Introduction of the Amendment of IAEA Safety Requirements Reflected Lessons Learned from Fukushima Nuclear Accident

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1. Introduction [1~5]

The IAEA Action Plan on Nuclear Safety was developed in response to the Fukushima accident and was approved by the IAEA Board of Governors and endorsed by the IAEA General Conference in September 2011. This Action Plan includes an action headed: 'Review and strengthen IAEA Safety Standards and improve their implementation'. This review included, among other things, the regulatory structure, emergency preparedness and response, and nuclear safety and engineering aspects (site selection and evaluation, assessment of extreme natural hazards, including their combined effects, management of severe accidents, station blackout, loss of heat sink, accumulation of explosive gases, the behavior of nuclear fuel and the safety of spent fuel storage). Finally, the proposed amendments were approved by all four Safety Standards Committees at their meetings in June and July 2014, and were endorsed by the Commission on Safety Standards (CSS) at its meeting in November 2014.

The following five Safety Requirements publications were amended: Governmental, Legal and Regulatory Framework for Safety (GSR Part 1, 2010), Site Evaluation for Nuclear Installations (NS-R-3, 2003), Safety of Nuclear Power Plants: Design (SSR-2/1, 2012), Safety of Nuclear Power Plants: Commissioning and Operation (SSR-2/2, 2011), and Safety Assessment for Facilities and Activities (GSR Part 4, 2009). Figure 1 shows IAEA Safety Standards Categories

Major amendments of five Safety Requirements publications were introduced and analyzed in this study.

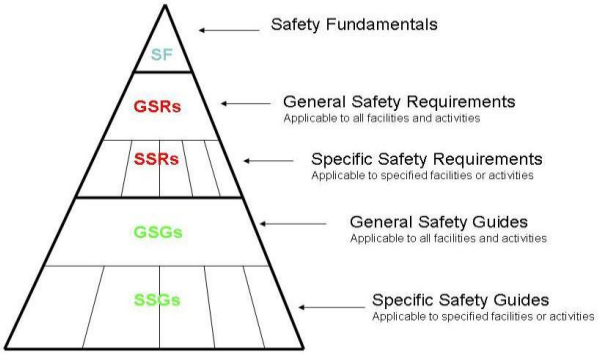

Fig. 1. IAEA Safety Standards Categories [1]

2. Amendment of Governmental, Legal and Regulatory Framework for Safety [2]

The revisions relate to the following main areas:

- Independence of the regulatory body;
- Prime responsibility for safety;
- Emergency preparedness and response;
- International obligations and arrangements for international cooperation;
- Liaison between the regulatory body and authorized parties;
- Review and assessment of information relevant to safety;
- Communication and consultation with interested parties.

2.1 Independence of the regulatory body

Requirement 4: Independence of the regulatory body (2.7 - 2.13)
2.8 To be effectively independent from undue influences on its decision making, the regulatory body: (a) shall have sufficient authority and sufficient competent staff; (b) shall have access to sufficient financial resources for the proper and timely discharge of its assigned responsibilities; (c) shall be able to make independent regulatory judgements and regulatory decisions, at all stages in the lifetime of facilities and the duration of activities until release from regulatory control, under operational states and in accidents; (d) shall be free from any pressures associated with political circumstances or economic conditions, or pressures from government departments, authorized parties or other organizations; (e) shall be able to give independent advice and provide reports to government departments and governmental bodies on matters relating to the safety of facilities and activities. This includes access to the highest levels of Government: (f) shall be able to liaise directly with regulatory bodies of other States and with international organizations to promote co-operation and the exchange of regulatory related information and experience.

2.2 Prime responsibility for safety

Requirement 6: Compliance with regulations and responsibility for safety (2.14-2.18)
2.16. The person or organization responsible for a facility or an activity, having prime responsibility for safety, shall actively evaluate progress in science and technology as well as relevant information from the feedback of experience, in order to identify and to make those safety improvements that are considered practicable.

