

**WENRA
WORKING GROUP ON WASTE AND
DECOMMISSIONING (WGWD)**

**DECOMMISSIONING
SAFETY
REFERENCE LEVELS
REPORT**

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Executive Summary

The Western European Nuclear Regulator's Association (WENRA) is an international body made up of the Heads and senior staff members of Nuclear Regulatory Authorities of European countries with nuclear power plants. The main objectives of WENRA is to develop a common approach to nuclear safety, to provide an independent capability to examine nuclear safety in applicant countries and to be a network of chief nuclear safety regulators in Europe exchanging experience and discussing significant safety issues.

To accomplish these tasks two working groups within the WENRA have been established - Reactor Harmonisation Working Group (RHWG) and Working Group on Waste and Decommissioning (WGWD).

This document contains the results of the work of WGWD in the area of the decommissioning of nuclear installations. The objective of this report is to provide safety reference levels for these activities, which were based on RHWG report and corresponding IAEA documents (requirements, guidances, etc). Although the IAEA safety standards establish an essential basis for safety of all nuclear installations covering also their decommissioning, the WENRA safety reference levels incorporate more this activity specific requirements.

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WENRA Policy Statement

We, the heads of the national Nuclear Safety Authorities, members of WENRA, commit ourselves to a continuous improvement of nuclear safety in our respective countries.

Nuclear safety and radiation protection are based on the principle of the prime responsibility of the operators. The role of national regulators is to ensure that this responsibility is fully secured, in compliance with the regulatory requirements.

In order to work together, we created the Western European Nuclear Regulators' Association (WENRA) with the following main objectives:

- to build and maintain a network of chief nuclear safety regulators in Europe;
- to promote exchange of experience and learning from each other's best practices;
- to develop a harmonized approach to selected nuclear safety and radiation protection issues and their regulation, in particular within the European Union;
- to provide the European Union Institutions with an independent capability to examine nuclear safety and its regulation in Applicant Countries.

In order to develop a harmonized approach, we are:

- sharing our experience feedback and our vision;
- making efforts to further exchange of personnel, allowing an in-depth knowledge of working methods of each other;
- developing common reference safety levels in the fields of reactor safety, decommissioning safety, radioactive waste and spent fuel management facilities in order to benchmark our national practices.

We recognise the IAEA standards form a good basis for the continuous improvement of national nuclear regulatory systems and nuclear safety.

The reference levels that we have developed represent good practices in our countries from which we can also seek to learn from each other to further improve nuclear safety and its regulation. Hence, we are committed:

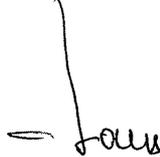
- by the year 2010 to improve and harmonise our nuclear regulatory systems, using as a minimum the reference levels;
- to influence the revision of the IAEA standards when appropriate;
- to regularly revise the reference levels when new knowledge and experience are available.

We strive for openness and improvement of our work. For that purpose we will:

- keep the European Nuclear Safety and Radiation Protection Bodies not belonging to WENRA, and the EU Institutions, informed of the progress made in our work;
- make our public reports available on the Internet (www.wenra.org);
- invite stakeholders to make comments and suggestions on these reports.

Signed in Stockholm December 2005

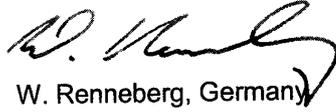
J-P. Samain, Belgium


S. Tzotchev, Bulgaria


D. Drabova, Czech Republic


J. Laaksonen, Finland


A-C. Lacoste, France


W. Renneberg, Germany


I. Lux, Hungary

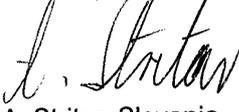

S. Giulianelli, Italy

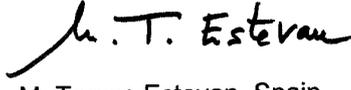

S. Kutas, Lithuania


P. Müskens, the Netherlands


V. Zsombori, Romania


M. Ziakova, Slovakia


A. Stritar, Slovenia


M. Teresa Estevan, Spain


J. Melin, Sweden


U. Schmocker, Switzerland


M. Weightman, United Kingdom

Glossary

Ageing

General process in which characteristics of a structure, system or component gradually change with time or use.

Management of ageing

Engineering, operations and maintenance actions to control within acceptable limits the ageing degradation of structures, systems or components.

Clearance

Removal of radioactive materials or radioactive objects within authorized practices from any further control by the regulatory body. (Removal from control in this context refers to control applied for radiation protection purposes.)

Decommissioning

Administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility (except for a repository or for certain nuclear facilities used for the disposal of residues from the mining and processing of radioactive material, which are 'closed' and not 'decommissioned'). For a repository, the corresponding term is closure.

Decommissioning plan

An initial or final document – depending on the operational phase of the facility - with detailed information about the concept and schedule for the decommissioning and dismantling of the nuclear facility.

Initial decommissioning plan based on the decommissioning strategy includes the feasibility of decommissioning, main steps of the decommissioning/dismantling and the end state of the facility and is the basis for the estimation of decommissioning costs. This document is of general nature during the design and operational phase and will be updated during the operational phase to the level as appropriate.

Final decommissioning plan as the basis to start major decommissioning activities shall be prepared before the beginning of the decommissioning phase together with the safety case. This detailed document will be updated as required during the decommissioning stages.

Decommissioning strategies

Immediate dismantling is the strategy in which the equipment, structures and parts of a nuclear facility containing radioactive contaminants are removed or decontaminated to a level that permits the facility to be released for unrestricted use, or with restrictions imposed by the regulatory body. In this case decommissioning implementation activities begin shortly after permanent cessation of operations. It implies prompt and complete decommissioning and involves the removal and processing of all radioactive material

from the facility to another new or existing licensed nuclear facility for either long-term storage or disposal.

Deferred dismantling (sometimes called safe storage, safe store or safe enclosure) is the strategy in which parts of a nuclear facility containing radioactive contaminants are either processed or placed in such a condition that they can be safely stored and maintained until they can subsequently be decontaminated and/or dismantled to levels that permit the facility to be released for other uses.

Entombment is the strategy in which radioactive contaminants are encased in a structurally long-lived material until radioactivity decays to a level permitting unrestricted release of the nuclear facility, or release with restrictions imposed by the regulatory body. Because radioactive material will remain on the site, this essentially means that the facility will eventually become designated as a near surface waste disposal facility as long as it can meet the requirements for a near surface disposal facility.

Decontamination

The complete or partial removal of contamination by a deliberate physical, chemical or biological process.

discharge, Authorized

Planned and controlled release of (usually gaseous or liquid) radioactive material into the environment in accordance with an authorization.

End state

A predetermined criterion defining the point at which the specific task or process is to be considered completed.

Licensee

The licensee is the organization having overall responsibility for a facility or activity (the responsible organization)

Remark: WGWD recognizes that this organisation may change as the facility passes to the decommissioning phase according to national strategies

Monitoring

1. The measurement of dose or contamination for reasons related to the assessment or control of exposure
2. Continuous or periodic measurement of radiological or other parameters or determination of the status of a system, structure or component. Sampling may be involved as a preliminary step to measurement.

Nuclear facility

A facility and its associated land, buildings and equipment in which nuclear materials are produced, processed, used, handled, stored or disposed of on such a scale that consideration of safety is required.

Nuclear safety

See ‘Protection and Safety’

Operation

All activities performed to achieve the purpose for which an authorized facility was constructed.

Protection and Safety

The protection of people against exposure to ionizing radiation or radioactive materials and the safety of radiation sources, including the means for achieving this, and the means for preventing accidents and for mitigating the consequences of accidents should they occur.

Safety is primarily concerned with maintaining control over sources, whereas (radiation) protection is primarily concerned with controlling exposure to radiation and its effects. Clearly the two are closely connected: radiation protection is very much simpler if the source in question is under control, so safety necessarily contributes towards protection. Sources come in many different types, and hence safety may be termed nuclear safety, radiation safety, radioactive waste safety or transport safety, but protection (in this sense) is primarily concerned with protecting humans against exposure, whatever the source, and so is always radiation protection.

Radiation protection: The protection of people from the effects of exposure to ionizing radiation, and the means for achieving this.

Nuclear safety: The achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of workers, the public and the environment from undue radiation hazards.

Quality management system

The new term reflects the evolution in the approach from the initial concept of ‘Quality Control’ (controlling the quality of products) through ‘Quality Assurance’ (the system to assure the quality of products) and ‘Quality Management’ (the system to manage quality). The ‘Quality Management System’ is a set of interrelated or interacting elements (system) to establish policy and objectives and to achieve those objectives.

Radiation protection

See ‘protection and safety’

Regulatory body

An authority or a system of authorities designated by the government of a State as having legal authority for conducting the regulatory process, including issuing authorizations, and thereby regulating nuclear, radiation, radioactive waste and transport safety.

Safety assessment

Assessment of all aspects of the siting, design, operation and decommissioning of an authorized facility that are relevant to protection and safety.

Safety case

A collection of arguments and evidence in support of the safety of a facility or activity. This will normally include the findings of a safety assessment and a statement of confidence in these findings.

Safety policy

A documented commitment by the licensee to a high nuclear safety performance supported by clear safety objectives and targets and a commitment of necessary resources to achieve these targets. The safety policy is issued as separate safety management document or as visible part of an integrated organisation policy.

Structures, systems and components (SSCs)

A general term encompassing all of the elements (items) of a facility or activity which contribute to protection and safety, except human factors.

- **Structures** are the passive elements: buildings, vessels, shielding, etc.
- A **system** comprises several **components**, assembled in such a way as to perform a specific (active) function.
- A **component** is a discrete element of a system.

use

Authorized use: Use of radioactive materials or radioactive objects from an authorized practice in accordance with an authorization.

