Guide YVL B.7, Provisions for internal and external hazards at a nuclear facility

1 Scope of application

Guide YVL B.7 applies to provisions for internal and external hazards at a nuclear facility during the different phases of its life cycle. Certain requirements separately mentioned in this Guide only apply to a nuclear power plant. The Guide does not apply to underground rooms for final disposal of nuclear waste or to a research reactor. The scope of application is dealt with in more detail in chapter 2 “Justifications of the requirements”.

2 Justifications of the requirements

2.1 Chapter 1 Introduction

Requirements 102–106 present the upper-level provisions specified in the Guide. The purpose of Guide YVL B.7 is to specify Sections 14 and 15 of the Radiation and Nuclear Safety Authority Regulation on the Safety of a Nuclear Power Plant (STUK Y/1/2018) and Sections 17 and 18 of the Radiation and Nuclear Safety Authority Regulation on the Safety of Disposal of Nuclear Waste (STUK Y/4/2018), which present general requirements for addressing internal and external hazards. The Guide also specifies the requirements of the Radiation and Nuclear Safety Authority Regulation on the Emergency Arrangements of a Nuclear Power Plant (STUK Y/2/2018) as regards taking external hazards into account.

The Guide specifies certain requirements for the safety design of nuclear power plants presented in Guide YVL B.1 “Safety design of a nuclear power plant”, such as the separation requirements as regards physical separation.

Requirement 107 notes certain means commonly used in preparing for internal and external hazards. Requirement 108 presents general good design principles suitable for preparing for internal and external hazards. The principles are presented as concerning external hazards in the WENRA reference levels (RL T5.3 in the 2014 update), but they are also suitable for internal hazards. The principles are so general that they are not formally presented as requirements, but the requirements of the Guide correspond to these principles. The principles in question are a good starting point also when assessing questions related to internal and external hazards, for which there are no direct requirements in the regulations or guides.

2.2 Chapter 2 Scope of application

Guide YVL B.7 covers the life cycle of a nuclear facility from construction to decommissioning. Before bringing nuclear fuel to the facility, the Guide is applied under requirement 203 to the extent necessary for ensuring the functionality of the safety systems during the operation of the facility. During construction, systems, components and structures shall be protected so that external events do not impair their capability to carry out their functions during operation.

Requirement 204 states the principle that preparations for internal and external hazards shall also be made at a nuclear facility undergoing decommissioning in the scope justifiable considering the amount of radioactive substances contained in the nuclear facility and the risk of their release. This corresponds to the IAEA's Graded Approach principle. However, the Guide does not give detailed requirements for this; instead, STUK decides on the requirements as necessary in a separate decision when there are more detailed plans available for the implementation of decommissioning. Because the Guide will presumably have to be updated before the decommissioning of the nuclear facilities in its scope, it is not as yet necessary to prepare detailed application rules for the decommissioning phase.

Requirement 205 rules research reactors and underground rooms for final disposal of nuclear waste out of the scope of application of the Guide. Safety threats related to underground rooms for final disposal and the time periods to be analysed are mostly different from those concerning above-ground nuclear facilities, and the Guide is not as such applicable to them. However, the above-ground parts of the disposal facility have not been ruled out of the scope of application of the Guide. The size, purpose and design solutions of research reactors vary to a great extent, and it is not justifiable to apply the Guide to them generally. Instead, the necessary requirements should be set case-specifically. Because there is only one research reactor in Finland in the decommissioning phase and no new ones are planned, it is not necessary to assess the application of the requirements of the Guide to research reactors in more detail.

Requirement 207 states that the Guide concerns external hazards that may occur at the current Finnish sites or similar sites. The facility site-specific requirements presented in the Guide are intended to apply to facility sites located on the seashore with relatively flat topography and where buildings can be founded on bedrock.

The starting point of the Guide is that the heat sink for the turbine condenser is sea water and the final heat sink for the safety systems is sea water or the atmosphere. There are as yet no facilities planned in Finland that use lake or river water and/or turbine condenser cooling towers. This is why the Guide, for example, refers to the facility's cooling water as 'sea water'. Most of the requirements of the Guide are also applicable to nuclear facilities using lake or river water, but a facility site located by a lake or river might have special issues related to external hazards that have not yet been clarified during the preparation of the Guide.

For example, the Guide does not address hazards typical to Central European river valleys, river deltas, mountain areas or instable soil (landslides, mud slides, subsidence, avalanches, dam failures, tidal waves), which are discussed in detail in the IAEA's guides, for example, or hazards to cooling towers.