2.3 Emergency preparedness and response

Requirement 8: Emergency preparedness and response (2.21-2.27)
2.24. The government shall specify and shall assign clear responsibilities for so that timely and effective decisions can be made in an emergency, and shall make provision for effective coordination of and communication between authorized parties and response organizations. 2.25. (Omitted) 2.26. The government shall ensure that adequate training, drills and exercises, involving authorized parties and response organizations, including decision makers, are carried out regularly to contribute to an effective emergency response. The training, drills and exercises shall cover a full range of postulated emergencies (e.g. events affecting several facilities on one site, emergency exercise of long duration and emergencies with transboundary consequences). 2.27 The government shall ensure that arrangements, commensurate with the radiation risks, are in place to inform the general public and members of the public who are affected or are potentially affected about measures for emergency preparedness and response. These arrangements shall include arrangements for the provision of information before, during and after operation until release of the facility or radiation source from regulatory control. Members of the public concerned shall be informed of the potential for a nuclear or radiological emergency, the nature of the associated hazards, the ways in which people will be alerted or notified, and actions to be taken, as appropriate.

2.4 International obligations and arrangements for international cooperation

Requirement 14: International obligations and arrangements for international cooperation and assistance (3.2 – 3.3)
3.2 The features of the global safety regime include: (a) - (d) (Omitted) (e) Regular multilateral and bilateral cooperation between the relevant national and international organizations to enhances safety by means of harmonized approaches as well as to increases the quality and effectiveness of safety reviews and inspections, by means of sharing of knowledge and feedback of experience. 3.3. The government shall ensure that bilateral and multilateral arrangements are in place for benefiting from international cooperation and, as appropriate, from the provision of assistance in connection with a nuclear or radiological emergency.

2.5 Liaison between the regulatory body and authorized parties

Requirement 21: Liaison between the regulatory body and authorized parties (4.23 - 4.25)
4.24. The regulatory body shall foster mutual understanding and respect on the part of authorized parties through frank, open and yet formal relationships, providing constructive liaison on safety related issues and in-depth technical dialogue between experts.

2.6 Review and assessment of information relevant to safety

Requirement 26: Graded approach to review and assessment of a facility or an activity (4.40 - 4.49)
4.40. The regulatory body shall ensure, adopting a graded approach, that authorized parties routinely evaluate operating experience and periodically perform comprehensive safety reviews of facilities, such as periodic safety reviews for nuclear power plants. These comprehensive safety reviews are submitted to the regulatory body for assessment or are made available to the regulatory body. The regulatory body shall ensure that any reasonably practicable safety improvements identified in the reviews are implemented in a timely manner. 4.41 – 4.43 (Omitted) 4.44. The regulatory body shall assess the radiation risks associated with normal operation, anticipated operational occurrences and accidents, including possible events with a very low probability of occurrence, prior to operation of the facility or conduct of the activity, and periodically throughout the lifetime of the facility or the duration of the activity, to determine whether radiation risks are as low as reasonably achievable.

2.7 Communication and consultation with interested parties

Requirement 36: Communication and consultation with interested parties (4.67 - 4.70)
4.68. The regulatory - (Omitted) - body. In particular, there shall be consultation by means of an open and inclusive process with interested parties residing in the vicinity of authorized facilities and activities, and other interested parties, as appropriate. Interested parties including the public shall have an opportunity to be consulted in the process for making significant regulatory decisions, subject to national legislation and international obligations. The results of these consultations shall be taken into consideration by the regulatory body in a transparent manner. 4.69. The authorized party shall inform the public about the possible radiation risks (arising from operational states and accidents, including events with a very low probability of occurrence) associated with the operation of a facility or the conduct of an activity, and this obligation shall be specified in the regulations promulgated by the regulatory body, in the authorization or by other legal means.

3. Amendment of Safety Assessment for Facilities and Activities [3]

The revisions to GSR Part 4 relate to the following main areas:

- Margins for withstanding external events;
- Margins for avoiding cliff edge effects;
- Safety assessment for multiple facilities or activities at a single site;
- Safety assessment in cases where resources at a facility are shared;

3.1 Margins for withstanding external events

Requirement 10: Assessment of engineering aspects (4.27 - 4.39)
4.31. The external events – (Omitted) - induced events. Where appropriate, the safety assessment shall demonstrate that the design is adequately conservative, so that margins are available to withstand external events more severe than those selected for the design basis.

3.2 Margins for avoiding cliff edge effects

Requirement 13: Assessment of defense in depth (4.47 – 5.51)
4.51. Where practicable, the safety assessment shall confirm that there are adequate margins to avoid cliff edge effects that would have unacceptable consequences.