Restricted use: The use of an area or of materials, subject to restrictions imposed for reasons of radiation protection and safety. Restrictions would typically be expressed in the form of prohibition of particular activities (e.g. materials may only be recycled or reused within a facility).

Unrestricted use: The use of an area or of materials without any radiologically based restrictions.

List of Abbreviations

EIA	environmental impact assessment
EU	European Union
IAEA	International Atomic Energy Agency
NPP	nuclear power plant
OLC	operational limits and conditions
PIE	postulated initiating event
PSR	periodic safety review
QM	quality management
RHWG	(WENRA) Reactor Harmonisation Working Group
SSCs	structures, systems and components
SRLs	safety reference level
WENRA	Western European Nuclear Regulators
WGWD	(WENRA) Working Group on Waste and Decommissioning

Part I.

Introduction and Used Methodology

1. Introduction

This report is the result of an effort by the Working Group on Waste and Decommissioning of WENRA, from 2002 to 2006. It presents the safety reference levels (SRLs) for decommissioned facilities that are thought to be a good basis for future harmonisation on a European level.

The SRLs can not be considered as independent European safety requirements because current legislation in WENRA member states would not allow that due to fundamental differences reflecting the historical development in European countries. The SRLs are a set of requirements against which the situation of each country is assessed and it is each country's responsibility to implement actions to ensure that these levels are reached.

1.1. Background

WENRA, which has been established in February 1999, is the association of the Heads of nuclear regulatory authorities of European countries with at least one nuclear power plant in construction, operation or decommissioning phase. WENRA has been formally extended in 2003 to include future new European Union (EU) Member States. Currently following countries are members of WENRA: Belgium, Bulgaria, the Czech Republic, Finland, France, Germany, Hungary, Italy, Lithuania, the Netherlands, Romania, Slovenia, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

The original objectives of the Association were:

- to develop a common approach to nuclear safety and regulation, in particular within the EU,
- to provide the EU with an independent capability to examine nuclear safety and regulation in candidate countries,
- to evaluate and achieve a common approach to nuclear safety and regulatory issues which arise.

The second objective of WENRA has been fulfilled by the preparation of a report on nuclear safety in candidate countries having at least one nuclear power plant. After 1 May 2004, when most of these candidate countries became a regular EU Member States, the new WENRA tasks, based on first and third original Association's objectives, became:

- to develop an independent nuclear safety assessment capability, based on in-depth knowledge of nuclear installations, and
- to develop common approaches to nuclear safety and regulations and to encourage the harmonisation of practices.

To perform these tasks two working groups within the WENRA have been established - Reactor Harmonisation Working Group (RHWG) and Working Group on Waste and Decommissioning (WGWD). The work of WGWD has started in 2002.

1.2. Objective

The term "decommissioning" refers to administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a nuclear facility other than a

repository. These actions involve decontamination, dismantling and removal of radioactive materials, waste, components and structures. They are carried out to achieve a progressive and systematic reduction in radiological hazards.

Although the SRLs in this report are oriented toward the licensees of decommissioned facilities, who are responsible for their safety, they can also be used by the regulatory body for the review and assessment of decommissioned facilities' safety.

The harmonisation process has the goal to produce harmonised safety reference levels by 2006 in most areas and to implement these levels by 2010 in each country.

1.3. Scope

The decommissioning SRLs apply for nuclear reactors (of any power), fuel reprocessing facilities, fuel manufacturing facilities, uranium concentration and conversion facilities, uranium enrichment facilities, research facilities involving nuclear material, waste storage facilities and other waste management facilities. These reference levels are not intended to be applicable to uranium mining and milling, and for isotope production facilities other than reactors.

The point at which decommissioning starts will vary from country to country depending on national arrangements, ranging from the decision on shutdown the facility up to the begin of dismantling activities.

For the purposes of this document, it is assumed that the normal operational phase includes the removal of the bulk of fuel and radioactive materials from the facility in accordance with the safety case for normal operations. The decommissioning phase is assumed to start technically once further operations cannot be carried out using normal operational methods or within the bounds of the safety case for normal operation. The decommissioning phase is usually governed by a separate decommissioning license.

The decommissioning SRLs address mainly the radiological hazards resulting from the activities associated with the decommissioning of facilities, primarily with decommissioning after a planned shutdown. Non-radiological hazards can also arise during decommissioning activities. These hazards should be given due consideration during the planning process and in the risk analyses as far as they may influence the radiological hazards or risks.

Regulatory requirements for Environmental Impact Assessment (required by EU directives), waste disposal, conventional occupational health and safety, physical protection and decommissioning funding, are important for decommissioning. However, WGWD members do not all regulate all these matters and in that case, these matters are addressed by other national regulatory organisations. As a result, at this stage, WGWD did not take into account in detail these topics and has therefore concentrated on the nuclear safety requirements.

RHWG of WENRA developed SRLs for nuclear reactors. The principles underlying these levels apply to any type of nuclear facility both during operation and during the decommissioning phase, taking into account the magnitude of the hazard in a graded approach.

As this document is intended to cover a wide range of sites and facilities (from small isolated nuclear facility to large complex reprocessing or reactor sites), the reference levels will need to be implemented in different ways to be appropriate for the particular facility.

1.4. Structure

The report consists of two main parts.

Following this Introduction in Part I of the report, Section I-2. presents the general methodology that was followed to develop the SRLs and to analyse their application in participating countries.

Part II of the report presents the actual decommissioning reference levels.

2. Methodology

The working methodology of WGWD has gone through several steps and changes since 2002, when the working group was established. A list of topics to be covered by WGWD was defined taking into account the common field of responsibility of WENRA members.

By the drafting of report versions developed in 2002-2006 the importance of the IAEA documents developed till then has been recognised. Therefore the starting point for the definition of facility specific SRLs, which have been later included into the former Subpart B, were the topics addressed by corresponding IAEA documents (requirements, guidances, etc). This list has been carefully reviewed and validated by the WGWD. In the case of decommissioning, the available IAEA references were:

- A System for Feedback of Experience from Events in Nuclear Installations, Safety Guide, DS 288, Vienna (2005),
- Management Systems, Safety Requirements, DS 338, Vienna (2005),
- Decommissioning of Nuclear Power Plants and Research Reactors, Safety Series No. WS-G-2.1, IAEA, Vienna (1999),
- Decommissioning of Medical, Industrial and Research Facilities, Safety Series No. WS-G-2.2, IAEA, Vienna (1999),
- Predisposal Management of Radioactive Waste Including Decommissioning, Safety Standards Series No. WS-R-2, IAEA, Vienna (2000),
- Decommissioning of Nuclear Fuel Cycle Facilities, Safety Series No. WS-G-2.4, IAEA, Vienna (2001).
- Decommissioning of Facilities using Radioactive Material, Draft of DS 333 (2006-04-06)
- Safety of Fuel Cycle Facilities, Draft of DS 316 (2006-08-24)
- Predisposal Management of Radioactive Waste, Including Decommissioning, Safety Requirements No. WS-R-2, IAEA, Vienna (2000)

A first set of SRLs, based on RHWG report on harmonisation of reactor safety, has been established in 2002-2005. SRLs were posted on the website of the WENRA organisation at the beginning of 2006 and presented to stakeholders in the view to receive their comments before the 1st of June 2006. The WGWD has reviewed the comments provided by other member of WENRA and stakeholders and extensively modified the SRLs. Most of the comments recommended the group to address more specifically decommissioning issues in order to attribute the specific change of hazards during progressing dismanteling. A new set

of SRLs was established in 2006 in response to comments, as to facilitate a global benchmarking of the SRLs in the WENRA members country.

An evaluation of the implementation in the regulations and in the facilities shall be performed till mid-2007 in each WENRA members state. After this evaluation, the WENRA members shall develop a plan in order to implement the SRLs in their national regulations till the end of the decade.

**APPENDIX
TO PART I.**

The questionnaire of the analysis grid model applied to IAEA statements

WENRA WGWD – decommissioning regulations harmonisation		Country:
IAEA statement analysis grid		
IAEA statement reference:	IAEA doc reference:	Statement number:
<i>IAEA statement quotation</i>		
PRESENT SITUATION IN THE COUNTRY		
Is it a requirement? YES : <input type="checkbox"/>	Requirement part of general regulations? YES : <input type="checkbox"/>	
	Case-by-case license condition? YES : <input type="checkbox"/>	
Comments on requirement level including possible sanctions for licensee :		
Is it guidance (not mandatory)? YES : <input type="checkbox"/>	Comments :	
Is it specific to decomm. or general? specific <input type="checkbox"/>	Comments :	
Is it different for different types of facilities? YES : <input type="checkbox"/>	Comments :	
PROJECTS OF THE COUNTRY		
Will this situation change in the near future? YES : <input type="checkbox"/>		
Comments :		
GENERAL COMMENTS UPON SITUATION IN THE COUNTRY :		
PROPOSAL FOR WGWD		
Omit statement? YES : <input type="checkbox"/>	Take statement as it is? YES : <input type="checkbox"/>	Modify statement? YES : <input type="checkbox"/>
Not within regulator scope <input type="checkbox"/>		Relaxing <input type="checkbox"/>
Not useful or applicable <input type="checkbox"/>		Editorial change only <input type="checkbox"/>
		Strengthening <input type="checkbox"/>
		Grading for different type of facilities <input type="checkbox"/>
Proposal for WGWD requirement (if statement is to be modified) :		
Additional statement on topic not covered by IAEA needed? YES : <input type="checkbox"/>		
Proposal :		
GENERAL COMMENTS ON WGWD REQUIREMENT PROPOSAL :		

This questionnaire was answered by the members of WGWD as a basis for selection of preliminary set of IAEA statements for further analysis (see Chapter 2.1)

Part II.

