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Safety of Nuclear Fuel Reprocessing Facilities

DRAFT SPECIFIC SAFETY GUIDE XXX

DS 360

New Safety Guide

IAEA

INTERNATIONAL ATOMIC ENERGY AGENCY

FOREWORD
by Yukiya Amano
Director General

EDITORIAL NOTE

An appendix, when included, is considered to form an integral part of the standard and to have the same status as the main text. Annexes, footnotes and bibliographies, if included, are used to provide additional information or practical examples that might be helpful to the user.
The safety standards use the form 'shall' in making statements about requirements, responsibilities and obligations. Use of the form 'should' denotes recommendations of a desired option.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide on the Safety of Nuclear Fuel Reprocessing Facilities recommends how to meet the requirements established in the Safety Requirements publication on the Safety of Nuclear Fuel Cycle Facilities (Ref. [1]) and supplements and develops those requirements.

1.2. The safety of nuclear fuel reprocessing facilities[1] is ensured by means of their proper siting, design, construction, commissioning, operation, and decommissioning. This Safety Guide addresses all these stages in the lifetime of a reprocessing facility as defined in (Ref. [1]), on an industrial scale, with emphasis placed on the safety in their design and operation.

1.3. The radioactivity and radio-toxicity of spent fuel, dissolved spent fuel, fission product solutions, plutonium and other actinides and their solutions is high. Close attention should be paid to ensuring safety at all stages of reprocessing spent fuel. Uranium, plutonium, fission products and all waste from reprocessing facilities should be handled, processed, treated and stored safely, to maintain low levels of radiation and minimizing radioactivity discharged to the environment and limiting the potential impact of an accident on workers, the public and the environment.

OBJECTIVE

1.4. The objective of this Safety Guide is to provide recommendations that, in light of experience in Member States and the present state of technology, should be followed to ensure safety for all stages in the lifetime of a reprocessing facility. These recommendations specify actions, conditions or procedures necessary for meeting the requirements established in (Ref. [1]). This Safety Guide is intended to be of use to designers, operating organizations and regulators for ensuring the safety of reprocessing facilities.

SCOPE

1.5. This Safety Guide provides recommendations on meeting the requirements established in (Ref. [1]: Sections 5–10 and Appendix IV). The safety requirements applicable to all types of fuel cycle facilities (i.e. facilities for uranium ore processing and refining, conversion, enrichment, fabrication of fuel including mixed oxide fuel, storage and reprocessing of spent fuel, associated conditioning and storage of waste, and facilities for the related research and

[1]Referred to in this document as “reprocessing facilities”.

development) are established in the main text of (Ref. [1]). The requirements specifically applicable to reprocessing facilities are established in (Ref. [1]: Appendix IV).

1.6. This Safety Guide deals specifically with:

(a) The handling of spent fuel;

(b) Dismantling, shearing[2] or decladding[3] and dissolution of spent fuel;

(c) Separation of uranium and plutonium from fission products;

(d) Separation and purification of uranium and plutonium;

(e) Production and storage of plutonium and uranium oxides or uranyl nitrate as a feed material to form 'fresh' uranium or mixed (UO_2/ PuO_2) oxide fuel rods and assemblies, and;

(f) The initial treatment and handling of the various waste streams.

1.7. The fuel reprocessing processes covered by this Safety Guide are a mixture of high and low hazard, chemical and mechanical processes, including high hazard fine particulate processes and hazardous solid, liquid, gaseous and particulate (dry, air and water borne) wastes and effluents.

1.8. This Safety Guide is limited to the safety of reprocessing facilities themselves, the protection of their workers and the public, and the environment. It does not deal with the ancillary process facilities in which wastes and effluents are treated, conditioned, stored or disposed of except in so far as all wastes produced should comply with the requirements in (Refs. [1]: paras. 6.31-6.32 and 9.54-9.57, Appendix IV: paras. IV.49-IV.50, IV.80-IV.82 and [2]). It should be noted that many of the hazards in these facilities are similar to those in a reprocessing facility due to the characteristic of the materials being treated etc.

1.9. The implementation of other safety requirements such as those on the legal and governmental framework and regulatory supervision established in (Ref. [3]) and those on the integrated management system and the verification of safety established in (Ref. [4]), are not addressed in this Safety Guide. Recommendations on meeting the requirements for the integrated management system and for the verification of safety are provided in (Ref. [5]).

1.10. Sections 3–8 of this Safety Guide provide recommendations on radiation protection measures for meeting the safety requirements established in (Ref. [6]). The recommendations

[2]Shearing: Cutting spent fuel into short lengths to allow dissolution inside the metallic cladding
[3]Decladding: Removing the metallic cladding of the spent fuel prior to dissolution.

in this Safety Guide supplement the recommendations on occupational radiation protection provided in (Ref. [7]).

STRUCTURE

1.11. This Safety Guide consists of eight sections and two annexes. These sections follow the general structure of (Ref. [1]). Section 2 provides general safety recommendations for a reprocessing facility. Section 3 describes the safety aspects to be considered in the evaluation and selection of a site to avoid or minimize any environmental impact of operations. Section 4 deals with safety considerations at the design stage including safety analysis for operational states and accident conditions[4] the safety aspects of radioactive waste management in the reprocessing facility and other design considerations. Section 5 addresses the safety aspects in the construction stage. Section 6 discusses safety considerations in commissioning. Section 7 provides recommendations on safety during operation of the facility, including the management of operations, maintenance, inspection and periodic testing, control of modifications, criticality control, radiation protection, industrial safety, management of waste and effluents, and emergency planning and preparedness. Section 8 provides recommendations on meeting the safety requirements for preparing for the decommissioning of a reprocessing facility. Annex I shows the typical main process routes for a reprocessing facility. Annex II provides examples of structures, systems and components[5] (SSCs) important to safety in reprocessing facilities, grouped in accordance with processes identified in Annex I.

1.12. This Safety Guide contains guidance specific to reprocessing facilities. The recommendations in this guide have been referenced to the corresponding requirements in (Ref. [1]) and other IAEA Safety Standards, where this does not destroy the readability of the text. This Safety Guide covers all the important stages in the lifecycle of a reprocessing facility, including site evaluation, design, construction, commissioning, operation, and preparation for decommissioning. It also considers modifications, maintenance, calibration, testing and inspection as well as emergency preparedness where there is specific guidance. Reference should be made to the referenced documents and other IAEA standards for requirements and guidance on generic topics (such as radioactive wastes or radiation

[4]Accident Conditions: as defined in (Ref. [8]) and developed subsequently including Design Base Accident (DBA) and Design Extension Conditions (DEC). DEC: Accident conditions that are not considered for design basis accidents, but that are considered in the design process of the facility in accordance with best estimate methodology, and for which releases of radioactive material are kept within acceptable limits (Ref. [9])

[5]SSCs important to safety: 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* (Ref. [8]).

protection) and Nuclear Security Series publications for security issues, that are not specific to reprocessing facilities, in accordance with the structure of the publications for nuclear facilities and operations, prepared by the IAEA.

2. GENERAL SAFETY GUIDELINES FOR A REPROCESSING FACILITY[6]

2.1. In reprocessing facilities, large quantities of fissile, radioactive and other hazardous materials are present (stored, processed and generated) often in easily dispersible forms (e.g. solutions, powders and gases) and sometimes subjected to vigorous chemical and physical reactions. Reprocessing facilities have the potential for serious nuclear and radiological emergencies. The potential hazards associated with reprocessing facilities should be considered when implementing the graded approach concept to the facility as detailed in (Refs. [1]: Section 1 and [10]).

2.2. The main risks are criticality, loss of confinement and radiation exposure from which workers, the public, and the environment need to be protected by adequate technical and administrative measures provided during siting, design, construction, commissioning, operation and decommissioning.

2.3. In normal operation reprocessing facilities produce significant gaseous and liquid effluent volumes with a variety of radioactive and chemical constituents. The facility's processes and equipment should be designed and operated to reduce and recycle these effluents as far as practicable, taking account of the possible accumulation of undesirable species or changes in composition of recycled reagents etc. In accordance with the optimization of protection specific design provision should be made to ensure recycled materials are safe and compatible with reuse in the facility, which may involve the generation of additional effluents.

2.4. Effluent and discharges should be optimized by the addition of specific engineering features to remove and reduce activity and toxic chemical levels. The facility (with any associated effluent treatment facilities) should monitor and report discharges and, as a minimum, comply with all authorized limits and optimize protection as far as practicable (Refs. [6], [2], [11], [12] and [13]). When carrying out periodic safety reviews past discharge records should be examined thoroughly to confirm that the current engineered provisions and operational practices are optimizing protection as far as practicable. In addition further improvements in process and effluent reduction and treatment technology should be examined for potential improvements.

[6] The requirements relating to the safety guidelines for a reprocessing facility are established in (Ref. [1]: Section 2).

2.5. The specific features of reprocessing facilities that should be taken into account for meeting the safety requirements specified in (Ref. [1]) are:

(a) The wide range and nature of radioactive inventories;

(b) The wide range and nature of process chemicals and their reaction;

(c) The range and nature of fissile material, i.e. criticality in both liquid and solid systems;

(d) The range of dispersible or difficult to control radioactive material present includes:

- Particulates;
- Solids: contaminated items, scrap etc.;
- Liquids: aqueous, organic;
- Gaseous and volatile species.

2.6. These specific features associated with reprocessing facilities result in a broad range of hazardous conditions and possible events that need to be considered in the safety analysis to assure that they are adequately prevented, detected and/ or mitigated.

2.7. For the implementation of defence in depth (Ref. [1]: Section 2), the first two levels are the most significant; as the risks should be eliminated mainly by design and appropriate operating procedures (Sections 4 and 7 below). However all levels of defence in depth should be addressed (Ref. [1]: paras. 2.4-2.8). The third level should be provided by the iteration and development of the safety assessment and the design to incorporate appropriate passive and active SSCs important to safety with the necessary robust auxiliary systems, infrastructure (services, maintenance etc.) and appropriate operation instructions and training (Sections 4 and 7). The recommendations for accident conditions (Level 4 and 5) are addressed in the sub-sections on emergency preparedness (paras. 4.163-4.169 and 7.118-7.121).

2.8. The design, construction and operation of a reprocessing facility require well-demonstrated process technologies and engineering knowledge. Engineering solutions adopted to ensure reprocessing facility safety should be of high quality, proven by previous experience or rigorous (in accordance with a graded approach) testing, research and development, or experience of operating prototypes. This strategy should be applied during the design of the reprocessing facility, development and design of equipment, the construction, operation, modification and preparations for decommissioning of the reprocessing facility, including any upgrading and modernization.

2.9. Due to the anticipated long lifetime of industrial scale reprocessing facilities and taking into account the specific mechanical, thermal, chemical, and radiation conditions of the processes, the potential for ageing and degradation of SSCs important to safety requires particular attention, especially for those components judged difficult or impracticable to replace. In selecting and designing reprocessing facility SSCs important to safety the processes that could cause the degradation of structural materials should be taken into account. Programmes should be developed and implemented to detect and monitor ageing and degradation processes. These should include provisions for monitoring, inspection, sampling, surveillance and testing and, to the extent necessary, specific design provisions and equipment for inaccessible SSCs important to safety.

2.10. Reliability of process equipment should be ensured by adequate design, specification, manufacturing, storage (if necessary), installation, commissioning, operation, maintenance and facility management supported by the application of an integrated management system (which provides for quality assurance and quality control) during all the phases of the facility's lifetime. Inspection and testing should be against unambiguous, established performance standards and expectations.

2.11. Adequately designed passive and then active engineering SSCs important to safety are more reliable than administrative controls and should be preferred in operational states and in accident conditions (Ref. [1]: para. 6.6). Automatic systems should be highly reliable and designed to maintain process parameters within the operational limits and conditions or to bring the process to a safe and stable state, which is generally a shutdown state[7] (Ref. [1]: Appendix IV: para. IV.47).

2.12. When administrative controls are considered as an option, the criteria for implementation of automated versus administrative control should be based on the response time requirement and careful consideration of the hazards and risk involved in a failure to act. Where the choice of optimum response (from a number of possible choices) is a significant factor in choosing administrative controls (operator action), consideration should be given to providing a simple, active control response and/ or passive design features to limit potential hazards (additional defence in depth) in the event of a failure to take the sufficient or timely action.

[7] No radioactive material or liquid movements, with ventilation and (essential) cooling only.

2.13. Other SSCs related to instrument and control (I&C, facility control system, indicating and recording instrumentation, alarm and communications systems) in addition to those SSCs specifically identified as important to safety in the safety analysis are relevant to reprocessing facility overall safety. Adequate and reliable controls and appropriate instrumentation should be provided to maintain variables within specified ranges and initiate automatic protective action where necessary. Where computers or programmable devices are used in such systems, evidence should be provided that the hardware and software are designed, manufactured, installed and tested appropriately[8].

2.14. All reprocessing facilities should have alarm systems to initiate full or partial facility evacuation in the case of emergencies (criticality, fire, high radiation, etc.).

2.15. Ergonomic considerations should be applied to all aspects of the design and operation of reprocessing facilities. In particular careful consideration should be given to human factors, in control rooms, remote control stations and work locations. This consideration should extend not only to controls, alarms and indicators related to SSCs important to safety and operational limits and conditions (OLCs) but to all control, indication and alarms systems and the control room(s).

2.16. Utility supply services are necessary to maintain the reprocessing facility safety systems in an operational state at all times, and they also provide services to SSCs important to safety. Continuity of service should be achieved by robust designs including sufficient diverse and redundant supplies. It is essential that services for reprocessing facility safety systems should be designed so that, as far as possible, the simultaneous loss of both normal and back-up services will not lead to unacceptable consequences. Wherever possible the consequences of loss of motive power to valves etc. should be assessed and the item designed to be "fail-safe[9]".

2.17. The situations when "shut-down" of the reprocessing facility process is necessary to put the facility in a safe and stable state (no movement or transfer of chemicals and/ or fissile materials) should be analyzed, well defined in procedures in accordance with the assessment performed and implemented, depending on the nature or urgency of the hazard or risk. Such situations include potential criticality sequences, natural or man-made internal or external events. The subsequent recovery sequences should be similarly analyzed, defined and

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[8]I.e. In accordance with the established integrated management system. For software this should include verification and validation

[9]The fail-safe state of a valve, controller or other device: the valve position etc. shown, by analysis, to be the least likely to cause a deterioration in system or facility safety. Fail-safe devices are designed to "fail" to this position usually in response to a loss (failure) of motive power or control input, e.g. a spring which moves the valve to a pre-set position in the event of a power failure. The device may still fail in any position due to other causes e.g. mechanical failure and these events should be analysed in the safety assessment.

implemented in a timely manner e.g. the managed recovery/ reduction of fissile material in a multi-stage contactor[10].

2.18. To maintain the facility in a safe state, some systems should continuously operate or should be restarted within a defined delay if they become unavailable e.g.:

(a) Active heat removal systems in storage areas or buffer tanks, accountancy vessels or HA waste packages to remove decay heat;

(b) Dilution (gas flow) systems to prevent hazardous hydrogen concentration;

(c) Safety significant control, instrumentation and utility supply systems.

[10]Contactor: a liquid-liquid extraction device.

3. SITE EVALUATION

3.1. (Ref. [14]) and its supporting guides (Refs. [15], [16], [17], [18] and {[19]}) establish the requirements and present recommendations for site safety evaluation, site selection criteria and site selection process for a fuel reprocessing facility. These should be considered in relation to the requirements identified in (Ref. [1]: paras 5.1-5.8 and Appendix IV: para. IV.1).

3.2. In the siting of new reprocessing facilities particular attention should be given to:

(a) The site's ability to accommodate normal operational radioactivity releases, including:

a. The physical factors affecting the dispersion and accumulation of released radioactivity and the radiological risk to people;

(b) The suitability of the site to accommodate the engineering and infrastructure requirements of the facility, including:

(c) Waste processing and storage (for all phases of the facility's life);

(d) Reliable provision of utility supply services;

(e) The capability for safe and secure on-site and off-site transport of nuclear fuel and other radioactive and chemical materials (including products and radioactive waste, if required);

(f) Off-site support and supplies in the case of emergency (including diversity of water supplies).

(g) Feasibility of implementing emergency arrangements, including those for the evacuation of the site personal and, as appropriate, the population from the affected areas and arrangements for access for off-site emergency services to the site (Ref. [10]);

(h) Flooding:

(i) Some aspects of reprocessing facilities are particularly affected by potential flooding (criticality, water penetration through openings in static barriers, damage to vulnerable items e.g. gloveboxes);

(j) Physical security measures in accordance with the guidance provided in the Nuclear Security Series publications (Ref. [20]).

3.3. (Refs. [1] and [14]) specify the requirements for site evaluation, ongoing site evaluation and the use of a graded approach for reprocessing facilities. In addition, for reprocessing facilities, care should be taken and an adequate justification made for any grading of the application of site evaluation requirements. Particular attention should be paid to the following during the reprocessing facility's life-cycle (including decommissioning):

(a) Appropriate monitoring and systematic evaluation of site characteristics;

(b) Incorporation of periodic, on-going evaluation of the site parameters for natural processes and phenomena and man-induced factors in the facility design basis;

(c) Identification and account taken of all foreseeable variations in the site evaluation data (e.g. new or planned significant industrial development, infrastructure or urban developments);

(d) Revision of the safety assessment report (periodic safety review or equivalent) to take account of on- and off-site changes that could affect safety on the reprocessing facility site considering all ongoing site evaluation data and the development of scientific knowledge and evaluation methodologies and assumptions;

(e) Consideration of anticipated future changes to site characteristics and of features that could have an impact on emergency arrangements and the ability to carry our emergency response actions for the facility.

4. DESIGN[11]

GENERAL

Main safety functions for reprocessing facilities

4.1. The main safety functions (Ref. [1]: Appendix IV: para. IV.2) i.e. those functions, the loss of which, may lead to exposure to or releases of radioactive material having possible radiological consequences for workers, the public or the environment are those designed for:

1) Prevention of criticality;
2) Confinement of radioactive materials (including removal of decay heat and dilution of radiolysis gases);
3) Protection against external exposure.

The main safety functions are further developed in (paras. 4.13-4.62).

Specific engineering design guidance

4.2. Due to their expected long service life, substantial inventory of radioactive and radiotoxic materials, the potential for criticality, and use of aggressive physical and chemical processes the design of reprocessing facilities should be based upon the most rigorous application of the requirements of (Ref. [1]: Section 6) as a high hazard facility, and should pay particular attention to the re-use and recycling of materials to reduce discharges and waste generation.

4.3. For reprocessing facilities in particular, protection of the public and the environment for normal operation relies on robust, efficient and effective facility design, particularly for the minimization of effluent arisings and the pre-disposal or pre-discharge treatment of effluents.

4.4. For abnormal states the protection of people and the environment should mainly rely on the prevention of accidents and, should they occur, mitigation of their consequences by robust and fault tolerant design providing defence in depth in accordance with a graded approach. These provisions should be supplemented by on- and off-site emergency arrangements to protect human life, health, property and the environment in accordance with (Ref. [10]) as a last level of the defence in depth concept.

4.5. The following requirements and guidance applies:

[11] The requirements for design for a reprocessing facility are established in (Ref. [1]: Section 6 and Appendix IV: paras. IV.2-IV.50)

(a) The requirements for the confinement of radioactive materials are established in (Ref. [1]: paras. 6.37–6.39, 6.52, 6.53 and Appendix IV: IV.21–IV.25). During normal operation, internal dose should be avoided by design, including static and dynamic barriers, adequate zoning etc. The use of personal protection (personal protective equipment, (Ref. [6])) should be minimized in accordance with the optimization of protection;

(b) The requirements for the removal of decay heat are established in (Ref. [1]: paras. 6.52 and Appendix IV: IV.4–IV.6). In view of the decay heat generated, all thermal loads and processes should be given appropriate consideration in design. Particular care should be paid to the need to ensure the provision of adequate cooling, passively if possible, in accident states.

(c) The requirements for the need to address the generation of radiolytic hydrogen and other flammable or explosive gases and materials are established in (Ref. [1]: paras. 6.53, 6.54 and Appendix IV: IV.33). In view of the widespread potential for the generation of radiolytic hydrogen, the need for adequate diluting air flows (or alternative techniques as appropriate) should be given appropriate consideration in design. Particular care should be paid to the need to ensure the provision of adequate diluting air flow where applicable, without the need for ventilation fans or compressors, if possible, in accident states or other provisions for defence in depth e.g. catalytic recombiners.

(d) The requirements for protection against external exposure are established in (Ref. [1]: paras. 6.40–6.42 and Appendix IV: IV.26–IV.30). Owing to the radiation fields associated with high beta-gamma activity, alpha activity and neutron emissions appropriate combinations of requirements for source limitation, shielding, distance and, time are necessary for the protection of workers. For reprocessing facilities particular attention should be paid to the provisions for maintenance operations in both design and operation.

(e) The requirements and general guidance for the prevention of criticality are established and given in (Refs. [1]: paras. 6.43–6.51, Appendix IV: IV.9–IV.20 and [21]). All processes with fissile materials should be designed in such a way as to avoid an accidental criticality.

(f) The design requirements for provisions for decommissioning of a reprocessing facility are established in (Ref. [1]: paras. 6.35-6.36) should be strictly implemented due to their long operational life, large throughput of radioactive and radiotoxic materials and the cumulative effects of modifications etc.

4.6. Ref. [22] and its supporting Guide [23] establish the general requirements and present recommendations for preparation for decommissioning.

Other engineering design guidance

4.7. For nuclear fuel reprocessing facilities, the design authority[12] should develop a set of standardized designs and conditions for their implementation during design and modification of the facility, based upon proven experience that can be applied to a wide range of applications. The assessment step should be then to verify the application conditions of these standardized designs. For example, standardized designs should be applied to assure the continuity and integrity of containment, the ventilation of potentially contaminated areas, the transfer of highly active liquids, and the maintenance activities for the reprocessing facility.

4.8. As reprocessing facilities have long operational lifetimes provisions to allow for on-site repair of major equipment should be anticipated, as far as reasonably achievable (e.g. space reservation for remote operation, three dimensional design data of the equipment and hot cells etc.).

Design basis accidents and safety analysis

4.9. The definition of a design basis accident[13] (DBA) and design basis external (DBE) event, in the context of nuclear fuel cycle facilities, can be found in (Ref. [1]: Annex III: para. III-10). The safety requirements relating to DBAs and DBEs are established in (Ref. [1]: paras. 6.4–6.9).

