IAEA SAFETY STANDARDS
for protecting people and the environment

Step 8

Submitting the draft for review by the Member States

Design of Auxiliary Systems and Supporting Systems for Nuclear Power Plants

DS 440

DRAFT SAFETY GUIDE

New Safety Guide

FOREWORD

Later

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide was prepared under the IAEA programme for establishing safety standards for nuclear power plants. The basic requirements for the design of safety systems for nuclear power plants are established in the Safety Requirements publication, Safety Standards Series No. SSR-2/1 (Rev.1) on Safety of Nuclear Power Plants: Design [1]. This Safety Guide describes how the requirements for the design of the auxiliary and supporting systems, hereinafter referred to as AS&SSs, in nuclear power plants should be met.

1.2. AS&SS provide services that may include electricity, service gas, water, compressed air, conditioning air, communication equipment, lifting and lowering items, fuel and lubricants which are important for the operation and safety of the plant. Their reliability should be commensurate with their importance for safety.

1.3. This publication represents a new Safety Guide in the IAEA Safety Standards Series.

OBJECTIVE

1.4. The objective of this Safety Guide is to provide recommendations and guidance for designers, operators, regulators and technical support organizations on the design of AS&SS. It supplements the requirements established in [1] that are relevant to the AS&SSs.

SCOPE

1.5. This Safety Guide applies primarily to the AS&SS of land based stationary nuclear power plants with water cooled reactors designed for electricity generation or for other applications for heat production (such as district heating or desalination). For other reactor types, some parts of this Safety Guide might not be applicable or may need some engineering judgement in their interpretation, or additional AS&SSs should be considered.

1.6. As defined in Section 2, this safety guide provides design recommendations for the AS&SSs of PWRs, BWRs and PHWRs. The list of AS&SS considered in this Safety Guide is established in Section 2. The scope does not extend to the detailed design of specific components of these systems, for example heat exchangers. For plants designed with earlier standards, comprehensive safety assessments are to be carried out considering these recommendations in order to identify safety improvements that are oriented to prevent accidents with radiological consequences and mitigate such consequences should they occur. Reasonably practicable or achievable safety improvements are to be implemented in a timely manner.

STRUCTURE

1.7. Section 2 provides a definition of the AS&SS and describes their extent. Section 3 recalls general concepts and design recommendations that are common to all the AS&SSs, as applicable. Section 4 presents specific design considerations for selected examples of AS&SSs.

2. GENERAL ASPECTS

DEFINITION AND FUNCTIONS OF AUXILIARY SYSTEMS AND SUPPORTING SYSTEMS

2.1. A nuclear power reactor has the following main (or primary) systems: the reactor core, the reactor coolant system and the containment structure and containment system and their associated safety systems and safety features (SSR-2/1 (Rev.1), Req. 43 to 58). By exclusion, the remaining systems are considered as auxiliary systems (SSR-2/1 (Rev.1), Req. 59 to 82) to the main systems and their associated features. General definition and extent of the auxiliary systems are given in the following sections.

2.2. According to the stepwise approach to define auxiliary systems detailed in Figure 1, an auxiliary system is a system that, on its own, has no primary function in ensuring the operation of the nuclear power plant, but it has to be available for other systems, including the main systems to ensure their functions. Additionally, an auxiliary system could be also a system that provides services to the operation of the nuclear power plant (e.g., communication systems, compressed air system).

2.3. Auxiliary systems can provide “essential services” that are interpreted as resources necessary to maintain the safety system operability. They can also provide supplies to systems important to safety. Such services could include electricity, water, compressed air, fuel and lubricants.

2.4. In this safety guide, the term “supporting systems” designates those auxiliary systems that support safety functions. However, in general, the term of “Auxiliary Systems and Supporting Systems” (AS&SS) is used consistently with SSR-2/1 (Rev.1) terminology.

EXTENT OF THE AUXILIARY SYSTEMS AND SUPPORTING SYSTEMS

2.5. The AS&SS systems to be addressed in this safety guide are stepwise determined on the basis of their definition in paragraph 2.2, and whether or not they are addressed in existing safety guides or safety guides being revised. In particular, heat transport systems (SSR-2/1 (Rev.1), Req. 70) are partially addressed in the revision of NS-G-1.9 [2], fire protection systems (SSR-2/1 (Rev.1), Req. 74) are covered in [3], and radiation protection systems (SSR-2/1 (Rev.1), Req. 81 and 82) are addressed in NS-G-1.13 [4].

2.6. The steam supply system and feedwater system (SSR-2/1 (Rev.1), Req. 77) are addressed in the revision of the NS-G-1.9.

2.7. Applying the stepwise gap approach to the definition of paragraph 2.2, and taking into account the requirements of SSR-2/1 (Rev.1), the list of AS&SS to be considered in this safety guide is the following:

- Communication Systems (SSR-2/1 (Rev.1), Req. 37);
- Heat transport systems (SSR-2/1 (Rev.1), Req. 70);

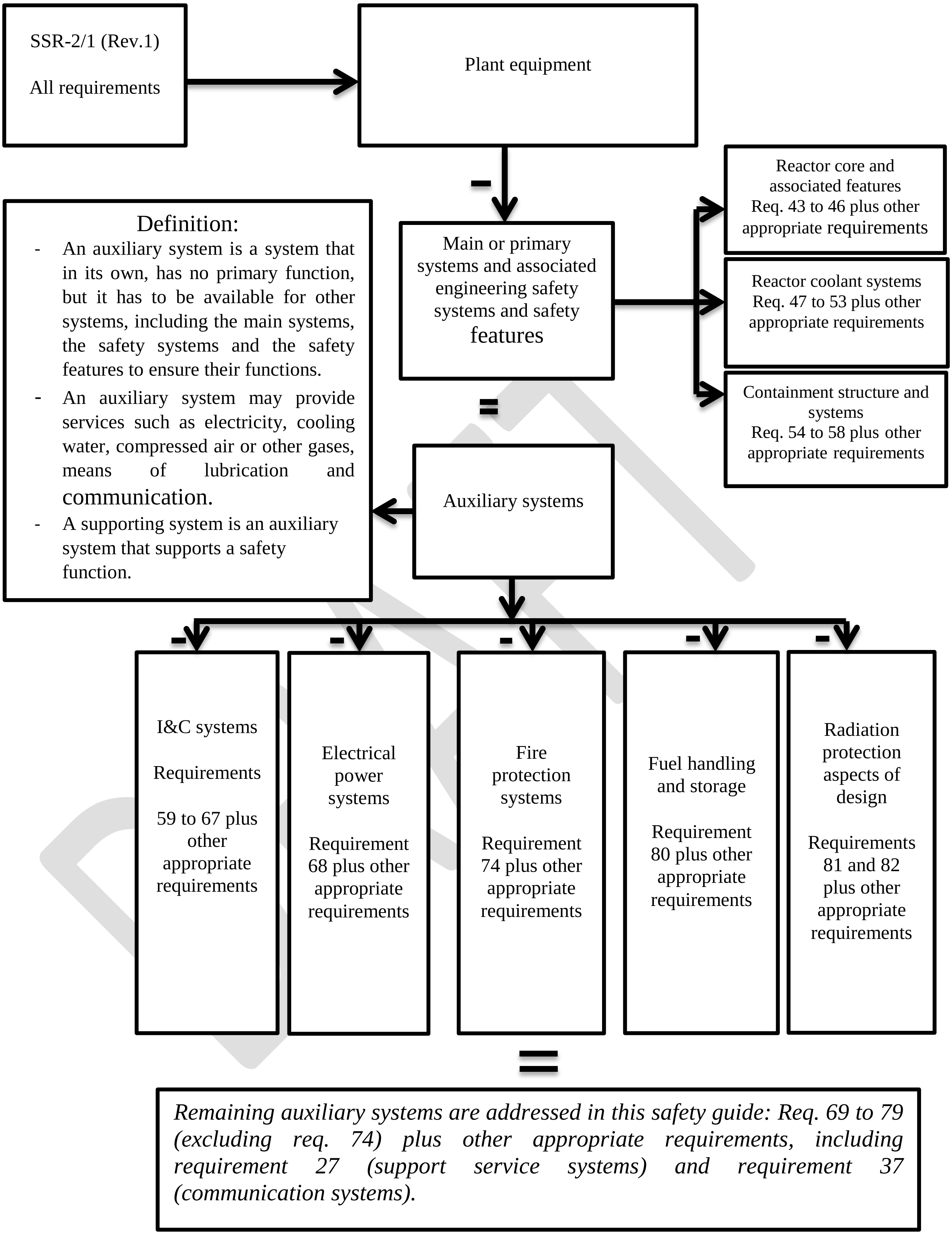
- Process and post-accident sampling system SSR-2/1 (Rev.1), Req. 71)
- Compressed Air System (SSR-2/1 (Rev.1), Req. 72);
- Air Conditioning Systems and Ventilation Systems, addressed in this safety guide under “Heating, Ventilation and Air Conditioning” (SSR-2/1 (Rev.1), Req. 73);
- Lighting and Emergency Lighting Systems (SSR-2/1 (Rev.1), Req. 75);
- Overhead Lifting Equipment (SSR-2/1 (Rev.1), Req. 76);
- Systems of Treatment of Radioactive Effluents and Radioactive Waste (SSR-2/1 (Rev.1), Req. 78 and 79);
- AC Sources Support Systems (emergency power sources support systems and alternate AC power sources systems) (SSR-2/1 (Rev.1), Req. 68, para. 6.45).
- Other systems, not explicitly mentioned by the SSR-2/1 (Rev.1), but which are usually considered in the international practice and which depend on the design; these are:
    - Equipment and Floor Drainage System,
    - Emergency Raw Water Reserve,
    - De-mineralized Water System,
    - Potable and Sanitary Water System.

However, in this safety guide, only those systems important to safety are considered.

2.8. The detail of the recommendations provided in Section 4 for the design of selected AS&SS is consistent with the importance of those AS&SS.

SAFETY FUNCTIONS

2.9. AS&SS can directly or indirectly contribute to fulfil safety functions, e.g., to ensure essential services (such as electrical, pneumatic, hydraulic power supplies, lubrication) as a support function for a safety system or a safety feature for design extension conditions (DECs). For each AS&SS, safety functions are described, as appropriate, in Section 4.



Definition:

- An auxiliary system is a system that in its own, has no primary function, but it has to be available for other systems, including the main systems, the safety systems and the safety features to ensure their functions.
- An auxiliary system may provide services such as electricity, cooling water, compressed air or other gases, means of lubrication and communication.
- A supporting system is an auxiliary system that supports a safety function.

Remaining auxiliary systems are addressed in this safety guide: Req. 69 to 79 (excluding req. 74) plus other appropriate requirements, including requirement 27 (support service systems) and requirement 37 (communication systems).

Figure 1. Stepwise approach to define the addressed AS&SS

3. GENERAL CONSIDERATIONS IN DESIGN

3.1. This section describes general concepts and provides recommendations for design, that are common to the AS&SS of NPPs, and that are applicable, as appropriate, to all water cooled reactors. The recommendations listed in this section give a guidance to fulfil requirements set forth in SSR-2/1 (Rev.1) for AS&SS, in particular the overarching requirement 69 directly related to performance of AS&SS.

OBJECTIVES OF THE DESIGN

3.2. The design of AS&SS should follow the design objectives of SSR-2/1 (Rev.1), hence to assist the fulfilment of the fundamental safety functions as required in SSR-2/1 (Rev.1), Req. 4.

3.3. The provisions necessary to meet these objectives may vary with any given system, as well as the reactor type, the operating conditions and the plant site conditions.

3.4. According to SSR-2/1 (Rev.1), Req. 69, the design of AS&SS "shall be such as to ensure that the performance of these systems is consistent with the safety significance of the system or component that they serve at the nuclear power plant".

3.5. The design of the AS&SS should be conducted taking into account design recommendations for safety and security in an integrated manner in such way that safety and security measures do not compromise each other. Recommendations for security are detailed in [15].

3.6. The safety class of AS&SS systems or components should be assigned with due consideration of the safety class of the systems or components served by them, and the consequence of the failure of the AS&SS.

3.7. Each system providing an essential service should have the capacity, duration, availability, robustness and reliability to meet the maximum demands of its dependent systems, with appropriate safety margins.

3.8. For passive designs, most of the safety systems rely on the driving forces of buoyancy, gravity, and stored energy sources. This means that they contain no active components (for example: no pumps and include valves that are operated by either air pressure or direct current (DC) electric power from batteries, or use check valves actuated by the pressure differential across the valve). These designs may induce much less need of safety classified AS&SS to support the safety functions.

3.9. The reliability of a safety function depends not only on the systems ensuring its fulfilment but also on the reliability of AS&SS that are needed for the good operability of the supported systems. Therefore, the reliability of AS&SS should be commensurate with the reliability of the supported systems, i.e., the requirements of AS&SS should be consistent with those applied to the supported systems. Hence, the design of AS&SS should be assessed with the same detail as for the main systems supported by AS&SS and the following design basis for structures, systems and components, reflecting SSR-2/1 (Rev.1), applies, as appropriate, to the design of the SSCs of AS&SS.

DESIGN BASIS

General

3.10. The design basis for the safety classified SSC of AS&SS should include any condition created by normal operation, anticipated operational occurrences, accident conditions (design basis accidents (DBA) and design extension conditions (DEC)). Load combinations created by internal and external hazards should also be included in the design basis of the SSC of AS&SS.

