IAEA
SAFETY
STANDARDS
SERIES

Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material

SAFETY GUIDE

No. TS-G-1.2 (ST-3)

INTERNATIONAL
ATOMIC ENERGY AGENCY
VIENNA

IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish standards of safety for protection against ionizing radiation and to provide for the application of these standards to peaceful nuclear activities.

The regulatory related publications by means of which the IAEA establishes safety standards and measures are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety, and also general safety (that is, of relevance in two or more of the four areas), and the categories within it are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides.**

Safety Fundamentals (blue lettering) present basic objectives, concepts and principles of safety and protection in the development and application of nuclear energy for peaceful purposes.

Safety Requirements (red lettering) establish the requirements that must be met to ensure safety. These requirements, which are expressed as 'shall' statements, are governed by the objectives and principles presented in the Safety Fundamentals.

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The IAEA's safety standards are not legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations in respect of their own activities. The standards are binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA.

Information on the IAEA's safety standards programme (including editions in languages other than English) is available at the IAEA Internet site

www.iaea.org/ns/coordinet

or on request to the Safety Co-ordination Section, IAEA, P.O. Box 100, A-1400 Vienna, Austria.

OTHER SAFETY RELATED PUBLICATIONS

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PLANNING AND PREPARING FOR EMERGENCY RESPONSE TO TRANSPORT ACCIDENTS INVOLVING RADIOACTIVE MATERIAL

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

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SAFETY GUIDE

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FOREWORD

by Mohamed ElBaradei
Director General

One of the statutory functions of the IAEA is to establish or adopt standards of safety for the protection of health, life and property in the development and application of nuclear energy for peaceful purposes, and to provide for the application of these standards to its own operations as well as to assisted operations and, at the request of the parties, to 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 nuclear energy.

The following bodies oversee the development of safety standards: the Commission on Safety Standards (CSS); the Nuclear Safety Standards Committee (NUSSC); the Radiation Safety Standards Committee (RASSC); the Transport Safety Standards Committee (TRANSSC); and the Waste Safety Standards Committee (WASSC). Member States are widely represented on these committees.

In order to ensure the broadest international consensus, safety standards are also submitted to all Member States for comment before approval by the IAEA Board of Governors (for Safety Fundamentals and Safety Requirements) or, on behalf of the Director General, by the Publications Committee (for Safety Guides).

The IAEA's safety standards are not legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations in respect of their own activities. The standards are binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA. Any State wishing to enter into an agreement with the IAEA for its assistance in connection with the siting, design, construction, commissioning, operation or decommissioning of a nuclear facility or any other activities will be required to follow those parts of the safety standards that pertain to the activities to be covered by the agreement. However, it should be recalled that the final decisions and legal responsibilities in any licensing procedures rest with the States.

Although the safety standards establish an essential basis for safety, the incorporation of more detailed requirements, in accordance with national practice, may also be necessary. Moreover, there will generally be special aspects that need to be assessed on a case by case basis.

The physical protection of fissile and radioactive materials and of nuclear power plants as a whole is mentioned where appropriate but is not treated in detail; obligations of States in this respect should be addressed on the basis of the relevant instruments and publications developed under the auspices of the IAEA. Non-radiological aspects of industrial safety and environmental protection are also not explicitly considered; it is recognized that States should fulfil their international undertakings and obligations in relation to these.

The requirements and recommendations set forth in the IAEA safety standards might not be fully satisfied by some facilities built to earlier standards. Decisions on the way in which the safety standards are applied to such facilities will be taken by individual States.

The attention of States is drawn to the fact that the safety standards of the IAEA, while not legally binding, are developed with the aim of ensuring that the peaceful uses of nuclear energy and of radioactive materials are undertaken in a manner that enables States to meet their obligations under generally accepted principles of international law and rules such as those relating to environmental protection. According to one such general principle, the territory of a State must not be used in such a way as to cause damage in another State. States thus have an obligation of diligence and standard of care.

Civil nuclear activities conducted within the jurisdiction of States are, as any other activities, subject to obligations to which States may subscribe under international conventions, in addition to generally accepted principles of international law. States are expected to adopt within their national legal systems such legislation (including regulations) and other standards and measures as may be necessary to fulfil all of their international obligations effectively.

EDITORIAL NOTE

An appendix, when included, is considered to form an integral part of the standard and to have the same status as the main text. Annexes, footnotes and bibliographies, if included, are used to provide additional information or practical examples that might be helpful to the user.

The safety standards use the form 'shall' in making statements about requirements, responsibilities and obligations. Use of the form 'should' denotes recommendations of a desired option.

The English version of the text is the authoritative version.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. The use of radioactive material is an important part of modern life and technology. Radioactive material is used extensively in medicine, industry, agriculture, research, consumer products and electrical power generation. Tens of millions of packages containing radioactive material are consigned for transport each year throughout the world. The quantity of radioactive material in these packages varies from negligible quantities in shipments of consumer products to very large quantities in shipments of irradiated nuclear fuel.

1.2. In order to ensure the safety of people, property and the environment, national and international transport regulations have been developed. They are used by the appropriate authorities in each State to control the transport of radioactive material. Stringent measures are required in these regulations to ensure adequate containment, shielding and the prevention of criticality in the event of a transport accident. Radioactive material is transported by land (road and rail), inland waterways, sea and air. These modes of transport are regulated by international 'modal' regulations. For example, the sea mode is covered by the International Maritime Dangerous Goods Code, which is issued by the International Maritime Organization [1]. The consignors, carriers and consignees of radioactive material are required to comply with the requirements set forth in the State or international modal regulatory documents. The IAEA's 1998 General Conference noted 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" [2].

1.3. Despite the extensive application of these stringent safety controls, transport accidents involving packages containing radioactive material have occurred and will occur. Whenever a transport accident involving radioactive material occurs, and although many will pose no radiation safety problem, emergency response actions are needed to ensure that radiation safety is maintained. If a transport accident occurs that results in a significant release of radioactive material, loss of shielding or loss of criticality control, the consequences should be controlled or mitigated by proper emergency response actions. Historically, there have been no reported transport accidents involving radioactive material that have resulted in serious radiological consequences. Despite this excellent safety record, plans should be developed, responsibilities should be defined and preparedness actions should be taken to ensure that an adequate emergency response capability is available when transport accidents involving radioactive material do occur.

1.4. The type of emergency planning and preparedness for responding to transport accidents involving radioactive material is, to some extent, similar to that required for responding to transport accidents involving the other types of dangerous goods, such as flammables, explosives, poisonous gases, corrosives and toxic chemicals, that are in transport every day.

1.5. The responses to an accident involving any type of dangerous goods can be initiated properly once it has been determined that dangerous goods are present and the material has been properly identified. The various international and State regulatory bodies require the use of communication tools to allow those who are first on the scene of a transport accident to define the hazard involved and hence determine how to respond properly. Thus emergency response organizations and personnel should be required to develop or should be provided with practical emergency response plans and procedures. They should demonstrate an adequate level of preparedness such that they are ready to provide the necessary response to transport accidents involving all types of dangerous goods, including radioactive material. The plans and procedures should ensure that the basic knowledge, skills and equipment are available to deal effectively with the wide range of possible consequences of such accidents.

1.6. A Safety Guide, Emergency Response Planning and Preparedness for Transport Accidents Involving Radioactive Material, was published in 1988[1]. This Safety Guide reflected the requirements of the 1985 edition of the Transport Regulations[2]. The publication of the 1996 edition of the IAEA's Transport Regulations [3][3] necessitated that Safety Series No. 87 be reviewed and revised to reflect the new regulatory requirements.

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[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Emergency Response Planning and Preparedness for Transport Accidents Involving Radioactive Material, Safety Series No. 87, IAEA, Vienna (1988).

[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] In June 2000 errata were issued for the English language edition of ST-1. The English edition was reprinted in 2000 with the corrections shown in the errata and given the new designation of TS-R-1 (ST-1, Revised) and the French and Spanish editions were reprinted in 2002 with similar corrections.

1.7. In order to update the previous recommendations on emergency planning for transport accidents involving radioactive material, the IAEA convened a consultants services meeting and followed this with a technical committee meeting in 1996. Additional actions were later taken by the Secretariat to make this Safety Guide final. These included adding recently published information from the IAEA Safety Requirements publication on Preparedness and Response for a Nuclear or Radiological Emergency [4] and a related IAEA TECDOC [5].

OBJECTIVE

1.8. The objective of this Safety Guide is to provide guidance to the public authorities and others (including consignors, carriers and emergency response authorities) who are responsible for developing and establishing emergency arrangements for dealing effectively and safely with transport accidents involving radioactive material. It may assist those concerned with establishing the capability to respond to such transport emergencies. It provides guidance for those States whose involvement with radioactive material is just beginning. It also provides guidance for those States that have already developed their radioactive material industries and the attendant emergency plans but that may need to review and improve these plans. This Safety Guide is neither a collection of rules nor a list of approved steps and actions.

1.9. This Safety Guide reflects the requirements specified in the 1996 edition of the Transport Regulations as revised in 2000 [3] and those of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [6]. It provides guidance on various aspects of emergency planning and preparedness, including the assignment of responsibilities. This Safety Guide may be used to assist in the preparation of national, regional and local emergency plans and procedures, account being taken of the specific governmental and legislative structures.

1.10. In using this Safety Guide it should be recognized that emergency response plans and the ways in which they are implemented may vary from State to State (see, for example, para. 103 of the Transport Regulations [3]). In each State the responsible authorities should decide how best to apply the information contained in this Safety Guide, considering the actual shipments that may be encountered and the associated hazards. Additional detailed guidance on the many components of an emergency programme is available from a variety of other sources, some of which are cited in this Safety Guide.

SCOPE

1.11. This Safety Guide has been developed to deal specifically with the particular problems associated with transport emergencies involving radioactive material. It should be recognized that the emergency planning and preparedness elements for responding to transport related accidents involving radioactive material are, to a great extent, similar to those for other dangerous goods. It is for this reason that all emergency planning and preparedness elements for responding to transport accidents involving radioactive material should be co-ordinated with those required for responding to transport related accidents involving other dangerous goods. In addition, while this Safety Guide has been developed for responding to accidents known to involve radioactive material, the concepts involved herein should also be applied to transport accidents where the presence of radioactive material is suspected.

1.12. A loss or theft of radioactive material during transport is not specifically dealt with in this Safety Guide. However, procedures developed for the notification of transport accidents involving radioactive material by various international, State and local organizations may also be applicable to cases of loss or theft during transport.

1.13. Detailed information concerning the nature and hazards of radioactivity and radioactive material is not included in this Safety Guide. This information can be found in publications listed in the References and Bibliography.

STRUCTURE

1.14. This Safety Guide provides a framework for planning and preparing for the appropriate responses to transport accidents. It provides guidance on the responsibilities that various agencies and individuals will have in planning, preparing and actually responding to transport accidents. Finally, it elaborates on the steps necessary to provide an adequate response.

1.15. To support this guidance, six appendices are provided. They contain:

- A review of features of the Transport Regulations [3] as they influence emergency response,
- An emergency response reference matrix to guide the first on the scene responders,
- Guidance on suitable instrumentation for assessing radiation levels and contamination,
- An overview of emergency response actions that can be taken to guide the efforts of an emergency manager when at the scene,

— A discussion of examples of responses to accidents and how some of the principles outlined in the guidance have been or could have been applied,
— An example of an equipment kit for a radiation protection team.

1.16. To support the guidance, annexes are also provided as follows:

— A sample of the emergency response guidance that was provided to a carrier by a consignor of radioactive material, and
— A sample of the emergency response guidance that is provided by governments.

2. FRAMEWORK FOR PLANNING AND PREPARING FOR RESPONSE TO ACCIDENTS IN THE TRANSPORT OF RADIOACTIVE MATERIAL

2.1. IAEA safety standards [3, 6] establish a framework for requiring an adequate emergency response capability for responding to transport accidents involving radioactive material.

2.2. The Safety Fundamentals publication Radiation Protection and the Safety of Radiation Sources [7] sets out the objectives of protection and safety as follows:

> "**Protection objective:** to prevent the occurrence of deterministic effects in individuals by keeping doses below the relevant threshold and to ensure that all reasonable steps are taken to reduce the occurrence of stochastic effects in the population at present and in the future.
> "**Safety objective:** to protect individuals, society and the environment from harm by establishing and maintaining effective defences against radiological hazards from sources."

2.3. The Fundamentals [7] also note that to achieve these objectives "a system of protection founded on basic principles is needed. Intervention may be necessary to deal with the radiological consequences of an accident…". Intervention in this case is defined as "any action intended to reduce or avert exposure or the likelihood of exposure to sources which are not part of a controlled practice or which are out of control as a consequence of an accident". Thus a transport accident involving radioactive material, irrespective of the magnitude or the nature of the accident, should be responded to using these objectives and principles.

2.4. The requirements on actions to be taken have been established at an international level [6]. These include:

- — Requiring intervention in the case of accidents or emergencies in which an emergency plan or emergency procedures have been activated;
- — Requiring each registrant or licensee responsible for sources for which prompt intervention may be required to ensure that an emergency plan exists;
- — Requiring employers to provide workers who could be affected by an emergency plan with the appropriate information, instruction and training.

2.5. The Transport Regulations [3] require that emergency provisions, as established by the relevant national and/or international organizations, be observed in the event of radioactive material transport accidents or incidents. Further, they require that emergency procedures account for the formation of dangerous substances, other than radioactive, that may result from interactions between the radioactive contents of a consignment and substances in the environment in the event of an accident.

2.6. The Transport Regulations [3] provide the framework for much of the needed protection. They establish stringent design, test and operational controls on the packaging and transport of radioactive material. They impose the regulatory controls exercised by the competent authorities at the State level. They impose these controls through a graded approach on packaging and on both the operational and regulatory controls. This graded approach can be useful to emergency responders in determining the hazard posed by the packages and their contents should they be involved in transport accidents. In addition, a regime of communications is used to allow the personnel involved in responding to an accident to identify the contents, assess the potential hazard and determine the appropriate response actions. These features of the Transport Regulations [3] and the manner in which they may influence the potential consequences and emergency response actions in the event of a transport accident involving radioactive material are summarized in Appendix I. In Ref. [4] five categories of nuclear and radiation related threats for emergency preparedness and response purposes are established, where emergency planning for category I is the most demanding (i.e. it is viewed as having the greatest potential consequences) and for category IV is the least demanding (category V is a special case). The transport of radioactive material is rated in category IV.

2.7. The goal of a programme for planning and preparedness for an emergency involving radioactive material should be to assist in building competence and confidence that an emergency arising from a transport accident would be managed effectively; that is, that the objectives and requirements elaborated in the Safety

Fundamentals and Safety Requirements publications can be met. Any response should be capable of being undertaken in a timely, effective, appropriate and co-ordinated manner wherever the accident may occur.

3. RESPONSIBILITIES FOR PLANNING AND PREPARING FOR RESPONSE TO ACCIDENTS IN THE TRANSPORT OF RADIOACTIVE MATERIAL

GENERAL

3.1. When a transport accident involving radioactive material occurs, several governmental organizations, the consignor, the carrier and their personnel may have responsibilities to act to mitigate its consequences. In most transport accident situations this response consists of life saving, medical aid, fire suppression and control, and the normal police work associated with any accident. In addition, consideration should be given to calling in specialized organizations trained to deal with radioactive material to assess the accident and implement the 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.

RESPONSIBILITIES OF THE NATIONAL CO-ORDINATING AUTHORITY

3.2. The responsibilities for planning and dealing with a transport accident involving radioactive material are generally divided among several involved organizations and persons [7]. The severity of the accident in terms of its consequences generally determines the level of governmental response and involvement. Because the governmental responsibilities and responses are dependent on the legal framework of the State concerned, and therefore may vary between different States, designation within a State of a ‘national co-ordinating authority’ to provide a focal point may be useful for developing and co-ordinating governmental response plans for transport accidents involving radioactive material. This may be useful for co-ordinating the development of national, provincial and local emergency response plans and facilitating proper emergency preparedness.

3.3. The national co-ordinating authority should consult with other organizations and agencies to ascertain their functions, roles and responsibilities in responding to an emergency. The local and provincial response plans and procedures (para. 3.9) should be checked by the lead agency to ensure that they are in full compliance with the national emergency plan. It should also, as part of the planning process, determine what resources these organizations and agencies have that may be useful in responding to a transport accident involving radioactive material.

3.4. At each governmental level several organizations and agencies that have responsibilities concerning transport accidents may exist. One agency should be assigned the lead agency responsibility; others should be assigned supportive roles. Assigning lead agency responsibility provides a focal point for developing emergency response plans and demonstrating emergency preparedness capabilities. The concept of a lead agency is also applicable in cases where only a single national plan is envisioned.

3.5. The national co-ordinating authority concept, if applied, should also be extended to the assignment of a co-ordination and control responsibility at the accident site. At the accident scene an 'incident commander' should be designated with the authority and responsibility to direct the on-scene response. The agency or organization assigned this operational responsibility may or may not (depending upon the governmental framework) be the same agency or organization assigned the responsibility for co-ordinating the development of plans. The national co-ordinating authority selected for this operational response function should have the authority and responsibility to direct and control the activities of supporting agencies and organizations during an actual emergency once its representatives arrive on an accident scene. This authority and responsibility typically would be assigned to the individual in the organization who has the primary role during each phase of the response. As the emergency progresses this would typically flow from the first responders to a local official and finally to a national official or command group for events involving several jurisdictions or ministries.

RESPONSIBILITIES FOR NOTIFICATION AND COMMUNICATION

3.6. Although the persons and organizations involved may be different, notification and communications concerning transport accidents involving radioactive material should be handled in a manner similar to that used for other transport incidents involving dangerous goods [8]. The use of communication networks and procedures that are common to all dangerous goods could be advantageous in terms of maintaining a high level of expertise and ensuring the proper and complete staffing of the communication facilities.

3.7. The establishment of regional emergency centres for any kind of accident that are manned 24 hours per day by trained staff should be considered. These centres could provide an effective liaison capability for alerting the appropriate agencies to the actions required. The centres should have information on the areas of jurisdiction of all the agencies that may become involved. They should have available up to date lists of names and the telephone numbers of agencies to be notified and experts who can be expeditiously dispatched to the accident scene. Ideally, the staff at the centres should also have the capability to give advice on how to handle accidents involving a broad spectrum of hazardous materials. Such centres could prove particularly advantageous in the case of an accident where a large number of agencies may become involved. The responsibility for establishing and maintaining such centres should be defined at the governmental level. The centres should also establish provisions to notify forthwith directly or through the IAEA those States that may be affected by a transboundary emergency[4]. Provisions should be in place also to notify the IAEA promptly of a transboundary emergency and to respond to requests for information relating to the emergency in accordance with IAEA requirements [4, 9].

RESPONSIBILITIES OF GOVERNMENTS

3.8. In developing governmental response plans and procedures for transport accidents involving radioactive material, the relevant government bodies:

— Should establish legislation to define the areas of responsibility and the functions of the various national authorities having expertise in this field;
— Should define the responsibilities of national, provincial and local governments;
— Should establish radiation protection services;
— Should identify the authorities to be notified when a transport accident involving radioactive material occurs and establish a communications and notification system;
— Should determine and periodically review and test the adequacy of the plans, as well as the adequacy of the available trained personnel and equipment;
— Should provide for the periodic review and update of the plans;

[4] Transboundary emergencies are events that are of actual, potential or perceived radiological significance for other States. This includes events that have resulted in significant exposures or contamination in other States, lost or stolen dangerous sources that could have passed over a national border, events influencing international trade or travel, and events perceived to be of radiological significance by the news media or public in another State.

— Should establish, where appropriate, liaison with the authorities in relevant States for notification concerning accidents whose consequences may extend beyond national boundaries;
— Should define the responsibility for public information and education concerning the transport of radioactive material;
— Should establish (or ensure establishment of) appropriate training programmes;
— Should provide resources to implement the plans when required.

3.9. Provincial and local governments should develop their own emergency response plans and procedures. At the local level planning should at least encompass the development of the capability to recognize a radioactive material package, being familiar with basic precautions and knowing who should be called on to provide further assistance [6]. It should cover the operation of their own organizations and the deployment of their own resources. The development of these plans should be co-ordinated among governments at the local, provincial and national level. Anticipated actions under any plan should be supported, as necessary, by checklists.

RESPONSIBILITIES OF CONSIGNORS AND CARRIERS

3.10. The primary responsibility for ensuring preparedness for a given shipment of radioactive material in principle should rest with the consignor. The consignor should ensure that, before undertaking the transport of radioactive material, carriers are fully aware of the procedures to be followed in the event of a transport accident. An example of guidance that was provided to a carrier prior to undertaking the transport of radioactive material is provided in Annex I.

3.11. Although the prime responsibility for safe shipping is with the consignor, the carrier also has responsibilities both for safety during transport and for the proper reaction in the event of an accident. In general, both the carrier and the consignor should be prepared to respond to an accident and provide the appropriate technical assistance to emergency responders.

3.12. The consignor should ensure that adequate arrangements are available to deal effectively with transport accidents involving radioactive material. These arrangements could include being prepared to provide information about the shipment, knowing how to deal with such an accident and providing emergency and/or technical assistance to an accident site, when requested or required.

3.13. In addition, the consignor should make available to the carrier the appropriate emergency instructions and other information concerning emergency responses.

3.14. The carrier should ensure that proper emergency instructions are carried on board the transport unit. All efforts should be made by the carrier to ensure that applicable emergency information will be available to the first on the scene personnel, even in the event that the carrier personnel are incapacitated.

3.15. Carrier personnel should be instructed that immediately after an accident, if they are able to do so, they should inform the police (or another appropriate emergency agency), the consignor and other appropriate authorities of the event. They should also be instructed to act according to the relevant emergency procedures.

RESPONSIBILITIES OF THE RADIATION PROTECTION TEAM

3.16. To support the emergency response organizations that generally respond to all transport accidents, specially trained and equipped radiation protection teams should be available to assess properly any consequences of an accident involving the release of radioactive material. The teams should be identified as a part of governmental emergency response planning. Team members should be experienced persons with professional and technical training in the radiological safety field.

3.17. Communications capabilities with the teams should exist on a 24 hours per day, 7 days per week basis so that the team members can be quickly and reliably notified when their assistance is required at an accident scene. Rapid means of transport for the team and its equipment, with preapproved funds, should be available to ensure the timely movement from their locations to the site of an accident.

3.18. More specifically, the team should be authorized, prepared and equipped to:

- — Travel to the site, with the appropriate equipment, in an expeditious manner;
- — Evaluate the radiological hazard;
- — Take the appropriate steps to minimize personnel exposure to radiation and/or radioactive material;
- — Take the appropriate steps to minimize the spread of radioactive contamination;
- — Provide technical information and advice to the appropriate authorities that would help in the treatment of affected people;
- — Carry out other general emergency measures as required.

3.19. For large area or long term monitoring and assessment, additional personnel and equipment to augment the team at the accident site may be required. Methods for identifying the personnel, equipment and supplies required to support a large area or long term monitoring and assessment should be documented during the emergency planning process.

4. PLANNING FOR RESPONSE TO ACCIDENTS IN THE TRANSPORT OF RADIOACTIVE MATERIAL

GENERAL

4.1. Radioactive material is transported by land (road and rail), inland waterways, sea and air. The Transport Regulations [3], summarized briefly in Appendix I, are applied to these shipments throughout the world, either directly by national regulations or by way of the requirements of relevant international modal organizations. The Transport Regulations [3] require that emergency provisions, as established by the relevant national or international organizations, shall be observed to protect persons, property and the environment.

4.2. A minimum level of planning for emergency response arising from transport accidents involving radioactive material is appropriate in every State [4]. As noted in Section 3, emergency response planning for transport accidents involving radioactive material is a responsibility that should be discharged by the responsible government authorities, consignors (shippers) and carriers.

4.3. Five categories of nuclear and radiation related threats have been established for emergency preparedness and response purposes [4]. The first category poses the greatest potential for large releases. The fourth category relates to areas of “little or no known threat”. Transport is identified in the fourth of these five categories. This category provides for the minimum level of preparedness, but applies to “all States because accidents involving… transport of radioactive material are possible anywhere”.

EMERGENCY PLANNING AND PREPAREDNESS

4.4. A main national plan for responding to transport accidents involving radioactive material should be developed. All provincial and local plans should be based on this plan. Consignors and carriers should also have emergency plans and the appropriate preparedness procedures. The responsibilities of different organizations are dealt with in Section 3. For protecting workers in the event of transport accidents, planning should be undertaken by both the consignor and the carrier, whereas, for protecting the public, planning should be undertaken by the appropriate local, regional, national and international officials [6].

4.5. The main national plan should be flexible enough to cope with a wide variety of accidents. However, the plan should at least cover:

(a) The planning basis;
(b) The responsibilities, capabilities and duties of the organizations involved;
(c) The procedures for alerting and notifying key organizations and persons;
(d) The methods for warning and advising the public;
(e) The intervention and action levels for exposure and contamination;
(f) The protective measures;
(g) The procedures for response actions;
(h) The resources for medical and public health support;
(i) The procedures for training, exercises and updating plans;
(j) Public information.

4.6. For determining the planning basis the responsible authorities should conduct an assessment of the radioactive material transported in their State and the systems used for transporting this material in their State. They should generally determine which types of shipments (material and package types) pass through these systems and which main routes are used. For States that have large numbers and types of radioactive material consignments, consideration may be given to performing assessments using statistical sampling to facilitate identifying those areas where accidents are more frequent and locations in which the possible accidents may have consequences that are more serious. A planning basis should then be defined with account taken of the potential consequences of the results of these analyses.

4.7. Clear step by step procedures should be prepared for implementing the emergency plan, using the graduated response (e.g. local, provincial and national responses) required for the severity of the accident and its consequences. This response could range from a simple confirmation that there is no radiological hazard, with a minimal involvement of expert responders, to situations where large scale remedial measures may be required at the accident site, including a significant involvement of experts.