4.10. The specification of a DBA or DBE (or equivalents) will depend on the facility design its siting, and national criteria. However, particular consideration should be given to the following hazards in the specification of design basis accidents for reprocessing facilities:

(a) Postulated initiating events:

- Loss of cooling (for decay heat removal etc.);
- Loss of electrical power;

[12]Design authority: the function of an operating organisation with the responsibility for, and the knowledge to maintain the design integrity and the overall basis for safety of the reprocessing facility throughout the full lifecycle of that facility. Design authority relates to the attributes of the operating organisation rather than the capabilities of individual post holders.

[13]In the context of nuclear fuel cycle facilities, a design basis accident (DBA) is an accident against which a facility is designed according to established design criteria such that the consequences are kept within defined limits. These accidents are events against which design measures are taken when designing the facility. The design measures are intended to prevent an accident or to mitigate its consequences if it does occur

- Nuclear criticality accident.

(b) Postulated initiating events induced by natural and human-induced hazards:

- Internal and external explosion;
- Internal and external fire;
- Dropped loads and associated handling events;
- Natural phenomena (earthquake, flooding, tornadoes, etc.);
- Aircraft crash.

The events listed in above may occur as a consequence of a postulated initiating event (PIE), selected PIEs are listed in (Ref. [1]: Annex I).

4.11. Reprocessing facilities are characterized by a wide diversity of radioactive materials distributed throughout the facility and by the number of potential events that may result in radioactive releases to the environment with the potential for public dose. Therefore operational states and accident conditions of each reprocessing facility process should be assessed on a case by case basis (Ref. [1]: para. 6.9 and Annex III: para. III-10-III-11). When an event may simultaneously challenge several facilities at one site, the assessment should address the implications at the site level in addition to at each facility.

Structures, systems and components important to safety

4.12. The likelihood of the design basis accidents (or equivalent) should be minimized, and any associated radiological consequences should be controlled by means of SSCs important to safety (Ref. [1]: paras. 6.5–6.9 and Annex III). Annex II of this Safety Guide presents examples of SSCs important to safety and representative events that may challenge the associated safety functions.

SAFETY FUNCTIONS

Criticality Prevention

General

4.13. The requirements for criticality prevention in reprocessing facilities are established in (Ref. [1]: paras. 6.43-6.51, Appendix IV: IV.9-IV.20) and general recommendations on criticality prevention are presented in (Ref. [21]).

4.14. Criticality hazard should be controlled by design as far as practicable (Ref. [1]: para. 6.43 and Appendix IV: para. IV.10). Where a credible hazard cannot be eliminated the prevention of criticality by means of design, the double contingency principle is the preferred approach (Refs. [1]: para. 6.45 and [21]).

4.15. Those system interfaces at which there is a change in the state of the fissile material or in the criticality control mode should be specifically assessed (Ref. [1]: para. 6.48 and Appendix IV: para. IV. 14). Particular care should also be taken to ensure that all transitional, intermediate or temporary states that occur or could reasonably be expected to occur under all operational or accident conditions are assessed.

4.16. When required by the safety analysis, the prevention of the precipitation of fissile material within solutions should be prevented by e.g. the following methods:

(a) The use of interlocks and preventing permanent physical connection from reagents units to the equipment in which fissile material is located;

(b) Acidification of cooling loops for the equipment containing nuclear material solutions (to prevent precipitation in case of leakage from the cooling loop into the equipment) and consideration of the need for the cooling loops themselves to be meet subcritical design requirements.

4.17. In a number of locations in a reprocessing facility the criticality control mode for equipment containing fissile liquid includes the geometry or shape of the containment. The overall design should provide for any potential leakage to a criticality safe (secondary) containment. This should drain or have an emptying route to criticality safe vessels, depending on the exact design. The evaluation of such designs should include the potential for such leaks to evaporate and crystallize or precipitate either at the leak site or on nearby hot vessels or lines and consider the need for localized drip trays to recover and direct potential liquid leaks away from hot vessels to favourable geometry collection vessels. Level measurement or liquid detectors should also be installed in the drip trays to provide additional defence in depth. The evaluation should include the possibility, for small leaks of hot or high concentration liquids, for evaporation or crystallization to occur local to the leak site and should consider the need for frequent inspection, continuous closed circuit television cameras and adequate lighting.

4.18. The need for additional design provisions to detect leaks or similar abnormal occurrences involving liquids containing fissile solids (slurries) or solid (powder) transfer systems should also be carefully considered and appropriate criticality control measures should be developed.

4.19. In accordance with the criticality safety analysis, instruments specifically intended to detect accumulation and inventories of fissile material should be installed where required. These instruments should also be used to verify the fissile inventory of the equipment during decommissioning"

Criticality Safety Assessment

4.20. The aim of the criticality safety assessment, as required in (Ref. [1]: Appendix IV: para. IV.11) is to demonstrate that the design of equipment and the operating conditions in the reprocessing facility are such that the values of controlled parameters are always maintained in the sub-critical range. Further guidance on criticality safety assessment is provided in (Ref. [21]).

4.21. The criticality safety assessment should include a criticality safety analysis, which should evaluate sub-criticality for all operational states (i.e. normal operation and anticipated operational occurrences) and also during and after DBA conditions. The criticality safety analysis should be used to identify hazards, both external and internal, and to determine the radiological consequences. The criticality safety analysis should involve the use of a conservative approach with account taken of:

(a) Uncertainties in physical parameters, the possibility of optimum moderation conditions and the presence of non-homogeneous distributions of moderators and fissile materials;

(b) Anticipated operational occurrences and their combinations if they cannot be shown to be independent;

(c) Facility states that may result from internal and external hazards.

4.22. The use of appropriate and qualified computer codes that are validated and verified (i.e. compared with benchmarks to determine the effects of code bias and code on the calculated, effective multiplication factor, (k_{eff}) used within their applicable range and with appropriate data libraries of nuclear reaction cross-sections. Detailed guidance is provided in (Ref. [21]: paras. 4.20-4.25).

4.23. An alternative method of analysis is to specify, for physical parameters such as mass, volume, concentration, geometrical dimensions, a 'safe value' as a fraction of their critical value[14], taking in to account all parameters, as necessary, e.g. the optimum values for

[14]The parameter value for k_{eff} = 1.

moderation or neutron poisons etc., and demonstrating that these parameters will always be less than their safe value under all normal, abnormal and DBA conditions.

Design for Criticality Mitigation

4.24. The requirements to be applied to the criticality detection systems and associated provisions are established in (Ref. [1]: para. 6.50).

4.25. The areas containing fissile material for which criticality accident alarm systems to initiate immediate evacuation are necessary[15] should be defined according the facility layout, the process, national safety requirements and by the criticality safety analysis.

4.26. The potential for fitting additional shielding, remote operation and other design measures to mitigate the consequences of a criticality accident, if one does occur, should be assessed in accordance with the defence in depth requirements (Ref. [1]: paras. 2.4-2.8 and Appendix IV: para. IV.29).

Confinement of radioactive materials

Static and dynamic confinement[16,17]

4.27. "Containment[18] shall be the primary method for confinement against the spread of contamination" (e.g. in areas where significant quantities of radioactive materials are held). "Confinement shall be provided by two complementary containment systems — static (e.g. physical barrier) and dynamic (e.g. ventilation)" and "the static containment shall have at least one static barrier between radioactive materials and operating areas (workers) and at least one additional static barrier between operating areas and the environment" (Ref. [1]: Appendix IV: paras IV.21 and IV.22).

4.28. In reprocessing facilities (for most areas) according to a graded approach three barriers (or more as required by the safety analysis) should be provided. The first static barrier normally consists of process equipment, vessels and pipes or gloveboxes. The second static barrier normally consists of cells around process equipment or, when gloveboxes are the first containment barrier, the rooms around the glovebox(s). The final static barrier is the building itself. The design of the static containment system should take into account openings between different confinement zones (e.g. doors, instrument or pipe penetrations). These openings

[15]To minimize personnel doses in case of repeat or multiple criticality events.

[16] The requirements for confinement for a reprocessing facility are established in (Ref. [1]: paras. 6.38 and Appendix IV: paras. IV.21-IV.25).

[17]Confinement: Prevention or control of releases of radioactive material to the environment in operation or in accidents (Ref. [8]).

[18]Containment: Methods or physical structures designed to prevent or control the release and the dispersion of radioactive substances (Ref. [8]).

should be designed to ensure that confinement is maintained during operation, especially maintenance (e.g. provision of permanent or temporary, additional barriers (Ref. [1]: Appendix IV: paras. IV.22 and IV.28) and, as far as practicable, in accident conditions.

4.29. Each static barrier should be complemented by dynamic containment system(s) which should establish a cascade of pressure between the environment outside the building and the contaminated material inside and across all static barriers within the building. The dynamic systems should be designed to prevent the movement or diffusion of radioactive or toxic gases, vapours and airborne particulates through any openings in the barriers to areas of lower contamination or concentration of these materials. The design of these systems should address as far as practicable:

(a) Normal and accident conditions;

(b) Maintenance which may cause localized changes to conditions (e.g. opening access doors, removing access panels);

(c) Where more than one ventilation system is used, protection in the event of a failure of a lower pressure (higher contamination) system, where pressure differentials and airflows may be reversed;

(d) Ensuring that all static barriers including any filters or other effluent control equipment can withstand the maximum differential pressures and airflows generated by the system.

4.30. Reprocessing facilities should be designed to retain and detect liquid leakage from process equipment, vessels and pipes and to recover the volume of liquid to the primary containment (Ref. [1]: Appendix IV: para. IV.38) promptly. It is particularly important in both design and operation situations where the first static barrier provides other safety duties e.g. favorable geometry for criticality avoidance or exclusion of air for flammable liquids etc. Great care should be taken when dealing with spills or leaks from liquids streams with high fissile content and to consider effects such as crystallization due to cooling or evaporation of leaked liquors. The chemical compatibility of the streams should also be considered in the design.

4.31. Similar attention should be paid to those sections of reprocessing facilities handling solid (powder) radioactive, fissile or toxic materials. Designs for the detection of leaks, accumulations of leaked materials and their return to containment or the process are particular challenging and care should be taken to ensure these designs are based upon well proven designs or subject to rigorous qualification. In either case, commissioning should rigorously test their effectiveness. As far as practicable, considering both risk and the optimization of protection, operator intervention should be avoided.

4.32. The ventilation systems should include, as a minimum, both a building (cells and rooms) ventilation system and a `process equipment (e.g. vessels in a cell) ventilation system.

4.33. The building ventilation systems, including redundant sub-systems[19], filtration and other discharge control equipment, should be designed and assessed according to the type and design of static barriers (cells, gloveboxes, building), the classification of areas according to the hazards, the nature of potential airborne contamination (i.e. the level of surface contamination and the risk of additional contamination) and the requirements for maintenance (Ref. [1]: Appendix IV: para. IV.23).

4.34. The process equipment ventilation system(s) creates the lowest pressure within the facility collects and treats most of radioactive gas and particulates generated by the processes. Careful attention should be paid to the need to install effective washing, draining and collection systems to reduce the build-up of contamination and activity and facilitate future decommissioning.

4.35. All filtration stages of the ventilation systems which require testing should be designed in accordance with relevant standards such as those of the International Organization for Standardization (ISO), (Ref. [1]: Appendix IV: para. IV.25).

4.36. For the portions of the process involving powders, primary filters should be located as close to the source of contamination as practical (e.g. near the gloveboxes) to minimize the potential build-up of powders in the ventilation ducts. Particular care should be taken with fissile material powders where ventilation duct manifolds may be of less favorable geometry to avoid accumulation of fissile material (Ref. [1]: Appendix IV: para. IV.25).

4.37. On-line and standby fans should be provided according to the safety assessment results. Alarm systems should be installed to alert operators to system malfunctions resulting in high or low differential pressures.

4.38. Firefighting features to prevent the propagation of a fire through ventilation ducts and to maintain the integrity of firewalls[20], should be installed unless the likelihood of a fire spreading or the consequences of such a fire are acceptably low (Ref. [1]: Appendix IV: para. IV.36).

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[19]To permit continuous availability during maintenance, filter changes etc.

[20] Engineered feature specifically designed to prevent, limit or delay the spread of fire

Protection of workers

4.39. The static barriers (at least one between radioactive materials and operating areas) normally protect workers from radioactive contamination. Their design should be specified so as to ensure their integrity and effectiveness. Their design specifications should include e.g. weld specifications; selection of materials; leak-tightness, specification of penetration seals for electrical and mechanical penetrations; ability to withstand seismic loads, and as appropriate; the ease of carrying out maintenance work (Ref. [1]: Appendix IV: para. IV.21). Careful attention should be paid to the need to install effective washing, draining and collection systems at containment barriers, to reduce the build-up of contamination and activity and facilitate future decommissioning.

4.40. For regularly maintained or accessed items (sampling stations pumps etc.) consideration should be given to their installation in shielded bulges[21] or gloveboxes, adjacent to process cells where required, depending upon the radiation type and level. These reduce the local radioactive inventory and allow for special washing or decontamination features. Their provision should be balanced against the need to obtain representative samples (short sample lines etc.) and the additional waste for decommissioning.

4.41. Where easily dispersed radioactive materials are processed, the main risk is loss of containment with the potential for contamination or ingestion; gloveboxes are often the preferred design solution. These should be welded stainless steel enclosures with windows (of suitable materials), arranged either singly or in interconnected groups. Access to equipment inside the glovebox is through holes (ports) fitted with gloves which maintain the containment barrier. Seals on glovebox window etc. should be capable of testing for leak tightness in operation and gloves should be replaceable without breaking containment.

4.42. For normal operation, the need for personal protective respiratory equipment should be minimized through careful design of static and dynamic containment systems and of devices for the immediate detection of low levels of airborne radioactive material[22], and their location (para. 4. 39 and Ref. [1]: Appendix IV: para. IV.21).

4.43. At the design stage, provision should be made for the installation of equipment to monitor airborne radioactive material (Ref. [1]: Appendix IV: para. IV.26). The system design

[21]Bulge: typically a shielded, stainless steel, windowless, glovebox type enclosure with mechanically sealed openings to allow for the remote removal of items into shielded transport flask via a shielded docking port.
[22]Careful consideration should also be given to the need to discriminate against natural radioactive species (e.g. radon).

and the location of monitoring points should be chosen taking into account the following factors:

(a) The most likely locations of workers;

(b) Airflows and air movement within the facility;

(c) Evacuation zoning and evacuation routes;

(d) The use of mobile units for temporary controlled areas, e.g. for maintenance.

4.44. To avoid the inadvertent spread of contamination by personnel, control points with contamination monitoring equipment for workers (feet, hands and working suits) should be located at the exit airlocks and barriers from potentially contaminated areas. These should be located as close to workplaces with contamination hazards to the extent practical (Ref. [1]: para. 6.42).

4.45. As far as practicable tools and equipment should not be routinely transferred through air locks or across barriers. Where such transfers are unavoidable the provisions of para 4.44 apply to the monitoring of the tools and equipment. Consideration should be given in design to the provision of specific storage locations for lightly contaminated tools and equipment. More heavily contaminated items should be decontaminated for reuse or sent to an appropriate waste route.

Protection of the public and the environment

4.46. To the extent required by safety analyses all engineered ventilation discharge points should be equipped with airborne activity reduction equipment designed to provide protection during normal, abnormal and in accident conditions. As far as practicable, the final stage of treatment should normally be located close to the point at which gaseous discharges to the environment occurs.

4.47. According to national requirements, the facility discharge authorization and to demonstrate optimization of protection of the public and the environment (and in accordance with the graded approach), the design of reprocessing facilities should also provide measures for the uninterrupted monitoring and control of the stack exhaust(s)[23] and for monitoring of the environment around the facility (Refs. [1]: Appendix IV: para. IV.32, [6]: requirements 14, 15 and 32).

[23] Discharges

4.48. To allow early detection of leaks batch-wise transfer should be the preferred design for the transfer of liquid process effluents to their treatment facilities, where practicable. Equipment should be provided for the monitoring of loss of any containment barrier (e.g. level detection and sampling in cell sumps[24] or collecting vessels, activity-in-air detection etc.).

4.49. Detailed recommendations for the treatment and monitoring of radioactive effluents are outside the scope of this guide but similar considerations to that for airborne discharges (paras. 4.44-4.45) apply to liquid discharge points and sampling of liquid effluent discharges and their dispersion in the environment.

Cooling and the removal of decay heat

4.50. Radioactive decay heat, exothermic chemical reactions (e.g. neutralization of acidic or alkaline solution), and physical heating and cooling/ condensation processes may result in:

(a) Boiling of solutions;

(b) Changes of state e.g. (melting, concentration, crystallization, water content etc.) relevant to radiological or criticality safety;

(c) Transition to auto-catalytic (e.g. red-oil) or accelerated or run-away chemical reactions and fires;

(d) Destruction of components of containment barriers;

(e) Degradation of radiological protection shielding, and;

(f) Degradation of neutron absorbers or neutron decoupling devices.

The cooling systems should be designed to prevent uncontrolled environmental releases of radioactive material, exposure of workers and the public, and criticality accidents (e.g. for highly active[25] (HA) liquid waste storage vessels and PuO_2 containers), (Ref. [1]: Appendix IV: paras. IV.4 and IV.6).

4.51. Cooling capacity, the availability and reliability and the need for emergency power supplies for the cooling systems to remove heat from radioactive decay and chemical reactions are defined in the safety analysis, (Ref. [1]: Appendix IV: paras. IV.4-IV.5). Where practicable, passive cooling should be considered during design.

[24] A purpose designed “low-point” in a (normally stainless steel lined) cell base to collect any liquid arising from leakage or overflow. Where necessary this should take criticality considerations into account.
[25] Also referred to as high level (HL) liquid waste.

Prevention of hazardous concentration levels of gases from radiolysis and other hazardous explosive or flammable materials

4.52. Radiolysis in water (including cooling water) or organic materials may result in the production and build-up of degradation products. These products may be flammable/ explosive (e.g. H_2, CH_4, organic nitrate/ nitrites (red oils), peroxides) or corrosive (e.g. Cl_2, H_2O_2) and may damage containment barriers. A dilution system (air or inert gas) should be provided to prevent explosive gaseous mixtures and the subsequent loss of confinement, resulting from radiolysis in vessels as far as practicable. For product containers and other systems, design should take into account potential corrosion and gas (pressure) production (e.g. for PuO_2 powder or Pu contaminated waste), (Ref. [1]: Appendix IV: IV.33).

4.53. Unstable products from exothermic chemical reactions may result in explosions and loss of confinement. Design requirements, guidance contained in international and national standards and international experience should be used to prevent the build-up of explosive products. The design requirements should address the monitoring and alarming of process parameters and the minimization of inventories in order to prevent chemical explosions (e.g. red oils in evaporators, HN_3 in extraction cycles), (Ref. [1]: Appendix IV: para. IV.33).

4.54. Pyrophoric metals (U or Zircaloy particles from fuel shearing or cladding removal) may cause fires or explosions. The design should avoid their unexpected accumulation and provide an inert environment as necessary (Ref. [1]: Appendix IV: para. IV.33).

4.55. To ensure that hazardous or incompatible mixtures of materials cannot occur in leak and overflow collection systems including:

(a) The routing of overflow systems designed to prevent uncontrolled leaks;

(b) Drip trays to collect leaks and their drain routes;

(c) Collecting vessels;

(d) Recovery routes, and;

(e) The potential for any system passing through a cell to leak into a cell sump or the equivalent for inactive services and reagent feeds.

Should be fully evaluated in the design assessment.

Protection against external exposure

4.56. The aim of protection against external radiation exposure is to maintain doses below the limits given in (Ref. [6]: Schedule III: paras. III.1 and III.2), optimize protection and to meet the requirements and guidance identified in para. 4.5 using the following elements, separately or in combination:

(a) Limiting the radiation source strength (where practicable) during operation and maintenance (e.g. by prior decontamination or washing before a maintenance operation);

(b) Shielding the radiation source including temporary shielding;

(c) Distancing the radiation source from personnel (position of work stations, remotely controlled operation, etc.);

(d) Limiting the exposure time of personnel (automation of operation, alarmed dosimeters, etc.);

(e) Controlling access to areas where there is a risk of external exposure;

(f) Using personal radiation protection (torso & organ shields). For normal operation, the need for personal protective equipment should be minimized through careful design.

4.57. Dose optimization in design should also take into account operational constraints on the maintenance staff. In addition the use of time limitation as the main method of dose management should be minimized, and the routine wearing of personal protective equipment (shielding) should be avoided.

4.58. In a high beta-gamma activity facility (HA units), the design of shielding should consider both the radiation source strength and location. In a medium or low activity facility, a combination of radiation source strength and location, exposure time and shielding should be utilized for protection of workers for both whole body and extremity doses. A general shielding design guide should be to shield as close as possible to the radiation source.

4.59. The requirements for maintenance including examination, inspection and testing should be considered in the design of equipment installed in HA cells paying particular attention to radiation and contamination levels throughout the lifetime of the reprocessing facility (Ref. [1]: Appendix IV: para. IV.28).

(a) For the mechanical and electrical parts of HA units: the design of the layout and of the equipment should allow for adequate remote maintenance (e.g. master slave manipulators);

(b) For transfers of liquids, non-mechanical mean (e.g. air or jet lift with disentrainment[26] capabilities, or fluidic devices as appropriate) should be preferred or mechanical items, pumps, valves etc. should be designed for remote maintenance (e.g. in connection with the use of shielded equipment maintenance flasks[27]).

4.60. Radioactive inventories should take into account deposition factors inside pipes and equipment, from processed materials and their daughter products: e.g. particulates, activity coating[28] within pipes (HA sections) and gloveboxes (americium). The potential for the accumulation of radioactive material in the process equipment and secondary systems (e.g. ventilation ducting) during operation should be minimized by design or provision made for its removal.

4.61. In a reprocessing facility, process control relies (in part) on analytical data from samples. In order to minimize operational exposure, automatic and remote operation should be preferred for the sampling devices, the sample transfer network to the laboratories and the analytical laboratories (Ref. [1]: para. 6.40).

4.62. Depending on national and international regulations and the safety assessment, the monitoring system for radiation protection should consist principally of::

(a) Fixed gamma/ neutron area monitors and stationary “sniffers”[29] for activity monitoring in air (beta/ gamma, alpha) for access and/ or evacuation purposes;

(b) Mobile gamma/ neutron area monitors and mobile sniffers for activity monitoring in air (beta/ gamma, alpha) for personnel protection and evacuation purposes during maintenance and at barriers between normal access and controlled areas;

(c) Workers (personal) monitors consistent with the radiation type.