If nuclear facilities were planned to be built in Finland in places that differ significantly from the current locations, external hazards would be examined case-specifically during EIA and decision-in-principle proceedings. If necessary, STUK issues the safety requirements concerning them by a separate decision.

The Guide does not apply to protection against unlawful action (requirement 206), which is discussed in Guide YVL A.11 “Security of a nuclear facility”. However, certain phenomena mentioned in Guide YVL B.7 may be caused by an accident or intentional activity, and some of the same technical solutions can be used in making provisions against them.

Requirements for protection against internal and external hazards are provided in several other YVL Guides. The most important of these are mentioned in requirement 208.

This Guide does not present separate requirements for reporting those events to STUK that are caused by internal and external threats to the nuclear facility. Instead, requirement 208 refers to Guide YVL A.10 “Operating experience feedback of a nuclear facility”, which presents the general reporting requirements. In the interpretation of requirements A07 and A08 of Annex A of Guide YVL A.10, which concern the reporting of external and internal events, it is necessary to take into account requirement 701 of the Guide in question, which stipulates as follows: *The licensee shall promptly notify STUK of any events affecting the nuclear or radiation safety of a nuclear facility by calling STUK’s 24h emergency number and include such events in the next daily report. Even events that do not directly affect nuclear or radiation safety but may be anticipated to arouse public interest shall be notified following the same procedure.*

Requirement 210 states that fire safety is discussed in Guide YVL B.8 and that general legislation pertaining to construction as well as fire and rescue services, particularly the Decree of the Ministry of the Environment on the Fire Safety of Buildings (848/2017), also apply to nuclear facilities.

The definition of internal and external events in different contexts in international and national practices is somewhat shaky. Hazards to a particular building from the outdoor areas, other plant buildings or different units of the same site area have been defined as internal or external hazards in different contexts. Perfect harmonisation of the definitions will not necessarily be reached in the near future. However, it is essential that all hazards are appropriately addressed under some title.

Requirement 211 presents the systems, structures and components that the Guide is applied to. The principal rule is that the Guide is applied to systems, structures and components important to safety, unless a requirement separately specifies its scope of application. In accordance with the collected definitions, systems, structures and components important to safety shall refer to systems, structures and components in safety classes 1, 2 and 3 class and systems in class EYT/STUK. However, requirement 211 excludes from the scope of application the systems that belong to class EYT/STUK solely on the grounds that the system monitors radiation, surface contamination or radioactivity in the plant, in tools, in employees or in the environment (e.g. the environmental radiation monitoring network). In addition, the requirements of Chapter 4 concerning seismic design are applied to seismic category S2A equipment and structures to the extent necessary to protect systems important to safety.

2.3 Chapter 3 Layout design of the nuclear facility

The layout design of the site area and the buildings of the nuclear facility is important in protection against internal and external hazards.

This Guide discusses protection against internal hazards from the point of view of layout design. Fire protection at nuclear facilities is discussed in detail in Guide YVL B.8 “Fire protection at a nuclear facility”. Taking internal hazards into account in component design is discussed, for example, in Guide YVL E.4 “Strength analyses of nuclear power plant pressure equipment”.

Chapter 3.1 presents requirements for the layout design of the site area. The layout design of a new nuclear facility shall take into account the existing facilities in the area.

The requirements of Chapter 3.1 are mostly general: for example, they state that certain phenomena shall be taken into account in the layout design of the site area (302, 303, 309, 310) or that the phenomena shall not cause danger, or the danger shall be minimal (304, 305, 307).

The chapter does not specify which failure criteria shall be complied with. The fulfilment of the requirements shall be assessed as a whole, taking into account the safety characteristics of the facility, the requirements concerning defence in depth presented in Guide YVL B.1 and the probabilistic safety goals presented in Guide YVL A.7 “Probabilistic risk assessment and risk management of a nuclear power plant”.

In Chapter 3.1 and also elsewhere in the Guide, expressions are used according to which the possibility or probability of an event shall be low or very low. There is no exact definition for a low or very low possibility or probability; the interpretation depends on the context. The Guide generally uses the term ‘possibility’ when it is has been used in STUK’s regulations and the term ‘probability’ when discussing an event which is generally modelled in the PRA or for which a justified quantitative probability estimation can otherwise be presented. The expression ‘very low’ is generally used in this Guide when it has been used in STUK’s regulations. Its meaning is close to the expression ‘practically excluded’. The expression usually relates to events that can directly lead to severe damage at the nuclear facility or environmental consequences. Expressions ‘low probability’ and ‘low possibility’ are used in this Guide in connection with events that typically do not endanger several safety systems or safety divisions or defence-in-depth levels at the same time.