3.11. Design conditions and design loads should be derived, as appropriate, from combinations of bounding conditions determined for the relevant plant states or hazards.

3.12. Performances of the SSCs of AS&SS should be derived from the needs induced by the safety functions that the SSCs have to ensure.

Postulated initiating events

3.13. The design should prevent that failures of AS&SSs under the scope of this Safety Guide would lead to a postulated initiating event. If this is not possible, the design should include appropriate measures for the mitigation of this event, considering the effects of the failure of the AS&SS on other plant systems.

Internal hazards

3.14. The following recommendations provide guidance to fulfil the overarching Requirement 17 of SSR-2/1 (Rev.1), in particular paragraph 5.16 specific to internal hazards.

3.15. Internal hazards that should be considered for the SSC of AS&SS design are those of internal origin that may jeopardize the performance of this SSC. A list of typical internal hazards usually considered is provided for guidance; however, this list should be supplemented as needed to include design specific hazards relevant for the SSC of AS&SS:

- Breaks in high energy systems likely to jeopardize the performance of the SSC of AS&SS;
- Heavy load drop;
- Internal missiles;
- Fires and explosions;
- Flooding;
- Electromagnetic interferences.

3.16. Layout and design provisions should be provided to protect the SSC of AS&SS and its associated systems against the effects of the internal hazards:

- The SSC of AS&SS should be protected against impacts of high energy hazards (internal missiles, pipe whipping, heavy load drops) or designed to withstand their loads and the loads caused by explosions as well;
- The redundancies of the systems should be segregated to the extent possible or adequately separated, and protected as necessary to prevent the loss of the safety function performed by the systems;
- The implemented segregation, separation and protection should also be adequate to ensure that the modelling of the system response described in the analysis of PIEs is not compromised by the effects of the hazard;
- A single hazard should not have the potential for a common cause failure between AS&SS supporting safety systems designed to control design basis accidents, and safety features required in the event of accidents with core melting.

3.17. More detailed recommendations are provided in [3] and [5].

External hazards

3.18. The following recommendations provide guidance to fulfill the requirements relevant to external hazards (in particular, Requirement 17 of SSR-2/1 (Rev.1)):

3.19. AS&SS needed to ensure the operation of systems required to mitigate accident conditions should be designed to withstand the design basis earthquake (DBE) and should be protected against the effects of other external hazards and against common cause failure mechanisms that could be generated by those hazards.

3.20. Any SSC whose failure could compromise the operation of above AS&SS should be designed to withstand the design basis earthquake (DBE) and should be protected against the effects of other external hazards and against common cause failure mechanisms that could be generated by those hazards.

3.21. Any SSC of AS&SS whose failure could initiate accident conditions should be designed to withstand the design basis earthquake (DBE) and should be protected against the effects of other external hazards and against common cause failure mechanisms that could be generated by those hazards.

3.22. For each hazard, components of AS&SS whose operability or integrity is required during or after the hazard should be identified and specified in the design basis of the components.

3.23. Methods, design and construction codes used should provide adequate margins to justify that cliff edge effects would not occur in the event of a slight increase of the severity of the external hazards.

3.24. Short term actions related to AS&SS and necessary to meet the dose limits and engineering criteria established for the supported system in the event of design basis accidents or design extension conditions should be accomplished with permanent systems (SSR-2/1 (Rev.1), Req. 17, para. 5.17).

3.25. The autonomy of systems supporting safety functions should be longer than the time necessary prior to crediting off-site support services. The autonomy can be achieved crediting the provisions taken at the unit and at the site provided that the potential for some specific hazards to give rise to impacts on several or even all units on the site simultaneously has been considered (SSR-2/1 (Rev.1), Req. 17, para. 5.15B).

3.26. Compliance with SSR-2/1 (Rev.1), Req. 17, para. 5.21A requires that the SSCs ultimately necessary to prevent early or large releases be still operable in case of external natural hazards exceeding those considered for design taking into account the site hazard evaluation. This applies to AS&SS equipment whose operability is required for this purpose.

3.27. For external flooding, this would mean that either all the structures hosting the above mentioned systems are located at an elevation higher enough than the design basis flood elevation, or that adequate safety features (e.g., water tight doors) should be provided in the design to protect these structures and ensure that mitigating actions can be maintained.

3.28. More detailed recommendations are provided in [6] and [9].

Accident conditions

3.29. Accident conditions relevant for the design of the AS&SS should be those having the potential to cause excessive mechanical loads or to jeopardize the safety functions to which the considered auxiliary system is participating.

3.30. Depending on the design, the failure of some AS&SS has the potential to lead accident conditions, including severe accidents. Therefore, particular attention should be paid to ensure a high reliability of such systems, in particular for accident sequences associated to a loss of off-site power and accident sequences associated to a loss of the cooling chains or a loss of the ultimate heat sink.

3.31. When considering multiple failure DEC, the failure of AS&SS supporting safety systems or safety features should be taken into account.

3.32. Accident conditions should be used for determining capabilities, loads and environmental conditions in the design of the part of the AS&SS needed for these conditions.

3.33. More detailed recommendations are provided in [7] to fulfill requirements 18-20 of SSR-2/1 (Rev.1).

Reliability

3.34. The following recommendations provide guidance to fulfil the requirements 21-30 of SSR-2/1 (Rev.1).

3.35. In order to achieve the adequate reliability of AS&SS supporting safety functions, the following factors should be considered:

- Safety classification and the associated engineering aspects' requirements for design and manufacturing;
- Design criteria relevant for the systems (e.g., number of redundant trains, seismic qualification, environmental qualification, power supplies);
- Consideration of vulnerabilities to common cause failures by means of diversity, physical separation, independence;
- Layout provisions to protect the systems against the effects of internal and external hazards;
- Periodic testing and inspection;
- Maintenance;
- Use of equipment designed to be fail-safe.

Systems designed to manage design basis accidents:

3.36. The design should be such that the safety functions of category 1 or 2, as defined in SSG-30 [8], for which a part of an AS&SS is needed in the event of design basis accidents can be fulfilled despite the consequential failures caused by the postulated initiating event and a single failure postulated in any part of the system needed to accomplish the functions. Unavailability for maintenance, testing or repair should be considered in addition.

3.37. The AC power source should be designed as to have adequate capability to supply power to electrical equipment needed to accomplish the safety functions in the event of design basis accidents. AS&SS equipment required to operate in accident conditions should be powered by the emergency or the alternate power supply source.

3.38. Vulnerabilities for common cause failures between the redundancies of the AS&SS supporting safety systems should be identified, and design or layout provisions should be implemented to make the redundancies independent to the extent practical.

3.39. Recommendations related to the reliability of the systems with regard to the effects of internal or external hazards and environmental conditions are addressed in sections to internal hazards, external hazards and environmental qualification respectively.

Safety features for design extension conditions without significant fuel degradation:

3.40. The reliability of AS&SS supporting safety systems designed for given safety functions should be taken into account when analysis is conducted for identifying needs for additional safety features to fulfil these safety functions.

3.41. The more likely combinations of PIEs and common cause failures (CCFs) between the redundancies of the safety systems should be analysed. If consequences exceed the limits for DBAs, the vulnerabilities should be removed or additional design features should be implemented to cope with such situations. The additional safety features for the concerned safety functions that are reactor technology and design dependent, should be designed and installed such they should be unlikely to fail for the same common cause.

3.42. Similar recommendations as for safety systems designed to manage design basis accidents should be applied, taking into account that meeting single failure criterion is not required and that the relevant additional safety features are expected to be unlikely to fail for the same CCF leading to the failure of systems designed for design basis accidents.

3.43. The additional safety features should be preferably power supplied by the alternate AC power source.

Safety features implemented to mitigate the consequences of an accident with core melting:

3.44. SSCs of AS&SS necessary to mitigate the consequences of an accident with core melting should be capable of being supplied by any of the available power sources.

3.45. Independence between safety systems and specific safety features necessary to mitigate the consequences of an accident with core melting should be implemented in the design. In particular, an AS&SS should not serve both a safety system and a safety feature for a DEC with core melting, unless duly justified.

3.46. Similar recommendations as for safety systems designed to manage design basis accidents should be applied, taking into account that meeting single failure criterion is not required and that the relevant additional safety features are expected to be unlikely to fail for the same CCF leading to the failure of systems designed for design basis accidents.

3.47. Recommendations related to the reliability of the AS&SS with regard to the effects of internal or external hazards and environmental conditions are addressed in the relevant paragraphs.

Defence-in-depth

3.48. The following recommendations provide guidance to fulfil the requirement 7 of SSR-2/1 (Rev.1).

3.49. For a given set of safety functions, AS&SS could participate in the different plant states.

3.50. The following recommendations contribute to implement independence between levels of defence-in-depth:

- For a given safety function, successive items, belonging to different levels of defence, necessary to fulfil that safety function, should be identified;
- Vulnerabilities to CCF between those items should be identified and the consequences assessed. Where the challenge to the safety function leads to unacceptable consequences, the vulnerabilities to CCF should be removed to the extent possible. In particular, safety features designed to mitigate the consequences of accidents with core melting should be independent from equipment designed to mitigate consequences of design basis accidents;
- Independence implemented between systems should not be compromised by vulnerabilities to CCF in I&C systems necessary for the actuation or the monitoring of the systems.

Safety classification

3.51. The following recommendations provide guidance to fulfil Requirement 22 of SSR-2/1 (Rev.1).

3.52. The safety classification of any part of an AS&SS required to support a system to ensure a safety function should be commensurate with the classification of the system supported by this AS&SS. In case part of an auxiliary system is supporting safety systems or safety features of different safety classes, it should have the same safety classification as the system or component having the highest safety classification.

3.53. According to Member States' practices, generally the effect of the failure of a SSC should be considered both on the accomplishment of the function, and on the level of the radioactive releases. For items to which both effects are relevant, the safety class and the associated quality requirements needed to achieve the expected reliability are defined with due account taken of those two effects. For items which do not contain radioactive material, the safety class and the quality requirements are directly derived from the consequences assuming the considered function is not accomplished.

3.54. Engineering requirements applicable to a whole system (e.g., single failure criterion, independence, emergency power supplied) should be commensurate with the consequences assuming the function is not accomplished.

3.55. The safety classification should be established in a consistent manner such that all parts of systems necessary for the accomplishment of a single function are assigned in the same safety class.

3.56. Following the above recommendations:

- In the event of a design basis accident, systems necessary to perform or to support a safety function should be assigned in SSG-30 safety class 1 or 2;

- Systems implemented to cope with the loss of safety systems (DEC conditions without significant fuel degradation) should be assigned in SSG-30 safety class 2 or safety class 3;
- Systems necessary to perform or to support a safety function in the event of an accident with core melting should be assigned at least in SSG-30 class 3.

3.57. More detailed guidance is provided in the Safety Guide SSG-30 [8].

Environmental qualification

3.58. The following recommendations provide guidance to fulfil the requirement 30 of SSR-2/1 (Rev.1).

3.59. The SSCs of the part of the AS&SS supporting a safety function should be qualified to perform their functions in the entire range of environmental conditions that might prevail prior to or during their operation until their mission is completed, or should otherwise be adequately protected from those environmental conditions.

3.60. The relevant environmental and seismic conditions that may prevail prior to, during and following an accident, the ageing of the SSC throughout the life time of the plant, synergistic effects, and margins should all be taken into consideration in the environmental qualification [9] and [10].

3.61. Environmental qualification should be carried out by means of or, as necessary, the combination of:

- type testing on equipment representative of that to be supplied;
- actual testing on the supplied equipment;
- application of relevant past experience in similar applications;
- analysis based on reasonable engineering extrapolation of test data or operating experience under pertinent conditions.

3.62. Environmental qualification should include the consideration, as appropriate, of such factors as temperature, pressure, humidity, radiation levels and local accumulation of radioactive aerosols, vibration, steam impingement, flooding and contact with chemicals. Margins and synergistic effects should also be considered. In cases where synergistic effects are possible, materials should be qualified for the most severe effect, or the most severe combination or sequence of effects.

3.63. Techniques to accelerate the testing for ageing and qualification may be used, provided that there is an adequate justification.

3.64. For components subject to the effects of ageing by various mechanisms, a design life and, if necessary, the replacement frequency should be established. In the qualification process of such components, samples should be aged to simulate the end of their design lives before being tested.

3.65. Components that have been used for qualification testing (actual testing on the supplied equipment) should generally not be used in the construction of the nuclear power plant, subsequent to testing, unless it can be shown that the conditions and methods of testing do not themselves produce any unacceptable degradation of safety performance.

3.66. Qualification data and results should be documented as part of the design documentation.

Codes and standards

3.67. The following recommendations provide guidance to fulfil the requirement 9 of SSR-2/1 (Rev.1).

3.68. Codes and standards have been developed by various national and international organizations, covering areas such as, but not limited to:

- mechanical design;
- structural design;
- selection of materials;
- fabrication of equipment and components;
- inspection of fabricated and erected SSCs;
- electrical design;
- design of instrumentation and control systems;
- environmental and seismic qualification;
- fire protection;
- shielding and radiological protection; and
- quality assurance.

3.69. For the design of safety classified SSC of AS&SS, widely accepted codes and standards should be used. The selected codes and standards should be applicable to the particular concept of the design and should form an integrated, comprehensive and consistent set of standards and criteria. If different codes and standards are used for different aspects of the same item or area, their consistency should be clearly demonstrated.