POSTULATED INITIATING EVENTS

Internal initiating events

Fire[30]

4.63. In reprocessing facilities, fire hazards (Ref. [1]: Appendix IV: para. IV.33)are associated with the presence of:

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[26]A system or device for separating the liquid from the motive air or steam with minimum carry-over (entrainment) of activity into the ventilation system.
[27]Sometimes referred to as a Mobile Equipment Replacement Cask.
[28]Called “plate-out” in some Member States
[29]Air sampling point/head.
[30]The requirements for fire at a reprocessing facility are established in (Refs. [1]: Section 2, para. 6.55 and Appendix IV: paras. IV.33-IV.36)

(a) Flammable materials such as: pyrophoric materials; solvents; reactive chemicals; electrical cabling, and;

(b) Potentially inflammable materials such as: polymeric neutron shielding (normally associated with gloveboxes) and; process and operational waste (wipes, protective suits etc.) including office waste.

4.64. Fire in reprocessing facilities can lead to the dispersion of radioactive and/ or toxic materials by breaching containment barriers. It may also cause a criticality accident by affecting the system(s) used for the control of criticality by: changing the dimensions of processing equipment; altering the moderating or reflecting conditions due to the presence of firefighting or fire suppression media, or; destruction of neutron decoupling devices.

Fire hazard analysis

4.65. Fire hazard analysis involves systematic identification of the causes of fires, assessment of the potential consequences of a fire and, where appropriate, estimation of the probability of the occurrence of fires. It should consider, explicitly, potential external and internal fires including fires involving nuclear material[31] directly and indirectly. Fire hazard analysis is used to assess the inventory of (flammable) fuels and initiation sources and to determine the appropriateness and adequacy of measures for fire protection. Computer modelling of fires should be used in support of the fire hazards analysis in complex and high hazard applications, as necessary. These analyses can provide valuable information on which it is possible to base design decisions or to identify weaknesses that might otherwise have gone undetected. Even if the likelihood of a fire occurring may seem low, it may well have significant consequences with regard to nuclear safety and, as such, appropriate protective measures should be undertaken (e.g. delineating small fire compartment[32] areas) to prevent fires or prevent the fire from propagating.

4.66. The analysis of fire hazards should also include a systematic review of the provisions made for preventing, detecting, mitigating and fighting fires.

[31]In some member states potential fires involving nuclear materials directly 'Nuclear Fires' (e.g. an actinide loaded solvent fire) or general (internal, conventional) fires 'Fires' (e.g. a control room fire caused by an electrical fault) affecting the facility are considered separately and explicitly in the safety assessment for additional clarity and to help to ensure all potential radiological and non-radiological hazards from both categories of fire are addressed adequately.

[32]A room or suite of rooms within a firewall, potentially with separate fire detection and firefighting provisions, inventory controls and evacuation procedures.

4.67. An important aspect of the fire hazard analysis (Ref. [1]: para. 6.55) for a reprocessing facility, is the identification of areas of the facility that require special consideration. In particular, fire hazard analysis should include:

(a) Areas where fissile material is processed and stored;

(b) Areas where radioactive material is processed and stored

(c) Process gloveboxes, especially those in which plutonium is processed;

(d) Workshops and laboratories in which flammable or combustible liquids and gas, solvents, resins, reactive chemicals are used and/ or stored;

(e) Areas where pyrophoric metal powders are processed (e.g. from Zr or U shearing/ decladding);

(f) Areas with high fire loads, such as waste storage areas;

(g) Rooms housing systems and components important to safety, (e.g. last stages filters of the ventilation systems, electrical switch rooms), whose degradation might have radiological consequences or consequences in terms of criticality that are unacceptable;

(h) Process control rooms and supplementary control rooms;

(i) Evacuation routes.

Fire prevention, detection and mitigation

4.68. Prevention is the most important aspect of fire protection. Reprocessing facilities should be designed to limit fire risks through the incorporation of measures to ensure that fires do not occur and, if they do occur, to detect, limit and contain their spread. Measures for mitigation should be put in place to reduce to a minimum the consequences of fire in the event that a fire breaks out despite preventive measures.

4.69. To accomplish the dual aims of fire prevention and mitigation of the consequences of a fire, a number of general and specific measures should be taken, including the following:

(a) Minimization of the combustible load of individual areas, including the effects of fire enhancing chemicals such as oxidizing agents;

(b) Segregation of the areas where non-radioactive hazardous material are stored from the process areas;

(c) Installation of a fire detection monitoring system designed to allow early detection and accurate identification of the location of any fire, rapid dissemination of the information and, where installed, activation of automatic devices for fire-suppression;

(d) Selection of materials including building materials, process and glovebox components and materials for penetrations, in accordance with their functional requirements and fire-resistance ratings;

(e) Compartmentalization of buildings and ventilation ducts as far as possible to prevent the spreading of fires;

(f) Avoiding the use of flammable liquids or gases outside their flammability limits;

(g) Suppression or limitation of the number of possible ignition sources such as open flames, welding or electrical sparks and their segregation from combustible material;

(h) Insulation of hot or heated surfaces;

(i) Consistency of the fire extinguishing media with the requirements of other safety analyses, especially with the criticality control requirements (Ref. [1]: Appendix IV: para. IV.17).

4.70. To accomplish the dual aims of fire prevention and mitigation the design and the control of the ventilation system should aim at limiting the spread of fire, at maintaining as long as possible the dynamic containment system for the area (room or cell) involved in the fire and protecting the final level of filtration.

4.71. The design of ventilation systems should be given particular consideration with regard to fire prevention including the following aspects:

(a) Limiting the accumulation of flammable dust or other materials;

(b) Providing means of removing or washing-out inaccessible ventilation ducts;

(c) Ventilation ducts should be airtight and resistant to heat and corrosive products that might result from a fire;

(d) Ventilation ducts and filter units for dynamic containment which may constitute weak points in the fire protection system unless they are of suitable design;

(e) Fire dampers should be mounted in the ventilation system unless the likelihood of a wide-spread fire and fire propagation is acceptably low and their effect on ventilation should be carefully considered;

(f) The fire resistance of the filter medium should be carefully considered and spark arrestors should be used to protect filters as necessary;

(g) The location of filters and fans should be carefully evaluated for ability to perform during a fire;

(h) Careful consideration should be given to the potential need to reduce or stop ventilation flows in the event of a major fire to aid fire control.

4.72. Lines crossing the boundaries of the fire compartments and firewalls (e.g. gases, process, electrical and instrument cables and lines) should be designed to ensure that fire does not spread.

4.73. Evacuation routes for fire and criticality events should be considered in design in accordance with national regulations and the safety assessment. They should follow the same routes as far as possible consistent that the aim of reducing the number of different evacuation routes, where this does not impact significantly on fire or criticality safety.

***Explosion*[33]**

4.74. Explosion due to explosive chemicals can cause the release of radioactive materials. The potential for explosions can result from the use of chemical materials (e.g. organic solvents and reactants, hydrogen, hydrogen peroxide, and nitric acid), degradation products, pyrophoric materials (e.g. zirconium or uranium particles), the chemical or radiochemical production of explosive materials (e.g. hydrogen, red oils) or the mixing of incompatible chemicals (e.g. strong acids and alkalis).

4.75. To prevent the release of radioactive materials resulting from an explosion, in addition to the requirements of (Ref. [1]: para. 6.54), the following provisions to be considered during design should include:

(a) Maintaining the separation of incompatible chemical materials in normal and abnormal situations (e.g. recovery of leaks);

(b) Controlling parameters (e.g., concentration, temperature, pressure) to prevent situations leading to explosions;

(c) Using of blow-out panels to mitigate the effects of explosions of non-radioactive materials;

[33] The requirements relating to explosion for a reprocessing facility are established in (Ref. [1]: Section 2, para. 6.54 and Appendix IV: paras. IV.33-IV.36)

(d) Limiting of the quantity or of the concentration of the explosive materials;

(e) Designing the ventilation systems to avoid the formation of an explosive atmosphere and/ or to maintain explosive gases concentration below their lower explosive limit;

(f) Designing of the equipment or structures to withstand the effects of an explosion;

(g) Where design options exist consideration should be given to adopting processes with lower potential risk for fire or explosion.

4.76. Chemicals should be stored in well ventilated locations or racks outside the process or laboratories areas

***Handling events*[34]**

4.77. Mechanical, electrical or human errors during the handling of radioactive or non-radioactive materials may result in the degradation of criticality controls, confinement, shielding, or other systems important to safety and associated controls or in reduction of defence in depth. A reprocessing facility should be designed to:

(a) Eliminate the need to lifts load where practicable, especially within the facility, by using track guided transport or other stable means of transport;

(b) Limit the consequences of drops and collisions (e.g. minimizing lift height, qualification of containers against the maximum drop, design of floors to withstand the impact of dropped loads, installation of shock absorbing features, definition of safe travel paths etc.);

(c) Minimize the failure frequency of mechanical handling systems[35] (e.g. cranes, carts, etc.) by appropriate design, including control systems, with multiple fail-safe features (brakes, wire ropes, action on power loss, interlocks etc.);

(d) Well-trained, selected qualified operatives working within a robust integrated management system.

These measures should be supported by ergonomic design, human factor analysis and the definition of appropriate administrative control measures.

***Equipment Failure*[36]**

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[34] The requirements relating to handling events for a reprocessing facility are established in (Ref. [1]: Section 2 and Appendix IV: para. IV.42)

[35]Some regulatory bodies have specific requirements for design for “nuclear lifts” e.g. multi-roped cranes, maximum load as a smaller fraction of test load than non-nuclear loads etc.

[36] The requirements relating to equipment failure for a reprocessing facility are established in (Ref. [1]: Section 2, para. 4.2 and Appendix IV: para. IV.37)

4.78. A reprocessing facility should be designed to cope with the failure of equipment which would result in a degradation of confinement, shielding, criticality control or reduction of defence in depth. As part of design the fail state of all SSCs important to safety should be assessed and consideration given (in accordance with a graded approach) to the design or procurement of items that fail-safe. Where no fail-safe state can be defined, consideration should be given to ensure that the functionality (safety function) of SSCs important to safety is maintained (by duplication, diversity and independence as necessary).

4.79. Special consideration should be given to failure of computer systems, computerized control or software, in evaluating failure and fail-safe conditions, by application of appropriate national or international codes and standards

Loss of support systems[37]

4.80. The requirements for the loss of support systems for a reprocessing facility are established in (Ref. [1]: Section 2, para 6.28 and Appendix IV: paras. IV.40-IV.41).

4.81. A reprocessing facility should be designed to cope with potential short- and long- term loss of support systems such as the supply of electrical power that may have consequences for safety. The loss of support systems should be considered both for individual item of equipment and facility wide, and; on multi-facility sites, the reprocessing facility's ancillary and support facilities (e.g. waste treatment and storage facilities and other site facilities).

4.82. Electrical power supplies to reprocessing facilities should be of high reliability[38]. In the event of loss of normal power, according to the facility status and to the safety analysis requirements, a robust emergency electrical power supply should be provided to relevant SSCs important to safety, including the following (Ref. [1]: Appendix IV: para. IV.41):

(a) Heat removal systems;

(b) Dilution system for hydrogen generated by radiolysis;

(c) (Some) exhaust fans of the dynamic containment system;

(d) Fire detection systems;

[37] Typical reprocessing facility support systems including utilities are: off- and on-site electrical power, compressed air (instrument air and pneumatic power, steam, cooling water, ventilation systems, emergency electrical power, uninterruptable power supply (instrument power), battery back-up, reagent and chemical supplies, inert gas supplies etc. and all other services and supplies the loss of which may have consequences for safety.

[38] Diverse and redundant electric power sources, switching and connections; design of the power supplies to withstand external risks; using uninterruptible power sources when necessary.

(e) Monitoring systems for radiation protection;

(f) Criticality accident alarm systems;

(g) I&C associated with the above items;

(h) Lighting.

4.83. Consideration should be given to the need to provide emergency power for an extended period in the event of major external events and to which SSCs important to safety, including selected monitoring and alarm systems and other services should be (remain) available in the event of a prolonged utilities outage.

4.84. The chronology for restoring electrical power to reprocessing facilities should be specified during design and take account of:

(a) The “current power status” (off, running on emergency supply, time to loss of back-up power etc.) of the items;

(b) The safety significance or priority of the item being restored to (normal) service;

(c) The interruptions of supply during switching operations, and;

(d) The initial power demand of items within the reprocessing facility and supply capabilities and capacity.

Outline emergency instructions should also be developed during design (Ref. [1]: Appendix IV: para. IV.41).

4.85. The assessments performed for the loss of electrical power supplies or other support services (e.g. cooling, radiolysis, ventilation) should be part of the reprocessing facility assessment (Ref. [1]: Appendix IV: para. IV.40).

4.86. The loss of general support supplies such as compressed air for instrumentation and control, cooling water for process equipment, ventilation systems and inert gas supplies may also have consequences for safety. In the design of a reprocessing facility, suitable measures to ensure the supplies or other means to ensure safety should be provided, e.g.:

(a) In accordance with the safety assessment the design of supply systems should be of adequate reliability with diversity and redundancy as necessary;

(b) The maximum period of loss of supply for all supplies should be assessed and considered in design;

(c) Loss of pneumatic supply to pneumatically actuated valves. In accordance with the safety analysis, valves should be used that are designed to fail-safe, as far as practical;

(d) Loss of cooling water may result in the failure of components such as evaporator condensers, diesel generators, and condensers/ dehumidifiers in the ventilation system. Adequate back up capacity or independent, redundant supplies should be provided in the design.

Pipe or Vessel Leaks[39]

4.87. The materials of the equipment of reprocessing facilities should be selected to cope as far as possible with the corrosion risk due to the chemical and physical characteristics of the processed gases and liquids. The design of all containment should include an adequate allowance for the combined effects of all degradation mechanisms with particular attention paid to both general and localized effects due to corrosion, erosion, mechanical wear, temperature, thermal cycling, vibration, radiation and radiolysis etc.

4.88. Where cooling circuits are installed, especially in HA systems, the effects of "water-side" corrosion, water chemistry, radiolysis (peroxide production etc.) and stagnant coolant (no cooling required or standby system), should be included in design considerations.

4.89. To fulfil requirements regarding confinement, the potential leaks of the first containment barriers should be collected and recovered (e.g. drip-trays or clad floor and collecting sumps for active cells) When large volumes of HA liquid wastes are stored a safety assessment should be made for the number of empty tanks to be available in case of failure(s). See also (Ref. [1]: para. 6.17).

4.90. The potential effects of corrosion on the dimensions of equipment containing fissile materials should be taken into account in the criticality assessments (e.g. thickness of the walls of process vessels whose criticality control mode is geometry) (Ref. [1]: Appendix IV: para. IV.18). Consideration should also be given to the corrosion of support structures for fixed neutron absorbers and, where absorbers are in the process medium, to corrosion of the absorber itself e.g. packing in evaporator condensers.

4.91. Where possible, in accordance with safety and technical requirements, process parameters, e.g. operating temperature of evaporators and the specification for acceptable use of reagents or feeds recycled from facility effluents should be optimized to give acceptable

[39] The requirements relating to pipe and vessel leaks for a reprocessing facility are established in (Ref. [1]: Section 2, para 6.17, 6.38, Appendix IV: paras. IV.18, IV.27 and IV.38-IV.39)

corrosion rates balanced with the minimization of waste and process performance and efficiency.

Internal flooding[40]

4.92. Flooding by process fluids (e.g. water, nitric acid) including utility feeds in reprocessing facilities may lead to: the dispersion of radioactive materials; changes in moderation and/ or reflection conditions; the failure of electrically powered safety related devices; failure of or false activation of alarms and trips, and; the slowing or stopping of ventilation flows or fans. The design should address these issues, particularly the potential effect of a large leak on the utility feeds and I&C connections for SSCs important to safety. Segregation of electrical and instrument services and liquid or gaseous feeds should be strictly enforced as far as practicable. All floor and wall penetrations for electrical and instrument services should be protected against liquid ingress. Where possible electrical and instrument feeds should be routed at high level. Particular care should be taken with the routing of steam and cooling water pipework due to their potential to release large volumes of vapour or liquid.

4.93. Where vessels or pipes containing liquids pass through rooms containing fissile material the criticality analysis should take into account the presence of the maximum credible amount of liquid within the considered room as well as the maximum credible amount of liquid which could flow from any connected rooms, vessels or pipework.

4.94. Walls (and floors if necessary) of rooms where flooding could occur should be designed to withstand the liquid load and other equipment important to safety should not be affected by flooding. The dynamic effects of large leaks and the potential failure of any temporary 'dams' formed by equipment or internal structures should also be considered.

4.95. The potential hydraulic pressure and up-thrust on large vessels, ducting and containment structures during flooding should be considered in design.

Use of hazardous[41] chemicals

4.96. For reprocessing facilities conservative assessments of chemical hazards to workers and releases of hazardous chemicals to the environment are made on the basis of the standards used in the chemical industries and the requirements of national regulations, taking into account any potential for radiological or nuclear hazards. Where possible these chemicals

[40] The requirements relating to internal flooding for a reprocessing facility are established in (Ref. [1]: Section 2 and Appendix IV: para. IV.39)

[41] Further guidance on hazardous chemicals is given in (Refs. [24] and [25])

should be chosen or used under physical conditions where they are intrinsically safe, by design.

4.97. Based on safety assessments, design should take into account effects of hazardous chemical releases from failures or damage of equipment that can lead to unsafe conditions at the reprocessing facility either by direct action of the chemicals involved (corrosion, dissolution, damage) or, indirectly, by causing the evacuation of control rooms, or toxic effect on workers etc.

Use of non-atmospheric pressure equipment[42]

4.98. As far as practicable, provisions for in-service testing of equipment installed in controlled areas and cells should be defined according to national requirements on pressurized and/ or sub-atmospheric equipment. If this is not possible, additional safety features should be specified at the design stage (e.g. oversizing with regards to pressure, increased safety margins, special justification for alternative testing regimes etc.) and in operation (e.g. reinforced monitoring of process parameters). A specific safety assessment of any proposed alternative testing and operational regime should be made with the objective of demonstrating that the probability of failure and the consequences or risk, as appropriate, are consistent with the accident criteria for the facility. The potential consequences of an explosion, implosion or leak, including during testing, should be assessed and complementary safety features identified to minimize potential consequences, consistent with a defence in depth approach.

External initiating events

General

4.99. The fuel reprocessing facility should be designed in accordance with the nature and severity of the external hazards, either natural or man-made, identified and evaluated according to (Ref. [14]) and its associated safety guides (Section 3). The reprocessing facility specific features are identified in the following paragraphs under appropriate headings.

4.100. The design of the fuel reprocessing facility should be consistent with the nature and severity of the external hazards, either natural or man-made, identified and evaluated according to (Ref. [14]) and its associated safety guides (Section 3). The reprocessing facility specific features are identified in the following paragraphs under the appropriate headings.

[42]Most equipment in reprocessing plants operates at or close to atmospheric pressure; exceptions are evaporators operating a reduced pressures from safety considerations, possibly some equipment designed to resist potential violent or run-away reactions and service supplies (air, steam etc.).

Earthquake

4.101. To ensure that the design provides the required degree of robustness a detailed seismic assessment (Ref. [14] and [15]) should be made of the reprocessing facility design including seismically induced:

(a) Loss of cooling;

(b) Loss or support services including utilities;

(c) Loss of containment functions (static and dynamic);

(d) Loss of safety functions for ensuring the return of and maintaining the facility to a safe status after an earthquake (structural functions, functions of prevention of other risks (e.g. fire, explosion, load drop, flooding) etc.;

(e) The effect on criticality safety functions such as geometry and/ or moderation (Ref. [1]: Appendix IV: para. IV.44) of;

- Deformation (geometry control);
- Displacement (geometry control, fixed poisons);
- Loss of material (geometry control, soluble poisons)

4.102. Emergency control rooms or control panels (paras. 4.167-4.168) should be accessible and operable by staff after a design basis earthquake. Equipment required to maintain the reprocessing facility in a safe and stable state and monitor the facility and environment should be tested (as far as practicable) and qualified using appropriate conservative methodologies including the use of an earthquake simulation platform (Ref. [1]: Appendix IV: para. IV.45).

4.103. Depending on the reprocessing facility site characteristic and facility location, as evaluated in the site assessment (Section 3), the effect of a tsunami induced by an earthquake and other extreme flooding events should be addressed in the facility design (Ref. [1]: Appendix IV: para. IV.46).

External fires and explosions

4.104. The reprocessing facility design should address external fire and explosion hazards as identified in the site evaluation (Section 3).

External toxic hazards

4.105. Toxic and asphyxiant hazards should also be assessed to verify that anticipated maximum gas concentrations meet acceptance criteria. It should also be ensured that external toxic or asphyxiant hazards would not adversely affect the control of the facility.

Extreme weather conditions

4.106. A reprocessing facility should be protected against extreme weather conditions as identified in the site evaluation (Section 3) by means of appropriate design provisions. These should generally include (Ref. [1]: Appendix IV: para. IV.46):

(a) The ability to maintain availability of cooling systems during extreme temperatures and other extreme conditions;

(b) The ability of structures important to safety to withstand extreme weather loads, particular assessment of parts of the facility structure designed to provide containment with little or no shielding function (e.g. alpha active areas);

(c) Prevention of flooding of the facility;

(d) Safe shutdown of the facility in accordance with the operational limits and conditions and keeping the facility in a safe and stable state, and where necessary;

(e) Keeping ground water level within the acceptable limits during flooding.

Tornadoes

4.107. The design of buildings and ventilation systems should comply with specific national regulations relating to hazards from tornadoes (Ref. [1]: Appendix IV: para. IV.46).

4.108. Tornadoes are capable of lifting and propelling large, heavy objects (e.g. automobiles or telephone poles). The possibility of impacts from such missiles should be taken into consideration in the design stage for the facility, for both the initial impacts and the effects of secondary fragments arising from striking concrete walls or from other forms of transfer of momentum (Ref. [1]: Appendix IV: para. IV.46).

Extreme temperatures

4.109. The potential duration of extreme low or high temperatures should be taken into account in the design of cooling systems and support systems, to prevent unacceptable effects such as:

(a) Freezing of cooling circuits (including cooling towers and outdoor actuators);

(b) Loss of efficiency of cooling circuits (hot weather);

(c) Adverse effects on building venting, heating and cooling system to avoid poor working conditions and humidity excess in the buildings and adverse effects on SSCs important to safety.

Administrative actions to limit or mitigate the consequences of such events can only be relied upon if the operators have the necessary information, sufficient time to respond and the necessary equipment e.g. portable air conditioning (Ref. [1]: Appendix IV: para. IV.46).