3.3 Safety assessment for multiple facilities or activities at a single site

Requirement 10: Assessment of engineering aspects (4.27 - 4.39)
4.37. For sites with multiple facilities or multiple activities, account shall be taken in the safety assessment of the effects of external events on all facilities and activities, including the possibility of concurrent events affecting different facilities and activities, and of the potential hazards presented by each facility or activity to the others.

3.4 Safety assessment in cases where resources at a facility are shared

Requirement 10: Assessment of engineering aspects (4.27 - 4.39)
4.38. For facilities on a site that would share resources (whether human resources or material resources) in accident conditions, the safety assessment shall demonstrate that the required safety functions can be fulfilled at each facility in accident conditions.

4. Amendment of Site Evaluation for Nuclear Installations [4]

The revisions to NS-R-3 relate to the following main areas:

- The potential occurrence of events in combination;
- Establishing levels of hazard for the design basis for the installation and their associated uncertainties;
- Multiple facilities at a single site;
- Monitoring of hazards and periodic review of site specific hazards.

4.1 The potential occurrence of events in combination

GENERAL CRITERIA (2.4 – 2.15)
2.5. Proposed sites for a nuclear installation shall be evaluated with regard to the frequency and severity of external natural and human induced events and potential combinations of such events that could affect the safety of the installation. 2.15. An assessment shall be made of the feasibility of implementation of emergency plans. All on-site and collocated installations shall be considered in the assessment, with special

emphasis on nuclear installations that could experience concurrent accidents.

4.2 Establishing levels of hazard for the design basis for the installation and their associated uncertainties

GENERAL CRITERIA (2.4 – 2.15)
2.6. Information on frequency and severity derived from the characterization of the hazards resulting from external events shall be used in establishing the design basis hazard level for the nuclear installation. Account shall be taken of uncertainties in the design basis hazard level.

Surface faulting (3.5 – 3.7)
3.6. A fault shall be considered capable if, on the basis of geological, geophysical, geodetic or seismological data (including paleo-seismoloical, geomorphological data, etc.), one or more of the following conditions applies: (a) – (c) (Omitted)

Floods due to precipitation and other causes (3.18 - 3.23)
3.21. The hazards for the site due to flooding shall be derived by the use of appropriate from the models.

4.3 Multiple facilities at a single site

Other important human induced events (3.51 - 3.55)
3.51. The region shall be investigated for installations (including collocated units of nuclear power plants and installations within the site boundary) in which flammable, explosive, asphyxiant, toxic, corrosive or radioactive materials are stored, processed, transported and otherwise dealt with that, if released under normal conditions or accident conditions, could jeopardize the safety of the installation. This investigation - (Omitted).

4.4 Monitoring of hazards and periodic review of site specific hazards

5. MONITORING OF HAZARDS (5.1 - 5.2)
5.2. Site specific hazards shall be periodically reviewed using updated knowledge, typically every ten years, and shall be re-evaluated when necessary. A review after a shorter interval shall be considered in the event of evidence of potentially significant changes in hazards (for example, in the light of the feedback of operating experience, a major accident or the occurrence of extreme events). The implications of such a review of site specific hazards for the safe operation of the nuclear installation shall be evaluated.

5. Amendment of Safety of Nuclear Power Plants: Design [5]

For SSR-2/1, the approved revisions relate to the following main areas:

- Strengthening the prevention of unacceptable radiological consequences to the public and the environment;
- Strengthening severe accident mitigation measures so that, if an accident occurs, off site contamination is avoided or minimized;
- Preventing severe accident through strengthening the plant design basis, including strengthening the independence of level four of defense-in-depth, consideration of external hazards and sufficient margins.

5.1 Strengthening the prevention of unacceptable radiological consequences to the public and the environment

Requirement 7: Application of defense in depth (4.9 - 4.14)
4.14. The levels of defense in depth shall be independent as far as practicable to avoid the failure of one level reducing the effectiveness of other levels. In particular, safety features for design extension conditions (especially features for mitigating the consequences of accidents involving the melting of fuel) shall as far as be practicable independent of safety systems.

Requirement 12: Features to facilitate radioactive waste management and decommissioning (4.21)
4.21. In particular, the design shall take due account of: (a) - (b) (Omitted) (c) The facilities necessary for the management (i.e. segregation, characterization, classification, pretreatment, treatment and conditioning) and storage of radioactive waste generated in operation and provision for managing the radioactive waste that will be generated in the decommissioning of the plant.

