IAEA Safety Standards

for protecting people and the environment

Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities

Specific Safety Guide

No. SSG-47

IAEA
International Atomic Energy Agency

IAEA SAFETY STANDARDS AND RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

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

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety. The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

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

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

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

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

RELATED PUBLICATIONS

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

Reports on safety in nuclear activities are issued as **Safety Reports**, which provide practical examples and detailed methods that can be used in support of the safety standards.

Other safety related IAEA publications are issued as **Emergency Preparedness and Response** publications, **Radiological Assessment Reports**, the International Nuclear Safety Group's **INSAG Reports**, **Technical Reports** and **TECDOCs**. The IAEA also issues reports on radiological accidents, training manuals and practical manuals, and other special safety related publications.

Security related publications are issued in the **IAEA Nuclear Security Series**.

The **IAEA Nuclear Energy Series** comprises informational publications to encourage and assist research on, and the development and practical application of, nuclear energy for peaceful purposes. It includes reports and guides on the status of and advances in technology, and on experience, good practices and practical examples in the areas of nuclear power, the nuclear fuel cycle, radioactive waste management and decommissioning.

DECOMMISSIONING OF NUCLEAR POWER PLANTS, RESEARCH REACTORS AND OTHER NUCLEAR FUEL CYCLE FACILITIES

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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''.

IAEA SAFETY STANDARDS SERIES No. SSG-47

DECOMMISSIONING OF NUCLEAR POWER PLANTS, RESEARCH REACTORS AND OTHER NUCLEAR FUEL CYCLE FACILITIES

SPECIFIC SAFETY GUIDE

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FOREWORD

by Yukiya Amano
Director General

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

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

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

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

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

THE IAEA SAFETY STANDARDS

BACKGROUND

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive substances have many beneficial applications, ranging from power generation to uses in medicine, industry and agriculture. The radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled.

Activities such as the medical uses of radiation, the operation of nuclear installations, the production, transport and use of radioactive material, and the management of radioactive waste must therefore be subject to standards of safety.

Regulating safety is a national responsibility. However, radiation risks may transcend national borders, and international cooperation serves to promote and enhance safety globally by exchanging experience and by improving capabilities to control hazards, to prevent accidents, to respond to emergencies and to mitigate any harmful consequences.

States have an obligation of diligence and duty of care, and are expected to fulfil their national and international undertakings and obligations.

International safety standards provide support for States in meeting their obligations under general principles of international law, such as those relating to environmental protection. International safety standards also promote and assure confidence in safety and facilitate international commerce and trade.

A global nuclear safety regime is in place and is being continuously improved. IAEA safety standards, which support the implementation of binding international instruments and national safety infrastructures, are a cornerstone of this global regime. The IAEA safety standards constitute a useful tool for contracting parties to assess their performance under these international conventions.

THE IAEA SAFETY STANDARDS

The status of the IAEA safety standards derives from the IAEA's Statute, which authorizes the IAEA to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property, and to provide for their application.

With a view to ensuring the protection of people and the environment from harmful effects of ionizing radiation, the IAEA safety standards establish fundamental safety principles, requirements and measures to control the radiation exposure of people and the release of radioactive material to the environment, to restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation, and to mitigate the consequences of such events if they were to occur. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste.

Safety measures and security measures[1] have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. They are issued in the IAEA Safety Standards Series, which has three categories (see Fig. 1).

Safety Fundamentals

Safety Fundamentals present the fundamental safety objective and principles of protection and safety, and provide the basis for the safety requirements.

Safety Requirements

An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. If the requirements are not met, measures must be taken to reach or restore the required level of safety. The format and style of the requirements facilitate their use for the establishment, in a harmonized manner, of a national regulatory framework. Requirements, including numbered ‘overarching’ requirements, are expressed as ‘shall’ statements. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

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[1] See also publications issued in the IAEA Nuclear Security Series.

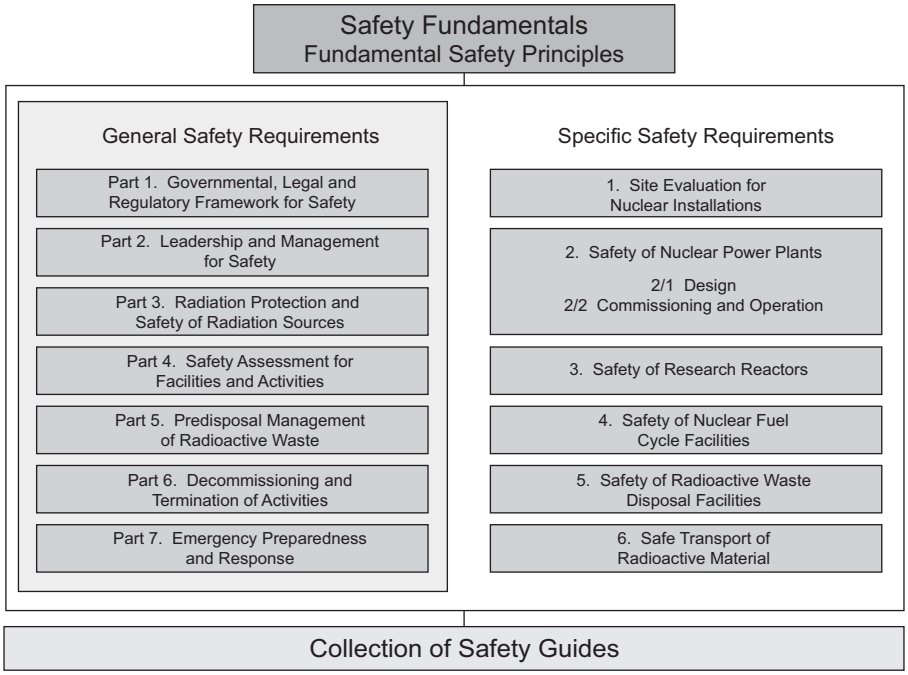

FIG. 1. The long term structure of the IAEA Safety Standards Series.

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as 'should' statements.

APPLICATION OF THE IAEA SAFETY STANDARDS

The principal users of safety standards in IAEA Member States are regulatory bodies and other relevant national authorities. The IAEA safety standards are also used by co-sponsoring organizations and by many organizations that design, construct and operate nuclear facilities, as well as organizations involved in the use of radiation and radioactive sources.

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be used by States as a reference for their national regulations in respect of facilities and activities.

The IAEA's Statute makes the safety standards binding on the IAEA in relation to its own operations and also on States in relation to IAEA assisted operations.

The IAEA safety standards also form the basis for the IAEA's safety review services, and they are used by the IAEA in support of competence building, including the development of educational curricula and training courses.

International conventions contain requirements similar to those in the IAEA safety standards and make them binding on contracting parties. The IAEA safety standards, supplemented by international conventions, industry standards and detailed national requirements, establish a consistent basis for protecting people and the environment. There will also be some special aspects of safety that need to be assessed at the national level. For example, many of the IAEA safety standards, in particular those addressing aspects of safety in planning or design, are intended to apply primarily to new facilities and activities. The requirements established in the IAEA safety standards might not be fully met at some existing facilities that were built to earlier standards. The way in which IAEA safety standards are to be applied to such facilities is a decision for individual States.

The scientific considerations underlying the IAEA safety standards provide an objective basis for decisions concerning safety; however, decision makers must also make informed judgements and must determine how best to balance the benefits of an action or an activity against the associated radiation risks and any other detrimental impacts to which it gives rise.

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and five safety standards committees, for emergency preparedness and response (EPReSC) (as of 2016), nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of

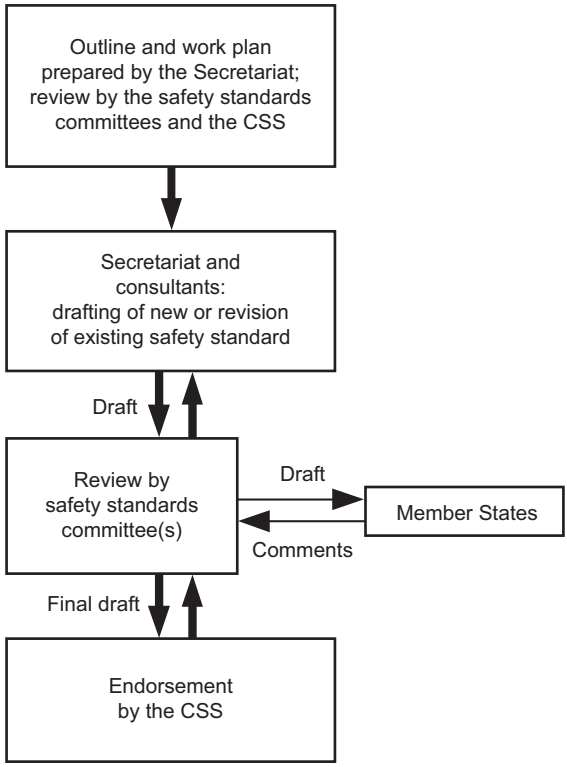

FIG. 2. The process for developing a new safety standard or revising an existing standard.

the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards. It articulates the mandate of the IAEA, the vision for the future application of the safety standards, policies and strategies, and corresponding functions and responsibilities.

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international

expert bodies, notably the International Commission on Radiological Protection (ICRP), are taken into account in developing the IAEA safety standards. Some safety standards are developed in cooperation with other bodies in the United Nations system or other specialized agencies, including the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the International Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

INTERPRETATION OF THE TEXT

Safety related terms are to be understood as defined in the IAEA Safety Glossary (see http://www-ns.iaea.org/standards/safety-glossary.htm). Otherwise, words are used with the spellings and meanings assigned to them in the latest edition of The Concise Oxford Dictionary. For Safety Guides, the English version of the text is the authoritative version.

The background and context of each standard in the IAEA Safety Standards Series and its objective, scope and structure are explained in Section 1, Introduction, of each publication.

Material for which there is no appropriate place in the body text (e.g. material that is subsidiary to or separate from the body text, is included in support of statements in the body text, or describes methods of calculation, procedures or limits and conditions) may be presented in appendices or annexes.

An appendix, if included, is considered to form an integral part of the safety standard. Material in an appendix has the same status as the body text, and the IAEA assumes authorship of it. Annexes and footnotes to the main text, if included, are used to provide practical examples or additional information or explanation. Annexes and footnotes are not integral parts of the main text. Annex material published by the IAEA is not necessarily issued under its authorship; material under other authorship may be presented in annexes to the safety standards. Extraneous material presented in annexes is excerpted and adapted as necessary to be generally useful.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. Many facilities[1] that use nuclear and other radioactive material or radioactive sources in a variety of applications are reaching the end of their operating lifetimes and will be facing permanent shutdown[2] in the near future. Factors such as national energy policies, changing energy markets or unforeseen conditions (e.g. major accidents) might result in facilities reaching permanent shutdown earlier than planned. Even new facilities currently being planned or constructed will ultimately reach permanent shutdown. These facilities will all need to be decommissioned. This Safety Guide recommends a consistent approach to planning and implementing the decommissioning of both new and existing facilities, incorporating lessons learned from previous decommissioning projects.

1.2. As defined in IAEA Safety Standards Series No. GSR Part 6, Decommissioning of Facilities [1], "…'decommissioning' refers to the administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility". While decommissioning is the last stage in the lifetime of a facility, aspects of decommissioning, such as designing for the minimization of radioactive waste (especially long lived radioactive waste), planning for decommissioning and record keeping, are required to be considered throughout the lifetime of the facility, beginning with the initial planning and design of the facility.

1.3. Decommissioning actions include the decontamination, dismantling and removal of structures, systems and components (SSCs), including management of the resulting radioactive waste and radiation protection of workers carrying out the decommissioning, as well as the conduct of characterization surveys to support decommissioning. These actions are carried out to achieve the progressive and systematic reduction in radiological hazards during decommissioning and are taken on the basis of planning and assessment to ensure safety, protection

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[1] The term 'facility' means buildings and their associated land and equipment, including the surface and subsurface soil, and any surface or subsurface water or aquifers. In this Safety Guide, the term 'facility' is used with a limited scope, to cover the types of facilities considered in this Safety Guide, as described in paras 1.14 and 1.15.

[2] The term 'permanent shutdown', as used in this Safety Guide, means that the facility has ceased operations and operation will not be recommenced.

of workers and the public and protection of the environment, and in order to demonstrate that the decommissioned facility achieves the planned end state.

1.4. Decontamination, dismantling and other decommissioning actions may be carried out immediately following permanent shutdown or may be deferred until after a safe enclosure[3] period. As a consequence, the time period for the conduct of decommissioning actions typically ranges from a few months for simple and small facilities undergoing immediate dismantling, to decades for large and complex facilities using the deferred dismantling strategy (for example, to allow for radioactive decay). Decommissioning may include the phased release of parts of the facility from regulatory control during the conduct of decommissioning actions. On completion of all planned decommissioning actions and on reaching the planned end state, the authorization for decommissioning can be terminated. The site and remaining structures of the facility, if any, will be available for unrestricted or restricted reuse, depending on the end state.

1.5. Depending on the national regulatory system, decommissioning of a facility might be subject to the granting of a licence specifically for decommissioning or an authorization to perform decommissioning actions in the framework of a licence granted for the whole lifetime of the facility until the facility is released from regulatory control. In this Safety Guide, the term 'authorization for decommissioning' is used to mean whichever of these regulatory concepts is relevant.

1.6. The decommissioning of a facility is usually conducted as a project. A decommissioning project is a collaborative initiative, involving supporting analyses and studies, which is carefully planned to ensure the safety of the planned actions and to achieve partial or complete removal of regulatory controls from a facility. A decommissioning project usually starts when preparation of the final decommissioning plan is initiated or, in some cases, when an authorization for decommissioning is granted.

1.7. Adequate planning for decommissioning and implementation of decommissioning actions are required to ensure the protection of workers, the public and the environment. With the expansion of the nuclear industry worldwide and with many facilities nearing the end of their operating lifetimes, experience has shown the importance of planning for decommissioning for new

[3] The term 'safe enclosure' means the period during the implementation of the deferred dismantling strategy in which the facility is placed and maintained in a safe, long term storage condition until decontamination and dismantling actions are performed.

facilities during their siting, design and construction. When the end of operation of a facility is approaching, or immediately after permanent shutdown, detailed planning for decommissioning (i.e. development of a final decommissioning plan) is required prior to the commencement of decommissioning actions. However, there are still some existing facilities close to the end of their operating life or already permanently shutdown that do not have a decommissioning plan in place, and for such facilities a final decommissioning plan is required to be developed as soon as possible.

1.8. This Safety Guide supersedes Decommissioning of Nuclear Power Plants and Research Reactors, issued in 1999[4], and Decommissioning of Nuclear Fuel Cycle Facilities, issued in 2001[5].

1.9. Guidance on the decommissioning of medical, industrial and research facilities is provided in IAEA Safety Standards Series No. SSG-49, Decommissioning of Medical, Industrial and Research Facilities [2].

1.10. Requirements and guidance on radiation protection, regulatory control of discharges of radioactive effluents to the environment and associated management of radioactive waste are provided in IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [3] and IAEA Safety Standards Series No. GSG-9, Regulatory Control of Radioactive Discharges to the Environment [4].

1.11. Requirements and guidance on radiological criteria for the release of materials, equipment and sites from regulatory control are provided in GSR Part 3 [3]; IAEA Safety Standards Series No. RS-G-1.7, Application of the Concepts of Exclusion, Exemption and Clearance [5]; and IAEA Safety Standards Series No. WS-G-5.1, Release of Sites from Regulatory Control on Termination of Practices [6].

1.12. Requirements and guidance on the transport of radioactive material and the associated safety and environmental aspects are provided in IAEA Safety Standards Series No. SSR-6 (Rev. 1), Regulations for the Safe Transport of Radioactive Material, 2018 Edition [7] and IAEA Safety Standards

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[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Power Plants and Research Reactors, IAEA Safety Standards Series No. WS-G-2.1, IAEA, Vienna (1999).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Fuel Cycle Facilities, IAEA Safety Standards Series No. WS-G-2.4, IAEA, Vienna (2001).

Series No. SSG-26, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2012 Edition) [8].

OBJECTIVE

1.13. The objective of this Safety Guide is to provide guidance for regulatory bodies, licensees, technical support organizations and other interested parties on planning for decommissioning, conducting decommissioning actions, demonstrating completion of decommissioning and terminating the authorization for decommissioning of facilities. It aims to assist States in ensuring that decommissioning of facilities is conducted in a safe and environmentally acceptable manner in accordance with good international practice.

SCOPE

1.14. This Safety Guide provides guidance on meeting the safety requirements applicable to decommissioning, primarily those established in GSR Part 6 [1], but also in other Safety Requirements publications. This Safety Guide addresses decommissioning considerations and actions for the safe decommissioning of nuclear power plants, research reactors and other nuclear fuel cycle facilities. The following types of facility are included in the scope of this Safety Guide: uranium conversion plants, uranium enrichment plants, nuclear fuel fabrication plants, research reactors including subcritical and critical assemblies, nuclear power plants, facilities for the storage of spent fuel, reprocessing facilities and facilities for the predisposal management of radioactive waste. Uranium mines and thorium mines and facilities for disposal of radioactive waste are outside the scope of this Safety Guide, as they are subject to closure and not to decommissioning. Surface processing facilities for the mining and processing of uranium and thorium are subject to decommissioning, and all the recommendations in this Safety Guide are also applicable to facilities of this type. For radioactive waste disposal facilities, this Safety Guide provides recommendations relevant for the decommissioning of support infrastructure (i.e. those parts of the facility other than the disposal area itself, which is subject to closure).

1.15. The guidance provided in this Safety Guide is applicable to the decommissioning of nuclear fuel cycle research and development facilities conducting research and development activities on processes and equipment for use on an industrial scale (e.g. pilot plants or demonstration plants).

1.16. This Safety Guide does not address the decommissioning of medical and industrial facilities, or of non-reactor research facilities conducting laboratory scale experiments and fundamental research studies on specific nuclear materials, such as prototype nuclear fuels (before and after irradiation in a reactor), or carrying out investigations of nuclear material or waste arising from new processes. Decommissioning of these types of facility is addressed in SSG-49 [2]. Although the general guidance on the decommissioning process is fully applicable to facilities that process naturally occurring radioactive material, this Safety Guide does not provide specific guidance for these types of facility. Additional guidance is provided in other Safety Guides [2, 9].

1.17. Decommissioning considerations and actions addressed in this Safety Guide take place over the whole lifetime of the facility, from the siting and design of the facility until termination of the authorization for decommissioning. On the basis of general considerations regarding safety, radiation protection and protection of the environment, as well as related regulatory aspects, this Safety Guide provides guidance on the selection of a decommissioning strategy, the development of decommissioning plans and the implementation of the final decommissioning plan. This Safety Guide addresses the application of a graded approach in the decommissioning of facilities, key decommissioning considerations during the facility's lifetime, planning and safety assessment for decommissioning, financing of decommissioning, the transition from operation to decommissioning, management of decommissioning, conduct of decommissioning actions, completion of decommissioning, and termination of the authorization for decommissioning.

1.18. Decommissioning of facilities involves a wide range of actions that are carried out in the presence of a variety of radiological and non-radiological hazards and associated risks. The level of detail of planning necessary for meeting the decommissioning requirements differs depending on the type and complexity of the facility, its radioactive inventory and the potential hazards expected during decommissioning, but the general approach to decommissioning remains the same. This general approach is adapted to the specific facility's situation by the application of a graded approach, which can affect the selection of the decommissioning strategy, the planning details, the conduct of decommissioning actions and the end state chosen.