3.70. For design and construction, the newest edition of codes and standards should be preferably considered. However, another edition might be used with appropriate justification.

Layout considerations

3.71. The layout of AS&SS should ensure access for necessary activities and minimize adverse interactions while not compromising security aspects, thus the layout should:

- make provision for construction, assembly, installation, erection, maintenance, decommissioning, and demolition;
- ensure appropriate conditions (e.g., easy access, lighting) to carry out necessary activities (e.g., inspection, maintenance);

- ensure that the radiation exposure of workers performing task on AS&SS are in line with the ALARA principle;
- minimize adverse interactions with other SSCs in all plant conditions;
- provide alternative means to access to AS&SS that could require local manual operations;
- ensure safe means to escape and to get access for rescue, with normal and emergency lighting.

3.72. Unauthorized access, including remote access to computer systems, or interference with AS&SS should be prevented by design.

3.73. As a general rule, all AS&SS should be designed and routed so that, in the event of a fault or accident, sufficient capability to perform the safety functions those AS&SS are supporting will remain.

Interface considerations

3.74. Cross-connection of AS&SS providing essential services to each other or with lower safety class of AS&SS that could compromise the functionality of those should be avoided, unless it can be proven that the cross-connection is beneficial in terms of safety. Where such cross-connections are established, provision should be made to enable the isolation of the essential service from these other services if necessary.

Considerations for a multiple unit nuclear power plant

3.75. The following recommendations provide guidance to fulfil the Requirement 33 of SSR-2/1 (Rev.1), regarding a multiple unit nuclear power plant.

3.76. The design should be such that AS&SS supporting safety systems or safety features for DEC should not be shared between units of a multiple unit nuclear power plant.

3.77. Means allowing interconnections between units should be considered in the design in order to further enhance safety.

Use of Probabilistic Safety Assessment in the design

3.78. The following recommendations provide guidance to fulfil Requirement 10 of SSR-2/1 (Rev.1), regarding the use of probabilistic safety assessment (PSA).

3.79. The use of PSA should not be considered as a substitute to a design approach that is based on deterministic requirements, but as a part of the process to identify safety enhancements and to judge their effectiveness.

3.80. PSA should complement the deterministic safety assessment, in particular in checking and in adjusting the list of multiple failure conditions involving AS&SS, and in identifying additional safety features to achieve a balanced design.

3.81. In this respect, PSA should be considered as a good tool to assess the consequences of the loss of AS&SS on the supported system or function. However, PSA should be used taking into account its limitations.

3.82. As a complement to a number of investigations related to fabrication, testing, inspection, evaluation of the operating experience, PSA should be used with deterministic safety assessment in demonstrating a very low probability of early or large releases for postulated design extension conditions with core melting. This should include the reliability of involved part of AS&SS supporting a safety function, e.g., heating, ventilation and air conditioning (HVAC) systems and other aspects usually considered in Level 2 PSA.

4. SPECIFIC CONSIDERATIONS IN DESIGN

4.1. The recommendations below are given for selected examples of AS&SS of a common design. It is recognized that for other designs, including passive designs, the configurations of the systems may be different; hence, some of the recommendations may not be appropriate or may need some judgement in their interpretation and adaptation to those systems.

4.2. The selected examples of AS&SS include all those AS&SS explicitly identified as such in SSR-2/1 (Rev.1), and other AS&SS, selected owing to their importance for safety.

4.3. For the selected examples, the recommendations are provided according to the following structure:

- System / equipment functions;
- Specific design basis.

4.4. If no information is provided, general considerations apply as given in Section 3.

4.5. Owing to the importance of the reliability of AS&SS supporting safety systems or safety features for DECs to fulfill their safety functions, the recommendations provided in Section 4 are aimed at ensuring a high reliability of those AS&SS.

COMMUNICATION SYSTEMS

4.6. The following recommendations provide guidance to fulfil Requirement 37 of SSR-2/1 (Rev.1), regarding effective means of communication to be provided throughout the nuclear power plant to facilitate safe operation in all modes of normal operation and to be available for use following all postulated initiating events and in accident conditions.

4.7. Usually the means devoted to communication include:

- An alarm system designed as an acoustic loudspeaker system that can deliver site alarms or unit alarms from the main control room or supplementary control room (also referred to as remote shutdown panels). Different kinds of alarms can be transmitted: fire and other evacuation alarm, general alarm,
- A verbal communication system permitting the search for personnel within the plant. This system is composed of:
    - a wired communication system for direct voice communication between the main control room (or the supplementary control room when the control room is unavailable) and local control stations;
    - a page system to enable plant-wide paging of personnel;
    - specific audible means for alerting personnel in noisy areas.
- The telephone communication systems. These systems include:

  - The main telephone system used for general communications. The capacity of this system is consistent with the normal operational needs of the plant;
  - The secondary telephone system that constitutes a back-up telephone system used in case of unavailability of the main telephone system;
  - A wireless system that can be used in normal and emergency conditions (e.g. e.g. satellite telephone).
- The off-site communication system that provides communication links with external organizations and facilities, including safety authorities. It is particularly used in case of emergency planning and response.
- Other television systems to monitor maintenance actions outside of the main control room or major components (e.g., reactor coolant pumps, strategic places in the containment).

System/equipment function

4.8. An appropriate communication system should be provided for the purpose of information flow and transfer of instructions between the different locations so that all persons present at the nuclear power plant and on the site can be given warnings and instructions, in normal operational states, AOO and in accident conditions. The communication system should also provide the appropriate mobility necessary for the performance of mobile activities.

4.9. To contact the staff responsible for managing and supervising plant operations within the station or in the immediate vicinity, two independent systems should be provided:

- a loud-speaker system,
- a dedicated paging system to allow plant-wide paging of personnel.

4.10. The emergency preparedness and response center should be equipped with diverse communication systems which are suitable to alert the on- and off-site organizations responsible for nuclear emergency preparedness and response, as well as to communicate with the main control room and supplementary control room, and the off-site nuclear emergency preparedness and response organizations.

4.11. Communication facilities should be provided in the main control room to facilitate safe and efficient plant operation. Special consideration should be given to the design of communication facilities to be used in accident conditions to communicate with the emergency preparedness and response centre.

Specific design basis

4.12. Communication systems essential to the safe operation should be designed and routed in order to have the capacity to provide effective intra-plant communications (internal communication system) and effective plant-to-off-site communications (external communication system) during normal plant operation, AOO, accident conditions, and relevant internal or external hazards.

4.13. The internal and the external communication systems should have a backup power source.

4.14. Communication systems essential to the safe operation and emergency communication system ensuring a safety function (safety category 3) should have an appropriate safety classification.

4.15. Effective communication should not be impeded by interference from other electronic or electrical equipment. However, wireless communication equipment should not affect important to safety items by interference.

4.16. The main control room should be designed as the communication centre of the plant for normal operation and during the early stage of an accident.

4.17. The alarm system should be designed to deliver:

- Site alarms for accident conditions which affect the whole site. These alarms are broadcasted to all locations on the site.
- Local plant alarm for accident conditions whose impact is limited to one part of the plant.

4.18. The sound level of the audible alarm system (e.g., sirens) should be higher than the station background noise and compatible with the use of protective equipment by personnel. An illuminated alarm signal should be used in high-noise areas, in addition to the audible alarm system.

4.19. The paging system should reach all areas of the plant and be audible over the whole site, both inside and outside the buildings. The design should be such that it is possible to use this system from the main control room, the main control room having a priority over other available control points.

4.20. A main telephone system should be installed with the necessary number of access locations to respond to operational requirements. Its capacity should be sufficient to cover the needs of all the staff involved in work at the plant.

4.21. In case of unavailability of the main telephone system, a back-up telephone system should provide telephone links between all sensitive plant zones. This secondary telephone system should be totally independent from the main telephone system.

4.22. A wireless system with the capability to ensure normal and emergency communications with plant and off-site personnel should be installed. The wireless system should be independent of the main and secondary telephone systems, and should be tested for ‘dead zone’.

4.23. An external communication system should be provided for the Emergency Preparedness and Response needs. This system should provide links with the standby crisis team, the radiological monitoring teams and to outside organizations involved in emergency conditions. Safe, permanent, acoustic, and two-way voice links should be provided with the public authorities: These links should be direct “station to station” telephone links since no dialing is necessary.

4.24. The intra-plant and the external communication systems should be adequate for the coordination of emergency preparedness and response activities.

4.25. Other communication facilities including a television system should be provided to enable monitoring of specific important areas notably of difficult access such as the reactor coolant pumps areas or strategic locations inside the containment.

4.26. Detailed recommendations relevant to the diversity of communication systems (para. 8.39 to 8.46) are included in SSG-39 [11].

HEAT TRANSPORT SYSTEMS

4.27. The following recommendations provide guidance to fulfill the requirement 70 of SSR-2/1 (Rev.1) that address the need for removing the heat from systems and components that are required in operational states and accident conditions. The following paragraphs of this Section concern the heat transport systems other than those used for residual heat removal which are addressed in DS481 and DS487. The following systems are parts of heat transport systems:

- The water cooled components such as part of the SSCs cooled by the component cooling water system (e.g., thermal barrier of the reactor coolant pump, non-regenerative heat exchanger of the chemical and volume control system, pump motors and bearings); in some designs, component cooling water system can be either recirculated cooling water system (RCWS) or open loop water system;
- The chilled water system used to cool some Heating, Ventilation and Air Conditioning (HVAC) systems;
- The ventilation systems performing cooling by air renewal (circulation/ recirculation).

4.28. As the ventilation systems are addressed in the section 4.5, only the water cooled components and the chilled water system are concerned here after.

General common considerations for heat transport systems

System/equipment function

4.29. The heat transport system design should be such that sources of heat generation are sufficiently cooled to ensure that they continue to perform their design function(s), and that the systems that they serve are capable of performing their safety function under all operational and accident conditions.

Specific design basis

4.30. The design of a heat transport system should take into account all forms of heat loads likely to affect a particular process. Adequate cooling of SSCs by heat transport equipment such as heat exchangers and coolers (bearing, oil coolers, electrical equipment) should be provided so as the temperature limit is not exceeded.

4.31. In addition to the heat loads to be considered, the heat transport system capability should be ensured taking into account the design temperature limits of the heat sink and suitably pessimistic considerations (calculation performed with appropriate allowances for uncertainties).

4.32. When a heat transport system ensures the cooling of equipment needed for a safety function:

- This heat transport system should have a safety classification commensurate with the safety function supported and meet the corresponding design requirements. Notably, for heat transport pipes located outside buildings, the necessity to provide trace heating for protecting them against extreme cold weather or other relevant external hazards should be considered;
- The reliability of the cooling chain should be assessed taking into account the common-mode failures and if necessary a diverse part of the cooling chain should be implemented.

4.33. The risk of a leak of the reactor coolant or cooling medium through the boundary should be considered and the consequences of this leak should be assessed with regard to a possible cooling function loss, radiological impact or dilution induced by mixing of boron water with clear water.

4.34. A heat transport system supporting a safety function should include a means of monitoring coolant levels and/or direct leak detection to facilitate early detection of coolant loss. On detection of coolant loss, reserve supplies of coolant should be available to provide make-up. Sufficient stocks of coolant should be provided to ensure adequate cooling after all situations to be considered in accident conditions and adequate provisions should be made to replenish stocks and ensure long-term heat removal. Alternatively, the installation of completely separate safety trains, including a make-up for each train, is another solution for providing appropriate cooling provision in the short term and in the longer term.

Chilled water system (CDWS)

4.35. Usually, the CDWS provides chilled water for cooling HVAC loads (e.g., cooling of the main control room ventilation, of the electrical building ventilation or containment ventilation during power operation) and some other process loads. The chillers of the CDWS are cooled by the Component Cooling Water System (CCWS), or by air.

System/equipment function

4.36. An NPP should include CDWS system supplying, in normal operation, AOO and accident conditions, a sufficient quantity of chilled water in specific areas for ensuring cooling of HVAC systems (e.g., electrical building and main control room ventilations) and process loads.

Specific design basis

4.37. The part of the CDWS used as a supporting system needed for a system ensuring a safety function (safety category 1 or 2) in case of DBA should have an appropriate classification and meet the corresponding design requirements (redundancy, emergency power supplied, protection against the internal and external hazards, the periodical tests, quality assurance, and, designed and fabricated according acceptable design codes).

4.38. CDWS lines penetrating the containment should be provided with appropriate automatic containment isolation features [12]. This part of the CDWS system should be safety classified (safety category 1) and should meet the corresponding design requirements.

4.39. The performance of the chillers of CDWS should be based on:

- the extreme design temperature of the CCWS water when CDWS is cooled by CCWS or by the extreme design site conditions when cooled by air, and
- the maximum heat loads.

4.40. Some plant designs have heat transport systems for items important to safety separate from those for items not important to safety. If this is not the case, adequately classified isolation of the part of the system serving items that are not essential for safety should be ensured (Requirement 70 of SSR-2/1 (Rev.1)).

4.41. The reliability of heat transport to the ultimate heat sink should be assessed. If this reliability is insufficient, diversity should be installed (e.g., cooling of some chillers by air if this cooling is initially performed by CCWS and vice versa).

4.42. Due to condensation concerns, all the cold parts of the CDWS system should be insulated after painting except parts regarding the accessibility to common maintenance points.

4.43. Equipment in contact with outside air should be protected against corrosion, notably for the plant located near the sea side and protected against freezing.