Requirement 20: Design extension conditions (5.27 - 5.32)
5.31. The design shall be such that the possibility of conditions arising that could lead to early or to large radioactive releases is 'practically eliminated'. 5.32. The design shall be such that for design extension conditions, protective measures that are limited in terms of times and areas of application

shall be sufficient for the protection of the public, and sufficient time shall be available to take such measures.

Requirement 42: Safety analysis of the plant design (5.72 - 5.75)

5.73. The safety analysis shall provide assurance that uncertainties have been given adequate consideration in the design of the plant and in particular that adequate margins are available to avoid cliff edge effects and large or early radioactive releases.

5.2 Strengthening severe accident mitigation measures so that, if an accident occurs, off site contamination is avoided or minimized

THE CONCEPT OF DEFENCE IN DEPTH (2.12 - 2.14)

2.13
(1) - (4) (Omitted)
(5) The purpose of the fifth and final level of defense is to mitigate the radiological consequences of radioactive releases that could potentially result from an accident. This requires the provision of adequately equipped emergency response facilities and emergency plans and emergency procedures for on-site and off-site emergency response.

Requirement 67: Emergency response facilities on the site (6.42)

The nuclear power plant shall include the necessary emergency response facilities on the site. Their design shall be such that personnel will be able to perform expected tasks for managing an emergency under conditions generated by accidents and hazards.

6.42. Information about important plant parameters and radiological conditions at the nuclear power plant and in its immediate surroundings shall be provided to the relevant emergency response facilities in the on-site emergency control centre. Each facility shall be provided with means of communication with, as appropriate, the control room, the supplementary control room and other important locations at the plant, and with on-site and off-site emergency response organizations.

5.3 Preventing severe accident through strengthening the plant design basis, including strengthening the independence of level four of defense-in-depth, consideration of external hazards and sufficient margins.

THE CONCEPT OF DEFENCE IN DEPTH (2.12 - 2.14)

2.13 Paragraph 3.31 of the Safety Fundamentals states that "Defense in depth is implemented primarily through the combination of a number of consecutive and independent levels of protection that would have to fail before harmful effects could be caused to people or to the environment. If one level of protection or barrier were to fail, the subsequent level or barrier would be available. The independent effectiveness of the different levels of defense is a necessary element of defense in depth".
(1) - (3) (Omitted)
(4) The purpose of the fourth level of defense is to mitigate the consequences of accidents that result from failure of the third level of defense in depth. This is achieved by preventing the progression of the accident and mitigating the consequences of a severe accident. The safety objective in the case of a severe accident is that only protective actions that are limited in terms of lengths of time and areas of application would be necessary and that off-site contamination would be avoided or minimized. Sequences that lead to early or large radioactive releases are required to be 'practically eliminated'.
(5) (Omitted)

Requirement 17: Internal and external hazards (5.16 - 5.22)

5.16. Items important to safety shall be designed and located, with due consideration of other implications for safety, to withstand the effects of hazards or to be protected, in accordance with their importance to safety, against hazards and against common cause failure mechanisms generated by hazards.

5.17. For multiple unit plant sites, the design shall take due account of the potential for specific hazards to give rise to impacts on several or even all units on the site simultaneously.

5.18 Internal hazards : (Omitted)

5.19 – 5. 22 : External hazards

5.19. The design shall include due consideration of those natural and human induced external events (i.e. events of origin external to the plant) that have been identified in the site evaluation process. Causation and likelihood shall be considered in postulating potential hazards. In the short term, the safety of the plant shall not be permitted to be dependent on the availability of off-site services such as electricity supply and firefighting services. The design shall take due account of site specific conditions to determine the maximum delay time by which off-site services need to be available.

5.20 (Omitted)

5.21. The design of the plant shall provide for an adequate margin to protect items important to safety against levels of external hazards to be considered for design, derived from the hazard evaluation for the site, and to avoid cliff edge effects.

5.22. The design of the plant shall also provide for an adequate margin to protect items ultimately necessary to prevent large or early radioactive releases in the event of levels of natural hazards exceeding those considered for design, derived from the hazard evaluation for the site, as in para. 5.21.