1.19. This Safety Guide addresses the radiation risks resulting from actions associated with decommissioning of facilities, and the management of radioactive waste and material arising from the decommissioning actions. It is intended primarily for facilities with a normal operational history (e.g. without a severe

accident), followed by a planned permanent shutdown. However, many of the considerations are also applicable to decommissioning after an accident that has resulted in serious damage to the facility or extensive contamination of the site and the surrounding area. In such cases, this Safety Guide may be used as a basis for developing special decommissioning provisions to address the post-accident situation.

1.20. The management of fresh nuclear fuel or spent nuclear fuel, the management of other process material used during operation, and the management of radioactive waste generated in the operational stage are repeated or continual actions that are subject to the operating licence. Thus, these actions should not be considered part of a decommissioning project. If the removal of spent fuel and waste from operation is not possible prior to decommissioning, this should be reflected in the final decommissioning plan and the removal of such waste should be performed under the authorization for decommissioning or under a separate operating licence for processing or storage of spent fuel and waste from operation. Other IAEA safety standards address these aspects, including IAEA Safety Standards Series Nos SSG-15, Storage of Spent Nuclear Fuel [10]; GSR Part 5, Predisposal Management of Radioactive Waste [11]; SSG-40, Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors [12]; SSG-41, Predisposal Management of Radioactive Waste from Nuclear Fuel Cycle Facilities [13]; and WS-G-6.1, Storage of Radioactive Waste [14].

1.21. The hazards associated with facilities might include chemical, biological and industrial hazards, in addition to radiological hazards, and consideration should be given to achieving a balanced approach to addressing all hazards. For example, non-radiological hazards, such as those due to the release of asbestos or polychlorinated biphenyl, might be encountered during decommissioning actions. This Safety Guide does not explicitly address non-radiological hazards, but they should be given due consideration in all aspects of decommissioning, including planning for decommissioning, management of decommissioning, financing of decommissioning, conduct of decommissioning actions and completion of decommissioning.

1.22. In cases where only a part of a facility is being decommissioned, this Safety Guide applies only to decommissioning actions associated with the part of the facility being decommissioned. However, the potential safety implications for any continuing operations in other parts of the facility need to be addressed. An example might be the decommissioning of a laboratory facility associated with an operating research reactor.

1.23. The management of residues from mining and processing, such as tailings and waste rock, is outside the scope of this Safety Guide and is considered in IAEA Safety Standards Series No. WS-G-1.2, Management of Radioactive Waste from the Mining and Milling of Ores [9]. While this Safety Guide applies to facilities associated with the processing and storage of radioactive waste, it does not address the disposal of radioactive waste and the closure of disposal facilities. Those issues are considered in other IAEA safety standards [15–18].

1.24. This Safety Guide applies to planned, authorized activities. Although some reference is made to remediation in the context of a facility's decommissioning, this Safety Guide does not apply to remediation situations, which are addressed in other IAEA safety standards [3, 19].

1.25. Security aspects have to be considered during decommissioning, but they are outside the scope of this publication. The IAEA issues Fundamentals and Recommendations on nuclear security in the IAEA Nuclear Security Series [20–23][6]. Requirements pertaining to interfaces of safety with nuclear security are established in IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety [24]. Aspects relating to accounting for and control of nuclear material for security and safeguards purposes might continue to exist during decommissioning (as stated in para. 4.31), especially for nuclear fuel cycle facilities, but are outside the scope of this Safety Guide. Those aspects as they relate to nuclear security are addressed in Ref. [25]. More generally, aspects relating to physical protection of sensitive targets, such as targets whose failure could lead to a radiological release to the environment, are of concern.

STRUCTURE

1.26. Section 2 addresses the issues relating to protection of people and protection of the environment, including the application of a graded approach for the whole decommissioning process and optimization of protection and safety. Section 3 describes the responsibilities of the major parties involved in decommissioning. Guidance on the management of decommissioning is provided in Section 4, while Section 5 describes the selection of a decommissioning strategy. Section 6 addresses financing of decommissioning. Planning for decommissioning during all stages of the facility's lifetime is addressed in Section 7. Section 8 describes

[6] Draft nuclear security guidance on security during the lifetime of a nuclear facility is in preparation.

the conduct of decommissioning actions. Section 9 addresses the completion of decommissioning, including surveys and reporting to support termination of the authorization for decommissioning.

1.27. The Appendix provides examples of considerations for safety assessment during decommissioning of facilities. Annex I provides an example of an outline of a final decommissioning plan. Annex II provides an example of the content of a final decommissioning report. Annex III provides an example of the content of a final radiological survey report. Annex IV provides a list of typical supporting documents for the final decommissioning plan. Annex V provides a list of reference publications that contain additional information on specific organizational, financial, technical and safety issues relating to decommissioning.

2. PROTECTION OF PEOPLE AND PROTECTION OF THE ENVIRONMENT

Requirement 1 of GSR Part 6 [1]: Optimization of protection and safety in decommissioning

"Exposure during decommissioning shall be considered to be a planned exposure situation and the relevant requirements of the Basic Safety Standards shall be applied accordingly during decommissioning."

2.1. The principles of radiation protection and safety for radiation sources are provided in GSR Part 3 [3] and IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [26]. During decommissioning, proper protection of workers, the public and the environment against radiation risks is required.

2.2. Arrangements for radiation protection during decommissioning are required to be addressed in the decommissioning plan and have to be based on the national requirements for radiation protection. Optimization of protection is required to be implemented, with account taken of the specifics of the decommissioning project.

2.3. Although the principles and aims of radiation protection during operation and during decommissioning are fundamentally the same, the methods and procedures for implementing radiation protection may differ during decommissioning owing to differences in the physical conditions of the facility,

the need for access to highly activated components or contaminated equipment or areas, and the removal of SSCs. During decommissioning, the principal focus of radiation protection is the protection of workers against occupational radiation exposure in planned exposure situations and emergency exposure situations. Special situations might need to be considered, which might require the use of temporary measures and specialized equipment and the implementation of certain non-routine procedures.

2.4. Proper consideration is required to be given to the protection of workers and the public and protection of the environment against the consequences of incidents that might occur during decommissioning. When appropriate, a system of multiple, independent provisions for protection and safety (defence in depth) that is commensurate with the likelihood and magnitude of potential exposures should be applied. Further requirements and guidance are provided in IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [27] and IAEA Safety Standards Series No. WS-G-5.2, Safety Assessment for the Decommissioning of Facilities Using Radioactive Material [28].

2.5. Cases in which special attention should be paid to the protection of workers include those in which workers have to work in close proximity to contaminated components being dismantled, which could lead to significant exposure or spread of contamination. Special attention should be paid to preventing and reducing the exposure of workers by using specific and appropriate personal protective equipment. Personal protective equipment may need to be tailored to specific work conditions, for example enhancing the resistance of protective gloves to puncture in order to avoid injuries that might result in an intake of radionuclides.

2.6. Incidents that might occur during decommissioning could lead to radiological impacts outside the boundaries of the facility undergoing decommissioning. To protect workers, the public and the environment from exposure due to the spread of radioactive substances, active safety systems such as ventilation systems and fire protection systems might need to be retained for some period during decommissioning or might need to be adapted to the risks present during decommissioning actions. In the case of on-site or off-site contamination, actions might be necessary to remediate the contaminated areas or to prevent the further spread of radioactive substances, for example via contaminated water. Such issues are addressed in other IAEA safety standards [3, 19, 29].

2.7. Remedial actions for the area immediately surrounding a facility that is covered by the operating licence may be part of the decommissioning project when the facility has been permanently shut down after an accident. Decommissioning does not include remedial actions outside the area covered by the operating licence. For areas outside the licensed area that are contaminated owing to a severe accident, remedial actions should be implemented separately from the decommissioning actions inside the licensed part of the site. This is important because decommissioning funds are not collected to remediate areas outside the licensed site. Such remediation should be considered as a separate project. The remediation of small areas outside the licensed part of the site that have been contaminated owing to small leakages during normal operation should be considered part of decommissioning of the facility.

2.8. Special attention should be paid to the removal of emergency provisions that might have been implemented to mitigate the consequences of an accident. Records and data of the nature and extent of such existing emergency provisions should be considered during planning for decommissioning.

2.9. In addition to protection of workers and the public, licensees are required to consider and plan for protection of the environment during decommissioning (para. 2.3 of GSR Part 6 [1]). An environmental impact assessment should be developed concurrently with the final decommissioning plan, consistent with national requirements. As noted in IAEA Safety Standards Series No. GSG-10, Prospective Radiological Environmental Impact Assessment for Facilities and Activities [30], the term 'environmental impact assessment' is included in many international instruments and national legislations and regulations, and refers to a procedure within a governmental decision making process for identifying, describing and assessing prospectively the effects and the risk of effects of a particular proposed activity or facility on aspects of environmental significance.

2.10. Protection of the environment should be ensured during decommissioning and, if necessary through restrictions on the future use of the site, after its completion. Adequate controls should be defined in the authorization for decommissioning and should be subject to approval by the regulatory body to ensure mitigation of significant radiological impacts on the environment, both on the site and in the surrounding area. Specific measures required by the regulatory body on the basis of the environmental impact assessment should be overseen to ensure their implementation by the licensee, depending on the end state described in the final decommissioning plan.

2.11. The licensee should indicate in the environmental impact assessment for decommissioning, which supports the final decommissioning plan, how compliance with applicable requirements for protection of the environment will be ensured, including responsibilities and measures for monitoring, control and surveillance during decommissioning and after its completion, if necessary.

Requirement 2 of GSR Part 6 [1]: Graded approach in decommissioning

"A graded approach shall be applied in all aspects of decommissioning in determining the scope and level of detail for any particular facility, consistent with the magnitude of the possible radiation risks arising from the decommissioning."

2.12. As defined in the IAEA Safety Glossary [31], a graded approach is an application of safety requirements that is commensurate with the characteristics of the facility, activity or source and with the magnitude and likelihood of the exposures. A graded approach should be applied in all aspects of decommissioning in a way that does not compromise safety and the protection of people and the environment, and that ensures compliance with all relevant safety requirements and criteria.

2.13. The application of a graded approach supports the effective use of resources, and helps to optimize efforts devoted to planning, the development of decommissioning documentation, the conduct of supporting analyses and assessments, and the conduct of decommissioning actions, while complying with requirements for safety and environmental protection. The depth of the analyses and the level of detail in the documentation should be commensurate with national regulatory requirements. The factors to be taken into account in applying a graded approach should include, but are not limited to, the following:

— The stage in the lifetime of the facility (siting, design, construction, commissioning, operation, shutdown or decommissioning). Different analyses might be needed for preparation of an initial decommissioning plan at the design stage and for preparation of a final decommissioning plan prior to conduct of decommissioning actions.
— The complexity and the operational history of the facility.
— The physical state of the facility, specifically the integrity of the SSCs, and, in particular, the extent to which ageing or abandoned building structures might have been compromised owing to a lack of adequate maintenance.

— The radiological inventory (source term), biological inventory and chemical inventory and the hazards associated with the decommissioning of the facility.
— The scope of the project (e.g. for a part of a facility, a whole facility, a single facility at a multifacility site or an entire multifacility site) and the extent to which the proposed decommissioning actions could adversely affect ongoing operations with safety significance elsewhere at the facility or at nearby facilities.
— Uncertainty of the information (e.g. information on the quality and extent of the characterization of the facility) and the reliability and availability of relevant supporting information (e.g. drawings and records of modifications) to be used as input data for planning and for the associated safety assessment.
— The complexity of and the risks associated with the planned decommissioning actions.

2.14. Successful decommissioning depends on adequate and organized planning and the systematic conduct of the decommissioning actions in accordance with the licence conditions. The application of a graded approach has an impact throughout the decommissioning project, specifically in the following areas:

— Radiological characterization of the facility (the scope and extent of the efforts applied);
— Documentation (the scope of the final decommissioning plan, its content and the level of detail necessary (including the safety assessment) might differ depending on the complexity and hazard potential of the facility, and should be consistent with national regulatory requirements);
— The licensing process;
— Identification of the SSCs (SSCs already present in the facility or new SSCs) that are necessary for the safe decommissioning of the facility, and specification of the associated safety criteria and associated control requirements;
— Control of decommissioning actions;
— The monitoring programme;
— Determining the overall cost estimate;
— Management of the decommissioning project (e.g. organizational structure); specific guidance on the management of decommissioning is provided in Section 4;
— Staffing and training;
— Regulatory oversight;
— The involvement of interested parties.

Requirement 3 of GSR Part 6 [1]: Assessment of safety for decommissioning

"Safety shall be assessed for all facilities for which decommissioning is planned and for all facilities undergoing decommissioning."

2.15. Decommissioning of facilities is associated with numerous radiological and non-radiological hazards. In addition to existing radiological hazards associated with a permanently shutdown facility, decommissioning actions might create new hazards that need to be considered, for example through the use of cutting tools or the generation of airborne contamination and secondary radioactive waste[7]. Therefore, through planning for decommissioning, those hazards should be adequately assessed and managed.

2.16. Safety assessment is required to be performed to support development of the final decommissioning plan and to support the conduct of associated specific decommissioning actions by demonstrating that safety and the protection of workers and the public are optimized and that exposures do not exceed relevant limits or constraints.

2.17. Depending on the complexity of the decommissioning actions and the duration of the decommissioning project, the final decommissioning plan may be supported by a single overall safety assessment for the entire project, or by a summarized safety assessment that covers the entire project and provides links to a set of more detailed safety assessments developed separately for each decommissioning phase or work package, with due account taken of the interdependences between the different phases.

2.18. The safety assessment should be conducted to define protective measures, optimizing radiation protection with due regard to industrial safety and with account taken of human and organizational factors in accordance with the requirements of GSR Part 4 (Rev. 1) [27] and the recommendations of WS-G-5.2 [28].

2.19. The licensee should adequately control the work of any subcontractors involved in development of the safety assessment. The results of the safety assessment or part of the safety assessment developed by subcontractors, depending on their relevant knowledge and experience in specific

[7] Secondary radioactive waste is a by-product from the processing of primary radioactive waste.

decommissioning techniques, should be reviewed, made subject to approval or acceptance and implemented by the licensee in accordance with the integrated management system. The results of the safety assessment should also be reviewed and made subject to approval by the regulatory body to ensure overall safety during decommissioning.

2.20. The results of the safety assessment will determine which safety functions and related SSCs used in the operational stage will no longer be needed after operation has permanently ceased. However, some of the safety functions will continue to be required during decommissioning, and decommissioning can also give rise to the identification of new safety functions and the commissioning of associated SSCs. The safety assessment should demonstrate consistency among the safety measures during the entire process of decommissioning, and it should be updated when necessary to reflect the ongoing changes in the status of the facility, as decommissioning actions progress.

2.21. The safety assessment should demonstrate that interdependences between planned decommissioning actions are taken into account, and that any negative impacts of one action on another, as well as the possible generation of additional hazards, are properly taken into account.

3. RESPONSIBILITIES ASSOCIATED WITH DECOMMISSIONING

3.1. The decommissioning process for a facility involves several organizations, the key organizations being the government, the regulatory body and the licensee. This section addresses the responsibilities of these three organizations in the planning, conduct and completion of decommissioning of facilities.

Requirement 4 of GSR Part 6 [1]: Responsibilities of the government for decommissioning

"The government shall establish and maintain a governmental, legal and regulatory framework within which all aspects of decommissioning, including management of the resulting radioactive waste, can be planned and carried out safely. This framework shall include a clear allocation of responsibilities, provision of independent regulatory functions and requirements in respect of financial assurance for decommissioning."

3.2. In preparing and implementing the national framework for decommissioning, the government should establish the overall objectives of decommissioning as part of its obligation to establish and maintain a governmental, legal and regulatory framework for all aspects of decommissioning, including management of the resulting radioactive waste. The policy should be developed by the government in cooperation with relevant organizations, including the licensee, and in consultation with the public.

3.3. A framework for regulating decommissioning is required to be established in national legislation. The enabling legislation should be straightforward, feasible and consistent with the relevant national policies, so that the need for its subsequent amendment is minimized.

3.4. Although it is preferable that regulatory responsibilities for decommissioning are held by a single regulatory body, in some States such responsibilities are divided among several bodies already having responsibilities for protection and safety. It should be ensured that the regulation of all aspects of nuclear safety, radiation safety, transport safety, waste safety, industrial safety and environmental safety is covered adequately and that the responsibilities of the governmental bodies involved are clearly specified and assigned. The legislation should establish clear lines of authority and responsibility, so as to avoid gaps or overlaps between different regulatory bodies having responsibilities for decommissioning.

3.5. One of the main responsibilities of the government is to ensure that mechanisms for providing adequate financial resources are put in place, so that an appropriate level of funding is available to decommission facilities in a safe and timely manner.

3.6. If decommissioning has to be performed in a situation for which the government has not established a legal and regulatory framework, for example to address safety issues relating to deteriorating structures, the decommissioning should be planned and managed on a case by case basis in consultation with the regulatory body or regulatory bodies having responsibility for nuclear, radiation, transport, waste, industrial and environmental safety. In such cases, the licensee should consult the regulatory body with regard to the development and implementation of a decommissioning plan.

Requirement 5 of GSR Part 6 [1]: Responsibilities of the regulatory body for decommissioning

"The regulatory body shall regulate all aspects of decommissioning throughout all stages of the facility's lifetime, from initial planning for decommissioning during the siting and design of the facility, to the completion of decommissioning actions and the termination of authorization for decommissioning. The regulatory body shall establish the safety requirements for decommissioning, including requirements for management of the resulting radioactive waste, and shall adopt associated regulations and guides. The regulatory body shall also take actions to ensure that the regulatory requirements are met."

3.7. When developing regulations, the regulatory body should clearly identify the facilities and actions to which regulatory requirements are to be applied. The regulatory body is required to establish safety criteria and regulations for all aspects of decommissioning, including for management of the associated radioactive waste. The regulatory body should oversee the implementation of the criteria and regulations and should control compliance by the licensee with the criteria and regulations for planning for decommissioning, conduct of decommissioning actions and completion of decommissioning, including for termination of the authorization for decommissioning.

3.8. The regulatory body should supplement its regulations with guidance documents, where appropriate, to help the licensee in complying with the safety criteria and regulatory requirements.

3.9. The regulatory body should follow consistent procedures for establishing, revising and revoking regulations and guidance. Interested parties should be involved in the process. The regulatory body should ensure that regulations and guidance are kept up to date and should establish procedures for their periodic review.

3.10. Experience in applying the regulations should be examined and any problems or difficulties that might arise should be duly considered. The status of applicable requirements should also be examined taking into consideration the state of the art of science and technology (e.g. new safety related developments and lessons from decommissioning experience in the State and in other States).

3.11. The regulatory body should develop a process for consideration of applications for an authorization for decommissioning, including the regulatory

review process. This process should identify milestones and decision points and should specify the period of time for the regulatory review. The process could include an acceptance review and a review of the final decommissioning plan and its supporting documents in accordance with national requirements. According to GSR Part 6 [1], para. 7.16, "Interested parties shall be provided with an opportunity to examine the final decommissioning plan and, as appropriate and subject to national regulations, supporting documents, and to provide comments prior to its approval."

3.12. The regulatory body should require notification by the licensee of any significant changes to the planned actions as described in the final decommissioning plan that might have implications for safety of the decommissioning or for the end state of the facility. Such changes should be subject to an assessment by the licensee, with account taken of the nature and potential magnitude of the associated risk. The regulatory body should review this assessment in accordance with national arrangements and should consider amending or renewing the authorization for decommissioning, as appropriate.