CCWS (portion other than for residual heat removal)

System/equipment function

4.44. The CCWS should achieve the following functions:

- To remove heat from equipment and transfer it to the ultimate heat sink in operational states and accident conditions;
- To ensure a protection against release of radiological contamination into the ultimate heat sink.

Specific design basis

4.45. Heat transfer capacity of the CCWS during accidents is addressed in [2], revised as DS481.

4.46. When the CCWS cools components containing reactor coolant (e.g., thermal barrier of the reactor coolant pump as applicable):

- The CCWS should be a closed loop to prevent leak of primary coolant to be released into the ultimate heat sink.
- CCWS chemistry should be controlled to prevent corrosion.
- An activity monitoring system should be designed to detect radioactivity in the CCWS.
- The CCWS should be protected against over pressure caused by leaks occurring in heat exchangers with interfaces with coolant systems operated at higher pressure. In this case, the CCWS should be designed to prevent primary coolant leaks outside of the containment by means of isolation of the pressurized portion of CCWS.

PROCESS AND POST-ACCIDENT SAMPLING SYSTEM

4.47. The following recommendations provide guidance to fulfil requirements 71 and 82 of SSR-2/1 (Rev.1).

4.48. The Process and Post-Accident Sampling System (PPASS) provides all the samples to be analysed during normal operation or in post-accident sampling. According to the analysis to be performed, these samples are distributed to diverse facilities including the radiation monitoring process facility. The following recommendations concern all the sampling carried out and the process radiation monitoring facility. In some design the nuclear sampling and the radiation monitoring process are not joined in a single system and constitute two separate systems.

System/ equipment function

4.49. The PPASS should be capable to provide the water and gaseous samples, during all normal modes of operation, needed for analysing the chemical and radiochemical characteristics of the reactor coolant and associated AS&SS (e.g., Emergency Core Cooling System, Residual Heat Removal System, Chemical and Volume Control System, and Reactor Water Clean-up for BWR) as well as the containment atmosphere and the secondary system.

4.50. The PPASS should have the capability to sample all normal process systems and principal components including AS&SS (e.g., systems for treatment of effluent) needed to monitor the compliance with the operational limits and conditions.

4.51. The PPASS should have the capability to provide samples needed to get information during normal operation allowing the operator to identify conditions that could jeopardize the integrity of the reactor coolant pressure boundary.

4.52. The PPASS should confine radioactive substances when a sample line is connected to a system containing radioactive fluid, should collect, condition and deliver representative samples of fluids (liquids and gases) to one or more sampling stations.

4.53. As regards the spent fuel pool, the PPASS should have the capability to detect conditions that could result in excessive radiation levels and excessive personnel exposure and to provide information necessary for the control of water chemistry required for the integrity of the fuel assembly cladding, the internal structures of the spent fuel pool and the cooling systems of the spent fuel pool.

4.54. The PPASS should perform monitoring of boron concentration in the RCS (during Normal Operation and accident conditions for PWR, and after an ATWS event for BWR) and gadolinium for PHWR.

4.55. In normal conditions, AOO, DBA and as far as possible in DEC, the radiation measures of the PPASS should:

- ensure the monitoring of confinement barriers;
- ensure the monitoring of radioactive releases and provide the information needed for performing the diagnosis of the plant radioactivity state;
- where necessary, for warning of risk for personnel exposure;
- provide the information needed to implement automatic or manual actions to limit radiological consequences by confinement of radioactive materials.

In particular, the radiation measures should, as applicable:

- monitor the activity of the steam generator in order to detect an unacceptable steam generator tube leak and the necessity to initiate the isolation actions of the SG impacted;
- monitor during the cold shutdown the activity of the containment and the fuel building in order to detect a fuel handling accident needing evacuation alarm and actions for ensuring the radioactivity confinement;
- monitor the activity of gas effluents in order to verify the compliance with the regulatory limits of the radioactive releases;
- provide the information needed to ensure the confinement of radioactive substances located in the the controlled areas outside containment; and
- provide the information needed to perform the diagnosis of radioactivity level in AOO and accidental conditions.

4.56. Sampling points for some systems should be installed for intermittent monitoring by laboratory analyses (especially for systems which do not operate in normal operation conditions).

Specific design basis

4.57. In normal operation, the PPASS should be designed to provide the samples needed to ensure fulfillment of design requirements and operational needs. The PPASS design should be consistent with the monitoring needed to support compliance with the requirements on water and gas characteristics of the reactor coolant and associated AS&SS (moderator and its auxiliaries for PHWR), containment atmosphere and secondary system.

4.58. The PPASS should be designed to function in all DBA and during DEC for which samples are needed (e.g., samples from both the gas and the water within the reactor containment during severe accidents).

4.59. The selection of sampling points is design dependent. For each sampling, according to its significance, it should be decided whether:

- a continuous analysis, using on-line monitors installed on a sampling line, is needed, or
- an occasionally analysis by taking intermittent samples manually is sufficient.

4.60. A systematic analysis should be performed by a laboratory located within the plant. For specific infrequent analysis, the use of a laboratory located outside the plant or outside the site could be acceptable. In all cases, the design and arrangement of the PPASS should be such that the time span between the sampling and the analysis is minimized; this could be achieved by reducing distances or considering fast transportation means of the samples.

4.61. Provisions should be made to ensure representative samples from liquid and gaseous process streams and tanks. For example, a sample within a tank would be performed on the recirculation loop in order to avoid sampling from low points or potential sediment traps. For a process stream sample, sample points should be located in turbulent flow zones. Where necessary, fluids of the sampling should be cooled and reduced in pressure before analysis.

4.62. PPASS should permit the monitoring in normal operation of variables and systems that ensure safety including variables and systems that can affect the fission process, the integrity of the reactor core and the reactor coolant pressure boundary. The PPASS should provide information for evaluating whether safety systems and other systems important to safety are preserved from abnormal failure or in conditions permitting them to ensure their intended safety functions.

4.63. For example, PPASS should, as applicable:

- provide primary and secondary water chemistry permitting verification that key chemistry parameters, such as chloride, hydrogen, and oxygen concentrations, are within prescribed limits, assuring that mechanisms of corrosion will be mitigated and will not adversely affect the reactor coolant pressure boundary;
- allow verification in normal operation that the boron concentration of the refueling water storage tank water is adequate to guarantee core sub-criticality in case of relevant accident conditions; and
- provide samples to check that chemical concentration in the spray chemical additive tank is within the limits that guarantee, in the containment and during accident conditions, the meeting of iodine removal requirements as well as material compatibility requirements.

4.64. Sample discharge, purge and drain samples should be returned, whenever possible, to the system being sampled or to an appropriate waste treatment system in order to keep radiation exposures at ALARA. In case of recycling in the RCS for PWR (moderator for PHWR), the material of sampling component should meet the recommendations on the materials of RCS.

4.65. In order to control the radioactive releases, the sampling line should have a closed fail safe position.

4.66. Provisions should be taken for limiting the radioactive releases in case of reactor coolant sample line rupture (passive flow restriction or redundant isolation valves qualified and automatically closed).

4.67. The safety classification and the seismic resistance of a sampling line until the second isolation valve should be consistent with the ones of the system sampled.

4.68. Downstream the isolation valves, the PPASS providing samples from safety components should be considered as ensuring a safety function of safety category 3 and should have an appropriate safety classification.

4.69. Sampling lines connected to systems located inside the containment should be provided with appropriate automatic containment isolation features [12]. For example, sampling lines from the RCS, the residual heat removal system, or the emergency core cooling system have at least two isolation valves. These containment isolation features should be safety classified (safety classification appropriate with the safety function of safety category 1) and meet the associated design requirements (redundancy, emergency power supplied, protection against the internal and external hazards, the periodical tests, quality assurance, and, designed and fabricated according acceptable design codes). As in post-accident condition, it may be necessary, as applicable, to sample the primary coolant so as to check the boron concentration, to measure the primary activity and to determine the composition of the primary coolant fission products. To do these verifications, it should be possible to reopen the primary coolant lines sampling after a certain time when the radiological conditions at the sampling locations enable the implementation of specific provisions.

4.70. The system should be designed and constructed so that radiological dose to the plant workers is as low as reasonably achievable (ALARA).

4.71. Appropriate station layout and design features (e.g., radiological protection, radioactivity alarms, sufficient ventilation rate of air renewal) should be provided to reduce the potential doses to personnel who must perform or analyse a sampling or intervene near to a PPASS). Notably, to ensure the protection of operating staff, piping carrying the highly active contaminated fluid should be placed behind a biological shield wall. Frequently needed information should be displayed and actuators should be operable in front of the biological shielding wall.

4.72. For reducing radiation exposure, the following measures should be adopted in the system design:

- The work space in a zone of high radiation levels around PPASS components that require regular maintenance should be shielded from the radiation from other systems;
- Sufficient free work space should be foreseen for carrying out the maintenance of PPASS components;
- Methods for countermeasures (e.g., flushing) to avoid the sedimentation of radioactive sludge in sampling lines should be provided. In addition, the low points should be limited to avoid sedimentation in the sampling lines.

4.73. The design of the PPASS should allow the collection and analysis of highly radioactive samples during a post-accident condition. This concerns notably the reactor coolant, the containment sump and the containment atmosphere samples needed for the information related to the pH of water recirculation, the hydrogen concentration and the fission products within the containment atmosphere.

4.74. The design and arrangement of the sampling features should be such that the time between sampling and analysing is minimized. The reduction of distances or implementation of fast transportation systems should be considered.

4.75. Samples that are radioactive or potentially radioactive should be segregated from non-radioactive samples. The segregation level should be consistent with the requirements of the Equipment and Floor Drainage System (EFDS) and treatment of effluents.

4.76. When an analysis is performed outside the containment, re-injection of highly radioactive samples within the containment should be provided if there is a risk to exceed the treatment capability of such a waste.

4.77. Radioactive liquid samples should be processed in glove boxes made from a material, such as stainless steel, which have a surface that allows them to be easily decontaminated. The glove boxes, which should be specifically reinforced, should be kept at negative pressure and connected to permanent iodine traps via the ventilation system, ensuring biological protection for the sampler. Furthermore, a means for degassing samples if needed should be provided, in order to reduce the activity of the liquid sample taken.

4.78. Integrity of the first and second confinement barriers should be monitored continuously by measurement of the activity of fluids (e.g., reactor coolant and containment atmosphere) in contact with the barriers in all design conditions. For the second barrier, radioactive monitoring should be performed continuously on the atmosphere located near the reactor coolant pipes.

4.79. The activity of fluid (liquid or gas) which are not normally active but could be contaminated by leakages from radioactive systems (e.g., leakage of thermal barrier of the reactor coolant pump or heat exchanger of spray containment system), in case of loss of integrity of the confinement barrier, should be monitored.

4.80. The atmosphere of different buildings such as the reactor, fuel, nuclear auxiliary, safety system auxiliary and waste treatment buildings should be monitored continuously by radiation measures.

4.81. For detection of a leak of the confinement barrier, liquid from the component cooling system should be monitored by radiation measures as well as from the secondary side of the SG for PWRs and PHWRs.

4.82. For some post-accident conditions such as LOCA or severe accidents, the radiation measures should provide monitoring and counting of the radiological releases into the containment atmosphere. In addition, for BWRs this monitoring and counting should be extended to other areas containing RCS lines.

4.83. For the personnel protection, a continuous monitoring of the atmosphere of the containment should be provided to allow personnel intervention and to deliver alarm for personnel evacuation notably further to a fuel handling accident. In addition, surface contamination should be monitored in all areas containing large amount of radioactive liquids and solid waste.

4.84. The PPASS should provide information regarding the release of radioactive materials necessitating the initiation of actions for protecting the health and safety of personnel and the public.

4.85. As applicable, activity measures in the main steam pipes, blow-downs of the SGs and condenser should be provided to monitor secondary side activity continuously and provide operator’s alarm.

4.86. The PPASS should have the capability to monitor the radioactivity of gaseous radwaste storage tanks in order to detect abnormal levels of radioactivity in the radwaste processing facilities.

4.87. To ensure the habitability of the main control room in case of radioactive contamination of the site, radiation measures should monitor the main control room air inlet and activate the iodine and particulate filters of the main control room ventilation (see section on control room ventilation system).

4.88. Air contamination monitoring should be provided on the main ventilation ducts from rooms subject to contamination, e.g., rooms in the fuel and nuclear auxiliary buildings. In case of air contamination, part of the normal ventilation should be isolated and HEPA filters and iodine filters should be activated (see section on air conditioning systems and ventilation systems).

4.89. Any tank which may contain radioactive fluid as a result of leaks should be monitored in accordance with the waste processing system functions.

4.90. Continuous measures of activity concentration of liquid releases should be provided on the liquid radwaste discharge system when discharge is taking place. With threshold overshoot, automatic isolation of the discharge line should occur accompanied by an alarm.

4.91. All gaseous releases should be discharged through a single ventilation stack. The activity of noble gases within the stack should be recorded over a wide range of activity and should include alarm. In addition, iodine, aerosol, tritium and Carbon14 releases of the stack should be monitored.

4.92. Measures of exposure rate should be continuously provided for each sump susceptible to collect highly contaminated water. Moreover, automatic isolation of the discharge of sumps to the radwaste processing system should occur on radioactivity threshold overshoot.

4.93. In addition, the PPASS should to provide all the information required by the emergency plans.

4.94. More detailed guidance on radiation protection aspects in the design of nuclear power plants is provided in the safety guide NS-G-1.13 [4].