4.8. Pre-established radiation exposure and contamination levels should be defined by governmental authorities as operational intervention levels (OILs) [6]. These OILs are required to be consistent with international standards [6]. If these OILs are exceeded certain response and protective measures should be taken. A major consideration is that transport accidents may occur in any location, including remote areas where access for responders may be difficult and in populated areas where the control of public access may be required. As a result, response plans should include considerations for implementation on difficult terrain and in adverse weather conditions.

4.9. Since the type of emergency plans for responding to transport accidents involving radioactive material (designated as Class 7) is often the same in structure as the plans for responding to accidents involving other dangerous goods (Classes 1–6, and 8 and 9 [8]), many of the same organizations will be involved and many of the same actions will be required. It is therefore preferable, wherever possible, to integrate the transport emergency plans for radioactive material with the plans for responding to accidents involving other dangerous goods. For such a master plan, the incorporation of national or regional alerting centres for all types of transport accidents involving dangerous goods should be considered. Such a system would be activated more frequently than a separate system for a particular class of dangerous goods. The experience gained by this combined response system could strengthen its reliability and effectiveness. In doing this, however, it should always be noted that low probability, high consequence transport accidents involving radioactive material may result in certain problems that may require unique responses.

4.10. Emergency plans for dealing with accidents involving radioactive material should conform as closely as possible to the existing capabilities and procedures for dealing with other transport accidents. Police, fire fighting or military organizations frequently provide the first line of response action. The carrier's employees, or members of the public who may be directly involved and initially on the scene of the accident, will most likely contact the police. The carrier's employees involved in transporting radioactive material should be given advance instructions on the procedures to be followed in the event of an accident and in notifying the police and/or other organizations defined in the emergency plans. Annex I provides an example of such guidance. Since para. 555 of the Transport Regulations [3] requires that the consignor provide information in the transport documents specifying the emergency arrangements that are appropriate for the consignment, carriers should ensure that this is accomplished before undertaking transport.

4.11. The emergency plans and procedures should also include provisions to provide information to the first on the scene personnel (e.g. the police and fire brigades) on the immediate response required for a transport accident involving radioactive material, as discussed in para. 5.11.

4.12. Emergency plans and the implementation procedures should specify the distribution of copies of these documents. All the organizations involved in the overall emergency response system should receive copies of the plans and procedures and all changes to them. A mechanism should be established for those on the distribution list to receive, and acknowledge receipt of, changes to these documents.

4.13. Additional detailed guidance on emergency response planning and preparedness [4, 9] and on developing procedures for assessing and responding to emergencies [5] is available.

5. PREPARING FOR RESPONSE TO ACCIDENTS IN THE TRANSPORT OF RADIOACTIVE MATERIAL

GENERAL

5.1. In responding to transport accidents involving radioactive material the main actions to be taken are to:

(a) Rescue and provide emergency medical aid to any victims,
(b) Control fires and the other common consequences of transport accidents,
(c) Identify the hazards of the material involved,
(d) Control any radiation hazard and prevent the spread of radioactive contamination,
(e) Recover the package or packages and transport vehicle,
(f) Decontaminate personnel,
(g) Decontaminate and restore the thoroughfare and delineate the borders of other contaminated areas,
(h) Decontaminate in the vicinity and restore to a safe state.

Once the radioactive material is under control and traffic flow has been restored at the accident scene, the emergency should be considered ended. In addition, if a release or contamination has been identified, decontamination and the restoration of adjoining areas may be required. Although decontamination actions (items (f)–(h) above) are not part of immediate emergency response planning and preparedness, a brief discussion of these activities is provided in this Safety Guide to facilitate understanding.

5.2. Although the carrier and consignor and the national, provincial and local government organizations may all have a role in the response, the primary responsibility, in principle, should rest with the consignor and the carrier to ensure that adequate arrangements are available to deal effectively with accidents involving radioactive material. At all times during shipment, the consignor and/or carrier should be able to provide information concerning the hazards of the shipment and should be able to send a properly equipped and trained radiation protection team to the site of the accident.

5.3. The need for international co-operation in responding to transport accidents should be considered. The Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency [10] provide the basis for such co-operation. Further guidance on international co-operation is given in Ref. [9]. Information on obtaining radiological and specialized medical assistance can be found in Ref. [11].

PHASES OF RESPONSE FOR TRANSPORT ACCIDENTS

5.4. The response actions in any accident can be divided into three phases:

- The initial phase,
- The accident control phase,
- The post-emergency phase.

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 of the accident.

PHASES OF RESPONSE FOR ROAD TRANSPORT ACCIDENTS

5.5. The detailed discussion of the three response phases that follow (paras 5.6–5.60) deal directly with land based, road transport accidents. Special considerations for other than land based, road transport accidents are provided in paras 5.61–5.70.

Initial phase

5.6. The carrier and the consignor have responsibilities for some initial emergency actions. They should notify the local and other defined authorities at the earliest practicable time. However, because the operators of the vehicle and crew members may be incapacitated in the accident and may not be able to act, others, who may happen to be on the accident site, may report the accident, most likely to the local civil emergency services.

5.7. Local civil emergency services should assume responsibility and should respond appropriately to an accident and assume the initial command and control responsibilities when they arrive at the accident scene. Their capability for handling accidents involving radioactive material is often limited because of their lack of knowledge and because assistance from persons with radiation safety knowledge and specialized equipment may not be readily available in the early period following an accident. Planning at the local level will usually involve being able to recognize a radioactive material package, being familiar with the basic precautions to be taken and knowing who should be called on to provide further assistance [4]. Furthermore, in some cases sufficient information for assessing the hazard regarding the nature of the consignment may not be immediately available. For these reasons local government emergency response planning should provide for the proper initial steps required to acquire this information. Generally, local authorities should identify the consignor and contents of the package or packages involved and seek assistance from the responsible consignor and carrier, and from the provincial and national authorities. These organizations and authorities should, in turn, have access to expert advice and resources. An arrangement for such access should be specified in the emergency plans.

5.8. During the first minutes after an accident, emergency actions by the local first responders should be directed towards [4]:

— Saving lives;
— Attending to any injured persons;
— Isolating the location;
— Preventing or extinguishing fires;
— Identifying hazards;
— Determining the actions necessary to prevent a further threat to human life, property or the environment;
— Calling for the appropriate expert support.

Priority should be given to life saving and first aid actions. In general, the presence of radioactive material should not impede such actions, as the risks to the emergency responders will generally be low [4].

5.9. Essentially, only visual information will be readily available to the local, first on the scene personnel. This will be in the form of the transport documents, markings and labels on the packages and/or placards on the vehicles or freight containers (see Appendix I). Police, fire fighters or the other first on the scene personnel should be trained to recognize this visual information, to assess the situation by means of standard accident investigation procedures and to notify the appropriate experts for assistance and advice [4]. This will enable the proper decisions to be made on what further action is necessary (para. 5.76). Emergency response guides and procedures are essential resources for conducting a response action. Typical emergency guides reflecting the requirements of the 1996 edition of the Transport Regulations [3] are provided in Annex II. The level of response should be generally determined based upon the potential hazard posed by the contents of the packages involved. This can be assessed in terms of the external radiation levels associated with the undamaged packages (as defined by the labels, see Appendix I) and the contents of radioactive material present, which will be related to the United Nations numbers for the consignment (tabulated in Annex II). Additional guidance on the level of response the first responders may take is provided in the preliminary emergency response reference matrix given in Appendix II.

5.10. Police, fire fighters or other qualified emergency response personnel should ensure that the scene is kept clear out to an appropriate distance. A later assessment of radiation levels (information on instruments that may be used for these measurements is provided in Appendix III) may prove that these actions were unnecessary, but until the situation is properly evaluated such actions are prudent. Generally, the public should be excluded (evacuated) from an accident site. Only police, fire fighters and other emergency response personnel should be allowed in the limited access (exclusion) area (see paras 5.39–5.47), and only for life saving or other emergency services.

5.11. The distance for such exclusion will depend on the circumstances of the accident. A guideline has been developed [5] and is included in Appendix IV. In addition, Tables II–III to II–XIII of Annex II provide guidance on how to meet the requirements in the 1996 edition of the Transport Regulations [3].

5.12. The police or other emergency personnel should record the names and addresses of the persons involved at the accident scene or in the immediate vicinity. If contamination is later found the people who have left the scene should be contacted to arrange for radiological monitoring. If it is not known exactly how many people or vehicles have passed through the contaminated area, the public should be informed about the accident through the local news media.

5.13. A clear chain of communication should be established from the person in charge at the scene to the relevant authorities. The person in charge at the scene should ensure that an open line of communication is maintained.

5.14. An initial investigation should be carried out by emergency personnel, taking into account the effect on human life, property and the environment, and those outcomes that could occur because of circumstances related to the accident. This initial investigation should determine the subsequent actions to be taken during the accident control and post-emergency phases. The results of the investigation should also form the basis of an initial report to the emergency response organizations and involved persons.

5.15. The investigation should include inquiries that answer such questions as:

(a) Were there any injuries to people?
(b) What labels, markings, placards and transport documents are present?
(c) Is there (or was there) a fire near the radioactive material packages?
(d) Are there large quantities of flammable liquids or gases in the immediate vicinity of the accident site?
(e) Is there explosive, toxic or corrosive material in the immediate vicinity of the accident site?
(f) Has containment of any of the packages been breached?
(g) What kind of radiological or other hazards exist?
(h) What are the meteorological conditions (including wind direction)?
(i) Has relevant information concerning the location of the population, the expected path of runoff water, the accessibility of the site and alternative roads been gathered?
(j) Were significant exposures possible? If yes, obtain information to allow the dose to be estimated.

5.16. The investigation should evaluate the situation at the accident site by making four basic determinations:

(a) Confirming the presence of radioactive material,
(b) Identifying the specific radionuclides involved and their quantities,
(c) Ascertaining whether or not the integrity of the shipping containers or packages has been breached,
(d) Assessing the potential radiological and related hazards.

Each of these is addressed in more detail below.

Confirming the presence of radioactive material

5.17. The initial problem will probably be one of recognition. Some radioactive material may be shipped in corrosive, toxic or chemically irritating forms, but radioactive material is frequently not in these forms and if released its presence is not readily observable. Information confirming the presence of a package containing radioactive material is given by a visual inspection of the package; any markings or labels on the outside of the package; any placards on the outside of the vehicle, freight containers or tanks; and the available transport documents (see Appendix I).

5.18. If suitable radiation monitoring equipment is available to properly trained emergency personnel responding to the accident, it should be used to assist in confirming the presence or absence of radioactive material. The type of instrumentation selected for monitoring a specific accident site should be based on the type of radiation likely to be present. Guidance on the type of equipment to use, depending upon the radionuclides present, has been provided [12], and is reproduced in Appendix III.

Identifying the specific radionuclides involved and their quantity

5.19. The information summarized in Appendix I concerning transport documents and labels should be used to assist in recognizing and providing specifics concerning the nature of the consignment.

Ascertaining the integrity of the shipping containers or packages

5.20. A visual inspection of the consignment may indicate whether the shipping containers or packages have been damaged. The presence of fire, smoke and fumes could preclude an initial determination in this regard. The presence of other toxic materials that have been released as a result of the accident may also hamper the assessment. Saving lives, suppressing fires and dealing with flammable, explosive and toxic materials should generally take priority before any assessment of package integrity can or should be made.

5.21. External damage to a container or package of radioactive material does not necessarily mean that the interior packaging components containing the radioactive material or providing shielding have been breached. However, external damage is an indication that the package should be thoroughly examined by properly equipped and qualified personnel. Leaking liquids, gases or powders may indicate that package integrity has been compromised. All released material should be considered hazardous unless and until otherwise determined by competent personnel. Package integrity might also have failed with no visible indication. This can only be determined by radiological monitoring of the package with the appropriate instruments by qualified experts. Consequently, all packages involved in an accident should initially be treated with caution.

Assessing the potential radiological and related hazards

5.22. An early assessment of hazards should be undertaken. Early information at the scene is useful in determining the extent of the hazard and in preventing unnecessary radiological exposure to emergency response personnel and the public. Early information is also useful for medical personnel caring for any injured persons who might be contaminated.

5.23. A thorough evaluation of the radiological conditions at an accident site during the early phase of response may not be possible. It requires considerable knowledge and experience with radioactive material and specialized instruments. It may be a time consuming process, especially in cases involving the contamination of persons, objects and the environment. Such an evaluation will generally occur during the accident control phase.

5.24. Information concerning radiation levels, the loss of shielding and any release of radioactive material from a container or package generally may only be obtained early in the emergency response if radiation monitoring equipment is available to the first on the scene emergency response personnel (such as the police, fire, rescue and emergency medical services). If such is the case these personnel should be specifically trained in the operation of such equipment, in any limitations in the use of such equipment that may apply and in the proper interpretation of the results. These personnel should also be trained with respect to the limits on radiation levels for the packages under normal transport conditions and on the limits for personnel safety.

5.25. In the absence of trained and equipped personnel, and in order to gain a better understanding of the potential hazard associated with the contents of the packages included in a specific incident, the first on the scene personnel may apply the guidance set forth in Appendix II.

5.26. Appendix V presents four typical or hypothetical accident scenarios involving radioactive material.

Accident control phase

5.27. The basic information that is available as a result of the actions taken during the initial phase should be used by the individual responsible for the accident control phase (who may be identified as the 'incident commander') in defining the primary actions needed during the accident control phase. One method for defining these actions is provided in Appendix IV.

5.28. As a part of the emergency planning process, prior arrangements — authorizing, preparing and equipping a radiation protection team — should be made. This will allow the accident control phase to be handled properly by qualified, experienced and equipped persons or teams. This team should come from governmental authorities, nuclear establishments, hospitals or other organizations where radiological assessment and protection services exist. It should be capable and authorized to perform the necessary radiation monitoring, assess the hazard and provide appropriate advice.

5.29. The primary purpose of radiation monitoring is to provide timely information on the basis of which proper decisions can be made to initiate protective and recovery actions. In order to achieve these goals, measurements of radiation levels (in mSv/h) and local contamination levels (in Bq/cm^2) should be made. The decisions should be made based on the predetermined OILs, as discussed in para. 4.8. The following additional measurements should be considered, depending upon the results of these first measurements:

— Measurements of airborne radioactive material and ground contamination around the scene of the accident;
— Measurements for assessing exposure to members of the public, transport workers and emergency personnel (including, if appropriate, internal contamination).

5.30. The team responding to an accident should have available the appropriate radiation monitoring instruments and should include qualified, trained personnel to operate that equipment, otherwise valid assessments of the radiological hazard may not be possible. This equipment should be available as a basic instrument kit. It should be well maintained and properly calibrated for radiological monitoring. The initial work accomplished at the accident site by the team would be accomplished with this kit. The kit should contain equipment as defined by the appropriate competent authority. An example of an equipment kit for a radiation protection team is shown in Appendix VI. More detailed lists for various types of response teams, depending upon the severity of the accident, are provided in Appendix 7 of IAEA-TECDOC-953.

5.31. In some cases a mobile radiological laboratory may be needed.

5.32. The characteristics of many types of instruments that could be used in assessing the accident scene can be found in standard texts on instruments, for example Ref. [12].

5.33. The appropriate mobile communications capabilities should be provided for the team.

5.34. Based on the results of the measurements, a qualified person, for example the leader of the team, should evaluate the radiological hazards and provide advice to other emergency responders, including the emergency manager. A good practice to follow is to use a map or sketch of the accident area and to document the measurement results on it.

5.35. Other duties of the radiation protection team are discussed in paras 3.16–3.19. These duties may include instructing emergency personnel to provide for radiologically safe working conditions within the accident area. Specifically, the radiation protection team should consider conducting personal monitoring and decontamination and assisting the person in charge with communicating with the local population and the news media.

5.36. Based on an evaluation of the accident situation, a decision should be taken as to what must be done with the package(s) and what further remedial action is necessary. If fissile material is involved, special considerations, such as ensuring the appropriate spacing between groups of packages, should be defined and implemented to ensure criticality safety.

5.37. Where a release of radioactive material in a transport accident necessitates a decision concerning the evacuation of persons from certain areas, that decision and the subsequent actions should be made by the responsible local authorities and the decision should be based upon expert advice [6]. These same authorities would normally also make similar decisions concerning evacuation after transport accidents involving other hazardous materials.

5.38. Protective measures in transport accidents that should be considered where significant radiation or radioactive contamination may exist as a result of the loss of integrity of the packages include:

- — The control of access to and egress from the accident vicinity,
- — Protective actions within the cordoned-off area,
- — Personal protective measures,
- — Sheltering or evacuation,
- — The decontamination of persons,
- — Controlling potentially contaminated food and water supplies,
- — The protection of the local drainage system and/or area.

Some of these protective measures might have already commenced, as discussed above, in the initial phase.

Control of access and egress

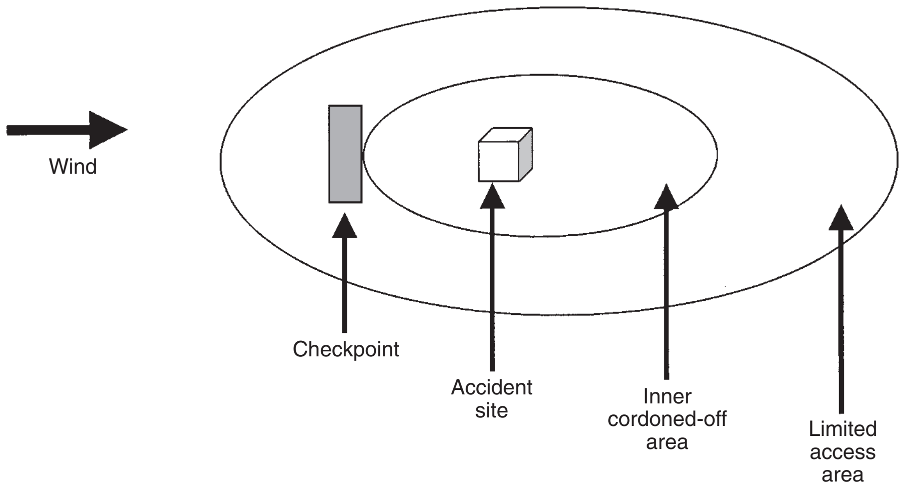
5.39. At each accident there are two principal areas of interest: a limited access area and an inner cordoned-off area (see Fig. 1). Limited access areas are areas that exclude public access. Cordoned-off areas are internal to limited access areas and are potentially contaminated and/or high radiation level areas that require controlled access and egress. See Appendix IV for additional details concerning distances.

5.40. The control of access to and egress from cordoned-off areas is accomplished using standard procedures. In addition to road blocking, cordoned-off areas should be established using any available material, such as rigid barricades, ropes and tapes. The size and shape of cordoned-off and limited access areas are highly dependent on the geographical terrain and other site conditions and may change during rescue operations. Factors affecting the shape and size of cordoned-off areas are the severity of the accident and the types and quantities of radioactive material released or the radiation levels outside packages, as well as weather conditions, the direction of the prevailing wind and monitoring results.

5.41. Access to and egress from cordoned-off areas by emergency personnel should be made only through an established checkpoint and/or decontamination point. This checkpoint and/or decontamination point should be located in the upwind direction and should serve as a radiological control station and a decontamination station for people, equipment and material, as well as an assembly point for emergency personnel. A written record should be maintained of all personnel access to or egress from cordoned-off areas.

Protective actions within cordoned-off areas

5.42. Emergency personnel working within cordoned-off areas may be exposed to a variety of hazards. These persons, and persons injured in the accident, may be exposed to radiation and may be contaminated with released radioactive material. Emergency workers should complete their work as quickly as possible in the cordoned-off area. Injured persons who need to be taken to a hospital should be wrapped in blankets, or other available coverings, which will help to control the spread of contamination, if present. If radiological monitoring instruments are available, it will be possible to confirm whether anyone is contaminated. If necessary for saving lives, injured persons should immediately be transported to medical facilities with the information that they may be radioactively contaminated. The receiving medical facility should be provided with the best available radiological information concerning the impending arrival of these injured persons. This information should be communicated as far in advance as possible by electronic means (such as radio, telephone, telefax, electronic mail). Contaminated persons taken to a hospital should be accompanied by a qualified person who is available to advise the hospital staff and to check the facilities for contamination after the patients' treatment. Evacuees who are not critically or seriously injured should be



Limited access area	Keep public away (para. 5.10).
(outer cordoned-off area)	Only police, fire fighters, ambulance service and other qualified personnel allowed inside (para. 5.10).
Inner cordoned-off area	Suspected to be contaminated (paras 5.42–5.45) or to have excessive radiation levels (para. 5.39) (external gamma dose rates >100 μSv/h [5] or predetermined evacuation distances as in Annex II).
	Only lifesaving/first aid/fire fighting actions or actions under personnel protective measures allowed (paras 5.39, 5.42, 5.47).
	Access or egress allowed only through the checkpoint/ decontamination point (para. 5.41).
Checkpoint and decontamination point	Locate upwind (para. 5.41).
	Provide a radiological control station to check for possible contamination (para. 5.41).
	If there is any contamination of persons or animals, arrangements should be made for decontamination (para. 5.41).
	If there is any contamination of equipment, vehicles or other items by radioactive material, it should be decontaminated or packed or suitably wrapped (para. 5.45).

Note: numbers in parentheses indicate paragraph numbers in this publication.

FIG. 1. Action areas and checkpoints for an emergency response scene.

detained to be radiologically monitored at a safe distance upwind from the accident scene. This monitoring point should be considered as part of a cordoned-off area.

5.43. As a conservative, safe practice all packages or containers of radioactive material that have been ejected from a vehicle as a result of an accident should also be encompassed by a cordoned-off area to await the arrival of qualified personnel to examine them and conduct radiological monitoring.

5.44. Runoff water from any fire fighting efforts or leakage from damaged containers or packages should be retained within a cordoned-off area by erecting temporary dykes using shovels or other available tools. However, fire fighting needed to protect lives or to mitigate the immediate hazard should not be delayed by actions to limit runoff.

5.45. Animals, vehicles, material, equipment or other items suspected of being contaminated should not be permitted to be removed from cordoned-off areas unless released by qualified radiological monitoring personnel.

5.46. Eating, drinking and smoking should be prohibited in cordoned-off areas.

5.47. The checkpoints controlling access by emergency personnel to the cordoned-off area should be upwind of the radioactive material packages. Emergency response personnel should approach any accident site where radioactive material might have been released from the upwind direction only to minimize the potential for the inhalation of any airborne radioactive material. The use of plastic sheets or tarpaulins should be considered to cover loose material to help minimize its dispersion by wind or rain.

Personal protective measures

5.48. Personal protective measures to minimize radiological exposure are essential when responding to transport accidents involving a release of radioactive material or the loss of package shielding. Such measures may include:

- Minimizing the time spent near the source of the radiation;
- Maximizing the distance from the source of the radiation;
- Using shielding between personnel and the source of the radiation, where available;
- Using respiratory protection equipment to reduce the possibility of inhaling radioactive material;
- Using protective clothing, followed by careful washing, to reduce the possibility of skin contamination or ingestion.

5.49. Fire fighting and radiological monitoring personnel are generally well equipped with standard protective clothing and respiratory protection equipment. This equipment should provide good protection against radioactive contamination and inhaling airborne radioactive material. It does not, however, protect them from direct gamma and neutron radiation, should those sources of penetrating radiation be present.

5.50. Police and emergency medical service personnel and other emergency workers will generally be less suitably equipped. They may acquire simple respiratory protection by covering their mouths and noses with an article of clothing or even soft absorbent paper products. However, if available, respirators should be used if the presence of airborne contamination is suspected. Any clothing, if it covers most of the body, provides a certain degree of protection against skin contamination.

5.51. Personal monitoring devices, such as pocket dosimeters, alarming dosimeters or badges (film or thermoluminescent dosimeters (TLDs)), should be used by emergency personnel as soon as they are available in order to measure personnel exposures. The members of the radiation protection team (paras 3.16–3.19) should be provided with the means to monitor and control their doses continuously in accordance with the applicable international standards [6].

5.52. Sheltering individuals may be necessary if dispersible radioactive material may be spread by local aerosol plumes or winds. Generally, houses and other buildings with closed doors and windows give good protection against contamination. Brick and concrete buildings provide better protection against penetrating radiation than most other types of construction.

5.53. Evacuating an area threatened by a release of radioactive material is the ultimate protective measure, but it should only be necessary in very rare circumstances in response to a transport accident. A precautionary evacuation of a limited area may be ordered while awaiting the arrival of radiological monitoring experts who are able to assess any potential radiological hazard. Decisions on evacuations should be governed by the predetermined operational intervention levels (see paras 4.8 and 5.29) or predetermined guides based on observable conditions at the scene (see Annex II).

Decontamination of persons

5.54. Removing the outer clothing and shoes of persons contaminated with radioactive material will minimize the spread of contamination. Skin decontamination requires shower and washing facilities and possibly some medical assistance in the case of open wounds, which are unlikely to be available at the site of a transport accident. Persons contaminated or suspected of being contaminated should be initially decontaminated at the accident site. They should later be thoroughly monitored and decontaminated in an appropriate facility. They should be provided with a change of clothing at the accident site, if possible, and the contaminated clothes should be collected for later washing or disposal. Contaminated persons should be wrapped in blankets to help limit the spread of contamination while they are being taken to the decontamination facilities.

Handling damaged packages

5.55. Access to any packages that are damaged or leaking their radioactive contents in excess of the allowable limits for the normal conditions of transport should be limited. Such packages may, under proper supervision, be removed to an acceptable interim location, but should not be forwarded until repaired or reconditioned and decontaminated (see paras 510 and 511 of the Transport Regulations [3]).

Post-emergency phase

Termination of emergencies

5.56. In most cases emergencies may be terminated when items (a)–(h) in para. 5.1 have been accomplished. Termination should be declared by the local responsible authorities. Before a declaration is made it should be ensured that no further hazard exists in the accident area and that all of the necessary protective measures have been taken or are being taken. This should be done to protect the public, property and the environment from further contamination and to minimize exposures that may result from the long term consequences of the accident. If appropriate, the termination of an emergency should be announced to the public by the responsible authority using the news media. The members of the public and the responders who were potentially exposed should be advised of the exposures and associated health risks. For potentially serious exposures advice on treatment should be obtained from medical professionals experienced in treating such cases. These could be obtained through the IAEA under the Emergency Response Network (ERNET) programme [11].