Decommissioning Safety Reference Levels

1. Safety area: Safety management

1.1. Safety issue: Responsibility

D-01: A licensee¹ shall be responsible for all aspects of nuclear safety on the facility. The continuity of responsibility shall be ensured throughout operation and decommissioning. In accordance with the graded approach, the decommissioning strategies and plans necessary to ensure safety shall be commensurate with the scale of the facility and the type of the inventory.

Related IAEA safety standards:

... The operator is also responsible for all aspects of safety and environmental protection during the decommissioning activities ... (DS 333, para 3.7).

D-02: The ultimate responsibility for safety shall remain with the licensee, although it is permissible to delegate the performance of specific tasks to a subcontractor. The licensee shall ensure that the work of contractors is appropriately controlled so that it is conducted safely.

Related IAEA safety standards:

The ultimate responsibility for safety shall remain with the operator, although it is permissible to delegate the performance of specific tasks to a subcontractor. The decommissioning management shall ensure that the work of contractors is appropriately controlled so that it is conducted safely... (DS 333, para 7.2)

D-03: The licensee shall provide financial assurances and resources to cover the costs associated with safe decommissioning, including management of resulting radioactive waste.

Related IAEA safety standards:

... The operator shall provide financial assurances and resources to cover the costs associated with safe decommissioning, including management of resulting radioactive waste. (DS 333, para 3.7).

1.2. Safety issue: Organisational structure

D-04: The licensee shall establish an organizational structure for the management and implementation of decommissioning, with the responsibility to ensure that decommissioning will be conducted safely.

Related IAEA safety standards:

An organization for the management and implementation of decommissioning shall be established as part of the operator's organization, with the responsibility to ensure that decommissioning will be conducted safely... (DS 333, para 7.1)

D-05: The adequacy of the organisational structure, for safe and reliable decommissioning of the facility, and for ensuring an appropriate response in emergencies, shall be assessed on a regular basis and in particular, if there is a major change in the plant state or hazard.

Related IAEA safety standards:

A safety assessment should form an integral part of the decommissioning plan. The operating organization is responsible for preparing the safety assessment and submitting it for review by the regulatory body. The safety assessment should be commensurate with the complexity and potential hazard of the installation and, in case of deferred decommissioning, should take into account the safety of the installation during the period leading up to final dismantling. (WS-G-2.1, para 5.3)

¹ Covers the possible change of licensee

In order to control all decommissioning activities, the operating organization should implement an effective management control system. This should include control of preparatory decommissioning activities (such as the installation of new safety systems) and recognition of the risks associated with the changing conditions that arise during decommissioning. (WS-G-2.4, para 7.7)

Administrative measures from the operational phase of the facility may be relevant to the decommissioning. These measures should be reviewed and modified to ensure that they are appropriate and, if necessary, additional administrative measures should be taken. ... (WS-G-2.4, para 7.9)

D-06: There should be a clear delineation of authorities and responsibilities, together with the interfaces and communication routes that will be used. This is particularly important when contractors or outside organizations are used.

Related IAEA safety standards:

... There should be a clear delineation of authorities and responsibilities, together with the interfaces and communication routes that will be used. This is particularly important when contractors or outside organizations are used. (WS-G-2.4, para 7.6)

D-07: The skills needed for decommissioning shall be evaluated and the minimum requirements for number and qualifications of staff in each position shall be established.

Related IAEA safety standards:

The skills needed for decommissioning shall be evaluated and the minimum requirements for qualifications of staff in each position shall be established. (DS 333, para. 7.3)

Decommissioning may be carried out in a sequence of operations separated by one or more periods of time (i.e. phased decommissioning). Some of these periods (i.e. decommissioning phases) may consist of inactive, safe enclosure. In such cases of multiple decommissioning phases, the operating organization should submit to the regulatory body a description of:

(a)....

...

(e) the number of staff needed and their qualifications, during any period of deferment. (WS-G-2.1, para. 5.12)

D-08: Provision shall be made to ensure that that institutional knowledge about the facility is maintained and is accessible. This may include provisions for retaining key staff or the transfer of their knowledge to other personnel before leaving.

Related IAEA safety standards:

Provision shall be made, as far as possible, to ensure that key staff is retained and that institutional knowledge about the facility is maintained and is accessible... (DS 333, para 5.9)

1.3. Safety issue: Quality management

D-09: A comprehensive quality management system shall be applied to all phases of decommissioning taking into account the continuous change of decommissioned facility.

Related IAEA safety standards:

A comprehensive quality assurance programme under the operator's management system [7] shall be applied to all phases of decommissioning... (DS 333, para 7.7)

1.4. Safety issue: Record keeping

D-10: Appropriate records and reports that are relevant to decommissioning (e.g. records on the use of the facility, events and incidents, radionuclide inventories, dose rates and

contamination levels) shall be retained during the life of the facility. In this way, the design and modifications of the facility and its operating history will be identified and factored into the decommissioning plan.

Related IAEA safety standards:

... Appropriate records and reports that are relevant to decommissioning (e.g. records on the use of the facility, events and incidents, radionuclide inventories, dose rates and contamination levels) shall be retained during the life of the facility. In this way, the design and modifications of the facility and its operating history will be identified and factored into the decommissioning plan (DS 333, para 5.9)

D-11: The licensee shall maintain an appropriate record system during the decommissioning phases, in particular to ensure that the radioactive material contained in the facility at the end of the operational phase is accounted for, and to facilitate remaining decommissioning.

Related IAEA safety standards:

Relevant documents and records shall be prepared by the operator, kept for an agreed time and maintained to a specified quality by appropriate parties before, during and after decommissioning. plan (DS 333, para 7.6)

2. Safety area: Decommissioning strategy and planning

2.1. Safety issue: Facilitating decommissioning during design, construction and operational phase

D-12: Account shall be taken of the need to decommission a facility at the time it is being planned, designed, constructed and operated. Measures, including design features, contamination and activation control, shall be described and justified in the safety documentation of the facility.

Related IAEA safety standards:

The responsibilities of the operator include:

- *establishing a decommissioning strategy and preparing and maintaining a decommissioning plan throughout the life of the facility;*
- *..... (DS 333, para 3.8)*

D-13: The licensee shall undertake a baseline survey, including radiological conditions of the site before construction, for comparison with the proposed end-state after decommissioning. For those practices for which such a baseline survey has not been done in the past, data from analogous, undisturbed areas with similar characteristics shall be used instead of pre-operational baseline data.

Related IAEA safety standards:

A baseline survey of the site, including obtaining information on radiological conditions, shall be performed prior to construction and updated prior to commissioning of a new facility. This information will be used to determine background conditions during the end state survey. For those practices for which such a baseline survey has not been done in the past, data from analogous, undisturbed areas with similar characteristics shall be used instead of pre-operational baseline data. (DS 333, para 5.8)

2.2. Safety issue: Site decommissioning strategy

D-14: The licensee shall establish a decommissioning strategy for each of its sites or groups of sites. If several facilities are located at the same site with different licenses as an alternative to a site specific strategy it shall be ensured that in each facility specific initial decommissioning plan any interactions and interdependencies between the facilities are taken into account.

Related IAEA safety standards:

The operator shall define a decommissioning strategy, on which the planning for decommissioning will be based. (DS 333, para 4.1)

D-15: A strategy shall be produced and documented including a description of the possible options and timescales for decommissioning. The factors to be considered should include safety and radiation protection aspects, interdependencies of different facilities on a site, possible burdens on future generations, and possible loss of knowledge and expertise. The report should explain the reasons for the preferred option, and options involving deferred decommissioning shall be rigorously justified.

Related IAEA safety standards:

The preferred decommissioning strategy shall be immediate dismantling. There may, however, be situations where immediate dismantling is not a practical strategy when all relevant factors are considered. These factors may include: the availability of waste disposal or long term storage capacity for decommissioning waste; availability of a trained workforce; availability of funds; co-location of other facilities on the same site requiring

decommissioning; technical feasibility; and optimization of the radiation protection of the workers, the public and the environment. If the deferred dismantling or entombment strategy is chosen, the operator shall provide a justification for the selection. The operator shall also demonstrate that, for the selected strategy, the facility will be maintained in a safe configuration at all times, will be adequately decommissioned in the future and that no undue burdens are imposed on future generations. (DS 333, para 4.2).

D-16: The strategy shall be consistent with existing related national strategies, e.g. on decommissioning or radioactive waste management and disposal.

Related IAEA safety standards:

.... The strategy shall be consistent with national decommissioning and waste management policy. (DS 333, para 4.1)

D-17: An initial decommissioning strategy (see D-16) shall be developed in the planning phase of a new site.

Related IAEA safety standards:

In the design of a facility, attention shall be paid to facilitate its ultimate decommissioning, to keep the exposure of personnel and the public arising from decommissioning as low as reasonably achievable (ALARA) as well as to ensure adequate protection of the environment and to minimize the quantity of radioactive waste generated. (DS 333, para 6.35)

D-18: The licensee shall propose an end-state in its decommissioning strategy, which is consistent with the national policy.

Related IAEA safety standards:

The emergency plan shall be approved by the regulatory body and tested in an exercise before the commencement of operation. There shall thereafter at suitable intervals be exercises of the emergency plan and the emergency equipment, some of which shall be witnessed by the regulatory body. Some of these exercises shall be integrated and shall include the participation of as many as possible of the organizations concerned. The plans shall be subject to review and updating in light of the experience gained. (DS 316; para 9.66)

D-19: The decommissioning strategy shall be reviewed by the licensee regularly and shall be updated as required. In particular, the decommissioning strategy shall be updated when planning a new facility on the site.

