excess of prescribed limits. Radioactive material is placed in the containment system within a package. Regulations for transport of radioactive material prescribe the limits of the removable contamination levels on the external surfaces of packages when they are forwarded for transport.

B2.8. Controlled areas

Restricting access to a particular area provides a basic method of implementing control over both radiation and contamination. This method is particularly useful in accident situations. For radiation, a controlled area keeps people remote from the source and hence controls the hazard by distance and time. For contamination, it keeps people remote from the loose radioactive material. If there is only one point where personnel are surveyed on entry and exit, then the radioactive material can be prevented from spreading outside of the area and hence is contained. Personnel can also be controlled to ensure that they have the necessary protective clothing on entry to the restricted area.

B2.9. Radiation protection programmes

A radiation protection programme is a system of measures that primarily ensures the health and safety of workers and the public from radiation and radioactive material. The Regulations require that a radiation protection programme be established for all aspects of the transport of radioactive material. The radiation protection programme should include a training programme for the concerned personnel. Record keeping is an important element of any radiation protection programme.

B2.10. Non-compliance

Any instance of non-compliance with the Regulatory requirements identified during transport should be brought to the notice of the consignor by the carrier.

Any instance of non-compliance with the Regulatory requirements identified at receipt of the consignment should be brought to the notice of the consignor by the consignee.

The carrier, consignor or consignee, as appropriate should take immediate steps to mitigate the consequences of non-compliance, investigate its causes, circumstances and consequences' take appropriate actions to remedy the causes of the non-compliance and to prevent recurrence and communicate, as soon as practicable, to the competent authorities on the causes of non-compliance and on corrective and preventive actions taken (paragraph 313).

REFERENCES FOR CHAPTER 24

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Standards Series, Safety Requirements No. TS-R-1, IAEA, Vienna (2005).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

EXERCISES FOR CHAPTER 24

EXERCISE B2.1. Working safely with radiation

REFERENCE SOURCES: Training Manual Chapter B2.6

DISCUSSION: It is possible to work with radiation observing the safety precautions.

PROBLEM: What are the three basic principles of radiation protection, i.e. the principles using which one may minimize the radiation dose?

ANSWER:

EXERCISE B2.2.

REFERENCE SOURCES: Training Manual Chapter B2.4

DISCUSSION: The quantity of radioactive contents of a package and the radiation level on the exterior of the package should be made known by stating the values on the labels.

PROBLEM: What is the unit in which the quantity of the radioactive content in a package (activity) is specified?

ANSWER:

EXERCISE B2.3.

REFERENCE SOURCES: Training Manual Chapter B2.6

DISCUSSION: The dose that may be received by a person is the product of the dose-rate and the period of exposure to radiation.

PROBLEM: A radiation monitor shows that in a storage area the radiation level at 2 m from a stack of packages is 0.008 mSv/hour (0.8 mrem/h). If a workers stays at that distance for a total of 100 hours in a year, what is the total dose that the worker will receive in one year?

ANSWER:

B3. REGULATION OF TRANSPORT OF RADIOACTIVE MATERIAL

B3.1. National Regulations

Transport of radioactive material is governed by national regulations of each State. The Member States of IAEA have adopted the IAEA Regulations within the frame work of the local laws. These national regulations specify the requirements relating to the type of the package, labeling and marking and documentation to be provided by the consignor and the responsibilities of the consignor and the carrier. The consignors, carriers and the public authorities concerned with transport of cargo ensure that the shipments are made in compliance with the applicable national regulations. It would be of great help if all public authorities who have an interface with movement of radioactive cargo are familiar with the applicable sections of the national regulations for the safe transport of radioactive material. It should be borne in mind that there could be some differences between the national regulations and the international regulations for the safe transport of radioactive material. These differences may occur because of the legal system specific to each state and also because of the procedure involved in amending regulations.

B3.2. Worldwide transport of radioactive material

Figure B3.1. provides a perspective of the worldwide transport of dangerous goods by all modes of transport. This figure also indicates how small the fraction of radioactive material shipments is in the overall picture.

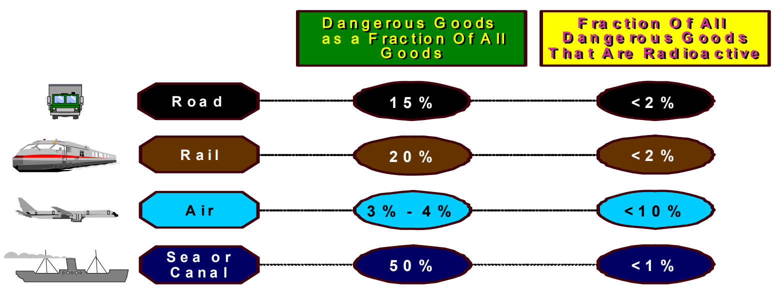


FIG. B3.1. Worldwide perspective of the transport of dangerous goods.