Chapter 3.2 “Protection of the nuclear facility against internal hazards” presents a list of phenomena and events that should at least be taken into account in the design. The list is not exhaustive; the hazards to be examined shall be justified facility-specifically. Protection against internal hazards is discussed in this Guide particularly from the point of view of layout design, so the requirements are presented under the main title concerning layout design.

Requirement 312 requires temperature control in rooms where temperatures can be so high or low that the operation of components located in them is endangered. According to requirement 5503 of Guide YVL B.1, *an analysis shall be provided of the consequences of any loss of the ventilation, heating and cooling of the spaces hosting systems important to safety, and of the temperature-related behaviour of such spaces during anticipated operational occurrences in plant operation*. The results of the analysis may also be used when assessing the need for temperature surveillance. Factors to be taken into account in the assessment include the thermal load of the rooms and the factors affecting the possibility of the loss of ventilation and heating. An example of the risks related to low temperature is the freezing of impulse pipes in the case of the loss of heating, especially if ventilation stays on.

Requirement 314 concerning internal floods requires that sea water pipe breaks shall also be examined during design-basis sea water levels, because the spreading of a flood caused by sea water pipe break and its effects may, depending on the layout solutions of the facility, be significantly worse when the sea water level is exceptionally high than when the level is normal.

According to requirement 315, design relating to protection against floods shall take into account conditions where process systems, penetrations or doors or hatches that are normally kept closed have been opened for maintenance or repair work. Factors to be taken into account in assessing the need for any measures include the size of the flood source, the spreading rate of the flood, the time available for countermeasures and the safety significance of the spreading of the flood.

Chapter 3.3 presents detailed requirements for the separation of safety divisions that complement the separation requirements presented in Guide YVL B.1 and the fire safety requirements presented in Guide YVL B.8.

The purpose of requirement 326 is to ensure that all the factors affecting the matter are taken into account in the design of the separation of safety divisions:

- In the design of the separation, it is necessary to take into account the systems, fire loads and ignition sources in the safety divisions under examination, in other rooms next to the safety divisions and in outdoor areas
- For the design of the separation, the worst events assessed as possible in the rooms and areas under examination shall be determined. The requirement specifically mentions fires, releases of poisonous gases and floods, but other possible events shall also be taken into account in the examination
- The worst fire that is considered possible in the rooms under examination shall be used as one basis for the design of the separation
- In addition to the direct fire and heat impact, the formation of smoke and poisonous gases shall also be examined as an effect of fire.

Chapter 3.4 discusses the doors, hatches and penetrations between safety divisions. The general principle is that they should be avoided, but in practice they are needed, for example, because of the aspects related to layout design and personal safety. The purpose of the requirements is to ensure that the doors, hatches and penetrations between safety divisions are designed so that they do not in practice weaken the separation.

The purpose of requirements 335 and 336 is to ensure that the interface between safety divisions is continuously leak-tight also when using any access openings between the safety divisions.

Chapter 3.5 presents requirements for the demonstration of the implementation of the technical requirements of Chapter 3 and the documents to be submitted to STUK.

According to requirement 340, a preliminary traffic plan for the site area shall be submitted to STUK for the review of the application for a decision-in-principle. According to requirements 342 and 346, a traffic plan for the site area shall be submitted to STUK for the review of the construction licence application and the operating licence application. Information to be presented in the preliminary traffic plan and the traffic plan include at least

- traffic flows and routes of person and freight traffic in the site area, unloading and loading points, including land, water and air transports, taking specifically into account transports of nuclear materials, radioactive materials, flammable liquids and gases and other dangerous materials
- arrangements made to avoid accidents
- securing the conditions for rescue and emergency preparedness activities and security arrangements
- any impact of heavy and large transports carried out during the life cycle of the facility on the dimensioning of traffic routes and structures important for safety, including underground structures.

Requirement 343 requires that a layout design plan and the related reports and layout drawings be submitted for the review of the construction licence application. The presentation of layout design plans for buildings is discussed in Annex A of Guide YVL B.1, which describes the matters presented in the system descriptions of buildings.

Requirement 343a requires that a 3D computer model (building information model) and the information model description shall also be submitted. The term ‘3D computer model’ in requirement 343a refers to the Building Information Model (BIM). The model contains features of systems, structures and components in proper format. IFC (Industry Foundation Classes), based on STEP files in accordance with the standard ISO 10303-21, has been established as the format (open and neutral) of the building information model. The open format BCF (Building Collaboration Format) has been developed for the transmission of comments and messages concerning the building information model. In Finland, the general building information model and infrastructure requirements are maintained by the forum for BIM collaboration BuildingSMART Finland.