COMPRESSED AIR SYSTEM (CAS)

4.95. The following recommendations provide guidance to fulfil the requirement 72 of SSR-2/1 (Rev.1).

4.96. Usually, the CAS provides compressed air to air service system, to pneumatic instruments and actuators. In the following paragraphs, emphasis will be given to a compressed air system which provides compressed air to pneumatic instruments and actuators.

System/ equipment function

4.97. A CAS should provide a continuous supply of compressed air to pneumatic instruments and actuators supporting components ensuring a safety function, in sufficient quality, cleanliness, volume flow and pressure in every design condition.

Specific design basis

4.98. The part of the CAS providing compressed air to actuate or control equipment that performs safety functions during normal operations, transients or accidents should have a safety classification consistent with the safety function supported and meet the corresponding design requirements.

4.99. If CAS provides air for important to safety and not important to safety components, the important to safety components should be able to be isolated from the not important to safety components.

4.100. The safety part of the CAS should ensure its function during adverse environmental phenomena, abnormal operation including loss of off-site power, or accident conditions notably a loss-of-coolant accident or main steam line break. In particular, where reserve air supply tanks are installed inside the containment, the increased internal pressures caused by the high temperatures in the containment during design basis accidents should be taken into account in their design.

4.101. If the operation of a pneumatic actuator is necessary during accident conditions, the autonomy of the compressed air system (such as by means of having reserve air tanks) should be consistent with the time during which the safety function needs to be ensured. Otherwise, installation of a backup compressed air system should be considered (safety guide NS-G-1.10 [12]).

4.102. Notably, if this autonomy is ensured by a compressed air storage tank, the upstream filling pipelines should be equipped with check valves, to maintain air supply of the consumers (to prevent depressurization through upstream pipelines that are not safety classified). Periodic tests for monitoring of the leak tightness of these check valves should be performed.

4.103. Where required to support essential systems, the availability of compressed air reserves should be sufficient to be consistent with the timescale for the availability of mobile equipment to refill compressed air tank.

4.104. The compressed air systems should be designed in such a way as to avoid a containment bypass or pressurization of the containment. Systems located inside the containment that are needed in the long term after an accident should therefore not depend on compressed air systems for fulfilling their safety functions. To avoid gradual pressurization of the containment due to the leakage of compressed air systems, consideration should be given to the installation of a dedicated post-accident compressed air system to supply instruments inside the containment with air exhausted from the containment (safety guide NS-G-1.10 [12]).

4.105. Compressed air lines penetrating within the containment should be provided with automatic isolation features. These containment isolation features should be safety classified (safety category 1) and meet the associated design requirements (redundancy, emergency power supplied, protection against internal and external hazards, the periodical tests, quality assurance, and, designed and fabricated according acceptable codes).

4.106. The quality of the compressed air being highly influenced by the quality of the intake air, provisions should be made for the selection of air intake position (e.g., dust-free environment, away from non-breathing gases like combustible gases).

4.107. Adequate compressed air quality (dew point, particle size, maximum total oil or hydrocarbon content, humidity, chemical pollutant) should be ensured at the consumption points in every operation condition and should be consistent with the consumers’ requirements. Therefore, periodic monitoring should be performed downstream the air compressor.

4.108. The pipeline routings should provide the draining of condensable gases and vapor. The possibility of liquid plugs should be avoided by utilizing adequate slope.

4.109. To increase reliability of the instrument air systems, ring topology and air distributors (headers) should be used. Redundant valves should be supplied by different air distribution headers.

AIR CONDITIONING SYSTEMS AND VENTILATION SYSTEMS

4.110. The following recommendations provide guidance to fulfil Requirement 73 of SSR-2/1 (Rev.1).

General common considerations for Heating, Ventilation, and Air Conditioning (HVAC) systems

4.111. The safety requirements of a HVAC system depend on its safety functions. It is usual to distinguish the following categories:

- The HVAC systems or part of these systems participating in the limitation of radioactive releases, in particular by filtering the air in specific areas: This category includes notably the engineered safety feature ventilation system (ESFVS) of the controlled area, the fuel building ventilation System (FBVS), the auxiliary and radwaste area ventilation system (ARAVS), the containment sweeping ventilation system, and annulus ventilation system if applicable;
- The HVAC systems maintaining the ambient conditions required for systems and components important to safety and the Control Room habitability: This category includes notably the electrical building ventilation system, the diesel generator building ventilation system, the pumping station ventilation system and the control room area ventilation system (CRAVS).

System/ equipment function

4.112. An NPP should include HVAC systems participating in the third fundamental safety function by a confinement of the radioactive substances limiting the radioactive releases in the environment for accident conditions.

4.113. The HVAC systems should ensure one or more of the following functions as appropriate:

- To maintain the ambient conditions of rooms in terms of temperature, humidity and airborne radioactive substances;
- To monitor and limit the gaseous radioactive releases during normal operation, anticipated operational occurrences (AOO) and accident conditions;
- To protect the personnel and/or equipment from risks coming from inside or outside the buildings.

4.114. The ambient conditions of rooms in terms of temperature, humidity and airborne radioactive substances should be maintained within the acceptable limits for equipment important to safety and the conditions compatible with the presence of personnel in renewing and filtering the air in rooms accessible by personnel. To reach these conditions, the HVAC should provide a sufficient minimum rate of air renewal that depends of the exposure risk.

4.115. The gaseous radioactive releases during normal operation, anticipated operational occurrences (AOO) and accidental conditions should be monitored and limited:

- in maintaining the pressure of rooms located in controlled areas below the atmospheric pressure in order to prevent the dispersion of radioactive substances into the atmosphere in normal operating conditions. For example, to maintain negative pressure in controlled areas flowrate intake air should be less than extraction flowrate air;

- in maintaining an air flow going from rooms with a lower contamination risk towards rooms with higher contamination risk, as practicable for accident conditions;
- in filtering the air in contaminable or potentially contaminable areas before discharging this air to the environment in order to meet authorized limits on discharges in normal operating conditions and AOO as well as to keep them as low as reasonably achievable, and to guarantee compliance with radioactive discharge objectives in accident conditions. The radioactivity of the air extracted from the controlled area should be monitored. This air should be discharged to the vent stack.

4.116. The personnel and/or the equipment should be protected against some risks coming from inside the buildings (more particularly anoxia, fire propagation and explosion in rooms were combustible gas can be produced) and from outside buildings (more particularly external explosion and extreme weather conditions).

Specific design basis

4.117. The list of iodine risk rooms, including rooms where systems containing active liquid are likely to release significant iodine activity during accident conditions should be considered in the design as well as adequate criteria for the confinement function of these rooms under the various accident conditions.

4.118. The ventilation of iodine risk areas should contribute to the limitation of radioactive releases.

4.119. The design of the HVAC systems participating in the limitation of radioactive releases should control and limit the discharge of radioactive substances during normal operation, AOO and accident conditions.

4.120. The design of the HVAC systems participating in the limitation of radioactive releases should filter the exhausted air by pre-filters, high-efficiency particulate air (HEPA) filters and, if necessary, by iodine filters before being discharged to the stack. The efficiency requested for the HEPA and iodine filters have to be consistent with the authorized radioactive releases in normal operation and AOO and with radiological objectives in accident conditions.

4.121. For determining the rate of air renewal, the following conditions should be considered:

- Areas where the risk of internal exposure is important;

- Areas where the risk of internal exposure is negligible;
- Areas where the risk of internal exposure is non negligible but without risk of iodine releases.

4.122. Particular measures should be taken to protect iodine filters from fire due to the air heating by electric resistance, the presence of high fire load and the risk of radioactive materials release by a fire. Such measures could include:

- Locating the filter in a fire compartment;
- Monitoring of the air temperature and automatic isolation of the air flow;
- Provision of automatic protection by means of a water sprinkler to cool the outside of the iodine filter vessel;
- Provision of a water spray system inside the charcoal vessel with a manual hose connection. In designing such a system, it should be recognized that if the flow rate of the water is too low, the reaction between overheated charcoal and water can result in the production of hydrogen. To prevent this, a high water flow rate should be used.

4.123. Where combustible filters are used in a HVAC system whose subsequent malfunction or failure could result in unacceptable radioactive releases, appropriate precautions should be taken. These could include the following measures:

- Filter banks should be separated from other equipment by means of adequate fire barriers;
- Appropriate methods (e.g., upstream and downstream dampers) should be used to protect the filters from the effects of fire;
- Fire detectors, carbon monoxide gas sensors (preferably after the filters) or temperature sensors (before the filters) should be installed inside the ducts before and after the filter bank.

4.124. The design of the HVAC systems participating in the limitation of radioactive releases, in particular iodine risk, should be adequate to the iodine risk and notably should take into account wind effects.

4.125. The design of the HVAC systems maintaining the ambient conditions (temperature, humidity, contamination and new air) necessary for the operation of components important to safety, the personnel accessibility and the habitability of the control room should take into account the basic atmospheric conditions and the extreme atmospheric conditions (e.g., temperature, humidity, and their duration) defined for the design of the NPP.

4.126. When part of a HVAC system is a support system required to permit to a safety system to ensure its safety function (safety category 1 or 2) in case of DBA, it should have an appropriate safety classification and consequently meet the associated design requirements such as:

- Redundant design to satisfy the single failure criterion;

- Powered by the on-site emergency AC power system;
- Protection against internal and external hazards. Notably, the redundant trains should be physically separated and the components should be seismic resistant. More particularly and unless duly justified:
  - Ventilation system should be designed to prevent explosive or toxic gases and heat from external sources from entering buildings containing items important to safety;
  - Intake and exhaust ventilation should be protected against external explosion;
- Inspection and periodic test for which guidance is detailed in [16];
- Components designed, manufactured, commissioned and tested according to acceptable quality standards;
- Components designed and manufactured according to acceptable design codes.

4.127. The HVAC system layout choice should not impair fire protection capabilities and should be designed to avoid the risk of fire spread. In particular:

- Ventilation systems should not compromise building compartmentation;
- Sufficient isolation by rated fire dampers or fire resistant ductwork should be installed if an HVAC duct has to cross areas belonging to different fire compartment or alternatively parts of the ventilation system (e.g., connecting ducts, fan rooms and filters) that are situated outside the fire compartment should have the same fire resistance as the crossed compartment;
- The temperature or pressure effects due to fire and HVAC operation during a fire should not compromise the separation provided by fire barriers;
- The intakes for the fresh air supply should be located away from the exhaust air outlets and smoke vents of fire compartment to the extent necessary to prevent the intake of smoke or combustion products and the malfunction of items important to safety.

4.128. When an HVAC system ensures a safety function, its operability should be maintained in case of fire in adjacent fire compartments. This requires that the counterpart located in other fire compartments is independent and fully separated from the part impacted by the fire.

4.129. The flow of air induced by the HVAC system or pressure differences requested for contamination control should not cause smoke or heat energy to flow away from the detectors and thus unduly delay actuation of the fire detector alarm.

4.130. When items such as ventilation equipment and fire dampers are controlled by fire detection systems, and where spurious operation would be detrimental to the plant, the interface between fire detection and HVAC system should be designed accordingly. For example, operation of HVAC equipment and fire dampers could be controlled by two diverse means of detection operating in series.

4.131. Within rooms equipped with fire gaseous protection system, particular means should be provided to ventilate the protected enclosure after the discharge of the gaseous protection system for ensuring that an atmosphere hazardous to personnel is dissipated and not moved to other areas.

4.132. In particular rooms such as the battery room, component that can release hydrogen in case of leak or stored fuel room, the rate of air renewal should be sufficient to avoid the accumulation of flammable or explosive gas or fuel-vapor mixtures and maintain the flammable gas concentration below the flammable limit. In addition, each electrical battery room that contains batteries which may generate hydrogen during operation should be provided with a separate ventilation exhaust arranged to discharge directly to the outside of the building.

4.133. If forced ventilation is necessary within the battery room, the ventilation system for the battery room should be powered from the same division as the battery in the affected room.

Specific considerations for HVAC systems contributing to the limitation of radioactive release

Engineered safety feature ventilation system (ESFVS) of the controlled area

- **System/ equipment function**

4.134. The engineered safety feature ventilation system (ESFVS) of the controlled area includes (but not limited to) the following:

- Emergency core cooling rooms located outside containment;
- Residual heat removal (RHR) rooms if the RHRS system is installed outside the containment;
- Containment spray system rooms located outside the containment.

4.135. The functions of the engineered safety feature ventilation system (ESFVS) of the controlled area should be to maintain required ambient conditions for personnel access, if necessary, and SSCs important to safety in normal operation, AOO and accident conditions.

4.136. The ESFVS system of the controlled area should provide a direct radiological confinement function; it participates to the compliance with the radiological objectives.

-Specific design basis

4.137. The ESFVS of the controlled area being both a system supporting a safety function (safety category 2) and a system ensuring a safety function (safety category 1 or 2), it should have an appropriate safety classification and consequently meet the associated design requirements (redundancy, emergency power supplied, protection against internal and external hazards, the periodical tests, quality assurance, and, designed and fabricated according acceptable design codes).

4.138. The ESFVS should be designed for directing ventilation air of non-controlled areas towards the controlled area.

4.139. The emergency core cooling rooms, the residual heat removal rooms and the containment spray system rooms should be considered as iodine risk areas where the risk of internal exposure is important during accident conditions.