B3.2.1. International Commission on Radiation Protection (ICRP) and the International Atomic Energy Agency (IAEA)

The International Commission on Radiation Protection (ICRP) has served as the global technical body in the field of radiation protection. It is tasked with the responsibility of ensuring that activities that utilize radiation or radioactive material are undertaken in a safe manner with respect to persons, property, and the environment. The ICRP issues periodic documents related to radiation protection, and the IAEA in turn considers and adopts the principles in these documents into its own safety-related publications.

B3.2.2. International Maritime Organization (IMO)

The International Maritime Organization (IMO), is a United Nations agency. The transport of dangerous cargoes has been one of the areas of interest of the IMO. The regulations, standards and recommendations (IMDG Code) that it has developed, are recognized, followed, and observed by ships of many nations.

B3.2.3. International Civil Aviation Organization (ICAO)

The International Civil Aviation Organization (ICAO) is also a United Nations agency. ICAO develops standards and recommends practices covering all areas of civil aviation. A set of Technical Instructions has been published that set out in detail the requirements for carrying dangerous goods by air. These Technical Instructions reflect the IAEA Regulations with regard to the carriage by air of radioactive material.

B3.2.4. International Air Transport Association (IATA)

IATA is an association representing airlines throughout the world. Its objectives are the promotion of safe, regular and economical air transport. IATA has developed their Dangerous Goods Regulations, which are generally consistent with the ICAO's Technical Instructions and hence the IAEA Regulations. Close co-ordination exists between IAEA, ICAO, and IATA. Changes have been made in the IAEA's Regulations regarding packages to be transported by air at the request of ICAO and IATA. Liaison continues to assure accurate and timely implementation of the IAEA's Regulations.

B3.2.5. Universal Postal Union (UPU)

The UPU is a specialized agency of the United Nations. Under the UPU Convention and Detailed Regulations, a consignment of radioactive material in which the activity does not exceed one tenth of the activity limit allowed in an excepted package, may be accepted for international transport by post if certain requirements are met.

B3.2.6. Regional agreements for modal transport

The transport of dangerous goods by rail, road, and inland waterway modes is not covered by an international organization on a worldwide basis. Rather, these are covered by several regional agreements such as:

- The Regulations Concerning the International Carriage of Dangerous Goods by Rail (RID);
- The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR);
- The European Agreement concerning the International Carriage of Dangerous Goods on Inland Waterways (ADN); and
- The Regulations for the Transport of Dangerous Goods on the Rhine (ADNR).

These organizations were established in Europe because of the large economic potential, which is concentrated on a confined area, and is distributed over many states. In addition, there is the MERCOSUR/MERCOSUL agreement that affects road, rail, air and sea transport among certain South American countries. The exchange of economic goods, including radioactive material and other dangerous goods, requires many transport operations, as well as sound regulatory control of these operations.

B3.3. Safe transport of radioactive material

The basic requirements of the regulations for the safe transport of radioactive material focus on design safety and administrative measures. Selecting the package of appropriate design achieves the desired design safety.

Prior to shipping the package, the consignor measures the radiation and contamination levels and the temperature on the external surface of the package to assure that the regulatory limits are not exceeded. The package is marked and labelled. The UN number appropriate to the radioactive content should be inscribed on the package and included in the transport documents. For example, the UN number of a radiopharmaceutial used in nuclear medicine is 2915. Typically the UN number of a Type B(U) package containing a cobalt 60 source used for teletherapy or sterilization of medical products is 2916. The transport documents include a declaration signed by the consignor certifying that the package meets all the applicable regulatory requirements and specific instructions to the carrier regarding routine operations and emergency instructions.

Packages are generally brought under three categories, viz., Category I-WHITE, Category II-YELLOW and Category III-YELLOW, on the basis of the radiation level on the exterior of the package.

The transport index (TI) is a number that is a measure of the dose-rate on the exterior of a package or overpack or freight container. TI is used for controlling accumulation of packages for the purposes of minimizing exposure to radiation. The number of packages stacked in a storage area or transported in a vehicle or in an aircraft or in a defined deck of a vessel area is so restricted that the sum of the transport indexes of the packages does not exceed the specified limits. The limits are stipulated in the regulations.

The radioactive materials, Uranium-233, Uranium-235 and Plutonium-239, are also described as fissile materials. Each package containing fissile materials in quantities and/or concentrations above certain specified limits is assigned a number called the Criticality Safety Index. The CSI is determined by the designer and the package design is approved by the Competent Authority. The total number of packages containing fissile materials stacked in a storage area or transported in a vehicle or in an aircraft or in a defined deck of a vessel area is so restricted that the sum of the CSIs of the packages does not exceed the specified limits. The limits are stipulated in the regulations.

B3.4. Measurement of radiation level

Packages containing radioactive material are brought under three categories, viz., Category I-WHITE, Category II-YELLOW and Category III-YELLOW. The radiation levels on the exterior of packages determine the category of the packages. Consignors are required to label the packages according to the category on the basis of measured radiation levels. Further, the presence of removable radioactive contamination on the exterior of packages is restricted to the prescribed limits. Radiation level is measured in units of μSv/h, as mentioned earlier. Contamination levels are measured in Bq/cm^2 . In large package storage areas carriers may provide the cargo handlers with portable radiation monitors. Where it is suspected that a package may have been damaged with a potential increase in the radiation levels or contamination levels, a radiation / contamination monitor should be used by the cargo handler to determine the actual condition of the package.