Requirement 343a also presents the general principles on what shall be presented in the 3D computer model for the operation of the authorities. The 3D computer model is principally a design tool. An authority may also utilise the 3D computer model in assessing the fulfilment of safety requirements. As regards internal and external hazards, the 3D computer model may be used to assist design and inspection, for example, in the following contexts: analyses justifying the sufficiency of the separation and the protection against internal and external hazards (for example, YVL B.7, requirements 342, 343c, 526 and 539, YVL B.8, YVL E.4), the planning of facility walkdowns (especially the recognition of any seismic interactions), the design of exit routes and the demonstration of conformity.

Important things for regulatory control to be presented in the 3D computer model at the construction license stage include the preliminary dimensioning of buildings, structures, main components, process equipment, piping, piping support design, the location of attachment plates, pipe whip restraints, cable routes, control rooms, electrical and I&C rooms and I&C and switchgear cabinets. In the construction licence phase, the attachment plates of equipment in safety class 1 are particularly important, but it is also important to present preliminary information on the attachment plates of equipment in lower safety classes. In addition, the 3D computer model should present from the safety point of view the penetrations between safety divisions and compartments, access routes, crane routes and other space reservations based on which it is possible to verify the implementation of separation principles and the requirements derived from them in order to provide protection against internal and external hazards.

Requirements 343b and 343c present requirements for the content of the 3D computer model and drawings. Requirements 346 and 348 address the update of information submitted in previous licensing phases for the operating licence application and during the operation of the facility.

According to requirement 345, the licensee shall submit to STUK for the review of the construction licence application the standards used in to be applied in the separation of safety divisions. The standards in question are those concerning fire protection, construction technology and mechanics, including standards concerning penetrations.

2.4 Chapter 4 Earthquakes

Chapter 4.1 presents the requirements for the design basis earthquake and its determination. The starting point is that the licensee/licence applicant determines the design basis earthquake facility site-specifically and seeks STUK's approval for it. According to requirement 401, the design basis earthquake shall be so defined that the anticipated frequency of occurrence of stronger bedrock motions is less than 10^{-5}/year at a median confidence level. In certain countries, the frequency of the exceedance of the design basis earthquake is 10^{-4}/year as an expectation value or a high confidence level value (1 σ). Because the distribution is typically skewed, the determinations often lead to approximately the same end result, although there are exceptions to this. In requirement 401, median confidence level refers particularly to the determination of the peak ground acceleration (PGA) and ground response spectrum used as the design basis. In other contexts, information of other confidence levels may be used if appropriate.

Requirement 401 discusses facility site rock surface motion, whereas the IAEA's guides use the word 'ground'. The Finnish version of Guide YVL B.7 published in 2013 used the expression 'maaperän kiihtyvyys' for ground acceleration, but in Finnish, 'maaperä' usually means loose soil. Because buildings important to the safety of nuclear facilities are usually founded directly on bedrock in Finland (see requirement 414), the Guide refers to rock surface.

In practice, the requirements of Chapter 4.1 mean that Probabilistic Seismic Hazard Analysis (PSHA) shall be used in the determination of the design basis earthquake. The method is well suited for Finnish conditions of diffuse seismicity (earthquakes cannot be linked to known transition zones). The Guide does not include exact requirements for methods or standards to be used in the determination, because there is no Finnish industry standard and the foreign standards are not necessarily appropriate as such in Finnish circumstances. Because there have not yet been any requirements for seismic design in other construction in Finland, the procedures concerning the definition of the seismic hazard for Finnish conditions have not yet been established. The selection of methods is left to the licence applicants and licensees, and STUK assesses their acceptability case-specifically. STUK does not require any particular standard or instruction to be followed in the determination of the design basis earthquake, but the procedure shall be systematic and intermediate results traceable.

According to requirements 403 and 404, information describing the facility site as well as possible shall be used for the determination of the design basis earthquake. The earthquake catalogue used in the determination shall be based on earthquakes observed in Finland and nearby areas in the neighbouring countries. Different methods may be accepted for ground motion prediction equations. Ground motion prediction equations presented in literature and determined in a similar area, whose suitability for the facility site under examination is justified, may be used in the calculation. Ground motion prediction equations may also be determined using observations from Finland and nearby areas or seismologically similar areas elsewhere in the world. Because there is only a limited amount of measurement data suitable for the determination of ground motion prediction equations available from Finland, usually it is necessary to use information collected from other similar areas, at least partially. In all cases, it is essential that the characteristics of measurement locations and measuring equipment are sufficiently well known.