3.13. In order for decommissioning to be performed in a safe and efficient manner, the regulatory body should contribute to the definition of a mechanism to provide adequate financial resources to ensure that appropriate funds will be available when necessary.[8] The regulatory body should verify or check the existence of such a mechanism. The financial resources needed and the timeline for the expenditure of the funds should be based on a decommissioning cost estimate prepared by the licensee.

3.14. On-site inspection is one of the elements of the regulatory regime and the regulatory body should allocate adequate resources to this task. The regulatory body should develop an inspection programme based on a graded approach, which should include the following key elements: a system for prioritizing inspections; on-site visits by inspectors; the review of safety assessments made by the licensee; investigation and follow-up of events; and submission of information on compliance with safety criteria by the licensee. The inspection programme could also make reference to the industrial safety programme.

3.15. The regulatory body is required to perform inspections during decommissioning, as stated in para. 8.5 of GSR Part 6 [1]. For that purpose, the regulatory body should establish inspection procedures. The regulatory

[8] The definition of the mechanism to provide adequate financial resources could be the responsibility of other governmental organizations.

body should especially ensure that selected key decommissioning actions are inspected (e.g. dismantling of activated components, removal of large and heavy components), as well as any specific actions involving survey of areas that might be inaccessible in the future (e.g. subsurface areas). Inspections should verify compliance with the safety objectives and criteria defined in the final decommissioning plan, compliance with the results and conclusions of the detailed safety assessment, and compliance with the limits and conditions of the authorization for decommissioning.

3.16. The regulatory body should ensure that the existing enforcement policy, addressing radiation protection and safety, and protection of the environment, covers aspects of decommissioning. The regulatory body should develop and use procedures for determining and exercising enforcement actions.

3.17. The regulatory body should maintain communication with the licensee to determine future decommissioning timelines and schedules, as well as changes in schedules. Knowledge of the timelines of the licensee and changes to schedules will allow the regulatory body to plan its activities and to ensure it has appropriate staffing levels and experience to avoid regulatory related delays in decommissioning.

3.18. The regulatory body should inform the public and other interested parties about the key decisions with regard to decommissioning of facilities for the purpose of transparency and to address public concerns relating to the safety of decommissioning. Information should be provided to interested parties as soon as such information becomes available: see IAEA Safety Standards Series No. SSG-12, Licensing Process for Nuclear Installations [32]. In addition, the regulatory body should communicate proactively and initiate dialogue with the public, and should demonstrate a willingness to listen to and respond to a broad variety of concerns: see IAEA Safety Standards Series No. GSG-6, Communication and Consultation with Interested Parties by the Regulatory Body [33].

3.19. As stated in para. 3.3 of GSR Part 6 [1], the regulatory body is required to establish requirements for ensuring that records important for the planning and implementation of decommissioning actions are collected and retained by the licensee. Certain records developed during the decommissioning project will be important for legal purposes after the facility's licence has been terminated. Such records should be identified and preserved, and the responsibility for their retention should be assigned clearly.

3.20. A strong safety culture is an important part of a decommissioning project, since actions are being performed that might not be routine and specialist personnel might be used to perform some of these actions. Safety culture might suffer under such conditions, and the regulatory body should cooperate with the licensee to maintain a strong safety culture throughout the decommissioning project. In addition, the regulatory body should maintain its own management system and sufficiently trained personnel to be able to fulfil its responsibilities for decommissioning. Requirements on leadership and management and on safety culture are established in IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [34].

Requirement 6 of GSR Part 6 [1]: Responsibilities of the licensee for decommissioning

"The licensee shall plan for decommissioning and shall conduct the decommissioning actions in compliance with the authorization for decommissioning and with requirements derived from the national legal and regulatory framework. The licensee shall be responsible for all aspects of safety, radiation protection and protection of the environment during decommissioning."

3.21. Prior to permanent shutdown of a facility, the licensee should discuss with the regulatory body and should reach agreement on the timing of decommissioning, the proposed decommissioning actions, applicable regulations and guidance, and relevant requests of the regulatory body. It has been demonstrated that early cooperation between the regulatory body and the licensee improves the planning and implementation of decommissioning, and can reduce delays in obtaining regulatory approval.

3.22. In preparing for decommissioning, the licensee might perform activities such as removal of spent fuel and waste that had been stored on the site during operation. Such activities should be carried out in accordance with the current operating licence of the facility to ensure the facility is maintained in a safe configuration during the transition from operation to decommissioning, until the final decommissioning plan is approved for implementation and the authorization for decommissioning is granted.

3.23. The licensee is responsible for ensuring that a sufficient number of trained and qualified workers are available for safely conducting decommissioning actions, for the overall safety performance, for demonstrating that the end state

of the facility ensures compliance with the end state criteria defined in the final decommissioning plan and for retaining decommissioning records, as required.

3.24. The responsibilities of the licensee for decommissioning end with the termination of the authorization for decommissioning by the regulatory body when the end state of decommissioning is achieved. However, for sites released with restrictions on their future use, the responsibility for institutional controls should be assigned to the licensee or to another organization.

3.25. More detailed recommendations on how the licensee should fulfil its responsibilities for decommissioning are provided in Sections 4–9 of this Safety Guide.

4. MANAGEMENT OF DECOMMISSIONING

Requirement 7 of GSR Part 6 [1]: Integrated management system for decommissioning

"The licensee shall ensure that its integrated management system covers all aspects of decommissioning."

4.1. The licensee should implement an appropriate integrated management system before the commencement of decommissioning actions. The management system should extend to all phases of the decommissioning project, including planning for decommissioning and preparatory actions performed during normal operation.

4.2. The requirements for an integrated management system should be applied using a graded approach (e.g. to the decommissioning documents and to the level of detail required). When developing plans and procedures for performing decommissioning tasks, the licensee should take into account safety aspects and the magnitude of risk and should apply resources commensurate with the complexity of the task to be performed, and should determine the oversight actions and define the training necessary to ensure that the tasks will be performed safely.

4.3. The integrated management system provides a single common framework in which decommissioning is undertaken. This framework should include planning

for decommissioning, conduct of decommissioning actions and completion of decommissioning, including management of decommissioning records. General requirements and guidance on the management system are provided in other IAEA safety standards [34–36]. A description of or reference to the management system, including a definition of its scope and intent, should be included in the final decommissioning plan.

4.4. The organizational structure that is to be adopted for decommissioning should define roles, responsibilities, authorities and key personnel of the licensee, including contractors, if applicable.

4.5. A work breakdown structure should be established for the overall management of the decommissioning project. A high level work breakdown structure, describing the decommissioning actions in broad terms, should be included in the final decommissioning plan. A detailed work breakdown structure should describe the project in terms of work packages and individual tasks, including interdependences between tasks.

4.6. Decommissioning of a large and complex facility or decommissioning of a multifacility site might benefit from the application of a phased approach, whereby the overall decommissioning project is divided into phases that are planned and implemented sequentially. In such cases, an overall summary decommissioning plan with supporting documents (i.e. safety assessment, environmental impact assessment) should be developed in advance, covering all the phases of the project, and should be maintained and updated during the implementation of the project. Such a summary plan should describe the phases, their sequence, the major actions in each phase and the interfaces between phases. In addition, each phase should have its own detailed decommissioning plan, supported by a detailed safety assessment and other supporting documents for that phase, which should be approved by the regulatory body before the work in that phase commences. When using a phased approach, a global overview of the entire project should be kept in order to ensure safety through coordination of actions performed in different phases, and to build the confidence of interested parties in the capability of the licensee to achieve the defined end state of the decommissioning project.

4.7. The licensee should develop a safety policy in cooperation with all personnel involved in the decommissioning project. This safety policy should set out the responsibility of all individuals to identify and to bring any safety concerns to the attention of senior management of the decommissioning project. In order to maintain effective management of safety and foster a strong safety

culture in the organization, the licensee should ensure that there is commitment to safety by all individuals, in accordance with the requirements established in GSR Part 2 [34].

4.8. Senior management of the decommissioning project should ensure that the safety policy applies to all individuals, and includes the authority to stop unsatisfactory work, the responsibility to report safety concerns and the requirements for maintaining a safe working environment. The safety policy of the licensee and the behavioural expectations of managers should be visible to individuals at every level of the organization and should extend to other organizations that perform delegated tasks.

4.9. The licensee is required to foster a safety culture to discourage complacency at all levels in the organization [1]. This is particularly important in decommissioning, where the facility's configuration is undergoing continual change. Managers should foster an attitude of willingness to learn in relation to safety matters and should promote the open exchange of information, upwards, downwards and horizontally within the organization.

4.10. The licensee should apply appropriate levels of control and supervision and should provide appropriate training for individuals in all organizations involved in the decommissioning project to ensure a high level of safety performance is maintained, particularly when high hazard tasks are to be performed or when a large number of contractors are engaged.

4.11. Decommissioning actions may involve additional organizations, including contractors and subcontractors who might not be familiar with the facility and the management system of the licensee. The licensee can delegate specific tasks to contractors or subcontractors, but is required to retain overall responsibility for safety [34].

4.12. Responsibilities and interfaces between the different organizations should be specified by the licensee, as the overall responsibility for safety remains with the licensee. As part of the integrated management system, arrangements for the control of contractors and subcontractors should be established, agreed by all organizations involved and recorded.

4.13. Based on an evaluation of the skills and knowledge needed to decommission a facility, a team composed of decommissioning specialists and appropriate site personnel should be formed to manage the decommissioning project. Specialized expertise might be necessary in areas such as:

— Radiological characterization;
— Radiation protection;
— Safety assessment;
— Cost estimation;
— Environmental protection;
— Industrial safety;
— Nuclear security and accounting for and control of nuclear material;
— Emergency preparedness;
— Regulatory and/or licensing expertise;
— Decontamination, dismantling and demolition;
— Robotics and remote handling;
— Predisposal management of waste (e.g. processing, storage and transport of waste);
— Site remediation and landscaping.

Although new skills might be required for decommissioning, attention should also be given to preserving the knowledge of key personnel who are familiar with the facility from its operational stage.

4.14. As decommissioning involves many new actions, which might have new hazards associated with them and were never performed during operation of the facility, the licensee should develop and implement a comprehensive training programme for all personnel involved in the decommissioning project, irrespective of whether former operations personnel are involved or the actions are performed by contractors. The training programme should ensure that a sufficient number of trained and qualified workers are available to safely conduct planned decommissioning actions. The training can be in the form of oral briefings, practical exercises, training lectures or comprehensive training courses.

4.15. When preparing for some decommissioning actions, specialized training might be necessary involving the use of mock-ups, models or computer-based simulations to ensure that the actions can be carried out safely and to incorporate any lessons into the work procedures. Additional refresher training might be necessary for decommissioning actions that are conducted infrequently.

4.16. In some cases, contractors may be used to perform all or some aspects of decommissioning (e.g. planning, conduct, completion of actions). This is likely to be the case if decommissioning occurs after a long period of safe enclosure, or when specialized decommissioning expertise or skills are necessary, such as the use of specific decontamination processes or application of specific dismantling or demolition tools. All personnel involved in decommissioning actions, both the

personnel from the licensee and personnel of the contractors, should be made familiar with the procedures for safe and effective conduct of their duties, in accordance with their specific roles. Thus, all project personnel who will perform decommissioning tasks should receive basic training in radiation protection and safety or should prove they have such knowledge. Additionally, depending on the actions to be performed, relevant personnel should receive specific training in:

— The design and layout of the facility;
— Technical characteristics of the facility and its operational history;
— Planned decommissioning actions and associated procedures;
— The use of personal protective equipment, such as masks and pressurized suits;
— Industrial safety, including hazards present, and the resulting risks and their control;
— Radiation protection;
— Practices and procedures for the management of radioactive material and radioactive waste;
— Emergency preparedness and response.

4.17. Training requirements should be identified, documented and communicated to contractors, and, before a specific decommissioning procedure is applied, it should be demonstrated that the contractor's personnel are adequately trained.

4.18. Different approaches can be used when planning decommissioning actions, which will have an impact on training activities. One example is to work from low hazard areas to higher hazard areas of the facility. This approach might be beneficial if personnel are inexperienced or new techniques or equipment are to be used. From the point of view of training, such an approach permits the gradual development and improvement of decommissioning skills and experience. Another possible approach is to remove the most highly radioactive material first to create a better working environment for subsequent phases of the decommissioning project. This approach might be appropriate when well-tested equipment is to be used or experienced personnel are to perform the decommissioning actions.

4.19. All decommissioning actions should be carried out in accordance with approved work procedures, which should be developed by taking into account the output of the safety assessment (the limits and conditions for safe decommissioning derived on the basis of the safety assessment). The procedures should define how the decommissioning actions are to be performed and, where appropriate, should identify steps to be taken in the event of an abnormal

occurrence. The procedures should be issued and controlled in accordance with the provisions of the integrated management system.

4.20. Decommissioning workers can initiate and should participate in the process of developing work procedures. The knowledge and experience of personnel involved in decommissioning should be utilized when drafting work procedures, and any learning and improvements coming from inactive trials (i.e. testing of a technique or tool in a radiologically clean environment) and from previous decommissioning actions should be incorporated into the work procedures. Experience from the operation of the facility (e.g. from the planning of maintenance or from annual outages) might be useful when planning decommissioning.

4.21. Each work procedure should be sufficiently detailed such that a qualified individual is able to perform the required actions. Consideration should be given to the layout of the area, the general design of the facility, staffing requirements and decommissioning experience at the facility. Procedures should be developed in accordance with established requirements and recommendations of the integrated management system.

4.22. To ensure consistency in format and content, work procedures should be prepared in accordance with the administrative procedure that governs the development, review and control of such documents, including a provision for periodic review. A mechanism should be established to verify that any work procedure has been approved (e.g. by means of signatures) and that it is current (e.g. through a list of the most recent dates of revision).

4.23. The approval process for the work procedures should be commensurate with the requirements of the authorization for decommissioning. Persons with appropriate competence and experience should be designated to prepare, review and approve the procedures. In order to develop safe, reliable and effective work procedures, human factors should be taken into account.

4.24. Administrative procedures used in the operational stage of the facility might be relevant for decommissioning. However, these procedures should be reviewed and modified as necessary to ensure that they are appropriate for the decommissioning actions that will be undertaken. All procedures, as well as their revisions and changes, should be subject to approval by the licensee to ensure that the decommissioning actions will be performed safely and that the work is integrated into the overall decommissioning work plan and schedule.

4.25. The administrative procedures should identify the permanent and temporary records on decommissioning and should identify records to be retained and archived, consistent with the licensee's plan for records management. When a strategy of deferred dismantling is adopted, records should be periodically checked to confirm that they are being preserved in a safe and retrievable media and format. Records can include the facility's logbooks and video footage and photographs to aid future decommissioning of the facility and to aid future training. Preferably, more than one copy of key records should be kept in different locations.

4.26. Periodic briefings adapted to the complexity of the decommissioning actions should be performed, as these are an integral part of the control of decommissioning actions. They give an opportunity for the work supervisor to check the workers' understanding of the scope of actions to be undertaken and their understanding of related decommissioning limits and conditions (the set of rules and parameters for safe decommissioning). The periodic review of decommissioning actions helps to identify key opportunities for learning, including the review of relevant experience from the conduct of similar actions in other projects or facilities.

4.27. If the licensee changes after permanent shutdown of the facility or during decommissioning, procedures are required to be put in place to ensure the transfer of responsibilities for decommissioning to the new licensee [1]. Such transfer of responsibilities should be controlled and understood, as the licensee maintains responsibility for safety and for compliance with the licence conditions [34–36]. The new licensee responsible for decommissioning should have qualified managers and technical expertise to manage the decommissioning project and should have sufficient financial resources to carry out safe decommissioning of the facility.

4.28. The configuration management process should be capable of managing a high rate of changes to the facility and the associated records, including drawings. The objective of the configuration management process is to keep records and procedures consistent with the current physical status of the facility at any time.

4.29. At the completion of decommissioning, the final decommissioning report is prepared, which should document the end state of decommissioning of the facility and should provide reference to the decommissioning records, typically including radiological surveys, effluent and environmental monitoring, personnel monitoring, and types and volumes of waste generated, as well as the destination

of waste removed from the facility. More details on the final decommissioning report are provided in Section 9 of this Safety Guide.

4.30. Reports relevant to the implementation and completion of decommissioning should be prepared and submitted to the regulatory body in accordance with the requirements for reporting specified in national regulations, in the authorization for decommissioning or in the final decommissioning plan.

4.31. Requirements pertaining to nuclear security and accounting for and control of nuclear material will normally be reduced during decommissioning as nuclear and radioactive material is removed from the facility. The requirements relating to site access and to nuclear security should be commensurate with the site conditions and with the security threats present [20–22]. In the case of deferred dismantling, nuclear security requirements will remain in effect through the entire project, including throughout the safe enclosure period.

5. DECOMMISSIONING STRATEGY

Requirement 8 of GSR Part 6 [1]: Selecting a decommissioning strategy

"The licensee shall select a decommissioning strategy that will form the basis for the planning for decommissioning. The strategy shall be consistent with the national policy on the management of radioactive waste."

5.1. The overall purpose of a decommissioning strategy is to serve as a basis for the decommissioning plan, and, in turn, to facilitate achieving the end state of the decommissioning project.

5.2. In principle, two possible decommissioning strategies are applicable: immediate dismantling and deferred dismantling. These strategies are defined in GSR Part 6 [1]. Generally, immediate dismantling is the preferred strategy, as it avoids transferring the burden of decommissioning to future generations. The immediate dismantling strategy should be understood as immediate and complete dismantling in a timely manner, with no delay in decommissioning. There might be situations in which immediate dismantling is not a practicable strategy when all relevant factors are considered and the deferred dismantling option would be the most suitable option. An example might be when one unit at a multiunit plant

ceases operation and decommissioning of this first unit has to wait for operations to cease at another unit, because of common systems used by multiple units. Release from regulatory control without restrictions should be the preferred end state and ultimate objective of decommissioning. No action (leaving the facility after operation as it is, and waiting for decay of the radioactive inventory) and entombment (encasing all or part of the facility in a structurally long lived material) are not acceptable decommissioning strategies.

5.3. The selection of a decommissioning strategy follows an iterative process. The selection of the decommissioning strategy should be based on an analysis of various options, which may lead to selecting a combined strategy that consists of some degree of immediate dismantling actions, followed by a preservation of the remaining parts of the facility, which are then dismantled after a period of safe enclosure. Such a combined strategy can include the early dismantling of some parts of the facility, usually externally accessible areas and auxiliary systems, while other parts (e.g. the reactor core) are placed in a state of safe enclosure. A preferred decommissioning strategy for a particular facility should be proposed by the licensee when developing the initial decommissioning plan, in coordination with the regulatory body. It should be reviewed and updated during the lifetime of the facility and, as appropriate, confirmed by the licensee when the decision to permanently shut down the facility is taken.

5.4. The selection of a decommissioning strategy should take into account the principles of radiation protection, namely justification, optimization and application of dose limits [3]. Justification for the selection of a particular decommissioning strategy is required in order to demonstrate the advantages of the selection made and the reasons for its choice, especially if deferred dismantling is selected, as the selection of this strategy implies to some extent a transfer of responsibilities for decommissioning to future generations. Any strategy that involves waiting periods should be justified in terms of safety, management of the decommissioning waste and radiation protection.

5.5. In accordance with the selected strategy, the final decommissioning plan should describe the timing and sequencing of decommissioning actions, and should describe how safety and protection of workers and the public and protection of the environment will be optimized.

5.6. Decommissioning, whether based on an immediate dismantling strategy or a deferred dismantling strategy, should commence shortly after permanent shutdown of the facility. Any transition period between permanent shutdown and approval of the final decommissioning plan should be as short as possible, and

should be managed under the operating licence. Some preparatory actions for decommissioning could begin during the transition period. However, care should be taken to ensure that decommissioning funds are not used to perform tasks that have not been considered in the decommissioning plan and in the related cost estimate (typical examples are the removal of waste from operation, the removal of spent fuel, or the disposition of excess experimental equipment at a research reactor).