5.57. Persons qualified in radiological protection should be used in decontamination and restoration. As a part of the emergency planning efforts, arrangements should be made to summon persons with additional expertise and equipment suitable for dealing with severe accidents.

5.58. Several decontamination and restoration methods may be employed, such as the following:

- — Washing or vacuum sweeping of roads and other objects and surfaces. This can be done with fire fighting or industrial equipment; the water should be collected.
- — The fixing of contaminants using paints, liquid to solid strippable plastics and paving materials such as asphalt. Depending upon the type of radioactivity involved, the fixing agent may be removed after it has solidified or it may be left in place.
- — Washing and cleaning hard surfaces and equipment with water and appropriate detergents or other chemicals, with the liquids collected.
- — The removal or resurfacing of contaminated surface layers of roads or the removal of contaminated earth.

5.59. The relevant local, provincial and national authorities should also be involved so as to ensure that decontamination and restoration are completed in a safe and proper manner and that vehicles, buildings, areas and equipment are not occupied or returned to service until they have been radiologically surveyed and declared safe for use.

Control of food and water supplies

5.60. It is unlikely that major protective measures involving agricultural land, the control and distribution of agricultural products, or potable water would have to be implemented because of contamination from a transport accident involving radioactive material. Although it is possible that an accident could affect these products, any contamination is likely to be localized to a specific area. Under such circumstances the agricultural products may have to be confiscated and disposed of under controlled conditions. If a potable water supply is contaminated by dispersed radioactive material it should be tested for contaminants, and control of the supply at its sources may then be necessary. In the event that an accident takes place near a waterway or on a bridge over water, the water should be monitored if a release of radioactive material is suspected.

SPECIAL CONSIDERATIONS RELATING TO TRANSPORT BY OTHER MODES

Rail transport

5.61. Road transport emergency response arrangements are generally applicable to rail transport. However, railways, which are often the carriers of spent fuel shipments and many other types of radioactive material, have their own internal network of communication encompassing train crews, railway control points and consigning organizations. It is desirable to have a system for railway emergency response properly integrated into a general emergency system for transport accidents involving dangerous goods. Any such system should include provisions to inform the local, regional and national authorities in the area of an accident of which emergency services may be required of them. In some States railway authorities own their own rights of way and will be directly involved in the accident response and cleanup operations.

Water transport

5.62. Accidents occurring during the water transport of radioactive material may occur in three principal environments: (1) inland waterways, (2) ports and harbours and (3) oceans and seas. Consistent with the recommendations of Section 4, marine transport companies engaged in the transport of radioactive material should have an emergency response plan that should be incorporated into the overall plan for handing all shipboard emergencies.

5.63. Emergencies involving radioactive material on inland waterways and in ports and harbours can be managed in a manner similar to those occurring on land. However, the spread of contamination in a waterway may be much greater than that involved in a land accident. Further, locating and recovering radioactive material and contaminated debris may be more difficult, because of dispersion.

5.64. Emergencies occurring in ports and harbours may have the benefit of specialized emergency response teams. These port and harbour teams are usually trained to respond to marine related emergencies involving dangerous goods and may also prove a valuable asset in handling a radiological emergency. They should be provided with the appropriate level of training as described below.

5.65. Accidents involving radioactive material that occur on the ocean or sea pose some specific problems. An accident may occur in a remote location where the only available personnel to deal with the emergency is the crew of the ship. Crews of ships carrying radioactive material should be knowledgeable in determining when an emergency exists and in the notification procedures to be followed to obtain quick and reliable information about the initial actions to be taken. The crew should know that the only assistance that they may receive in a timely manner may be advice given by radio, based upon information gathered on board the vessel.

5.66. Emergency planning to deal with accidents on board a vessel should comply with the relevant regulations of the vessel's flag State. Further, shipboard personnel should use the guidelines for dealing with accidents at sea published by the International Maritime Organization [13] or other response guides, such as that contained in Annex II.

5.67. Accidents at sea may not be covered in detail in a national emergency plan. Accordingly, a ship's master should be in possession of information regarding which authorities to contact in the event of an emergency in those ports at which the vessel is likely to call. Maritime authorities with whom the master may be in contact during a voyage should also know whom to contact in an emergency so that, should the ship need to go into port, the emergency services will have been alerted in advance. While at sea, emergency advice can be given to the ship by radio.

5.68. Vessels subject to the International Maritime Organization's Irradiated Nuclear Fuel (INF) Code [14] should have on board a shipboard emergency plan, developed in accordance with the Guidelines for Developing Shipboard Emergency Plans for Ships Carrying Materials Subject to the INF Code[5] promulgated by the International Maritime Organization [15].

Air transport

5.69. Accidents occurring during the air transport of radioactive material may occur either at airports or at locations along the route of the aircraft.

5.70. Arrangements for emergency response planning and preparedness for road transport are generally not applicable to air transport, except in the case of an accident occurring at an airport. An accident that occurs as a result of a crash of an aircraft may require a response in remote or not easily accessible areas, and may pose problems in locating and collecting the radioactive material, which may be scattered over a fairly wide area. Preparedness arrangements for aircraft accidents should be flexible and tailored to suit the circumstances of the time. However, even in this case it should be noted that, after any initial response to an aircraft accident, access to the site of the crash, the conduct of any investigation into it and the cleanup action are likely to be under the control of an air accident investigation team. At this time the carrier's responsibility may be limited to providing information about what was on the aircraft. In the event of an aircraft accident, the visual identification of the presence of

[5] The INF Code became mandatory on 1 January 2002 for all Member States of the International Maritime Organization.

packages of radioactive material depends on the ability to see their labels or markings. In the majority of cases the air transport of radioactive material involves radiopharmaceuticals of limited hazard. An example of the response to an aircraft accident involving radiopharmaceuticals is provided in Annex III.

TRAINING FOR EMERGENCY RESPONSE IN TRANSPORT ACCIDENTS

5.71. A training programme should be established for organizations that may be called upon to respond to transport accidents involving radioactive material. As appropriate, training should be given to the police, fire brigades, emergency medical services, radiation protection teams, other technical experts and representatives of the appropriate authorities based upon their response roles and functions to be performed.

5.72. Specifically, training should be provided for three groups:

- — The first on the scene personnel,
- — Technical experts,
- — The representatives of the appropriate authorities.

5.73. Provision should be made for periodic refresher training in order to maintain the proficiency of all personnel in the emergency response organization and to review accident experience and practical problems.

5.74. The consignors and carriers involved in the transport of radioactive material should provide training related to their emergency instructions and the potential hazards of the types of material involved. This training should be given to their own personnel and also offered to the appropriate personnel of governmental agencies.

5.75. Training programmes should be geared to the roles and responsibilities that personnel fulfil in responding to an accident. Generally, the responsibility for developing training materials, including information for the local first responders on recognition and initial response, and for ensuring that training is undertaken and materials are distributed should lie with the national authorities [4].

First on the scene personnel

5.76. Two levels of training should be considered for the first on the scene personnel. The first level of training for them should provide basic information to all that may be the first to reach the scene of a transport accident. For these personnel, such as the police and fire brigades, the training should cover the subjects clearly applicable to such accidents. For example, the basic training or instructions with which the local responders should be provided should include information on how to recognize packages containing radioactive material, the basic precautions that they should take for themselves and the public involved, how to make the proper decisions when radiation monitoring equipment or expertise is not available, and whom to call to obtain expert assistance [4]. This basic information should include the fundamentals of:

- Radiological hazards;
- The identification of the package contents through marking, labelling, placarding and transport documents (see Appendix I);
- Protective measures (see Annex II);
- The use of available measuring instruments, including personal dosimeters.

It also may include the fundamentals of:

- First aid,
- Fire control,
- Crowd control.

5.77. The second level of training for the first on the scene personnel should be directed at those who are expected to be in charge at the scene of a transport accident. For these officials the training should contain the first level of training (para. 5.76) and, in addition, should contain information on the following points:

- Communications;
- The organization of operations at the accident site;
- The applicable transport regulations;
- Follow-up actions (notifications, responsibilities, initiation);
- The assessment of radiation and contamination monitoring;
- The protection of people from radiation exposure and radioactive contamination;
- The provision of information to the news media.

Technical experts

5.78. For personnel with backgrounds in radiation protection or nuclear applications, who may be called upon for technical support and response in the event of a transport accident, a more extensive training programme should be implemented. Training for these persons should include, in addition to the subjects described in paras 5.76 and 5.77, the following:

- Accident assessment techniques using radiological monitoring instruments,
- The implementation of protective measures,
- The use of protective clothing and equipment,
- Basic meteorology,
- The collection of contaminated material,
- Sealing techniques for leaking packages,
- The overpacking (see para. 229 of the Transport Regulations [3]) of damaged packages,
- Dose estimation and/or reconstruction.

Representatives of the appropriate governmental authorities

5.79. The representatives of the appropriate governmental authorities should be trained on their roles and responsibilities in responding to an accident, the recommendations of this Safety Guide and a basic understanding of the Transport Regulations [3]. They should have access to information on existing emergency response plans and organizations that may be involved, as well as on communication procedures and dealing with representatives of the news media.

EMERGENCY DRILLS AND EXERCISES FOR RESPONSE TO TRANSPORT ACCIDENTS

5.80. Drills and exercises simulate actual emergencies. They are the best means of accomplishing, at a minimum, the following goals and objectives:

- Revealing weaknesses in plans and procedures,
- Identifying deficiencies in resources (both in human resources and equipment),
- Improving co-ordination among various response personnel and agencies,
- Clarifying individual roles and areas of responsibility,
- Enhancing overall emergency response capabilities,
- Improving the speed of response,
- Monitoring the benefits over time of improvements made to a response system.

The type of drill or exercise should be such that over a given period of time all of the aspects of the response plan can be tested. Participants in drills and exercises should be rotated to ensure that all personnel experience the response plan in action.

5.81. The representatives of the appropriate authorities should provide leadership in the development and conduct of drills and exercises for accidents involving the transport of radioactive material. Additionally, these representatives should participate in and monitor the adequacy of emergency exercises.

Drills

5.82. Drills, which are more limited in scope than exercises, are designed to develop and maintain the skills of response personnel. For example, a communication and notification drill may teach personnel how to make a notification of an accident, to alert and update various organizations on the status of the accident and to reinforce the operation of communication equipment. A fire fighting drill could be limited to the operation of fire fighting equipment.

Exercises

5.83. The primary purposes of exercises are to test the adequacy of the emergency response system, to ensure that all elements are fully capable of responding to any emergency and to strengthen the confidence of the personnel involved so that they can adequately handle an accident. Exercises provide the opportunity to review, test and improve emergency plans, procedures, practices and individual technical skills. Exercises are part of any emergency response programme.

5.84. Exercise scenarios should be developed and used to test the response capabilities and skills of the emergency response organization. Those developing the exercise should not participate in the exercise, but may be evaluators or controllers. Exercises should be based upon realistic accident scenarios that are designed to test all major aspects of the plans; should be structured to address the expected actions and accomplishments necessary to cope with a radiological emergency; should aim at testing the effectiveness of communication links, the mobilization of emergency forces and specialized teams, and the co-operation between the organizations and services involved; and should use the equipment and instruments specified in emergency plans.

5.85. Care should be taken in all communications and messages to indicate that the event is an exercise.

5.86. Provision should be made for testing radiological instruments and communication and other equipment. The condition of equipment should be checked periodically, in conjunction with drills or exercises, and at other times as warranted. Any faults or deficiencies should be corrected immediately. Using and testing radiological measuring instruments on simulated radioactive material packages should be considered to ensure the adequacy of accident assessment procedures.

5.87. Provision should be made for the critique of exercises by qualified observers. The results critique should be used as a basis for improving the emergency plans, procedures and training, as appropriate. The recording of communications and videotaping the exercises are valuable aids for the participants' learning. Reports and critiques of actual emergencies should also be used as training aids.

5.88. Provision should be made in the planning of exercises for a debriefing meeting. This should take place as soon as possible after the completion of the exercise in order to gather the comments of all those involved.

REVIEW OF TRANSPORT EMERGENCY PLANS

5.89. A person should be appointed to be responsible for reviewing, maintaining and updating each plan. The person should ensure that the plan is modified as appropriate to take account of the results of drills, exercises and actual emergencies. In addition, the person should update the information on names and telephone numbers whenever personnel and organizational changes require it, but in any event at least once every six months. Names and communication numbers should be included as an annex or appendix to the plan in order to simplify their frequent updating. The person responsible for reviewing and maintaining the plan should participate as an observer in the exercises in order to be able to feed back the experience into improvements in the plan.

5.90. After each drill, exercise and emergency the services and personnel involved should take part in a debriefing session. Their reports and experience should be evaluated. The conclusions and lessons learned should be considered for improving the plans.

5.91. Provision should be made, at a minimum, for an annual comprehensive review and update of emergency plans.

PUBLIC INFORMATION AND COMMUNICATION

5.92. Since there is considerable public sensitivity about the transport of radioactive material, for any accident that occurs involving radioactive material concerted efforts should be made to keep the news media and the public well informed at all times about the situation, actions taken and protective actions recommended (if any) [5]. Emergency plans and procedures therefore should not only address the proper technical response to any transport accident but should also address the manner in which the news media and the public will be provided with accurate information.

5.93. Transport accidents may result in inconvenience and potential risk to the public. In fact, any accident involving radioactive material, no matter how minor, tends to create a sense of alarm that is usually not appropriate to the actual hazards present. The public should be adequately and accurately informed about the real risks involved in the transport of radioactive material and about the existence of emergency plans. The public should be informed following an accident as to what happened, what the real hazards are and what is being done. This information should be timely, consistent and appropriate. There should be no undue delay in providing this information, as this could jeopardize the effectiveness of protective actions.

5.94. In general, the public will receive information through the news media. Consequently, this emphasizes the importance that should be attached to the presentation of information to the news media. To minimize the risk of conflicting statements being given to the news media, the responsibility of communicating with news media representatives should be assigned to and co-ordinated by a specific, well qualified individual. If practicable, all communication with the news media should be carried out by qualified professionals with public information training. It should be recognized that the news media may need to be used to provide information to the public concerning the measures being taken to control the accident and to restore the situation to normal.

Appendix I

FEATURES OF THE TRANSPORT REGULATIONS INFLUENCING EMERGENCY RESPONSE TO TRANSPORT ACCIDENTS

INTRODUCTION

I.1. Many radioactive material shipments are of radiopharmaceuticals that are being transported from manufacturers to hospitals, and radioactive material for use in industry and research. While the total number of shipments of radiopharmaceuticals and material used in industry and research is quite high, the mass, the volume and the activity of the radioactive material per package in these consignments are frequently low. In general, all or part of each shipment of this material involves road transport (e.g. from a supplier (consignor) to an airport or from an airport to a user (consignee)). In addition, a large number of shipments made by road and rail involve consumer products that contain very small quantities of radioactive material.

I.2. The movement of radioactive material by aircraft can be by commercial passenger or commercial cargo flights. Many types of radioactive material may be carried. Because of the short half-lives of many radiopharmaceuticals they are frequently transported by air. Most accidents that involve air shipments of radioactive material have occurred at airports during the handling of the packages.

I.3. Some radioactive material shipments are of material associated with the production of electricity. This includes the non-irradiated material in what is commonly called the front end of the nuclear fuel cycle and the irradiated material (fuel and waste) in what is commonly called the back end of the nuclear fuel cycle. Most of these shipments are undertaken by road, rail or sea, or possibly combinations thereof. Since irradiated nuclear fuel generally poses the greatest hazard, such material is packaged in very robust, accident resistant packagings, and therefore during transport and in most transport related accidents the threat to people or the environment is small.

I.4. The majority of shipments of radioactive material by oceangoing vessels involve domestic or international shipments of nuclear fuel cycle material. In addition, there is some transport of radioactive material on inland waterways and by coastal vessels.

I.5. In certain cases restrictions may be imposed on transport routing. For example, packages subject to operational controls during transport and packages containing liquid pyrophoric material are prohibited for transport by air. In the case of consignments of highly radioactive material, for example irradiated nuclear fuel, some States require that highly populated areas be avoided, if possible.

I.6. The transport of radioactive material is governed within States by national legislation. Since such transport may frequently involve transboundary operations, internationally agreed regulatory requirements have been developed. The Transport Regulations [3] and their supporting publications (e.g. Refs [16–18]) are the basis for the safe transport of radioactive material in most States by way of international modal and domestic transport regulations. The intent of the Transport Regulations [3] is that the packages will be designed, manufactured and maintained in such a way that even in the event of accidents the potential for radiological impact would be acceptably small and, where fissile material is involved, accidental criticality would be avoided.

I.7. The Transport Regulations [3] specify the basic design requirements for packages, tanks and freight containers for radioactive material to ensure safety. These include:

- Stringent containment requirements for radioactive material,
- Limits on the radiation levels outside the packages,
- Controls on critical reactions for any fissile material,
- Consideration of dissipation of any heat generated by the radioactive contents of the packages.

I.8. Because the Transport Regulations [3] are applicable to a wide variety of radioactive material spanning a wide range of radiotoxicity levels and physical and chemical forms, the package design requirements are imposed on a graded basis. In addition, the same graded approach is used in specifying requirements on the authorization of package designs, on the operational controls for the packages and shipments and on the manner in which hazards are communicated. As the potential hazard of the contents increases, the design, authorization, operational control and communication requirements commensurately become more demanding.

I.9. This appendix summarizes how the regulatory requirements may influence emergency response in the event of a transport accident involving radioactive material. It considers:

- The types of the packages and their contents,
- The allowed radiation levels and categories of the packages,
- The marking and labelling of the packages,
- The placarding of freight containers and vehicles,

— The transport documents.

All of these requirements facilitate communication in the event of an accident and help define the potential consequences of transport accidents.

TYPES OF PACKAGES

I.10. The various types of packages used for transporting radioactive material are described below. Depending upon the type of package required, the graded approach used in the Transport Regulations [3] specifies the tests for an individual package's design for routine conditions of transport, normal conditions of transport and accident conditions of transport.

Excepted packages

I.11. Excepted packages are permitted to contain only small quantities of radioactive material. They have minimal design requirements imposed upon them and are excepted from most marking and labelling requirements. They meet the stringent requirements specified in the Transport Regulations [3] with respect to radiation and contamination levels for packaging (e.g. see paras 516 and 517 of the Transport Regulations [3]). Examples are packages that contain certain types of timepieces, smoke detectors, some radiopharmaceuticals and the very low level radioactive sources used for testing instruments. Typically, excepted packages are constructed of cardboard. Internally contaminated but otherwise empty packagings may also qualify and be transported as excepted packages.

Industrial packages

I.12. Industrial packages are permitted to contain relatively large quantities of radioactive material. However, the materials permitted in these packages are of one of two types: they may either be in the form of low specific activity (LSA) material or be surface contaminated objects (SCOs). Three types of industrial packages (Type IP-1, Type IP-2 and Type IP-3) are allowed. The type of industrial package that is permitted depends on the characteristics of the LSA material or the SCO to be transported. The types of material and objects allowed to be shipped in IP-1, IP-2 and IP-3 packagings are:

— IP-1: SCO-I and LSA-I solids and LSA-I liquids under exclusive use.
— IP-2: SCO-II and LSA-II solids, LSA-I liquids not under exclusive use and LSA-II liquids and gases and LSI-III solids under exclusive use.

— IP-3: LSA-II liquids and gases and LSA-III material not under exclusive use.

I.13. Although the specific activity of LSA material and the contamination on SCOs is generally low, the total activity in a consignment could be significant. Some examples of LSA material and SCOs are:

— LSA-I: ores, unirradiated uranium and thorium, mill tailings and contaminated soil and debris with low activity concentrations. This material has a high degree of uniformity of activity distribution.
— LSA-II: reactor process wastes, filter sludges, absorbed liquids and resins, activated equipment, laboratory wastes and decommissioning wastes. This material has a lower degree of uniformity than LSA-I, therefore higher, localized concentrations of activity may be present and more stringent packaging requirements are imposed.
— LSA-III: solidified liquids, resins, cartridge filters and irradiated material. This material is essentially uniformly distributed in a solid compact binding agent. Radioactive material may also be distributed throughout a solid or a collection of solid objects within the packaging. This material is allowed to have higher specific activities and therefore more stringent packaging requirements are imposed.
— SCO-I and SCO-II: both categories are for non-radioactive solid objects that have internal or external surfaces that are contaminated. SCO-II allows for higher contamination levels than SCO-I. Examples would be decommissioning wastes such as contaminated piping, tools, valves, pumps and other hardware.

I.14. All industrial packages are required to meet general package requirements. Type IP-2 and Type IP-3 industrial packages are required to satisfy certain additional test requirements by demonstrating the ability to withstand the normal conditions of transport without a loss or dispersal of their contents or a loss of adequate radiation shielding integrity. The total activity is limited by the maximum dose rate 3 m from the unshielded material, object or collection of objects. Industrial packages are often boxes, steel drums, metal containers and tanks.

Type A packages

I.15. Type A packages are permitted to contain specified limited quantities of radioactive material. The Type A activity limits are determined based on the maximum acceptable radiological consequences following a failure under specified conditions. These activity limits, which are calculated values specified in the Transport Regulations [3] for each radionuclide, are for ‘special form’ (sealed capsules and indispersible solid radioactive material) and ‘other than special form’ radioactive material. The limits are known as the A_1 and A_2 values, respectively.

I.16. Type A packages are required to withstand the normal conditions of transport without a loss or dispersal of their contents or the loss of adequate shielding integrity. Experience has demonstrated that, despite severe external damage and distortion, only a very small fraction of packages shipped have suffered a loss of contents or a change in external radiation levels when improperly handled or involved in transport accidents. Type A packages, which are commonly used in transport, range from wood, fibreboard or cardboard constructions with glass, plastic or metal inner containers, to metal drums or lead filled steel packages. An increasing number of these packages are being used and multiple numbers of them are often shipped in consignments; that is, several packages together on a single conveyance or in an overpack or freight container. Examples of material transported in Type A packages include radiopharmaceuticals, radionuclides for industrial applications and radioactive wastes.

Type B packages

I.17. Type B packages are permitted to contain radioactive material in quantities greater than those allowed in Type A packages. Type B packages are required to be designed to withstand both the normal and accident conditions (i.e. the drop, puncture, crush, thermal and immersion tests) of transport [3, 16]. Type B packages may range in size from those with a gross mass of a few kilograms, containing radiography sources, to large packages having a gross mass of up to about 100 metric tonnes, containing, for example, irradiated nuclear fuel (spent fuel from nuclear power plants). Typically, Type B packages are of a steel construction and incorporate substantial radiation shielding. Experience to date has confirmed the suitability of this package design concept and has shown that the probability of the loss of radiation shielding or containment in the case of accidents involving such packages is very low. The Transport Regulations [3] require Type B package designs to be approved by the relevant competent authority or authorities.

Type C packages

I.18. Type C packages are designed to transport large activities (e.g. $3000 \times A_2$) of radioactive material by air. These packages are designed to withstand the Type B drop, puncture, thermal and immersion tests and, in addition, are also designed to withstand more severe tests, such as the enhanced thermal, impact and water immersion tests intended to simulate the conditions that may result from a severe aircraft accident. Type C package designs are subject to approval by the competent authority of the State of origin of the package design.

Packages containing uranium hexafluoride (UF_6)

I.19. Uranium hexafluoride is required to be packaged and transported in accordance with the provisions of ISO 7195, Packaging of Uranium Hexafluoride (UF_6) for Transport [19], or alternatives thereto, and with the specific requirements of the Transport Regulations [3].

Packages containing fissile material

I.20. Packages containing fissile material may be industrial packages or Type A, Type B or Type C packages. The designs of these packages are all subject to the approval of the competent authority. In addition to the requirements for the packages mentioned above, the Transport Regulations [3] include specific provisions for packages containing fissile material. Fissile material is capable of undergoing a self-sustaining neutron chain reaction. In the fission process an atomic nucleus splits into fission products, resulting in the release of radiation and heat. Uranium-233, uranium-235, plutonium-239, plutonium-241, or any combination of these radionuclides, is fissile material (see para. 222 of the Transport Regulations [3]).

I.21. The additional requirements for fissile material are intended to ensure criticality safety in the transport of this material by:

- — Limiting the quantity and geometric configuration of the fissile material,
- — Imposing strict package design features to ensure that criticality safety is provided under the accident condition tests,
- — Controlling the number of packages allowed to be carried on a single conveyance or to be stowed together during transport and in-transit storage.

I.22. The Transport Regulations [3] provide some exceptions from the requirements for packages containing fissile material, for example if the uranium-235 concentration is less than 1% or if the package contains only limited quantities of fissile material. These are known as ‘fissile excepted’ packages. In this case the other relevant packaging requirements related to the radioactive nature of the contents are applicable.

RADIATION LEVELS AND CATEGORIES FOR PACKAGES

I.23. Radiation levels under normal conditions of transport,

(a) When transported under non-exclusive use are limited so that

— The maximum radiation level at the package surface does not exceed 2 mSv/h, and
— The maximum radiation level 1 m from the surface does not exceed 0.1 mSv/h; and

(b) When transported under exclusive use by rail or by road or under exclusive use and special arrangement by vessel or by air are limited so that the radiation level at the surface of the package

— May exceed 2 mSv/h, but
— Shall not exceed 10 mSv/h.

I.24. These radiation level limits are included as part of the specification of categories of packages as summarized in Table I. Categories are used to define the labels placed on packages which provide information that can assist in ensuring adequate radiation protection during handling, stowage and storage of the packages. The categorization of packages can also assist emergency responders in understanding the level of risk posed by the undamaged packages in the event of an accident.