B3.5. Emergency situations

The cargo personnel should be able to handle emergency situations involving packages containing radioactive material. Packages may be received at a cargo complex in a damaged condition. While handling packages, they may be dropped or run over by vehicles like fork lifts causing damage to the packages. During storage, fire may brake out and a package containing radioactive material may get damaged. In an emergency situation, the cargo handler should observe certain basic precautions:

- Do not panic
- Rescue the injured
- If there is fire, fight fire
- Try to remove packages containing radioactive material from the fire zone
- After fire is put out, allow the packages to cool before approaching them
- Measure the radiation level around the packages approaching them from a safe distance
- If the package is visibly damaged, cordon a few metres around it, determining the safe distance on the basis of the measured radiation levels
- Place a placard warning the possibility of radiation hazard if the cordon is breached
- Note down the available particulars about the package
- Inform the managers about the particulars of the package including the names and addresses of the consignor and the consignee and the details of the consignment as read from labels affixed on the exterior of the package
- Act as directed by a radiation protection expert.

B3.6. Conclusion

It is clear that radioactive material is like any of the other dangerous goods and hence has to be treated as such. Because of the multitude of beneficial applications of radioactive materials, they have to be transported. The packages are designed and constructed to meet stringent standards of safety. Therefore, they are generally safe to handle. As a matter of regulatory requirement, packages have to be packed, marked, labelled and declared in the transport documents appropriately. It is the responsibility of the consignor to ensure that relevant regulatory requirements are met. Familiarity, on the part of the cargo personnel, with the regulatory requirements and the simple safety precautions outlined in this training course manual will contribute to the safe and unhindered movement of radioactive materials.

EXERCISES FOR CHAPTER B3

EXERCISE B3.1. Regulations governing transport of radioactive material

REFERENCE SOURCES: Training Manual Chapter B3.2

DISCUSSION: Transport of all dangerous goods including radioactive material are governed by regulations.

PROBLEM: What are the international regulations that apply to transport of radioactive material by sea / air ?

ANSWER:

EXERCISE B3.2. National regulations for safe transport of radioactive material

REFERENCE SOURCES: Training Manual Chapter B3.1

DISCUSSION: Each country has its own regulations governing transport of radioactive material.

PROBLEM: What are the national regulations in your country governing the transport of radioactive material?

ANSWER:

EXERCISE B3.3. Limiting accumulation of packages containing radioactive material

REFERENCE SOURCES: Training Manual Chapter B3.3

DISCUSSION: As a measure of control the number of packages that can be accumulated in a conveyance or storage area is limited by the regulations. For this purpose, a quantity called transport index (T.I.) is defined in the regulations. The transport indexes of packages in a conveyance or storage area are added up and accumulation of packages is restricted by a limit on the sum of the T.I.s.

PROBLEM: The packages to be loaded in a vehicle are described below. If the number of packages that can be loaded in a vehicle should be so limited that the sum of the transport indexes of the packages should not exceed 50, state whether all these packages can be loaded in a single vehicle and explain your answer.

T.I. of package	Number of Packages with The specified T.I.
0.5	8
0.2	12
0.8	4
1.2	8
0.3	15
0.9	5
0.4	6
1.2	7
1.1	4
1.4	6

ANSWER:

EXERCISE B3.4. Instruction to the carrier.

REFERENCE SOURCES: Training Manual Chapter B3.4

DISCUSSION: The vehicle crew has a role to play in ensuring that the radioactive cargo is safely delivered at its destination.

PROBLEM: State four instructions to the driver of a vehicle carrying radioactive material.

ANSWER:

EXERCISE B3.5. Labelling and marking	
REFERENCE SOURCES: Training Manual Chapter B3.3.	
DISCUSSION: The labels and markings on the package are an effective means of communication about the radioactive contents.	
PROBLEM: What information do you expect to find in the labels and markings on packages containing radioactive material?	
ANSWER:	

EXERCISE B3.6. Emergency response actions	
REFERENCE SOURCES: Training Manual Chapter B3.5	
DISCUSSION: While handling packages, it is possible that a mishap may occur. Measures should be taken to control the affected area and call in the experts quickly.	
PROBLEM: While handling packages containing radioactive material, a fork-lift runs over and damages a small package. What action will you recommend?	
ANSWER:	

TYPICAL TRAINING PROGRAMME SCHEDULE: SAFETY OF TRANSPORT OF RADIOACTIVE MATERIAL FOR CARGO PERSONNEL

Target audience: Employees of the port authorities, carriers, consignors and consignees responsible for moving and storing packages on and off conveyances and within facilities.

0900–0930	Module 23
0930–0945	Discussion
0945–1030	Module 24
1030–1100	discussion
1100–1115	Break
1115v1130	Module 25
1130–1145	Discussion
1145–1215	Question & Answer

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ISSN 1018-5518