Requirement 20: Design extension conditions (5.27 - 5.33)

5.27 An analysis of design extension - (omitted). This might require additional safety features for design extension conditions, or extension of the capability of safety systems to prevent, or to mitigate the consequences of, a severe accident, or to maintain the integrity of the containment. These - (omitted) - in the containment. The plant shall be designed so that it can be brought into a controlled state and the containment function can be maintained, with the result that significant early or large radioactive releases would be practically eliminated. The effectiveness - (omitted).

Requirement 32: Design for optimal operator performance (5.54 - 5.63)

5.56. The design shall support operating personnel in the fulfilment of their responsibilities and in the performance of their tasks, and shall limit the likelihood and the effects of operating errors on safety. The design process shall give due consideration pay attention to plant layout and equipment layout, and to procedures, including procedures for maintenance and inspection, to facilitate interaction between the operating personnel and the plant, in all plant states.

Requirement 33: Safety systems, and safety features for design extension conditions, of units of a multiple unit nuclear power plant (5.64)

Each unit of a multiple unit nuclear power plant shall have its own safety systems and shall have its own safety features for design extension conditions.

5.64. To further enhance safety, means allowing interconnections between units of a multiple unit nuclear power plant shall be considered in the design.

Requirement 53: Heat transfer to an ultimate heat sink (6.20 - 6.21)

The capability to transfer heat to an ultimate heat sink shall be ensured for all plant states.

6.20 Systems for transferring heat shall have adequate reliability for the plant states in which they have to fulfil the heat transfer function. This may require the use of a different ultimate heat sink or different access to the ultimate heat sink.

6.21 The heat transfer function shall be fulfilled for levels of natural hazards more severe than those considered for design, derived from the hazard evaluation for the site.

Requirement 58: Control of containment conditions (6.29 - 6.34)

6.31. Design provision shall be made to prevent the loss of the structural integrity of the containment in all plant states. The use of this provision shall not lead to early or to large radioactive releases.

6.32. The design shall also include features to enable the safe use of nonpermanent equipment14 for restoring the capability to remove heat from the containment.

Requirement 65: Control room (6.43-6.45)

6.43. Appropriate measures shall be taken, including the provision of barriers between the control room at the nuclear power plant and the external environment, and adequate information shall be provided for the protection of occupants of the control room, for a protracted period of time, against hazards such as high radiation levels resulting from accident conditions, release of radioactive material, fire, or explosive or toxic gases.

6.44. (Omitted)

6.45. The design of the control room shall provide an adequate margin against levels of natural hazards more severe than those to be considered for design, derived from the hazard evaluation for the site.

Requirement 68: Design for withstanding the loss of off-site power (6.48 - 6.55)

The design of the nuclear power plant shall include an emergency power supply capable of supplying the necessary power in anticipated operational occurrences and design basis accidents, in the

event of a loss of off-site power. The design shall include an alternate power source to supply the necessary power in design extension conditions.

6.48. The design specifications for the emergency power supply and for the alternate power source at the nuclear power plant due account shall be taken of the postulated initiating events and the associated safety functions to be performed, shall include, to determine the requirements for capability, availability, duration of the required power supply, capacity and continuity.

6.49. (Omitted)

6.50. The alternate power source shall be capable of supplying the necessary power to preserve the integrity of the reactor coolant system and to prevent significant damage to the core and to spent fuel in the event of the loss of off-site power combined with failure of the emergency power supply.

6.51. Equipment that is necessary to mitigate the consequences of melting of the reactor core shall be capable of being supplied by any of the available power sources.

6.52. The alternate power source shall be independent of and physically separated from the emergency power supply. The connection time of the alternate power source shall be consistent with the depletion time of the battery.

6.53. Continuity of power for the monitoring of the key plant parameters, and for the completion of short term actions necessary for safety shall be maintained in the event of a loss of the AC (Alternating Current) power sources.

6.54. (Omitted)

6.55. The design shall also include features to enable the safe use of nonpermanent equipment to restore the necessary electrical power supply.

Requirement 80: Fuel handling and storage systems (6.74 - 6.79)

6.78. For reactors using a water pool system for fuel storage, the design of the plant shall prevent the uncovering of fuel assemblies in all plant states that are of relevance for the spent fuel pool, so as to practically eliminate the possibility of early or large radioactive releases and to avoid high radiation fields on the site. include the following design of the plant:
(a) shall provide the necessary fuel cooling capabilities;
(b) shall provide features to prevent the uncovering of fuel assemblies in the event of a leak or a pipe break;
(c) shall provide a capability to restore the water inventory.