I.25. For Types IP-2, IP-3, A, B and C package designs, after being subjected to the prescribed tests for demonstrating the ability to withstand the normal conditions of transport, the radiation level may increase by no more than 20% at any point on the external surface. For Type B and Type C package designs, after being subjected to the prescribed tests for demonstrating the ability to withstand the accident conditions of transport, the radiation level may not exceed 10 mSv/h at 1 m from the package

TABLE I. MAXIMUM RADIATION LEVELS FOR EACH TYPE OF PACKAGE LABEL

Category of label	Conditions of transport		Maximum radiation level	
	Under exclusive use	Not under exclusive use	At the package surface (mSv/h)	At 1 m from the package surface (mSv/h)
I-WHITE	X	X	0.005	<0.0005
II-YELLOW	X	X	0.5	0.01
III-YELLOW		X	2	0.1
III-YELLOW	X		10	>0.1

surface. These requirements provide a significant radiation protection safety margin for those responding to accidents involving these types of packages.

MARKING OF PACKAGES

I.26. All packages, other than excepted packages transported by post (which are allowed to carry only very small quantities of radioactive material), are required to have markings that facilitate identification and the proper actions to be taken in the event of an accident.

I.27. For each excepted package not accepted for transport by post, the United Nations number (see Annex II), preceded by the letters ‘UN’, is required to be legibly and durably marked on the outside of its packaging. For excepted packages accepted for international movement by post, the appropriate requirements of the Transport Regulations [3] apply.

I.28. For all other package types the United Nations number (see Annex II), preceded by the letters ‘UN’, is required to be legibly and durably marked on the outside of the packaging. They are to be marked with an identification of either the consignor or consignee, or both. Each package of gross mass exceeding 50 kg is required to have its permissible gross mass legibly and durably marked on the outside of its packaging. In addition, these packages are required to be legibly and durably marked with the appropriate package type on the outside of the packaging.

— Each industrial package is required to be marked with ‘Type IP-1’, ‘Type IP-2’ or ‘Type IP-3’, as appropriate. Each Type IP-2 or Type IP-3 package is also required to be marked with the international vehicle registration code (VRI Code) of the State of origin of the design and the name of the manufacturer.
— Each Type A package is required to be marked with ‘Type A’ and with the VRI Code of the State of origin of the design and the name of the manufacturer.
— Each Type B(U), Type B(M) and Type C package design is required to be marked with the trefoil symbol (Fig. 2), with a serial number, with the identification number allocated to that design by the competent authority, and with ‘Type B(U)’, ‘Type B(M)’ or ‘Type C’, as appropriate.

I.29. The marking requirements for the different types of packages, and the references from the Transport Regulations [3], are summarized in Table II. The paragraph numbers shown in the table refer to the Transport Regulations [3].

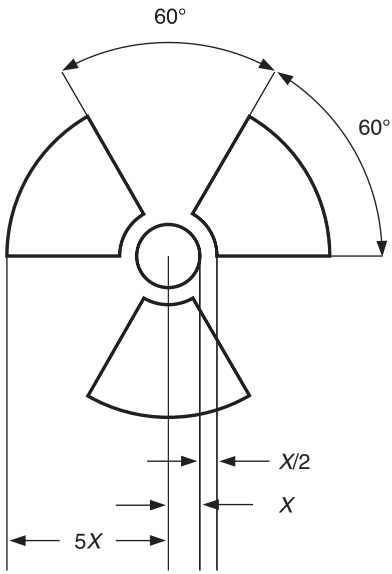


FIG. 2. Trefoil symbol marked on all Type B and Type C packages.

LABELLING OF PACKAGES

I.30. Packages containing radioactive material (other than excepted packages) are required to bear labels indicating their category (i.e. I-WHITE, II-YELLOW and III-YELLOW). The I-WHITE label indicates very low radiation levels outside a package, whereas II-YELLOW and III-YELLOW labels indicate radiation levels of significance (see Table I). The numbers in the brackets in the first column refer to the relevant paragraph numbers in the Transport Regulations [3]. In addition to the radioactive material labels, packages containing fissile material, if not excepted from the fissile material requirements, are required to bear a fissile label. These labels are depicted in Fig. 3. These labels not only control the manner in which radioactive material packages are handled and stowed during transport and stored during in-transit storage, they also facilitate communication on hazards to assist in the proper emergency response in the event of an accident.

I.31. The different types of labels indicate the relative radiation hazard outside the package. These maximum possible levels of radiation for each type of label are indicated in Table I. Additionally, the label is required to contain the names of the radionuclides and the total activity of the radionuclides in the package. For categories

TABLE II. MARKING REQUIREMENTS FOR RADIOACTIVE MATERIAL PACKAGES
(paragraph numbers shown are from the Transport Regulations [3])

Marking	Package type							
	Excepted	Type IP-1	Type IP-2	Type IP-3	Type A	Type B(U)	Type B(M)	Type C
Consignor or consignee identification or both (para. 534)	×	×	×	×	×	×	×	×
United Nations number (para. 535)	×	×	×	×	×	×	×	×
Proper shipping name (para. 535)		×	×	×	×	×	×	×
For package mass greater than 50 kg, permissible gross mass (para. 536)		×	×	×	×	×	×	×
Type IP-1, IP-2, IP-3, A, as appropriate (para. 537 (a)–(b))		×	×	×	×			
VRI Code of country of design origin and name of manufacturer (para. 537 (c))			×	×	×			
Competent authority identification for design (para. 538 (a))		×[a]	×[a]	×[a]	×[a]	×	×	×
Serial No. (para. 538 (b))		×[a]	×[a]	×[a]	×[a]	×	×	×
Type B(U), B(M), C, as appropriate (para. 538 (c)–(d))						×	×	×
Trefoil symbol (para 539)						×	×	×

Note: An × indicates a requirement.

[a] The requirement applies only if the package contains fissile material or if the package contains 0.1 kg or more of UF_6.

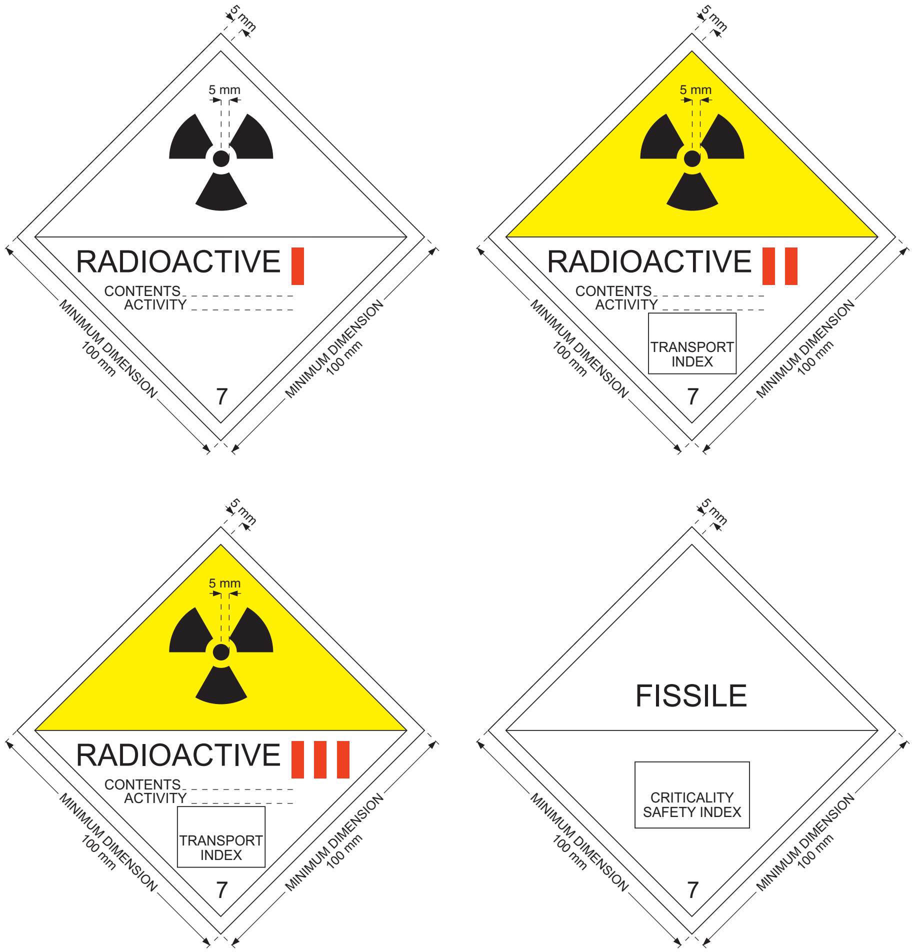


FIG. 3. Labels used on radioactive material packages and fissile material labels that can be added as appropriate.

II-YELLOW and III-YELLOW the labels will indicate the transport index (TI). The TI is a number that is used to provide control over radiation exposure, and is an indicator of the radiation level 1 m from the surface of the package.

I.32. Packages containing fissile material are additionally required to bear criticality safety labels, also shown in Fig. 3, with the criticality safety index (CSI) as stated in the appropriate approval certificate issued by the competent authority. The CSI is a number that provides information to assist in the control of criticality. Packages containing radioactive material having other dangerous properties are additionally required to bear the appropriate label in compliance with the relevant transport regulations for dangerous goods.

I.33. A photograph of an appropriately marked and labelled Type A package is shown in Fig. 4.

PLACARDING OF FREIGHT CONTAINERS AND VEHICLES

I.34. Rail and road vehicles carrying any labelled packages, large freight containers containing packages other than excepted packages, tanks containing radioactive material and certain consignments of LSA-I material or SCO-I in large freight containers or tanks are required to bear placards indicating the presence of radioactive material. The placards may take the form of one of those depicted in Fig. 5 or may be enlarged labels, as shown in Fig. 3. These placards may display the United Nations number for the consignment, which facilitates communication concerning how best to respond in the event of an accident. The applicable United Nations numbers and how they are applied to emergency response guides are illustrated in Annex II.

TRANSPORT DOCUMENTS

I.35. Each consignment is required to have transport documents (referred to in the Transport Regulations [3] as 'particulars of consignment', often referred to as shipping documents, shippers' declarations, freight bills, waybills, etc.). The information to be contained in the documents is specified in paras 515 and 549 of the Transport Regulations [3]. This information can assist those responding to an emergency in identifying the contents of the consignment and thereby facilitate the proper response in the event of an accident.

I.36. For excepted package shipments only the United Nations number is required.

I.37. For all other shipments of radioactive material the consignor is required to include the following (para. 549 of the Transport Regulations [3]):

- — The proper shipping name, as specified in table VIII of the Regulations.
- — The United Nations Class number '7'.
- — The United Nations number assigned to the material as specified in table VIII of the Regulations, preceded by the letters 'UN'.
- — The name or symbol of each radionuclide or, for mixtures of radionuclides, an appropriate general description or a list of the most restrictive radionuclides.

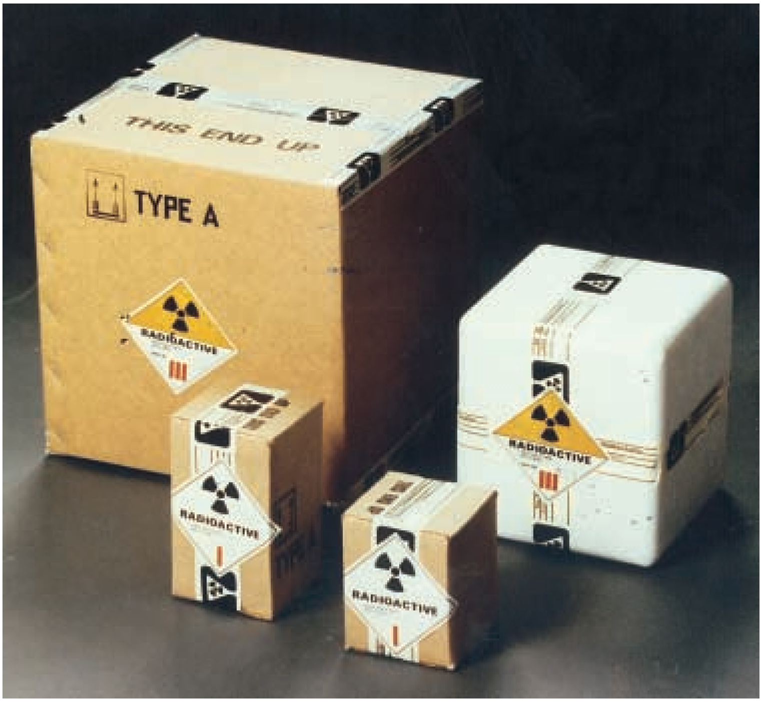


FIG. 4. A typical Type A package properly marked and labelled. Credit: Amersham International.

- A description of the physical and chemical form of the material, or a notation that the material is a special form radioactive material or low dispersible radioactive material. A generic chemical description is acceptable for the chemical form.
- The maximum activity of the radioactive contents during transport expressed in units of becquerels (Bq), with an appropriate SI prefix (see annex II of the Transport Regulations [3]). For fissile material the mass of fissile material in units of grams (g), or the appropriate multiples thereof, may be used in place of activity.
- The category of package (i.e. I-WHITE, II-YELLOW, III-YELLOW).
- The TI (categories II-YELLOW and III-YELLOW only).
- For consignments including fissile material other than consignments excepted under para. 672 of the Transport Regulations [3], the CSI.
- The identification mark for each competent authority approval certificate (e.g. for special form radioactive material, low dispersible radioactive material,

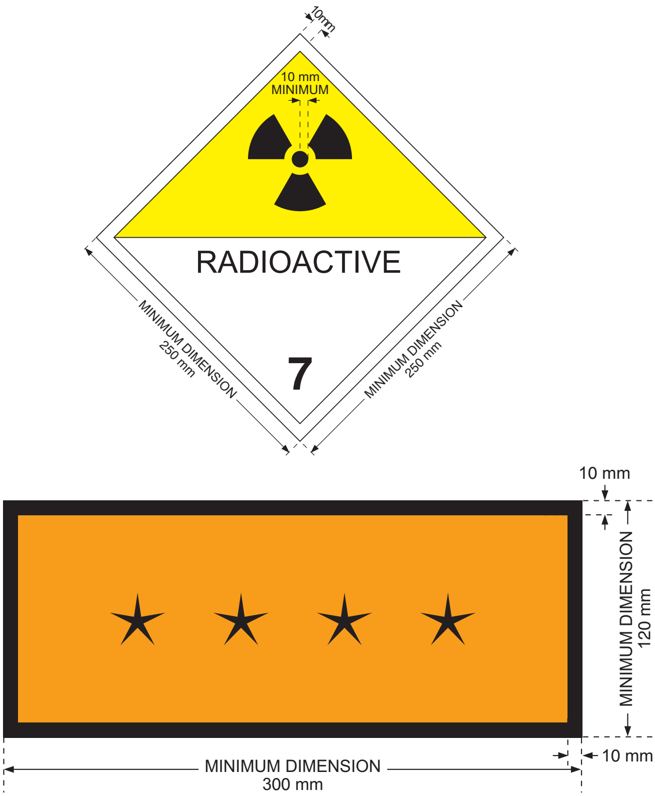


FIG. 5. Placards used on vehicles, tanks and freight containers carrying radioactive material.

special arrangements, the package design or shipment — see para. 802 of the Transport Regulations [3]) applicable to the consignment.

- For consignments of packages in an overpack or freight container, a detailed statement of the contents of each package within the overpack or freight container and, where appropriate, of each overpack or freight container in the consignment. If the packages are to be removed from the overpack or freight container at a point of intermediate unloading, it is required that the appropriate transport documents be made available.
- Where a consignment is required to be shipped under exclusive use, the statement 'EXCLUSIVE USE SHIPMENT'.
- For LSA-II, LSA-III, SCO-I and SCO-II, the total activity of the consignment as a multiple of A_2.

POTENTIAL CONSEQUENCES OF TRANSPORT ACCIDENTS

I.38. Emergency response planners should understand the possible circumstances and effects of accidents involving radioactive material. The IAEA has established a practical, step by step approach for developing integrated user, local and national emergency response capabilities [4]. This approach includes an elaboration of the basic concepts for establishing an emergency response capability, identifying potential radiological hazards at an accident scene, informing the public and emergency workers of the actions that should be taken and categorizing the potential threat.

I.39. The nature, characteristics and consequences of transport accidents involving radioactive material accidents depend on many factors, including the:

- — Type of package,
- — Physical and chemical form of the material,
- — Radiotoxicity and amount of radioactive material contained within the package,
- — Mode of transport,
- — Severity of the accident as it affects the integrity of the package involved.

Other factors, such as any other dangerous properties of the contents, the location of the accident and the prevailing weather conditions, may also influence the potential consequences.

I.40. Experience to date has confirmed that when radioactive material is packaged and transported in compliance with the Transport Regulations [3], the risks to persons, property and the environment from the transport of radioactive material are very low. However, for the purposes of preparing emergency response plans, consideration should be given to the possible causes of package failures that are beyond the design base of the package and that could create health hazards and/or contaminate the environment. The following effects could arise:

- — An extremely severe impact, which could breach the package containment system;
- — An intense long duration fire, which could cause a loss of shielding and/or containment of the package;
- — A defect in a package, which could reduce its ability to withstand the stresses for which it was designed.

I.41. The consequences of transport accidents range from a low radiological hazard (with a high probability of occurrence) to a potentially high radiological hazard (with a low probability of occurrence). Low hazard accidents may involve all types of packages. Potentially high hazard accidents basically involve only Type B and Type C packages, since the other packages contain radioactive material in a form or in a quantity that does not pose an immediate major radiological hazard to people, property or the environment. Appendix V provides three examples of actual accidents and one hypothetical accident involving radioactive material.

Excepted packages

I.42. Excepted packages are allowed to contain only minor amounts of radioactive material, and therefore the consequences of accidents, if any, involving excepted packages are minor and there are no radiological reasons for taking special protective actions. However, the possibility of contamination resulting from a breach of an excepted package should be considered for providing an appropriate response.

Industrial packages

I.43. The quantities and forms of LSA material and SCOs in industrial packages (IP-1, IP-2 and IP-3) are limited so that the external radiation level 3 m from the unshielded material or object, or collection of objects, does not exceed 10 mSv/h. Although this exposure rate is not insignificant, its magnitude is such that it can be dealt with in a safe manner should the packaging be lost in a severe accident.

I.44. Although the total activity in a consignment of an LSA material or an SCO may be significant, the nature of the contents is such that, if containment were to be lost in an accident, the potential radiological hazard would be relatively low. However, in the vicinity of an accident site, and given the potential internal and external exposures, protective actions should be taken. Ground contamination should also be taken into account, especially for many LSA-I and LSA-II materials that are transported in large packages and that may be dispersible.

Type A packages

I.45. The activity limits prescribed for Type A packages limit the immediate hazard in the vicinity of these packages in the event of a release of radioactive material or a loss of shielding.

I.46. The limits are based on a rationale used in defining the A_1 and A_2 values. The basic assumption in considering the consequences of accidents is that an unprotected person remaining 1 m from a damaged package for less than 30 minutes will not be accidentally exposed to more than 50 mSv. A full explanation of the basic assumptions is contained in appendix I of Ref. [16]. A dose of 50 mSv may be incurred from direct exposure to external radiation or may be a committed dose resulting from inhalation or ingestion. A dose of 50 mSv is considered acceptable under accidental conditions both for workers and members of the public.

Type B and Type C packages

I.47. Type B and Type C packages can contain material with an activity ranging from a few GBq to, in the case of spent fuel, several million GBq. Since the packages are designed to withstand accidents, any radiological impact is expected to be limited, in most cases, to the vicinity of the accident site. A breach of a Type B or a Type C package containing a large quantity of radioactive material may have a serious health and safety impact in the areas near the accident site. Thus a rapid response to assess the problem and bring the situation under control is required.

Packages containing fissile material

I.48. The potential consequences of accidents involving fissile material depend on the type of radioactivity, the fissile character and the amount of the material, and the accident conditions. In accidents of this kind there could also be hazards arising from criticality.

I.49. The radiological consequences of accidents involving fissile material, other than criticality accidents, may be those already described in paras I.38–I.47. For example, the radiological hazards of unirradiated nuclear fuel are not very significant, whereas the potential radiological hazards posed by the failure of an irradiated nuclear fuel flask are significant.

I.50. Criticality accidents are extremely unlikely to occur in view of the safety requirements imposed by the Transport Regulations [3] on the package design, the limits on the consignment size and the stowage procedures. In addition to the radiological consequences described above, should a criticality accident occur it could conceivably result in a power pulse, or power pulses, and concurrently an immediate, large pulsed increase of the radiation levels in the vicinity of the package. There would also be a residual radiation level increase following a criticality event. A criticality accident could also result in further damage to the package.

Potential consequences of the dispersible and non-dispersible forms of radioactive material

I.51. Radioactive material is shipped both in dispersible and in non-dispersible forms. Dispersible forms (e.g. powders, liquids, gases) include such material as radiopharmaceutical material for use in medical diagnosis or treatment and uranium ore concentrates. Material in non-dispersible form includes large, solid radioactive material pieces (i.e. large contaminated objects and irradiated nuclear fuel), solid radioactive material sealed in a capsule and low dispersible radioactive material.

I.52. If the material is non-dispersible it is unlikely to result in significant contamination, but there may be localized areas with radiation levels that could be hazardous. This could be caused by the degradation, loss or rearrangement of the package's shielding. However, it is possible for material shipped in a non-dispersible form to be dispersed owing to accident conditions, for example in extreme fire conditions.

I.53. If a transport accident involving a dispersible material were to occur, the conditions encountered by emergency response personnel may include the following:

- — High external radiation levels;
- — Contaminated persons, vehicles, wreckage, road and earth surfaces and airborne material;
- — Potential subsidiary hazards such as unburned flammables, corrosives and oxidizers.

Potential consequences of exposure and contamination by radioactive material

I.54. Persons may be subject to direct exposure to external radiation from both the dispersible and non-dispersible forms of the radioactive material involved in transport accidents.

I.55. Fires and the use of water or chemicals to suppress the fire can easily spread radioactive material around an accident site if the packages have been damaged sufficiently to breach the containment systems. Further, personnel working in a contaminated area at an emergency scene could become contaminated and could compound the dispersal of contamination by their efforts.

I.56. Dispersible radioactive material can contaminate local agricultural products and drinking water supplies, which in turn can cause a hazard by means of ingestion of these products and the affected water. Similarly, livestock (such as dairy cows) eating contaminated forage can pass these contaminants on to humans through the food chain (e.g. through milk).

I.57. Radioactive contamination can spread away from the vicinity in different ways. Two common methods involve weather (wind and precipitation) and the transport vehicles or equipment used by emergency crews being returned to service with undetected radioactive contamination.

Potential consequences from material having other dangerous properties

I.58. In addition to the radiation and criticality hazards, radioactive material may have other dangerous properties. In some cases, such subsidiary hazards may exceed the radiological hazards. An example of such a material is UF_6, which has a high hazard of chemical toxicity [20]. Other material having significant subsidiary hazards may include thorium and uranium as metals, which are susceptible when in a finely divided form such as powder or shavings to spontaneous combustion; radioactive oxidizers, such as uranyl nitrate or thorium nitrate; corrosive solutions of radioactive material, such as uranyl nitrate; and compressed radioactive gases. Any additional hazards should be considered in an emergency response when such material is encountered. These additional hazards should be identifiable by emergency responders from the dangerous goods labels and placards.

Appendix II

PRELIMINARY EMERGENCY RESPONSE REFERENCE MATRIX

II.1. The local, first on the scene emergency responders should, as discussed in Section 5, use a method for making an initial assessment of the potential hazards posed by the radioactive material packages involved in an accident. Since they will generally not have available the equipment or expertise they need to perform a technical assessment, their judgements will typically be based upon the information at hand. This will usually include information on the package type, the contents of the package, the accident environment (e.g. mechanical damage and the presence of fire) and a visual inspection for damage of the conveyances and packages involved.

II.2. The preliminary emergency response reference matrix presented in Table III provides a second method for making an early, conservative assessment of the potential hazard involved. The application of this matrix does not require the emergency responders to have knowledge of the specific radionuclides or their quantities; rather they should only have knowledge concerning the types of package and the associated United Nations numbers. This may be obtainable at the accident scene from a simple observation of the packages' markings and labels and vehicle or freight container placards.

II.3. This matrix is generic. It provides, for each given package type:

(a) The applicable United Nations numbers,
(b) A description of the typical contents that can be expected in that type of package,
(c) Guidance on the maximum allowable contents of radioactive material for that type of package,
(d) Guidance on the maximum radiation levels that can be expected for that type of package when it is undamaged,
(e) Guidance on the maximum radiation levels that can be expected for that type of package if it is damaged.

The paragraphs in the Transport Regulations [3] from which the values shown in the third, fourth and fifth columns of the matrix are derived are shown in brackets.

II.4. The maximum possible activity in each package type (shown in the third column of the matrix) is derived from the package design limits specified in the Transport Regulations [3]. They may also be established for some package designs by the competent authority approval requirements specified in the Transport Regulations [3]. In some cases the contents limits can only be established indirectly. For empty packages the limit is established from the internal contamination limits. For industrial packages the limit is established based upon the quantity of LSA material or SCO in the package that would result in an unshielded dose rate of 10 mSv/h at 3 m. In applying the contents limits specified in this matrix, the emergency responder should recognize that most packages will usually contain radioactive material in quantities less than the design limits. Basing emergency actions on this matrix will therefore usually result in actions that are prudent but that later may prove to have been unnecessary.

II.5. Similarly, in practice the maximum possible radiation levels for each package type will also generally be below the limits shown in the fifth and sixth columns of the matrix. Either the packages will be designed for lower radiation level values or they will not be filled to their maximum. The transport index — see Appendix I — can provide the emergency responder with additional insight into the actual maximum radiation levels 1 m from the surface of a package.

II.6. In many cases, especially for accidents involving Type B or Type C packages, the maximum radiation levels specified in the Transport Regulations [3] (see the fifth column of Table III) will not be experienced unless an extremely severe accident has occurred. However, if packages that are not designed to withstand accidents were to be involved in a severe accident, all of the shielding could be lost and radiation levels could be high. In that case the radiation levels of 0.1 mSv/h at 10 cm (for instruments and articles transported in excepted packages), of 10 mSv/h at 3 m (for LSA material and SCOs in industrial packages) and 100 mSv/h at 1 m (for material that have been lost from Type A packages) may be assumed to be the maximum possible radiation levels.