The requirements take into account that the seismic hazard analysis methods do not necessarily lead to a ground response spectrum, which would be applicable as such in the design; instead, the spectrum might require smoothing. In the design, it is also possible to use a form of ground response spectrum selected on other grounds if it is demonstrated that it covers the ground response spectrum determined for the facility site.

Requirement 408 requires a seismic hazard curve to be presented for the PRA and for the determination of a DEC C earthquake in accordance with Guide YVL B.1. The DEC C earthquake is also discussed in requirement 428a.

Figure 1 presents, as examples, the ground response spectrum for the design basis earthquake approved for the Hanhikivi 1 project (STUK decisions 2/J42219/2018 and 1/J42219/2018, 3 August 2018) and the ground response spectrum for the design basis earthquake approved in connection with the Olkiluoto 3 project (STUK decision C30/78, 6 November 2001). The figure is only intended to illustrate the ground response spectrum; the acceptability of the presented spectra in other contexts is not discussed here. The updates of the ground response spectra of Olkiluoto and Loviisa were submitted to STUK in early 2019, but their acceptability has not yet been assessed.

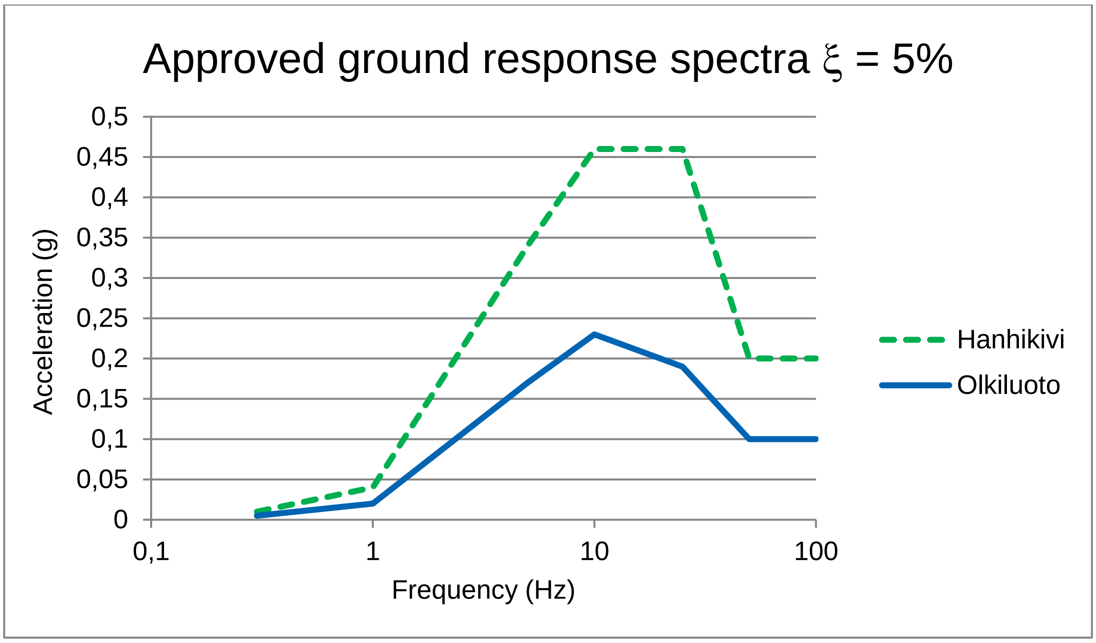

Figure 1. Horizontal ground response spectra approved in connection with the Hanhikivi 1 and Olkiluoto 3 projects and used as the design basis with a damping ratio value of 5%. The ground response spectrum of Olkiluoto has also been approved for the Loviisa plant site. STUK decisions 2/J42219/2018 and 1/J42219/2018, 3 August 2018 and C30/78, 6 November 2001.

Chapters 4.2 and 4.3 present certain essential principles of earthquake design and methods to demonstrate earthquake resistance. As regards detailed requirements, the chapter refers to industry standards and international guidance. The licence applicant shall present a systematic approach to seismic design. The application of combinations of requirements of different standards shall be justified in requirement management. The E series YVL Guides include more detailed requirements relating to the matter.

Requirements 410a, 416a and 416b discuss the analysis and assessment of the durability of systems, structures and components in seismic classes S1 and S2A and their design against external vibrations based on standards ASCE/SEI 4-16 and ASCE/SEI 43-05 and reports NUREG/CR-6919 and NUREG/CR-6026.