The design shall also include features to enable the safe use of nonpermanent equipment to ensure sufficient water inventory for the long term cooling of spent fuel and for providing shielding against radiation.

6.79. The design shall include the following:
(a) Means for monitoring and controlling the water temperature for operational states and for accident conditions that are of relevance for the spent fuel pool;, water chemistry and activity of any water in which irradiated fuel is handled or stored;
(b) Means for monitoring and controlling the water level for operational states and for accident conditions that are of relevance for the spent fuel pool; the fuel storage pool and means for detecting leakage;
(c) Means for monitoring and controlling the activity in water and in air for operational states and means for monitoring the activity in water and in air for accident conditions that are of relevance for the spent fuel pool;
(d) Means for monitoring and controlling the water chemistry for operational states.

6. Amendment of Safety of Nuclear Power Plants: Commissioning and Operation [6]

For SSR-2/2 the approved revisions relate to the following main areas:

- Periodic safety review;
- Emergency preparedness;
- Accident management; and
- Feedback from operating experience.

6.1 Periodic safety review

Requirement 12: Periodic safety review (4.44 – 4.47)

4.44. Safety reviews, such as the periodic safety assessments under alternative arrangements shall be carried out throughout the lifetime of the plant, at regular intervals and as frequently as necessary, (typically no less frequently than once in ten years). Safety reviews shall address, in an appropriate manner; the consequences of the cumulative effects of plant ageing and plant modification; equipment requalification; operating experience, including national and international operating experience; current national and international standards; technical developments; and organizational and management issues; and site related aspects. Safety reviews shall be aimed at ensuring a high level of safety throughout the operating lifetime of the plant.

4. 45 - 4.46 (Omitted)

4.47. On the basis of the results of the systematic safety assessment, the operating organization shall

implement any necessary corrective actions and reasonably practicable modifications for compliance with applicable standards with the aim of enhancing the safety of the plant by further reducing the likelihood and the potential consequences of accidents.

6.2 Emergency preparedness

Requirement 18: Emergency preparedness (5.2 - 5.7)

5.6. The emergency plan shall be tested and validated in exercises before the commencement of fuel loading. Emergency preparedness training, exercises and drills shall be planned and conducted at suitable intervals, to evaluate the preparedness of plant staff and staff from external response organizations to perform their tasks, and to evaluate their cooperation in coping with an emergency and in improving the efficiency of the response.

5.7. Facilities, instruments, tools, equipment, documentation and communication systems to be used in an emergency, including those needed for off-site communication and for the accident management program, shall be kept available. They shall be maintained in good operational condition in such a manner that they are unlikely to be affected by, or made unavailable by, accidents conditions. The operating organization shall ensure that relevant information on safety parameters is available in the emergency response facilities and locations, as appropriate, and that communication between the control rooms and these facilities and locations is effective in the event of an accident. These capabilities shall be tested periodically.

6.3 Accident management

Requirement 19: Accident management program (5.8 – 5.15)

The operating organization shall establish, and shall periodically review and as necessary revise an accident management program.

5.8. An accident management program shall be established that covers the preparatory measures, procedures and guidelines and equipment that are necessary for preventing the progression of accidents dealing with beyond design basis accidents, including accidents more severe than the design basis accidents, and for mitigating their consequences if they do occur. The accident management program shall be documented and shall be periodically reviewed and as necessary revised.

5.9. For a multi-unit nuclear power plant site, concurrent accidents affecting all units shall be considered in the accident management program. Trained and experienced personnel, equipment, supplies and external support shall be made available for coping with concurrent accidents. Potential interactions between units shall be considered in the accident management program.

5.10. The accident management program shall include instructions for the utilization of available equipment-safety related equipment as far as possible, but also conventional equipment.

5.11. The accident management program shall include contingency measures such as an alternative supply of cooling water and an alternative supply of electrical power to mitigate the consequences of accidents, including any necessary equipment. This equipment shall be located and maintained so as to be functional and readily accessible when needed.

5.12. The accident management program shall include the technical and administrative measures to mitigate the consequences of an accident.