4.140. If the RHRS is installed outside the containment:

- the ESFVS of the controlled area should be designed in taking into account the break of a RHRS line outside the containment,
- during shutdown states, the RHRS rooms should be maintained to a pressure lower than the pressure of engineered safety feature rooms of non-controlled area.

4.141. The part not important to safety of the ESFVS system should be automatically isolated in case of accident conditions.

Fuel building ventilation system (FBVS)

- System/ equipment function

4.142. The functions of the FBVS should be to maintain a suitable ambient temperature range and controlled environment for personnel access, if necessary, and engineered safety feature components in normal operation, anticipated operational occurrences and accident conditions.

4.143. The FBVS should ensure the confinement function of the fuel building and participate to the compliance with the radiological objectives.

- Specific design basis

4.144. The FBVS should be designed for controlling the concentration of airborne radioactive material in the spent fuel pool equipment areas to permit personnel access during normal operation, anticipated operational occurrences and after design basis fuel handling accident.

4.145. The controlled area of the fuel building should be considered as iodine risk area where the risk of internal exposure is important, unless analysis demonstrate that some rooms are not affected by iodine risk.

4.146. Part of the FBVS being needed to ensure, in case of design basis fuel handling accident, the confinement function (safety category 1 or 2) and for the operation of safety components (supporting a function of safety category 2), should have an appropriate safety classification and meet the associated design requirements.

4.147. The FBVS should be designed for directing ventilation air of non-controlled areas of the fuel building (if any) towards the controlled area.

4.148. The FBVS should be designed in order to:

- detect the need for isolating the part of the system devoted to the non-controlled area (if any),
- have the capability to isolate the part of the system not important to safety when necessary,

- actuate components not in operation in normal conditions that are required during accident conditions.

4.149. The FBVS should be designed:

- so as to limit the radioactive releases to the environment in order to meet the radiological objectives in case of fuel handling accident; ,
- for reducing, in normal operation and anticipated operational occurrences, the radioactivity of gaseous releases to the environment below the authorized limits and to keep them as low as reasonably achievable.

Effluent treatment building ventilation system (ETBVS)

- **System/ equipment function**

4.150. The functions of the ETBVS should be to maintain a suitable ambient temperature range and controlled environment for personnel access and correct equipment operation during normal operation.

4.151. The ETBVS should ensure the confinement function of the effluent treatment building in accident conditions, and in case of Design Basis Earthquake (DBE). Depending on safety analysis results, confinement function could be based on static confinement or dynamic confinement.

- **Specific design basis**

4.152. The ETBVS should be designed for controlling the concentration of airborne radioactive material in the controlled area of the effluent treatment building to permit personnel access during normal operation.

4.153. The ETBVS should be designed for reducing in normal operation the radioactivity of gaseous releases to the environment below the authorized limits and to keep them as low as reasonably achievable. The component of the ETBVS ensuring the safety function of controlling the radioactive releases should have an appropriate safety classification (at least safety category 3).

4.154. The ETBVS should be designed for directing ventilation air of non-controlled areas of the effluent treatment building towards the controlled area.

4.155. Design provisions (isolation, intake and exhaust ducts resistant to earthquake, etc.) should be taken if the confinement of radioactive substances within the controlled area of the ETBVS in case of design basis earthquake is ensured by static confinement.

Containment ventilation systems

- **Systems /equipment function**

4.156. The containment is usually divided into two separate areas:

- the service area, that personnel can access when the reactor is at power,

- the area containing the compartments of the main equipment of the RCS. That area is not accessible by personnel when the reactor is at power.

4.157. Several systems are used to perform the HVAC of the containment. They usually consist of:

- systems that ensure in closed loop the ventilation of the containment to maintain the ambient conditions required for the proper operation of instrumentation and equipment and for reducing radioactive discharge by reducing the concentration of aerosols and radioactive iodine inside the reactor building. These systems ensure notably the cooling of the reactor cavity in case of Loss Of Off-site Power (LOOP) and in case of Station Blackout (SBO);
- depending on the design, the containment sweeping ventilation system (CSWS), in operation during cold shutdown, maintains acceptable ambient conditions for operators, limits radioactive releases into the environment in case of a fuel handling accident in the containment, and performs during normal operation, before an intervention in the containment, a mini-sweeping of the service area atmosphere for reducing the activity due to the presence of noble gases.

- System/ equipment function

4.158. The CSWS should ensure the confinement function in case of fuel handling accident within the containment, as applicable.

4.159. The CSWS should be designed for controlling the concentration of airborne radioactive material and for participating to the maintenance of ambient conditions in the containment permitting personnel access during cold shutdown states and after design basis fuel handling accident. The CSWS should notably reduce the radioactivity due to noble gases and tritiated water vapor during shutdown states.

- Specific design basis

4.160. The part of the CSWS ensuring a confinement function (safety category 1 or 2) should have an appropriate safety classification and meet the corresponding design requirements (redundancy, emergency power supplied, protection against internal and external hazards, the periodical tests, quality assurance, and, designed and fabricated according acceptable design codes). It should notably have the capability to ensure its safety function in case of design basis earthquake.

4.161. The CSWS should limit the radioactive releases to the environment in order to meet the radiological objectives in case of fuel handling accident within the containment. The cases to be considered should include an outage with an open containment.

4.162. The CSWS should be designed:

- taking into account that during transfer of spent fuel in the fuel storage pool, a damaged fuel clad could induce releases of radioactive gases and aerosols in some area of the containment,

- for reducing in normal cold shutdown states the radioactivity of gaseous releases to the environment below the authorized limits and to keep them as low as reasonably achievable,
- for participating to the containment isolation (safety category 1), isolating devices should have an appropriate safety classification) in case of high level radioactivity within the containment in accident conditions;
- for improving efficiency of hydrogen control system in the containment.

Specific considerations for HVAC systems maintaining ambient conditions

Ventilation systems of non-controlled area containing equipment important to safety (VSNCA)

4.163. This section concerns ventilations systems that only maintain required environmental conditions for systems and components important to safety. Depending on the layout, these systems could include the electrical building ventilation system, the diesel generator building ventilation system, the pumping station ventilation system and the ventilation of the part of the safety auxiliary building, usually containing the emergency feed-water system and component cooling system.

- System/ equipment function

4.164. The design of the VSNCA systems should be such that the ambient conditions of rooms in terms of temperature, humidity and cleanliness, are maintained within acceptable limits for components important to safety and for personnel.

- Specific design basis

4.165. Part of the VNSCA that is needed to a system achieving a safety function (safety category 1 or 2) in case of DBA should have an appropriate safety classification and meet the associated design requirements (redundancy, emergency power supplied, protection against the internal and external hazards, the periodical tests, quality assurance, and, designed and fabricated according acceptable design codes).

4.166. HVAC in essential areas of the electrical building should be ensured in case of station blackout.

4.167. The particular risk of hydrogen explosion should be taken into account in the electrical rooms containing batteries.

4.168. In the electrical rooms, the air introduced by the ventilation should be sufficient quality to protect the electrical contacts from dust, dirt, sand grit and humidity.

4.169. More detailed guidance is provided in [14].

Main control room ventilation system, supplementary control room and on-site emergency response facilities ventilations systems

- System/ equipment function

4.170. The functions of the main control room ventilation system (CRAVS) are to maintain the operation of safety components and to maintain habitable the main control room in normal operation, AOO and accident conditions as well as in the event of smoke, explosive and toxic gases, and radioactive contamination of the external environment. This is ensured in maintaining suitable ambient conditions (temperature, humidity, clean and new air) and concentration of airborne radioactive substances to levels compatible with the habitability of the main control room and the operation of the components.

- **Specific design basis**

4.171. The CRAVS should be designed to ensure the operation of safety components (safety category 2) and should have an appropriate safety classification and meet the corresponding design requirements (redundancy, emergency power supplied, protection against the internal and external hazards, the periodical tests, quality assurance, and, designed and fabricated according acceptable design codes).

4.172. The CRAVS should be designed to automatically maintain the main control room at a pressure higher than the atmospheric pressure during normal and radiological accident conditions to avoid the introduction of radioactive substances in case of radioactive contamination of the site.

4.173. The CRAVS should be designed to clean the air introduced in the main control room by appropriate iodine and particulate filters during radioactive contamination of the site.

4.174. The design of the CRAVS should permit to isolate the main control room for avoiding the introduction of toxic gases via the intake vents.

4.175. The CRAVS or an associated system should permit to remove smoke in case of fire within the control room.

4.176. The supplementary control room ventilation system should not be a common system shared with the main control room. The same recommendations provided for the main control room ventilation system apply to the ventilation of the supplementary control room.

4.177. The on-site emergency response facilities’ ventilation system should not be a common system shared neither with the main control room, nor with the supplementary control room. It should be such that the habitability of the on-site emergency response facilities is ensured, with a reasonable assurance, under a wide range of hazardous conditions, including extreme hazardous conditions not considered in the nuclear power plant design.

Turbine building HVAC for BWR

4.178. In a BWR, the Turbine Building HVAC should maintain during normal operation, AOO and after a DBA, the ambient conditions of rooms in terms of temperature, humidity and airborne radioactive substances below the acceptable limits of SSCs and below the conditions compatible with the presence of personnel.

4.179. In a BWR, the gaseous radioactive releases should be monitored and limited in maintaining an air flow leading from rooms with a lower contamination towards rooms with higher contamination. The exhaust air from the Turbine Building should be discharged to the plant main stack.

LIGHTING AND EMERGENCY LIGHTING SYSTEMS

4.180. The following recommendations provide guidance to fulfil requirement 75 of SSR-2/1 (Rev.1), regarding lighting systems to be provided in all operational areas of the nuclear power plant in operational states and in accident conditions.

4.181. Usually the lighting systems are composed of:

- A normal lighting system that provides lighting needed to perform all operating tasks during normal operation;
- An emergency lighting system that provides lighting during all plant operating conditions including loss of off-site power, fire and accident conditions;
- A station blackout lighting system that provides lighting in case of total loss of external and internal power supply;
- An emergency exits lighting system that provides lighting for emergency exit for facilitating personnel evacuation.

System/ equipment function

4.182. The lighting systems and their power sources should have the capability for providing sufficient illumination to enable the plant operators to perform all manual operations required (e.g., maintenance actions or actions requested by emergency operating procedures) and to access all the areas where actions have to be carried out during normal operation, AOO and accident conditions (including loss of off-site power and fire) as well as to exit safely from essential areas of the plant in case of evacuation necessity.

Specific design basis

4.183. Emergency lighting system should be immediately available upon failure of the normal lighting system and in case of loss of off-site power supply until the emergency power supply is available.

4.184. Emergency lighting should be provided in areas where important safety equipment is located (but not limited to) as well as the access and rescue routes to these areas. This concerns notably the following areas:

- main control room,

- supplementary control room,
- site emergency response facilities,
- emergency generator area, SBO Diesel area,
- emergency switchgear, motor control centers, DC battery and AC/DC inverters areas,
- plant areas that may require manual actions identified in emergency operating procedures.

4.185. Emergency lighting of the main control room should be independent of any other lighting system available in the main control room. Average lighting level in the main control room should be adjusted, taking into account indicator and screen design, in order to reduce reflection effects, blinding effects and inconveniences for the staff. In addition, the main control room should be provided with several lighting areas, which can be manually adjusted to provide illumination suitable for the operators to perform their tasks.

4.186. The alternate power supply should provide sufficient level of visibility, at least, in the main control room, the supplementary control room and the emergency preparedness and response centre.

4.187. The station blackout lighting system should be supplied by DC batteries having their autonomy consistent with the recovery time of an internal or external power supply.

4.188. The emergency exits lighting system should provide a minimum level of lighting necessary to enable staff to safely exit the rooms and buildings. This lighting system should be supplied by DC batteries having a sufficient autonomy permitting personnel evacuation in all conditions including fire.

OVERHEAD LIFTING EQUIPMENT

4.189. The following recommendations provide guidance to fulfil requirement 76 of SSR-2/1 (Rev (Rev.1), regarding overhead lifting equipment to be provided for lifting and lowering items important to safety at the nuclear power plant, and for lifting and lowering other items in the proximity of items important to safety.

4.190. The Overhead Heavy Load Handling Systems (OHLHS) consists of all components and equipment for moving in the nuclear power unit all heavy loads with weight more than one fuel assembly and its handling device. The containment crane and the fuel building crane are part of the OHLHS. The refueling machines are not considered in this safety guide.

System/ equipment function

4.191. An OHLHS should provide a means to move and relocate heavy equipment within the power unit.

4.192. Loads to be handled by such handling devices are, for examples, those of:

- the drywell head (BWRs),

- the reactor vessel internals,
- the reactor vessel head,
- the reactor coolant pump motor.

Specific design basis

4.193. The design of an overhead lifting equipment should take measures preventing any unintentional dropping of loads that could affect items important to safety (SSR-2/1 (Rev.1), requirements 76). Measures acceptable are for example:

- Movement of the overhead lifting equipment is restricted by design or interlocks to areas away from stored fuel and equipment participating to the achievement of a safety function.
- Otherwise, load drop evaluation confirming the absence of unacceptable consequence.

4.194. Safe load paths should be defined for movement of heavy loads to minimize the potential for a load drop on irradiated fuel in the reactor vessel or spent fuel pool or on equipment necessary for reaching or maintaining the safe shutdown state of the reactor.

4.195. Structural steelwork and mechanism and components (e.g., chains, cables, wire ropes, slings) of lifting equipment should be designed with a safety margin in comparison to the yield strength under the nominal load.