5.7. The main factors influencing the selection of the decommissioning strategy include:

— The national policy and the regulatory framework;
— The type of facility and interdependences with other facilities or infrastructure located at the same site;
— Proposed reuse of the facility or site and the desired end state;
— The physical status (e.g. ageing components and structures) and the radiological status of the facility;
— Safety and nuclear security aspects;
— The availability of expertise (knowledge, skills and experience), technologies and infrastructure (tools, equipment, supporting facilities and services);
— The environmental impact of the facility and of its decommissioning;
— Societal and economic factors and the socioeconomic impact of decommissioning;
— The availability of infrastructure for radioactive waste management, including facilities for pretreatment, treatment, conditioning and storage of waste, as well as existing or anticipated waste disposal options;
— The availability of financial resources for decommissioning.

More detailed considerations relating to factors that influence the decommissioning strategy are provided in paras 5.19–5.42.

5.8. As described in Section 6 of this Safety Guide, the financial arrangements for decommissioning should be established early in the lifetime of the facility to enable safe decommissioning in a timely and efficient manner. Thus, for facilities that have carried out proper and early planning for decommissioning, a deferred dismantling strategy cannot generally be justified on the basis of poor financial planning or a lack of financial resources. For existing facilities, a lack of financial resources could be a real concern if the economic situation has changed significantly, for example owing to political decisions, or if proper

financial planning was not carried out. In this case, deferred dismantling should be considered until funds can be accumulated or obtained.

5.9. When updating the decommissioning plan, the licensee should check whether the decommissioning strategy is still appropriate. Relevant updates of the final decommissioning plan and supporting safety documentation (e.g. the safety assessment for decommissioning) during the conduct of decommissioning should reflect the progress of the work, the continual management and removal of the waste generated and the evolution of the radiological status and the physical status of the facility, in order to demonstrate that a safe configuration is maintained at all times and that the decommissioning project is still aligned with the decommissioning strategy selected.

5.10. For a multifacility site, a strategy for decommissioning of the site as a whole should be developed in order to identify and evaluate the interdependences between the facilities on the site, both those in operation and those permanently shut down. This site strategy for decommissioning should be used as a basis for the selection of individual decommissioning strategies for individual facilities on the site, and for development of the facilities' decommissioning plans. Each individual decommissioning strategy should be consistent with the site strategy for decommissioning, and should properly accommodate interfaces between the facilities. These interdependences should be detailed in the individual final decommissioning plans for each facility. The site strategy for decommissioning should be made available to the regulatory body as required or upon request.

5.11. The site strategy for decommissioning, reflected in the individual decommissioning plans for each facility on the site, should identify opportunities for synergies between individual decommissioning projects in order to optimize resources and efforts, and to use supporting facilities optimally. Site considerations that impact the selection of an individual decommissioning strategy and the development of the decommissioning plan for a facility located on a multifacility site include the following:

— A general approach to decommission first those facilities having the highest priority in terms of safety, waste management and radiation protection, prior to those facilities with lower priority issues, with consideration given to ageing and obsolescence of SSCs.
— A decision to decommission first the less contaminated or activated facilities and buildings, prior to the more contaminated facilities and buildings, to allow benefit to be gained from experience and from radioactive decay.

— The optimization of decommissioning actions, and their sequence, across the site by using pooled resources and skills as appropriate to avoid underutilization of workers (this might not be applicable in case of multiple owners or licensees on a multifacility site).
— Coordination of the use of specialized contractors and subcontractors, as appropriate, with account taken of the availability of the best qualified personnel, equipment and infrastructure at a given time, in accordance with the decommissioning schedule for each individual facility.
— Establishment of common facilities providing support for the predisposal management of radioactive waste (i.e. its processing, storage and removal from the site) and coordination of the use of such common facilities for different decommissioning projects on the site. This might require a revision of facilities' boundaries to allow the allocation of buildings, equipment and infrastructure for waste management tasks.
— The optimization of discharges of gaseous and liquid effluents from individual operating facilities and facilities undergoing decommissioning in accordance with the authorization for discharges approved by the regulatory body for the entire site.
— The need to use a consistent approach for final remedial actions and to apply consistent criteria across the entire site for release of the site from regulatory control, irrespective of whether the release from regulatory control is done in parts, after completion of each individual decommissioning project, or at once, after completion of the last decommissioning project on the site.

5.12. A licensee in charge of several decommissioning projects for different facilities at different sites in the same State could develop an overall decommissioning strategy (a corporate strategy) in order to optimize the decommissioning projects of individual facilities and related solutions for the management of radioactive waste.

5.13. Unforeseen permanent shutdown could occur during operation of a facility for financial, technical or political reasons. In such cases, the timing of the decision to permanently shut down the facility might not have been anticipated by the licensee. Consequently, a review of the preferred decommissioning strategy might be necessary on the basis of the situation that initiated the unforeseen shutdown, in order to evaluate whether a revision of the decommissioning strategy is necessary.

5.14. Unforeseen permanent shutdown of a facility might also be the result of an accident. In this case, the first objective is to bring the facility into a safe state before reviewing the decommissioning strategy and reviewing or implementing

any final decommissioning plan. The recovery actions undertaken are precursors to decommissioning actions, and the consequences of the recovery actions should be addressed in the final decommissioning plan. In selecting recovery actions, account should be taken of their consequences for decommissioning.

5.15. After a safe state has been achieved after an accident at a facility, a comprehensive survey of the physical and radiological conditions of the facility should be performed to determine if the selected decommissioning strategy is still feasible. When developing the final decommissioning plan after an accident, special attention should be given to the physical and radiological conditions of the facility, considering that it might be impossible to repair damaged SSCs, even if an acceptable safe state has been reached.

5.16. Incidents or accidents could lead to a spread of contamination outside the buildings of the facility, implying the need to implement remedial actions on the site where the facility is located. Such actions within the licensed part of the site are usually considered a part of the overall decommissioning of the facility. The extent of the on-site contamination might necessitate a change in the previously selected strategy and the end state, as well as the establishment of a long term decommissioning plan and remediation plan. Removal of contamination outside the licensed part of the site that has arisen as a consequence of an accident is addressed in IAEA Safety Standards Series No. WS-G-3.1, Remediation Process for Areas Affected by Past Activities and Accidents [19].

5.17. Entombment, in which all or part of the facility is encased in a structurally long lived material, should not be considered an acceptable strategy for planned decommissioning. It might be considered as a last option for managing facilities that have been damaged in an accident, if other options are not possible owing to high exposures of workers or technical difficulties.

5.18. Even under exceptional circumstances, the choice of entombment might lead to technical and regulatory difficulties, owing to a lack of specific regulations and guidance in the State and a lack of acceptability of entombment. Additionally, the intention to apply entombment might not be accepted by the public. In this context, all efforts should be made to reduce the parts of the facility that will be subject to entombment and to reduce to the extent possible the radioactive inventory that will be encased on the site, especially the long lived radionuclides. Entombment actions should not reduce the technical feasibility of surveillance and maintenance of the remaining barriers. If entombment is selected, it will impose a burden on future generations owing to the need for long term monitoring

of the site and owing to possible future actions necessary to prevent and reduce leakages of radioactive material from the facility.

FACTORS INFLUENCING THE SELECTION OF A DECOMMISSIONING STRATEGY

The national policy and the regulatory framework

5.19. The national policy on management of radioactive waste, which should include decommissioning aspects, may influence the choice of possible decommissioning strategies or combinations of options. For example, some decommissioning strategies might be excluded for political reasons or other non-technical reasons. Such policy requirements might be established for particular types of facility and might not apply universally to all the different types of facility in the State (e.g. nuclear power plants, research reactors and nuclear fuel cycle facilities).

The type of facility and interdependences with other facilities or infrastructure located at the same site

5.20. There may be different considerations relating to the selection of a decommissioning strategy for a facility depending on its type, size and complexity, the actions performed during operation of the facility, the residual inventory of radionuclides, the location of the facility and its relation and interdependences with other facilities on the same site.

5.21. The type of the facility to be decommissioned, its past functions and the extent of remediation necessary (e.g. soil or sediment, surface water and groundwater) might have a major impact on the selection of the decommissioning strategy for the facility. The decommissioning strategy for a particular facility should also take into account the characteristics of the site on which the facility is located. The capabilities of other facilities, if present on the site either in operation or shut down, could be used, as well as the experience of personnel of other such facilities. Such considerations might affect the options available for selection of a decommissioning strategy. Additionally, the location of the facility might pose challenges to decommissioning. For example, a facility might be located on a site on which many complex nuclear facilities are present, or a research reactor could be located in an operating medical facility or in a university campus.

5.22. When selecting a decommissioning strategy where more than one facility is located on a site, it might be beneficial to define an overall decommissioning strategy for the site. This might involve deferring dismantling of facilities already permanently shut down until the remaining facilities are permanently shut down. Then the decommissioning of all facilities could be performed in a single campaign, thereby avoiding any negative impact on the operating facilities and allowing for better utilization of personnel.

Proposed reuse of the facility or site and the desired end state

5.23. There might be a request for the reuse of part of the site or the entire site, or for the reuse of existing building structures after completion of decommissioning. The time frame for such reuse of the site, either restricted or unrestricted, is an important consideration for the selection of a decommissioning strategy. If the site is intended for construction of a new facility in the near future, such a request might influence the choice of the decommissioning strategy as it might give preference to immediate dismantling in order to start decommissioning actions as soon as possible after permanent shutdown.

5.24. In case of the decommissioning of a research reactor, very often the desired objective is reuse of all or part of the former reactor building for other, non-radiological purposes, particularly in a medical facility or in a university. In such cases, the desired end state would be decontamination of the existing building structures to a level suitable for the new use, and usually such an end state would be required to be achieved within several years. Taking into account only this aspect, the preferred decommissioning strategy in this case would be immediate dismantling.

5.25. There might be other aspects that simplify the selection of a decommissioning strategy for a facility or eliminate some strategies from consideration. For example, the availability of waste management routes, public opinion or the expectation that the facility should be decommissioned within a short period of time and the site released from regulatory control, might also give priority to the strategy of immediate dismantling.

The physical status and the radiological status of the facility

5.26. The diversity of types of nuclear facility makes characterization of the facility a critical step in the process of selecting a decommissioning strategy because the results of characterization are used in defining the scope of the proposed project.

5.27. The physical status and the radiological status of the facility at the end of its operational stage should be considered when selecting the decommissioning strategy.

5.28. The extent of contamination will depend greatly on the operational history (including past operating practices and events), and on the age and type of the facility. The age and type of the facility will have influenced the types of material used in construction, which in turn results in different levels and types of contamination in the facility.

5.29. The integrity and the condition of the buildings and the SSCs should be assessed at the end of the operational stage from the perspective of decommissioning needs. If necessary, buildings and SSCs should be secured and maintained for the time frame of the decommissioning project. If this cannot be accomplished and further restrengthening of the facility or the SSCs is not possible, immediate dismantling actions should be undertaken. Additionally, new safety systems might be necessary to ensure safety during decommissioning. Such aspects should also be taken into account when selecting the decommissioning strategy.

5.30. If a deferred dismantling strategy is selected, it should be verified (at the end of the operational stage) that after the safe enclosure period has ended, an assessment of the radiological status of the facility will be possible (i.e. through measurements) prior to starting decontamination and dismantling actions.

5.31. Depending on the activation and contamination levels within a facility and the related composition of radionuclides, the selection of the decommissioning strategy might have an impact on the radiation exposure of workers and the public and on the environment. High radiation levels might make deferred dismantling a more appropriate strategy by allowing radiation levels to decrease over time. When no benefit from radioactive decay is expected in a reasonable time, immediate dismantling is the preferred strategy.

Safety aspects

5.32. When selecting a decommissioning strategy, the licensee should consider the results of safety reviews performed during the operation of the facility. The results of conformity checks and reassessment should be addressed and analysed to confirm that the preferred decommissioning strategy is still applicable. When the decision to permanently shut down a facility is a result of such a periodic

safety review process, the weaknesses identified through the safety review should be considered carefully from the perspective of decommissioning.

5.33. The technical feasibility of the dismantling actions should be assessed in order to ensure that the preferred decommissioning strategy can be implemented safely, considering any modifications to the facility and changes in the design that might have been undertaken during operation and, in the case of deferred dismantling, considering the state of the facility at the end of the safe enclosure period. In the case of deferred dismantling, safety should be maintained during the entire safe enclosure period.

Availability of expertise, technologies and infrastructure

5.34. The availability and utilization of institutional knowledge (e.g. documentation of the operational history and/or retention and utilization of key personnel familiar with site specific conditions) should be considered in choosing a decommissioning strategy. Such documentation and expertise could decrease the potential for events, such as industrial accidents or undue exposures, and might help to reduce problems associated with loss of corporate (institutional) memory. The availability of personnel with operational knowledge is beneficial, in particular for the planning of dismantling actions, and therefore this might be an argument in favour of immediate dismantling.

5.35. The availability of existing systems and infrastructure (e.g. air supplies, ventilation systems, overhead cranes) and considerations on their ageing might make immediate dismantling advantageous, as such systems and infrastructure might require maintenance or recertification at a later time.

Environmental impact and socioeconomic impact

5.36. When the impact on the local economy is an important issue, immediate dismantling might be the preferred strategy because this could reduce the immediate negative societal effect by continuing to provide employment for the local workforce.

5.37. For most facilities, the number of employees (both directly employed at the facility and employed in the local community providing services to the facility and to its employees) will generally be lower during decommissioning than during operation of the facility. If deferred dismantling is selected as the strategy, the workforce will be reduced considerably during the safe enclosure period, and then increase again during later dismantling.

5.38. The environment around the facility could have changed since the building was constructed. An example might be a change in environmental conditions, such as an increase in the population surrounding the facility, that might make deferred dismantling unfeasible. Another example might be increased potential for erosion of a coastline where the facility is located.

Availability of infrastructure for radioactive waste management

5.39. Aspects of waste generation and waste management can have an impact on the selection of a decommissioning strategy. Some of the most important aspects are:

(a) The national policy for radioactive waste management (e.g. a policy in which release of material and waste from regulatory control is the preferred approach);
(b) The types, categories and amount of waste at the facility (including remaining waste from operation);
(c) The availability of waste processing facilities or infrastructure for all types of radioactive waste;
(d) Arrangements for the transport of radioactive waste;
(e) The availability of storage capacity for the waste;
(f) The availability of a disposal option.

5.40. If on-site or external waste processing facilities and storage facilities are available, then either immediate dismantling or deferred dismantling is a viable decommissioning strategy. If the waste management infrastructure is available, including for waste disposal, then immediate dismantling is the preferred strategy. In the absence of facilities and infrastructure for processing radioactive waste, or when storage or disposal capacities are not available, the preferred decommissioning strategy could include a period of safe enclosure until the necessary waste management infrastructure is available.

5.41. If the waste management infrastructure is not available when decommissioning is anticipated, efforts should be made to synchronize the timing of the development of the waste management infrastructure with the anticipated timing of decommissioning. Where this is not possible, the licensee should consider alternative options in order to facilitate implementation of the preferred decommissioning strategy.

5.42. The description above of the individual factors affecting the choice of decommissioning strategy includes some statements about a preferred

decommissioning strategy for a particular factor in order to provide examples. However, the selection of the preferred strategy for a particular facility will have to consider and balance all the factors together, rather than considering each factor in isolation.

6. FINANCING OF DECOMMISSIONING

Requirement 9 of GSR Part 6 [1]: Financing of decommissioning

"Responsibilities in respect of financial provisions for decommissioning shall be set out in national legislation. These provisions shall include establishing a mechanism to provide adequate financial resources and to ensure that they are available when necessary, for ensuring safe decommissioning."

6.1. Responsibilities for financing of decommissioning and a mechanism to provide adequate financial resources for the safe decommissioning of facilities should be in place prior to the start of operation of the facility.

6.2. Financial resources for decommissioning should be consistent with the chosen decommissioning strategy and with decommissioning actions described in the decommissioning plan. Necessary financial resources should be determined based on a cost estimate for decommissioning.

6.3. Typical costs associated with decommissioning include costs for the following:

(a) Decommissioning planning, including initial decommissioning planning prior to the start of operation of the facility, periodic updating of the decommissioning plan, preparation of the final decommissioning plan during transition from operation to decommissioning, application for and approval of an authorization for decommissioning and the detailed planning necessary for conduct of decommissioning actions;
(b) Pre-decommissioning actions, including actions performed during the transition phase, such as radiological characterization, post-operational decontamination of the facility's systems and training of personnel for decommissioning including setting up of mock-up facilities;

(c) Decommissioning actions, as described in the decommissioning plan, such as decontamination, dismantling of SSCs, demolition of buildings and structures, steps in the management of decommissioning waste that are defined as part of the decommissioning project, refurbishment of existing systems necessary to support decommissioning and replacement or commissioning of new systems necessary for decommissioning;
(d) Actions after termination of the authorization for decommissioning, such as monitoring in case of release of the facility with restrictions, preparation of the final decommissioning documentation and archival storage of decommissioning records, ongoing handling and processing of waste after completion of decommissioning, and temporary storage of waste and its subsequent disposal.

6.4. The cost estimate for decommissioning is one of the key supporting documents to the decommissioning plan and should be prepared by the licensee or by a specialized contractor. The first cost estimate should be performed in support of the initial decommissioning plan, and it should be revised and updated together with the revisions and updates of the decommissioning plan.

6.5. The cost estimate for decommissioning should cover all actions required to plan and perform the decommissioning. There will be additional costs for other actions, which might be included as part of the decommissioning, depending on the national legal framework. These typically include financing for the management of waste from operation, pre-decommissioning actions during the transition phase, waste storage and disposal, and spent fuel management.

6.6. The decommissioning cost estimate should distinguish between operating expenses and decommissioning expenses. A clear distinction should be made between actions for which the decommissioning fund can be used and the actions that are to be paid for from other funds, especially during transition.

6.7. The latest available versions of the decommissioning plan and its supporting documents should be used as a basis for preparation of the cost estimate. The level of detail of the data needed and used for the cost estimate, and the accuracy of the estimate, will vary depending on the stage in the lifetime of the facility and depending on the level of detail provided in each revision of the decommissioning plan.

6.8. With regard to the accuracy and associated uncertainties of the decommissioning cost estimate, there are typically three types of cost estimate made during the lifetime of the facility:

— An order of magnitude estimate — this type of cost estimate can be utilized prior to receiving the operating licence and is based on the initial decommissioning plan.
— A budgetary estimate — this type of cost estimate is based on the data provided in revisions of the decommissioning plan.
— A definitive estimate — this type of cost estimate can be utilized after the completion of detailed planning of the decommissioning actions, and is based on the data provided in the final decommissioning plan and in the associated working level documentation (procedures).

6.9. Responsibility for preparation of the cost estimate and its updates should reside with the licensee, but the work might be done by a contractor. An entity independent of the licensee should be involved in the preparation of the cost estimate or in its review to provide a third party or independent perspective of the approach and the reasonableness of the cost estimate, in accordance with the national regulatory framework.

6.10. Cost estimates and financial provisions should be reviewed periodically and should be adjusted as necessary to allow for proper consideration of inflation and other factors, such as technological advances, waste management costs or regulatory changes, especially in the case of a deferred dismantling strategy where decommissioning might be completed only decades after shutdown of the facility. The occurrence of incidents leading to spillage or inadvertent release of radioactive material should also prompt updating of the cost estimate.