Related IAEA safety standards:

This initial plan shall be reviewed and updated periodically, at least every five years or as prescribed by the regulatory body, or when specific circumstances warrant, such as if changes in an operational process lead to significant changes to the plan. Revisions or amendments shall also be made as necessary in the light of operational experience gained, new or revised safety requirements or technological developments. If an incident or accident occurs, the decommissioning plan shall be reviewed as soon as possible and modified as necessary. (DS 333, para 5.7)

2.3. Safety issue: Facility decommissioning plan during design, construction and operational phases

D-20: In accordance with the decommissioning strategy, the licensee shall establish and maintain facility decommissioning plans, the details of which are commensurate with the type and status of the facility (graded approach).

Related IAEA safety standards:

The responsibilities of the operator include:

- *establishing a decommissioning strategy and preparing and maintaining a decommissioning plan throughout the life of the facility;*
- *..... (DS 333, para 3.8)*

D-21: The initial decommissioning plan shall be established in the design phase of the facility.

Related IAEA safety standards:

An initial plan for decommissioning should be prepared and submitted by the operating organization in support of the licence application for the construction of a new reactor. Although the level of detail in the initial plan will necessarily be lower than that in the final decommissioning plan, many of the aspects listed in para. 5.11 should be considered in a conceptual fashion. A generic study showing the feasibility of decommissioning may suffice for this plan, particularly in standardized installations. Depending on applicable regulations, the plan should address the costs and the means of financing the decommissioning work. (WS-G-2.1, para 5.6)

D-22: The initial decommissioning plan shall:

- (a) take into account basic safety issues;
- (b) support the fact that decommissioning can be safely conducted using proven techniques or ones being developed;
- (c) include a generic study showing the feasibility of decommissioning;
- (d) include consideration of environmental aspects of decommissioning, such as management of waste and radioactive effluents;
- (e) address the costs of the decommissioning work and the means of financing it.

Related IAEA safety standards:

An initial plan for decommissioning shall be prepared which outlines the overall decommissioning process (Ref. [2], para. 3.13). This plan should be submitted by the operating organization to the regulatory body in support of the licence application for commissioning and/or operating the facility. This plan:

- (a) Should take into account basic safety issues;*
- (b) Should support the fact that decommissioning can be safely conducted using proven techniques or ones being developed;*
- (c) Should include a generic study showing the feasibility of decommissioning;*
- (d) Should include consideration of environmental aspects of decommissioning, such as management of waste and radioactive effluents;*
- (e) Should address the costs of the decommissioning work and the means of financing it. (WS-G-2.4, para 5.6).*

D-23: The decommissioning plan shall be reviewed by the licensee regularly, at least as frequently as the periodic safety review, and shall be updated as required. These updates of the decommissioning plan shall reflect, in particular, changes in the facility or regulatory requirements, and advances in technology.

Related IAEA safety standards:

During the operation of a reactor, the decommissioning plan should be reviewed, updated and made more comprehensive with respect to technological developments in decommissioning, incidents that may have occurred, including abnormal events, amendments in regulations and government policy, and, where applicable, cost estimates and financial provisions. All significant systems and structural changes during plant operation should be reflected in the process of ongoing planning for decommissioning. (WS-G-2.1, para 5.8)

D-24: The decommissioning plan shall be supported by an appropriate safety assessment for the decommissioning activities the details of which are commensurate with the type and status of the facility (graded approach).

Related IAEA safety standards:

.... The decommissioning plan should evolve with respect to safety considerations, based on operational experience and on information reflecting improved technology. All significant systems and structural changes during plant operation should be reflected in the process of ongoing planning for decommissioning. (WS-G-2.1, para 5.8)

The decommissioning plan shall be supported by an appropriate safety assessment covering the planned decommissioning activities and abnormal events that may occur during decommissioning. The assessment shall

address the occupational exposures and potential releases of radioactive substances with resulting exposure of the public. (DS-333, para 5.2)

D-25: The decommissioning plan shall identify existing facilities and equipment that will be used during decommissioning to ensure that the equipment is available when needed. The decommissioning plan shall also identify necessary changes to the existing safety systems which were used during operation and the need for replacement or new plants to carry out decommissioning operations.

2.4. Safety issue: Final decommissioning plan

D-26: When it has been decided to shut down a nuclear facility, the licensee shall inform the regulatory body.

D-27: If a facility is shut down and no longer used for its intended purpose, a final decommissioning plan shall be submitted to the regulatory body not later than two years after the shut down of the facility, unless an alternative schedule for the submission of the final decommissioning plan is specifically authorized by the regulatory body.

2.5. Safety issue: Decommissioning plan update during decommissioning operations

D-28: Depending on the timeframe of decommissioning, the decommissioning plan shall be reviewed regularly by the licensee during decommissioning operations, and shall be updated as required. These updates of the decommissioning plan are to reflect, in particular, changes in the decommissioning strategy, deviations from the scheduled program, changes in the facility or regulatory requirements and advances in technology.

Related IAEA safety standards:

The decommissioning plan shall be reviewed regularly and shall be updated as required to reflect, in particular, changes in the facility or regulatory requirements, advances in technology and, finally, the needs of the decommissioning operation. If an abnormal event occurs, a new decommissioning plan or modification of the existing decommissioning plan may be necessary. (WS-R-2.Para 6.3).

During the implementation of the decommissioning plan, revisions or amendments may need to be made to the plan in the light of operational experience gained, new or revised safety requirements, or technological developments. (WS-R-2.Para 6.4).

D-29: The licensee shall control modifications of planned decommissioning activities using a graded approach according to the classification with respect to their safety significance.

Related IAEA safety standards:

The operating organization shall establish a process whereby its proposals for changes in design, equipment, feed material characteristics, control or management are subject to a degree of assessment and scrutiny appropriate to the safety significance of the change, so that the specific and wider consequences of the modification are adequately assessed. The process shall ensure that a review of possible consequences of a foreseen modification or change in one facility will not adversely impact on the operability or safety of associated or adjacent facilities. (DS 316, para. 9.35)

D-30: The licensee shall ensure that no modification to the planned decommissioning activities, whatever the reason for it, compromise the safety of decommissioning.

Related IAEA safety standards:

The operating organization shall establish a process whereby its proposals for changes in design, equipment, feed material characteristics, control or management are subject to a degree of assessment and scrutiny

appropriate to the safety significance of the change, so that the specific and wider consequences of the modification are adequately assessed. The process shall ensure that a review of possible consequences of a foreseen modification or change in one facility will not adversely impact on the operability or safety of associated or adjacent facilities. (DS 316, para. 9.35)

2.6. Safety issue: Regulatory policy and permitting strategy

Unlike the other safety reference levels this chapter addresses mainly the regulatory authorities responsible for the control of decommissioning activities.

D-31: The established regulatory framework shall contain provisions to ensure that there is clear and unequivocal allocation of responsibility for safety during decommissioning. The continuity of responsibility for safety shall be ensured through regulatory control.

Related IAEA safety standards:

It is possible that predisposal management of radioactive waste will involve the transfer of the radioactive waste from one operator to another, or that the radioactive waste may even be processed in another country. Similarly, decommissioning may be carried out by an operator different from the operator responsible for facility operation.

Furthermore, decommissioning may be deferred or carried out in a series of discrete operations over time (phased decommissioning). The established legal framework shall contain provisions to ensure that there is clear and unequivocal allocation of responsibility for safety during the entire process of predisposal management of radioactive waste. This continuity of responsibility for safety shall be ensured through regulatory control, e.g. by a licence or a sequence of licences according to the national legal framework. (WS-R-2, para 3.2).

D-32: The entire decommissioning process shall be regulated by a license, which may be the same legal document as for the operating phase, or a specific license for decommissioning, or a sequence of licenses, according to the national legal framework.

Related IAEA safety standards:

WS-R-2, para 3.2 – see D-31

In the context of decommissioning, the post-operational phase of a nuclear facility, starting with the final shutdown and extending over the entire decommissioning process, shall be regulated, e.g. by a licence, a sequence of licences or other regulatory control, according to the national legal framework. (WS-R-2, para 3.4).

D-33: Depending on the licensing regime, a regulatory permission may be required to start major decommissioning operations (i.e. operations outside the operational phase safety case). This shall be based on the final decommissioning plan and the initial safety case for decommissioning.

D-34: Depending on the licensing regime, some safety-significant decommissioning operations may be subject to regulatory permissions. These shall be based on detailed safety analyses provided by the licensee².

D-35: Depending on the licensing regime, specific information on the progress of the decommissioning work against the plan shall be provided by the licensee.

² Unlike D-35 takes account of developments of the ongoing decommissioning operation, thus broadening the decision basis.

Related IAEA safety standards:

Unless otherwise required by the regulatory body, the operator shall establish and maintain decommissioning plans which are commensurate with the type and status of the facility. The initial decommissioning plan shall be established in the design phase of the facility (WS-R-2, para 3.13).

When it has been decided to shut down a nuclear facility, the operator shall submit an application for permission to decommission the facility for approval by the regulatory body, together with the proposed final decommissioning plan. If it is intended to defer decommissioning, it shall be demonstrated in the final decommissioning plan that such an option is safe. Furthermore, a line of reasoning shall be provided to show that no undue burdens are imposed on future generations (WS-R-2, para 6.5).

If final shutdown occurs before a decommissioning plan is prepared, decommissioning of the facility shall not be started until a satisfactory decommissioning plan has been approved by the regulatory body, unless otherwise decided by the regulatory body (see para. 6.2) (WS-R-2, para 6.6).