4.196. The overhead lifting equipment cranes should be designed to retain control of and continue to hold their maximum loads in case of design basis earthquake.

4.197. Use of overhead lifting equipment should be forbidden when an accident could induce radioactive releases higher than the radiological objective (e.g., interlock on the crane of the spent fuel cask transfer that prevents its use when the fuel building door is open).

4.198. The design of overhead lifting equipment should be such that manual operation should be capable of lowering the load in case of loss of power supply, loss of motive torque or mechanical failure.

4.199. Handling equipment, including transfer and lifting devices, should be designed to prevent damage to fuel and items important to safety as a result of impact in case of loss of electrical power or the occurrence of design basis earthquake.

4.200. To prevent the lifting of excessive loads, all handling equipment should be equipped with a load weighing device permanently visible by the Operator. This system should be completed with an overload protection system.

4.201. In case of loss of power supply, all electromechanical components of a handling equipment should be placed in a fail-safe position. When power supply is recovered after power interruption the equipment should be maintained in locked position until operator intervention.

4.202. Handling equipment should be equipped with an emergency stop button to stop all motion, in addition to upper limit switch and normal stop motion device.

4.203. Handling equipment which could impair a safety component should be equipped with a securing mechanism that could be ensured either by a safety brake acting on the drum or by a second hoisting mechanism. This securing mechanism should be actuated by a redundant over-speed detection or a redundant detection devices of the failed hoisting mechanism. In addition these detection devices should be completely independent of the operator commands and normal controls.

4.204. Handling equipment (more particularly girder and crane track) of the containment should be designed taking into account the complementary loads resulting of the ambient conditions induced within the containment by a loss of coolant accident.

4.205. Handling equipment should be tested prior to the commissioning with an important overload. Periodic Inspections and tests during normal operation should be carried out to ensure and verify the operation of ultimate safety devices: upper limit switch, over-speed interlock, overload interlock and restricted areas interlock.

4.206. Design provisions should be implemented in such a way that the polar/reactor building crane has decontaminable paints and or suitable smooth-surface coatings to allow the decontamination of potentially contaminated surfaces.

4.207. Those OHLHS that are credited in the Preliminary Decommissioning Plan should have a design life time and specific design provisions that are commensurate with the expected decommissioning activities.

TREATMENT OF RADIOACTIVE EFFLUENTS AND RADIOACTIVE WASTE SYSTEMS

4.208. The following recommendations provide guidance to fulfil requirements 78 and 79 of SSR-2/1 (Rev.1).

General common considerations

4.209. The design of the nuclear power plant should incorporate features that facilitate the safe handling, storage with sufficient margin, transport and disposal of radioactive waste and the control of effluent discharges (SSR-2/1 (Rev.1), requirements 78 and 79).

4.210. The design should include provisions for the safe management of solid, liquid and gaseous radioactive waste within the facility. Provisions for the storage of waste in transit and for the removal of waste should also be considered in the design (SSR-2/1 (Rev.1), requirements 78 and 79).

4.211. The design should be such as to minimize the generation of radioactive waste in all operational stages in the lifetime of the nuclear power plant, including decommissioning. Such considerations should be compatible with the safety analysis and with regulatory limitations on radiation doses (SSR-2/1 (Rev.1), requirement 12).

4.212. The treatment of radioactive waste and radioactive effluent systems in general include the collection, processing, recycling or release of radioactive waste produced by let-down, drainage, purge, venting, or leakage in the systems during normal operation, as well as other operational radioactive waste.

4.213. Design measures should include the following (SSR-2/1 (Rev.1), requirement 12):

- the choice of the material for components in contact with radioactive media, in particular those in contact with the reactor coolant, so that amount of radioactive waste will be minimized to the extent practicable and decontamination will be facilitated;
- chemistry for reactor coolant and other systems to minimize the production of corrosion product (e.g., dihydrogen concentration, possibility of zinc injection, pH control);
- provisions to minimize deposition of corrosion products that are or that can be activated when passing through the reactor core, in particular deposition on the fuel assemblies and on the structures around the reactor core;
- provisions in making a clear distinction between conventional waste areas within which waste produced is not liable to be contaminated or activated and nuclear waste areas where waste produced is liable to be contaminated or activated, and in minimizing the nuclear waste areas;
- adequate provisions that should be implemented at the design stage to facilitate the corresponding dismantling works. These should include the installation of large components in such a way that they can be removed and transported for subsequent treatment, the necessary handling devices, evacuation arrangements and biological shielding, as well as cleaning and decontamination in situ.

4.214. The following features for limiting exposure due to the radioactive waste generated during nuclear power plant operation should be included in the design (SSR-2/1 (Rev.1), requirement 81):

- provisions that reduce the quantity and concentration of the radioactive waste generated and transported within the nuclear power plant or released to the environment;
- provisions for the isolation of radioactive waste from site personnel and the public, with access control, e.g., by zoning the nuclear power plant according to the potential for radioactive contamination and radiation exposure;
- provisions for local detection, collection and treatment of liquid spills before they are discharged as effluents;
- provisions for the decontamination of the personnel and equipment and provisions for handling the radioactive waste arising from decontamination activities.

4.215. The treatment of radioactive waste and radioactive effluent systems should be such that these systems are protected, commensurate with the nature and extent of the risk, against internal and external hazards, in particular extreme weather conditions and flooding. For instance, the portions of circuits carrying concentrated boron acid should be located in heated rooms or being heat traced in order to avoid boron crystallization.

4.216. In addition, the design of the treatment of radioactive waste and radioactive effluent systems should include provisions that allow appropriate periodic inspection and testing of components important to safety, with suitable shielding for radiation protection, and with appropriate containment, confinement and filtering systems.

4.217. SSCs ensuring the confinement of radioactive waste and radioactive effluents should be designed for the Design Basis Earthquake.

Treatment of gaseous effluents system

System/equipment function

4.218. The design of the treatment of gaseous effluent system should include the following provisions:

- treatment and monitoring of gaseous effluents such that a minimum decay time is achieved before routing to a common release point;
- measurement of volume and activity of effluents to be released, and
- isolation of the discharge route if the release limits are exceeded.

4.219. These provisions may be achieved by collecting the gaseous effluents in a buffer tank and routing them under pressure to decay devices, or by on line release via a delay line (e.g., charcoal delay beds) and then via the ventilation system of the auxiliary building before release to the discharge point (e.g., stack).

4.220. Provision of means such as stacks for the discharge of gaseous low level radioactive waste, and of methods of sampling and monitoring of those discharges should be provided at the design stage.

Specific design basis

4.221. The design of the storage of gaseous effluent (decay devices) should be such that the number and the capacity of the storage tanks of gaseous effluents allow the decay of short lived gases before release.

4.222. The design of storage of gaseous effluent system should be such that the rupture of any of the gaseous effluent tanks has no, or only minor, radiological consequences, on or off the site, and do not necessitate any off-site protective actions.

4.223. The design should be such as to include the following provisions of protection against hazards:

- prevention of explosion risk in the rooms of hydrogenated gaseous effluent storage tanks for instance. Hydrogen ignition in the purge gas return system and in the connected components may be prevented for example by maintaining a continuous flow of nitrogen purge through connected components and by recombination.
- protection of the treatment of gaseous effluent system against pipe rupture. This may be achieved by following appropriate guidance, e.g., relevant guidance in [5].

4.224. The design of treatment of gaseous effluent system should incorporate provisions to limit the atmospheric contamination by radioactive gas releases. This should be achieved with equipment and structures of high reliability as well as by ensuring radiological detection and confinement. In particular, the cleanup equipment (storage devices or delay line) should be designed so to have the necessary retention factor so as to keep radioactive releases below the authorized limits on discharges, and the filter of the ventilation system should be designed so their efficiency can be tested, and their performance and function can be regularly monitored.

4.225. Lines of treatment of gaseous effluents penetrating the containment should be provided with automatic isolation features. These containment isolation features should be safety classified (safety function of safety category 1) and meet the associated design requirements.

Treatment of liquid effluents system

System/equipment function

4.226. The treatment of liquid effluents includes the reactor coolant treatment and boron recycling system, the liquid waste processing system and the liquid radwaste monitoring and discharge system.

- Reactor coolant treatment and boron recycling system:

4.227. The design of reactor coolant treatment and boron recycling should include the following:

- processing of the discharged reactor coolant via systems providing bleed function (that are the Chemical and Volume Control System for PWR designs, and Reactor Water Clean-up System for BWR designs);

- treatments usually applied are degassing to remove noble gas and hydrogen, purification, separation of boron and water to allow it to be recycled as boric acid and water make-up.

- monitoring of the resulting products and subsequent routing to the reactor boron and water makeup system for recycling or the liquid waste treatment systems, or the liquid waste release systems, or the solid waste treatment systems.

- Liquid waste processing system

4.228. The liquid waste processing system can be shared by different units of the power plant. The design of the system should provide storage, adequate treatment and monitoring of the different category of non-reusable spent liquid effluent collected by equipment and floor drainage system EFDS (see section on Equipment and floor drainage system), before transfer to the discharge system.

4.229. The design of the treatment of liquid effluent system should include the following provisions:

- selective front-end storage of all potentially contaminated liquid effluents according to the chemical composition and radioactivity of the various waste streams;
- analysis of the contents of each storage tank and subsequent adequate treatment so that the treated waste produced is of acceptable quality for re-use within the plant, or fulfils the conditions to be discharged to the environment;
- corresponding transfers to the storage capacity of the discharge system for monitoring;
- transfer of solid waste produced (e.g., concentrates, spent ion-exchange resins, spent filters) to the solid waste treatment system.

- Liquid Radwaste Monitoring and Discharge System

4.230. The Liquid Radwaste Monitoring and Discharge system collects liquid radioactive effluent from the nuclear island of each unit and from certain site facilities, monitors and accounts for its activity and its chemical and physical composition, and discharges it in a controlled fashion to the environment. The flow rate of the discharge to the environment depends on the level of activity of the effluent and the dilution capacity of the environment, so as to meet the limits set by discharge authorisation.

4.231. Regarding liquid effluent release, the following provisions should be considered at the design stage:

- measurement of the volumes of liquid effluents to be released;
- determination or adjustment of release rates according to discharge authorization;
- automatic isolation of the discharge line if authorized limits are exceeded.

Specific design basis

4.232. The design of the treatment of liquid effluent system should be such it has the capacity to monitor, control, collect, process, handle, store and dispose of liquid radioactive waste, and keep liquid releases to the environment as low as reasonable achievable and below the authorized limits on discharges.

4.233. The treatment of liquid effluent system should not be installed in the same zone as systems containing non-radioactive liquids so to avoid that leaks in the latter increase the volume of effluents to be treated. Otherwise, design provisions should be implemented to avoid these leaks or to collect them independently from the radioactive effluents.

4.234. All the tanks of radioactive liquid effluents should have a level control with high level alarm reported locally and in the control room allowing action to be taken to avoid tank overflow.

4.235. In order to avoid contamination of groundwater, the circuits and equipment containing radioactive liquids should be installed in rooms that provide holdup capacity for retention or should have recipients for retention of those liquids.

4.236. The design of treatment of liquid effluent system should be such that the rupture of any of the liquid effluent tanks has no, or only minor, radiological consequences, on or off the site, and do not necessitate any off-site protective actions.

Treatment of solid waste system

System/equipment function

4.237. The design of the treatment of solid waste system should include the following provisions:

- collection, storage and processing of solid waste, including sorting, volume reduction (e.g., shredding and use of compactor or incinerators), immobilization of compacted waste or ashes in packages, packaging of low-activity waste, hold-up storage, encapsulation and drumming of wet solid waste (e.g., spent resins and filters);
- temporary or long-term storage for drums on site before shipment to licensed radioactive waste disposal facilities; the minimum on-site storage capacity should be as specified;
- monitoring and removal of package surface contamination;
- assay of package inventories, and
- package weight measurement, marking and data recording.

Specific design basis

4.238. The design of the treatment of solid waste system should be such it has the means to control the release of radioactive materials in liquid effluents from the treatment of solid waste system and to handle solid wastes produced during normal reactor operation.

4.239. The treatment of solid waste system should be designed so as to detect conditions that may lead to excessive radiation levels and to provide adequate safety under normal and accident conditions.

4.240. More guidance may be adapted, as appropriate, from [4] and [13].

AC SOURCES SUPPORT SYSTEMS

4.241. The following recommendations provide guidance to fulfil the requirement 68 of SSR-2/1 (Rev.1), in particular para. 6.45.

Emergency Power Sources Support Systems

4.242. This paragraph concerns the design basis for any emergency power source (emergency diesel generator or combustion turbine unit) that provides an emergency power supply to items important to safety and that has to include:

- The capability of the associated fuel oil storage and supply systems to satisfy the demand within the specified time period;
- The capability of the emergency power source to start and to function successfully under all specified conditions and at the required time;
- Other AS&SS, such as coolant systems.

General common considerations for emergency power sources support systems

4.243. Each emergency power source is usually provided with its own completely independent supporting systems. These systems include the following:

- Systems for oil storage and oil transfer;
- Lubricating oil system;
- Cooling water system which can be external or included in the emergency power source;
- Air starting system/ DC motor starting;
- Combustion air intake and exhaust systems.

- System/equipment function

4.244. Each emergency power source should be provided with dedicated essential systems needed for its operation. The systems concerned are at least the fuel oil storage and oil transfer, lubricating oil, cooling water, combustion air intake and engine exhaust, air starting and electrical systems. In addition, the emergency power source should be protected against fire.