II.7. In applying this matrix it should be recognized that fissile material may be transported in IP-1, IP-2, IP-3, Type A, Type B(U), Type B(M) and Type C packages. These can be recognized from the additional ‘F’ type approval on the competent authority identification mark and from the fissile label (see Fig. 3). Fissile material is subject to the packaging requirements that apply to their radioactive characteristics and, in addition, to packaging requirements imposed because of their fissile characteristics. Detailed information is given in paras 671 and 673–682 and Schedule 13 of the Transport Regulations [3].

II.8. Similarly, UF_6 (both non-fissile and fissile) is subject to additional packaging requirements imposed because of its chemical characteristics. Uranium hexafluoride is typically transported in IP-1, IP-2, IP-3, Type A and Type B packages. Detailed information is given in paras 629–632 of the Transport Regulations [3].

TABLE III. PRELIMINARY EMERGENCY RESPONSE REFERENCE MATRIX FOR ASSISTING THE FIRST ON THE SCENE EMERGENCY RESPONDERS

(paragraph numbers refer to the Transport Regulations [3])

Package type	United Nations number	Typical package contents	Maximum allowable activity or contamination levels in a package	Maximum allowable radiation levels	
				Package undamaged	Package damaged
Excepted — empty packaging	2908	Unloaded packaging with limited residual contamination inside a package containment system	<400 Bq/cm^2, beta, gamma and low toxicity alpha material <40 Bq/cm^2, other alpha emitters (para. 520)	<5 µSv/h at the package's surface (para. 516)	Unspecified
Excepted — limited quantity of radioactive material	2910	Very small quantities of radioactive material	<10^{-3} A_1 (special form solids and gases) <10^{-3} A_2 (other than special form solids and gases) <10^{-4} A_2 (liquids) <2×10^{-2} A_2 (tritium gas) (para. 408)		
Excepted — instruments, articles and manufactured articles	2909, 2911	Instruments, articles, articles manufactured from depleted uranium or natural uranium or thorium	<A_1 (solid, special form) <A_2 (solid, other than special form) <10^{-1} A_2 (liquids) <10^{-2} A_1 (gases, special form) <10^{-2} A_2 (gases, other than special form) <2×10^{-1} A_2 (tritium gas) (para. 408)		<0.1 mSv/h at 10 cm from the external surface of any unpackaged instrument or article (para. 517)

TABLE III. (cont.)

Package type	United Nations number	Typical package contents	Maximum allowable activity or contamination levels in a package	Maximum allowable radiation levels	
				Package undamaged	Package damaged
Industrial package, Type IP-1	2912, 2913, 3326	LSA-I ores and concentrates of uranium or thorium, solid unirradiated natural or depleted uranium	Limited by the radiation level 3 m from the surface of the unshielded material, object or collection of objects (paras 411 and 521)	I-WHITE label: — <0.005 mSv/h at the package's surface II-YELLOW label: — <0.5 mSv/h at the package's surface — <0.01 mSv/h 1 m from the package's surface III-YELLOW label: — <0.5 mSv/h at the package's surface — <0.01 mSv/h 1 m from the package's surface III-YELLOW label transported under exclusive use: — <10 mSv/h at the package's surface — >0.1 mSv/h 1 m from the package's surface (limited by the surface radiation level) (para. 533)	10 mSv/h 3 m from the surface of the unshielded material, object or collection of objects (paras 411 and 521)
Industrial packages, Types IP-2 and IP-3	2912, 3321, 3322, 3324, 3325	LSA-I liquids, LSA-II and LSA-III non-combustible solids			
Industrial packages, Types IP-1, IP-2 and IP-3	2912, 2913, 3321, 3322, 3324, 3325, 3326	LSA-I liquids, LSA-II and LSA-III liquids, gases and combustible solids, SCO-I and SCO-II	Limited both by (a) The radiation level 3 m from the surface of the unshielded material or collection of objects (paras 411 and 521), and (b) A conveyance limit of 10 A_2 per hold or compartment of an inland waterway craft, or (c) A conveyance limit of 100 A_2 per conveyance for other than an inland waterway craft (para. 525)		

TABLE III. (cont.)

Package type	United Nations number	Typical package contents	Maximum allowable activity or contamination levels in a package	Maximum allowable radiation levels	
				Package undamaged	Package damaged
Type A	2915, 3332, 3327 3333	Moderate quantities of radioactive material in either special form or other than special form; typical contents may be radiopharmaceuticals, low level waste	$<A_1$ if radioactive material in special form $<A_2$ if radioactive material in other than special form (para. 413)	I-WHITE label: — <0.005 mSv/h at the package's surface II-YELLOW label: — <0.5 mSv/h at the package's surface — <0.01 mSv/h 1 m from the package's surface	<20% increase when exposed to the normal condition of transport tests (para. 646 (b)), <100 mSv/h at 1 m if contents outside the package (appendix I of Ref. [16])
Type B	2916, 2917, 3328, 3329	Quantities of radioactive material in excess of those allowed in industrial or Type A packages; typical contents may be irradiated nuclear fuel, high level wastes, Co-60 irradiators, Ir-192 and Pu-239	Limited by the package design approval (para. 415) If transported by air and not qualified as a low dispersible radioactive material: $<3000\ A_1$ or $100\ 000\ A_2$ if special form, or $<3000\ A_2$ if other than special form (para. 416)	III-YELLOW label: — <2 mSv/h at the package's surface — <0.1 mSv/h 1 m from the package's surface III-YELLOW label transported under exclusive use: — <10 mSv/h at the package's surface — >0.1 mSv/h 1 m from the package's surface (limited by the surface radiation level) (para. 533)	<20% increase when exposed to the normal condition of transport tests (para. 646 (b)), <10 mSv/h 1 m from the surface of the package when exposed to the accident conditions of transport (para. 656 (b))

TABLE III. (cont.)

Package type	United Nations number	Typical package contents	Maximum allowable activity or contamination levels in a package	Maximum allowable radiation levels	
				Package undamaged	Package damaged
Type C (for air carriage only)	3323, 3330	Quantities of radioactive material in excess of those allowed in industrial, Type A or Type B packages	Limited by the package design approval (para. 415)	I-WHITE label: — <0.005 mSv/h at the package's surface II-YELLOW label: — <0.5 mSv/h at the package's surface — <0.01 mSv/h 1 m from the package's surface III-YELLOW label — <2 mSv/h at the package's surface — <0.1 mSv/h 1 m from package's surface III-YELLOW label transported under exclusive use: — <10 mSv/h at the package's surface — >0.1 mSv/h 1 m from the package's surface (limited by the surface radiation level) (para. 533)	<20% increase when exposed to the normal condition of transport tests (para. 646 (b)), <10 mSv/h 1 m from the surface of the package when exposed to the standard and the air transport enhanced accident conditions of transport (paras 656 (b) and 669 (b))

Appendix III

GUIDE TO SUITABLE INSTRUMENTATION[6]

INTRODUCTION

III.1. In order to determine whether there is any radiological hazard and to make a reasonable but not especially accurate estimate of its magnitude, it is vital to use the proper instrumentation for assessing the radiological hazard at the site of a transport accident involving radioactive material.

III.2. A guide to suitable instrumentation for this purpose has been developed [12] and is copied here. That guide addresses how to identify and locate any sources of radiation, how to measure the dose rates for the different types of radioactive material and describes the additional supplies that should be part of an equipment kit for emergency response (see also Appendix VI).

IDENTIFYING AND LOCATING SOURCES OF RADIATION

III.3. Upon arrival at the accident scene the first responder may not know whether an exposure or contamination hazard exists. Many incidents involve suspected sources of radiation. The first responder should quickly establish whether radiation levels are above the previously determined background level. Other incidents may involve searching for lost sources of radiation, which could either be unshielded or still in their containers.

III.4. The best instruments for either purpose are those with sodium iodide detectors, of which some of the newer instruments may also give information about the radionuclides involved. Sensitive Geiger–Müller (GM) and proportional counter instruments are useful substitutes, although they are about an order of magnitude less sensitive to gamma emitters than sodium iodide scintillators in the 1 MeV energy range. To help in searching through outdoor wreckage, or in other difficult conditions, the instrument should preferably have an audio output and headphones.

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[6] The text and the table in this appendix are based upon text in Ref. [12].

MEASURING THE GAMMA DOSE RATE

III.5. Instruments of the type mentioned above are difficult to use for quantitative measurements because they are energy dependent over a wide range of gamma energies, and therefore the first responder not trained in the techniques of instrument calibration should use instruments for detection, not measurements. Measurements are best made with an energy compensated instrument that has a uniform response from about 50 keV upwards. Such instruments typically use energy compensated GM tubes, ionization chambers, plastic scintillators or proportional counters. The instrument should be capable of measuring dose rates from 1 μSv/h or more.

III.6. GM tube instruments are generally smaller and lighter than the other types and normally have an audio output. However, energy compensated GM instruments will not measure gamma and X ray energies below about 50 keV and are incapable of detecting particles.

III.7. Ionization chamber instruments are less easy to use at low dose rates than GM tubes: they suffer more from changes in temperature and humidity and are less robust. However, they will operate at gamma energies down to 10 keV, which is useful for radionuclides such as iodine-125, and can normally also be used for measuring beta dose rates. Scintillation instruments are very sensitive and can cover a wide range of gamma dose rates, at energies down to about 30 keV, but they tend to be heavy and are not useful for beta radiation.

MEASURING THE BETA DOSE RATE

III.8. Pure beta emitting sources are less common than gamma emitters, but can be encountered in beta backscatter and thickness gauges. Ionization chamber instruments can be used, as well as thin end window GM tubes.

MEASURING BETA CONTAMINATION

III.9. Beta contamination could be encountered in accidents involving radiopharmaceuticals, leaking sealed gamma sources (many are beta/gamma emitters) or the radiochemicals used in industry and agriculture. Suitable instruments are those using thin end window GM tubes, beta scintillation detectors or proportional counters with aluminized plastic or titanium windows.

III.10. The most serious problem in using these instruments is likely to be damage to the window, which leads to the total failure of the GM and proportional types, or serious light sensitivity, which leads to a lowered sensitivity in scintillation detectors. When checking for beta contamination, wipe samples (using filter or other paper) should be taken and the monitoring of these samples should be undertaken away from any other source of gamma or X rays.

III.11. Tritium is particularly difficult to detect because of its very soft (low energy) beta emission. The most suitable instruments are windowless gas flow proportional counters, but in practice it is probably satisfactory to rely upon a liquid scintillation counting of wipes after the event.

MEASURING X RAY DOSE RATES AND CONTAMINATION

III.12. X ray emitters are very common in radiopharmaceuticals. Suitable instruments include thin sodium iodide detectors and xenon filled proportional counters. Suspected contamination by X ray emitters will almost always require taking a wipe sample and monitoring it away from other sources of radiation, including the suspect package itself.

MEASURING ALPHA CONTAMINATION

III.13. Since alpha particles travel only short distances in air they are difficult to detect. Alpha particles cannot be detected through even a thin layer of water, blood, dirt, paper or other material. Various instruments have been designed to measure alpha radiation. To ensure that accurate measurements are obtained, the use of these instruments should only be undertaken by those who have had special training in their use. Suitable instruments include thin windowed zinc sulphide scintillation counters and thin windowed refillable proportional counters. Thin end window GM tubes are also satisfactory for levels down to about 5 Bq/cm^2.

SUPPLIES

III.14. Other useful equipment that should form part of a permanent equipment kit includes notebooks, waterproof pens, a hand torch, a pocket calculator, a steel tape measure, plastic bags, PVC tape for sealing bags and filter papers for taking wipes. A lead pot and tongs are useful for recovering small gamma sources; a pot with 25 mm walls is reasonably portable and offers a useful degree of shielding.

III.15. In addition to a normal personal dosimeter, it is desirable to carry a direct reading dosimeter, such as a quartz fibre electroscope dosimeter or, even better, an active alarm dosimeter.

III.16. The kit should include protective clothing, including gloves, rubber boots and safety helmets that are waterproof, visible and easily decontaminated. A camera should also be included as an aid to recording the incident.

III.17. The equipment listed here is suggested as the minimum that can be specified for an early response team. More detailed lists of equipment for special tasks are given in Ref. [21].

RADIONUCLIDE DATA AND GUIDE TO SUITABLE DETECTORS

III.18. A wide variety of radioactive material is transported throughout the world. Thus a large number of radionuclides could become involved in transport accidents. Table IV, from Ref. [12], gives the half-lives of virtually all of these radionuclides and their most prominent emissions. By taking into account the nature of these emissions and the capabilities of the various types of instruments, the table also indicates which instruments would be suitable for making measurements of dose rates and of contamination.

TABLE IV. RADIONUCLIDE DATA AND GUIDE TO SUITABLE DETECTORS [12]

Radio-nuclide	Half-life	Prominent radiations and maximum energies (MeV)	Suitability for dose rate measurements				Suitability for contamination measurements						
			Energy compensated Geiger–Müller	End window Geiger–Müller	Ionization chamber	Plastic scintillator	End window Geiger–Müller	Full energy β scintillator	High energy β scintillator	Xe filled proportional	Refillable proportional	α scintillator	NaI scintillator
H-3	12.3 a	β^- 0.019	—	—	—	—	—	—	—	—	—	—	—
Be-7	53.3 d	γ 0.48	R	U	R	R	—	—	—	R	—	—	R
C-14	5.7×10^3 a	β^- 0.156	—	R	R	—	R	R	—	R	R	—	—
Na-22	2.6 a	β^+ 0.55, γ 1.28	S	U	R	S	R	R	—	R	R	—	—
Na-24	15.0 h	β^- 1.4, γ 1.4, 2.8	S	U	R	S	R	R	R	R	R	—	U
P-32	14.3 d	β^- 1.7	—	R	R	—	R	R	R	R	R	—	U
S-35	87.5 d	β^- 0.17	—	R	R	—	R	R	—	R	R	—	—
Cl-36	3.0×10^5 a	β^- 0.71	—	R	R	—	R	R	—	R	R	—	—
K-42	12.4 h	β^- 3.6, γ 1.5	S	U	R	S	R	R	R	R	R	—	U
Ca-45	163.0 d	β^- 0.26	—	R	R	—	R	R	—	R	R	—	—
Ca-47*	4.5 d	β^- 0.69 (82%), 2.0 (18%), γ 1.3	S	U	R	S	R	R	—	R	R	—	—
Sc-46	83.8 d	β^- 0.36, γ 1.0	S	U	R	S	R	R	—	R	R	—	—
Cr-51	27.7 d	X 0.005, γ 0.3	S	U	R	S	—	—	—	P	—	—	P
Mn-54	312.5 d	γ 0.8	R	U	R	R	—	—	—	P	—	—	P
Fe-55	2.7 a	X 0.006	—	U	R	—	—	—	—	P	—	—	P
Fe-59	45.1 d	β^- 0.4, γ 1.2	S	U	R	S	R	R	—	R	R	—	—
Co-56	78.8 d	β^+ 1.5, γ 1–3	S	U	R	S	—	—	—	—	—	—	R
Co-57	271.4 d	γ 0.13	R	U	R	R	—	—	—	P	—	—	P
Co-58	70.8 d	β^+ 0.5, γ 0.8	S	U	R	S	U	U	—	P	U	—	P
Co 60	5.3a	β^- 0.3, γ 1.3	S	U	R	S	R	R	—	R	R	—	—

TABLE IV. (cont.)

Radio-nuclide	Half-life	Prominent radiations and maximum energies (MeV)	Suitability for dose rate measurements: Energy compensated Geiger–Müller	End window Geiger–Müller	Ionization chamber	Plastic scintillator	Suitability for contamination measurements: End window Geiger–Müller	Full energy β scintillator	High energy β scintillator	Xe filled proportional	Refillable proportional	α scintillator	NaI scintillator
Ni-63	100.0 a	β⁻ 0.066	—	U	R	—	—	P	—	—	P	—	—
Zn-65	243.8 d	γ 1.1	R	U	R	R	—	—	—	R	U	—	P
Se-75	119.8 d	γ 0.1–0.4	R	U	R	R	—	—	—	R	—	—	R
Br-82	1.5 d	β⁻ 0.4, γ 0.5–1.5	S	U	R	S	R	R	—	R	R	—	—
Kr-85	10.7 a	β⁻ 0.7	—	U	R	—	—	—	—	—	—	—	—
Rb-86	18.7 d	β⁻ 1.8, γ 1.1	S	U	R	S	R	R	R	R	R	—	—
Sr-85*	64.8 d	γ 0.5	R	U	R	R	—	—	—	R	—	—	R
Sr-89*	50.5 d	β⁻ 1.5	—	R	R	—	R	R	R	R	R	—	U
Sr-90	29.1 a	β⁻ 0.5	—	R	R	—	R	R	—	R	R	—	—
Y-88	106.6 d	γ 1.8	R	U	R	R	—	—	—	R	—	—	R
Y-90	2.7 d	β⁻ 2.3	—	R	R	—	R	R	R	R	R	—	U
Y-91	58.5 d	β⁻ 1.5	—	R	R	—	R	R	R	R	R	—	U
Zr-95	64.0 d	β⁻ 0.4, γ 0.7	S	U	R	S	R	R	—	R	R	—	—
Nb-95	35.2 d	β⁻ 0.16, γ 0.76	S	U	R	S	R	R	—	R	R	—	—
Mo-99	2.8 d	β⁻ 1.2, γ 0.7	S	U	R	S	R	R	R	R	R	—	U
Tc-99	2.1×10^5 a	β⁻ 0.3	—	R	R	—	R	R	—	R	R	—	—
Tc-99m	6.0 h	γ 0.14	R	U	R	R	—	—	—	—	—	—	R
Ru-103*	39.4 d	β⁻ 0.2, γ 0.5	S	U	R	S	R	R	—	R	R	—	—
Ru-106*	1.0 a	β⁻ 1.5–3.6, γ 0.5–2.9	S	U	R	S	R	R	R	R	R	—	U

TABLE IV. (cont.)

Radio-nuclide	Half-life	Prominent radiations and maximum energies (MeV)	Suitability for dose rate measurements				Suitability for contamination measurements						
			Energy compensated Geiger–Müller	End window Geiger–Müller	Ionization chamber	Plastic scintillator	End window Geiger–Müller	Full energy β scintillator	High energy β scintillator	Xe filled proportional	Refillable proportional	α scintillator	NaI scintillator
Ag-110m*	249.9 d	β^- 0.5, γ 0.6–1.5	S	U	R	S	R	R	R	R	R	—	U
Cd-109	1.3 a	X 0.02, γ 0.09	S	U	R	S	—	—	—	—	—	—	R
In-111	2.8 d	X 0.02, γ 0.2	S	U	R	S	—	—	—	R	—	—	R
Sn-113*	115.1 d	X 0.02, γ 0.4	S	U	R	S	—	—	—	R	—	—	R
Sn-119m*	293.0 d	X 0.02	—	U	R	U	—	—	—	R	—	—	R
Sb-124	60.2 d	β^- 0.1–2.3, γ 0.6	S	U	R	S	R	R	U	R	R	—	U
Sb-125*	2.7 a	β^- 0.6, γ 0.6	S	U	R	S	R	—	—	—	—	—	—
I-125	60.1 d	X, γ 0.03 [b]	—	U	R	U	—	—	—	R	—	—	R
I-129	1.6×10^7 a	β^- 0.15, X 0.03	—	U	R	S	R	R	—	R	R	—	R
I-131*	8.0 d	β^- 0.6, γ 0.4	S	U	R	S	R	R	—	R	R	—	—
Xe-133	5.3 d	β^- 0.3, γ 0.08	S	U	R	S	—	—	—	—	—	—	—
Cs-134	2.1 a	β^- 0.6, γ 0.7	S	U	R	S	R	R	—	R	R	—	—
Cs-137*	30.0 a	β^- 0.5, γ 0.7	S	U	R	S	R	R	—	R	R	—	—
Ba-133	10.7 a	γ 0.3	R	U	R	R	—	—	—	R	—	—	R
Ba-140 →	12.7 d	β^- 1.0, γ 0.5	S	U	R	S	R	R	U	R	R	—	U
La-140 ←	1.7 d	β^- 1–2, γ 0.3–2.5	S	U	R	S	R	R	R	R	R	—	U
Ce-139	137.7 d	γ 0.2	R	U	R	R	—	—	—	R	—	—	R
Ce-141	32.5 d	β^- 0.5, γ 0.15	S	U	R	S	R	R	—	R	R	—	—
Ce-144*	284.9 d	β^- 3, γ 1–2	S	U	R	S	R	R	—	R	R	—	—
Sm-151	89.9 a	β^- 0.6	—	U	R	—	R	R	U	R	R	—	—
Eu-152	13.3 a	β^- 0.7, γ 0.3–1.3	S	U	R	S	U	U	—	R	U	—	R

TABLE IV. (cont.)

Radio-nuclide	Half-life	Prominent radiations and maximum energies (MeV)	Suitability for dose rate measurements				Suitability for contamination measurements						
			Energy compensated Geiger–Müller	End window Geiger–Müller	Ionization chamber	Plastic scintillator	End window Geiger–Müller	Full energy β scintillator	High energy β scintillator	Xe filled proportional	Refillable proportional	α scintillator	NaI scintillator
Gd-153	242.0 d	X, γ 0.04–0.1	R	U	R	R	—	—	—	R	—	—	R
Tb-160	72.3 d	β^- 0.5–1, γ 0.1–1.3	S	U	R	S	R	R	U	R	R	—	—
Tm-170	128.6 d	β^- 1, X, γ 0.01–0.08	S	U	R	S	R	R	U	R	R	—	—
Yb-169	32.0 d	X, γ 0.01–0.3	R	U	R	R	R	R	—	R	R	—	R
T-185	75.1 d	β^- 0.4	—	R	R	—	R	R	—	R	R	—	—
Ir-192	74.0 d	β^- 0.7, γ 0.5	S	U	R	S	R	R	—	R	R	—	—
Au-198	2.7 d	β^- 1, γ 0.4	S	U	R	S	R	R	U	R	R	—	U
Au-199	3.1 d	β^- 0.4, γ 0.2	S	U	R	S	R	R	—	R	R	—	—
Hg-203	46.6 d	β^- 0.2, γ 0.3	S	U	R	S	R	R	—	R	R	—	—
Tl-204	3.8 a	β^- 0.8	—	R	R	—	R	R	U	R	R	—	U
Pb-210*	22.3 a	β^- 0.06, γ 0.05	S	U	R	S	—	—	—	U	—	—	U
Po-210	1384.d	α [c]	—	—	—	—	—	—	—	—	R	R	—
Ra-226*	1.6×10^3 a	α, β^- 3, γ 0.2–2	S	U	R	S	R	R	R	R	U	U	—
Th-228*	1.9 a	α, β^- 2, γ 0.1–3	S	U	R	S	U	U	—	—	R	R	—
Th-232*	1.41×10^{10} a	α, β^- 2, γ 0.5–2	—	—	—	—	U	U	—	—	R	R	—
U-238*	4.5×10^9 a	α, β^- 2, γ 0.1–2	S	U	R	S	U	U	—	—	R	R	—
Np-237*	2.1×10^6 a	α, γ 0.03–0.4	S	U	R	S	U	U	—	—	R	R	—
Pu-238	87.7 a	α	—	—	—	—	U	U	—	—	R	R	—
Pu-239	2.4×10^4 a	α, X 0.01–0.02	S	U	S	S	U	—	—	—	R	R	U
Am-241	432.0 a	α, γ 0.06	R	U	R	R	—	—	—	—	R	R	U

TABLE IV. (cont.)

Radio-nuclide	Half-life	Prominent radiations and maximum energies (MeV)	Suitability for dose rate measurements				Suitability for contamination measurements						
			Energy compensated Geiger–Müller	End window Geiger–Müller	Ionization chamber	Plastic scintillator	End window Geiger–Müller	Full energy β scintillator	High energy β scintillator	Xe filled proportional	Refillable proportional	α scintillator	NaI scintillator
Cm-244	18.1 a	α	————	————	————	————	U	U	—	—	R	R	—
Cf-252*	2.6 a	α, n 2[d], γ	R	U	R	R	U	U	—	—	R	R	—

Nuclide data. [a] Includes emissions from decay products that are likely to be present and are not shown in the table separately. Decays to progeny shown.

[b] The instruments listed in this table do not distinguish between photon source or energy, but their response may depend on the energy of the photons detected. For situations in which both X rays and γ rays are given, the range of values therefore correspond to both X rays and γ rays.

[c] No energies are quoted for α radiation as the energy of the detected alpha particles is likely to be greatly reduced, owing to the environment in which the measurement is being taken.

[d] Neutrons of 2 MeV are emitted.

Suitability of instruments. R= recommended. S = recommended when the low energy X rays or the beta emissions from the source are shielded either by packaging or because the material is in the form of an encapsulated source. U = usable in the absence of the recommended equipment. P = precautions required: results depend critically on instrument adjustment. — = not suitable. In the dose rate column, a long bar (————————————) indicates no external hazard.

Appendix IV

OVERVIEW OF EMERGENCY MANAGEMENT FOR A TRANSPORT ACCIDENT INVOLVING RADIOACTIVE MATERIAL

IV.1. An overview of the basic actions an emergency manager should perform in the event of a transport accident involving radioactive material is provided in Fig. 6 [5]. It provides guidance on how an emergency manager can approach assessing the radiological hazard at the accident site based on information from those who initiated the response, the personnel already on the accident scene and information obtained from the packages' markings and labelling, vehicle and freight container placarding and transport documents.

IV.2. The key to the success of this emergency management methodology is the use of a 'radiological assessor'. The position of radiological assessor should be held by the most senior member of the team (or teams) of radiological professionals that is sent to the scene of a transport emergency to assess the radiological hazards, provide radiation protection for the first responders and make recommendations to the on-scene emergency manager regarding protective actions. Contact points and telephone numbers for contacting and arranging for a radiological assessor to come to the scene of an accident should be provided to potential response initiators and emergency managers.