Chapter 3 of standard ASCE/SEI 4-16 presents the grounds for the assessment of the attenuation characteristics of frame structures in relation to the response levels of similar capacities and the cracking of concrete structures:

Chapter 3, Modelling of structures, Response Levels:

1. *Used nominal strength capacity of steel and concrete members < 50 %, no significant cracking in concrete*
2. *50 % ≤ used capacity ≤ 100 %, significant cracking in concrete*
3. *limited permanent distortion < used capacity < large permanent distortion.*

The starting point of requirement 416c is that the utilisation rates of massive concrete structures and other typical frame structures at nuclear facilities against design basis earthquakes are usually relatively low. In addition, the concrete structures are designed to be long-lived, which means that the cracking of concrete is designed to be minimal. In this case, it is primarily recommended to comply with response level 1 presented in standard ASCE/SEI 4-16. This is supported by NUREG/CR-6919, which presents recommendations for structural attenuation assumptions. Instead of the term ‘response level 1’, it uses the term ‘OBE (operating basis earthquake)’, and instead of ‘response level 2’, it uses the term ‘SSE (safe shutdown earthquake)’. The actual technical recommendation of report NUREG/CR-6919 is that when the utilisation rate of structural capacities does not exceed 80%, the OBE level is applied, which corresponds to response level 1. This is more demanding than ASCE/SEI 4-16, in which the equivalent utilisation rate of the capacity is 50%, as stated above.

With regard to DEC C earthquakes and other external vibrations greater than the design basis earthquake, the design objectives presented for frame structures primarily focus on preventing the collapse of frame structures, however, in such a way that the defined important safety systems still maintain their functionality. In this case, the natural response level is 2.

The response levels presented above are typical for frame structures based on acceleration tolerance in the conditions of Finland. With justified reasons, the response levels of these frame structures may be proposed as one step lighter when the physical behaviour of the frame structure can be demonstrated to be more flexible than normally, for example, by the acceptability of cracking of concrete structures that is greater than normal. On the other hand, if structural attenuation is to be systematically raised in order to drop acceleration levels, the corresponding design bases shall be presented with proper analyses instead of difficult standard interpretations. This is included in requirements 410 and 416.

Requirement 419 focuses on load combinations and combining horizontal and vertical acceleration assessments. In this regard, standards ASCE 4-16 and EN 1998 are referred to. The reference to standard EN 1998 only applies to combining loads.

With regard to load combinations, requirement 422 refers to the requirement specifications discussed in Guide YVL B.1 and the E series Guides. For example, as regards construction technology, standard SFS-EN 1990, which also contains a national appendix, is usually followed.

According to requirement 423, the partial safety factors of loads and materials shall be determined in accordance with approved requirement specifications. The value 1.0 shall primarily be used as the partial safety factor of the earthquake load, but the requirement gives the licensee the possibility to suggest other values to be used for a justified reason.

Requirement 428a requires that earthquakes exceeding the design basis be considered design extension conditions (DEC C) in accordance with Guide YVL B.1. The Guide does not specify how high accelerations the DEC C examinations should cover. In practice, an indicative value would be an acceleration corresponding to the occurrence frequency $1 \cdot 10^{-7}$/year at the facility site. This would be compatible with the probabilistic safety objectives of Guide YVL A.7. An alternative limit for DEC C examinations would be, for example, an acceleration approximately twice as large as the design value.

There are alternative ways to process seismic DEC C situations: some safety systems may be designed to withstand greater accelerations than the general seismic design basis, or it can be demonstrated that, taking ordinary design margins into account, safety functions can with great certainty also be implemented in connection with an earthquake exceeding the design basis, although some components and structures important to safety may be damaged. In practice, DEC C examinations have been performed before in combination with the seismic PRA, but for clarity, the results should be presented as margins of acceleration values in addition to probabilities. The procedure would correspond to the opinions presented in the EU stress tests and at the Extraordinary Review Meeting of the Convention on Nuclear Safety after the Fukushima accident.

Fragility curves include the probabilities of failure determined using dynamic analyses or distributions of material parameters as a function of ground acceleration. HCLPF (high confidence low probability of failure) indicates ground acceleration that results in a failure probability of 5% at a confidence level of 95%, which, as an expectation value, typically corresponds to a failure probability of approximately 1%. For example, according to the practice followed by US NRC for old nuclear power plants, systems, structures and components are considered to withstand the reference acceleration if their HCLPF values are higher than that.

Chapter 4.3.6 discusses equipment aggregates, which refer to combinations of related equipment that need to be considered in dynamic strength analyses as a single entity in order to check the boundary conditions used in analyses of different components. Aggregates formed by a pump or a fan, its motor and a machine foundation can be mentioned as examples. Diesel generators should also be analyzed as equipment aggregates. The report required by requirement 437 concerns equipment aggregates. The demonstration of the earthquake resistance of components belonging to an equipment aggregate is described in documents required by the E series YVL Guides. Actual system, structure and component-specific seismic plans are presented in technology-specific licensing documents.