WS-R-2 requirements n°6.5, 6.6 – 3.13

3. Safety area: Conduct of decommissioning

3.1. Safety issue: Safety classification

D-36: SSCs may be declassified / downgraded as they lose their importance to safety in the course of decommissioning activities. This must be justified by an update of the safety case which was the basis for classification of the respective component/system. The SSCs provide barriers for the prevention of the occurrence of postulated initiating events (PIEs) and for the mitigation of accident sequences.

Related IAEA safety standards:

The safety functions, and the structures, systems and components important to safety (SSCs) shall be identified to the extent appropriate to a graded approach. These SSCs provide barriers for the prevention of the occurrence of postulated initiating events (PIEs), the control and the limitation of accident sequences and the mitigation of the consequences. (DS 316, para. 2.13)

Non-radiological as well as radiological hazards associated with the decommissioning activities should be identified and evaluated in the safety assessment. As a result of this assessment, the protective measures can be defined that will ensure that the regulatory requirements are met. These protective measures may require changes to the existing safety systems that were used during operation. The acceptability of such changes should be clearly justified in the safety assessment. ... (WS-G-2.4, para. 5.14)

3.2. Safety issue: On-site emergency preparedness

Due to the great variety of facilities and the change of potential hazards during the course of decommissioning the content of the site emergency plan may vary from a full scope plan including the involvement of outside agencies to a justification that an emergency plan is not required. This site emergency plan can be based on the operational one but modified according to changed hazards during the decommissioning actions. The following SRLs therefore need to be applied in proportionate manner.

D-37: The licensee shall develop an on-site emergency plan in co-ordination with other bodies having responsibilities in an emergency, including public authorities, establish the necessary organizational structure and assign responsibilities for managing emergencies.

Related IAEA safety standards:

The operating organization shall develop an emergency plan in co-ordination with other bodies having responsibilities in an emergency, including public authorities, establish the necessary organizational structure and assign responsibilities for managing emergency (DS316 – para 9.62).

D-38: The on-site emergency plan of the licensee shall provide for arrangements to address the following:

- (1) The designation of persons who will be responsible for directing on-site activities and for ensuring liaison with off-site organizations;
- (2) The requirements for personnel training;
- (3) The list of likely accidents, including any combination of nuclear and non-nuclear hazards as necessary;
- (4) The conditions and criteria under which an emergency shall be declared, a list of job titles and/or functions of persons empowered to declare it, and a description of suitable means for alerting response personnel and public authorities;
- (5) The arrangements for assessment of the radiological conditions on and off the site (water, vegetation, soil, air sampling);

- (6) Provisions for minimizing the exposure of persons to ionising radiation and for ensuring medical treatment of casualties;
- (7) Assessment of the state of the facility and the actions to be taken on the site to limit the extent of radioactive release and spread of contamination;
- (8) The chain of command and communication, including a description of related facilities and procedures; There shall be a means of informing all persons on the site of the actions to be taken in the event of an emergency.
- (9) An inventory of the emergency equipment to be kept in readiness at specified locations;
- (10) The actions to be taken by persons and organizations involved in the implementation of the plan;
- (11) Provisions for declaring the termination of an emergency.

Related IAEA safety standards:

The emergency plan of the operating organization shall provide for arrangements to address the following:

- (1) *The designation of persons who will be responsible for directing on-site activities and for ensuring liaison with off-site organizations;*
- (2) *The requirements for personnel training;*
- (3) *The list of likely accident. If relevant, the description of possible severe accidents and their consequences ;*
- (4) *The conditions and criteria under which an emergency shall be declared, a list of job titles and/or functions of persons empowered to declare it, and a description of suitable means for alerting response personnel and public authorities;*
- (5) *The arrangements for assessment of the radiological conditions on and off the site (water, vegetation, soil, air sampling);*
- (6) *Provisions for minimizing the exposure of persons to ionising radiation and for ensuring medical treatment of casualties;*
- (7) *Assessment of the state of the facility and the actions to be taken on the site to limit the extent of radioactive release and spread of contamination;*
- (8) *The chain of command and communication, including a description of related facilities and procedures;*
- (9) *An inventory of the emergency equipment to be kept in readiness at specified locations;*
- (10) *The actions to be taken by persons and organizations involved in the implementation of the plan;*
- (11) *Provisions for declaring the termination of an emergency.(DS316 para 9.63)*

D-39: The on-site emergency plan shall be reviewed by the regulatory body and tested in an exercise before the commencement of decommissioning activities. There shall thereafter at suitable intervals be exercises of the emergency plan and the emergency equipment, some of which shall be witnessed by the regulatory body. Some of these exercises shall be integrated and shall include the participation of other organizations concerned.

Related IAEA safety standards:

The emergency plan shall be approved by the regulatory body and tested in an exercise before the commencement of operation. There shall thereafter at suitable intervals be exercises of the emergency plan and the emergency equipment, some of which shall be witnessed by the regulatory body. Some of these exercises shall be integrated and shall include the participation of as many as possible of the organizations concerned. The plans shall be subject to review and updating in light of the experience gained.(DS 316; para 9.66)

D-40: During decommissioning, the licensee shall review and modify as necessary the existing emergency plan, so that it stays appropriate for current and future states of the facility.

Related IAEA safety standards:

A programme for emergency planning shall be established and described in the decommissioning plan. This programme should be subject to approval by the regulatory body. Operating organizations should ensure that procedures to deal with unforeseen events are prepared and are put in place. Personnel should be trained in

emergency procedures. Provision should be made for regular testing and updating of these procedures by conducting exercises periodically. (WS-G-2.4 para 7.27)

3.3. Safety issue: Decommissioning experience feedback

D-41: The licensee shall establish and conduct an experience feedback procedure to collect, screen, analyse, document and provide experience and events at the facility in a systematic way to improve and ensure safe decommissioning. Relevant experience and events reported by other facilities shall also be considered as appropriate.

Related IAEA safety standards:

Arrangements shall be made so that available technical information on abnormal occurrences, incidents and accidents that have occurred in the facility or in similar ones are analysed for feedback and preventive action if necessary. (DS316 para 9.16)

D-42: The licensee shall ensure that results are obtained, that conclusions are drawn, measures are taken, good practices are considered and that timely and appropriate corrective actions are implemented to prevent recurrence and to counteract developments adverse to safety.

Related IAEA safety standards:

The operating organization shall be responsible for verifying the safety of the facility at all times. It shall establish or shall have access to an appropriate safety analysis capability to ensure that the necessary justifications are generated and maintained throughout the facility lifetime. It shall ensure that events with safety significance are reviewed in depth and that when necessary to prevent recurrence of accidents, equipment is modified, procedures are revised, personnel qualifications are reassessed and training is updated and given. (DS 316, para. 4.23)

3.4. Safety issue: Waste management

D-43: The licensee shall develop, document and implement processes to categorise and manage the particularly large quantities and different types of radioactive waste and other material that are produced during decommissioning, in accordance with the requirements set by the national regulatory authority and with the national waste management strategy.

Related IAEA safety standards:

Decommissioning of nuclear reactors invariably involves the generation of large amounts of radioactive wastes. In the course of decommissioning, waste will be generated in forms that are different from materials and wastes of the types routinely handled during the operational phase of a nuclear power plant or research reactor. Subject to safety considerations, "generation of radioactive waste shall be kept to the minimum practicable". (WS-G-2.1,para. 2.20)

Appropriate means shall be available to manage waste of all categories in a timely manner, with account taken of the overall decommissioning management strategy. Disposal is the preferred option for waste that is generated during decommissioning activities, but if disposal capacity is not available, waste shall be stored safely in accordance with applicable requirements. (DS 333, para. 4.6)

D-44: The licensee shall develop, document and implement processes to segregate radioactive waste from non-radioactive material in accordance with the requirements set by the national legal framework and with the national waste management strategy.

Related IAEA safety standards:

..... For example, appropriate decontamination and dismantling techniques and the reuse or recycling of materials can reduce the waste inventory. (WS-G-2.1,para. 2.20)

A large part of the waste and other materials arising during the decommissioning process may be sufficiently low in activity concentration for regulatory control to be wholly or partly removed. Some waste may be suitable for disposal in normal landfill sites, while some materials such as steel and concrete may be suitable for recycling or reuse outside the nuclear industry. The removal of regulatory controls should be accomplished in compliance with criteria established by the national regulatory body. (WS-G-2.4, para 7.21)

D-45: The licensee shall keep accurate record of the waste and other material generated by the decommissioning operations stored on the site.

Related IAEA safety standards:

.... The programme shall include the maintenance and archiving of documents and records relating to decommissioning, and the performance of all work activities and operations for decommissioning. (DS-333, para 7.7)

A final decommissioning report, including any necessary final confirmation survey, shall be prepared and retained with other records, as appropriate. (WS-R-2, para 6.13)

D-46: The licensee shall keep accurate record, for a timeframe defined in the national regulations or in the license, of the waste and other material generated by the decommissioning operations that has left the site.

Related IAEA safety standards:

On completion of decommissioning, appropriate records should be retained. In accordance with the national legal framework, these will be held and maintained for purposes such as confirmation of completion of decommissioning activities in accordance with the approved plan, recording the disposal of wastes, materials and premises, and responding to possible liability claims. (WS-G-2.1, para 8.1)

(Note: in the case where waste has been sent to interim storage, the licensee keeps responsibility as the waste owner)

3.5. Safety issue: On-site and off-site monitoring

D-47: Due to the changes of the facility, specific hazards and effluents associated with decommissioning, the licensee shall apply, review and modify as necessary its on- and off-site monitoring program.