IV.3. The radiological assessor may work alone or be part of a team of qualified experts. He or she should be responsible at the scene for surveys, contamination assessment and control, radiation protection support to emergency workers and the formulation of protective action recommendations. The assessor should also initiate and, in some cases, carry out source recovery, clean up and decontamination operations. He or she should also be responsible for establishing or approving a limited access and an inner cordoned-off area (see para. 5.39 and Fig. 1), for estimating and recording the dose received by emergency workers and/or the public, for requesting additional radiological assessment resources, as required, and for providing health physics expertise to carry out specialized hazard and dose assessment tasks.

IV.4. The overview leads the emergency manager from assessing the condition of the package (or packages), to structuring the management of the emergency based upon assessing the source or package type, defining the dominant radiological hazard and the hazard level, and then implementing the primary (main) actions. This overview is a top level guide. The emergency manager should rely on his or her and other experts' knowledge and judgements in undertaking the actions for properly managing the response at the accident scene.

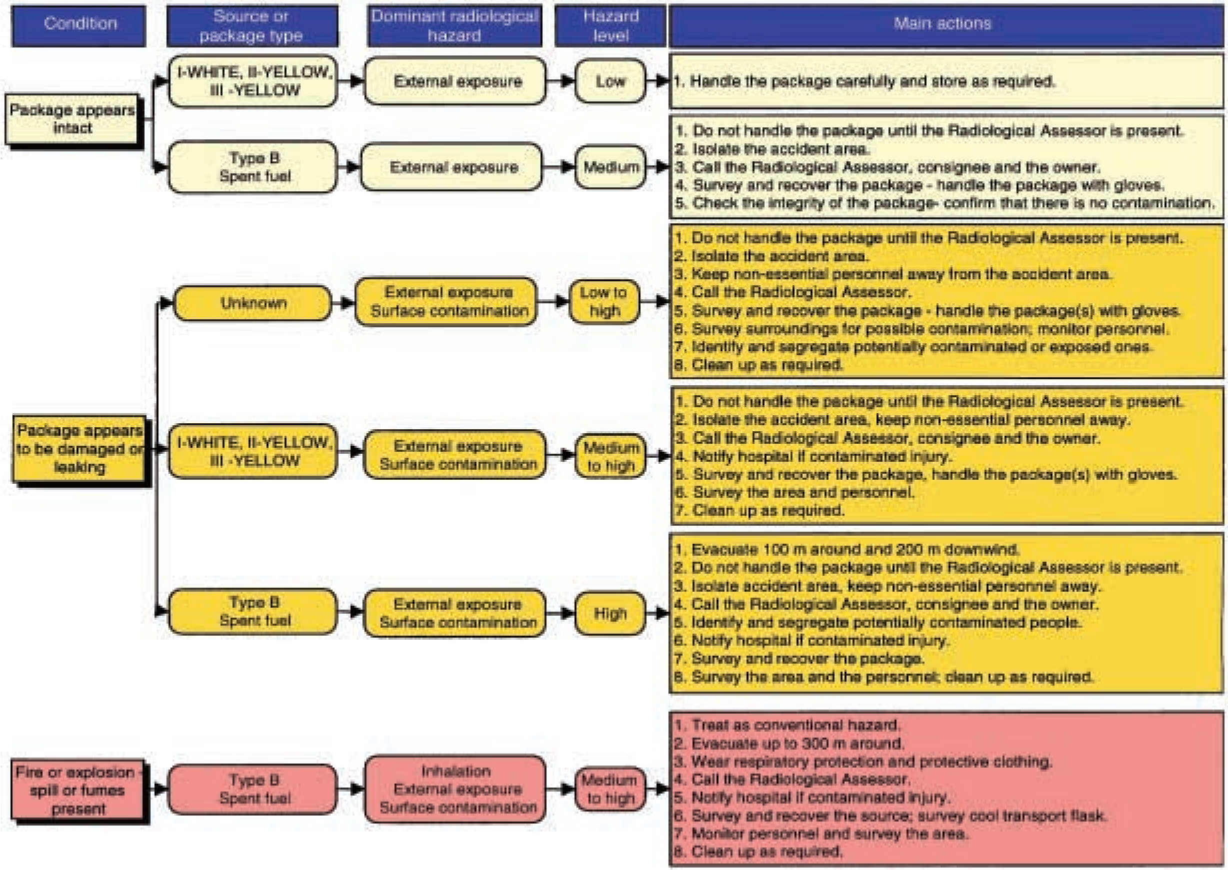

FIG. 6. Overview of basic emergency management actions for transport accidents involing radioactive material [5].

IV.5. The overview does not address, however, what actions should be taken for radioactive material having other dangerous properties (e.g. UF_6), nor does it address the actions for excepted packages. For hazards other than those of a radioactive nature the appropriate emergency response guides should be consulted (e.g. see Annex II). For excepted packages little hazard is posed by the radioactive material contents, even if the packaging has been damaged, since the allowed quantities and resulting radiation levels are so low (e.g. see Appendix I).

Appendix V

EXAMPLES OF RESPONSE TO TRANSPORT ACCIDENTS

V.1. This appendix provides four brief discussions concerning transport accidents involving consignments of radioactive material and outlines the typical emergency response actions. The first three deal with accidents that actually occurred. None of these accidents presented a severe radiological hazard, but they are provided to illustrate how response plans are applied.

V.2. The fourth accident deals with a hypothetical situation involving a radioactive material having other dangerous properties. It would probably not cause a severe radiological hazard. It is included to illustrate how response plans could be applied.

EMERGENCY RESPONSE TO A ROAD TRANSPORT ACCIDENT INVOLVING INDUSTRIAL PACKAGES CONTAINING LSA-I NATURAL URANIUM CONCENTRATES

Background

V.3. Natural uranium concentrate (yellow cake) is classified as LSA-I. It is usually transported in industrial packages, the most common being 200 L drums. These packages are not required to be designed to withstand accident conditions. A typical yellow cake consignment may consist of a road vehicle (tractor–trailer, lorry) loaded with 50 drums of concentrate. The amount of uranium involved is approximately 20 000 kg. The following summarizes the procedures followed in one accident involving yellow cake. The summary is based on an actual event that occurred in 1979 [22].

V.4. A tractor–trailer loaded with yellow cake overturned on a road located in a sparsely populated area in southeastern Colorado in the United States of America. The concentrate had been packaged, loaded and shipped in full compliance with all the relevant regulations.

V.5. Because of the lorry's overturning, 32 of the 50 drums were thrown through the top of the trailer and came to rest on the shoulder of the road. The drum lids were secured to the drums by bolted steel ring closures. During the accident 17 of the 32 drums thrown from the trailer lost their lids. In addition, 12 of the 18 drums that remained in the trailer lost their lids.

V.6. About 6000 kg of concentrate spilled from the open drums; 2500 kg were contained in the overturned trailer and 3500 kg were scattered over an area of 250–300 m^2 outside the trailer. The driver and his assistant were injured and trapped in the cab.

Emergency response

Phase 1: The initial phase

V.7. The police, being the first at the scene of the accident, removed the injured crew from the wreckage and sent them to the nearest hospital, where they were decontaminated and treated for cuts and fractures. Both the driver and the relief driver were examined in the hospital for internal contamination, but none was found.

V.8. The transport documents in the truck were accompanied by written detailed emergency instructions (see Appendix III), which had been prepared by the consignor of the yellow cake. These instructions directed the individuals who arrived first on the scene, in this case the police officers, to notify the shipper's office and to cover the spilled material with tarpaulins or heavy plastic sheeting to prevent airborne dispersion.

V.9. The police, after evacuating the crew, followed the shipper's instructions by notifying the Colorado Department of Health (the local competent authority). They also directed traffic around the scene of the accident.

Phase 2: The accident control phase

V.10. A radiological monitoring team arrived at the scene approximately 12 hours after the accident and made a survey of the area. The consignor sent a team by air with some equipment, arriving at the scene after 14 hours, followed by a lorry with additional and heavier equipment.

V.11. It was learned by the consignor's team that the spill was more extensive than was understood from the initial report and that the amount of material and human resources then available on the site was, therefore, inadequate. However, because the risk of the material spreading to the environment was low, sufficient time was available and was taken to plan the cleanup.

V.12. The Colorado Department of Health established the requirements for the cleanup operations, including the requirement that operations were to be continued until the natural background levels were achieved.

Phase 3: The post-emergency phase

V.13. The yellow cake was initially hand shovelled into new drums within a portable shelter covering about 10 m^2 of the spill area. The portable shelter was constructed of lumber and plastic sheeting. The spill area outside the housing remained covered. Contamination surveys and continual air monitoring were performed and a dyke and windbreak were constructed around the spill to prevent the spread of the yellow cake. Work progressed slowly. Five days after the accident five drums had been filled with dirt and yellow cake and 11 drums of the 50 in the shipment had been recovered. Vacuum cleaning and ventilation equipment was then brought to the site to speed the cleanup. A snow fence lined with plastic sheeting was set up to reduce the wind velocity in the work area and the vacuum cleaning and ventilation equipment was installed. Two days later it was realized that calm weather and light mist would allow work to proceed outside the portable shelter. All the 32 drums outside the trailer were recovered nine days after the accident and all 50 drums by the tenth day. Three more days were used to complete the final decontamination of the lorry, the spill area and the equipment used for the operation. Final surveys indicated several remaining contaminated areas, which were subsequently decontaminated further by additional soil removal. Topsoil replacement and grass reseeding were completed by the Colorado Department of Highways. After all the operations, the average exposure in the area was determined to be within the limits set by the competent authority, which then, 13 days after the accident, released the entire area for unrestricted use. All equipment was decontaminated to the standards set by the national competent authority for further unrestricted use.

Radiological safety

V.14. A radiological safety team provided by the consignor conducted the radiological safety programmes during the cleanup operations. It set up a cordoned-off area that included all of the area in which yellow cake could be detected. This cordoned-off area was marked off by using rope and appropriate signs indicating the potential dispersion of the concentrate. Three types of air samples were collected: (1) enclosed area samples, (2) open area samples taken in the limited access area and (3) perimeter samples taken close to the boundary of the cordoned-off area. The first two types of samples were used to evaluate personnel exposures, while the perimeter samples were used to evaluate dispersion beyond the cordoned-off area. Samples used to evaluate personnel exposures were taken with the air sampler at breathing elevation. Air sample data were used to evaluate exposure and conservative protection factors were assumed for the efficiency of the respirators used by the workers. A factor of 10 was used for half-face masks, while a factor of 50 was used for full-face masks. In addition to the environmental air sampling, soil and vegetation samples were taken in the spill area.

V.15. The decontamination programme involved radiation surveys of the ground, of personnel and of all the equipment or supplies that could have been contaminated. Each person leaving the cordoned-off area was surveyed. This included counting nasal smears, facial areas and the inside of the face masks. Showers were used at the site to ensure the decontamination of personnel. All the personnel were surveyed to ensure that they were carrying no detectable quantities of uranium off the site. All the equipment used in the operation was surveyed and decontaminated to meet the standards set out by the national competent authority before shipment or release for unrestricted use. All automobiles and motel rooms used by the cleanup personnel were also surveyed and found to be free from detectable contamination. External radiation doses to the personnel involved in the cleanup were measured using TLD badges.

V.16. Urine specimens were taken from 29 people known to be involved in the accident or to have been near the site at the early stages. Those people were the lorry crew, law enforcement and rescue personnel and some members of the public. Additionally, samples were obtained from 17 of the shipper's personnel who were involved in the cleanup job.

Discussion

V.17. The consignment in this case was identified by United Nations number 2912. For such a consignment the emergency responder should refer to the appropriate emergency response guide (e.g. Guide 162 of the 2000 North American Emergency Response Guide [23], see Annex II). These guides are, however, very general as they do not deal with specific material. In this case the shipper supplied a detailed set of instructions to be followed in the event of an accident (see Annex I). The local police, acting according to the instructions, covered the spill area and hence avoided the spread of the contamination and eased the cleanup job. The prompt reaction of the local police force might be attributed, to some extent, to the fact that some of the officers had undergone a training course in dealing with emergencies involving radioactive material.

EMERGENCY RESPONSE TO A ROAD TRANSPORT ACCIDENT INVOLVING EXCEPTED AND TYPE A PACKAGES OF RADIOPHARMACEUTICALS

Background

V.18. An accident occurred in Mississippi, USA, involving a caravan trailer towed by a lorry based station wagon (estate type vehicle) carrying a consignment of radiopharmaceuticals. Summarized below is the response to the accident. The summary is based on Ref. [24].

V.19. The vehicle involved in the accident was carrying 82 Type A and excepted packages originating from five different shippers for delivery to many medical institutions. A list of the packages is given in Table V.

V.20. At the time of the accident the vehicle was travelling on a divided four lane road at a speed of 80–90 km/h; the trailer was hit on the rear left hand side by an overtaking passenger car. Because of the impact the trailer was torn away from the towing vehicle and lay demolished beneath the passenger car some 70 m behind the towing vehicle. All of the cargo was ejected and was dispersed on both sides of the road over a distance of some 200 m. The accident scene is shown in Fig. 7.

V.21. Thirty packages were damaged to the extent that their outer packagings were destroyed. Two out of these 30 packages, one containing gallium-67 and the other

TABLE V. CONTENTS OF THE PACKAGES INVOLVED IN THE MISSISSIPPI, USA, ROAD TRANSPORT ACCIDENT

Number of packages	Type of package	Radio-nuclide	Activity (Bq)	Transport index (TI)	Physical form	Remarks
2	Excepted	H-3	1.8×10^{7}		Liquid	
2	Type A	F-32	3.7×10^{8}	0.2	Liquid	
10	Type A	Ga-67	2.3×10^{10}	6.9	Liquid	
28	Type A	Mo-99	1.9×10^{12}	82.6	Solid	Tc generators
5	Type A	Mo-99	3.7×10^{9}		Solid	Depleted Tc generators
1	Excepted	I-125	2.2×10^{6}		Liquid	
17	Type A and excepted	I-131	1.8×10^{10}	6.5	Liquid and solid	
12	Type A and excepted	Xe-133	1×10^{11}	0.8	Gas	
1	Excepted	Cs-137	1.1×10^{6}		Liquid	
4	Type A and excepted	Tl-201	1.4×10^{9}	0.1	Liquid and solid	
Total = 82			Total = 2×10^{12}	Total = 97		

Note: The total TI exceeds the maximal value of 50 cited in the Transport Regulations [3]. However, the carrier had special authorization from the competent authority to transport more than 50 TI.

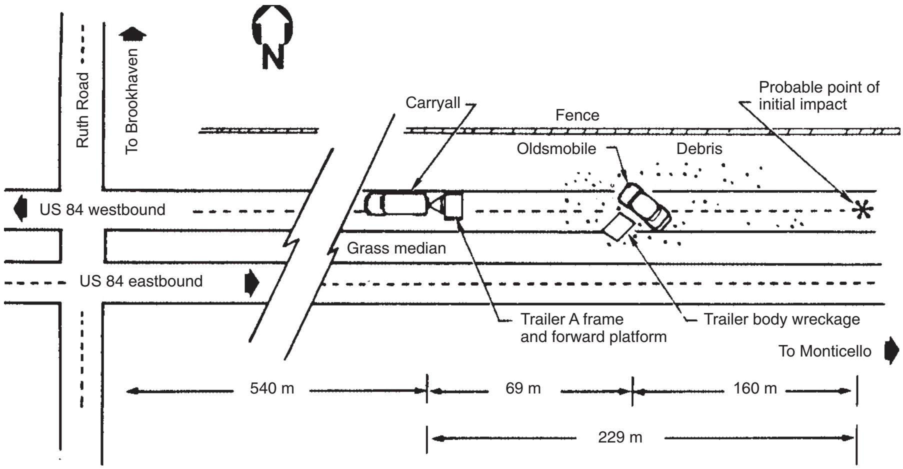

FIG. 7. Drawing of the Mississippi accident scene [24].

iodine-131, having activities of 200 MBq and 40 MBq, respectively, had their radioactive material vials ejected from their shielding and were subsequently broken.

Emergency response

Phase 1: The initial phase

V.22. Shortly after the accident the relief driver, acting according to his emergency procedures, contacted the local police and the Mississippi Emergency Management Agency. Within 15 minutes several police units were on the scene of the accident, followed by the local fire department. Fire fighters donned protective clothing and breathing apparatus. A representative of the local civil defence department arrived at the scene of the accident equipped with a radiation monitor, and a superficial survey confirmed elevated levels of radiation at the scene. The police cordoned off the area and waited for radiological assistance.

Phase 2: The accident control phase

V.23. According to pre-established procedures, the emergency management agency duly notified the Mississippi Division of Radiological Health (DRH) that an accident involving radioactive material had occurred. The division recruited four professionals, who left their headquarters in a mobile unit within 45 minutes and arrived at the scene two hours after the occurrence of the accident.

V.24. By the time the staff of the DRH arrived the area had already been cordoned off by the State Highway Patrol. The DRH staff looked over the accident scene, prepared an inventory of the sources involved in the accident from the consignors' bills of lading (transport documents) and conducted an extensive survey of the area with a suitable instrument. Also surveyed were the emergency vehicles at the scene, the civil defence and highway patrol officers, the trailer remnants and the damaged automobile. No activity was found on any of the above and the area survey indicated no public health hazard. A decision was then made by the team leader that the cleanup would be accomplished by personnel provided by the carrier and consignor.

Phase 3: The post-accident phase

V.25. Representatives of the carrier and the original consignors arrived at the scene of the accident approximately 8–10 hours after it had happened. Working under the guidance of the DRH team, they went about the task of cleaning up the debris. Small debris and packing material were placed in plastic bags and then into cardboard boxes and placed at the side of the road. Damaged and undamaged packages were also put into cardboard boxes and placed at the side of the road.

V.26. In the area where the iodine-131 source was found broken, approximately 0.08 m^3 of topsoil was removed and placed in three to four boxes and placed at the side of the road. Following the collection of the debris, a local contractor removed the remnants of the trailer and the damaged car from the site. A truck (lorry) was loaded with the accident debris and contaminated topsoil. A thorough and systematic survey of the area was then made. Background radiation levels of 8–12 μR/h were measured. Sixteen hours after the accident had occurred, and after a thorough wash, the highway was reopened for public use.

Discussion

V.27. The response to this accident can be used as a model for the proper handling of such incidents. Each group involved in the response action reacted promptly and knew its role well. The carrier gave proper instructions to its employees who, in turn, reacted accordingly. The police, the fire brigade and the emergency management agency performed their roles as planned. The DRH was ready with all of the appropriate human resources and equipment and arrived without delay. This agency also served as the lead agency throughout the handling of the accident.

V.28. A problem that may be encountered in an accident of this type is the possible lack of information concerning the exact composition of the consignment. It is typical for a carrier to make several deliveries and pickups during a particular assignment. The original integrated bill of lading, therefore, does not represent the contents exactly after the first delivery has been made. The responder, therefore, may consider reconstructing the inventory list, as was done in this case by the DRH.

EMERGENCY RESPONSE TO AN AIRCRAFT ACCIDENT INVOLVING EXCEPTED AND TYPE A PACKAGES OF RADIOACTIVE MATERIAL

V.29. Millions of packages containing radioactive material are shipped by air each year. Most of the consignments are excepted and Type A packages and they may contain a variety of items, from smoke detectors to radiopharmaceuticals, and have an activity range of several orders of magnitude. Aircraft accidents are characterized by large decelerations and frequently they are followed by fires. An aircraft accident involving some radioactive material is described, together with the response actions. The description is based on Ref. [25].

V.30. In 1979 a Douglas DC 8 passenger aircraft failed to stop at the end of the runway during its landing at Athens airport and crashed on to a public road passing parallel to the airport fence at a level 5 m below the runway. Because of the crash the aircraft caught fire. As part of its cargo, the aircraft carried 40 packages containing radioactive material. A list of the packages and their contents is given in Table VI.

Emergency response

Phase 1: The initial phase

V.31. Airport emergency teams were the first on the scene of the accident and were engaged in saving lives and fighting the fire. The airport authorities were unaware, for a period of five hours, of the fact that radioactive material was part of the flight's cargo. When this fact was brought to their attention they notified the local nuclear research centre, which was in accordance with their emergency preparedness plan.

V.32. The radiological emergency team arrived at the scene of the accident one hour later. At this stage the fire was not completely extinguished and the team could only make an external area survey. The members of the group located the area where the packages of the radioisotopes had been stowed, but no external contamination was detected. While waiting for the fire to be completely extinguished they performed a

TABLE VI. CONTENTS OF THE PACKAGES INVOLVED IN THE ATHENS, GREECE, AIR TRANSPORT ACCIDENT

No. of packages	Type of package[a]	Category	TI	Radioisotope	Activity (Bq)	Remarks
3	A	III-YELLOW	2.2	Pu-238	1.1×10^{10}	100 special form sources
				Na-22 Pm-147	7.5×10^{7} 3.7×10^{8}	Injection solutions
				I-125 H-3 C-14	2.3×10^{6} 1.4×10^{9} 3.7×10^{6}	Labelled compounds and RIA[b] kits
26	A	I-WHITE	0	I-125 H-3 C-14	3.7×10^{8} 1.2×10^{9} 6.6×10^{6}	Labelled compounds and RIA kits
11	Excepted		0	I-125 H-3	8.0×10^{6} 1.2×10^{7}	Labelled compounds and RIA kits
				C-14	7.0×10^{4}	Counting standard

[a] All Type A packages were cardboard boxes, each containing one or more sealed metal cans. The radioactive material was contained in glass vials or metal boxes within the sealed cans.
[b] RIA: radioimmunoassay.

contamination check on each member of the rescue team (police, fire fighters and the medical crew) using portable instruments.

V.33. No detailed information concerning the radioisotopes on board was available to the emergency team for at least 12 hours after the accident. Thus, initially, information on the potential hazards was gathered only on the basis of measurements taken at the site.

Phase 2: The accident control phase

V.34. As soon as access to the aircraft was permitted the radiological team, properly dressed, entered the cargo compartment and started to survey it in order to locate and collect the packages of radioactive material. The cargo was found to be mostly burnt.

Most of the cans had burst open to some extent and most of the glass vials were found to be broken or without their rubber stoppers. Most of the lead shielding had melted and was trapped within the metal cans.

V.35. After collecting some 5 m^3 of contaminated debris into metallic drums, a detailed radiation survey was carried out inside and outside the aircraft. Exposure rates within the cargo compartment were less than 0.01 mSv/h and proved to be due to sodium-22 contamination. No detectable contamination was found outside the storage compartment. Because of the measurements, the radiological team authorized the removal of the aircraft wreckage.

Phase 3: The post-accident phase

V.36. The drums containing the radioactive debris were sent to a nuclear research centre for analysis and burial. In the laboratory effort was made to locate the 100 plutonium-238 sources within the debris. After a long search 92 were found but eight were missing. Tests carried out on the plutonium sources revealed that a large number had undergone extensive damage, and on some of them small quantities of alpha transferable contamination was detected.

Discussion

V.37. Several features characterize an aircraft accident. In comparison with a lorry or rail accident, the probability of fire is higher and the decelerations involved are much greater. The number of people affected by such an accident, especially if a passenger aircraft crashes, may be significant. Fire fighting and rescue operations, which take priority over any other action, may strain all of the resources available for a long period. In addition, it should be realized that information concerning the nature of the cargo may not be available in the early stages of the response operation.

V.38. International Civil Aviation Organization [26] regulations require that the pilot in command be provided with a document containing detailed information concerning any dangerous cargo that is carried. This document contains, in addition to the information given in the transport documents, the exact loading locations. Unfortunately, such a document is not always available following an accident. In the incident described it took the airport authorities five hours to realize that radioactive material was involved in the accident and it took another day to obtain the exact list of the packages.

V.39. Considering the aforementioned limitations, the existence of a response plan, prepared beforehand, is very important. Only a well equipped and trained group of people can deal with a situation where little may initially be known. There are two other points to be considered. In the Athens accident the impact was at a low velocity. In many aircraft accidents, where the impact velocities are usually much higher, the areas to be monitored could be much larger. The response plan should consider such a possibility in allocating human resources and equipment. Another point that should be borne in mind is that, owing to the large forces and temperatures that may be involved in an aircraft accident, some of the items may have characteristics that are different from the ones they had before the accident. A very important example is a sealed source losing its integrity. It should be remembered that a sealed source that meets all of the tests described in ISO Standard 2919 [27] may not withstand the severe impact, crush and fire conditions that may be involved in a severe aircraft accident.

EMERGENCY RESPONSE TO A HYPOTHETICAL ACCIDENT INVOLVING PACKAGES CONTAINING UF_6

Background

V.40. In preparing emergency response plans it can be useful to consider entirely hypothetical accidents that have a very low probability of occurrence and, therefore, would not come within the scope of the package design basis. This section briefly outlines the emergency response that may be considered in such a hypothetical accident.

V.41. Uranium hexafluoride is transported in a solid state and may be transported in Type H(M) packages and in Type H(U) packages. For the purpose of this example it will be assumed that (1) a Type H(M) package that does not meet the thermal design requirements is being used and (2) this Type H(M) package is a US48Y (known in France as DV08), which is capable of carrying up to 12 500 kg of UF_6. Because of the characteristics of UF_6, and the manner in which it is loaded in the packaging, the integrity of this package is generally significantly above that required for a normal industrial package, as it is a pressure vessel.

V.42. In the event that a US48Y package of UF_6 is involved in a fire of long duration and high intensity, there are several mechanisms through which the container may be ruptured and its contents released to the atmosphere. For the purposes of demonstration the scenario leading to the worst consequences is described and a response to it is suggested.

Hypothetical accident scenario

V.43. An assumption is made that a Type H(M) package loaded with 12 500 kg of natural UF_6 is involved in a large fire and breaches.

V.44. The temperature of the UF_6 is assumed to have reached 120ºC, at which temperature it is already liquefied, having a vapour pressure of 0.675 MPa (6.75 kgf/cm^2). Once the package is ruptured, UF_6 can be expected to escape in a gaseous form. Under this set of conditions approximately 65% of the contents (8000 kg) will be released within a period of approximately one hour. These release phenomena have been confirmed by several authors [28–33].

V.45. The escaping gases are going to have, according to this scenario, a relatively low effective release height. If the release were to occur concurrently with the fire, the release height would be greater, followed by a larger dispersion and dilution.