According to requirement 438, a nuclear power plant shall have instructions for bringing the plant into a safe state after an earthquake. The shutdown shall be based on S1 category systems, structures and components. In addition, Guide YVL A.7 requires the earthquake situation and the shutdown to be analysed in the PRA as well. According to requirement 438a, nuclear power plants shall have instructions describing the inspections and other measures to be carried out after an earthquake, their dependency on the intensity of the earthquake at the site (ground acceleration) and the conditions for continued operation. The scope of the measures can be divided into a few categories depending on the observed peak ground acceleration.

In order to ensure earthquake design, facility walkdowns are required to be performed in the commissioning phase. They are intended to ensure that seismic design sufficiently covers the different interactions between systems, components and structures. Facility walkdowns are prepared for by going through the design bases and the most significant risks shown up by the PRA. During a facility walkdown, an experienced earthquake expert may observe problem areas that have been left unnoticed in the design phase and/or in the implementation methods.

2.5 Chapter 5 Other hazards external to the nuclear facility

Chapter 5 presents the requirements for external phenomena other than earthquakes to be taken into account in the design of a nuclear facility and principles for the selection of design values.

External hazards to the nuclear facility are facility site-specific, and their safety significance depends on the technical solutions of the facility. For this reason, the starting point of the Guide is that the licence applicant or licensee determines external hazards facility site-specifically and prepares an account on how they are taken into account in the technical solutions of the facility. The Guide presents the general principles to be taken into account when making provisions for external hazards.

According to requirement 502, the licence applicant shall prepare an account on how external hazards are taken into account in the design of the facility and submit the account to STUK in accordance with requirements 537 and 540 for the review of the construction licence application and the operating licence application.

Requirement 503 presents general principles for specifying the design bases concerning external hazards. Magnitudes of phenomena whose estimated frequency of exceedance at the facility site is less than $1 \cdot 10^{-5}$/year shall be used as the general design bases of the facility. Item c of requirement 503 presents a minor moderation concerning the probability level in a situation in which an external condition or event has no effect on the occurrence of a certain initiating event. In this situation, a design value whose frequency of exceedance is less than 10^{-4}/year can be used as the design basis for the systems needed for managing the initial event in question. An example of the situations in question is the sea water temperature used in the dimensioning of the capacity of sea water systems needed for the management of leaks in the primary circuit. A milder design basis can be accepted in a situation like this because the random occurrence of the initiating event in connection with exceptional external circumstances is highly unlikely. If the same systems are also needed for the management of initiating events caused by external conditions, a design value corresponding to the occurrence frequency of 10^{-5}/year shall be followed for that purpose.

In addition, rarer phenomena shall be considered as DEC C events. No lower limit has been set for the occurrence frequency of DEC C events to be taken into account in the design, because the frequency estimates involve major uncertainties. In practice, the acceptable lower limit is usually approximately $1 \cdot 10^{-7}$/year. For external hazards leading directly to core damage, however, it is reasonable to use a lower limiting value of occurrence frequency, especially if the determination of the occurrence frequency involves major uncertainties.

The general starting point of the Guide is that in the preparation for earthquakes and other external hazards, the same level of safety is aimed at.

If the above principles were followed, the probabilistic safety objectives of Guide YVL A.7 would be realised for the core damage frequency ($1{\cdot}10^{-5}$/year) with a high degree of certainty. The objective would also be realised for a large release ($5{\cdot}10^{-7}$/year) with moderate certainty, provided that there are not several possible events leading to core damage and the loss of the containment function with the frequency of slightly below $1{\cdot}10^{-7}$/year.

Because the frequency estimates involve major uncertainties, the Guide separately requires that both the general design basis and the DEC C design values shall include a sufficient margin in relation to the observed maximum values of the phenomena to be examined. The assessment of the sufficiency of the margin shall take into account the uncertainty related to the occurrence frequency, the safety significance of the consequences and any “cliff edge” events, i.e. situations in which even a small exceedance of the design value may lead to severe consequences.

The determination of the design basis of the high level of sea water is discussed in the Guide in more detail because the distribution determined based on measured observations involves major uncertainties, the extreme value distribution may change during the life of the plant due to the natural variability of the climate or the climate change caused by humans, it is very difficult to change the design values after the construction phase and, additionally, flooding caused by a minor exceedance of the design basis may, at least in some plant designs, lead to a situation that is very difficult to manage (a so-called cliff edge situation).