Snowfall and Ice Storms

4.110. Snow and ice are generally taken into account as an additional load on the roofs of buildings and, for “glaze” ice, vertical surfaces and utilities. The flooding resulting from snow or ice accumulation and infiltration and a possibility that it leads to damage of equipment important to safety (e.g., electrical systems) should be considered. The neutron reflecting or moderating effect of snow should be considered if relevant. (Ref. [1]: Appendix IV: para. IV.46).

Flooding[43]

4.111. For extreme rainfall attention should be focused on the stability of buildings (e.g., hydrostatic and dynamic effects), water level and, where relevant, the potential for mud slides.

4.112. For flooding events attention should be focused on potential leak paths (containment breaks) into active cells and SSCs important to safety at risk of damage. In all cases the equipment containing fissile material should be designed to prevent any criticality accident. Gloveboxes should be designed to be resistant (undamaged and static) to the dynamic effects of flooding and all glovebox penetrations should be above any potential flood levels (Ref. [1]: Appendix IV: para. IV.46). Electrical and instrument systems, emergency power (batteries and generation) systems and control rooms should be protected by design. Where necessary the design should ensure continued operation of selected functions in extreme events (defence in depth).

Inundation (natural and man-made) events

4.113. Measures for the protection of the facility against inundation events (dam burst, flash flood, storm surge, tidal wave, seiche, tsunami etc.) including both static (flooding) and

[43]Consideration should be given to the highest flood level historically recorded and siting the facility above the flood level, at sufficient elevation and with sufficient margin to account for uncertainties (e.g., postulated effects of global warming) to avoid major damage from flooding.

dynamic (run-up and draw-down) effects, will depend on the data collected during site evaluation for the area in which the facility is located. The design of buildings, electrical and I&C systems should comply with specific national regulations relating to these hazards (Ref. [1]: Appendix IV: para. IV.46), including the recommendations outlined in paras. 4.111-4.112. Particular attention should be given to the rapid onset of these events, the probable lack of warning and their potential for causing wide-spread damage, disruption of utility supplies and common-cause failures both within the reprocessing facility and to any other facilities on the site, locally and potentially region-wide depending on the magnitude of the event.

Accidental aircraft crash or externally generated missiles hazards

4.114. In accordance with the risk identified during the site evaluation (Section 3) reprocessing facilities should be designed to withstand the design basis impact (Ref. [1]: para. 5.5).

4.115. In evaluating the consequences of impact or the adequacy of the design to resist aircraft or secondary missile impacts, only realistic crash, rotating equipment or structural failure scenarios should be considered. These require the knowledge of such factors as the possible angle of impact or the potential for fire and explosion from aviation fuel. In general, fire cannot be ruled out following an aircraft crash, and the specific requirements for fire protection and emergency preparedness and response should be designed and implemented as necessary.

Terrestrial and aquatic flora and fauna

4.116. The potential for a wide range of interactions with flora and fauna should be considered in the design of reprocessing facilities including the potential for the restricting or blockage of cooling water and ventilation inlets and outlets, the effect of vermin on electrical and instrument cabling and their ingress into waste storage areas etc.). Where physical or, particularly, chemical control measures for flora and fauna are necessary these should be given the same level of evaluation as any other process chemical consistent with a graded approach based upon the potential risks.

INSTRUMENTATION AND CONTROL

Instrumentation and control systems important to safety

4.117. I&C systems important to safety for normal operation should include systems (Ref. [1]: Appendix IV: para. IV.47) for:

(a) Criticality control:

- Depending on the method of criticality control, the control parameters should include mass, concentration, acidity, isotopic/ fissile content, quantity of moderators as appropriate (Ref. [1]: Appendix IV: para. IV.11);
- Specific control parameters required from criticality safety analyses e.g. burn-up measurement for spent fuel assemblies/ elements before shearing/ decladding, when burn-up credit is used in the criticality control or soluble poison concentrations in reagent feeds (Ref. [1]: para 6.45 and Appendix IV.: para. IV.15);

(b) Process control, the key safety related control systems of concern are those for:

- Removing decay heat;
- Diluting hydrogen due to radiolysis and other sources;
- Vessel levels;
- Controlling temperature and other conditions to prevent red oil explosions etc.;

(c) Fire detection systems;

(d) Glovebox and cell controls:

- Monitoring dynamic containment in cells and gloveboxes ('Control of ventilation', below);
- Monitoring cell and glovebox sump levels (leak detection systems);

(e) Control of ventilation:

- Monitoring and control of differential pressure to ensure that the airflows in all areas of the reprocessing facility are flowing in the correct direction, i.e. towards areas that are more contaminated;
- Ventilation (stack) flows for monitoring of environmental discharge;

(f) Control of occupational radiation exposure:

- External exposure.

  i. Sensitive dosimeters with real-time displays and/ or alarms should be used to monitor occupational radiation doses;

  ii. Portable equipment and installed equipment should be used to monitor whole body exposures and exposures of the hands to gamma radiation and neutron emissions.

- Internal exposure, due to the specific hazards of airborne radioactive materials, the following provisions should be considered:

  i. Continuous air monitors to detect airborne radioactive materials should be installed as close as possible to the working areas to ensure the early detection of any dispersion of airborne radioactive materials;

  ii. Devices for detecting surface contamination should be installed/ located close to the relevant working areas and also close to the exits of rooms in which relevant working areas are located;

  iii. Detectors and interlocks associated with engineered openings (i.e. access controls);

(g) Control of liquid discharges and gaseous effluents:

- Monitoring of liquid and gaseous effluents discharges;
- Monitoring (the operation of) sample system for environmental discharges;
- Site environmental monitoring systems.

Instrumentation

4.118. Instrumentation should be provided to monitor the variables and systems of the facility over their respective ranges for:

(1) Normal operation;

(2) Anticipated operational occurrences;

(3) Design basis accidents and, as far as practicable;

(4) Design extension conditions.

The aim should be to ensure that adequate information can be obtained on the status of the facility and correct responses can be planned and taken in accordance with normal operating or emergency procedures or accident guidelines as appropriate, for all facility states (Ref. [1]: Appendix IV: para. IV.47).

4.119. Adequate and reliable controls and appropriate instrumentation should be provided for monitoring and controlling all the main variables that can affect the safety of the process and the general safety condition of the facility. These instruments include: radiation levels; airborne contamination conditions; monitoring of effluent releases; criticality conditions; fire conditions; ventilation conditions, and; for obtaining any other information about the facility necessary for its reliable and safe operation. Provision should be made for the automatic measurement and recording of relevant values of parameters important to safety (Ref. [1]: Appendix IV: para. IV.47).

4.120. According to the requirements of the safety analysis and any defence in depth consideration, I&C systems should incorporate redundancy and diversity to ensure an appropriate level of reliability and availability. This should include the requirements for a reliable and uninterruptable power supply to the instruments as necessary.

Local instrumentation

4.121. In reprocessing facilities many areas may be impossible or very difficult to access, with short working times due to high radiation and/ or contamination levels. As far as possible the need to access such areas to operate, view or maintain: instruments; local indicators, or; control stations should be avoided. Where location in such environments is unavoidable separate enclosures or shielding should be used to protect instruments or personnel as appropriate (Ref. [1]: Appendix IV: para. IV.47).

Sample taking and analysis

4.122. The preference in reprocessing facilities should be for measurement by:

1) In-line instruments;

2) At-line[44] instruments;

3) Sampling with local analysis (e.g. reagent dilution);

4) Sampling with distant (central laboratory etc.) analysis.

4.123. In choosing the type of instrument to install the following factors should be considered:

[44]Devices that remove a small sample or flow (proportional sampling) from a process flow or vessel for measurement rather than measuring in the bulk material directly.

(a) The availability of capable equipment and its discrimination, reliability and stability;

(b) The availability of suitable process locations including, for sampling and analyses important to safety:

- Diversity and redundancy considerations;
- The requirement for assurance of “representative and fresh[45]” sample delivery and measurement.

(c) Realistic (e.g. in-situ, on-line or removed, off-line) calibration and testing options, and;

(d) The ergonomics of maintenance and replacement, including dose considerations and timeliness issues.

4.124. In reprocessing facilities the safety of many chemical processes relies on the quality and the timeliness of chemical and radiochemical analysis performed on samples taken from vessels and equipment at strategic points in the processes, e.g. Pu concentration, Pu isotopic composition, solution acidity. For these strategic sample points, all the aspects related to the quality of sample taking and labelling, its safe transfer to the analytical laboratories, the quality of the measurements and their reporting to the facility operators should be documented, and justified as part of the integrated management system (Ref. [1]: Appendix IV: para. IV.47). The use of bar-coding or similar systems should be considered to reduce the opportunity for error.

4.125. Where applicable sampling systems should be automated. The use of completely automated systems (from sampling request to result receipt) for frequent analytical measurements should be considered where beneficial to safety for avoiding operational exposure, exposure risk and potential human errors (Ref. [1]: para, 6.16 and Appendix IV: para. IV.28).

Control systems

4.126. The recommendations in paras. 2.10-2.13 apply to all control systems in a reprocessing facility. In particular the hierarchy: passive > active > administrative (operator action) should be applied consistent with the graded approach and the available reaction time (grace period). The defence in depth principle of avoiding challenge to safety features or controls should also be considered.

[45]In this context “representative and fresh” means that, where the main process, effluent etc. flow is not being measured directly suitable means must be provided to demonstrate (to the same reliability as specified for the SSC by the safety assessment) that the sample is fully representative of the main flow in composition at the time of sampling and measurement (with allowable deviation specified in the safety assessment) and is delivered to the point of measurement reliably.

4.127. Appropriate information should be made available to the operator for monitoring the actuation of, and facility response to, remote and automatic actions. The preference should be for independent indication showing the effect of an action e.g. a flow meter showing a flow stopping or starting rather than e.g. a valve position indicator. As far as practical all displays (instrument, computer, facility and process schematics or mimic displays) and all control rooms and control stations should follow good ergonomic practice. The layout of instrumentation and the manner of presentation of information should provide the operating personnel with a clear and comprehensive view of the status and performance of the facility, to assist the operators to comprehend the facility status rapidly and correctly, make informed decisions and execute those decisions accurately.

4.128. Devices should be installed that provide, in an effective manner, visual and, as appropriate, audible indications of operational states that have deviated from normal conditions and that could affect safety. Specifically information should be displayed in such a way that operators can easily determine if a facility is in a safe state and, if not, readily determine the appropriate course of action to return the facility to a safe and stable state (Ref. [1]: Appendix IV: para. IV.47).

4.129. For radioactive material and important reagent transfers, where there are no specific safety measures, the following should be adopted, as far as practicable, to allow early detection of operational occurrences as part of defence in depth (Ref. [1]: para. 2.7 and Appendix IV: para. IV.47):

1) The use of transfers by batch between unit/ building/ facilities (para. 4.48);

2) Characterization of a batch before transfer;

3) The use of an authorization procedure allowing the receiving installation to authorize the start of transfer and monitor the transfer process.

Where transfers are initiated automatically, especially if frequent, consideration should be given to appropriate automatic means of detecting failures to start or stop transfers.

Control rooms

4.130. Control rooms should be provided to centralize the main data displays, controls and alarms for general conditions at the facility. Occupational exposure should be minimized by locating the control rooms in parts of the facility where the levels of radiation are low. For specific processes, it may be useful to have dedicated, localized control rooms to allow the remote monitoring of operations, thereby reducing exposures and risks to operators. Particular consideration should be paid to identifying those events, both internal and external to the control rooms that may pose a direct threat to the operators, to the operation of the control room and to the control of the reprocessing facility itself (Ref. [1]: para. 2.7 and Appendix IV: para. IV.47).

HUMAN FACTOR CONSIDERATIONS[46]

Human factors in operation, inspection, periodic testing, and maintenance

4.131. Human factors should be considered at the design stage. Issue to be considered include:

(a) Possible effects on safety of human errors (with account taken of ease of intervention by the operator and the system tolerance of human error);

(b) Potential for occupational exposure.

4.132. Reprocessing facility design should evaluate all work locations under normal facility states, including maintenance, and should identify situations where and when human intervention is required under abnormal and accident conditions with the aim of facilitating the operator's activities and being resistant to human error. This should include the optimization of the design to prevent or reduce the likelihood of operator error (e.g. locked valves, segregation and grouping of controls, fault identification, logical displays, segregation of process and safety systems displays and alarms etc.). Particular attention should be paid to situations where operator action is anticipated in accident conditions for rapid, fault-free and fault tolerant, problem identification and operator selection of an appropriate response or action.

4.133. Human factor experts and experienced operators should be involved from the earliest stage of the design. Areas that should be considered include:

(a) Application of ergonomic requirements to the design of working conditions:

- The operator – process interface, e.g. well laid-out electronic control panels displaying all the necessary information and no more;
- The working environment, e.g. good accessibility to, and adequate space around equipment, good lighting, including emergency lighting, and suitable finishes to surfaces to allow areas to be kept clean easily;

[46] The requirements relating to the consideration of human factors are established in (Ref. [1]: paras. 6.15 and 6.16).

(b) Provision of fail-safe equipment and automatic control systems for accident sequences for which reliable and rapid protection is required;

(c) Consideration of the advantages and drawbacks of automatic action vs operator (manual) action in particular applications

(d) Good task design and job organization, particularly during maintenance work, when automated control systems may be disabled;

(e) Facility minimum safety staffing levels should be assessed by the task analysis of the operator responses required during the most demanding occurrences;

(f) Consideration of the need of additional space and access requirement during the lifetime of the facility;

(g) Provision of dedicated storage locations for all special tools and equipment;

(h) Choice of location and clear, consistent and unambiguous labelling of equipment and utilities so as to facilitate maintenance, testing, cleaning and replacement;

(i) Minimization of the need to use additional means of personal protective equipment and, where it remains necessary, careful attention to their selection and design.

4.134. Consideration should be given to providing computer aided tools to assist operators in detecting, diagnosing and responding to events.

4.135. In the design and operation of gloveboxes, the following specific ergonomic considerations should be taken into account:

(a) In the design of equipment inside gloveboxes, account should be taken of the potential for conventional industrial hazards that may result in injuries to workers, including internal radiation exposure through cuts in the gloves and/ or wounds on the operator's skin, and/ or the possible failure of confinement;

(b) Ease of physical access to gloveboxes and adequate space and good visibility in the areas in which gloveboxes are located;

(c) Consideration of the requirement for glovebox and glovebox window seal etc. maintenance including the need for personal protective equipment during these operations.

(d) Careful consideration of the number and location of glove and posting ports, with the use of mock-ups and extensive testing of glovebox ergonomics at the manufacturer before delivery recommended;

(e) The potential for damage to gloves and the provisions for glove, and, where applicable, filter changing.

SAFETY ANALYSIS

4.136. The safety analysis of reprocessing facilities should assess the variety of hazards and places where radioactive materials are located (Ref. [1]: paras. 2.6, 2.10-2.15, 4.2 and 4.24) to ensure a comprehensive risk assessment for the whole facility and all activities and all credible postulated initiating events in accordance with (Ref. [26]).

4.137. The list of hazards defined in (Ref. [1]: Annex III) should be developed by identifying all postulated initiating events and the resulting event scenarios and carrying out detailed analyses to define appropriate SSCs important to safety and OLCs (Ref. [1]: Annex III: Step 3.A).

4.138. For reprocessing facilities the safety analysis should be performed (iteratively with the design development Ref. [1]:Annex III) with the objectives of achieving:

(a) Doses to workers and the public during operational states that should be within acceptable limits for those states and consistent with the optimization of protection[47] (Ref. [6]: principles: 11 and 12);

(b) Radiological and chemical consequences of DBAs (or equivalent) to the public that should be within the limits specified for accident conditions and consistent with the optimization of protection (Ref. [6]);

(c) Final OLCs.

4.139. The use of bounding cases (Ref. [1]: Annex III: para. III-10) has limited application in reprocessing facilities due to variety of equipment used, materials handled and processes employed. These should only be used where the accidents grouped together can be demonstrated to be within a representative bounding case after a thorough analysis. The use of such bounding cases is nevertheless important in reducing unnecessary duplication of safety analyses and should be used when practicable and justified.

[47]optimization of protection (and safety): The process of determining what level of protection and safety makes exposures, and the probability and magnitude of potential exposures, "as low as reasonably achievable, economic and social factors being taken into account" (ALARA), as required by the International Commission on Radiological Protection System of Radiological Protection (Ref. [8]). See also (Ref. [27]: principles 5 and 6)

Safety analysis for operational states

Occupational radiation exposure and exposure of the public

4.140. At the design stage of a new reprocessing facility, radiation doses to the workers should be estimated early-on in the design process and should be iteratively re-calculated and refined as the design proceeds as this maximizes opportunities for the optimization of protection. A common initial approach is to first allocate an (estimated) internal dose based on experience and then to assess the external radiation protection (shielding, layout etc.).The assessment of the occupational external doses should be based on conservative assumptions including the following:

1) Calculations with a bounding radiation source strength on the basis of:

- Maximum inventory including activity, energy spectrum, and neutron emission of all radioactive materials, and;
- Accumulation factors (e.g., accounting for deposition of radioactive material inside pipes and equipment);

2) Two approaches are possible to assess external doses (Ref. [1]: paras. 2.6, 2.10-2.12 and 4.24):

   i. Define a limit for dose that will allow any worker to be present without time constraints, and irrespective of the distance between the (shielded) radiation source and the worker, or;

   ii. Identify and take into account the type of and time required for the work activity to be performed by each worker and the distance between the worker and the (shielded) radiation source;

3) Calculations to determine the shielding requirements for case 2) i or 2) ii, as appropriate.

4.141. The calculation of estimated dose for the public should include all the radiological contributions originating in the facility, i.e. direct or indirect (e.g. sky or ground shine) radiation, intake of radioactive material and doses received through the food chain as a result of authorized discharges of radioactive material. The maximum values for each contribution should be used for the dose calculation where a range is calculated. Conservative models and parameters should be used to estimate doses to the public. The doses should be estimated for the representative person(s).

Releases of hazardous chemical materials

4.142. This Safety Guide addresses only those chemical hazards that can give rise to radiological hazards (Ref. [1]: para. 2.2). Facility specific, realistic, robust (i.e. conservative), estimations of purely chemical hazards to workers and release of hazardous chemicals to the environment should be performed, in accordance with the standards applied in the chemical industries (Refs. [1]: paras. 2.6, 2.10-2.12, 4.24, [24] and [25]).

Safety analysis for accident conditions

Methods and assumptions for safety analysis for accident conditions

4.143. The acceptance criteria associated with the accident analysis should be defined in accordance with (Ref. [26]: requirement 16) and with respect to any national regulations and relevant criteria.

4.144. To estimate the on-site and off-site consequences of an accident, the range of physical processes that could lead to a release of radioactive material to the environment or loss of shielding should be considered in the accident analysis and the bounding cases[48], encompassing the worst consequences should be determined (Ref. [1]: paras. 2.6, 2.10-2.12 and 4.24).

4.145. Accident consequences should be assessed following the requirements given in (Ref. [26]) and relevant parts of its supporting guides.

Assessment of possible radiological or associated chemical consequences

4.146. Safety assessments should address the consequences associated with possible accidents. The main steps in the development and analysis of accident scenarios should include (Ref. [1]: paras. 2.6, 2.10-2.12 and 4.24):

(a) Analysis of the actual site conditions (e.g. meteorological, geological and hydro-geological site conditions) and conditions expected in the future;

(b) Identification of workers and members of the public who could possibly be affected by accidents; i.e. representative person(s) people living in the vicinity of the facility;

(c) Specification of the accident configurations, with the corresponding operating procedures and administrative controls for operations;

[48]Sometimes referred to as “limiting cases”

(d) Identification and analysis of conditions at the facility, including internal and external initiating events that could lead to a release of material or of energy with the potential for adverse effects, the time frame for emissions and the exposure time, in accordance with reasonable scenarios;

(e) Specification of the SSCs important to safety that are credited to reduce the likelihood and/ or to mitigate the consequences of accidents. These SSCs important to safety should be qualified to reliably perform their functions in the accident conditions;

(f) Characterization of the source term (material, mass, release rate, temperature, etc.);

(g) Identification and analysis of intra-facility transport pathways for material that is released;

(h) Identification and analysis of pathways by which material that is released could be dispersed in the environment;

(i) Quantification of the consequences for the representative person(s) identified in the safety assessment.

4.147. Analysis of the actual conditions at the site and the conditions expected in the future involves a review of site meteorological, geological and hydrological conditions at the site that may influence facility operations or may play a part in transporting material or transferring energy that is released from the facility (Ref. [1]: Section 5).

4.148. Environmental transport of material should be calculated using qualified codes and using data derived from qualified codes, with account taken of meteorological and hydrological conditions at the site that would result in the highest exposure of the public.

4.149. The identification of workers and members of the public (the representative person) who may potentially be affected by an accident should involve a review of descriptions of the facility, demographic information and internal and external dose pathways (e.g. patterns of food consumption).

MANAGEMENT OF RADIOACTIVE WASTE

General

4.150. The general requirements for optimization of protection and safety for waste and effluent management and the formulation of a waste strategy are given in Ref. [2] with additional guidance in (Refs. [28], [29], [11], [12] and [30]), aspects which are particularly relevant or specific to reprocessing facilities are emphasized below

4.151. The requirements and recommendations on facility design from the relevant IAEA standards (Refs. [8], [11] and [12]) apply fully to the wastes streams (solid, liquid and, gaseous) and effluents resulting from the operation of reprocessing facilities and from their eventual decommissioning. However any associated waste treatment and conditioning processes and facilities, not integral to the reprocessing facility, are excluded from the scope of this guide (para. 1.8, Ref. [1]: Appendix IV).

4.152. For safety, environmental and economic reasons, an essential objective of radioactive waste management is to minimize the generation of radioactive waste (in both activity and volume) from reprocessing (Refs. [2]: requirement 8 and [27]: principle 7).

4.153. Due to the nature and diversity of the composition of spent fuel (structural parts, spectrum of fission products, activation products and actinides) and to the chemical processes involved, reprocessing facility commissioning, operation and eventual decommissioning result in wastes with a wide variation in type, radiological characteristics, chemical composition and quantity. The design of reprocessing facility should try, as far as practicable, to identify designated disposal routes for all wastes anticipated to be produced during the life cycle of the facility. Where necessary and practicable, process options should be chosen or design provision should be made to facilitate the disposal of such wastes by existing routes. The identification of disposal routes should account for not only the isotopic composition of the waste but also its chemical and physical characteristics (e.g. flammable, heat generating etc.).