- Specific design basis

4.245. The essential AS&SS required for the operation of the emergency power source should be considered as supporting systems of equipment ensuring a safety function of category 1. They should have the same safety classification as the emergency power source and should meet the associated design requirements:

- Redundant design to satisfy the single failure criterion;
- Powered by the on-site emergency AC power system;
- Protection against internal and external hazards. Notably, the redundant trains should be adequately separated; the essential AS&SS should remain functional after the DBE and protected against storms and flooding;

- Periodic inspections and periodic testing;
- Components designed and fabricated, erected, and tested according to acceptable quality standards;
- Components designed and fabricated according to acceptable design codes.

4.246. The essential AS&SS required for the operation of the emergency power source should be housed within seismic Category I building.

Emergency Power Source Fuel Oil Storage and Transfer System

4.247. Usually, each emergency diesel generator is fitted with a short term fuel oil tank fed from a main storage fuel oil tank while combustion turbine is fed directly from the fuel oil storage system through fuel oil forwarding pumps. The short term fuel oil tank is sized to permit at least two hours operation at full load.

4.248. The main storage tank feeds the emergency diesel generator's short term fuel oil tank, or the combustion turbine by mean of transfer pumps or forwarding pumps. It can provide independently the fuel oil for ensuring emergency power source operation at full load for the autonomy requested for design basis accidents. In addition, the main storage tank can be refilled for ensuring long term operation.

- System/ equipment function

2.249. Each emergency power source should be fitted with independent and reliable fuel oil storage and transfer system ensuring the supply of fuel oil needed for its operation following the loss of off-site power and a design basis accident.

4.250. Each oil storage tank should have the capability to be refilled during accident condition for ensuring emergency power source long term operation considering adequate and acceptable sources of fuel oil available off-site as well as the means of transporting and recharging the fuel oil storage tank.

4.251. The quantity of oil stored within the site should have the capability to ensure the operation of all emergency power sources of a NPP further to a loss of off-site power supply induced by an earthquake (no recovery of the off-site power supply during a long time).

- Specific design basis

4.252. The fuel oil quality should be verified periodically in order to ensure that fuel oil satisfies minimum operating requirements at all times.

4.253. The fuel oil storage and transfer system should be protected against extreme weather conditions.

4.254. Each storage tank should be equipped with a fill and vent line located outside. These components should be protected to minimize any chance of damage from vehicles or external hazard. In addition the fill and vent point should be located higher than the probable maximum flood level.

4.255. Protective measures should be taken to minimize the causes of fires and explosions induced by the fuel oil storage and transfer system. Notably, the design should include:

- the capability to detect and control system leakage, including isolating system portions in the event of excessive leakage,
- tank dikes to contain the fuel oil in the case of a tank breach,
- all oil tanks should be located at a sufficient distance away from the main control room to preclude any danger to control room personnel or equipment resulting from an oil tank explosion and/or fire.

4.256. In the case of emergency diesel generators, the design should include an overflow line on the short term fuel oil tank to return excess fuel oil delivered by the transfer pump back to the fuel oil storage tank.

4.257. The design should be such that the physical location of the emergency diesel generator short term fuel oil tank is located at an elevation providing sufficient positive pressure at the engine-driven fuel oil pump(s). Any required booster pump must be powered from a reliable power supply, start as soon as the engine receives a start signal, and operate until system fuel oil pressure is established by the engine-driven fuel oil pump.

4.258. Each storage tank should be double walled, and the annulus between the two walls should be equipped with a leak detection system.

Emergency power source cooling water system

4.259. Each emergency power source unit is usually supplied with a cooling system. This cooling is performed by a closed loop mounted integrally with the emergency power source. Included in each cooling package are a jacket water electric heater and keep-warm pump, 3-way temperature-regulating valve, lube oil cooler.

- System/ equipment function

4.260. Each emergency power source should be equipped with a cooling water system transferring heat to an ultimate heat sink for maintaining the emergency power source temperature within the limits specified by the manufacturer, following a start signal.

4.261. The cooling water systems should be provided with heaters and circulating pumps, which keep the engine warm under standby conditions, enabling the emergency power source to be started without causing mechanical damage.

- **Specific design basis**

4.262. The design should include measures to preclude long-term corrosion and organic fouling that would degrade system cooling performance. Particular precautions should be taken as regards the compatibility of any corrosion inhibitors or antifreeze compounds with component materials.

4.263. When the emergency power source receives a start signal, the cooling water system should change automatically of operating mode (standby conditions to the cooling water configuration).

Emergency power source lubrication system

4.264. The lubrication system of an emergency power source consists of an oil sump in its frame, an oil cooler, as well as an oil strainer and a filter.

- **System/ equipment function**

4.265. Each emergency power source should be equipped with a lubrication system containing:

- an oil filtering system maintaining required oil quality during engine operation,
- an oil cooling system maintaining the oil temperature within limits specified by the manufacturer,
- a keep-warm system maintaining lubricating oil passages in a warmed and filled state when the emergency power source is in the standby mode.

- **Specific design basis**

4.266. The lubrication system should be fitted with protective measures (e.g., relief ports) to prevent unacceptable explosions and to mitigate consequences of such events;

4.267. The design should be such that oil capacity of lubrication system is sufficient to ensure the operation of the emergency power source further to a loss of off-site power supply induced by an earthquake. In addition, the capacity of lube oil storage at the site should permit to ensure more long term operation.

Alternate AC Power Sources Support Systems

System/equipment function

4.268. Each Alternate AC Power Source should be provided with dedicated essential AS&SS needed for its operation further to the loss of off-site power and emergency power sources. The systems concerned are at least the fuel oil storage and oil transfer, lubricating oil, cooling water, combustion air intake and engine exhaust, air starting and electrical systems.

Specific design basis

4.269. The common cause failures between the AS&SS of the emergency power sources and the ones of the Alternate Power Source should be minimized.

4.270. A weather event, another external event or internal event should not damage an essential auxiliary system of the emergency power source and an essential auxiliary system of the Alternate Power Source.

4.271. The AS&SS of the Alternate AC Power Source should ensure their function during a time consistent with the recovery time of an off-site power supply or, failing that, an emergency power source.

4.272. The essential AS&SS of the Alternate AC Power Source should be resistant to the Design Basis Earthquake.

4.273. During the periodic test of the Alternate AC Power Source, the operability of the AS&SS should be verified as well as the fuel oil quality.

4.274. More detailed recommendations are given in SSG-34 [14].

OTHER SYSTEMS

4.275. The following recommendations provide guidance for the design of other AS&SS not explicitly mentioned in SSR-2/1 (Rev.1), but which are considered within the international practice as such.

Equipment and Floor Drainage System (EFDS)

4.276. There is no specific requirement for the EFDS in SSR-2/1 (Rev.1) but the safety requirements of EFDS are linked to the requirements 79 of SSR-2/1 (Rev.1) that concerns notably the incorporation in the design of the plant suitable means to keep liquid radioactive releases to the environment as low as reasonably achievable.

System/ equipment function

4.277. The EFDS should collect selectively the liquid and gaseous effluents produced by the RCS, nuclear AS&SS, the refueling cavity and spent fuel pool, as well as potentially-contaminated liquids produced in the plant (such as floor drains, laundry and decontamination waste) in order to route them to the adequate storage and radwaste treatment.
For PHWR, any leakage from a system containing heavy water is collected and pumped back to the system.

4.278. During normal operation, the EFDS should contribute to:

- the monitoring of leak-tightness of the reactor coolant system and the leak measurement within the containment;
- the limitation of radioactive release discharge to the environment via recovery of effluents and by optimization of effluent discharge versus effluent treatment.

4.279. In accident conditions, the EFDS should have the capability for re-injection of highly contaminated liquids from the auxiliary buildings, or secondary containment, into the containment should the level of effluent radioactivity be too high to be treated at short term (storage needed prior to their treatment) or should the amount of fluids exceed the waste treatment capacity.

4.280. The system should help to limit the retention of activity in the nuclear island buildings and to limit discharge to the environment by monitoring of activity during normal operation. The EFDS could contribute directly to the safety functions that are part of the facility's hazards protection against the consequences of internal flooding and explosion (hydrogen explosion prevention by dealing with hydrogenated effluents).

Specific design basis

4.281. The EFDS should be designed to:

- collect liquid effluents and transfer them to various systems according to the ability of the effluents to be recycled or according to their radiological characteristics;
- collect hydrogenated or aerated liquid effluents from the primary system for recycling in case of boron recovery (in Coolant Storage and Treatment System CSTS for example);
- collect non-recyclable liquid effluents to transfer them to be treated, if necessary, and then collected, monitored and discharged to the environment, and
- purge the primary system for example before it is opened for de-fueling, and venting.

4.282. The EFDS should have sufficient capability to collect and dispose of radioactive and nonradioactive liquid effluents for their controlled and safe processing.

4.283. As radioactive liquid effluents require a treatment different from that for non-radioactive effluents, radioactive and non-radioactive liquid should be collected separately.

4.284. EFDS components should be classified on the basis of their functions and their role as barriers, and should meet the associated design requirements, in particular to be subject to periodic testing and inspection. The following EFDS equipment is usually safety classified:

- equipment monitoring reactor coolant system leaks;
- Monitoring equipment credited in flooding analysis;
- Equipment necessary for containment isolation. ;
- ;

4.285. EFDS lines penetrating the containment should be provided with appropriate automatic containment isolation features [12] meeting the single failure criterion. This part of the EFDS system should be safety classified (safety category 1) and meets the associated design requirements.

4.286. EFDS components carrying activity and those whose failure leads to off-site radiological consequences should be considered as important to safety with a corresponding safety classification.

4.287. For preserving their required performance, safety portions of the EFDS should be isolatable from the not important to safety parts.

4.288. The EFDS drainage capacity should prevent loss of system safety functions induced by flooding from pipe breaks, tank leak and other potential flooding sources (e.g., break induced by earthquake in a tank non-seismic design).

4.289. EFDS Sumps should be covered in order to prevent the transfer of contaminated effluent to the atmosphere and the pollution of effluents to be recycled. They should be equipped with provisions in order to prevent the retention of contaminated effluent at the floor of the building in normal situations.

4.290. The pumps which are submerged in EFDS sumps should not require important maintenance, therefore design of the sumps should be such that they are protected against the drop of various objects which could damage or obstruct the pumps.

4.291. The submerged EFDS sump pumps should be equipped with strainers to protect them against small particulates and fragments the sumps may contain.

4.292. EFDS building sumps should be provided with water level instrumentation that alarms on high water levels. When necessary each sump/tank should be equipped with a binary level measurement. In case of high level measurement, an alarm should warn the operator of a flooding risk inside a building.

4.293. In areas where contamination may arise, the EFDS design should prevent the possibility of spread of contamination to other areas.

4.294. In order to maintain the operability of the EFDS in case of fire in adjacent fire compartments, as far as practicable, the EFDS should be independent of the counterparts in other fire compartments

Interfacing Water Systems

Demineralized Water Reserve

4.295. Demineralized water reserve is, for example, needed to supply the emergency feedwater system of PWRs notably in case of unavailability of the ultimate heat sink.

- **System/ equipment function**

4.296. Demineralized water reserve should permit to supply the emergency feedwater systems in order to provide a long term cooling by the steam generators in case of loss of ultimate heat sink or external hazards.

- **Specific design basis**

4.297. The demineralized water reserve of a site should be designed to supply the emergency feedwater systems in case of loss of ultimate heat sink or/and in case of external hazards. For external hazards, at least the following combination should be considered:

- Storms inducing the loss of off-site power and a flooding of the ultimate heat sink,
- Earthquake inducing the loss of off-site power and ultimate heat sink.

4.298. The demineralized water reserve and the associated system should be considered as ensuring a safety function of category 3. It should have an appropriate safety classification. If this safety function is ensured further to an earthquake, the demineralized water reserve and the associated system should be seismic resistant.

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ANNEX 1: LIST OF ACRONYMS

ALARA: As low as reasonably achievable
AOO: Anticipated Operational Occurences
ARAVS: Auxiliary and Radwaste Area Ventilation System
ASME: American Society of Mechanical Engineers
AS&SSs: auxiliary systems and supporting systems
ATWS: Anticipated Transient without SCRAM
CAS: Compressed Air System
CCWS Component Cooling Water System
CRAVS: Control Room Ventilation System, also named MCR HVAC
CSTS: Coolant Storage and Treatment System
CSWS: Containment Sweeping Ventilation System
CVCS: Chemical and Volume Control System
CDWS: Essential Chilled Water System
DBA: Design Basis Accident
DBE: Design Basis Earthquake
DEC: Design Extension Condition
ESFVS: Engineered Safety Feature Ventilation System
ETBVS: Effluent Treatment Building Ventilation System
FBVS: fuel building ventilation System
HEPA: High-Efficiency Particulate Air
HVAC: Heating, Ventilation and Air Conditioning
LOCA: Loss of Coolant Accident
LOOP: Loss of Off-site Power
EFDS: Equipment and Floor Drainage System
OHLHS: Overhead Heavy Load Handling Systems
PHWR: Pressurized Heavy Water Reactor
PPASS: Process and Post-Accident Sampling System
RCS: Reactor Coolant System
RCWS: Recirculated Cooling Water System
SBO: Station Black-Out
SSCs: Systems, Structures, Components
UHS: Ultimate Heat Sink
VSNCA: Ventilation systems of non-controlled area containing safety equipment

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