V.46. The escaping UF_6 reacts with the humidity in the atmosphere, producing UO_2F_2 and HF. The amount of water necessary to hydrolyse 8000 kg of UF_6 is 800 kg (this amount of water represents the contents of some 50 000 m^3 of air at 25ºC and 50% relative humidity). It is obvious, therefore, that as the plume of UF_6 expands and travels downwind this reaction is going to occur until all of the UF_6 is reacted. UO_2F_2 is a toxic substance and HF is a corrosive substance. The risk associated with breathing non-hydrolysed UF_6 is slightly higher than the risk associated with breathing UO_2F_2 and HF combined.

V.47. Also, from the standpoint of contamination, it should be noted that gaseous HF does not deposit on the ground; surface contamination can only be caused by particulate UO_2F_2. Hydrated HF, which tends to settle slowly, may have some corrosive effects, but does not present a significant health hazard. Non-hydrolysed UF_6 may settle, especially near the source, and react with moisture.

V.48. Thus the principal hazards are from breathing and contamination, and are generally governed by chemical rather than radiological risks. A release of 8000 kg of UF_6 at the end of a fire, in stable weather conditions and with a mild wind (of about 2 m/s), may cause severe poisoning (mostly by HF) at a downwind distance of 1–2 km for people remaining within the plume during its passage. It is, however, very unlikely that people irritated by the fumes of HF would voluntarily remain in the plume for sufficient time to cause poisoning. The people at risk therefore are those who are near the point of the release, where the concentrations are very high, or those who are forced to stay in the plume area without protective breathing devices because they are somehow incapacitated.

V.49. As the plume moves with the wind, the solid UO_2F_2 will begin to settle and deposit on the ground, resulting in contamination [34, 35]. Ground contamination is not an immediate issue to be dealt with during the course of the accident. Its impacts are from a long term exposure to low level radiation and possible resuspension and the consequent inhalation of the radioactive material if proper measures to control the spread of contamination are not taken. The areas that could require decontamination may extend to several kilometres. While the decontamination of flat solid surfaces is quite easy, the cleaning of soils contaminated with a soluble uranium compound poses a serious problem. The use of water to avoid resuspension is not recommended, as the solutions so formed could penetrate into the ground, which may then necessitate the removal of much higher quantities of soil. If possible, lime solution should be used to 'fix' the contamination.

Emergency response

Phase 1: The initial phase

V.50. Immediate emergency actions concerning the release of UF_6 are provided in guides such as those reproduced in part in Appendix III. In this case the material transported is identified by United Nations number 2978 and the emergency responder will refer to, for example, NAERG2000 Guide 166 (see Annex II) [23].

V.51. It is worthwhile to discuss some of the points in these instructions in more detail.

(a) Water should not be allowed to come into contact with UF_6. The reaction of UF_6 with water is exothermic and therefore enhances the release. A water fog, or water curtain, is very effective if used, at some distance downwind, to reduce the concentration of HF and UO_2F_2 in the plume and to minimize the area that may eventually require decontamination.

(b) Positive pressure breathing apparatus should be used by all emergency teams near the site of the accident. Regular respirators do not provide any protection from UF_6 and provide very little protection from HF. However, they do provide adequate protection from UO_2F_2 and therefore can be used during the decontamination process.

(c) People in the downwind sector should be warned, and if the release is of significant magnitude their evacuation should be considered.

(d) All rescue personnel involved in the accident should be monitored for external and internal contamination after the emergency is over. Equipment and safety gear should be cleaned before it is returned to unlimited use.

Phase 2: The accident control phase

V.52. For the accident control phase a monitoring team is on the scene. The team should be equipped with suitable instruments for the measurement of uranium contamination. The recommended instruments are either alpha monitors (usually based on gas proportional counters) or scintillation counters capable of measuring the weak gamma radiation of uranium. Air sampling devices should be placed in appropriate locations to measure airborne uranium aerosols.

V.53. Using these instruments, the monitoring team should be able to make a contour map of limited access and cordoned-off areas and to recommend what locations should be evacuated, if any, and where decontamination actions are most urgent.

V.54. In most cases the monitoring team should be responsible for monitoring all the individuals involved in the operation.

Phase 3: The post-accident phase

V.55. The post-accident phase is the cleanup stage. Compared with the two previous stages it cannot be done quickly. Before proceeding with this stage, thorough preparation and planning should be undertaken. The factors to be considered are:

- What is the degree of contamination?
- What is the relative importance of the contaminated areas?
- Is there a possibility of a further dispersion of the contaminants?
- To what level should the decontamination be done?

V.56. It is very important to have one individual or one agency responsible for the operation. Monitoring team(s) should also be present during this phase in order to provide feedback information and to monitor personnel. Air sampling should be performed at all times during the campaign.

Appendix VI

EXAMPLE EQUIPMENT KIT FOR A RADIATION PROTECTION TEAM

VI.1. In this section a typical list is given of the equipment that should be considered for a radiological response team. This list was derived from Ref. [36] and IAEA-TECDOC-953, Method for the Development of Emergency Response Preparedness for Nuclear or Radiological Emergencies, IAEA, Vienna (1997). It should be considered as an example. When preparing an actual list, local factors should be considered.

PURPOSE

VI.2. The purpose of the equipment is to allow

— Measurements of gamma and/or beta dose rates from cloud shine, ground deposition or sources to be made;
— The evaluation of unknown situations.

MINIMUM STAFFING PER TEAM

VI.3. The staffing for the radiological response team will be determined by the local conditions. A minimum of two persons, trained annually in radiological assessment, is recommended.

MINIMUM EQUIPMENT PER TEAM

VI.4. The minimum equipment recommended per team is as follows.

Radiation survey instruments:

— High range gamma survey instruments: one piece.
— Low range survey instruments: two pieces.
— A check source for low range survey instruments.
— Contamination detection instruments (including one suitable for detecting alpha emitting radionuclides).

Personal protection equipment:

- Self-reading dosimeters for each team member.
- Electronic dosimeters.
- Permanent dosimeters for each team member.
- Protective overalls, overshoes, hard hats and gloves: three sets per person.
- Respiratory equipment.
- Decontamination supplies.
- A first aid kit.

Communication equipment:

- Portable radio communications: one set.
- Digital cameras and/or video equipment.
- A cellular telephone.
- A portable computer.
- A facsimile capability.
- A global positioning system navigation device.

Supplies:

- Identification badges for each team member;
- Binoculars;
- Environmental sampling supplies;
- Handling tools;
- Labels, tags, signs and plastic bags;
- Transport containers;
- Waste containers;
- Stopwatches;
- A torch (flashlight) for each team member;
- Extra batteries (for instruments and flashlights);
- A compass;
- Radiation warning labels, exclusion tape and signs;
- Administrative supplies, writing pads, etc.;
- Plastic for preventing the contamination of instruments;
- A log book;
- Cases for the shipment of equipment.

Supporting documentation:

- Standard survey maps,

— Equipment operation manuals,
— Response co-ordination procedures,
— Procedures for conducting monitoring,
— Procedures for recording results,
— Procedures for relating results to worker turn-back limits,
— Procedures for personal radiation protection.

Transport equipment:

— All-terrain vehicles (where appropriate),
— A helicopter (where appropriate).

REFERENCES

[1] INTERNATIONAL MARITIME ORGANIZATION, International Maritime Dangerous Goods Code, IMDG Code, 2000 edition, IMO, London (2000).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Resolutions and Other Decisions of the General Conference, GS(42)/RES/DEC/(1998), IAEA, Vienna (1999).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material (ST-1, 1996 edition, revised), Safety Standards Series No. TS-R-1, IAEA, Vienna (2000).

[4] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, UNITED NATIONS OFFICE FOR THE CO-ORDINATION OF HUMANITARIAN AFFAIRS, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, Safety Standards Series No. GS-R-2, IAEA, Vienna (in press).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Generic Procedures for Assessment and Response During a Radiological Emergency, IAEA-TECDOC-1162, Vienna (2000).

[6] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[7] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, Radiation Protection and the Safety of Radiation Sources, Safety Series No. 120, IAEA, Vienna (1996).

[8] UNITED NATIONS COMMITTEE OF EXPERTS ON THE TRANSPORT OF DANGEROUS GOODS, Recommendations on the Transport of Dangerous Goods: Model Regulations, Rep. ST/SG/AC.10/1/Rev.11, UN, New York (1999).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Emergency Notification and Assistance Technical Operations Manual, Emergency Preparedness and Response Series, EPR-ENATOM, IAEA, Vienna (2000)

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Convention on Early Notification of a Nuclear Accident and Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, Legal Series No. 14, IAEA, Vienna (1987).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Emergency Response Network ERNET, Emergency Preparedness and Response Series, EPR-ERNET 2000, IAEA, Vienna (2000).

[12] NATIONAL RADIOLOGICAL PROTECTION BOARD, National Arrangements for Incidents involving Radioactivity (NAIR) Handbook, 1995 edition, NRPB, Chilton (1995).
[13] INTERNATIONAL MARITIME ORGANIZATION, Emergency Procedures for Ships Carrying Dangerous Goods: Group Emergency Schedules (EmS), Rep. IMDG Code Supplement (Amdt. 30-00), IMO, London (2000).
[14] INTERNATIONAL MARITIME ORGANIZATION, Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High Level Radioactive Wastes in Flasks on Board Ships, IMDG Code Supplement, IMO, London (2000).
[15] INTERNATIONAL MARITIME ORGANIZATION, Guidelines for Developing Shipboard Emergency Plans for Ships Carrying Materials Subject to the INF Code, Resolution A.854(20), IMDG Code Supplement, IMO, London (1997).
[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, Safety Standards Series No. TS-G-1.1 (ST-2), IAEA, Vienna (2002).
[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance for the Safe Transport of Radioactive Material, Safety Series No. 113, IAEA, Vienna (1994).
[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Compliance Assurance for the Safe Transport of Radioactive Material, Safety Series No. 112, IAEA, Vienna (1994).
[19] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Packaging of Uranium Hexafluoride (UF_6) for Transport, ISO 7195:1993(E), ISO, Geneva (1993).
[20] INTERNATIONAL ATOMIC ENERGY AGENCY, Recommendations for Providing Protection During the Safe Transport of Uranium Hexafluoride, IAEA-TECDOC-608, Vienna (1991).
[21] INTERNATIONAL ATOMIC ENERGY AGENCY, Generic Procedures for Monitoring in a Nuclear or Radiological Emergency, IAEA-TECDOC-1092, Vienna (1999).
[22] UNITED STATES NUCLEAR REGULATORY COMMISSION, Review and Assessment of Package Requirements (Yellowcake) and Emergency Response to Transportation Accidents, Rep. NUREG-0535, USNRC, Washington, DC (1979).
[23] UNITED STATES DEPARTMENT OF TRANSPORTATION, North American Emergency Response Guidebook, USDOT, Washington, DC (2000).
[24] MOHR, P.B., MOUNT, M.E., SCHWARTZ, M.W., A Highway Accident Involving Radiopharmaceuticals Near Brookhaven, Mississippi on December 3, 1983, Rep. UCRL-53587, Lawrence Livermore Natl Lab., Livermore, CA (1985). (Also listed under Rep. NUREG/CR-4035.)
[25] HADJIANTONIOU, A., ARMIRIOTIS, J., ZANNOS, A., “The performance of Type A packaging under air crash and fire accident conditions”, Packaging and Transportation of Radioactive Materials, PATRAM ’80 (Proc. 6th Int. Symp. Berlin (West), 1980), Bundesanstalt für Materialprüfung, Berlin (West) (1980) 826–832.
[26] INTERNATIONAL CIVIL AVIATION ORGANIZATION, Technical Instructions for the Safe Transport of Dangerous Goods by Air, DOC 9284-AN/905, 1999–2000 edition, ICAO, Montreal (1998).
[27] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Sealed Radioactive Sources: Classification, ISO 2919:1980(E), ISO, Geneva (1980).

[28] OKAMOTO, T., KIYOSE, R., Evaluation of UF_6 vapour release in a postulated accident, J. Nucl. Sci. Technol. **15** (1978) 455–460.
[29] PRICE, A., "Safety aspects of UF6 manufacture and reconversion at Springfield Works", Safety Problems Associated with the Handling and Storage of UF_6 (Proc. Specialists Meeting Boekelo Netherlands, 1978), OECD, Paris (1978) 122.
[30] NORSWORTHY, D.F., HOWARTH, C., "Safety considerations involved in the cases of containers for storage of UF_6 tails", Safety Problems Associated with the Handling and Storage of UF_6 (Proc. Specialists Meeting Boekelo Netherlands, 1978), OECD, Paris (1978) 197.
[31] ERICSSON, A.M., "Atmospheric dispersion and consequences of a UF_6 release caused by valve rupture on a hot 30B cylinder", ibid., p. 283.
[32] BOUZIGNES, H., MEZIN, M., MESTRE, E., "Fundamentals of UF_6 release", ibid., p. 333.
[33] MAITRE, P., MESLIN, T., PAGES, P., Evaluation of Safety in the Transportation of Natural Uranium Hexafluoride, Rep. BNWL-tr-269, Battelle Pacific Northwest Labs, Richland, WA (1977).
[34] UNITED STATES NUCLEAR REGULATORY COMMISSION, Rupture of Model 48Y UF_6 Cylinder and Release of Uranium Hexafluoride, Rep. NUREG-1179, Vol. 1, USNRC, Washington, DC (1986).
[35] UNITED STATES NUCLEAR REGULATORY COMMISSION, Assessment of the Public Health Impact from the Accidental Release of UF_6 at the Sequoyah Fuels Corporation Facility at Gore, Oklahoma, Rep. NUREG-1189, Vols I and II, USNRC, Washington, DC (1986).
[36] AMERICAN NUCLEAR SOCIETY, Criteria for Emergency Response Plans and Implementing Procedures, ANSI/ANS-3.8.3-1987, ANSI, Washington, DC (1987).

Annex I

EXAMPLE OF GUIDANCE ON EMERGENCY RESPONSE TO CARRIERS

I–1. Emergency response guidance should be given to the carriers by the consignors (see para. 555 (c) of the Transport Regulations [I–1]). An example of such guidance was provided by the shipper in the truck (lorry) shipment of industrial packages containing LSA-I natural uranium concentrates that was involved in a road accident in Colorado, USA. This accident and the response to it are described in Appendix V. These instructions are copied as Table I–I [I–2].

TABLE I–I. SAMPLE SHIPPER EMERGENCY INSTRUCTIONS

Your cargo is: Uranium concentrate

This material:

1. Is not explosive.
2. Will not burn.
3. Is a naturally occurring radioactive material of low specific activity. It should not be inhaled, eaten or allowed to get into an open wound.
4. Can be approached without danger for injury from external radiation.

In the event of an accident, as soon as possible:

1. Take the preliminary precautions listed below. Display these instructions as necessary to the local authorities on the scene to obtain their help (see 2 below).
2. Call (or have the local authority call for you) the Manager, ____, Telephone _____. If possible, have the local law or civil authority participate in the call.

Containers are leaking or damaged too seriously to be moved. Lorry or railroad car may or may not be damaged.

1. Caution humans to stay away from the material. Keep them at a distance of at least 25 feet (approximately 8 m). Extreme distance is not necessary. Use the civil authorities to help, if necessary.
2. Assure the local authorities that there is no danger from the radiation, but that people should avoid breathing any dust from the material.
3. Avoid trackage of material by humans or vehicles. Obtain help from the local civil authorities if necessary to reroute traffic around the spill area.
4. Keep material from running into streets, gutters, sewers, etc., if possible. A simple method for doing this might be to dig a trench around the material or construct an earthen dyke several inches high.
5. Prevent the material from being scattered by the wind by carefully covering it with canvas or dirt.
6. Avoid breathing dust from the material. When covering the material, obtain a simple respirator, if possible. If none is available, work the material in such a manner as not to stir up excessive dust.

TABLE I–I. (cont.)

Fire involving the vehicle or in the immediate vicinity of the vehicle
1. Isolate the vehicle from other humans and property, if possible. Use the civil authorities for help.
2. Obtain fire fighting help from the local group.
3. The material you are hauling will not burn.
4. Keep fire away from uranium containers, if possible.
5. Use a respirator if necessary to avoid breathing smoke from any fire involving your cargo because of the possibility of airborne particles if the drums are ruptured.
6. Do not spray water into open or leaking containers. There is no reaction with water but a heavy stream of water will spread the material and make cleanup more difficult.

REFERENCES TO ANNEX I

[I–1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material (ST-1, 1996 edition, revised), Safety Standards Series No. TS-R-1, IAEA, Vienna (2000).

[I–2] UNITED STATES NUCLEAR REGULATORY COMMISSION, Review and Assessment of Package Requirements (Yellowcake) and Emergency Response to Transportation Accidents, Rep. NUREG-0535, USNRC, Washington, DC (1979).

Annex II

EMERGENCY RESPONSE GUIDES

II–1. Various international and State governmental agencies issue emergency response guides. For example, the North American Emergency Response Guides (NAERG) for dangerous good shipments, including radioactive material, are periodically updated. The radioactive material requirements in the 1996 edition of the Transport Regulations [II–1] were included in the 2000 version of NAERG (i.e. NAERG2000) [II–2]. Because these illustrate the type of guidance available to assist those responding to emergencies involving dangerous goods, they are provided in this annex.

II–2. Most other such guides were being updated at the time of publication of this Safety Guide. For example, the International Maritime Organization issues a supplement to the IMDG Code that includes emergency procedures, but the edition available at the time of publication [II–3] reflects the 1985, not the 1996, edition of the Transport Regulations.

II–3. In addition to international and State governmental organizations issuing emergency response guides, non-governmental bodies also issue similar guides. For example, European legislation on the transport of dangerous goods by road (ADR) requires that the consignor provide the driver, for each trip, with written emergency instructions for each dangerous substance (or group of dangerous substances presenting a similar danger) carried on board the truck. Such instructions are drawn up according to a specified format, and include details of:

- The load,
- The nature of the danger,
- Personal protection,
- The general actions to be taken by the driver,
- Additional and/or special actions to be taken by the driver,
- The actions to be taken in the case of a fire,
- The first aid actions that may need to be taken,
- Supplementary information for emergency services (optional),
- Additional information.

II–4. Standardized instructions for transporting dangerous goods in Europe by road are available from the European Chemical Industry Council (CEFIC). CEFIC is a Brussels based organization representing, directly or indirectly, 40 000 large and small chemical companies in Europe that account for about 2 million employees and for more than 30% of the world's chemicals production. These instructions are provided in the form of Transport Emergency Cards or Tremcards. A set of approximately 750 Tremcards (group cards as well as cards for single substances) is currently available in 27 different languages and for all ADR classes of dangerous goods, including radioactive material. The requirements for radioactive material from the 1996 edition of the Transport Regulations [II–1] are expected to be included in the Tremcards during 2001.

II–5. The radioactive material consignments to which each NAERG2000 guide applies is summarized in Tables II–I and II–II.

II–6. Table II–I lists the applicable guide for each appropriate United Nations number and proper shipping name based upon NAERG2000 [II–2].

II–7. The proper shipping names are frequently not written as provided in the Transport Regulations [II–1]. The Transport Regulations [II–1] specify that the portion provided in capital letters is the proper shipping name and that the separation of part (or parts) of the proper shipping name by the lower case ‘or’ indicates that only the relevant portion of the proper shipping name is to be used. As can be seen by an inspection of Table II–I, the proper shipping names commonly used are not depicted all in capital letters.

II–8. Because the United Nations numbers had significant changes from the 1985 to the 1996 editions of the Transport Regulations, the Canadian, Mexican and US authorities chose to include the old and the new United Nations numbers and proper shipping names to ensure that all consignments would be covered during the transition from the old to the new regulatory requirements. Table II–II presents those United Nations numbers and proper shipping names that are no longer in the Transport Regulations [II–1] but which may still be used during the transition period from the 1985 edition to the 1996 edition.

II–9. These two tables are presented with each of the United Nations numbers in ascending order, since it is the United Nations numbers on placards and transport documents by which the contents of consignments can usually be identified by the emergency responders. Each United Nations number, which identifies either the nature of the contents of the packages, the type of package or both, is related to a specific applicable NAERG2000 guide.

II–10. The specific guidance provided in NAERG2000 Guides 161 to 166 is reproduced in Tables II–III to II–VIII.

TABLE II–I. LISTING OF CURRENT UNITED NATIONS NUMBERS FOR RADIOACTIVE MATERIAL AND PROPER SHIPPING NAMES WITH THE APPLICABLE NAERG2000 GUIDES *(based upon NAERG2000 [II–2])*

United Nations number	Proper shipping name[a]	NAERG guide number
2908[b]	**RADIOACTIVE MATERIAL, EXCEPTED PACKAGE — EMPTY PACKAGING**	
2908	Radioactive material, excepted package, empty packaging	161
2908	*Radioactive material, empty packages*	161
2909	**RADIOACTIVE MATERIAL, EXCEPTED PACKAGE — ARTICLES MANUFACTURED FROM NATURAL URANIUM or DEPLETED URANIUM or NATURAL THORIUM**	
2909	Radioactive material, excepted package, articles manufactured from depleted Uranium	161
2909	Radioactive material, excepted package, articles manufactured from natural Thorium	161
2909	Radioactive material, excepted package, articles manufactured from natural Uranium	161
2909	*Radioactive material, articles manufactured from depleted Uranium*	161
2909	*Radioactive material, articles manufactured from natural Thorium*	161
2909	*Radioactive material, articles manufactured from natural Uranium*	161
2910	**RADIOACTIVE MATERIAL, EXCEPTED PACKAGE — LIMITED QUANTITY OF MATERIAL**	
2910	Radioactive material, excepted package, limited quantity of material	161
2910	*Radioactive material, excepted package, articles manufactured from depleted Uranium*	161
2910	*Radioactive material, excepted package, articles manufactured from natural Thorium*	161
2910	*Radioactive material, excepted package, articles manufactured from natural Uranium*	161
2910	*Radioactive material, excepted package, empty packaging*	161
2910	*Radioactive material, excepted package, instruments or articles*	161
2910	*Radioactive material, limited quantity, n.o.s.*[c]	161
2911	**RADIOACTIVE MATERIAL, EXCEPTED PACKAGE — INSTRUMENTS or ARTICLES**	
2911	*Radioactive material, excepted package, instruments or articles*	161
2911	*Radioactive material, instruments or articles*	161

TABLE II–I. (cont.)

United Nations number	Proper shipping name[a]	NAERG guide number
2912	**RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY (LSA-I) non-fissile or fissile excepted**	
2912	Radioactive material, low specific activity (LSA-I)	162
2912	*Radioactive material, low specific activity (LSA), n.o.s.*	162
2913	**RADIOACTIVE MATERIAL, SURFACE CONTAMINATED OBJECTS (SCO-I or SCO-II) non-fissile or fissile excepted**	
2913	Radioactive material, surface contaminated objects (SCO-I)	162
2913	Radioactive material, surface contaminated objects (SCO-II)	162
2913	*Radioactive material, surface contaminated objects (SCO)*	162
2915	**RADIOACTIVE MATERIAL, TYPE A PACKAGE, non-fissile or fissile excepted**	
2915	Radioactive material, Type A package	163
2916	**RADIOACTIVE MATERIAL, TYPE B(U) PACKAGE, non-fissile or fissile excepted**	
2916	Radioactive material, Type B(U) package	163
2917	**RADIOACTIVE MATERIAL, TYPE B(M) PACKAGE, non-fissile or fissile excepted**	
2917	Radioactive material, Type B(M) package	163
2919	**RADIOACTIVE MATERIAL, TRANSPORTED UNDER SPECIAL ARRANGEMENT, non-fissile or fissile excepted**	
2919	Radioactive material, transported under special arrangement	163
2977	**RADIOACTIVE MATERIAL, URANIUM HEXAFLUORIDE, FISSILE**	
2977	Radioactive material, Uranium hexafluoride, fissile	166
2977	*Uranium hexafluoride, fissile containing more than 1% Uranium-235*	166
2978	**RADIOACTIVE MATERIAL, URANIUM HEXAFLUORIDE non-fissile or fissile excepted**	
2978	Radioactive material, Uranium hexafluoride, non-fissile or fissile excepted	166
2978	Uranium hexafluoride, fissile excepted	166
2978	Uranium hexafluoride, non-fissile	166
2978	*Uranium hexafluoride, low specific activity*	166
3321	**RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY MATERIAL (LSA-II), non-fissile or fissile excepted**	
3321	Radioactive material, low specific activity (LSA-II)	162
3322	**RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY MATERIAL (LSA-III), non-fissile or fissile excepted**	
3322	Radioactive material, low specific activity (LSA-III)	162

TABLE II–I. (cont.)

United Nations number	Proper shipping name[a]	NAERG guide number
3323	**RADIOACTIVE MATERIAL, TYPE C) PACKAGE, non-fissile or fissile excepted**	
3323	Radioactive material, Type C package	163
3324	**RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY (LSA-II), FISSILE**	
3324	Radioactive material, low specific activity (LSA-II), fissile	165
3325	**RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY (LSA-III), FISSILE**	
3325	Radioactive material, low specific activity (LSA-III), fissile	165
3326	**RADIOACTIVE MATERIAL, SURFACE CONTAMINATED OBJECTS (SCO-I or SCO-II), FISSILE**	
3326	Radioactive material, surface contaminated objects (SCO-I), fissile	165
3326	Radioactive material, surface contaminated objects (SCO-II), fissile	165
3327	**RADIOACTIVE MATERIAL, TYPE A PACKAGE, FISSILE non-special form**	
3327	Radioactive material, Type A package, fissile	165
3328	**RADIOACTIVE MATERIAL, TYPE B(U) PACKAGE, FISSILE**	
3328	Radioactive material, Type B(U) package, fissile	165
3329	**RADIOACTIVE MATERIAL, TYPE B(M) PACKAGE, FISSILE**	
3329	Radioactive material, Type B(M) package, fissile	165
3330	**RADIOACTIVE MATERIAL, TYPE C PACKAGE, FISSILE**	
3330	Radioactive material, Type C package, fissile	165
3331	**RADIOACTIVE MATERIAL, TRANSPORTED UNDER SPECIAL ARRANGEMENT, FISSILE**	
3331	Radioactive material, transported under special arrangement, fissile	165
3332	**RADIOACTIVE MATERIAL, TYPE A PACKAGE, SPECIAL FORM non-fissile or fissile excepted**	
3332	Radioactive material, Type A package, special form	164
3333	**RADIOACTIVE MATERIAL, TYPE A PACKAGE, SPECIAL FORM, FISSILE**	
3333	Radioactive material, Type A package, special form, fissile	165

[a] Proper shipping names not in italics represent those corresponding to the 1996 edition, whereas those presented in italics indicates either that the proper shipping name corresponds to the 1985 edition of the Transport Regulations or that the proper shipping name is a variation from the text specified in the Transport Regulations.