4.154. The recovery and recycle of, especially contaminated, reagents and chemicals contributes significantly to the minimization of effluent arising and maximization of process efficiency, as does the decontamination for reuse or disposal of process equipment. The design of reprocessing plants should maximize such recovery, recycling and reuse to optimize protection of the public and the environment taking into account worker doses and technological constraints on the use of recycled materials. The design should include appropriate facilities for carrying out such activities and include consideration and minimization of the secondary waste produced in the overall waste strategy.

4.155. For identified, existing disposal routes etc., the reprocessing facility design should establish the characteristics for each. It should provide (or identify existing) equipment and facilities for characterizing, pretreating, treating, and transporting, as necessary, waste to the appropriate identified disposal route, interim storage or further waste treatment facility.

4.156. For wastes for which there is no identified disposal route the reprocessing facility design should take an integrated approach taking account of optimizing protection, local and national regulations and regulatory limits and the best available information for potential disposal routes in accordance with (Ref. [2]: paras. 1.6, 1.8 and requirements 4 and 6). As disposal is the final step of radioactive waste management, any interim waste processing techniques and procedures applied should provide waste forms and waste packages compatible with the anticipated waste acceptance requirements for disposal, attention should also be paid to the retrievability of wastes destined for interim storage.

4.157. The design should accommodate, as far as reasonable practicable, provisions for the rerouting of effluents and wastes to allow the future use of emerging technologies, improved knowledge and experience, or regulatory changes. This applies particularly to gaseous and volatile waste from reprocessing facilities which pose particular challenges in both capturing the waste and its disposal.

4.158. The design should incorporate, or have provision to provide incrementally, sufficient intermediate waste storage capacity for the facility lifetime including, as necessary decommissioning. This should include, in accordance with the safety assessment, the provision of “spare” capacity if necessary, as part of a defence in depth strategy, in case of e.g. a potential waste storage tank failure.

Management of gaseous and liquid discharges

4.159. The gaseous effluent activity discharge from a reprocessing facility should be reduced by process specific ventilation treatment systems, dehumidification (to protect filters) and filtration, which normally consists of a number of high efficiency particulate air (HEPA) filters in series.

4.160. Filter status and performance monitoring equipment should be installed including:

(a) Differential pressure gauges to identify the requirement for filter changes;

(b) Activity or gas concentration measurement devices and discharge flow measuring devices with continuous sampling;

(c) Test (aerosol) injection and sampling equipment (filter efficiency).

4.161. Liquid effluents to be discharged to the environment should be treated to reduce the discharge of radioactive materials and hazardous chemicals. The use of filters, ion-exchange beds or other technology should be considered where appropriate to optimize protection of the public and the environment. Analogous provisions to para. 4.160 should be made to allow the efficiency of these systems to be monitored.

4.162. The design and location of effluent discharge systems for a reprocessing facility should be chosen to maximize the dilution and dispersal of discharged effluents (Ref. [8]: para 4.3) and eliminate, as far as practicable, the discharge of particulates and insoluble liquid droplets which could compromise the intended dilution of radioactive effluents.

EMERGENCY PREPAREDNESS

4.163. A comprehensive hazard assessment in accordance with (Ref. [10]: para 3.7) should be performed in relation to reprocessing facilities prior to commissioning. The results of the hazard assessment should provide a basis for identifying the emergency preparedness category relevant to the facility and the on-site and, as relevant, off-site areas where protective actions and other response actions may be warranted in case of a nuclear or radiological emergency (Refs. [10] and [31]).

4.164. The operating organization of a reprocessing facility should develop on-site emergency arrangements including an emergency plan that takes into account the identified hazards associated with the facility and the potential consequences (Refs. [1]: para. 9.62 and [10]). The content, features and extent of the plan should be commensurate with the assessed hazards (paras. 4.144-4.150). The plan should be coordinated and integrated with those of off-site response organizations (Ref. [10]) and submitted to the regulator for approval.

4.165. The emergency plan should address and elaborate all the functions to be performed during an emergency response (Ref. [10]) as well as infrastructural elements (including training, drills and exercises) needed in support of these functions. Ref. [32] provides an outline of emergency plans that may be used in development of specific emergency plans for a reprocessing facility.

4.166. Reprocessing facility design should take into account the requirements for on-site infrastructure needed for an effective emergency response (including the emergency response facilities, suitable escape routes and logistical support) defined in (Ref. [10]) and elaborated in

(Ref. [31]). The design should also take account of the need for on- and off-site discharge and environmental monitoring in the event of accident (Refs. [6], [10] and [31]).

4.167. A reprocessing facility should capable to being brought to a safe and long-term stable state, including maintaining availability of the necessary facility status and monitoring information in and following abnormal and accident conditions (Refs. [1]: paras. 2.6, 6.22-6.24, 9.26, [10]: para. 4.39). As far as practicable the control room(s) should be designed and located so as to remain habitable during postulated emergencies (e.g. separate ventilation, low calculated dose in case of a criticality event etc.).

4.168. For events that may affect control rooms themselves, e.g. fire, externally generated hazardous chemical releases etc., the control of selected (on the basis of safety assessments) reprocessing facility safety functions should be provided by the use of appropriately located supplementary control rooms or alternative arrangements e.g. emergency control panels.

4.169. Infrastructure for off-site emergency preparedness (e.g. emergency centers) and response infrastructure (medical facilities) should be considered according to the reprocessing facility site characteristics and location (Refs. [1]: para. 9.63 and [10]: paras. 4.78-4.79).

5. CONSTRUCTION

5.1. General guidance on the construction and construction management of nuclear installations is given in (Ref. [33]).

5.2. A reprocessing facility project will involve large number of designers and contractors, over a considerable span of time, with the likelihood that design, construction and early commissioning will be taking place simultaneously in different facility sections. The operating organization should ensure that the relevant recommendations in (Ref. [33]) are put in place to ensure that adequate procedures to minimize potential problems and deviations from the design intent as design and construction proceeds, as part of a comprehensive integrated management system for control and communication.

5.3. The operating organization should consider minimizing the number of designers and contractors, as far as practicable, for consistency and standardization to support safe and effective operation and maintenance. Fewer external organizations (particularly multiple layers of sub-contractors) eases the process of control and communication between the operating organization and external designers and contractors. It also facilitates the transfer knowledge to the operating organization and allows the operating organization to benefit from their experience more effectively. This approach should be balanced by the need to use specialist designers for some design elements (e.g. criticality alarm systems) and the need to make, where justified (para. 2.8), safety and other improvements using proprietary designs and equipment and access to the necessary expertise for expert review. In all cases the integrated management system should include provisions to ensure that the necessary information is transferred to the operating organization.

5.4. As large chemical and mechanical facilities, the construction of reprocessing facilities should use modularized, standardized components as far as practical. In general this approach will allow better control of quality and testing before delivery to site. This practice should also aid commissioning, operation, maintenance and decommissioning.

5.5. As recommended in (Ref. [33]) equipment should be tested and proven at manufacturers' and/ or operators' sites before installation at the facility as far as possible. Testing and verification of specific SSCs important to safety should be performed before construction and installation when appropriate (e.g., verification of shielding efficiency, neutron decoupling devices, geometry for criticality purposes, welding) since this may not be possible or be limited after installation.

5.6. The operating organization should have effective processes in place to prevent the installation of counterfeit, fraudulent or suspect items, as well as non-conforming or sub-standard components. Such items or components can have an impact on safety even years after commissioning of the reprocessing facility (e.g. sub-standard stainless steel used for vessel construction).

5.7. The recommendations (Ref. [33]) relevant to the care of installed equipment should also be strictly followed particularly those with respect to the exclusion of foreign[49] material and the care of installed equipment.

Existing facilities

5.8. Major construction work or refurbishment at existing reprocessing facilities presents a wide range of potential hazards to operating and construction personnel, the public and the environment. Where major refurbishment or construction work is taking place, areas where construction works are in progress should be isolated from other reprocessing facility facilities in operation or already constructed, as far as reasonably practicable, to prevent negative interactions due to the ongoing activities and possible events in the either area, (Section 7: Control of Modifications and Ref. [33]).

[49]Adventitious items etc. which may cause breakdowns, blockages or flow restrictions, either in-situ or by displacement to a more restricted location (e.g. a pump, valve, ejector nozzle). They may also cause or promote corrosion by forming electrochemical cells, crevices or impeding heat transfer etc.

6. COMMISSIONING

6.1. This guide addresses only the commissioning of safety related aspects of reprocessing facilities. Performance demonstration and/ or process optimization, except in so far as supporting the safety case, SSCs important to safety or OLCs is a matter for the operating organization. However failure of a reprocessing facility to meet its design intent in both performance and process areas may have significant implications for safety if major process or facility modifications are necessary after active operations have started and this should be considered in specifying the scope of commissioning. For reprocessing facilities the verification process defined in the (Ref. [1]: Section 8), should be followed rigorously, due to the high hazard potential and complexity of the facilities. Where possible, lessons learned from the commissioning and operations of similar reprocessing facilities should be sought out and applied.

6.2. The commissioning process, established in (Ref. [1]: Section 8) should be completed prior to the operation stage. The commissioning should be carried out, as far as practical, as if the facility were fully operational in particular all the requirements for good operational practices, housekeeping, and controlled area barrier procedures should be increasing applied through commissioning.

6.3. The operating organization should make the best use of the commissioning stage to become completely familiar with the facility. It should also be opportunity to further develop a strong safety culture and positive behavioral attitudes throughout the entire organization. This approach should be applied considering the full range of operations:

(a) During campaigns of fuel reprocessing;

(b) Start-up and run-down periods;

(c) Work conducted between campaigns and emergency responses.

6.4. The head of the facility[50] (or equivalent role) has responsibility for safety throughout the reprocessing facility. To provide advice on commissioning, a safety committee[51] should be established at this stage (if one has not already been established). The safety committee should consider:

(a) Any changes or modifications required for, or as a result of, commissioning;

[50]The title of this person will vary in different Member States. It is the most senior manager with ultimate responsibility for decisions effecting safety at the facility. Where a facility has more than one safety committee they may advise managers with safety responsibilities for part of the facility but all should have access to the most senior manager in case of disagreement on safety issues.
[51]Or equivalent body.

(b) The results of commissioning;

(c) The facility safety case, and;

(d) Any modifications to the safety case as a result of commissioning.

6.5. Prior to commissioning the expected values for parameters important to safety to be measured during commissioning should be established. These values - along with any uncertainties in their determination and maximum and minimum allowable variations (as appropriate) - should determine the acceptability of commissioning results. Any measurements during commissioning which fall outside the acceptable range should be the subject of retest (and safety assessment, if necessary).

6.6. During commissioning, operational limits and normal values for safety significant parameters should be confirmed as established in the safety assessment and validated where they are set by the regulatory authority. In addition any limits (margins) required due to measurement precision or uncertainties and any acceptable variation of values (range) due to facility transients or other small perturbations should also be validated and/ or confirmed. Considerations in this area should include changing from one facility state to another (e.g. at the start and end of a campaign). Such limits and values may include the type, quantity and state of the fuel to be accepted (including such factors as the 'burn up' and duration expired since the fuel was discharged from the reactor). These parameters should be embedded in any instructions related to safety, including emergency instructions.

6.7. Where necessary (in accordance with a graded approach[52]) commissioning tests should be repeated a sufficient number of times under varying conditions, to verify their reproducibility. Particular attention should be applied to the detection, control and exclusion of foreign material, examples of which include spent welding rods, waste building materials and general debris. This type of material may be inadvertently introduced during construction and one of the objectives of the commissioning process is to confirm that all such foreign materials have been removed, whilst enhancing controls to limit further introduction.

6.8. Commissioning typically requires the use of temporary works (such as utility supplies, supports for items of plant and access openings in building structures) or devices (temporary electrical or instrument supplies and connections to allow the testing of items isolation or the injection of test signals). The operating organization should establish suitable controls to

[52]In commissioning "grading" should be applied in in accordance with the potential hazard or risk of the item being commissioned (or temporarily modified) failing to deliver its safety function on demand at any time in its anticipated operational (qualified) life.

control the use of temporary works and devices (including the use of the modification process as required). These controls should include establishing a process for registering all such works and devices, appointing a responsible person to oversee the application of the controls, a process to approve the introduction of such works and devices and a process to verify that all such works and devices have either been removed at the end of commissioning or are properly approved to remain in place (as a modification) and included in the safety case for operations.

6.9. Commissioning also often requires the ‘temporary’ modification of equipment; the removal or reduction of protective ‘barriers’ (physical and administrative); the bypassing of trip and control systems including those associated with SSCs important to safety and the use of procedures and training of personnel to support these non-routine activities. The operating organization should introduce controls as described in para. 6.8 to control these activities and all such procedures should be controlled under the same integrated management system as all operational procedures. Particular care should be taken that all ‘temporary’ or ‘commissioning procedures’ are withdrawn as soon no longer required and that none remain in the facility at the end of commissioning.

6.10. Where inactive simulates or temporary reagent supplies are introduced for commissioning purposes, care should be taken that they have identical characteristics (for achieving the commissioning purpose) to material to be used during operations as far as practicable. If not identical, before approval for use, the effect of any differences should be analyzed to determine the potential effects of any constituents or contaminants which might affect the integrity of the facility over its lifetime. This analysis should also identify any effects on the validity of commissioning results arising from these differences. Similar controls should be introduced to ensure that readily available supplies are not substituted for the correct facility feeds e.g. normal, potable water for demineralized water unless a full evaluation of the potential effects has been made.

6.11. Some stages of commissioning may require regulatory approval in accordance with national regulations, both prior to starting and at completion. The regulatory body should define hold points and witness points commensurate with the complexity and potential hazard of the activity and facility, as appropriate, to ensure proper inspection during commissioning. The purpose of these hold points should be principally to verify compliance with regulatory requirements and license conditions. The operating organization should establish and maintain effective communications with the regulatory body, so as to ensure full understanding of the regulatory requirements and to maintain compliance with those requirements.

6.12. The commissioning programme may vary according to Member States' practices. Nevertheless, the following activities should be performed, as a minimum:

(a) Confirmation of the shielding and containment/ confinement performance;

(b) Demonstration of criticality detection and alarm system availability;

(c) Emergency drills and exercises to confirm that emergency plans and arrangements are adequate and deliverable;

(d) Demonstrating and confirming the satisfactory training and assessment of personnel;

(e) Demonstration of the other detection and alarm systems (e.g. fire) availability.

6.13. Clear communications between management, supervisors and workers and between and within different shifts of workers under normal and abnormal circumstances and with the relevant emergency services is a vital component of overall facility safety. Commissioning provides the opportunity, not only to commission and exercise these lines of communication and associated equipment, but also to become familiar with their use. The adoption and training of personnel in use of the a range of human performance techniques to aid communication is strongly recommended (these should include: International Phonetic Alphabet; three-way communications; pre-job briefing; post-job review; questioning attitude, and; peer review). Commissioning should also be used to develop a standard format(s) for log books and shift handover procedures and to train and assess personnel in their use.

COMMISSIONING PROGRAMME

Commissioning by facility section

6.14. Because of the complexity and size of reprocessing facilities it may be appropriate to commission the facility by sections. If this is the case, the operating organization should ensure that sections already commissioned are suitably maintained and that the knowledge and experience gained during commissioning of each section is retained.

6.15. Reassurance or verification testing of (commissioned) SSCs important to safety should also be included in the commissioning programme, in accordance with the opportunity or risk of their being altered in any way during subsequent construction or installation, and the extent of testing possible.

6.16. The safety committee should provide advice on the safety of arrangements for controlling such section by section commissioning and the arrangements for communications between the commissioning team and other groups in the facility. The Committee should also advise on whether any safety components tested earlier in the programme require reassurance testing prior to the next stage of commissioning (as a check on arrangements in 6.14). This may also apply to recently commissioned sections if there is a significant delay in proceeding to the next stage of commissioning due to e.g. the need for modifications or safety case revision.

6.17. Consideration should be given to the need to sequence the commissioning so that facilities required to support the section being commissioned are able to provide such support at the appropriate time (or suitable alternative arrangements are made). This should involve considerations of “upstream[53]” facilities (including supplies of utilities such as electrical power, steam, reagents, cooling water and compressed air), “downstream[54]” facilities (including waste treatment, aqueous and aerial discharges, environmental monitoring) and “support[55]” facilities (including automatic sampling benches, sample transfer network, analytical laboratories). The safety committee should provide advice on the safety of arrangements for any such sequencing particularly with respect to any environmental issues if downstream facilities are not available.

COMMISSIONING STAGES

6.18. For a reprocessing facility, the commissioning should be divided into a number of distinct stages, according to the objectives to be achieved. Typically, this may involve four stages:

Stage 1: Construction testing:

i. For some SSCs important to safety, where verification of compliance may not be possible after construction and installation is complete, testing should take place during construction and installation. This testing should be observed by representative(s) of the operating organization and the outcome should be reported with the first stage of commissioning, Examples of typical items include seismic(ally qualified) supports or

[53]Parts of the fuel cycle facility or site that provide feeds (reagent, utilities etc.) to the section being commissioned
[54]Parts of the fuel cycle facility or site that accept products or waste from the section being commissioned
[55]Parts of the facility ancillary to the section being commissioned but which are required to allow or monitor its operation

restraints, wall (shielding/ barrier) homogeneity control, pipe welding control, vessel construction control and parameters relevant to various passive SSCs important to safety;

ii. When the direct testing of safety functions is not practically possible, alternative methods of adequately demonstrating their performance should be made in agreement with the national authority, before later stages of commissioning commence. These methods may include the verification and audit of materials; supplier's training records etc. It should be noted that this places further emphasis on the importance of an effective integrated management system;

iii. Testing of other SSCs may be performed at this stage, in accordance with national requirements.

iv. Further recommendations are given in relevant sections of (Ref. [33]).

Stage 2: Inactive or 'cold processing' commissioning:

i. In this stage, the facility's systems are systematically tested, both individual items of equipment and the systems in their entirety. As much verification and testing as practicable should be carried out because of the relative ease of taking corrective actions in this stage, unimpeded by the introduction of radioactive material;

ii. In this stage, operators should take the opportunity to further develop and finalize the operational documents and to learn the details of the systems. Such operational documents should include those related to the operation and maintenance of the facility and those relevant to any anticipated operational occurrences, including emergencies;

iii. The completion of inactive commissioning also provides the last opportunity of examine the facility under inactive conditions. This is a valuable opportunity to simulate transients or the complete failure of support systems, e.g., ventilation, electrical power, steam, cooling water and compressed air. Such tests and simulations should be used to improve the responses available by comparing the outcomes and responses to those identified in calculations of simulated events;

iv. This is also a final opportunity to ensure that all required maintenance can be completed, once the facility is active. This is particularly applicable to all hot cells and items of equipment which can only be maintained by remote means. As maintenance is known to be a major contributor to worker doses in reprocessing facilities the opportunity should also be taken to verify active maintenance procedures and controls, optimize dose control arrangements and identify any aids required to simplify or make maintenance quicker;

v. Reprocessing facilities are complex facilities and, to avoid any potential error the clear, consistent and unambiguous labelling of rooms, pieces of equipment, systems, components, cables, pipes etc. consistent with training materials and operational documentation should be checked and finalized during inactive commissioning;

vi. Particular attention should also be paid to confirming that all physical connections have been made as expected. This should involve confirmation that all process lines, service connections and utility lines start and end in the expected places and that they follow the expected routes, as defined in the design documentation. Exceptions which may occur should be assessed for their safety consequences and should then either be corrected or accepted, with suitable approvals and updating of documentation.

Stage 3: Trace active or uranium commissioning:

i. Natural or depleted uranium should be used[56] in this stage, to avoid criticality risks, to minimize doses due to occupational exposure and to limit possible needs for decontamination. This stage provides the opportunity to initiate the control regimes that will be necessary during active commissioning, when fission products and fissile materials are introduced. Safety tests performed during this commissioning period should mainly be devoted to confinement checking. This should include: (i) checking for airborne radioactive material; (ii) smear checks on surfaces; and (iii) checking for gaseous discharges and liquid releases. Unexpected accumulations of material should also be checked for;

ii. For the timely protection of workers, all local and personnel dosimetry should be operational with supporting management arrangement when radioactive material is introduced;

iii. This stage should also be used to provide some measurable verification of items which were previously only calculated theoretically (particularly discharges). The use of tracers[57] should also be considered to enhance or allow such verification;

[56]In some Member States this may require regulatory approval.
[57] Tracers - Small quantities of very low active (or inactive) materials that mimic the behaviour of the operational material to determine process parameters

iv. Emergency arrangements (on- and off-site) should be in place including: procedures; training; sufficient numbers of trained personnel; emergency drills and exercises; and; demonstration of capability on- and off-site e.g. simulated, large scale public warning and evacuation exercises, prior to active commissioning (Ref. [10]).

Stage 4: Active or 'hot processing' commissioning:

i. Regulatory permission to operate the facility is generally issued to the operating organization before the start of this stage. In this case, 'hot processing', commissioning will be performed under the safety procedures and organization of the operating organization as for a fully operational facility;

ii. In any event, during active commissioning, and as far as defined and applicable, the safety requirements valid for the operation stage of the facility should be applied in full, unless a safety assessment is made to suspend or modify the regime and any required approval by the regulatory body has been granted;

iii. The full requirements of the operational radiation protection programme should also be implemented (if not already in palace) including personnel monitoring;

iv. Compared to inactive commissioning, active commissioning requires major changes in the facility control arrangements and staff skills e.g. related to confinement, criticality, cooling and radiation. The management should ensure that both the facility and the workforce are fully ready for the change to active commissioning before it is implemented. For the workforce, the safety culture should be enhanced at this stage so as to further contribute to safe operation;

v. This stage enables the process to be progressively brought into full operation by steadily increasing both the quantity and activity of the spent fuel fed into the facility, as far as such an incremental approach is practicable;

vi. This stage provides further measurable verification of items which were previously only calculated (particularly for dose rates to the workforce and environmental discharges). The feedback from such measurable verification should be used to inform corrective actions accordingly and to update the assumptions in any estimates and calculations;

COMMISSIONING REPORT[58]

6.19. The requirements for a commissioning report are established in (Ref. [1]: Appendix IV: paras. IV.55-IV.57).

6.20. Commissioning reports should be prepared for each stage of commissioning. The objective of the commissioning report is to provide a comprehensive record of the commissioning stage completed and to provide evidence of both the facility's and the operating organization's readiness to proceed safely to the next stage of commissioning.

6.21. The commissioning report should describe the safety commissioning tests to demonstrate the facility's compliance with the design, the design intent and the safety assessment or by summarizing the necessary corrective actions. Such corrective actions may include making changes to the safety case or adding or changing safety features or work practices. All such changes should be treated as modifications. If commissioning tests are "brought forward" from subsequent stages to the reported stage or "put back" to a subsequent stage this should also be described and justified in the commissioning report for the reported stage.