6.11. Mechanisms to provide financial assurance might include insurance, trust funds, surety-bonds, prepayments or other financial guarantees, for example internal or external funds. A combination of these methods can also be utilized. Many research reactors are State owned, and thus the State budget covers the costs for decommissioning. In any case, financial provisions are required to be in place prior to approval of the issue of a licence, a licence renewal or a licence extension for the operation of the facility.

6.12. The mechanism by which financial assurance is guaranteed should be sufficiently robust so that it will withstand changes in government (for government owned and financed facilities), changes in ownership of a private company (especially following sale of the company to a party that resides outside

the State) or changes within financial institutions (where financial assurance is guaranteed, e.g. by a bond secured by a financial institution).

6.13. In the case of decommissioning after an accident, after the completion of the recovery actions when the facility is brought to a safe condition, a revised cost estimate should be made based on the reassessment of the selected decommissioning strategy and in accordance with the final decommissioning plan.

6.14. If the end state of a decommissioning project is the release of the facility or site from regulatory control with restrictions, the financial provisions have to include costs associated with the long term monitoring, surveillance and implementation of the defined restrictions to ensure all the necessary controls remain effective and long term safety is maintained for the entire period of time when these controls are necessary.

6.15. If spent fuel storage facilities or radioactive waste storage facilities remain on the site after the end of decommissioning, they should be licensed as new operating facilities. The decommissioning fund should not be used for operational costs of such new facilities for waste or spent fuel management.

7. PLANNING FOR DECOMMISSIONING DURING THE LIFETIME OF THE FACILITY

Requirement 10 of GSR Part 6 [1]: Planning for decommissioning

"The licensee shall prepare a decommissioning plan and shall maintain it throughout the lifetime of the facility, in accordance with the requirements of the regulatory body, in order to show that decommissioning can be accomplished safely to meet the defined end state."

7.1. As stated in para. 7.3 of GSR Part 6 [1], planning for decommissioning is required to start at the design stage and to continue throughout the lifetime of a facility. This approach will facilitate the conduct of decommissioning; optimize protection of decommissioning workers, the public and the environment; minimize the generation of radioactive waste; and enable proper estimation of decommissioning costs.

7.2. For a given facility, the degree of detail in the decommissioning plan will increase significantly from the initial decommissioning plan to the final decommissioning plan. The decommissioning plan should be prepared on the basis of the selected decommissioning strategy and should be submitted to the regulatory body for approval, in accordance with the national regulatory framework.

7.3. Decommissioning should be facilitated by planning and preparatory work undertaken throughout the entire lifetime of the facility. Figure 1 illustrates

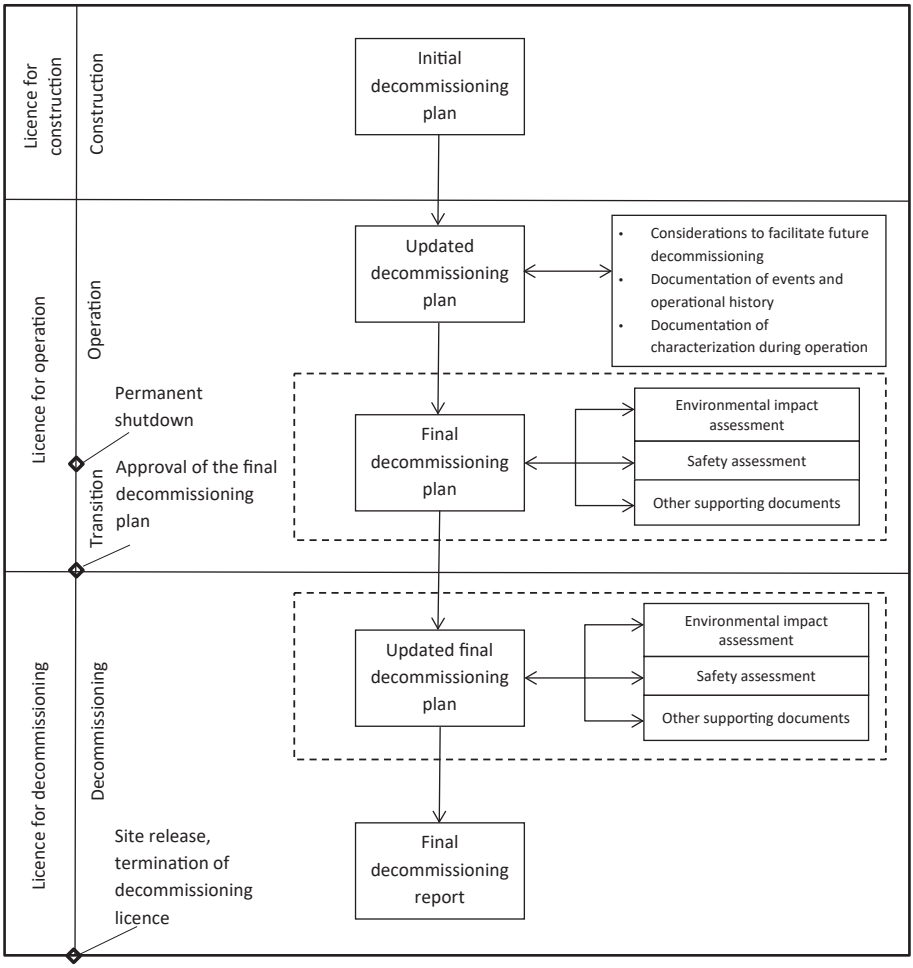

FIG. 1. An example of the evolution of the decommissioning plan during the lifetime of a facility.

the relationship between the lifetime of the facility and the evolution of the decommissioning plan. The decommissioning plan should be periodically reviewed and updated. Aspects of the decommissioning plan to be considered during the lifetime of the facility, as well as aspects relating to unforeseen shutdown, are described in later parts of this section.

7.4. For many older existing facilities, decommissioning might not have been considered at the design stage or during construction and subsequent operation. For such facilities, planning for decommissioning is required to start as early as possible once the deficiency has been recognized. Furthermore, in addition to planning for decommissioning, possible modifications to buildings and systems during the remaining operating lifetime should be used to incorporate features that will facilitate decommissioning, such as the use of components made of materials resistant to activation, the introduction of purification systems to reduce the spread of contamination and the creation of access points for easier decontamination of hot cells.

CONSIDERATIONS DURING DESIGN AND CONSTRUCTION

7.5. At the design stage of a new facility, the designer or the licensee should ensure that decommissioning considerations are taken into account prior to application to the regulatory body for a design certification or for a construction license. The initial decommissioning plan is required to be prepared during the design stage and is required to be submitted to the regulatory body together with the application for an operating licence.

7.6. Relevant features and aspects that should be considered during the design stage of a facility to facilitate decommissioning, and which should not reduce but might enhance the safe operation and maintenance of the facility, include the following:

(a) Minimization of the number and size of contaminated areas to facilitate decontamination during decommissioning;
(b) Facilitation of access to SSCs, including compartmentalization of processes (e.g. through incorporation of hatches and large doors);
(c) Minimization of underground piping and of embedded pipes in the building structures (e.g. through the use of pipe trenches and pipe sleeves);
(d) Use of modular construction in order to facilitate the dismantling of SSCs;
(e) Separation and isolation of non-radioactive and radioactive components and systems, such as separation of electrical and mechanical components;

(f) Facilitation of the removal and/or decontamination of material or equipment, including by means of built-in decontamination mechanisms, such as protective coverings and liners in process cells and areas where liquids might be present;
(g) Use of materials that are resistant to activation, that are resistant to degradation by chemicals and that have sufficient wear resistance to minimize the spread of activated corrosion products;
(h) Design of the facility to avoid undesired accumulations of chemical or radioactive material, and utilization of processes for minimizing and/or reducing the volume of waste generated;
(i) Enabling of remote decontamination, maintenance and monitoring, where necessary;
(j) Enabling waste from operation or temporarily stored waste to be easily retrieved;
(k) Minimization of the use of hazardous substances that could result in mixed hazardous and radioactive waste;
(l) Consideration of the provision of defence in depth measures to reduce the risk of inadvertent releases of radioactive material;
(m) Identification of and reservation of locations for new facilities that might support decommissioning (i.e. new waste management facilities);
(n) Consideration of provisions for the installation of 'test coupons' to facilitate the radiological characterization of SSCs.

7.7. During construction, or at the latest before the commencement of initial operation of the facility, samples of radiologically clean (non-activated and non-contaminated) construction materials (e.g. concrete, steel, graphite or aluminium) should be collected and kept to enable the determination of relevant background levels of radiation (such as the concentration of naturally occurring radionuclides in the construction materials) and the conduct of chemical analyses in support of activation studies.

7.8. A baseline radiological site survey should be planned and performed for the proposed site of the planned facility and its surrounding area to establish background concentration levels of radionuclides of natural and artificial origin for use in assessing the future impact of the facility. The licensee should identify the key radionuclides and the media (e.g. soil and sediment or surface water and groundwater) to be sampled and measured, so the results can be used for:

(a) Future evaluation of the impact of the facility on the site and the surrounding area from its operation;

(b) Establishment of end state criteria and demonstration of compliance with the proposed end state.

If a pre-construction background survey was not performed for the site, survey data from an undisturbed area with similar characteristics or results of a survey of similar building materials should be used.

7.9. The background data should be updated prior to the commissioning of any new facility or the construction of additional buildings and structures on an existing site, including an evaluation of naturally occurring radionuclides in building materials, to maintain the possibility of termination of the authorization for decommissioning in the future without the need to demolish buildings or structures.

INITIAL DECOMMISSIONING PLAN

7.10. The early development of an initial decommissioning plan ensures that decommissioning has been considered in the design of the facility. The initial decommissioning plan will be limited in detail, because it will be based on experience from previous projects and assumptions, which need to be validated at a later time (see paras 7.11–7.19). The initial decommissioning plan is required to be submitted by the licensee to the regulatory body in support of the licence application or authorization for operating the facility. The initial decommissioning plan:

(a) Should preferably be based on the immediate dismantling strategy; however, a deferred dismantling strategy for individual facilities might be considered, such as in the case of a multifacility site;
(b) Should include a generic feasibility study of decommissioning, based on the selected decommissioning strategy, which should consider design provisions and operating experience for facilitating decommissioning, including the proposed end state (preferably release without restrictions), related key decommissioning actions and basic safety issues;
(c) Should include a schedule for major decommissioning actions;
(d) Should include the approach for management of radioactive waste, and should provide initial identification of waste classes and an initial estimate of waste quantities;
(e) Should provide a basis for a preliminary cost estimate of the decommissioning project and should specify the means to ensure financial provisions for the decommissioning;

(f) Should demonstrate that the decommissioning can be performed in a safe manner.

UPDATING OF THE DECOMMISSIONING PLAN

7.11. As stated in para. 7.5 of GSR Part 6 [1], the decommissioning plan is required to be updated by the licensee and is required to be reviewed by the regulatory body periodically (typically every five years or as prescribed by the regulatory body), or when specific circumstances warrant. Other reasons that might necessitate updating of the decommissioning plan include:

(a) Design or process modifications;
(b) Changes in financial conditions, funding assurance or funding requirements;
(c) Changes to relevant regulatory or safety requirements and criteria, e.g. radiation protection standards or environmental protection standards;
(d) A change of the selected decommissioning strategy and/or the planned end state;
(e) Commissioning of a radioactive waste disposal facility and availability of waste acceptance requirements or criteria for disposal;
(f) Feedback from operating and decommissioning experience, and technological developments;
(g) Extension of the facility's operating period;
(h) Changes in contractors and/or suppliers;
(i) Incidents, events or situations with relevant consequences for decommissioning, such as changes in the estimation of the radiological inventory.

7.12. Updates of the decommissioning plan will become more reliable and will be based on actual operating experience and data as the facility approaches the end of its operating life.

7.13. Waste management should be addressed either as a part of the decommissioning plan or as a stand-alone document that is referenced and summarized in the decommissioning plan. Information about the waste management approach that will be applied should be included. This approach might be the same as the waste management approach used during operation of the facility (see paras 8.34–8.43).

7.14. Experience from decommissioning projects has indicated that a lack of attention to documentation and record keeping could result in safety problems

and in a costly misallocation of resources. Records from all the stages of the lifetime of the facility (including siting, design, construction, commissioning, operation and decommissioning) that are of importance for the planning and conduct of decommissioning should be identified, preserved and made available when necessary. The process of developing the initial decommissioning plan, updating the decommissioning plan and preparing the final decommissioning plan should use pertinent records to ensure safety and to enhance efficiency in the decommissioning of the facility. These records should include:

(a) Records of the history of the facility, including:
   — Design specifications and information from siting and construction, including as-built drawings, photographs, diagrams of piping and cable penetrations and other details helpful for decommissioning purposes;
   — Fuel failures and records from accounting for and control of nuclear material;
   — Criticality safety records (see IAEA Safety Standards Series No. SSG-27, Criticality Safety in the Handling of Fissile Material [37]);
   — Use of chemicals and their inventories;
   — Incidents leading to spillage or inadvertent release of radioactive material, including information about actions, corrective measures and the termination of such events;
   — Radiation survey data and contamination survey data (i.e. the radionuclide inventory and its distribution throughout the facility, particularly for areas of the facility that are rarely accessed or especially difficult to access);
   — Releases and leaks that could have affected surface water, groundwater, soil and sediment;
   — Waste storage locations and/or waste disposal locations.
(b) Records of modifications to the facility and experience from maintenance works, including:
   — Updated as-built drawings, videos and photographs, including details of the materials used;
   — As-built drawings and background samples for added buildings;
   — Special repair or maintenance actions and techniques (e.g. effective temporary shielding arrangements or techniques for the removal of large components);
   — Details of the design, the composition of added materials, and the history and location of all temporary experiments and devices.

7.15. During the facility's operation, records should be retained as appropriate to meet the needs of future decommissioning and as dictated by national requirements. In the case of a deferred dismantling strategy, where long periods of

storage of records are anticipated prior to final dismantling and site remediation, records should be periodically checked to confirm that they are being preserved in a safe and retrievable media and format.

7.16. During the operation of the facility, radioactive waste from operation should be properly managed and removed from the premises of the facility to dedicated disposal facilities, to the extent practicable, to simplify the transition to decommissioning. If this is not the case, the updates to the decommissioning plan should take into account the management of waste from operation as part of decommissioning.

7.17. The transition from operation to decommissioning starts after permanent shutdown of the facility. The transition period should be as short as practicable. The end of the transition period is defined by the date on which the authorization for decommissioning is granted or by the date of approval of the final decommissioning plan.

7.18. During the transition period, the facility is subject to the operating licence. All applicable operational requirements on the facility remain in place, unless the regulatory body has agreed to reductions of the requirements on the basis of a reduction of the hazards, for example through the removal of radioactive waste or spent nuclear fuel from the facility.

7.19. Some activities preparatory to decommissioning may be carried out after permanent shutdown of the facility under the operating licence, such as management of waste from operation and management of residual materials (including drainage of systems and removal of combustible materials to reduce the fire loads), characterization of the facility, removal of spent nuclear fuel, modification of the facility and preparation of systems to support decommissioning, and preliminary decontamination of the facility's systems (as part of the post-operational clean-up).

THE FINAL DECOMMISSIONING PLAN

Requirement 11 of GSR Part 6 [1]: Final decommissioning plan

"Prior to the conduct of decommissioning actions, a final decommissioning plan[3] shall be prepared and shall be submitted to the regulatory body for approval."

"[3] The final decommissioning plan is that version of the decommissioning plan submitted for approval to the regulatory body prior to implementation of the plan. During implementation of this final plan, revisions or amendments may subsequently be needed as the activity progresses."

7.20. As stated in para. 7.9 of GSR Part 6 [1], the licensee is required to inform the regulatory body (or the government, if so required) prior to shutting down a facility permanently. The licensee should also inform the regulatory body about its intention to decommission the facility. Additionally, at this time or at the latest during the transition from operation to decommissioning, the licensee should initiate studies to support development of the final decommissioning plan. These studies should identify the systems, equipment and infrastructure from the operational stage that will need to be maintained for use during decommissioning, and should specify, and if necessary research, any new systems, equipment and infrastructure that will need to be installed to support decommissioning.

7.21. For large or complex decommissioning projects, the final decommissioning plan is likely to be supported by additional documents (such as a waste management plan, a safety assessment and an emergency plan). For small or simple decommissioning projects, the final decommissioning plan could be a stand-alone document that incorporates most of the supporting information, although usually an emergency plan and a security plan are requested as separate documents even for simple projects. A graded approach should be applied with regard to the content of the final decommissioning plan and its supporting documents, so that the information provided is adequate to document and demonstrate safety of the proposed decommissioning actions.

7.22. A safety assessment is a key supporting document to the final decommissioning plan. The licensee is required to prepare this document and submit it for review to the regulatory body in accordance with national regulatory framework. The scope of the safety assessment, its content and the degree of detail may vary depending on the complexity and hazard potential of the facility.

7.23. Before submission of the final decommissioning plan and the safety assessment to the regulatory body, these and other selected supporting documents (see Annexes I–IV for examples) should be subjected to an internal independent review performed by the licensee. The purpose of this independent review is to provide confidence that the proposed tasks are feasible and that suitable and sufficient safety controls have been identified.

7.24. Characterization surveys should be performed by the licensee to support the development of the final decommissioning plan. Outcomes of these characterization surveys should be expressed in terms of activation and contamination maps of the SSCs, rooms, buildings and land areas around the facility, as applicable.

7.25. Some information from activities in older facilities might not have been documented, particularly information concerning unusual events. It may be useful to interview senior staff or even staff who have already retired, to access their experience and knowledge concerning past events. This will be valuable to supplement the characterization of the facility.

7.26. Results and maps might be available from surveys that were performed during the operational period of the facility. However, such maps might need to be updated to take into account radioactive decay, the in-growth of progeny products and previous decontamination actions. Furthermore, such maps should show the results of any special surveys conducted to determine the penetration depth of contamination or activation in structures, soil and sediments and the extent of radioactivity. For completeness, contamination in shielded or self-shielded components, such as inside pipes and other equipment, should be determined to the extent possible.

7.27. Radiological characterization data should include a description of the site area (e.g. the premises of the facility, the surrounding environment, ground and surface water, soil and sediments), contamination levels, dose rate levels, and chemical and physical forms of material. Characterization surveys should also identify adjacent uncontaminated zones. During planning of decommissioning actions, special attention should be given to preventing cross contamination of such zones. Radiological characterization of the facility should comprehensively describe contamination levels and activation levels.

7.28. If radioactive material or waste from operation remains at the facility (including in subsurface soils and groundwater), this radioactive material will have to be included in the characterization survey. Special attention should be

given to the inventory of disused radioactive sources and the storage of packages with unknown and uncharacterized radioactive material. Existing storage areas for liquid radioactive waste are also of importance for decommissioning, as removal and processing of this type of waste might require considering also the physical and chemical status, as well as the design life of related storage tanks. Additional characterization of the site to evaluate the potential for migration of radionuclides should be considered.

7.29. When preparing the decommissioning plan, experience from ongoing or completed decommissioning projects of similar facilities should be utilized.

7.30. The final decommissioning plan should be a living document, to be updated to reflect the current status of the facility and the ongoing progress of the project. The final decommissioning plan should be supported by a safety assessment, which covers all phases of the decommissioning project.

7.31. Some phases of decommissioning could be conducted in parallel, in accordance with the final decommissioning plan. The success of the implementation of a phased approach is linked to the definition of clear objectives for specific phases. The final decommissioning plan should define the starting point and end point of each phase.

7.32. Where decommissioning of a facility is to take place in discrete phases, an interim report should be prepared when each planned phase is completed. The report should describe the physical condition of the facility, as well as the remaining hazards.