5.13. The accident management program shall include training necessary for the implementation of the program.

5.14. In developing the accident management program and its procedures, the possibility of the degradation of regional infrastructure, and adverse working conditions (e.g. elevated radiation levels, elevated temperatures, lack of lighting, limited access to the plant from off the site) for operators, as well as the degradation of operating conditions for equipment, shall be taken into account so as to ensure that actions expected for accident management will be feasible and will be able to be taken in a timely and reliable manner.

5.15. Arrangements for accident management shall provide the operating staff with appropriate competence, systems and technical support in relation to beyond design basis accidents. These arrangements and relevant guidance shall be available before the commencement of fuel loading, shall be validated and then shall be periodically tested as far as practicable in exercises and used in training and drills and they shall address the actions necessary following beyond design basis accidents, including severe accidents. In addition, arrangements shall be made, as part of the accident management program and the emergency plan, to expand the emergency arrangements, where necessary, to include the responsibility for long term actions.

6.4 Feedback from operating experience

Requirement 24: Feedback of operating experience (5.33 – 5.39)

5.33. The operating organization shall establish and implement a program to report, collect, screen, analyses, trend, document and communicate operating experience at the plant in a systematic way. It shall obtain and evaluate available information on relevant operating experience at other nuclear installations to draw and incorporate lessons for its own operations, including its emergency arrangements. It shall also encourage the exchange of experience within national and international systems for the feedback of operating experience. Relevant lessons from other industries shall also be taken into consideration, as necessary.

7. Conclusions

The five IAEA safety requirements publications which are GSR Part 1&4, NS-R-3 and SSR-2/1&2, were amended to reflect the lesson learned from the Fukushima accident and other operating experiences. Specially, 36 provisions were modified and the new 29 provision with 1 requirement (No. 67: Emergency response facilities on the site) of the SSR-2/1 were established.

Since the Fukushima accident happened, a new word, design extension conditions (DECs) which cover substantially the beyond design basis accidents (BDBA), including severe accident conditions, was created and more elaborated by the world nuclear experts. The definition of design extension conditions is that postulated accident conditions that are not considered for design basis accidents, but that are considered in the design process of the facility in accordance with best estimate methodology, and for which releases of radioactive material are kept within acceptable limits [4]. Design extension conditions could include conditions in events without significant fuel degradation and conditions with core melting [4]. Figure 2 shows the range of the DECs.

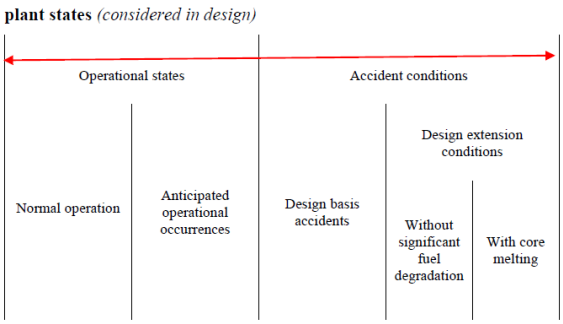

Fig. 2. Plant States to Considered in Design [5]

The amendment of the five IAEA safety requirements publications are focused at the prevention of initiating events, which would lead to the DECs, and mitigation of the consequences of DECs by the enhanced defense in depth principle.

The following examples of the IAEA requirements to prevent the initiating events are: margins for withstanding external events; margins for avoiding cliff edge effects; safety assessment for multiple facilities or activities at a single site; safety assessment in cases where resources at a facility are shared; consideration of the potential occurrence of events in combination; establishing levels of hazard for the design basis for the installation and their associated uncertainties; consideration of hazards due to surface faulting and flooding; monitoring of hazards and periodic review of site specific hazards; strengthening the prevention of unacceptable radiological consequences to the public and the environment; preventing severe accident through strengthening the plant design basis, including strengthening the independence of level four of defense-in-depth, consideration of external hazards and sufficient margins; periodic safety review; emergency preparedness; feedback of operating experience.

The following examples of the IAEA requirements to mitigate the consequences of DECs are: role of the government and the regulatory body for emergency preparedness and response, strengthening severe accident mitigation measures; well defined and updated accident management program.

Remaining challenges for ensuring nuclear safety is to fulfill faithfully the revised IAEA requirements by Member States. Through the review of the amended IAEA requirements, it is needed to reflect carefully them with the relevant domestic regulations, technical standards and regulatory guides, as necessary. Considering the importance and urgency, the relevant parties may voluntarily implement the revised IAEA requirements, as appropriate, even before legislation.

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