6.22. The commissioning report should include a review of the results of facility radiation and contamination surveys, sampling and analytical measurements, particularly those related to waste, effluent and environmental discharges.

6.23. To demonstrate the operating organization readiness the commissioning report should also describe:

(a) The numbers, specialties, training, development and assessment of the facility staff including managers;
(b) The development of the facility integrated management system and the necessary procedures and instructions;
(c) Internal and external dose data by work group summarizing any dose investigation carried out.
(d) Audits and summaries of operating organization and operator feedback on facility activities such as:
  - The organization of activities and tasks;
  - Briefings, procedures, work methods, ergonomics and human factors;
  - Equipment and tools;

[58] In some member State the format and content of commissioning reports may be defined by the regulatory body.

- Support activities (radiation surveys, decontamination, use of personal protective equipment, and responses to issues arising during tasks etc.;
- Human factors and ergonomics reviews carried out on selected activities;
- Emergency drills and exercises;
- Safety culture.

6.24. Any incidents or events that have occurred during the commissioning stage should also be summarized in the commissioning report and any learning from experience identified. Consideration should be given to using FINAS guidelines (Ref. [34]) to categorize and analyze events.

6.25. Detailed findings from commissioning, including the results of all tests, calibrations and inspections, may be held in supporting documents but the report should list all SSCs important to safety and OLCs commissioned and tested (including surveillance and maintenance activities). In addition any safety assessment assumptions or data which had to be confirmed during plant commissioning should be reported.

6.26. The commissioning report should be reviewed by the safety committee and by the facility's senior managers in accordance with the integrated management system and approved by the senior facility manager before submission to the regulatory body as required by national regulations.

7. OPERATION

ORGANIZATION OF REPROCESSING FACILITIES

7.1. Given the large scale and complexity of reprocessing facilities, there is a particular need for rigorous control, planning and co-ordination of the work to be undertaken in the facility, whether for operations, routine maintenance, non-routine maintenance – such as may be conducted between campaigns – and projects (modifications). The organization of the reprocessing facility should provide for this need, typically through a consistent and systematic method of approving, planning and coordinating such work (within the integrated management system). Provision of accurate and timely information to all those involved should be a further characteristic of such systems. (Ref. [1]: Section 4) defines the requirements for the organization of reprocessing facilities.

7.2. The requirements for staff training, minimum staffing etc. are given in (Ref. [1]: paras. 9.3-9.14, 9.52, 9.53 and Appendix IV: para. IV.67).

7.3. Suitable arrangements should be made to gather, assess and propagate any lessons learned during the Commissioning stage of the facility and, continually, during the Operations stage. Similar arrangements should be put in place to adopt lessons learned from other organizations which operate reprocessing facilities or other hazardous facilities (e.g. chemical plants).

7.4. Round the clock continuity of organization should be provided in order to ensure that the appropriate authority is present on the site, with appropriate access to suitably qualified and experienced personnel (whether on-site or available to be called in, commensurate with the grace time for manual intervention). This should include operations, engineering, radiation protection, emergency management and other personnel as necessary.

7.5. The operating organization should:

(a) Establish and maintain appropriate interfaces (field implementation of communication procedures) between:

- Shift and day operations staff (especially maintenance and radiation protection personnel) within the reprocessing facility (reprocessing facilities typically operate on a 24 hours/ 365 days a year basis even when not processing material);
- The reprocessing facility and other site facilities particularly waste treatment facilities and utility supplies that are closely coupled to the reprocessing facility. For

example: to ensure the effective management of the timing, quality (content) and quantity of transfers, as well as confirming the availability of receipt storage capacity or to ensure that the facility operators have the latest information on the continuity of utility supplies etc.;

- The reprocessing facility and the on-site radioactive material transport department, if any;
- The reprocessing facility and any organization engaged to make modifications to the facility (e.g., projects to improve throughput or to provide additional capacity);
- The reprocessing facility and wider emergency services involved in the reprocessing facility emergency response functions (Ref. [1]: paras. 9.62-9.67);

(b) Review periodically the operational management structure, training, experience and expertise of reprocessing facility staff (individually and collectively) to ensure that, as far as reasonably foreseeable, sufficient knowledge and experience is available at all times, and in reasonably foreseeable circumstances (e.g., staff absences). The requirement in Ref. [1]: para 9.19 for control of organizational change should be extended to include key safety personnel and other posts based upon this analysis.

7.6. The safety committee(s) in reprocessing facilities, as defined in (Ref. [1]: para. 9.15) should be developed from that established for commissioning. Its function should be specified in the integrated management system, it should be adequately staffed and it should include diverse expertise and appropriate independence.

QUALIFICATION AND TRAINING OF PERSONNEL

7.7. The safety requirements for the qualification and training of facility personnel are established in (Ref. [1]: paras. 9.8-9.13). Further guidance can be found in (Ref. [35]: paras. 4.6-4.25).

7.8. The safety risks and hazards for operators, maintenance staff and other personnel such as the decontamination team should be carefully considered when establishing the training programme. In particular, all staff handling fissile material including waste containing fissile material should have a sound understanding of criticality safety and the relevant physical phenomena.

7.9. The need for training all levels of management should be considered so that personnel involved in management and operation of the facility fully understand the complexity and the range of hazards in reprocessing facilities at a level of detail consistent with their level of responsibility.

7.10. Comprehensive training should cover both automatic and manual operations. Dedicated training facilities should be established as necessary with the training emphasis activities according to their potential safety consequences.

7.11. For manual activities, training should include but is not limited to:

(a) Use of master-slave manipulators and other remote equipment (HA);

(b) Maintenance, clean down and projects activities which may involve intervention in the active parts of the facility and/ or changes to facility configuration;

(c) Sampling of materials from the facility;

(d) Work within gloveboxes, glovebox glove changes, glovebox "posting[59]" activities etc.;

(e) Decontamination, preparation of work areas, erection and dismantling of temporary enclosures and waste handling;

(f) Barrier procedures, self-monitoring and the use of personal protective equipment

(g) Responses to be taken in situations which are outside normal (including emergency response actions).

7.12. For automatic modes of operation training should include but is not limited to:

(a) Comprehensive control room training;

(b) Alarm handling;

(c) Alertness to the possibility of errors in automatic and remote system;

(d) Alertness to unexpected changes (or lack of changes) in key parameters;

(e) The particular differences in operation which may occur during the ramp-up and ramp-down of a campaign;

(f) Responses to be taken in situations which are outside normal operations (including emergency response actions).

[59]The transfer of items in to, out of and between gloveboxes.

FACILITY OPERATION

Operating documentation

7.13. For reprocessing facilities the requirements for operating instructions established in (Ref. [1]: paras. 9.21-9.27) should be strictly adhered to.

7.14. In order to ensure that, under normal circumstances, the reprocessing facility operates well within its OLCs, a set of operational sub-limits should be defined at lower levels by the operating organization. The resulting margins should be derived from the design considerations and from experience of operating the facility (both during commissioning and in operations) to maximize safety margin whilst minimizing breaches of the sub-limits.

7.15. Authority to make operating decisions should be assigned to suitable management levels in accordance with the OLCs, the operational sub-limits and the potential safety implications of the decision. The integrated management system should specify the authority and responsibilities of each management level and, where necessary individual post-holders. If a sub-limit or an OLC is exceeded, the appropriate level of management should be informed (Ref. [1]: Appendix IV: para. IV.63). Where immediate decisions or responses are required for safety reasons, the circumstances should be defined, as far as practicable, in procedures following guidance provided by the integrated management system and the appropriate shift or day staff trained and authorized to make the required decisions.

7.16. Any excursion outside the sets of OLCs sub-limits should be adequately investigated by the operational organization and the lessons learned should be applied to prevent a recurrence. As required by national regulations the regulator should be notified of such excursions and any immediate actions taken, in a timely manner and kept informed of the subsequent investigations and their outcome.

7.17. Operating documents should be prepared which list all the limits and conditions, and define the procedures to restore the process to within the limits and sub-limits (Ref. [1]: paras. 9.22 and 9.26). Annex II gives examples of parameters which can be used for defining OLCs.

7.18. All limits and conditions should be clearly identified in procedures and in directly relevant procedural ‘steps’. In particular procedures and procedural steps relevant to OLC’s should be highlighted in a consistent manner. Provision should be made in the integrated management system to ensure that such identification and highlighting is carried out comprehensively and consistently. Consideration should be given to classifying procedures in accordance with their safety significance (a graded approach) including those for controlling and minimizing environmental discharges and radiological or chemical hazards to the workers, the environment and the public. Such classifications schemes should be taken into account when setting priorities for: peer review; routine review; training; re-training; assessment, and; in the internal[60] reporting of minor events and "near-misses".

7.19. Operating procedures should be developed to directly control process operations. To maximize the benefit of the reprocessing facilities robust design, these should be: user-friendly; accurate; cover all operational states, including ramp-up and ramp-down. Procedures for non-operational, abnormal operational and accident conditions should also be in place. Operators should be fully trained and assessed, using simulations or exercises where appropriate, in these procedures.

7.20. The documents prepared should also systematically link to the safety case and OLCs, either directly or through interface documents, to ensure that safety requirements are comprehensively implemented in the instructions.

Specific provisions

7.21. The development and maintenance of a feed programme (Ref. [1]: para IV.58) is important to safety in a reprocessing facility. The operating organization should establish organizational responsibility for the feed programme, clear procedures which specify how the feed programme should be managed, provision of independent verification methods, etc.

7.22. Reprocessing facilities are generally designed to accept a specific range of fuel types, with given ranges of burn-up etc. The feed programme should take into account fuel parameters (e.g. irradiation data, initial enrichment, duration of cooling following discharge from the reactor), and facility safety constraints.

7.23. Reprocessing facility process control generally relies on a combination of instrument readings and analytical data from samples. The analytical activities should be managed and operated so as to minimize doses to workers. The waste resulting from these activities should be managed according to established procedures. Analytical instruments and methods should be used under an integrated management system and subject to suitable calibration and verification. Decisions made on the basis of sample analysis should take proper account of the accuracy of the sampling process, analytical methods used and, where relevant, the delay between sampling and result being available.

[60]Within or to the operating organization.

7.24. Reprocessing facility operation is often divided into campaigns (driven by operational, commercial or safety constraints) and inter-campaigns period (for modifications to equipment, performing maintenance and safeguards purposes). Maintenance is safer during these period but increased interventions result in higher contamination and dose risks. Intensive maintenance periods often require the use of less experienced personnel. The operating organization should take action to address the specific risks of intensive maintenance during inter-campaigns periods, which may include specific training, the allocation of more experienced workers to teams of less experienced personnel, additional supervision of work etc.

7.25. The integrated management system should include provision for a program of facility internal audits whose purpose, amongst others, is to periodically confirm that the facility is being operated in accordance with operating procedures (including its OLCs, safety case and license conditions). Suitably qualified and experienced persons should carry out such audits and consideration should be given to using personnel independent of the direct management chain. See also (Ref. [1]: para. 9.71).

7.26. Operator, including senior management, walk-arounds should be specified and programmed with the aim of ensuring that, as far as practicable, all areas of the facility are subject to regular surveillance with particular attention paid to the recording, evaluating and reporting abnormal conditions. This programme of walk-arounds should include a suitable level of independence (for example, including personnel from other facilities on- or off-site). Examples of conditions to be observed should include:

(a) Local instrument readings and visual indications relevant to liquid levels or leaks including sump levels, containment and ventilation failure;

(b) Safety checks having been completed within the specified range of dates (e.g., on access equipment[61], lifting equipment, fire extinguishers and electrical equipment);

(c) Conditions at access points to supervised and controlled areas;

(d) Number and condition of temporarily restricted access (radiation or contamination) areas;

(e) Availability and functioning of personnel contamination monitors;

(f) Accumulation of waste;

(g) Proper storage of materials and equipment;

[61] Ladders, scaffolding, access platforms and powered access equipment (hydraulic platforms) etc.

(h) Ready availability of emergency equipment;

7.27. After the batch transfer of process liquids, staff should confirm, as far as practicable, that the volume transferred from the sending vessel corresponds to the volume received (para 4.46 and 4.129).

Exclusion of foreign material

7.28. Suitable controls should be established to ensure, as far as is reasonably practicable, that foreign material is excluded from the process. These controls should build upon those developed during commissioning and are particularly relevant to maintenance activities and to the supply and delivery of process reagents.

Maintenance, calibration, periodic testing and inspection

Maintenance, (including periodic testing and inspection)

7.29. As reprocessing facilities are large and complex facilities, maintenance should be coordinated and managed to ensure that unanticipated interactions, either with operation or between two maintenance activities will not result in negative safety consequences.

7.30. The integrated management system should ensure that all maintenance activities are reviewed for evidence of reliability or performance issues. Higher risk, complex or extended maintenance tasks should be regularly reviewed to benefit from lessons learned and to implement continual optimization of doses and environmental discharges. The safety committee should routinely review the reports generated for the most significant SSCs important to safety and any other significant findings with consideration of their implications on facility safety.

7.31. Prior to any maintenance activities, consideration should be given to radiological checks of the work areas, the need for decontamination and the need for periodic surveys during the maintenance period and before return to service.

7.32. Maintenance (and any preparatory operations) which involves temporary changes to confinement and/ or shielding should always be thoroughly analyzed beforehand, including any temporary or transient stages, to ensure that contamination and doses are acceptable, and appropriate compensatory measures, where possible, and monitoring requirements are defined (paras. 7.70-7.71).

7.33. During maintenance, isolation between the equipment being maintained and plant in operation or other facilities with radioactive inventory should be ensured as far as reasonably practicable.

7.34. Hands-on maintenance should be performed after equipment drain down and wash-out/ decontamination, as far as practicable, with the objective that active materials are removed and radiation and contamination risks reduced.

7.35. For maintenance tasks with high anticipated doses or dose risk, consideration should be given to providing mock-up and/ or electronic models of the area, or other training methods, to develop task familiarity, develop operator aids and allow work techniques to be optimized, including the development of "stand-off" tools where practicable.

Calibration

7.36. The accurate and timely calibration of equipment is important to the safe operation of a reprocessing facility. Calibration procedures and standards should cover equipment used by facilities and by organizations which support the reprocessing facility, such as analytical laboratories, suppliers of radiation protection equipment, reagent suppliers etc. The operating organization should satisfy itself that such externally supplied or located equipment is properly calibrated at all times. Where necessary tracability to national or international standards should be provided.

7.37. The frequency of calibration and periodic testing of instrumentation important to safety i.e. part of the SSCs important to safety (including those related to the analytical laboratories) should be defined (from the safety analyses) in the OLCs.

MODIFICATION CONTROL

7.38. The integrated management system for a reprocessing facility should include a standard process for all modifications (Ref. [1]: para. 9.35). The process should use a modification control form or equivalent management tool. The facility should prepare procedural guidelines and provide training to ensure that responsible personnel have the necessary training and authority to ensure that projects are carefully considered for potential hazards during installation (e.g. non-routine crane lifts), commissioning and operation and modification control forms raised and the modification safety assessed as necessary. Conservative decision making should be used when making decisions about modifications.

7.39. The modification control form should contain (or have appended) a description of what the modification is and why it is being made. The modification control form should be used to identify all the aspects of safety that may be affected by the modification (including procedures and emergency management) and to demonstrate that adequate and sufficient safety provisions are in place to control the potential hazards both during and after the modification with any temporary or transient stages clearly identified and assessed. The modification control form should also identify any (potential) need for a license revision/ renewal by the regulatory body.

7.40. Modification control forms should be scrutinized by and be subject to approval by qualified and experienced persons to verify that the arguments used to demonstrate safety are suitably robust. This should be considered particularly important if the modification could have an effect on doses to the workers, the public, environment or criticality safety. The depth of the safety arguments and the degree of scrutiny to which they are subjected should be commensurate with the safety significance (potential hazard) of the modification (graded approach). Review of modification control forms should be by the safety committee (or an equivalent committee) with suitable expertise and the capability for independent examination of the proposal and suitable record keeping of their recommendations. The head of the reprocessing facility should authorize specific personnel the responsibility for the approval and control of modifications. Such authorizations should be regularly reviewed and withdrawn of continued as appropriate.

7.41. The modification control form should also specify which documentation and training will need to be updated as a result of the modification (e.g. training plans, specifications, safety assessment, notes, drawings, engineering flow diagrams, process instrumentation diagrams and operating procedures).

7.42. Procedures for the control of documentation and training should be put in place to ensure that, where necessary (as specified in the modification control form), training has been given and assessed and documentation changed before the modification is commissioned and that all (the remaining) documentation and training requirements changes are completed within a reasonable time period following the modification.

7.43. The modification control form should specify the functional checks (commissioning) that are required before the modified system may be declared fully operational again.

7.44. The modifications made to a facility should be reviewed on a regular basis to ensure that the combined effects of a number of modifications with minor safety significance do not have unforeseen effects on the overall safety of the facility. This should be part of (or additional to) a periodic safety review or equivalent process.

7.45. No modifications affecting OLCs or SSCs important to safety should be put into operation unless all the requirements specified on the modification control form are confirmed to be in place and the required number of operators are have been trained in their use, including their maintenance etc.

OPERATIONAL CRITICALITY SAFETY

7.46. The requirements for criticality safety in a reprocessing facility are established in (Ref. [1]: paras. 9.49-9.50 and Appendix IV: paras. IV.66-IV.76) and general recommendations are made in (Ref. [21]). The procedures and measures for controlling criticality hazards should be strictly applied.

7.47. Operational aspects of the control of criticality hazards in reprocessing facilities should include:

(a) Rigidly following the pre-determined feed programme;

(b) Watchfulness for unexpected changes in conditions that could increase the risk of a criticality accident;

(c) Training of personnel in the factors affecting criticality as well as in facility procedures related to the avoidance and control of criticality;

(d) Management of moderating materials, particularly hydrogenated materials;

(e) Management of mass in transfers of fissile materials, where mass control is used;

(f) Reliable methods for detecting the onset of any of the deviations from ‘normal’ conditions, particularly those parameters relied upon for the avoidance of criticality;

(g) Periodic calibration or testing of systems for the control of criticality hazards;

(h) Evacuation drills to prepare for the occurrence of a criticality and/ or the actuation of a criticality accident alarm.

7.48. For each reprocessing campaign, prior to starting feed to the dissolver, the settings of criticality control instrument alarm parameters should be checked and changed if necessary based on the feed programme of the campaign. The feed programme should be supported by appropriate fuel monitoring instruments, as far as possible and administrative controls, to confirm that the fuel characteristics match the feed programme. All software used to support feed programme calculations should be suitably validated and verified.

7.49. When burn up credit is used in the criticality safety analysis, appropriate burn-up measurements are required and care should be taken to allow for the associated measurement uncertainties.

7.50. In chemical cycles, particular care should be given to the control and monitoring of those stages of the process where fissile materials are concentrated or may be concentrated (e.g. by evaporation, liquid/liquid extraction, or other means such as precipitation/ crystallization). A specific concern for reprocessing facilities is Pu-polymer creation which can arise from hydrolysis in high Pu and low acid concentration condition in solution. It can potentially lead to precipitation, local high Pu concentrations (in contactor stages) resulting in the retention of Pu in the contactor and/ or Pu loss to U product or waste streams with criticality and/ or internal dose implications.

7.51. If identified by the safety analysis, the following issues should be addressed in facility procedures:

(a) Isolation, often by disconnection and/ or suitable locking devices, of water or other reagent wash lines;

(b) Normal and allowable fissile concentration(s);

(c) The feed setting and control of reagents (solvent and aqueous) flows;

(d) The conditioning of fissile solutions (heating/ cooling etc.) according to the facility flow sheet (technical basis).

These requirements should be supported by appropriate alarm settings on the instruments for monitoring the feeds and solutions.

7.52. Where there are any uncertainties in the characteristics of fissile materials, conservative values should be used for parameters such as fissile content and isotopic composition. Particular issues may be encountered when carrying out maintenance work and during inter-campaign periods when material or residues from different campaigns may become mixed.

7.53. The requirements for criticality avoidance and conservative decision making may require, in some circumstances (e.g. loss of reagent feed) that the transfer of fissile material within a separation process has to be brought to a sudden stop in accordance with the OLCs, whilst the situation is assessed and recovery planned. As far as possible all such situations should have been anticipated, assessed and included within appropriate procedures including step by step “recovery” procedures to return the facility to a safe and stable state. Nevertheless criticality staff should be involved in all such decisions and should subsequently analyze the event for feedback and learning.

RADIATION PROTECTION[62]

7.54. The operating organization should have a policy to optimize internal and external exposure including the requirement to ensure doses are below all national dose limits and within any dose constraints set by the operating organization. It should include the minimization of exposure to sources of radiation by all available means and administrative arrangements including the use of time and distance during operations and maintenance activities.

7.55. The operational radiation protection program (ORPP) should take into account the large inventories, the variety of sources, the complexity and size of reprocessing facilities.

7.56. The ORPP should include provisions for detecting changes in the radiation status (e.g. hot spots, slow incremental increases or reductions of radiation/ contamination levels) of equipment (e.g. pipe, vessel, drip-trays, filters), rooms (e.g. contaminated deposits, increase of airborne activity), or from effluent or environment monitoring. It should also ensure prompt definition of the problem and the identification and implementation of timely corrective and/ or mitigation actions.

7.57. The radiological protection surveillance network inside and outside the reprocessing facility buildings should be complemented by regular, routine surveys by trained personnel. These should be organized to provide, as far as practicable, regular surveillance monitoring of the whole reprocessing facility site. Particular attention should be paid to the recording, labelling/ posting where necessary, evaluating and reporting abnormal radiation level or abnormal situations. The frequency of surveillance should be related to the relative risk of radiation or contamination in the individual survey areas. Consideration should be given by the radiation protection personnel to assigning a frequency of survey to each facility area based upon easily identified boundaries. The use of photographs or drawings of the area/ equipment should be considered to report the survey findings.

[62]The requirements for radiation protection for operation are given in (Refs. [1]: paras. 9.36-9.45, Appendix IV: IV.77-IV.78, [6] and [7]).

7.58. Radiation protection personnel should be part of the decision making process to apply the dose optimization requirement (e.g. for the early detection and mitigation of hot spots), and for proper housekeeping (e.g. waste segregation, packaging and removal).