7.33. In some decommissioning projects it might be advantageous to remove large components in one piece (e.g. steam generators from nuclear power plants) for storage and processing outside the facility's building or to transport them to another facility away from the site for further segmentation, treatment and conditioning. In such cases, this should be reflected in the decommissioning plan and the relevant safety issues should be addressed (e.g. transport safety).

7.34. Experience has shown that in most cases it is possible to utilize 'off the shelf' dismantling techniques that are commercially available. In such cases, time does not need to be dedicated to research studies for development of new tools and techniques.

7.35. The introduction of new techniques might require specific analysis to assess the suitability and the safety of the new technique or equipment and to implement

adequate controls, and also might require additional training of personnel. Such training should start during planning for the use of the new technique, to provide feedback to the planning process. It should be used to confirm basic assumptions and the inputs to the safety assessment, to identify related components and equipment important to safety and to develop working procedures, administrative procedures and engineering procedures. Specialist training on particular SSCs might be necessary. There might also be a need to use mock-ups for practice if new, high dose rate or difficult actions are to be performed.

7.36. Decommissioning waste is required to be disposed of in appropriate waste disposal facilities, subject to their availability. Large and complex decommissioning projects will require radioactive waste management facilities for the processing and storage of decommissioning waste. Such temporary facilities should be planned as part of the decommissioning planning effort and can be commissioned under the authorization for decommissioning or under separate licences issued by the regulatory body.

7.37. While the bulk of the radioactive waste from nuclear power plants will be low level radioactive waste, a small percentage will be intermediate level waste with a very high contact dose rate, requiring shielded packages for safe storage. Such shielded packages might not be required for storage of radioactive waste from other types of nuclear fuel cycle facility.

7.38. Criticality safety is required to be considered:

(a) In the plans for decommissioning of nuclear power plants and research reactors, if spent fuel assemblies are still located in the facility;
(b) In the plans for decommissioning of nuclear fuel cycle facilities and facilities for management of spent nuclear fuel;
(c) In the assessment of the safety of planned actions involving fissile material;
(d) In the design of waste packages and waste storage facilities for fissile material.

7.39. In case of a deferred dismantling strategy, preparation for safe enclosure requires specification of the safe enclosure area that will be preserved for the deferral period. The boundaries of the buildings, premises and equipment concerned; the physical status and radiological status of the facility to be reached before commencing the period of safe enclosure; and the safety systems (passive systems should be preferred, but active systems might sometimes also be appropriate) that will remain in operation to ensure safe preservation, should all be defined.

7.40. Preparatory actions for safe enclosure should be supported by characterization surveys and by a safety assessment to demonstrate that the work to be done (e.g. removal of waste, removal from service and/or dismantling of unnecessary SSCs, decontamination) can be performed safely. The deferral period (safe enclosure period) should, furthermore, be supported by a safety assessment to demonstrate that the barriers of the safe enclosure area can withstand internal and external events that might occur during the period of safe enclosure.

7.41. A surveillance and maintenance plan for the safe enclosure period should be developed on the basis of the outcomes of the safety assessment. The safety assessment for the deferred dismantling strategy should be the basis of identification of the safety functions and the safety parameters (e.g. confinement, shielding, temperature, humidity, level of discharges to the environment) that should be provided and maintained by the means described in the surveillance and maintenance plan. The possibility of corrosion and brittle fracture of materials, as well as ageing and obsolescence of materials (spare parts) should be considered carefully. During the safe enclosure period the licensee should perform a review of the safety of the facility as a whole at regular intervals, to demonstrate that it continues to be in its expected condition.

7.42. Near the end of the safe enclosure period, the final decommissioning plan should be updated and supported by an appropriate safety assessment for the final dismantling phase. This safety assessment should be equivalent to the safety assessment for a decommissioning project based on an immediate dismantling strategy. The update should consider additional preparatory actions that will be necessary to reopen the facility in order to commence dismantling actions.

7.43. As the decommissioning project is undertaken, there might be modifications to the planned decommissioning actions based on new data, unexpected events, experience feedback and other factors. The final decommissioning plan and the related supporting documentation may therefore need to be updated during its implementation as the decommissioning actions progress. These updates might require further approval by the regulatory body. The final decommissioning plan should describe a change control process through which minor changes to actions described in the final decommissioning plan are permitted without the need to seek approval by the regulatory body. The impact of updates to the final decommissioning plan on the environmental impact assessment should also be considered. The environmental impact assessment should be updated when a previously unconsidered potential environmental impact is identified.

PUBLIC INVOLVEMENT

7.44. In accordance with paras 7.16 and 9.6 of GSR Part 6 [1], interested parties are required to be involved in the licensing process for decommissioning, as well as in the process for termination of the authorization for decommissioning, and are required to be given an opportunity to provide comments before decisions are taken by the regulatory body and prior to the granting or termination of an authorization for decommissioning.

7.45. Experience has shown that interested parties mainly focus their attention on the selected decommissioning strategy and its justification, the nature and extent of planned dismantling actions, the management and long term storage of radioactive waste on the site, the facility's end state, especially in the case of restricted reuse, the financial management of the decommissioning fund and the socioeconomic impacts of the decommissioning.

7.46. Public inquiries or consultations should be organized by the regulatory body with participation of the licensee to provide an opportunity for interested parties to give comments on the final decommissioning plan and appropriate supporting documents, in accordance with national regulations [33]. Such inquiries should be held primarily with the local communities from the area of the facility to be decommissioned. It is good practice for the licensee to establish and support public outreach programmes, independent of the regulatory body, to provide opportunities for community involvement and to enhance public understanding of and trust in the decommissioning approach and process.

7.47. The results of the public inquiries and consultations of interested parties should be made public to show how the comments have been addressed by the regulatory body during the licensing process for decommissioning, if applicable.

UNANTICIPATED PERMANENT SHUTDOWN

7.48. If the permanent shutdown of a facility is unanticipated, owing to political, economic or social demands, or owing to an accident, the facility is required to be brought to a safe condition by the licensee under an appropriate licence, until an approved final decommissioning plan can be implemented.

7.49. The selection of the decommissioning strategy is required to be reviewed taking into consideration the cause and consequences of the event that resulted in premature permanent shutdown, especially the effect of the event on the condition

of the facility. If any actions are required to place a facility into a safe condition as a result of the unanticipated permanent shutdown, such actions should preferably be undertaken under the operating licence or under an amended operating licence that covers these actions.

7.50. An unanticipated shutdown might occur during operation when a final decommissioning plan and its supporting documents are not available yet. In such a case, the final decommissioning plan and supporting documents are required to be prepared as soon as possible. This task should normally be performed by the licensee, but in case of unplanned shutdown owing to an accident it might be transferred to another organization that takes over the responsibility for decommissioning.

7.51. In case of an unanticipated shutdown owing to an accident, the facility should be brought to a safe condition by applying emergency measures and recovery (stabilization) actions. After the emergency phase is over, information should be collected as soon as possible about the radiological status and physical status of the facility and the final decommissioning plan should be developed, which should take into account damage caused by the accident.

7.52. Planning for the decommissioning of a facility damaged by an accident will involve an extensive update of the characterization surveys previously performed. If accessibility to parts of the facility has deteriorated as a result of the accident, increased use of remote handling equipment for the decommissioning might be foreseen. Special attention should be paid to the removal of emergency provisions that might have been implemented to mitigate the consequences of the accident. Records and data of the nature and extent of such existing safety provisions should be considered during planning for decommissioning.

7.53. The decommissioning process for a facility damaged by an accident should follow the same principles and main steps as for decommissioning of a facility with a normal operational history. Technical challenges are likely to be larger, owing to high dose rates and contamination levels, higher uncertainties of information about the physical and radiological status of the facility and possible new categories of waste, and especially owing to the presence of large amounts of unstructured material and waste. Overall, such technical challenges might lead to selection of a deferred dismantling strategy. Nevertheless, decommissioning of such a facility should be planned and should be considered as an authorized activity that should, in principle, comply with the same set of safety criteria as decommissioning after normal operation and planned shutdown. In the case of a severe accident, the decommissioning plan of such a facility should be consistent

and coordinated with the decommissioning strategy for the site as a whole, and with the strategy for off-site remediation.

8. CONDUCT OF DECOMMISSIONING ACTIONS

Requirement 12 of GSR Part 6 [1]: Conduct of decommissioning actions

"The licensee shall implement the final decommissioning plan, including management of radioactive waste, in compliance with national regulations."

8.1. Conduct of decommissioning involves implementation of the decommissioning strategy and related actions, as described in the final decommissioning plan.

8.2. Modifications of the existing infrastructure of the facility might be necessary to facilitate immediate dismantling or, in some cases, to prepare the facility for a period of safe enclosure. The main modifications might involve:

— Modification or substitution of SSCs that are important for ensuring safety during decommissioning, such as ventilation systems and containment systems;
— Isolation and removal of SSCs that are not needed for decommissioning, such as criticality detection systems in the case where the facility has been verified to be free of fissile material;
— Establishment of new access routes and transport routes for personnel, equipment and waste to and from the facility;
— Installation of additional equipment, such as remotely operated equipment for size reduction and waste handling equipment;
— Establishment of an on-site waste storage area.

8.3. The preliminary removal of excess radioactive material and the decontamination of process equipment should be carried out as early as possible. These steps are advantageous in reducing the radiation risks posed, because, in the case of some nuclear fuel cycle facilities, a significant amount of radioactive contamination or nuclear material might remain in the process equipment of the facility after its permanent shutdown. If this is performed successfully,

the hazard (such as criticality or high dose rates) can be reduced or removed from consideration in the safety assessment for the decommissioning actions. This allows more flexibility in how the decommissioning of the facility will be undertaken. For example, it allows for reduction of the amount of liquid used for decontamination, allows for removal of the operational SSCs associated with the hazard (i.e. criticality detection and alarm systems) or minimizes the potential for cross contamination of redundant equipment.

8.4. Consideration should be given to the early removal, confinement or immobilization of any remaining loose contamination, where practicable, as this reduces the challenge posed to the ventilation system (the possibility of its contamination) and the exposure of workers undertaking the decommissioning actions. Records of such actions should be kept, including the level of residual contamination.

8.5. If the licensee adopts a deferred dismantling strategy, safe configuration of the facility is required to be maintained and records should be periodically checked to confirm that they are being preserved in a safe and retrievable media format. For a deferred dismantling strategy, the main modifications to the facility could involve:

— Establishment of physical protection measures;
— Establishment of barriers to isolate the safe enclosure area;
— Isolation and removal of SSCs that are not needed;
— Establishment of alternative SSCs (preferably passive SSCs);
— Creation of storage areas for equipment, materials and waste.

8.6. At the end of the preparatory phase for safe enclosure, the regulatory body should perform an inspection to verify that the facility is in the state as planned and approved (i.e. it is ready for the passive safe enclosure period).

8.7. If actions for decontamination and dismantling are deferred in part or as a whole, the licensee is required to ensure the safety of the facility through an approved monitoring, surveillance and maintenance programme. In the review of the systems required to support the deferred dismantling strategy, the SSCs that are not required should be identified, so that the surveillance and maintenance carried out on these systems can be reduced or terminated.

8.8. A surveillance and maintenance programme for the safe enclosure period should be prepared prior to commencement of this period and should be made subject to approval by the regulatory body. The programme should set out the

type and periodicity of the surveillance and maintenance actions, and should reference the procedures to be used.

8.9. There are many techniques and methods available for decommissioning. It is preferable to select proven techniques that are commercially available and technically mature. The available techniques to be deployed to carry out the decommissioning actions should be evaluated to confirm their feasibility and suitability, in accordance with the final decommissioning plan. The following factors might influence the choice of the decommissioning techniques to be deployed:

— The potential impact on workers and the environment; for example, preference should be given to techniques that do not generate high levels of airborne radioactivity or techniques that avoid exposing workers to high dose rates through the use of remote handling equipment or robotics;
— A cost–benefit analysis comparing the radiological benefits and waste management benefits of the decommissioning techniques with the expected overall costs;
— The availability of suitable waste containers, routes and facilities for storage and disposal;
— The types and physical properties (e.g. the size, shape and accessibility) of the redundant equipment and structures to be dismantled;
— Maturity of the technology that will be deployed for the decommissioning actions and the time frame for development of new technologies;
— Reliability of the dismantling equipment and tools and simplicity of their operation, decontamination and maintenance;
— The impact on adjacent systems and structures and on other work in progress within the facility;
— Time and schedule constraints, such as the availability of waste processing facilities;
— Requirements for special resources and training, such as resources for and training on the use of remotely operated equipment;
— The generation of secondary radioactive waste from decontamination actions;
— The potential impact on workers and the environment arising from the presence of hazardous and non-radioactive contaminants.

8.10. In some cases, special tools and equipment might be necessary or standard tools and equipment might need to be used in special conditions. Equipment should be tested in simulated conditions before its use, from the points of view of both its safe operability and its maintainability. Benefits can be derived from

computer-based simulations, providing the necessary benchmarking has been performed, as well as from physical mock-ups, in order to select decommissioning techniques, to evaluate options, to aid in the design and to train workers.

8.11. SSCs to which little attention has been given, or to which access has been limited during the operational stage of the facility, might have suffered degradation. Such systems should be given special consideration when decommissioning techniques are considered. Examples of this include storage tanks for liquid radioactive waste and remote handling systems.

8.12. Decommissioning of a facility might be aided in certain instances by partial or total decontamination of the equipment and SSCs to be dismantled. Decontamination can be applied to internal or external surfaces and covers a broad range of actions directed at the removal or reduction of radioactive contamination in or on equipment and SSCs of the facility. Given this, the process of decontamination associated with the decommissioning actions can be conducted before, during or after dismantling. Before any decontamination technique is selected, an evaluation of its effectiveness, of the potential for reducing total exposure, and of the benefit in terms of generation of waste and effluents should be performed. The decontamination process should also be evaluated to ensure it is compatible with waste processing systems as well as storage and/or disposal options. The main objectives of decontamination include:

— To reduce the internal and external exposure of workers during decommissioning actions;
— To minimize the volume and to decrease (lower) the class of the radioactive waste;
— To increase the opportunities for recycling and reuse of components, equipment or structures of the facility.

8.13. As the decommissioning actions progress, new hazards[9] might emerge. Decommissioning workers should highlight any such new hazards at daily briefings and feedback sessions. New hazards should be addressed properly, so as to maintain overall safety of the decommissioning actions undertaken.

8.14. A primary output from the decommissioning safety assessment is the identification of SSCs important to safety in accordance with a graded approach.

[9] For example, new hazards might arise during size reduction using a diamond wire system, where sharp edges are generated, and a number of additional control measures might need to be adopted, such as the application of protective covers.

The SSCs provide the means for the prevention, detection, control and limitation of events and the mitigation of the potential consequences.

8.15. The development and updating of the list of SSCs important to safety should be based on the design of the existing facility, the presence of the infrastructure of the facility to enable decommissioning and the safety assessment concerning the decommissioning actions. The SSCs from the operational stage of the facility might be required to facilitate decommissioning, and the condition of these SSCs should be evaluated in accordance with the safety assessment for decommissioning. The evaluation should take the following into account:

— The condition of the SSCs;
— The extent of inspection, monitoring and maintenance of the SSCs during operation;
— The requirement for the SSCs to perform a safety function during decommissioning;
— The expected duration of the decommissioning actions.

8.16. Areas that should be covered in the assessment include:

— Evaluation of the existing structures of the facility for stability and structural capability;
— Evaluation of the confinement capability of the existing infrastructure of the facility, including tanks, vessels, piping and ventilation ducting;
— Adequacy and integrity of the existing facility's infrastructure required for decommissioning, including electrical distribution systems;
— Availability and adequacy of the support systems for the existing SSCs, including alarm systems (especially for fire, radiation and contamination), lighting systems and ventilation systems;
— Interfaces with other facilities with regard to processes and infrastructure, in the case of a multifacility site.

8.17. Decommissioning actions might involve the deliberate removal of SSCs that fulfilled specific safety functions during operation of the facility (e.g. confinement, shielding, ventilation and cooling). Such actions should be recorded and aligned with the ongoing decommissioning phases, work packages and tasks identified in the final decommissioning plan.

8.18. Removal from service of such SSCs is a key issue in decommissioning, and a decision to remove SSCs from service should be carefully assessed by the licensee before it is implemented. A good practice is to establish a list of

SSCs important to safety in decommissioning and to update this list in line with the ongoing decommissioning actions. This information can be used to update the facility's inspection programme, surveillance programme and maintenance programme.

8.19. During decommissioning, radioactive and non-radioactive effluents will be generated. The discharge of radioactive effluents requires authorization from the regulatory body and control in compliance with appropriate national regulations. The expected discharges of effluents during decommissioning might be in a different form and with a different radionuclide composition than the discharges during operation. It is typical for effluent discharges to vary through the different phases of decommissioning. For example, as decommissioning leads to a progressive reduction of radiological hazards, radioactive discharges might decrease.

8.20. In some instances, decommissioning actions might result in elevated discharges for a limited period of time. Hence, the authorization for discharges in decommissioning should be revised as appropriate. An example of this occurs when a reactor undergoing decommissioning is part of a site with other operating facilities. The authorizations for discharges for the reactor and for the entire site should then be reviewed and revised as appropriate, taking into consideration the decommissioning actions to be undertaken. Guidance for the development and implementation of an environmental monitoring programme can be found in IAEA Safety Standards Series No. RS-G-1.8, Environmental and Source Monitoring for Purposes of Radiation Protection [38].

8.21. Depending on the end state of the decommissioning project, demolition of the remaining structures of the former facility might be required. In many cases, the decommissioning actions are aimed at ensuring that the demolition of the building structures does not involve exposure to radiation. Where building structures to be demolished are contaminated, radiation protection considerations should be addressed. In such cases, specific techniques such as water spraying and the use of local containment systems should be applied to reduce the exposure of decommissioning workers and the impact on the environment. Care should be exercised during demolition to ensure that contaminated material is segregated from non-contaminated material and from non-radiological hazardous materials.

8.22. During decommissioning, records should be maintained of key decommissioning actions. Such records include information concerning the quantities and types of radionuclides remaining at the facility, their location and distribution, and the volume of radioactive waste generated. Such records

could be used to demonstrate that all radioactive material that was present at the beginning of decommissioning has been properly accounted for and that its final disposition (e.g. restricted reuse or disposal) has been identified and confirmed. Documentation should also take into account material, structures and land that have been removed from regulatory control. Such documentation should be prepared by the licensee and provided to the regulatory body as part of the final decommissioning report.

REGULATORY OVERSIGHT DURING CONDUCT OF DECOMMISSIONING ACTIONS

8.23. The regulatory body's inspection programme for a facility undergoing decommissioning should follow a graded approach. The decommissioning inspection programme should be commensurate with the decommissioning actions and the associated hazards. Relevant guidance is provided in IAEA Safety Standards Series No. GSG-13, Functions and Processes of the Regulatory Body for Safety [39].

8.24. During periods of intensive decommissioning actions, regulatory oversight should be performed by individuals with appropriate competence, with focus on safety and potential risks, and should be coordinated to coincide with conduct of actions that have high potential safety implications, such as movement of or reduction in size of large components. Inspections in this period might focus on topics such as exposures of workers, environmental protection, contamination control, control of movement of nuclear material, industrial safety, transport of radioactive waste, and the radiological condition of areas that might not be easily accessible at a later time during decommissioning.

8.25. If a deferred dismantling strategy is chosen, the frequency and scope of inspections may be reduced during a period of safe enclosure. Inspections during the period of safe enclosure should focus on surveillance and preservation of the facility (e.g. preventing degradation that might result in loss of control of material and the spread of contamination), adequacy of record keeping, site monitoring and surveillance and radiation protection.