Related IAEA safety standards:

The radiation protection programme should be clearly set out in the decommissioning plan. Those involved in its execution should be properly trained and have access to appropriate equipment for carrying out radiation surveys, including equipment for measuring external dose rates and surface contamination levels and for sampling air concentrations. (WS-G-2.1, para 7.14)

All decommissioning work should be planned and carried out using work order procedures and radiation work permits, with adequate involvement of radiation protection expertise to determine the required radiation protection measures. Moreover, the promotion of awareness of safety issues should be accorded high emphasis in planning and implementation. Those charged with the day to day responsibility for radiation protection should have the resources, access to decommissioning management and independence necessary to effect an adequate radiation protection programme. (WS-G-2.1, para 7.15)

The decommissioning plan should specify the requirement for on-site and off-site monitoring during decommissioning. On-site monitoring should provide information to identify and assist in mitigating the radiological hazards. It should also be used in the planning of specific decommissioning activities. It should ensure that all potential release points are monitored. On-site monitoring should consist not only of personnel monitoring but also of spatial monitoring for airborne contaminants, such as, having:

- (a) appropriate monitoring equipment for dose rate and contamination surveys for workplaces, components and materials during decontamination, dismantling and handling;*
- (b) appropriate monitoring protocols and equipment for packaging and handling of radioactive waste within the site, as well as for transportation of the waste offsite;*

- (c) appropriate monitoring equipment for airborne contaminants;
- (d) appropriate monitoring equipment for timely screening of large quantities of low level radioactive material for clearance purposes; and
- (e) appropriate equipment and protocols to monitor the distribution of radionuclides in the installation. (WS-G-2.1, para 7.16)

The off-site monitoring programme inherited from the operational period will require modification appropriate to the conditions existing during decommissioning. Discharges of radionuclides via airborne and liquid pathways should be controlled, monitored and recorded, as required by the regulatory body or other relevant competent authority. Relevant recommendations are provided in Refs [11, 12, 22]. (WS-G-2.1, para 7.17)

3.6. Safety issue: Maintenance, Testing and Inspection

D-48: The licensee shall prepare, and implement documented programmes for maintenance, testing, surveillance and inspection of SSCs important to safety during decommissioning to ensure that their availability, reliability and functionality remain in accordance with the safety case. The programmes shall take into account operational limits and conditions and be re-evaluated in the light of experience.

Related IAEA safety standards:

The operating organization shall prepare and implement a programme of maintenance, testing, surveillance and inspection of those structures, systems and components which are important to safety. This programme shall be in place prior to fuel loading and shall be made available to the regulatory body. It shall take into account operational limits and conditions as well as any other applicable regulatory requirements and it shall be re-evaluated in the light of experience. (NS-R-2, 6.1)

The maintenance, testing, surveillance and inspection of all plant structures, systems and components important to safety shall be to such a standard and at such a frequency as to ensure that their levels of reliability and effectiveness remain in accordance with the assumptions and intent of the design throughout the service life of the plant. (NS-R-2, 6.2)

Effective maintenance, surveillance and inspection (MS&I) are essential for the safe operation of a nuclear power plant. They ensure not only that the levels of reliability and availability of all plant structures, systems and components (SSCs) that have a bearing on safety remain in accordance with the assumptions and intent of the design, but also that the safety of the plant is not adversely affected after the commencement of operation. (NS-G-2.6, 1.1)

The maintenance programme for a nuclear power plant should cover all preventive and remedial measures, both administrative and technical, that are necessary to detect and mitigate degradation of a functioning SSC or to restore to an acceptable level the performance of design functions of a failed SSC. The purpose of maintenance activity is also to enhance the reliability of equipment. The range of maintenance activities includes servicing, overhaul, repair and replacement of parts, and often, as appropriate, testing, calibration and inspection. (NS-G-2.6, 2.1)

D-49: The licensee shall address the ageing of SSCs by establishing, if necessary, provisions for their maintenance, testing and inspection.

D-50: The programme shall include periodic inspections or tests of SSCs important to safety during decommissioning in order to demonstrate their reliability and to determine whether they are acceptable for continued safe decommissioning or whether any remedial measures are necessary.

Related IAEA safety standards:

The programme shall include periodic inspections or tests of systems, structures and components important to safety in order to demonstrate their reliability and to determine whether they are acceptable for continued safe operation of the plant or whether any remedial measures are necessary. (NS-R-2, 6.3)

The systems and components of the plant should be examined for possible deterioration so as to assess whether they are acceptable for continued safe operation of the plant or whether remedial measures should be taken. Emphasis should be placed on examination of the pressure boundaries of the primary and secondary coolant systems, because of their importance to safety and the possible severity of the consequences of failure. (NS-G-2.6, 2.13 and 10.2)

D-51: Data on maintenance, testing, surveillance and inspection of SSCs important to safety during decommissioning shall be recorded, stored and analysed. Such records shall be reviewed to look for evidence of incipient and recurring failures, to initiate corrective maintenance and review the preventive programme of maintenance accordingly.

Related IAEA safety standards:

Data on maintenance, testing, surveillance and inspection shall be recorded, stored and analysed to confirm that performance is in accordance with design assumptions and with expectations on equipment reliability. (NS-R-2, 6.10)

The operating organization should monitor the performance or condition of SSCs against the goals it has set to provide reasonable assurance that the SSCs are capable of performing their intended function. (NSG 2.6 2.7)

A brief but complete review of the repairs carried out should be made and documented. This review should explicitly identify the cause of failure, the remedial action taken, the component that failed and its mode of failure, the total repair time and, if different, the outage time and, finally, the state of the system after repair. Even if a system is found to be within its calibration limits, this fact should be recorded, together with details of any replacement or any adjustment carried out at the discretion of maintenance personnel. For major failures of components important to safety, a root cause analysis should be carried out in order to prevent recurrence. (NS-G-2.6, 5.32, 8.47).

A common database should be established in order to share relevant data and evaluations of results among the organizations that are involved in the planning and implementation of MS&I activities. (NS-G-2.6, 2.16)

An adequate condition monitoring programme should be established in support of optimisation of the maintenance programme. Such a monitoring programme should be based on the following assumptions as a minimum:

- *that the monitored parameters are appropriate indicators for the condition of the SSCs,*
- *that acceptance criteria are available,*
- *that all potential failure modes are addressed,*
- *that the behaviour of the potential failure is traceable and predictable. (NS-G-2.6, 2.8)*

The maintenance group should periodically review the maintenance records for evidence of incipient or recurring failures. When a need for remedial maintenance is identified, either in this review or during preventive maintenance of the plant, the maintenance group should initiate remedial maintenance in accordance with the administrative procedures mentioned above. If appropriate, the preventive maintenance programme should be revised accordingly. Replacement of defective items (NS-G-2.6, 8.48)

D-52: Repairs to SSCs important to safety during decommissioning shall be performed promptly as practicable. Priorities shall be established with account taken first of the relative importance to safety of the defective SSC.

Related IAEA safety standards:

Repairs to structures, systems and components shall be performed as promptly as practicable. Priorities shall be established with account taken first of the relative importance to safety of the defective structure, system or component (NS-R-2, 6.5)

D-53: Following any abnormal event which is significant for the safety of decommissioning activities, the licensee shall carry out any necessary remedial actions, including inspection, testing, maintenance and repair, as appropriate.

Related IAEA safety standards:

Following any abnormal event, the operating organization shall revalidate the safety functions and functional integrity of any component or system which may have been challenged by the event. Necessary remedial shall include inspection, testing and maintenance as appropriate (NS-R-2, 6.9)

D-54: The licensee shall apply, review and modify as necessary its maintenance and testing program, considering the rapid changes of the facility during decommissioning.

3.7. Safety issue: Control of work activities

D-55: No decommissioning operation may be undertaken without a prior assessment of its impact on safety taking into account the postulated initiating events with internal causes included in the safety case.

D-56: The licensee shall set up a system to ensure that work control procedures are amended as the state of the facility changes.

Related IAEA safety standards:

Administrative measures stemming from the operational phase of the installation may be relevant during decommissioning. These measures should be reviewed and modified to ensure that they are appropriate to the decommissioning. The requirement for additional measures should be addressed. The administrative control measures may be required to be endorsed by the regulatory body. (WS-G-2.1, para 7.9)

In order to control all decommissioning activities, the operating organization should document and implement appropriate management systems. An example of such documentation is provided in Annex II. (WS-G-2.1 para 7.11)

D-57: No decommissioning operation that may have an impact on safety shall be undertaken without appropriate written work procedures.

Related IAEA safety standards:

Decommissioning tasks shall be controlled through the use of written procedures. These procedures shall be subject to review and approval by the appropriate operator organizations responsible for ensuring safety and practicability. A methodology for issuing, modifying and terminating work procedures shall be established. (DS-333, para 7.5)

3.8. Safety issue: Care-and-maintenance periods

D-58: The facility shall be made passively safe so far as it is reasonably practical before entering a care-and-maintenance phase, which means that the need for active safety systems, monitoring, and human intervention to ensure safety is minimised.

D-59: Before the start of care-and-maintenance periods, the licensee shall develop an adequate care-and-maintenance program which

- ensures safety by its implementation, and
- shall not impair future decommissioning.

Related IAEA safety standards:

Maintenance may be important during deferred decommissioning since part of the safety of the installation may rely on systems that have to retain their capability to perform for extended periods of time. Periodical monitoring of all the safety related components of the installation should be incorporated into the decommissioning plan. (WS-G-2.1 para 6.21)

4. Safety area: Safety verification

4.1. Safety issue: Contents and updating of the safety case

D-60: The licensee shall provide a safety case and use it as a basis for continuous support of safe decommissioning.