Protection against exposure

7.59. During operation (including maintenance) protection against internal and/ or external exposure should be provided to optimize dose. Limitation of exposure time and use of additional shielding and remote operations and the use of mock-ups should be considered, as necessary, for personnel training and optimization of complex or high dose tasks to minimize exposure times and exposure rates and minimize risks.

7.60. A high standard of housekeeping should be maintained within the facility. Cleaning techniques which do not cause airborne contamination should be used. Waste arising from maintenance or similar interventions should be segregated by type (i.e. disposal route), collected and directed to interim storage or disposal route as appropriate, in a timely manner[63].

7.61. Regular radiation and contamination surveys of facility areas and equipment should be carried out to confirm the adequacy of facility containment and cleaning programmes. Prompt investigations should be carried out following increased radiation or contamination levels. The objective should be to ensure that all areas have radiation and contamination levels which optimize operator protection, balancing the radiation hazards and risk from working in an area "as it is" with that of reducing those risks by e.g. decontamination, shielding etc.

7.62. To aid operators in assessing the risk of any task and in assigning the frequency of routine (contamination/ radiation) surveys (rounds), consideration should be given to assigning facility areas a contamination and/ or radiation classification. These should be based initially on the classifications used in the facility design and developed on advice from radiation protection staff as necessary. The areas and the boundaries between them should be regularly checked and adjusted to match current conditions or other action taken (as para. 7.61). Continuous air monitoring should be carried out to alert facility operators if airborne contamination levels exceed predetermined action levels. The action levels should be set as near as possible to the level normal for the area. Mobile air samplers should be used near contamination sources and at the boundaries of contaminated areas as necessary, e.g. during

[63]Allowing waste (including suspect or radioactive and contaminated waste) to accumulate in the work area contributes to worker doses both directly as sources and indirectly by impeding work progress, delays and complicates the identification of (new) sources of contamination, particularly airborne contamination, and can lead to the need to increase radioactivity survey and decontamination action levels (increase in "background" levels).

maintenance or other operations, when there is a risk of contamination spreading. Prompt investigation should be carried out following high airborne contamination readings.

7.63. Newly contaminated areas should be delineated with proper posting and barriers provided where required by facility procedures. Temporary confinement should be used to accommodate the higher levels of contamination (e.g. temporary enclosure with contamination check at entry points and a dedicated, local ventilation system). A register should be maintained of such areas, barriers and enclosures.

7.64. The register should be reviewed regularly by an appropriate level of management. The objective should be to reduce the number of temporary contaminated areas either by decontamination or, where possible the elimination of the root cause which may require modifications to the facility or its procedures.

7.65. Good communications between operators, radiation protection personnel, maintenance staff, and more senior management should be established and maintained to ensure timely corrective actions.

7.66. Personnel should be trained to adopt the correct behavior during operational states e.g. training on general and local radiation protection requirements.

7.67. Personnel should be trained in the use of dosimeters and personnel protective equipment (i.e. lead gloves and apron) including dressing and undressing and in self-monitoring. Personal protective equipment should be maintained in good condition, periodically inspected and readily available.

7.68. Personnel and equipment should be checked for contamination and decontaminated, if necessary, prior to exiting contaminated areas.

7.69. Careful consideration should be given to the combination of radiological & industrial hazards (oxygen deficiency, heat stress, etc.) with particular attention paid to the risk/ benefit balance for the use of personnel protective equipment, especially air-fed systems.

Recommendations for intrusive maintenance[64]

7.70. Intrusive maintenance is considered a normal or regular occurrence in reprocessing facilities. The procedures for such work should include:

[64]Intrusive maintenance: Maintenance involving the significant reduction of shielding, the breaking of static containment or significant reduction of dynamic containment, or a combination of these.

(a) Estimation of doses for all staff (including decontamination workforce) prior to the work starting;

(b) Preparatory activities to minimize individual and collective doses for all staff , including:

- Identification of specific risks due to the intrusive maintenance;
- Operations to minimize the radiation source (inventory)for local doses e.g. flush out and rinsing of parts of the process;
- Consideration of the use of mock-ups, remote devices, additional shielding or personnel protective equipment, monitoring devices and dosimeters;
- Identification of relevant procedures within the work permit, which also defines individual and collective protection requirements e.g. personnel protective equipment, monitoring devices and dosimeters, time and dose limitations;

(c) Measurement of exposure during the work;

- If doses (or dose rates) are significantly higher than anticipated, consideration should be given to withdrawing personnel to re-evaluate the work;

(d) Implementation of feedback to identify possible improvements.

- For extended maintenance activities feedback should be applied to the ongoing task.

7.71. Procedures that address the following points should be defined and applied according to level of risk[65]:

(a) A temporary controlled area should be created that includes the work area. According to the risk this may include, as necessary:

- an enclosure[66] with temporary ventilation system with filtration and/ or exhausting to the facility ventilation system;
- Barriers with appropriate additional radiation and/ or airborne contamination monitors;

[65]Where the level of risk is difficult to determine (new tasks, initial breaking of containment following a fault etc.) precautions should initially be cautious, based on the assessed hazard and operational experience, until the risk assessment can be reviewed in the light of new data.

[66]An “enclosure” is a (usually temporary) combination of a static barrier (containment) supplemented by a dynamic barrier (ventilation) with appropriate entry facilities, completely enclosing (boxing-in) a work area and sealed, as far as practical to local surfaces (walls/ floors etc.) to limit and minimize the spread of contamination. Where possible these should be modular with a rigid or heavy duty plastic outer “skin” (resistant to damage) and a lighter-weight (thinner), easily de-contaminable, inner skin to allow for maximum recycling and reuse and to minimise waste volumes. In some Member States these are called “tents” or “greenhouses” etc.

(b) Personal protective equipment (e.g. respirators, over-suits etc.) as specified, should be provided at the entry points and used when dealing with potential releases of radioactive materials;

(c) In accordance with the assessed risk, a dedicated trained person(s), usually radiation protection personnel, should be present local to the work place to monitor the radiological, and other safety related conditions with the authority to halt the work and withdraw personnel in case of unacceptable risk (e.g. oxygen deficiency, if air fed equipment is in use).This dedicated person(s) should also provide assistance to the maintenance staff in dressing, monitoring and undressing from personal protective equipment;

These recommendations are applicable when the normal containment barrier is to be reduced or removed as part of maintenance/ modification activity.

Monitoring of occupational exposures

7.72. There should be appropriate provisions for the measurement of radiation doses to individuals. Instrumentation should be provided, where appropriate, to give prompt, reliable and accurate indication of airborne and direct radiation in normal operation and accidental conditions.

7.73. Personnel exposures should be estimated in advance and monitored during work activity, using suitably located devices and/ or personal dosimeters (preferably alarmed) where appropriate (para. 7.75).

7.74. The extent and type of workplace monitoring should be commensurate with the expected level of airborne activity, contamination, radiation type or the potential for these to change, at the work places.

7.75. Personal dosimeters should be used as necessary, with, where available, alarms set for both cumulative dose and dose rate.

7.76. The selection and use of personal dosimeters and mobile radiation detectors should be adapted to the expected spectrum of radiation energies (alpha, beta/ gamma, neutron) and the physical states (solid, liquid and/ or gaseous forms) of radioactive materials.

7.77. Monitoring equipment of local and individual doses and airborne activity for reprocessing facilities should include, as necessary:

(a) Film, solid trace or electronic beta/ gamma and neutron dosimeters, criticality 'lockets' or belts, TLDs (Thermo-Luminescence Dosimeter) & indium foil criticality event detectors;

(b) TLD extremity dosimeters, (e.g. finger doses).

(c) Mobile airborne activity monitors with immediate, local alarm (for maintenance work/ tents and temporary enclosures and air locks);

(d) Mobile air samplers for low level monitoring.

7.78. The methodology for assessing internal dose should be based on timely collection of air sampling data in the workplace, combined with worker occupancy data. Where necessary the relationship between fixed detectors and individual doses should be verified by the use of personal air samplers in sampling campaigns of, preferably, limited duration.

7.79. In the event of abnormal radiation or contamination being detected in a room or area, checks of the staff having been present in the area should be carried out and the appropriate decontamination or medical intervention implemented according to the results. The details of such interventions are outside the scope of this publication.

7.80. In addition to personal and area monitoring routine in-vivo monitoring and biological sampling should be implemented according to national regulations. The effect of hazardous chemicals and the radiological effects should be taken into account in surveillance programmes as necessary.

7.81. Further guidance on occupational radiation protection and the assessment of occupational exposures due to internal and external exposure to radiation can be found in (Refs. [36], [37] and [38])

FIRE, CHEMICAL & INDUSTRIAL SAFETY MANAGEMENT

7.82. The potential for fire or exposure to chemical and other industrial risks are significant for reprocessing facilities due to the size and complexity of reprocessing facilities, the nature of the materials processed and stored and the processes used.

7.83. The list of conventional non-nuclear hazards found in reprocessing facilities is extensive due to the factors identified above and could include:

(a) Conventional hazardous chemicals in the process or at storage ;

(b) Electrical works;

(c) Fire and explosion ;

(d) Superheated water and steam ;

(e) Asphyxiation hazard;

(f) Dropped loads;

(g) Falls from elevated working places;

(h) Noise;

(i) Dust.

Chemical hazards

7.84. Reprocessing facilities should be designed and operated to protect workers from the hazards associated with the use of strong acids and hazardous chemicals, particularly at elevated temperatures, throughout the process and the use of organic solvents in the extraction stages.

7.85. In the facility and analytical laboratories, the use of reagents should be controlled by written procedures (nature, and quantity of authorized chemicals) to prevent explosion, fire, toxicity and hazardous chemical interactions. Where necessary eye protection and local ventilation should be specified and provided. Consideration should be given for the need for breathing apparatus, chemical spill equipment and suitable protective wear for chemical emergencies.

7.86. Chemicals should be stored in well aerated locations or dedicated, secure storage arrays outside the process or laboratories areas, preferably in low occupancy areas.

7.87. Personnel should be informed of the chemical hazards that exist. Operating personal should be properly trained on the process chemical hazards in order to adequately identify and respond to the problems that may lead to chemical accidents.

7.88. As required by national regulations, a health surveillance programme should be set up to routinely monitor the health of workers who may be exposed to harmful chemicals.

Fire and explosion hazards

7.89. Flammable, combustible, explosive and strongly oxidizing materials are used in the reprocessing facilities (e.g. organic solvents in the extraction stage, nitric acid throughout and other materials and reagents with relatively low flammability limits). Emergency systems and arrangements to prevent, minimize and detect hazards associated with these materials should be properly maintained, and regularly exercised, to ensure that a rapid response can be deployed to any incident and its impact minimized.

7.90. To minimize the fire hazard of pyrophoric metals (Zr or U particles), periodic checking and cleaning of shearing hot cells or other location where these materials could accumulate should be implemented. In some cases routine “flushing” (high flow rate washing) of equipment may be necessary.

7.91. The work permit and facility procedures and instructions should include an adequate assessment and, as necessary, a check-sheet on the potential nuclear consequences of fires resulting from activities which involve potential ignition sources, e.g. welding, and should define the precautions necessary for performing the work.

7.92. The prevention and control of waste material accumulations (contaminated and ‘clean’) should be rigorously enforced to minimize the ‘fire load’ (potential) in all areas of a reprocessing facility. Auditing for waste accumulations should be an important element in all routine inspection and surveillance activities by all levels of personnel. Periodic inspections by fire safety professionals should be part of the audit programme.

7.93. To ensure efficiency and operability of fire protection systems suitable procedure, training and drills should be implemented including:

(a) Periodic testing, inspection and maintenance of the devices associated with fire protection systems (fire detectors, extinguishers, fire dampers);

(b) General and detailed (location specific) instructions and related training for fire fighters;

(c) Firefighting plans;

(d) Fire drills, including the involvement of off-site emergency services;

(e) Training for operating staff and emergency teams.

MANAGEMENT OF RADIOACTIVE WASTE

7.94. A strategy for the management of radioactive waste should be established by the licensee (para. 4.150) and implemented on the reprocessing facility site consistent with the types of waste to be processed and the national waste management policy and strategy.

7.95. Waste minimization should be an important objective for reprocessing facility management and operators. As part of the management system an integrated waste management plan and supporting procedures should be developed, implemented, regularly reviewed and updated as required. All facility personnel should be trained in the "waste hierarchy" (eliminate, reduce, re-use, recycle, dispose), the plan requirements and the relevant procedures. Waste minimization targets should be set, regularly reviewed and a system for continuous improvement (waste volumes/ activity in relation to work carried out) should be in place (Ref. [1]. paras 9.5`4-9.56).

7.96. All waste should be treated and stored in accordance with pre-established criteria and the national waste classification scheme. Waste management should take into consideration both on-site and off-site storage capacity as well as disposal options and operational disposal facilities (if available). Every effort should be made to characterize the wastes as fully as possible, especially those without a recognized disposal route. Where a disposal facility is in operation, waste characterization should be performed in such a way that compliance with the waste acceptance requirements can be demonstrated. The available information characterizing the waste should be held in secure and recoverable archives (Ref. [1]: Appendix IV: paras IV.80 and IV.82).

7.97. Operational arrangements should be such so as to avoid the creation of radioactive waste or reduce to a practical minimum the radioactive waste generated (reducing secondary waste generation and the re-use, recycling and decontamination of materials). Trends in radioactive waste generation should be monitored and the effectiveness of applied waste reduction and minimization measures demonstrated. Equipment, tools and consumable material entering hot cells, shielded boxes and gloveboxes should be minimized as far as practicable.

7.98. The accumulation of radioactive waste on site should be minimized, as far as practicable. All accumulated waste should be stored in purpose designed storage facilities designed and operated to equivalent standards as the reprocessing facility itself.

7.99. Segregation and characterization practices for radioactive wastes should be developed and applied to provide a foundation for safe and effective management of these wastes from generation through to disposal. Particular care should be taken to segregate and ensure criticality safety for waste containing fissile material.

7.100. Consideration should be given to segregating solid waste according to its area of origin, as being indicative of its potential radioactive "fingerprint[67]" and thus routes for processing, storage and disposal. These "fingerprints", in conjunction with rapid, limited,

[67]'Fingerprint': The mixture of radioactive nuclides and their ratios which characterise the waste. Such "fingerprints" may be estimated from the material processed in the area and confirmed during initial operation of the facility.

local radiometric measurements (e.g. total beta/ gamma) should be used as sorting criteria local to where the waste has been generated. This permits rapid waste segregation and choice of appropriate waste handling techniques and should be considered in relation to optimizing operator protection in both the initial handling of waste and in the subsequent detailed characterization and, if necessary, waste sorting in dedicated waste handling areas where remote or automatic equipment should be used to optimize operator safety and reduce radiation risks.

7.101. The waste collection and further processing (i.e. pretreatment, treatment and conditioning) should be organized according to pre-established criteria and procedures defined to meet the requirements for established or planned routes for storage and disposal.

7.102. Facility decontamination methods should be adopted which minimize primary and secondary waste generation and facilitate the subsequent treatment of the waste e.g. the compatibility of decontamination chemicals etc. with available waste treatment routes.

7.103. As far as reasonably achievable, decontamination should be used for reducing and/ or minimizing environmental impact and maximizing nuclear material recovery. Decontamination of alpha contaminated (e.g. Pu) waste should be as complete as economically practicable to reduce and/ or minimize the impact of long lived emitters on the environment, provided recovery routes are available for the decontamination waste stream.

7.104. Exemption and clearance procedures for waste should be provided according to national regulation. The procedure should be used as fully as practicable, to minimize the volumes of material going to active disposal routes and thus the size of disposal facility required.

7.105. Information about radioactive waste needed for its safe management and eventual disposal now and in the future should be collected, recorded and preserved according to an appropriate integrated management system (Ref. [32]).

Effluent management

7.106. Reprocessing facilities usually have a number of discharge points corresponding either separately or collectively to the specific authorized discharges. The operation organization should establish an appropriate management structure to operate and control each of these discharge points and the overall reprocessing facility discharges.

7.107. For reprocessing facilities, discharge streams should be measured where possible before discharge or where not, in real time. When used, sampling devices and procedures should provide representative and timely results of the real flows to or batch releases into the environment.

7.108. The aim of the operating organizations should be that all discharges are optimized and within, as a minimum, authorized limits. The personnel involved should have the authority to shutdown processes and facilities, subject to safety considerations, when they have reason to believe that these aims may not be met.

7.109. The operating organization should set a list of performance indicators to help monitor and review the discharge optimization programs. The indicators should be related to maximum upper limits, e.g. monthly goals for discharges to the environment.

7.110. Periodic estimate of the impact to the public (representative person(s)) should be made using data on effluent releases and standard models agreed with the national authorities.

Gaseous discharges

7.111. The radioactive gaseous discharges should be treated, as appropriate by dedicated off-gas treatment systems, and HEPA filters.

7.112. After a filter change, tests and/ or verification of the change procedure should be carried out to ensure that filters are correctly seated and provide at least the removal efficiency used or assumed in the safety analyses.

7.113. The efficiency of the last stage of filtration before stack release (or as otherwise required by the safety analysis) should be tested as defined in the OLCs.

Liquid discharges

7.114. All liquids collected from the reprocessing facility site (e.g. from rain water, underground water around buildings, process effluents) that have to be discharged into the environment should be assessed and managed according to authorizations.

7.115. The liquid effluent system (collection and discharge piping, temporary storage if any) should be correctly operated, and its effectiveness maintained as part of the reprocessing facility.

7.116. Reprocessing facility liquid discharge authorizations usually specify an annual quantity of radioactive species and if necessary, effluent physical and chemical characteristics. They may also have further conditions designed to optimize the environmental impact e.g. discharge at high tide, above a minimum river flow etc. Operational procedures should be implemented to meet the authorization requirements.

7.117. Where possible, the reprocessing facility should be operated, as far as the design allows, accommodating batch wise discharges, which allow verification of the necessary parameters by sampling and timely analysis prior to release.

EMERGENCY PREPAREDNESS

7.118. The scale, complexity and the level of potential hazards of reprocessing facilities mean that arrangements for emergency preparedness (for protecting workers, the public and the environment in the event of an accidental release) and maintaining and updating the emergency plan are particularly important. The requirements are established in (Refs. [1]: paras. 9.62-9.67, [10], [31] and [39]) and elaborated in Section 4: 'Emergency preparedness').

7.119. The operating organization should carry out regular emergency exercises, some of which should involve off-site resources, to check the adequacy of the emergency arrangements, including the training and preparedness of on- and off-site personnel and services including communications.

7.120. The emergency arrangements should be periodically reviewed and updated (Refs. [10] and [31]) taking account of any lessons learned from facility operating experience, emergency exercises, modifications, periodic safety reviews and from emergencies that have occurred with similar facilities, emerging knowledge and changes to regulatory requirements.

7.121. Further information on emergency preparedness and the elaboration of responses relevant to reprocessing facilities can be found in (Refs. [10] and [31]).

8. PREPARATION FOR DECOMMISSIONING

8.1. Requirements and recommendations for the decommissioning of nuclear fuel cycle facilities are given in (Refs. [22] and [23]). These require, inter alia, that:

(a) The initial decommissioning strategy is selected in accordance the national policy on the management of radioactive waste;

(b) The decommissioning strategy, decommissioning plan and safety assessment (appropriate to the development stage of the decommissioning strategy and plan) are produced early in design;

(c) Decommissioning is included in the optimization of protection by iteration of the facility design, decommissioning strategy and plan and safety assessment;

(d) Adequate financial resources are identified to carry out decommissioning including the management of the resulting radioactive waste.

8.2. The decommissioning plan and safety assessment should be developed and periodically reviewed throughout the reprocessing facility's commissioning and operational phases (Ref. [22], requirements: 8 and 10) to take account of new information and emerging technologies to ensure that:

(a) The (updated) decommissioning plan is realistic and can be carried out safely;

(b) Updated provisions are made for adequate resources, and;

(c) The radioactive wastes anticipated remain compatible with available (or planned) interim storage capacities and disposal routes.

8.3. Facilities should be, sited, designed, constructed, operated (maintained and modified) to facilitate eventual decommissioning, as far as practicable. Due to their size, complexity and the diverse waste arising during operation and decommissioning, particular care should be taken that the following aspects are addressed throughout the lifetime of the reprocessing facility:

(a) Design features to facilitate decommissioning (e.g. measures to minimize contamination penetrating in the structures, installed provision for decontamination, etc.);

(b) Physical and procedural methods to prevent the spread of contamination;

(c) Consideration of the implications for decommissioning when modifications to and experiments on the facility are proposed;

(d) Identification of reasonably practicable changes to the facility design to facilitate or accelerate decommissioning;

(e) Comprehensive record preparation for all significant activities and events at all stages of the facility's life, archived in a secure and readily retrievable form, indexed in a documented, logical and consistent manner;

8.4. Minimizing the eventual generation of radioactive waste during decommissioning.General requirements in the event of decommissioning being significantly delayed after a reprocessing facility has permanently shut down for decommissioning or shut-down suddenly (e.g. as a result of a severe process failure or accident) are given in (Ref. [22]) and include the potential need to revise the decommissioning strategy, the decommissioning plan and the safety assessment.

8.5. For any period between a planned or unplanned shutdown and prior to decommissioning starting, safety measures should be implemented to maintain the reprocessing facility in safe and stable state, including measures to prevent criticality; spread of contamination; fire, and; to maintain appropriate radiological monitoring. Consideration should be given for the need for a revised safety assessment for the 'shut down' facility state and to using 'knowledge management' methods to retain the knowledge and experience of operators in a durable and retrievable form. Wherever practicable, hazardous and corrosive materials should be removed from process equipment to safe storage locations when placing a reprocessing facility into a prolonged shutdown state.