8.26. Regulatory oversight is required to be performed by the regulatory body throughout the entire lifetime of the facility, including the phase in which decommissioning actions are conducted. The frequency and scope of inspections should be established to be consistent with associated risks and hazards, and the operator's ability to deal with the tasks involved in the relevant decommissioning

phase. In some cases, regulatory oversight might continue after the completion of decommissioning and termination of the authorization for decommissioning, for example in the case of restricted release of the site.

8.27. Depending on the nature and extent of the decommissioning actions to be performed, regulatory oversight should focus on the preparation and conduct of actions having a significant impact on safety and being of public concern.

8.28. In conducting decommissioning, the licensee can implement internal procedures to allow minor modifications of decontamination and dismantling techniques that do not have an adverse effect on safety. Such procedures are required to be subject to approval by those parts of the licensee's organization responsible for ensuring safety. Such procedures should be subject to oversight by the regulatory body prior to and during their implementation, in accordance with national requirements.

EMERGENCY ARRANGEMENTS

Requirement 13 of GSR Part 6 [1]: Emergency response arrangements for decommissioning

"Emergency response arrangements for decommissioning, commensurate with the hazards, shall be established and maintained, and events significant to safety shall be reported to the regulatory body in a timely manner."

8.29. Prior to the decommissioning of a facility, there is usually an emergency plan in place for the facility during its operation, or for the whole site where the facility is located, as required by IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [29]. A review of this emergency plan should be made before commencement of decommissioning actions, to ensure it is adequate for decommissioning (in some cases new organizations might be involved, and new possible emergency situations and/or security threats and vulnerabilities might become relevant). If an emergency plan does not exist, an emergency plan should be developed commensurate with the magnitude and likelihood of potential exposures and risks posed by the facility.

8.30. Hazards should be reassessed to identify those that are applicable for decommissioning, and emergency arrangements should be revised accordingly.

A range of postulated events should be identified and emergency plans and procedures to deal with them should be developed, in accordance with the requirements of GSR Part 7 [29]. Examples of such an event could be a loss of confinement function or a dropped waste package, either within the facility or on transfer to a storage facility or disposal site.

8.31. The licensee is required to ensure that adequate resources, including personnel, equipment, means for communication, logistical support and emergency response facilities, are available and that procedures, coordination and organization are in place in accordance with the approved emergency plan. Personnel should be qualified, trained in emergency procedures and fit for duty, and consideration should be given to the need for the periodic review and updating of these procedures by means of regular exercises.

8.32. The emergency plan and related procedures should cover on-site response and, where necessary, off-site response, including the timely notification of appropriate off-site authorities (the government, the regulatory body and support organizations) and the public.

8.33. Guidance for emergency preparedness and response is provided in IAEA Safety Standards Series No. GS-G-2.1, Arrangements for Preparedness for a Nuclear or Radiological Emergency [40] and IAEA Safety Standards Series No. GSG-2, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency [41].

RADIOACTIVE WASTE MANAGEMENT

Requirement 14 of GSR Part 6 [1]: Radioactive waste management in decommissioning

“Radioactive waste shall be managed for all waste streams in decommissioning.”

8.34. Decommissioning of nuclear power plants, research reactors and other nuclear fuel cycle facilities invariably involves the generation of large amounts of material and waste in forms that might be different from the material and the waste categories routinely handled during the operational stage of the facility. A waste management plan that covers all the anticipated decommissioning waste streams and waste categories should be developed. The waste management plan should define the manner by which material and radioactive waste will

be removed from the facility and the means for segregating radioactive waste from non-radioactive and hazardous waste. The waste management plan for decommissioning should be part of the decommissioning plan.

8.35. If existing waste processing systems cannot cope with the waste generated during decommissioning with respect to the volumes or types of waste expected, the construction of new facilities for storage or waste processing or the use of existing facilities for storage should be considered. Such considerations should take place in the framework of updating the initial decommissioning plan. Consideration should also be given to minimizing cross contamination of waste and materials, and minimizing the generation of secondary waste, which might require additional storage or processing capacities on the site. A separate authorization for such activities might be required by the regulatory body.

8.36. In general, an update of the existing waste management plan for the operational stage of the facility should be performed, with consideration given to the additional materials and waste categories associated with the decommissioning. The waste management plan should anticipate periods in which the processing of high volumes of waste will be necessary and should propose means of minimizing any impacts of such waste processing on the decommissioning actions or the operations of other facilities at a multifacility site. The licensee should ensure that the waste management plan for decommissioning is implemented and maintained.

8.37. Waste generated in decommissioning should be segregated into different categories (radioactive waste and non-radioactive waste, hazardous waste and non-hazardous waste), in accordance with accepted procedures and criteria. Specific plans for the reuse, recycling, storage or disposal of the waste should be developed. Such plans should aim to minimize the volume of waste to be disposed of as radioactive waste, facilitate future downstream processing of the waste and reduce overall costs. The proper determination and documentation of the characteristics of the waste form, the waste container and/or the waste package should be ensured to provide data necessary for future management of the waste (e.g. for its disposal).

8.38. Decisions on the processing of radioactive waste generated in decommissioning should take into account existing or anticipated options for waste disposal.

8.39. Verification of the waste characteristics and waste packages should be based on procedures that typically include direct measurements on the material,

laboratory measurements of representative samples, the use of properly derived radionuclide vectors (e.g. scaling factors, and correlations between difficult to measure radionuclides and easy to measure radionuclides) and adequate identification of the waste origin.

8.40. Transport of radioactive waste from the facility to the processing, storage or disposal facilities has to conform to national transport regulations. The requirements for the transport of radioactive material are established in SSR-6 (Rev. 1) [7] and the associated guidance is provided in SSG-26 [8]. Precautions should be taken to prevent the external contamination of disposal containers, which could spread contaminants during transport.

8.41. The licensee should ensure that each waste package generated in decommissioning is provided with a durable label bearing an identification number and relevant information, and that proper records of each waste package and all the unpackaged waste are kept as part of the integrated management system. All records should be securely stored on a specific database, easily accessible and capable of being retrieved over an extended period of time after completion of decommissioning. Information for each individual waste package should include the following as a minimum:

— The origin of waste (including the material, item or components the waste package contains);
— The identification number of the package;
— The type of the waste package;
— The volume or weight of the package;
— The radioactive inventory (total activity, nuclide composition or spectrum and activities of main radionuclides);
— Results of the measurement of surface contamination;
— The maximum dose rate in contact and at a distance of 1 m from the external surface of the package (to derive the transport index) and the date of measurement;
— Corresponding classification of the radioactive waste in accordance with the national classification system or the classification system set out in IAEA Safety Standards Series No. GSG-1, Classification of Radioactive Waste [42].

8.42. Management of waste, spent fuel and process material from operation should take place under the operating licence during the transition from operation to decommissioning. This will ensure that any delays in the removal of waste from operation and a costly extended shutdown mode of the facility at the end of

its operation are avoided, and the facility is efficiently brought to a condition in which decommissioning can begin.

8.43. The removal of spent fuel assemblies and waste from operation before implementation of any decommissioning actions might be difficult when the related waste management facilities are not available or when these actions are included as part of the decommissioning programme. In such cases, the removal of spent fuel assemblies and of the remaining waste and material will have to be addressed in the final decommissioning plan and associated waste management plan. Planning for decommissioning during operation should help to identify any milestones and tasks that have to be completed to facilitate decommissioning, including timely arrangements for management of radioactive waste from both operation and decommissioning.

9. COMPLETION OF DECOMMISSIONING ACTIONS AND TERMINATION OF AUTHORIZATION FOR DECOMMISSIONING

Requirement 15 of GSR Part 6 [1]: Completion of decommissioning actions and termination of the authorization for decommissioning

"On the completion of decommissioning actions, the licensee shall demonstrate that the end state criteria as specified in the final decommissioning plan and any additional regulatory requirements have been met. The regulatory body shall verify compliance with the end state criteria and shall decide on termination of the authorization for decommissioning."

9.1. On completion of decommissioning, the licensee is required to prepare a final decommissioning report and to retain it as specified in national requirements. The final decommissioning report should include key relevant reporting documents, such as the final radiological survey report.

9.2. The final decommissioning report should summarize the final status of the facility. The final physical and radiological status of the remaining structures, if any, of the facility and/or the site at the time of release from regulatory control or at the time of its conversion to another use should be described. A summary of or reference to the results of the final radiological survey report should be provided.

Furthermore, the final decommissioning report should provide information on any remaining restrictions on the site, if they exist. A review of the environmental impact assessment might be necessary, depending on the final radiological status of the facility, as required by national requirements. The final decommissioning report should summarize the activities performed in decommissioning, and should also provide additional information on the decommissioning project, as appropriate.

9.3. After the completion of decommissioning actions, the final decommissioning report should be submitted by the licensee in a timely manner to the regulatory body. Additionally, the licensee could prepare more specific documentation of the decommissioning project, for example details about methods and tools applied for conducting decommissioning actions and a summary of lessons from the decommissioning project that could be utilized in similar decommissioning projects in the future.

9.4. The final decommissioning report is required to be reviewed by the regulatory body to ensure that the decommissioning end state, for both the physical status and radiological status, has been reached in compliance with the final decommissioning plan and the related requirements of the authorization for decommissioning [1]. The results of the review of the final decommissioning report should be made available by the regulatory body in a timely manner to allow further work to be performed, if deemed necessary by the regulatory body, in the event that non-compliance with the end state criteria is identified.

9.5. A final radiological survey of the facility is required to be performed to demonstrate that the decommissioning objectives, as described in the final decommissioning plan, in the authorization for decommissioning or in the national regulations, have been fulfilled, and that the residual radioactivity meets the end state criteria for restricted or unrestricted release from regulatory control.

9.6. The final decommissioning plan should include a plan for the final radiological survey (as described in Annex I), which, as such, is also subject to approval by the regulatory body. The final survey plan should be reviewed and revised, if necessary, in accordance with additional information obtained from radiological surveys conducted during the decommissioning process. Any changes to the design and implementation of the plan for the final survey should be discussed with the regulatory body during the planning period for the survey, and should be submitted to the regulatory body for review and approval before the final survey is conducted. The final radiological survey may be carried out in phases, as portions of decommissioning actions are completed, to enable

parts of the facility or the site to be released from regulatory control. If the final radiological survey is to be completed in phases, the licensee should put procedures in place to ensure that the surveyed areas are not impacted by ongoing decommissioning actions on other parts of the site.

9.7. The end state criteria established by the regulatory body for release of the facility fully or partially from regulatory control should be convertible into measurable quantities that can readily be compared with the results of the field measurements. Sampling methods should be implemented as defined and should be justified in the final survey plan. The radionuclides present will influence the survey and sample methods adopted. The final survey plan and procedures should provide sufficient data and detail to produce a report of the final radiological survey. The final radiological survey report, as a part of the final decommissioning report, should be submitted to the regulatory body for approval. The results of the survey will be a major portion of the final decommissioning report.

9.8. The regulatory body should perform inspections during implementation of the final radiological survey to verify that the survey procedures are being properly implemented and are in compliance with requirements. The regulatory body should perform independent confirmatory radiological surveys and sampling to ensure compliance with the end state criteria for the site or with the implementation of restrictions at the site. Such independent surveys should be conducted by experts with special training in this field.

9.9. The regulatory body should verify that the site meets the end state criteria [6]. In the event that the site or remaining structures of the former facility do not comply with the initially approved end state criteria for release from regulatory control, a reassessment of the situation should be performed by the licensee and presented to the regulatory body for review.

9.10. The regulatory body should ensure that relevant plans, records and reports (addressing decontamination, demolition and dismantling actions, as well as remediation of surface water, groundwater, soil and sediment, and the final radiological survey) are prepared by the licensee, and are retained for an appropriate time frame.

9.11. When deviations from the end state criteria are considered unacceptable or are not properly justified, the regulatory body may require the licensee to resume decommissioning actions to reach the end state as foreseen in the final decommissioning plan.

9.12. If the approved end state, as set out in the final decommissioning plan, cannot be achieved, deviations from that end state should be clearly identified, their consequences should be assessed, and a new end state should be described and submitted to the regulatory body for approval. Such deviations should be addressed in the final decommissioning report. Sometimes an update of the final decommissioning plan may also be necessary, if additional decommissioning actions are needed to achieve the new end state.

9.13. In order to achieve termination of the authorization for decommissioning for some or all of the facilities on a multifacility site, partial or restricted release from regulatory control might be sought. In such cases, restrictions on access to or use of the facilities might be necessary to ensure protection of people and protection of the environment.

9.14. If restrictions are necessary for access to or for the use of the remaining parts of the facility or site, the regulatory body should ensure that an appropriate mechanism is put in place to demonstrate compliance with these restrictions.

9.15. For sites released from regulatory control with restrictions, appropriate arrangements for continuous control should be put in place to ensure protection of people and protection of the environment. The restrictions should be documented and established as part of the institutional controls, so that future uses of the site are not contrary to the restrictions. An example of such documentation is a land deed restriction. Responsibility for implementing and maintaining these controls should clearly be assigned to an organization or institution. The implementation of controls is required to comply with regulatory requirements and monitoring and surveillance for compliance is required to be put in place, as approved by the regulatory body.

9.16. A long term surveillance and maintenance plan for an area released with restrictions is required to be prepared by the licensee and submitted for approval by the regulatory body. Interested parties should be informed of any site restrictions and of the results of monitoring and surveillance. Legal and financial arrangements should be made for implementation of a long term surveillance and maintenance plan. The regulatory body should conduct regulatory oversight to ensure compliance with the long term monitoring and surveillance requirements and to ensure that maintenance is being performed to meet site restrictions and institutional control requirements.

9.17. If the waste from decommissioning needs to be stored on the site for a long period of time after the completion of decommissioning, an application

for the construction of a new storage facility for radioactive waste is required to be prepared by the licensee and submitted to the regulatory body for review, approval and issue of a licence. Requirements and guidance for the storage of radioactive waste are provided in GSR Part 5 [11], SSG-40 [12], SSG-41 [13] and WS-G-6.1 [14]. If spent fuel remains on the site, the recommendations provided in SSG-15 [10] should be applied. Preparation of a decommissioning plan is required for any waste storage facility or spent fuel storage facility established on the site. On-site disposal of decommissioning waste is not a recommended practice in the case of decommissioning after normal operation, and is not addressed in this Safety Guide.

9.18. It is permissible to progressively release buildings and land areas from regulatory control. In the event that such an approach is envisaged, a discussion between the licensee and the regulatory body should be initiated as soon as possible.

9.19. If a partial site release and reduction of the licensed part of the site is an objective, this should be reflected in the final decommissioning plan, the radiological survey plan and procedures to demonstrate compliance with the national requirements for site release. The request for release from regulatory control of a particular part of the facility or part of its site should take into account the radiological end state criteria for the final release of the entire site and its future use. For example, release of part of the site should not be based on end state criteria derived from a restricted release (industrial reuse) scenario if the licensee's plans for the entire site are to reuse it without restrictions after completion of decommissioning for the entire site.

9.20. Comments from interested parties (e.g. the public) are required to be solicited and addressed before the authorization for decommissioning is terminated. Appropriate consideration should be given to communication with the public, especially if the end state is release from regulatory controls with restrictions.

9.21. Prior to terminating the authorization for decommissioning, the regulatory body should communicate relevant issues to and reach its decision in agreement with other relevant competent authorities that have authority or responsibilities for other issues or aspects relating to the site.

9.22. When the end state criteria for release of the site have been met in accordance with the defined decommissioning end state, the regulatory body should formally notify the licensee, other relevant competent authorities and

interested parties of the decision to release the site from regulatory control. In the event of a decision to release the site with restrictions, the notification should specify the restrictions, the associated measures to be applied and the time frames for the application of these measures, as well as the entities responsible for the implementation, monitoring and regulatory control of the restrictions.

9.23. The regulatory body should specify a period for which the documents associated with decommissioning are to be maintained and retained. The documents retained should be consistent with national requirements.

9.24. An adequate records management system should be applied to the records relating to release of the site after the completion of decommissioning. It should cover some records produced before the termination of the authorization for decommissioning, such as the description of the nature and level of residual radioactivity, and should also cover the decisions relating to the release of the site, made prior to and after decommissioning of the site, and their rationale, and information that verifies that the end state criteria for the site have been met. Record keeping is of particular importance where restrictions are imposed on the future use of the site.

9.25. If specific restrictions are required to be imposed upon future owners or users of the decommissioned facility and its site, these restrictions should be included in a legal document and should be enforceable.

9.26. The nature and extent of the decommissioning records to be preserved after termination of the authorization for decommissioning should be determined taking into consideration a possible transfer of ownership of the site after its final release from regulatory control. Provisions for the long term management of the knowledge base of the former facility should be put in place. The responsibility of keeping relevant records for potential litigation or other purposes should be transferred to other institutions, in accordance with national laws and regulations.

9.27. Records might be required to identify and justify actions that were taken in the event that a later review of the end state of the facility or of the decommissioning project takes place because of, among other things, new regulatory requirements (e.g. on clearance levels) or the development of more advanced, higher resolution detection equipment. The past decommissioning actions might be in conflict with such new developments, especially for decommissioning with restricted release as an end state, and such information will provide a history and bases for these past actions. Typically, the regulatory body

or another national authority will take over keeping the records from the licensee for decommissioning. The duration of records control is usually determined by national regulations (e.g. for records of occupational exposures, for records of importance for potential future liabilities). Other records might need to be kept for institutional purposes or for other reasons.

Appendix

CONSIDERATIONS FOR SAFETY ASSESSMENT FOR DECOMMISSIONING OF FACILITIES

GENERAL CONSIDERATIONS FOR SAFETY ASSESSMENT

A.1. The aim of the safety assessment for decommissioning is to determine the safety functions necessary in decommissioning and the related SSCs that will deliver these safety functions, as well as relevant procedures, in accordance with a graded approach. The SSCs important to safety provide the means for the safe conduct of decommissioning actions, for prevention of the occurrence of initiating events leading to abnormal events, for the control and limitation of accidents and the mitigation of the potential consequences. In addition, the requirements for maintenance or replacement of systems for mechanical handling, ventilation, power supply and waste handling should be considered in the safety assessment as part of the engineering assessment.

A.2. The safety assessment should employ a systematic methodology to demonstrate compliance with safety requirements for decommissioning, including a methodology for the release of material, buildings and sites from regulatory control.

A.3. The safety assessment should be commensurate with the complexity and potential hazard of the facility and, in the case of deferred dismantling, should take into account the safety of the facility in the period leading up to final dismantling.

A.4. Analyses of accident scenarios should be performed and protective measures for preventing accidents or minimizing the likelihood of their occurrence and for mitigating their potential consequences should be proposed. The protective measures might require changes to the existing safety systems that were used during the operational stage. The acceptability of such changes should be clearly justified in the safety assessment. Protective measures are either engineered features or administrative controls to provide the necessary radiation protection.

A.5. Postulated initiating events that could lead to elevated radiation levels or to a release of radioactive material and associated hazardous chemical substances should be identified. The resulting set of identified postulated initiating events should be confirmed to be comprehensive and should be defined in such a

way that the postulated initiating events cover credible failures of the SSCs of the facility, as well as human errors that could occur during decommissioning actions. The set of postulated initiating events should include both internal events and external events.

A.6. Human factors are an important aspect of the safety of facilities, as the state of the facility changes frequently with decommissioning actions. The safety assessment should consider the potential for human error in accordance with the complexity and hazard potential of the facility concerned (e.g. large numbers of equipment, tanks, pipes and valves containing unexpected residual radioactive material and contaminated liquid). Ergonomic factors in dismantling should be analysed and planned for to avoid injury or prolonged exposure.