[b] United Nations number and proper shipping names in bold type are as presented in the 1996 edition of the Transport Regulations.

[c] n.o.s.: not otherwise specified.

TABLE II–II. LISTING OF UNITED NATIONS NUMBERS FROM THE 1985 EDITION OF THE TRANSPORT REGULATIONS FOR RADIOACTIVE MATERIAL AND PROPER SHIPPING NAMES WITH THE APPLICABLE NAERG2000 GUIDES

United Nations number	Proper shipping name	NAERG guide number
2918	Radioactive material, fissile, n.o.s.[a]	165
2974	Radioactive material, special form, n.o.s.	164
2975	Thorium metal, pyrophoric	162
2976	Thorium nitrate, solid	162
2979	Uranium metal, pyrophoric	162
2980	Uranyl nitrate, hexahydrate, solution	162
2981	Uranyl nitrate, solid	162
2982	Radioactive material, n.o.s.	163

[a] n.o.s.: not otherwise specified.

TABLE II–III. NAERG2000 GUIDE 161, RADIOACTIVE MATERIALS (LOW LEVEL RADIATION)
(quoted verbatim from Ref. [II–4])

Potential hazards

Health

Radiation presents minimal risk to transport workers, emergency response personnel, and the public during transportation accidents. Packaging durability increases as potential hazard of radioactive content increases.

Very low levels of contained radioactive materials and low radiation levels outside packages result in low risks to people. Damaged packages may release measurable amounts of radioactive material, but the resulting risks are expected to be low.

Some radioactive materials cannot be detected by commonly available instruments.

Packages do not have RADIOACTIVE I, II, or III labels. Some may have EMPTY labels or may have the word ‘Radioactive’ in the package marking.

Fire or explosion

Some of these materials may burn, but most do not ignite readily.

Many have cardboard outer packaging; content (physically large or small) can be of many different physical forms. Radioactivity does not change flammability or other properties of materials.

Public safety

Call Emergency Response Telephone Number on Shipping Paper first. If Shipping Paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.

Priorities for rescue, life-saving, first aid, and control of fire and other hazards are higher than the priority for measuring radiation levels.

Radiation Authority must be notified of accident conditions. Radiation Authority is usually responsible for decisions about radiological consequences and closure of emergencies.

Isolate spill or leak area immediately for at least 25 to 50 meters (80 to 160 feet) in all directions.

Stay upwind.

Keep unauthorized personnel away.

Detain or isolate uninjured persons or equipment suspected to be contaminated; delay decontamination and cleanup until instructions are received from Radiation Authority.

Protective clothing

Positive pressure self-contained breathing apparatus (SCBA) and structural firefighters’ protective clothing will provide adequate protection.

Evacuation

Large spill

Consider initial downwind evacuation for at least 100 meters (330 feet).

Fire

When a large quantity of this material is involved in a major fire, consider an initial evacuation distance of 300 meters (1000 feet) in all directions.

Emergency response

Fire

Presence of radioactive material will not influence the fire control processes and should not influence selection of techniques.

Move containers from fire area if you can do it without risk.

Do not move damaged packages; move undamaged packages out of fire zone.

Small fires

Dry chemical, CO_2, water spray or regular foam.

Large fires

Water spray, fog (flooding amounts).

Spill or leak

Do not touch damaged packages or spilled material.

Cover liquid spill with sand, earth or other non-combustible absorbent material.

Cover powder spill with plastic sheet or tarp to minimize spreading.

First aid

Medical problems take priority over radiological concerns.

Use first aid treatment according to the nature of the injury.

Do not delay care and transport of a seriously injured person.

Apply artificial respiration if victim is not breathing.

Administer oxygen if breathing is difficult.

In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes.

Injured persons contaminated by contact with released material are not a serious hazard to health care personnel, equipment or facilities.

Ensure that medical personnel are aware of the material(s) involved, take precautions to protect themselves and prevent spread of contamination.

TABLE II–IV. NAERG2000 GUIDE 162, RADIOACTIVE MATERIALS (LOW TO MODERATE LEVEL RADIATION)
(quoted verbatim from Ref. [II–4])

Potential hazards

Health

Radiation presents minimal risk to transport workers, emergency response personnel, and the public during transportation accidents. Packaging durability increases as potential hazard of radioactive content increases.

Undamaged packages are safe. Contents of damaged packages may cause higher external radiation exposure, or both external and internal radiation exposure if contents are released.

Low radiation hazard when material is inside container. If material is released from package or bulk container, hazard will vary from low to moderate. Level of hazard will depend on the type and amount of radioactivity, the kind of material it is in, and/or the surfaces it is on.

Some material may be released from packages during accidents of moderate severity but risks to people are not great.

Released radioactive materials or contaminated objects usually will be visible if packaging fails.

Some exclusive use shipments of bulk and packaged materials will not have "RADIOACTIVE" labels.

Placards, markings, and shipping papers provide identification.

Some packages may have a "RADIOACTIVE" label and a second hazard label. The second hazard is usually greater than the radiation hazard; so follow this Guide as well as the response Guide for the second hazard class label.

Some radioactive materials cannot be detected by commonly available instruments.

Runoff from the control of cargo fire may cause low-level pollution.

Fire or explosion

Some of these materials may burn, but most do not ignite readily.

Uranium and Thorium metal cuttings may ignite spontaneously if exposed to air (see Guide 136).

Nitrates are oxidizers and may ignite other combustibles (see Guide 141).

Public safety

Call Emergency Response Telephone Number on Shipping Paper first. If Shipping Paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.

Priorities for rescue, life-saving, first aid, and control of fire and other hazards are higher than the priority for measuring radiation levels.

Radiation Authority must be notified of accident conditions. Radiation Authority is usually responsible for decisions about radiological consequences and closure of emergencies.

Isolate spill or leak area immediately for at least 25 to 50 meters (80 to 160 feet) in all directions.

Stay upwind.

Keep unauthorized personnel away.

Detain or isolate uninjured persons or equipment suspected to be contaminated; delay decontamination and cleanup until instructions are received from Radiation Authority.

TABLE II–IV. (cont.)

Protective clothing

Positive pressure self-contained breathing apparatus (SCBA) and structural firefighters' protective clothing will provide adequate protection.

Evacuation

Large spill

Consider initial downwind evacuation for at least 100 meters (330 feet).

Fire

When a large quantity of this material is involved in a major fire, consider an initial evacuation distance of 300 meters (1000 feet) in all directions.

Emergency response

Fire

Presence of radioactive material will not influence the fire control processes and should not influence selection of techniques.

Move containers from fire area if you can do it without risk.

Do not move damaged packages; move undamaged packages out of fire zone.

Small fires

Dry chemical, CO_2, water spray or regular foam.

Large fires

Water spray, fog (flooding amounts).

Dike fire-control water for later disposal.

Spill or leak

Do not touch damaged packages or spilled material.

Cover liquid spill with sand, earth or other non-combustible absorbent material.

Dike to collect large liquid spills.

Cover powder spill with plastic sheet or tarp to minimize spreading.

First aid

Medical problems take priority over radiological concerns.

Use first aid treatment according to the nature of the injury.

Do not delay care and transport of a seriously injured person.

Apply artificial respiration if victim is not breathing.

Administer oxygen if breathing is difficult.

In case of contact with substance, wipe from skin immediately; flush skin or eyes with running water for at least 20 minutes.

Injured persons contaminated by contact with released material are not a serious hazard to health care personnel, equipment or facilities.

Ensure that medical personnel are aware of the material(s) involved, take precautions to protect themselves and prevent spread of contamination.

TABLE II–V. NAERG2000 GUIDE 163, RADIOACTIVE MATERIALS (LOW TO HIGH LEVEL RADIATION)
(quoted verbatim from Ref. [II–4])

Potential hazards

Health

Radiation presents minimal risk to transport workers, emergency response personnel, and the public during transportation accidents. Packaging durability increases as potential hazard of radioactive content increases.

Undamaged packages are safe. Contents of damaged packages may cause higher external radiation exposure, or both external and internal radiation exposure if contents are released.

Type A packages (cartons, boxes, drums, articles, etc.) identified as ‘Type A’ by marking on packages or by shipping papers contain non-life endangering amounts. Partial releases might be expected if ‘Type A’ packages are damaged in moderately severe accidents.

Type B packages, and the rarely occurring Type C packages, (large and small, usually metal) contain the most hazardous amounts. They can be identified by package markings or by shipping papers. Life threatening conditions may exist only if contents are released or package shielding fails. Because of design, evaluation, and testing of packages, these conditions would be expected only for accidents of utmost severity.

The rarely occurring ‘Special Arrangement’ shipments may be of Type A, Type B or Type C packages. Package type will be marked on packages, and shipment details will be on shipping papers.

Radioactive White-I labels indicate radiation levels outside single, isolated, undamaged packages are very low (less than 0.005 mSv/h (0.5 mrem/h)).

Radioactive Yellow-II and Yellow-III labeled packages have higher radiation levels. The transport index (TI) on the label identifies the maximum radiation level in mrem/h one meter from a single, isolated, undamaged package.

Some radioactive materials cannot be detected by commonly available instruments.

Water from cargo fire control may cause pollution.

Fire or explosion

Some of these materials may burn, but most do not ignite readily.

Radioactivity does not change flammability or other properties of materials.

Type B packages are designed and evaluated to withstand total engulfment in flames at temperatures of 800°C (1475°F) for a period of 30 minutes.

Public safety

Call Emergency Response Telephone Number on Shipping Paper first. If Shipping Paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.

Priorities for rescue, life-saving, first aid, and control of fire and other hazards are higher than the priority for measuring radiation levels.

Radiation Authority must be notified of accident conditions. Radiation Authority is usually responsible for decisions about radiological consequences and closure of emergencies.

TABLE II–V. (cont.)

Isolate spill or leak area immediately for at least 25 to 50 meters (80 to 160 feet) in all directions.
Stay upwind.
Keep unauthorized personnel away.
Detain or isolate uninjured persons or equipment suspected to be contaminated; delay decontamination and cleanup until instructions are received from Radiation Authority.

Protective clothing

Positive pressure self-contained breathing apparatus (SCBA) and structural firefighters' protective clothing will provide adequate protection against internal radiation exposure, but not external radiation exposure.

Evacuation

Large spill

Consider initial downwind evacuation for at least 100 meters (330 feet).

Fire

When a large quantity of this material is involved in a major fire, consider an initial evacuation distance of 300 meters (1000 feet) in all directions.

Emergency response

Fire

Presence of radioactive material will not influence the fire control processes and should not influence selection of techniques.
Move containers from fire area if you can do it without risk.
Do not move damaged packages; move undamaged packages out of fire zone.

Small fires

Dry chemical, CO_2, water spray or regular foam.

Large fires

Water spray, fog (flooding amounts).
Dike fire-control water for later disposal.

Spill or leak

Do not touch damaged packages or spilled material.
Damp surfaces on undamaged or slightly damaged packages are seldom an indication of packaging failure. Most packaging for liquid content have inner containers and/or inner absorbent materials.
Cover liquid spill with sand, earth or other non-combustible absorbent material.

First aid

Medical problems take priority over radiological concerns.

TABLE II–V. (cont.)

Use first aid treatment according to the nature of the injury.
Do not delay care and transport of a seriously injured person.
Apply artificial respiration if victim is not breathing.
Administer oxygen if breathing is difficult.
In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes.
Injured persons contaminated by contact with released material are not a serious hazard to health care personnel, equipment or facilities.
Ensure that medical personnel are aware of the material(s) involved, take precautions to protect themselves and prevent spread of contamination.

TABLE II–VI. NAERG2000 GUIDE 164, RADIOACTIVE MATERIALS (SPECIAL FORM/LOW TO HIGH LEVEL EXTERNAL RADIATION)
(quoted verbatim from Ref. [II–4])

Potential hazards

Health

Radiation presents minimal risk to transport workers, emergency response personnel, and the public during transportation accidents. Packaging durability increases as potential hazard of radioactive content increases.

Undamaged packages are safe; contents of damaged packages may cause external radiation exposure, and much higher external exposure if contents (source capsules) are released.

Contamination and internal radiation hazards are not expected, but not impossible.

Type A packages (cartons, boxes, drums, articles, etc.) identified as 'Type A' by marking on packages or by shipping papers contain non-life endangering amounts. Radioactive sources may be released if 'Type A' packages are damaged in moderately severe accidents.

Type B packages, and the rarely occurring Type C packages, (large and small, usually metal) contain the most hazardous amounts. They can be identified by package markings or by shipping papers. Life threatening conditions may exist only if contents are released or package shielding fails. Because of design, evaluation, and testing of packages, these conditions would be expected only for accidents of utmost severity.

Radioactive White-I labels indicate radiation levels outside single, isolated, undamaged packages are very low (less than 0.005 mSv/h (0.5 mrem/h)).

Radioactive Yellow-II and Yellow-III labeled packages have higher radiation levels. The transport index (TI) on the label identifies the maximum radiation level in mrem/h one meter from a single, isolated, undamaged package.

Radiation from the package contents, usually in durable metal capsules, can be detected by most radiation instruments.

Water from cargo fire control is not expected to cause pollution.

Fire or explosion

Packagings can burn completely without risk of content loss from sealed source capsule.

Radioactivity does not change flammability or other properties of materials.

Radioactive source capsules and Type B packages are designed and evaluated to withstand total engulfment in flames at temperatures of 800°C (1475°F).

Public safety

Call Emergency Response Telephone Number on Shipping Paper first. If Shipping Paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.

Priorities for rescue, life-saving, first aid, and control of fire and other hazards are higher than the priority for measuring radiation levels.

Radiation Authority must be notified of accident conditions. Radiation Authority is usually responsible for decisions about radiological consequences and closure of emergencies.

Isolate spill or leak area immediately for at least 25 to 50 meters (80 to 160 feet) in all directions.

TABLE II–VI. (cont.)

Stay upwind.
Keep unauthorized personnel away.
Delay final cleanup until instructions or advice is received from Radiation Authority.

Protective clothing

Positive pressure self-contained breathing apparatus (SCBA) and structural firefighters' protective clothing will provide adequate protection against internal radiation exposure, but not external radiation exposure.

Evacuation

Large spill

Consider initial downwind evacuation for at least 100 meters (330 feet).

Fire

When a large quantity of this material is involved in a major fire, consider an initial evacuation distance of 300 meters (1000 feet) in all directions.

Emergency response

Fire

Presence of radioactive material will not influence the fire control processes and should not influence selection of techniques.
Move containers from fire area if you can do it without risk.
Do not move damaged packages; move undamaged packages out of fire zone.

Small fires

Dry chemical, CO_2, water spray or regular foam.

Large fires

Water spray, fog (flooding amounts).

Spill or leak

Do not touch damaged packages or spilled material.
Damp surfaces on undamaged or slightly damaged packages are seldom an indication of packaging failure. Contents are seldom liquid. Content is usually a metal capsule, easily seen if released from package.
If source capsule is identified as being out of package, do not touch. Stay away and await advice from Radiation Authority.

First aid

Medical problems take priority over radiological concerns.
Use first aid treatment according to the nature of the injury.
Do not delay care and transport of a seriously injured person.

TABLE II–VI. (cont.)

Persons exposed to special form sources are not likely to be contaminated with radioactive material.
Apply artificial respiration if victim is not breathing.
Administer oxygen if breathing is difficult.
Injured persons contaminated by contact with released material are not a serious hazard to health care personnel, equipment or facilities.
Ensure that medical personnel are aware of the material(s) involved, take precautions to protect themselves and prevent spread of contamination.

TABLE II–VII. NAERG2000 GUIDE 165, RADIOACTIVE MATERIALS (FISSILE/LOW TO HIGH LEVEL RADIATION)
(quoted verbatim from Ref. [II–4])

Potential hazards

Health

Radiation presents minimal risk to transport workers, emergency response personnel, and the public during transportation accidents. Packaging durability increases as potential radiation and criticality hazards of the content increase.

Undamaged packages are safe. Contents of damaged packages may cause higher external radiation exposure, or both external and internal radiation exposure if contents are released.

Type AF or IF packages, identified by package markings, do not contain life-threatening amounts of material. External radiation levels are low and packages are designed, evaluated, and tested to control releases and to prevent a fission chain reaction under severe transport conditions.

Type B(U)F, B(M)F and CF packages (identified by markings on packages or shipping papers) contain potentially life endangering amounts. Because of design, evaluation, and testing of packages, fission chain reactions are prevented and releases are not expected to be life endangering for all accidents except those of utmost severity.

The rarely occurring “Special Arrangement” shipments may be of Type AF, BF or CF packages. Package type will be marked on packages, and shipment details will be on shipping papers.

The transport index (TI) shown on labels or a shipping paper might not indicate the radiation level at one meter from a single, isolated, undamaged package; instead, it might relate to controls needed during transport because of the fissile properties of the materials.

Some radioactive materials cannot be detected by commonly available instruments.

Water from cargo fire control is not expected to cause pollution.

Fire or explosion

These materials are seldom flammable. Packages are designed to withstand fires without damage to contents.

Radioactivity does not change flammability or other properties of materials.

Type AF, IF, B(U)F, B(M)F and CF packages are designed and evaluated to withstand total engulfment in flames at temperatures of 800°C (1475°F) for a period of 30 minutes.

Public safety

Call Emergency Response Telephone Number on Shipping Paper first. If Shipping Paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.

Priorities for rescue, life-saving, first aid, and control of fire and other hazards are higher than the priority for measuring radiation levels.

Radiation Authority must be notified of accident conditions. Radiation Authority is usually responsible for decisions about radiological consequences and closure of emergencies.

Isolate spill or leak area immediately for at least 25 to 50 meters (80 to 160 feet) in all directions.

Stay upwind.
Keep unauthorized personnel away.
Detain or isolate uninjured persons or equipment suspected to be contaminated; delay decontamination and cleanup until instructions are received from Radiation Authority.

Protective clothing

Positive pressure self-contained breathing apparatus (SCBA) and structural fire fighters' protective clothing will provide adequate protection against internal radiation exposure, but not external radiation exposure.

Evacuation

Large spill

Consider initial downwind evacuation for at least 100 meters (330 feet).

Fire

When a large quantity of this material is involved in a major fire, consider an initial evacuation distance of 300 meters (1000 feet) in all directions.

Emergency response

Fire

Presence of radioactive material will not influence the fire control processes and should not influence selection of techniques.
Move containers from fire area if you can do it without risk.
Do not move damaged packages; move undamaged packages out of fire zone.

Small fires

Dry chemical, CO_2, water spray or regular foam.

Large fires

Water spray, fog (flooding amounts).

Spill or leak

Do not touch damaged packages or spilled material.
Damp surfaces on undamaged or slightly damaged packages are seldom an indication of packaging failure. Most packaging for liquid content have inner containers and/or inner absorbent materials.

Liquid spills

Package contents are seldom liquid. If any radioactive contamination resulting from a liquid release is present, it probably will be low-level.

TABLE II–VII. (cont.)

First aid
Medical problems take priority over radiological concerns.
Use first aid treatment according to the nature of the injury.
Do not delay care and transport of a seriously injured person.
Apply artificial respiration if victim is not breathing.
Administer oxygen if breathing is difficult.
In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes.
Injured persons contaminated by contact with released material are not a serious hazard to health care personnel, equipment or facilities.
Ensure that medical personnel are aware of the material(s) involved, take precautions to protect themselves and prevent spread of contamination.

TABLE II–VIII. NAERG2000 GUIDE 166, RADIOACTIVE MATERIALS (URANIUM HEXAFLUORIDE/WATER SENSITIVE)
(quoted verbatim from Ref. [II–4])

Potential hazards

Health

Radiation presents minimal risk to transport workers, emergency response personnel, and the public during transportation accidents. Packaging durability increases as potential radiation and criticality hazards of the content increase.

Chemical hazard greatly exceeds radiation hazard.

Substance reacts with water and water vapor in air to form toxic and corrosive hydrogen fluoride gas and an extremely irritating and corrosive, white-colored, water-soluble residue.

If inhaled, may be fatal.

Direct contact causes burns to skin, eyes, and respiratory tract.

Low-level radioactive material; very low radiation hazard to people.

Runoff from control of cargo fire may cause low-level pollution.

Fire or explosion

Substance does not burn.

Containers in protective overpacks (horizontal cylindrical shape with short legs for tie-downs), are identified with “AF” or “B(U)F” on shipping papers or by markings on the overpacks. They are designed and evaluated to withstand severe conditions including total engulfment in flames at temperatures of 800°C (1475°F).

Bare filled cylinders, identified with UN2978 as part of the marking, may rupture in heat of engulfing fire; bare empty (except for residue) cylinders will not rupture in fires.

The material may react violently with fuels.

Radioactivity does not change flammability or other properties of materials.

Public safety

Call Emergency Response Telephone Number on Shipping Paper first. If Shipping Paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.

Priorities for rescue, life-saving, first aid, and control of fire and other hazards are higher than the priority for measuring radiation levels.

Radiation Authority must be notified of accident conditions. Radiation Authority is usually responsible for decisions about radiological consequences and closure of emergencies.

Isolate spill or leak area immediately for at least 25 to 50 meters (80 to 160 feet) in all directions.

Stay upwind.

Keep unauthorized personnel away.

Detain or isolate uninjured persons or equipment suspected to be contaminated; delay decontamination and cleanup until instructions are received from Radiation Authority.

Protective clothing

Wear positive pressure self-contained breathing apparatus (SCBA).

Wear chemical protective clothing which is specifically recommended by the manufacturer. It may provide little or no thermal protection.
Structural firefighters' protective clothing provides limited protection in fire situations only; it is not effective in spill situations.

Evacuation

Large spill

Consider initial downwind evacuation for at least 100 meters (330 feet).

Fire

When a large quantity of this material is involved in a major fire, consider an initial evacuation distance of 300 meters (1000 feet) in all directions.

Emergency response

Fire

Do not use water or foam on material itself.
Move containers from fire area if you can do it without risk.

Small fires

Dry chemical or CO_2.

Large fires

Water spray, fog or regular foam.
Cool containers with flooding quantities of water until well after fire is out.
If this is impossible, withdraw from area and let fire burn.
Always stay away from tanks engulfed in fire.

Spill or leak

Do not touch damaged packages or spilled material.
Without fire or smoke, leak will be evident by visible and irritating vapors and residue forming at the point of release.
Use fine water spray to reduce vapors; do not put water directly on point of material release from container.
Residue buildup may self-seal small leaks.
Dike far ahead of spill to collect runoff water.

First aid

Medical problems take priority over radiological concerns.
Use first aid treatment according to the nature of the injury.
Do not delay care and transport of a seriously injured person.
Apply artificial respiration if victim is not breathing.
Administer oxygen if breathing is difficult.

TABLE II–VIII. (cont.)

In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes.
Effects of exposure (inhalation, ingestion or skin contact) to substance may be delayed.
Injured persons contaminated by contact with released material are not a serious hazard to health care personnel, equipment or facilities.
Ensure that medical personnel are aware of the material(s) involved, take precautions to protect themselves and prevent spread of contamination.

REFERENCES TO ANNEX II

[II–1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material (ST-1, 1996 edition, revised), Safety Standards Series No. TS-R-1, IAEA, Vienna (2000).

[II–2] UNITED STATES DEPARTMENT OF TRANSPORTATION, North American Emergency Response Guidebook, USDOT, Washington, DC (2000).

[II–3] INTERNATIONAL MARITIME ORGANIZATION, Emergency Procedures for Ships Carrying Dangerous Goods: Group Emergency Schedules (EmS), Rep. IMDG Code Supplement (Amdt. 30-00), IMO, London (2000).

[II–4] UNITED STATES DEPARTMENT OF TRANSPORTATION, North American Emergency Response Guidebook, USDOT, Washington, DC (2000).

BIBLIOGRAPHY

INTERNATIONAL ATOMIC ENERGY AGENCY (Vienna)

Mutual Emergency Assistance for Radiation Accidents, Supplement to 1980 Edition, IAEA-TECDOC-284 (1983).

Discussion of and Guidance on the Optimization of Radiation Protection in the Transport of Radioactive Material, IAEA-TECDOC-374 (1986).

Competent Authority Regulatory Control of the Transport of Radioactive Material, IAEA-TECDOC-413 (1987).

Emergency Planning and Preparedness for Accidents Involving Radioactive Materials Used in Medicine, Industry, Research and Teaching, Safety Series No. 91 (1989).

Generic Assessment Procedures for Determining Protective Actions during a Reactor Accident, IAEA-TECDOC-955 (1997).

Method for the Development of Emergency Response Preparedness for Nuclear or Radiological Accidents, IAEA-TECDOC-953, Vienna (1997).

Directory of National Competent Authorities' Approval Certificates for Packages, Shipments, Special Arrangements and Special Form Material, and Shipment of Radioactive Material, IAEA-TECDOC-1171 (2000) (updated annually since 1989).

National Competent Authorities Responsible for Approvals and Authorizations in respect of the Transport of Radioactive Material, List No. 31, 2001 edition (2001) (updated annually since 1967).

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, 1990 Recommendations of the International Commission on Radiological Protection, Publication 60, Pergamon Press, Oxford and New York (1991).

— Protection from Potential Exposures: Application to Selected Radiation Sources, Publication 76, Pergamon Press, Oxford and New York (1996).

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE INLAND TRANSPORT COMMITTEE, Regulations concerning the International Carriage of Dangerous Goods by Rail (RID), UNECE, Geneva (1993).

— European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) and Protocol of Signature, ECE/TRANS/110, UNECE, Geneva (1995).

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