Related IAEA safety standards:

The operating organization shall establish and justify the safety of its facility through a set of documents named the 'safety case'. The safety case shall be the basis for the safe siting, construction, operation and decommissioning of the facility including the justification for changes. It shall be an important link between the operating organization and the regulatory body since it is the main body of documents for granting the authorizations necessary under national legislative requirements. (DS-316, para 2.10)

D-61: The safety case shall address all relevant safety issues and may consist to the following items:

- describe the site, the facility layout and facility performance during decommissioning activities; and demonstrate how safety is achieved,
- contain detailed descriptions of the safety functions; all safety systems and safety-related SSCs; their design basis and functioning in all decommissioning states including anticipated decommissioning occurrences and accidents identify applicable regulations codes and standards,
- describe the relevant aspects of the decommissioning organization and the management of safety,
- contain the evaluation of the safety aspects related to the site,
- outline the general safety objectives of decommissioning, design concept and the approach adopted to meet the fundamental safety objectives,
- describe the safety analyses performed to assess the safety of the facility in response to PIEs against safety criteria and radiological release limits (see Appendix),
- describe the on-site emergency operation procedures and accident management guidelines, the inspection and testing provisions, the qualification and training of personnel, the decommissioning experience feedback programme, and the management of ageing,
- contain the technical bases for the operational limits and conditions,
- describe the policy, strategy, methods and provisions for radiation protection,
- describe the emergency preparedness arrangements,
- describe the on-site radioactive waste management provisions.

Related IAEA safety standards:

The experience from previous decommissioning should be appropriately taken into account as a matter of principle. The following list of items to be considered for the final decommissioning plan should thus be updated whenever previous decommissioning experience permits:

- (a) a description of the nuclear reactor, the site and the surrounding area that could affect, and be affected by, decommissioning;
- (b) the life history of the nuclear reactor, reasons for taking it out of service, and the planned use of the nuclear installation and the site during and after decommissioning;
- (c) a description of the legal and regulatory framework within which decommissioning will be carried out;
- (d) explicit requirements for appropriate radiological criteria for guiding decommissioning;
- (e) a description of the proposed decommissioning activities, including a time schedule;
- (f) the rationale for the preferred decommissioning option, if selected;
- (g) safety assessments and environmental impact assessments, including the radiological and non-radiological hazards to workers, the public and the environment; this will include a description of the proposed radiation protection procedures to be used during decommissioning;

- (h) a description of the proposed environmental monitoring programme to be implemented during decommissioning;
- (i) a description of the experience, resources, responsibilities and structure of the decommissioning organization, including the technical qualification/skills of the staff;
- (j) an assessment of the availability of special services, engineering and decommissioning techniques required, including any decontamination, dismantling and cutting technology as well as remotely operated equipment needed to complete decommissioning safely;
- (k) a description of the quality assurance programme;
- (l) an assessment of the amount, type and location of residual radioactive and hazardous non-radioactive materials in the nuclear reactor installation, including calculational methods and measurements used to determine the inventory of each;
- (m) a description of the waste management practices, including items such as:
 - identification and characterization of sources, types and volumes of waste;
 - criteria for segregating materials;
 - proposed treatment, conditioning, transport, storage and disposal methods;
 - the potential to reuse and recycle materials, and related criteria; and
 - anticipated discharges of radioactive and hazardous non-radioactive materials to the environment;
- (n) a description of other applicable important technical and administrative considerations such as safeguards, physical security arrangements and details of emergency preparedness;
- (o) a description of the monitoring programme, equipment and methods to be used to verify that the site will comply with the release criteria;
- (p) details of the estimated cost of decommissioning, including waste management, and the source of funds required to carry out the work; and
- (q) a provision for performing a final confirmatory radiological survey at the end of decommissioning. (WS-G-2.1, para 5.11)

D-62: The safety case for decommissioning shall include, in particular, aspects such as: ~~rapid~~ dynamic changes in facility state, radiological characterisation plan of the facility, management of large quantities of radioactive material, conventional and nuclear safety issues from demolition and dismantling and also the unusual working environment.

Radiological hazards that are of particular importance in the case of decommissioning include: extensive cutting of activated and contaminated material, modification of safety barriers, entry into areas of the plant that were normally inaccessible, decontamination of large items, dispersion of contamination during demolition.

Significant non-radiological hazards that are of particular importance in the case of decommissioning include: lifting and handling of heavy loads, use of hazardous materials for decontamination, stability of decontaminated structures, demolition.

Related IAEA safety standards:

An organization for the management and implementation of decommissioning shall be established as part of the operator's organization, with the responsibility to ensure that decommissioning will be conducted safely... (DS 333, para 7.1).

During the operation of a reactor, the decommissioning plan should be reviewed, updated and made more comprehensive with respect to technological developments in decommissioning, incidents that may have occurred, including abnormal events, amendments in regulations and government policy, and, where applicable, cost estimates and financial provisions. The decommissioning plan should evolve with respect to safety considerations, based on operational experience and on information reflecting improved technology. All significant systems and structural changes during plant operation should be reflected in the process of ongoing planning for decommissioning. (WS-G-2.1, para 5.8)

D-63: The safety case for decommissioning shall cover planned new installations, facilities and systems that are necessary according to the decommissioning plan.

Related IAEA safety standards:

.... In such cases of multiple decommissioning phases, the operating organization should submit to the regulatory body a description of:

- (a) ...;
- (b) existing or new systems or programmes necessary for maintaining the installation under proper control, such as engineered barriers, ventilation, drainage and environmental/safety monitoring;
- (c) systems to be installed or replaced to carry out deferred dismantling;
- (d) the proposed frequency at which the above items would be reviewed; and
- (e) the number of staff needed and their qualifications, during any period of deferment. (WS-G-2.1, para 5.12)

D-64: The initial safety case for decommissioning shall be produced by the licensee with the final decommissioning plan prior to the beginning of decommissioning activities.

Related IAEA safety standards:
See D-61

D-65: To support the safety case for decommissioning, the licensee shall examine records³ and conduct surveys and measurements to verify the inventory and locations of radioactive, fissile or other hazardous materials in the facility and the surrounding potentially affected areas.

Related IAEA safety standards:

A survey of radiological and non-radiological hazards is an important input for the safety assessment and for implementing a safe approach during the work and should be conducted to identify the inventory and location of radioactive and other hazardous materials. In planning and implementing surveys, use should be made of existing records and operating experience. A characterization report should be prepared which documents the information and data obtained during the characterization process. The report should be retained as part of the official records of the installation. (WS-G-2.1, para 6.1)

An adequate number of radiation and contamination surveys should be conducted to determine the radionuclides, maximum and average dose rates, and contamination levels of inner and outer surfaces of structures or components throughout the reactor installation. For completeness, contamination in shielded or self-shielded components, such as inside pipes and pumps, should be characterized. Results of such surveys will aid in the preparation of radiation and contamination maps. Furthermore, special surveys to determine the penetration depth and the extent of contamination may be required to assist in the selection of appropriate procedures for decontamination or dismantling. For activated components, calculations should be used together with selective verification sampling. (WS-G-2.1, para 6.2)

An inventory of all hazardous chemicals present in the installation should be conducted. Hazardous materials such as asbestos require special consideration to prevent harm to human health. Substances such as oils found in nuclear reactors in general, or sodium residues found in fast breeder reactors, may present significant risk of fire or explosion which has to be dealt with in an appropriate manner. (WS-G-2.1, para 6.3)

The removal of spent fuel from the reactor installation at the end of its operational lifetime should preferably be performed as part of operations or as one of the initial activities in decommissioning. Its timely removal from the installation is beneficial and will simplify monitoring and surveillance requirements. The time for fuel removal will vary considerably, depending upon the type and size of the reactor, the condition of the fuel, and also on the constraints for its transport and off-site management. Other activities associated with decommissioning may be conducted concurrently with fuel removal, but potential interference should be evaluated. (WS-G-2.1, para 6.3)

D-66: To support the safety case for decommissioning, the licensee shall conduct surveys of the facility for comparison with last recorded design information.

Related IAEA safety standards:

A survey of radiological and non-radiological hazards is an important input for the safety assessment and for implementing a safe approach during the work and should be conducted to identify the inventory and location of radioactive and other hazardous materials. In planning and implementing surveys, use should be made of

³ Experience show that records are not generally adequate to provide a sound basis for the safety case and that confirmatory surveys and measurements have to be conducted to verify the basic information on facility state.

existing records and operating experience. A characterization report should be prepared which documents the information and data obtained during the characterization process. The report should be retained as part of the official records of the installation. (WS-G-2.1, para 6.1)

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D-67: The licensee shall update the safety case to reflect modifications and new relevant regulatory requirements, as soon as practicable and in accordance with safety relevance of the modification after the new information is available and applicable. The licensee shall use the safety case as a basis for assessing the safety implications of changes to the facility or to decommissioning practices.

Related IAEA safety standards:

During the operation of a reactor, the decommissioning plan should be reviewed, updated and made more comprehensive with respect to technological developments in decommissioning, incidents that may have occurred, including abnormal events, amendments in regulations and government policy, and, where applicable, cost estimates and financial provisions. The decommissioning plan should evolve with respect to safety considerations, based on operational experience and on information reflecting improved technology. All significant systems and structural changes during plant operation should be reflected in the process of ongoing planning for decommissioning. (WS-G-2.1, para 5.8)

D-68: OLCs shall be reviewed and updated in the light of experience and every time modifications in the facility or in the safety case warrant it, and changed if necessary.

Related IAEA safety standards:

The operating organization shall carry out at regular intervals periodic safety reviews of the These reviews shall also ensure that all changes in OLCs, maintenance programmes, drawings, operation, maintenance, and emergency procedures have been properly captured in the current arrangements and procedures. (DS 316, para. 2.17)

D-69: The licensee shall maintain an up-to-date safety case that corresponds to the actual state of the facility in the decommissioning process, based on the latest consolidated safety case.