A.7. The likelihood and consequences of external events should be assessed, with account taken of the decommissioning strategy and the site characteristics (e.g. seismic hazards, flooding, extreme temperatures, influence from or dependence on any neighbouring facilities, and accidental aircraft crash), the likelihood of potential initiating events (e.g. human error, fire, flood, dropped loads, collapse or failure of buildings or structures, and the release of hazardous chemicals) leading to an accident, and the consequences of such accidents.

A.8. The implementation of the results of the safety assessment should lead to the definition of decommissioning limits and conditions, which are the set of rules that establish parameter limits, the functional capability and the performance levels of equipment and personnel for the safe decommissioning of a facility. The decommissioning limits and conditions should also define the required intervals for periodic testing and inspection of SSCs important to safety.

A.9. Dismantling may involve the deliberate destruction and removal of engineered SSCs that had fulfilled specified safety functions during operation of the facility (e.g. confinement, shielding, ventilation or cooling). If these safety functions are still required, they should be provided by suitable alternative means or SSCs (e.g. tents, temporary systems or structures, fire systems, electrical systems and/or administrative procedures) for as long as is required on the basis of the safety assessment. The appropriateness of the alternative means of fulfilling these safety functions should be demonstrated. Procedures for changing the means by which safety functions are provided during decommissioning should be justified and demonstrated in advance of their implementation.

A.10. The safety assessment should address the main safety issues and objectives of the final decommissioning plan. In accordance with the result of the

safety assessment that is developed for the entire decommissioning project and covering all phases of decommissioning, the licensee should develop detailed safety assessments for each phase, where relevant, to demonstrate safety of actions foreseen for a given phase.

A.11. A given phase of decommissioning can be subdivided into discrete work packages or tasks for which specific safety assessments can be performed. Such detailed safety assessments for the first phase of decommissioning should be performed during the transition period, while detailed safety assessment for the other phases may be performed later, but prior to the beginning of each phase.

A.12. In all phases of decommissioning of a facility, the workers, the public and the environment are required to be properly protected from hazards resulting from the decommissioning actions, for both normal situations and abnormal situations. Safety assessments are required to contain an analysis of radiological hazards associated with decommissioning actions and are required to demonstrate compliance with the regulatory requirements and criteria. Non-radiological hazards should also be evaluated. In decommissioning, a number of conventional occupational health hazards will play a larger role than during operation of a facility, for instance in connection with the dismantling and demolition of large components and structures. The risk arising from these hazards will need to be addressed, but is outside the scope of this Safety Guide.

A.13. The licensee should consider the following when assessing the radiological hazards and non-radiological hazards associated with decommissioning of a facility:

— The presence and nature of all types of contamination;
— Hazards associated with the possible in-growth of radionuclides (such as ^{241}Am);
— The potential for criticality hazards associated with the possible accumulation of fissile material in the process equipment during operation or during decommissioning actions (such as decontamination);
— The complexity of strategies for waste management owing to the diversity of waste streams;
— For multifacility sites, hazards associated with facilities that are not under decommissioning;
— Inaccessible areas and buried pipes;
— Separation and concentration of material stored in tanks;
— Hazardous chemicals located in SSCs and in buildings, soil, sediment, surface water and groundwater;

— Changes in chemical and physical forms of materials;
— Non-radiological hazards, such as fire or explosion, associated with decommissioning actions.

A.14. In the planning stage for decommissioning, the degree and extent of contamination in a facility should be clearly determined, characterized, evaluated and classified. Surveys should be conducted to determine the inventories and locations of radioactive material and other hazardous materials. An accurate characterization of the facility will provide the input for the decommissioning safety assessment.

A.15. Safety issues such as radiation exposure (e.g. external exposure due to direct irradiation, and internal exposure due to inhalation, ingestion or cuts and abrasions), potential criticality and loss of confinement leading to an uncontrolled release of radionuclides are required to be considered in the safety assessment for decommissioning.

A.16. For facilities that were shut down a long time before the start of decontamination or dismantling, a survey of equipment and buildings should be made to assess hazards associated with the deterioration of SSCs. In addition, consideration should be given to the materials of the physical barriers and process equipment for which mechanical properties might have changed during operation, owing to factors such as fatigue (e.g. from cyclic mechanical or thermal loading), stress corrosion, erosion, chemical corrosion or irradiation. In implementing decontamination actions, consideration should be given to the risk associated with the ageing of physical barriers and process equipment.

A.17. If suitable alternative means (e.g. mobile tents and administrative procedures) are necessary when dismantling process equipment and physical barriers, the nature and number of the alternative means and the requirements on their performance should be commensurate with the degree and extent of existing contamination and with the risk of spreading contamination during dismantling. Special attention should be paid to specific aspects, such as the potential for dispersion of residual alpha emitters. In many situations, mobile tents might become the first confinement barrier during decommissioning. The design of this first confinement barrier should be described in the safety assessment (e.g. static confinement, ventilation systems, filtration systems, resistance to fire and mechanical resistance) and its use should be justified. The associated SSCs should be defined within the safety assessment and should be taken into account in the decommissioning limits and conditions.

A.18. The licensee should determine design considerations for fire safety on the basis of a fire safety analysis. Special attention should be given to the use of thermal cutting techniques (e.g. plasma cutting) and non-thermal cutting techniques (e.g. the use of grinders and saws) and the associated risk of outbreak of fire during dismantling, especially when mobile confinement tents and personal protective equipment are used.

A.19. During decommissioning, additional consideration should be given to the following:

(a) The closer proximity of radiation sources to personnel (owing to the removal of shielding or interlocks to gain access to sources), and hence the greater potential for radiation exposure;
(b) The greater potential for the creation of airborne radionuclides, owing to the removal of containment or barriers during dismantling.

A.20. The safety assessment for decommissioning may identify a number of potentially significant non-radiological hazards, which might have radiological consequences during the decommissioning of the facility. These non-radiological hazards might not normally have been encountered in the operational stage. These hazards include the lifting and handling of heavy loads, drop of loads, fire or explosion, collapse of structures and the generation of hazardous materials during the actions for decontamination and dismantling. The method for dealing with most of the non-radiological hazards should be managed in accordance with national regulations, and in addition a strong safety culture will help to ensure that such hazards are identified and adequately controlled.

SPECIFIC ISSUES TO BE CONSIDERED IN THE SAFETY ASSESSMENT FOR NUCLEAR POWER PLANTS AND RESEARCH REACTORS

A.21. The decommissioning of nuclear power plants and research reactors will involve the handling of both activated and contaminated material. The management of components located in the reactor core and its vicinity, which have been activated during operation, might benefit from radioactive decay.

A.22. Work performed in the transition period is often done under the operating licence and in accordance with the safety assessment developed for the operational stage of the facility. Because of this, operating experience and the safety assessment for operation of the facility are essential for the transition from operation to decommissioning. This is especially true for research reactors, where

modifications of systems, removal of past experiments and partial dismantling of experimental devices and equipment such as glove boxes are performed periodically during operation.

A.23. For existing research reactors with a long operational history, information on past experiments and incidents is often not available, owing to either missing records or retirement of experienced personnel. In such cases, more extensive characterization might be needed for carrying out the safety analysis, possibly supplemented by interviews with retired personnel.

SPECIFIC ISSUES TO BE CONSIDERED IN THE SAFETY ASSESSMENT FOR NUCLEAR FUEL CYCLE FACILITIES

A.24. For uranium enrichment facilities, fuel fabrication facilities and reprocessing plants, special attention should be given to actions that could increase the criticality risk, such as decontamination using liquids, waste treatment, conditioning and storage of waste packages.

A.25. The generation of heat by radioactive decay, if not adequately controlled, could result in a release of radioactive material. Heat generation should be taken into account in decommissioning, owing to the presence of highly active material (solid or liquid) in the facility.

A.26. Radiolysis, if not adequately controlled, could result in a release of hydrogen with the risk of explosion. Radiolysis should be taken into account as appropriate in planning for decommissioning actions and in assessing safety. Possible accumulation of hydrogen in waste due to radiolysis should also be considered in the development of the waste treatment process and in the design of the waste packaging. The possibility for accumulation of hydrogen might affect the design and the operation of storage facilities and the transport conditions of the waste packages.

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[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Release of Sites from Regulatory Control on Termination of Practices, IAEA Safety Standards Series No. WS-G-5.1, IAEA, Vienna (2006).

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Annex I

SUGGESTED STRUCTURE AND CONTENT OF THE FINAL DECOMMISSIONING PLAN AND SUPPORTING DOCUMENTS

I–1. The final decommissioning plan is the key document in the entire decommissioning process. It contains the information on which the regulatory body will base its decision regarding the safety of the decommissioning project as proposed by the licensee. The final decommissioning plan is of great importance for the licensee and all organizations involved in the decommissioning process as it establishes the strategy and objectives of decommissioning. There is a range of documentation supporting the final decommissioning plan that will be referenced and summarized in the final decommissioning plan. This is particularly likely to be the case for large and complex decommissioning projects. For smaller facilities, such supporting documents could be integrated into the final decommissioning plan itself, where appropriate (some supporting documents could contain restricted information, for example the security plans). See also Ref. [I–1].

I–2. This annex provides an example outline of the possible content of a final decommissioning plan for a facility. In accordance with a graded approach, the level of detail will depend on the complexity of the decommissioning actions.

I–3. The content of the final decommissioning plan is specified by the regulatory body.

0. SUMMARY

1. INTRODUCTION

    1.1. Scope and context of the decommissioning project

    1.2. General information regarding the licensee and existing licences

2. DESCRIPTION OF THE SITE AND FACILITY

    2.1. Site location and site description

    2.2. Description of the facility, including related SSCs

2.3. Operational history of the facility, including modifications and events

2.4. Radiological characterization of the facility, including surface and subsurface soils and water

2.5. Interdependences with other facilities on the site (in the case of a multifacility site)

3. DECOMMISSIONING STRATEGY

3.1. Description of the overall decommissioning strategy for the site (in the case of a multifacility site)

3.2. The selected decommissioning strategy, including the end state

3.3. Justification of the selected decommissioning strategy

4. INTEGRATED MANAGEMENT SYSTEM FOR DECOMMISSIONING

4.1. The safety management policy, including the policy for safety culture

4.2. The organizational structure, including responsibilities and authorities

4.3. Staffing and qualification, including training

4.4. Engagement of interested parties, including interfaces with the regulatory body

4.5. Documentation and record keeping

4.6. The approach to project management, including the involvement of contractors

5. CONDUCT OF DECOMMISSIONING ACTIONS

5.1. The work breakdown structure, including related phases and their schedule

5.2. Decontamination and dismantling methods and techniques

5.3. Surveillance and maintenance

6. WASTE MANAGEMENT AND MATERIAL MANAGEMENT

6.1. Identification of radioactive waste and radioactive material

6.2. Waste classification and waste streams, waste acceptance criteria and criteria for release from regulatory control

6.3. Predisposal management of solid and liquid radioactive waste, including waste from supporting facilities

6.4. Identification of non-radioactive waste and non-radioactive material

6.5. Disposition of all waste streams

7. FINANCIAL RESOURCES

7.1. Availability of financial resources, including cost estimates

7.2. Allocation of financial resources

7.3. Review and update of financial resources

8. RADIATION PROTECTION [I–2]

8.1. Radiation protection principles and objectives

8.2. The radiation protection programme

8.3. Monitoring, control and surveillance during decommissioning

9. SAFETY ASSESSMENT [I–3]

9.1. Safety assessment framework, including safety requirements and safety criteria

9.2. Methodology for the safety assessment

9.3. Identification of hazards and initiating events and identification of scenarios for analysis for normal and abnormal situations

9.4. Hazard analysis

9.5. Results of the safety assessment

9.6. Implementation of the results of the safety assessment, including the determination of limits and conditions for decommissioning actions

9.7. Surveillance and maintenance of safety measures

10. ENVIRONMENTAL IMPACT ASSESSMENT

10.1. Identification of the discharges to the environment during decommissioning actions

10.2. Identification of both on-site and off-site sources of radiation that cause direct exposure of the public and have an impact on the environment

10.3. Radiological impact assessment for the public and the environment for decommissioning actions

10.4. Non-radiological impact assessment

10.5. Measures for protection and control

11. EMERGENCY ARRANGEMENTS [I–4]

11.1. Basis for emergency planning, including possible emergency situations and potential consequences

11.2. Organization and responsibilities

11.3. Plans and procedures for emergency response

11.4. Arrangements for emergency preparedness

12. PHYSICAL PROTECTION AND ARRANGEMENTS FOR ACCOUNTING FOR AND CONTROL OF NUCLEAR MATERIAL[1]

12.1. Legal and regulatory policy and framework

12.2. Organization and responsibilities

12.3. Physical protection programme and measures

12.4. Programme and measures for accounting for and control of nuclear material

13. FINAL RADIOLOGICAL SURVEY

13.1. Objectives of the final radiological survey

13.2. Methodology for conducting the final radiological survey

13.3. Definition of sampling parameters and background levels of radiation

13.4. Types of equipment, instruments, techniques and procedures

13.5. Methodology for evaluating the results of the final radiological survey

REFERENCES TO ANNEX I

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[I–4] INTERNATIONAL ATOMIC ENERGY AGENCY, Method for Developing Arrangements for Response to a Nuclear or Radiological Emergency, EPR-METHOD (2003), IAEA, Vienna (2003).

Annex II

SUGGESTED STRUCTURE AND CONTENT OF THE FINAL DECOMMISSIONING REPORT

II–1. The final decommissioning report is prepared by the licensee as a basis for the regulatory decision to terminate the authorization for decommissioning. This report:

(a) Summarizes the final decommissioning plan, its updates and any related licences;
(b) Includes the final radiological survey report(s);
(c) Describes remaining restrictions on the site or restrictions relating to the existence of remaining facilities on the site after completion of decommissioning, if any, and describes necessary controls and plans for their removal in the future;
(d) Provides information on radiation exposures of workers;
(e) Provides information on radioactive discharges to the environment;
(f) Provides information on the management of radioactive waste and radioactive material.

II–2. In addition, the licensee might include additional information in the final decommissioning report for its own use. In order to improve the conduct of decommissioning projects in the future, the licensee could summarize and share experience and lessons from the project in the final decommissioning report, or could provide details about methods and tools applied in conducting decommissioning actions.

Annex III

SUGGESTED STRUCTURE AND CONTENT OF THE FINAL RADIOLOGICAL SURVEY REPORT

III–1. The report of the final radiological survey presents the final conditions at the facility and the site at the conclusion of the physical decommissioning actions. The final radiological survey report is usually part of the final decommissioning report.

III–2. The final radiological survey report includes the following information:

(a) Conduct of the final radiological survey and the survey results:
  (i) A summary of the survey, including changes from the final radiological survey plan and comparison with the initial (baseline) radiological survey;
  (ii) The sampling performed (e.g. maps indicating sampling and measurement points, type and number of measurements, and analyses performed);
  (iii) Measurement data and analytical results;
  (iv) Evaluation of data, comparison with established guidelines, and reporting in accordance with the national regulatory framework;
  (v) Quality management aspects relating to the final radiological survey.

(b) Summary and conclusion:
  (i) Concise description of the final radiological situation at the facility, including any areas that were not surveyed;
  (ii) Identification of all site areas and SSCs that can be released for unrestricted use;
  (iii) Description of any institutional controls that will be required for any areas that have not been released, including overview drawings and maps.

Annex IV

EXAMPLES OF DECOMMISSIONING RELATED DOCUMENTS

IV–1. In practice, the final decommissioning plan, as described in Annex I, is supported by a set of documents (depending on national regulatory requirements) that provide additional information explaining aspects of the decommissioning plan. A typical example is the safety assessment report, which for decommissioning of facilities is usually a stand-alone document, providing more detail on the safety aspects of decommissioning than presented in chapter 9 of the final decommissioning plan (in accordance with the content presented in Annex I).

IV–2. The supporting documents may include the following:

- Historical site assessment;
- Characterization survey report;
- Safety assessment report;
- Decommissioning limits and conditions;
- Environmental impact assessment;
- Radiation protection programme;
- Industrial health and safety plan;
- Waste management plan;
- Quality management plan (as part of the integrated management system);
- Emergency response plan;
- Security plan and plan for accounting for and control of nuclear material;
- Funding provisions and cost estimate;
- Public relations plan.

Annex V

RELEVANT LITERATURE

This annex provides a list of reference publications that contain additional information on specific organizational, financial, technical and safety issues relating to decommissioning. The reference publications are grouped in accordance with the main topic discussed.

CONTENT OF THE DECOMMISSIONING PLAN

INTERNATIONAL ATOMIC ENERGY AGENCY, Standard Format and Content for Safety Related Decommissioning Documents, Safety Reports Series No. 45, IAEA, Vienna (2005).

NUCLEAR ENERGY AGENCY, Achieving the Goals of the Decommissioning Safety Case: A Status Report Prepared on Behalf of the WPDD by its Task Group on the Decommissioning Safety Case, NEA No. 5417, OECD (2005).

INTERNATIONAL ATOMIC ENERGY AGENCY, Planning, Management and Organization Aspects of the Decommissioning of Nuclear Facilities, IAEA-TECDOC-1702, IAEA, Vienna (2013).

TRANSITION FROM OPERATION TO DECOMMISSIONING

INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Considerations in the Transition from Operation to Decommissioning of Nuclear Facilities, Safety Reports Series No. 36, IAEA, Vienna (2004).

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DECOMMISSIONING STRATEGIES

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INTERNATIONAL ATOMIC ENERGY AGENCY, Radiological Characterization of Shut Down Nuclear Reactors for Decommissioning Purposes, Technical Reports Series No. 389, IAEA, Vienna (1998).

NUCLEAR ENERGY AGENCY, Radiological Characterisation for Decommissioning of Nuclear Installations: Final Report of the Task Group on Radiological Characterisation and Decommissioning (RCD) of the Working Party on Decommissioning and Dismantling (WPDD), NEA/RWM/WPDD(2013)2, OECD (2013).

SAFETY ASSESSMENT

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DECOMMISSIONING TECHNOLOGIES

INTERNATIONAL ATOMIC ENERGY AGENCY, State of the Art Technology for Decontamination and Dismantling of Nuclear Facilities, Technical Reports Series No. 395, IAEA, Vienna (1999).

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MANAGEMENT OF MATERIAL AND RADIOACTIVE WASTE FROM DECOMMISSIONING

INTERNATIONAL ATOMIC ENERGY AGENCY, Derivation of Activity Concentration Values for Exclusion, Exemption and Clearance, Safety Reports Series No. 44, IAEA, Vienna (2005).

INTERNATIONAL ATOMIC ENERGY AGENCY, Monitoring for Compliance with Exemption and Clearance Levels, Safety Reports Series No. 67, IAEA, Vienna (2012).

INTERNATIONAL ATOMIC ENERGY AGENCY, Monitoring for Compliance with Remediation Criteria for Sites, Safety Reports Series No. 72, IAEA, Vienna (2012).

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INTERNATIONAL ATOMIC ENERGY AGENCY, Managing Low Radioactivity Material from the Decommissioning of Nuclear Facilities, Technical Reports Series No. 462, IAEA, Vienna (2008).

DECOMMISSIONING COSTING

NUCLEAR ENERGY AGENCY, International Structure for Decommissioning Costing (ISDC) of Nuclear Installations, NEA No. 7088, OECD (2012).

INTERNATIONAL ATOMIC ENERGY AGENCY, Cost Estimation for Research Reactor Decommissioning, IAEA Nuclear Energy Series No. NW-T-2.4, IAEA, Vienna (2013).

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