ABBREVIATIONS

DBA	Design Base Accident
DBE(E)	Design Base External (Event)
HA	Highly (radio-)Active
HEPA	High Efficiency Particulate Air (filters)
HL	High (radioactive) Level
I&C	Instrument and Control
OLC	Operational Limits and Conditions
ORPP	Operational Radiation |Protection Programme
SSC	Structures, Systems and Components (important to safety)
TLD	Thermo-luminescent Dosimeter

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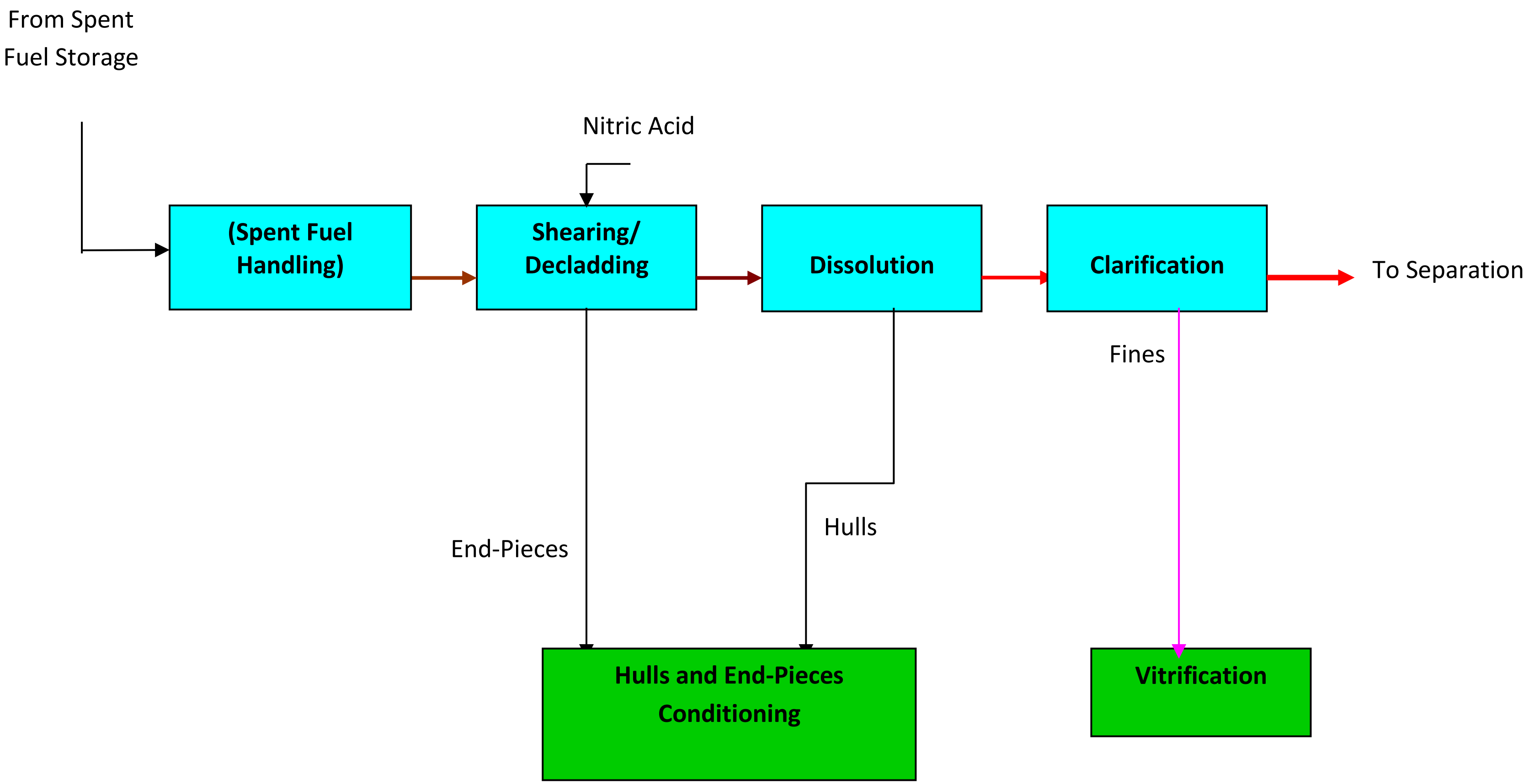
ANNEX I: REPROCESSING FACILITIES MAIN PROCESS ROUTES

ANNEX I A

REPROCESSING FACILITIES

MAIN PROCESS ROUTES

(HEAD-END)

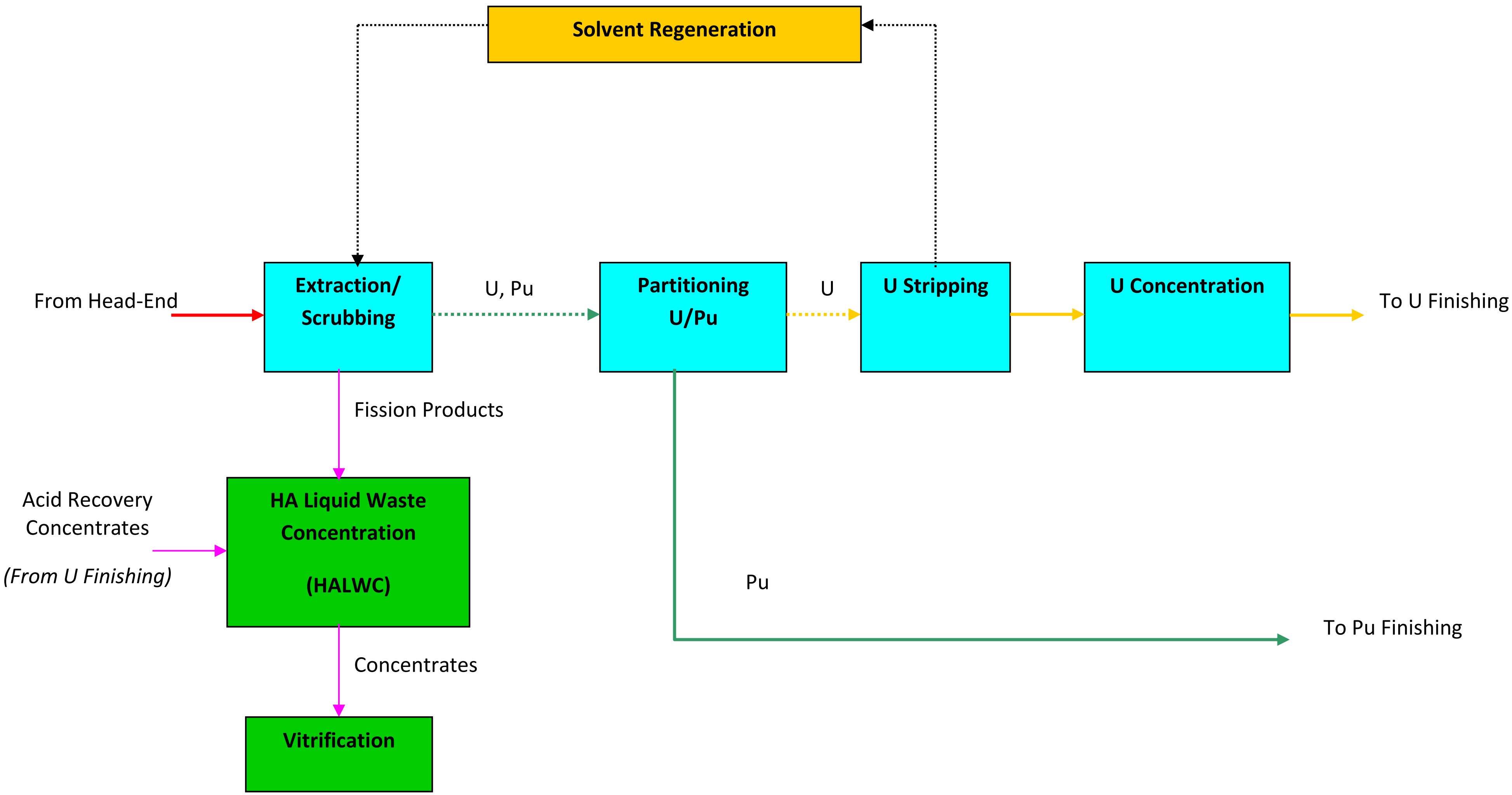


ANNEX I B

REPROCESSING FACILITIES

MAIN PROCESS ROUTES

(SEPARATION)

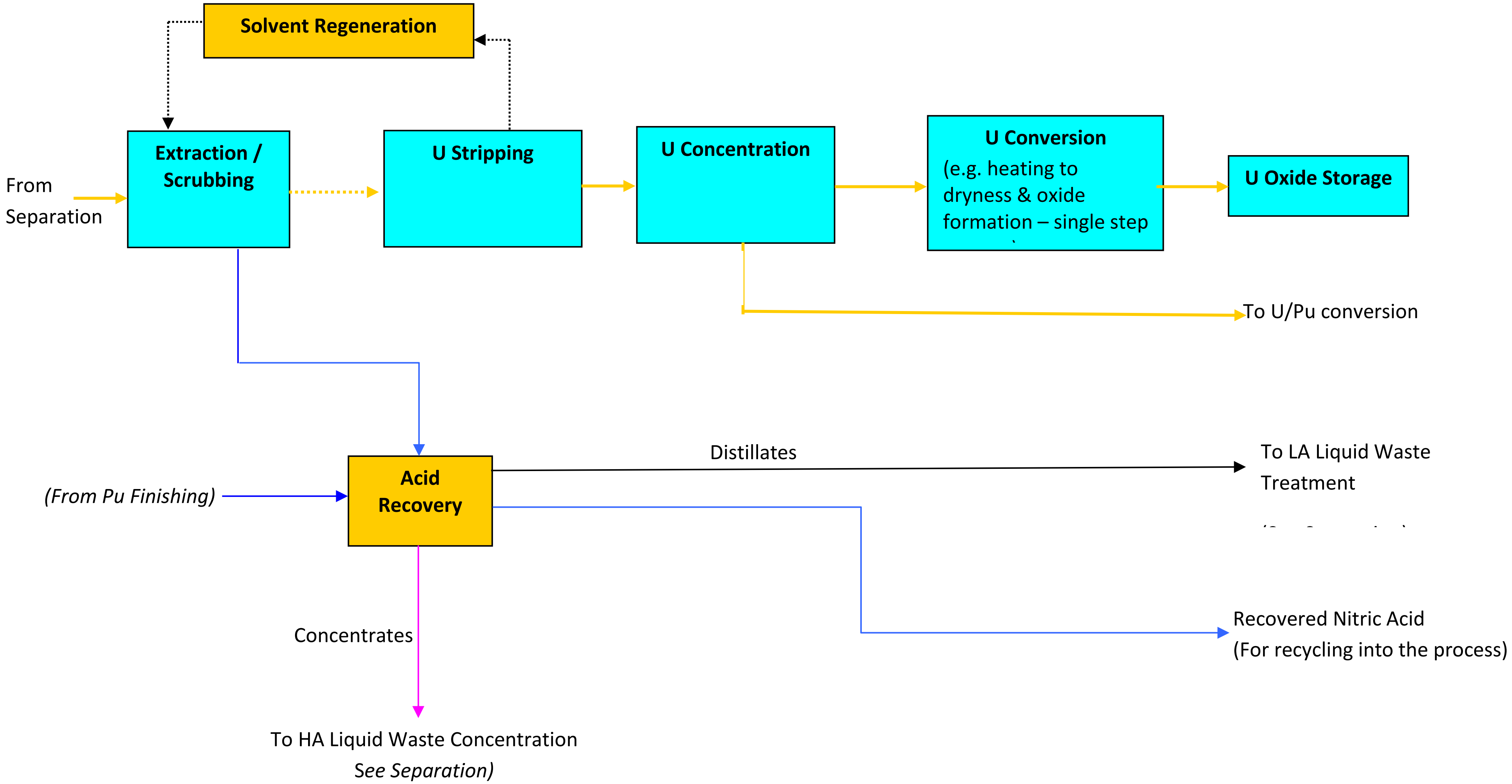

Solvent Regeneration
From Head-End
Extraction/
Scrubbing
U, Pu
Partitioning
U/Pu
U
U Stripping
U Concentration
To U Finishing
Fission Products
Acid Recovery
Concentrates
(From U Finishing)
HA Liquid Waste
Concentration
(HALWC)
Pu
To Pu Finishing
Concentrates
Vitrification

ANNEX I C

REPROCESSING FACILITIES

MAIN PROCESS ROUTES

(U FINISHING)

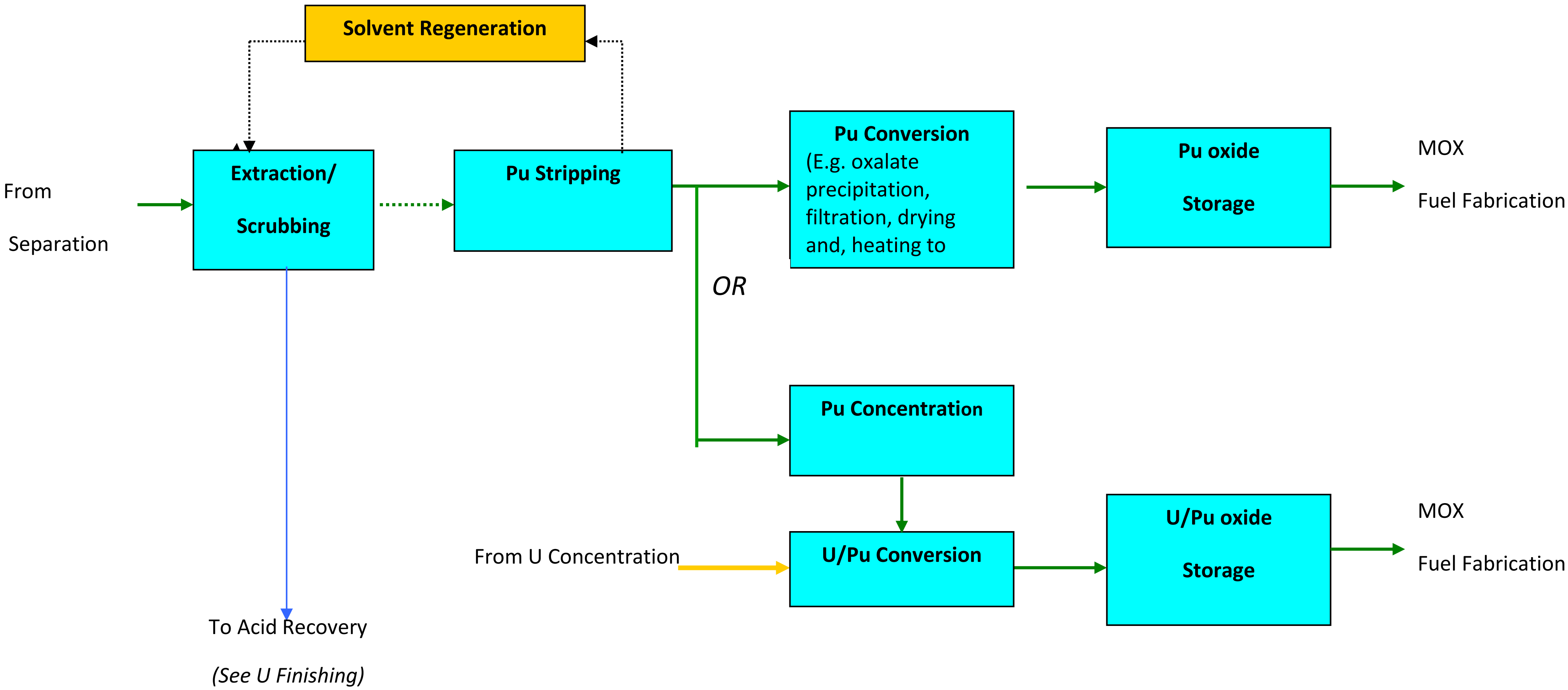


ANNEX I D

REPROCESSING FACILITIES

MAIN PROCESS ROUTES

(Pu FINISHING)



ANNEX II: SAFETY FUNCTIONS

MAIN STRUCTURES, SYSTEMS AND COMPONENTS IMPORTANT TO SAFETY, POSSIBLE CHALLENGES TO SAFETY FUNCTIONS AND EXAMPLES OF PARAMETERS FOR DEFINING OPERATIONAL LIMITS AND CONDITIONS FOR REPROCESSING FACILITIES

Main safety functions (MSF):

1. Prevention of criticality
2. Confinement:
    - 2a. Barriers;
    - 2b. Cooling;
    - 2c. Prevention of radiolysis and generation of other hazardous explosive or flammable materials
3. Protection against external exposure

HEAD-END PROCESS (See ANNEX 1A for Process Areas)

*This table identifies, for a typical reprocessing facility, the main "devices" (SSCs) which detect deviations from normal, planned or expected conditions, Operating Limit and Conditions parameters (OLCs, defined in the safety assessment), the potential consequences of continued deviation (Consequential Events) and the main safety function (MSF) , (see above) by or as part of the "consequential event"

Process area	Main SSCs important to safety	Consequential events	MSF* (Initially) Challenged	OLC Parameters
Feeding	Camera, detector	Safety concern in the process	Potential for all	Fuel Assembly identification (Feed programme)
	Spent Fuel Burn-up measurement system	Criticality event	1	Burn-up value
Shearing/Decladding	Shearing machine	Zr Fire	2c	Cleanliness of the shearing machine (accumulation of material)
		Criticality event	1	
Dissolution	See « Vessel »		2	
	Measurement systems for Temperature, Density, Acidity of the solution	Criticality event	1	Temperature, Density, Acidity

Process area	**Main SSCs important to safety**	**Consequential events**	**MSF* (Initially) Challenged**	**OLC Parameters**
	Control of the solution poisoning (if required)	Criticality event	1	Neutron poison concentration
Clarification	See « Vessel »		3	
	Analytical measurement	Criticality event in the fines Storage vessel	1	H/Pu ratio
	Filter cleaning/Centrifuge cleaning systems	Potential release of activity	2b	Cleaning system parameters
Hulls and end-pieces conditioning	Measurement of the fissile materials of contents in hulls	Non-acceptance by the hulls conditioning facility	1	Residual fissile material
« Vessel »	Vessels Containing Radioactive Solution	Leakage of Active Solution	2a	Detection of Leakage (Level Measurement/Sampling in Drip Tray or Sumps, Contamination measurements in Cells and rooms)
	Cooling supply system (if any)	Overheating/ Boiling/ Crystallization/ Corrosion	2b	Flow Rate of Cooling Water, Temperature of active solution
	Heating supply system (if any)	Overheating/ Boiling/ Crystallization/ Corrosion	2a, 2b, 2c	Flow Rate of Heating Fluid, Temperature of active solution
	Supply system in air for dilution of radiolysis gases (if any)	Explosion (H2)	2c	Flow Rate of diluting air for dilution
	Level measurement	Overflowing	2a	Leakage (and safety issues in downstream process)
	Pressure measurement (where necessary)	Vessel failure	2a	Leakage

Process area	Main SSCs important to safety	Consequential events	MSF* (Initially) Challenged	OLC Parameters
	Measurement of parameters related to criticality control (if needed)	Criticality event	1	Specific OLCs

SEPARATION PROCESS (See ANNEX 1B)

Process area	Main SSCs important to safety	Consequential events	First challenged SF*	OLC Parameters
Extraction/Scrubbing	See « Vessel »		3	
	Temperature control	Fire (Organics)	2a	Solution Temperature in mixer settlers or columns
	Organics content measurement	Loss of Defense in Depth (DiD) for downstream process	2a	Diluent/ Solvent ratio
	Reagents feeding system	Leakage of Pu with FP	1	Reagents Flow rate
Partitioning U/Pu	Temperature control	Fire (Organics)	2a	Solution Temperature in mixer settlers or columns
	Organics content measurement	Loss of DiD for downstream process	2a	Diluent/ Solvent ratio
	Reagents feeding system	Leakage of Pu with U	1	Reagents’ Flow rate
	Neutron measurement at the column	Criticality event (Prevention)	1	Neutron measurement along the column

Process area	Main SSCs important to safety	Consequential events	First challenged SF*	OLC Parameters
	Critically event detection system	Criticality event (Mitigation)	1	Criticality accident alarm system (CAAS)
U Stripping/ U concentration	Temperature control	Explosion (Red Oil)	2c	Temperature
	Process parameters control	Explosion (Red Oil)	2c	Administrative controls
Solvent Regeneration	Temperature control	Explosion (Hydrazine) Fire (organics)	2c,	Temperature
	Analytical measurement	Explosion (Hydrazine) Fire (organics)	2c, 2a	Administrative controls
HA Liquid Waste Concentration	See « Vessel »		3	
	Temperature control	Explosion (Red Oil)	2c	Temperature
	Parameter(s) related to the destruction of nitrates	Overpressure	2c	Administrative controls

U PRODUCT TREATMENT PROCESS (See ANNEX 1C)

Process area	Main SSCs important to safety	Consequential events	First Challenged SF*	OLC Parameters
U Extraction/ Scrubbing	Temperature control	Fire (Organics)	2a	Temperature
	Process parameters control	Fire (Organics)	2a	Administrative controls
U Stripping	Temperature control	Fire (Organics)	2a	Temperature
	Process parameters control	Fire (Organics)	2a	Administrative controls
U concentration	Temperature control	Explosion (Red Oil)	2c	Temperature
	Process parameters control	Explosion (Red Oil)	2c	Administrative controls

U Concentration	See « Vessel »		3	
U Oxide storage	See « Vessel »		3	
Solvent Regeneration	Temperature control	Fire (Organics)	2a	Temperature
	Analytical measurement	Fire (Organics)	2a	Administrative controls
Acid recovery	Temperature control	Explosion (Red Oil)	2c	Temperature
	Process parameters control	Explosion (Red Oil)	2c	Administrative controls

Pu PRODUCT TREATMENT PROCESS (See ANNEX 1D)

Process area	Main SSCs important to safety	Consequential events	First Challenged SF*	OLC Parameters
Pu Extraction/ Scrubbing/ Stripping	See « Vessel »		1, 3	
	Temperature control	Fire (Organics)	2a	Temperature
	Process parameters control	Fire (Organics)	2a	Administrative controls
Pu concentration	Process parameters control	Criticality	1	
Pu Conversion	Process parameters controls	Criticality	1	Temperature
Pu Oxide Storage	Thermal criteria for storage	Potential release of activity	2a	Temperature, Ventilation flowrate
	Storage rack	Criticality	1	“Size” (Design, Commissioning)
Solvent regeneration	Temperature control	Fire (Organics)	2a	Temperature
	Analytical measurement	Fire (Organics)	2a	Administrative controls

CONTRIBUTORS TO DRAFTING AND REVIEW

Carr, V.	International Atomic Energy Agency
Diaz Toro, D.	United States Nuclear Regulatory Commission (NRC), United States of America
Dubac, J.	AREVA SA, France
Giitter, J.G.	United States Nuclear Regulatory Commission (NRC), United States of America
Gater, R.	International Atomic Energy Agency
Gordon, I	Sellafield Ltd., United Kingdom
Kurashige, T.	Japan Nuclear Energy Safety Organization (JNES), Japan
Magruder, S.	United States Nuclear Regulatory Commission (NRC), United States of America
Marc, A.	Société Générale pour les Techniques Nouvelles (SGN), France
Nepeypivo, M.	Scientific and Engineering Centre for Nuclear and Radiation Safety (SEC NRS), Russian Federation
Nocture, P.	International Atomic Energy Agency
Ueda, Y.	Japan Nuclear Energy Safety Organization (JNES), Japan