Related IAEA safety standards:

This initial plan shall be reviewed and updated periodically, at least every five years or as prescribed by the regulatory body, or when specific circumstances warrant, such as if changes in an operational process lead to significant changes to the plan. Revisions or amendments shall also be made as necessary in the light of operational experience gained, new or revised safety requirements or technological developments. If an incident

or accident occurs, the decommissioning plan shall be reviewed as soon as possible and modified as necessary. (DS-333, para 5.7)

If deferred dismantling is instituted, the safety documentation and decommissioning plans should be periodically reviewed to ensure that they represent current installation conditions. (WS-G-2.1, para 5.20)

D-70: The licensee shall consolidate the safety case at major steps in the decommissioning program. This consolidation has the goal to produce a revised, integrated and consistent safety case including all necessary amendments.

Related IAEA safety standards:

This initial plan shall be reviewed and updated periodically, at least every five years or as prescribed by the regulatory body, or when specific circumstances warrant, such as if changes in an operational process lead to significant changes to the plan. Revisions or amendments shall also be made as necessary in the light of operational experience gained, new or revised safety requirements or technological developments. If an incident or accident occurs, the decommissioning plan shall be reviewed as soon as possible and modified as necessary. (DS-333, para 5.7)

If deferred dismantling is instituted, the safety documentation and decommissioning plans should be periodically reviewed to ensure that they represent current installation conditions. (WS-G-2.1, para 5.20)

4.2. Safety issue: Periodic safety review

D-71: The licensee shall carry out at regular intervals a review of the safety of the facility (a periodic safety review).

Related IAEA safety standards:

The operating organization shall carry out at regular intervals a review of the facility safety case to ensure that it remains fully valid and that modifications made to the facility, as well as changes in its operating arrangements or utilization, are accurately reflected. In conducting these reviews, the operating organization shall explicitly consider the cumulative effects of modifications and ageing. These reviews shall also ensure that all changes in OLCs, maintenance programmes, drawings, operation, maintenance, and emergency procedures have been properly captured in the current arrangements and procedures. (DS-316, para 2.17).

D-72: The review shall confirm the compliance of the decommissioning activities and states with its licensing requirements and any deviations shall be resolved. It shall also identify and evaluate the safety significance of deviations from applicable current safety standards and best practices and take into account the cumulative effects of changes to procedures, modifications to the facility and the decommissioning organization, technical developments, decommissioning experience accumulated and ageing of SSCs.

Related IAEA safety standards:

In accordance with the national regulatory requirements, the operating organization shall carry out periodic safety reviews to confirm that the safety case remains valid. Such reviews need to consider the cumulative effect of changes to procedures, modifications to the facility and the operating organization, technical developments, operating experience and ageing. (DS 316, 4.25)

D-73: All reasonably practicable improvement measures shall be taken by the licensee as a result of the review.

Related IAEA safety standards:

Central to the management and verification of safety is the ability of an organization to establish effective review and improvement as an ongoing process. To establish this process the operating organization shall periodically conduct a review of the facility operational and safety performance to identify, understand and correct adverse trends that may have an impact on safety. (DS 316, para 9.70)

D-74: A periodic safety review shall be carried out at least every ten years. If the latest consolidated case has been produced in accordance with the general principles of periodic safety review, then the ten year period starts from the date of that case.

D-75: The scope and methodology of the review shall be clearly defined and justified. As a minimum the following areas shall be covered by the review:

- assessment of the monitoring and surveillance data, and of the operating experience to determine the actual condition of systems, structures and components
- updated radioactive inventory
- current safety analyses and their use
- organisational arrangements
- radiation protection arrangements
- safety performance and the effectiveness of safety and quality management
- staffing and qualification of staff
- emergency preparedness
- radiological impact on the public and on the environment
- waste storage conditions
- ageing of the safety significant structures, systems and components
- advances in science and technology
- changes in the environment of the facility, including external natural and man-made hazards
- changes in regulations
- feedback from past decommissioning operations
- feedback from similar facilities

Related IAEA safety standards:

The scope of a PSR includes all nuclear safety aspects of a nuclear power plant (DS 307, para 3.1).

It is recommended that the scope should include, as a minimum, the safety factors: Plant, Safety analysis, Performance and feedback of experience, Management, Environment and Global assessment (DS 307, para 6.2)

Each safety factor is reviewed using current methods...There is a need to record the results of the review in a systematic and auditable manner. Probabilistic safety assessment ... is a useful contributor to a PSR (DS 307, paras 3.3, 3.6 and 6.5)

4.3. Safety issue: License termination conditions

D-76: At the completion of decommissioning, the licensee shall not be relieved of further responsibility for the facility or site unless the regulatory body has agreed.

Related IAEA safety standards:

On completion of decommissioning, it shall be demonstrated that the end state criteria as defined in the decommissioning plan and any additional regulatory requirements have been met. The operator shall only be relieved of further responsibility for the facility after the approval by the regulatory body. (DS-333, para 9.1)

At the completion of decommissioning, and before the operator can be relieved of further responsibility for the facility or site in accordance with the national legal framework, the operator shall provide to the regulatory body such information as may be required (WS-R-2, para 3.18)

D-77: Before a facility or site can be released and the licensee relieved of further responsibility, a survey shall be performed to demonstrate that the end point conditions, as established by the regulatory body, have been met.

Related IAEA safety standards:

The facility shall not be released from regulatory control nor shall authorization be terminated until the operator has demonstrated that the end state in the decommissioning plan has been reached and that any additional regulatory requirements have been met. The regulatory body shall evaluate the end state of the site by performing a through inspection of the remaining facility after decommissioning activities have been completed to ensure that the end point criteria have been met. (DS-333, para 9.2)

Before a site may be released for unrestricted use, a survey shall be performed to demonstrate that the end point conditions, as established by the regulatory body, have been met. (WS-R-2, para 6.11)

D-78: A license can be terminated if a facility or site can be released:

- for unrestricted use, or
- for restricted use if appropriate institutional control is maintained ensuring protection of human health and the environment (e.g. new nuclear license, state-managed land-use control system...).

D-79: In the case where the facility or site cannot be released for unrestricted use, the licensee shall provide a safety case including a long term impact assessment, an appropriate surveillance regime and any proposed land use restrictions.

Related IAEA safety standards:

If a facility cannot be released for unrestricted use, appropriate controls shall be maintained to ensure the protection of human health and the environment. These controls shall be specified and shall be subject to approval by the regulatory body. Clear responsibility shall be assigned for implementing and maintaining these controls. The regulatory body shall ensure that a programme to apply and to monitor compliance with the remaining regulatory requirements has been established. (DS-333, para 9.6)

4.4. Safety issue: Final decommissioning report

D-80: A final decommissioning report shall be prepared that documents, in particular the end state of the facility or site, and this report shall be submitted to the regulatory body for review.

Related IAEA safety standards :

A final decommissioning report shall be prepared that documents, in particular the end state of the facility or site, and this report shall be submitted to the regulatory body for review. (DS 333 para 9.3)

D-81: A system shall be established to ensure that all records are maintained in accordance with the records retention requirements of the quality assurance system and the regulatory requirements.

Related IAEA safety standards :

A system shall be established to ensure that all records are maintained in accordance with the records retention requirements of the quality assurance system and the regulatory requirements. (DS 333 para 9.4)

Appendix: Postulated initiating events

External postulated events

Natural phenomena

- Extreme weather conditions (precipitation: rain, snow, ice, frazil, wind, lightning, high or low temperature, humidity)
 - Flooding
 - Earthquake
 - Natural fires
 - Effect of terrestrial and aquatic flora and fauna (blockage of inlet and outlets, damages on structure)

Human induced phenomena

- Fire, explosion or release of corrosive/hazardous substance
- (from surrounding industrial and military installations or transport infrastructure)
- Aircraft crash (accidents)
- Missiles due to structural/mechanical failure in surrounding installations
- Flooding (failure of a dam, blockage of a river)
- Power supply and potential loss of power
- Civil strife (infrastructure failure, strikes and blockages)

Internal postulated events

- Loss of energy and fluids: Electrical power supplies, air and pressurised air, vacuum, super heated water and steam, coolant, chemical reagents, and ventilation;
- Improper use of electricity and chemicals
- Mechanical failure including drop loads, rupture (pressure retaining vessels), leaks (corrosion), plugging
- Instrumentation and control, human failures
- Internal fires and explosions (gas generation, process hazards)
- Flooding, vessel overflows

Related IAEA safety standards:

Selected postulated initiating events (DS 316 Appendix 1)

External postulated initiating events

Natural phenomena

- *Extreme weather conditions
precipitation : rain, snow, ice, frazil, wind, tornadoes, hurricanes, cyclones, dust or sand storm, lightning,
high or low temperature, humidity*
- *Flooding*
- *Earthquake and eruption of volcano*
- *Natural fires*
- *Effect of terrestrial and aquatic flora and fauna (blockage of inlet and outlets, damages on structure)*

Human induced phenomena

- *Fire, explosion or release of corrosive/hazardous substance*

- *(from surrounding industrial and military installations or transport infrastructure)*
- *Aircraft crash*
- *Missiles due to structural/mechanical failure in surrounding installations*
- *Flooding (failure of a dam, blockage of a river)*
- *Power supply and potential loss of power*
- *Civil strife (terrorism, sabotage, infrastructure failure, strikes and blockages)*

Internal postulated events

- *Loss of energy and fluids : Eletrical power supplies, air and pressurized air, vacuum, super heated water and steam, coolant, chemical reagents, and ventilation;*
- *Use of electricity and chemicals*
- *Mechanical failure including drop loads, rupture (pressure retaining vessels), leaks (corrosion), plugging*
- *Instrumentation and control, human failures*
- *Internal fires and explosions (gas generation, process hazards)*
- *Flooding, vessel overflows*