In the determination of the design basis of the high level of sea water, the following three approaches shall be used and the highest value given by them shall be selected (requirements 503, 504, 514, 515):

1. the fitting of an extreme value distribution to observations, and the design basis value determination under requirement 503 corresponding to the occurrence frequency of 10^{-5}/year and the analyses concerning the DEC C situation under requirement 506 for a lower occurrence frequency
2. the separation of phenomena affecting water level in the Baltic Sea (water volume in the Baltic Sea, seiche, wind, air pressure, tide) and the definition of the water level corresponding to their simultaneously occurring maximum values in accordance with requirement 515
3. the water level corresponding to a recurrence time of one hundred years, i.e. approximately the highest water level measured near the facility site added with two meters, as stipulated by requirement 504.

This water level shall be added with a site-specifically evaluated wave margin.

The purpose of the procedure is to ensure that statistical analyses and physical phenomena are taken into account and the effect of individual observations does not become significant, at least in the non-conservative direction. According to the current view, the design basis of the Olkiluoto plant units, for example, fulfils the above criteria.

The same methods can be used in mapping and selecting DEC C events as in the screening analysis of the weather risk analysis.

The requirement for ensuring combustion air supply to emergency power engines presented in requirement 513 is also applied to the combustion air supply to any other engines important to safety and other air intakes important to safety.

Chapters 5.5 “Ice and frazil ice” and 5.6 “Other external events endangering seawater and raw water supply” present requirements for preventing and preparing for the blockage of the sea water system. Guide YVL B.1 presents the general requirement for preparing for the complete loss of the final heat sink regardless of the reason. Ice, particularly frazil ice, algae, other plant life, organisms and their remains and oil and other fouling chemicals have been mentioned as events that cause blocking. The phenomena in question have been selected for the example list because they can cause sudden disturbances to the availability of seawater. There are experiences of blocking or the danger of blocking caused by frazil ice, algae and mussels at the Finnish nuclear power plants. The plant life or organisms may be carried with sea water or grow in the systems of the plant. For example, mussels get through the filters at the larval stage.

Other possible reasons for blocking include sand, sludge and mud carried with sea water. These may enter sea water during hydraulic engineering work at the facility site or in its vicinity, during exceptional rain or flooding or due to ships’ backwash.

The availability and quality of cooling water shall be taken into account in the selection of the facility site. The sea bottom quality in the sea water intake area is to be considered in the selection of the facility site and the design of sea water intake as a factor affecting water purity. According to Section 8 of Regulation STUK Y/1/2018, the site of a nuclear facility shall be such that heat removal to the environment can be reliably implemented.

According to requirements 519 and 521, the design of sea water intake and outlet structures as well as sea water systems shall apply design solutions where the possibility of a blockage by frazil ice or other reasons is minor. In practice, the requirement can be implemented through different bar screen and band screen solutions, the heating of incoming sea water and the screens or alternative water intake for safety systems, but the required technical solutions have not been specified in the Guide.

According to requirement 524, the purity of sea water shall be monitored. The Guide does not specify how the monitoring is to be implemented. For example, observations during facility walkdowns can be considered sufficient for the time being, but the usability of any technical solutions should be monitored and assessed.

Chapter 5.7 discusses protection against external fires and explosions. Design bases concerning these are also discussed in Guides YVL B.8 and YVL A.11. For external fires and explosions, it is necessary to examine whether fire safety requirements and security measure requirements sufficiently cover their effects.

Requirement 533 states the principle that studies and analyses of external events shall be traceable and the initial data, result documentation and reference material shall be archived. The methods and procedures and the organisations and persons participating in the studies and analyses and their tasks shall also be described in the material. This is not possible in all cases, for example, for the source information of reference reports, but the principle shall be followed to the extent that is practically possible. Traceability is necessary, among other things, for the assessment of analyses concerning the preparation for external hazards carried out in connection with periodic safety reviews.

With regard to external hazards, a two-step division corresponding to the WENRA recommendations has been adopted (general design basis and rare events). During the preparation of the first version of the Guide, a more risk-based approach was also considered. This approach would have addressed combining external hazards to different event categories, but it was rejected as too complex and incompatible with the WENRA recommendations.

2.6 Section 6 Regulatory oversight by the Radiation and Nuclear Safety Authority

The chapter concerning regulatory oversight by the Radiation and Nuclear Safety Authority describes the monitoring of the fulfilment of the requirements presented in the Guide in different phases of the life cycle of the nuclear facility. The fulfilment of the requirements is assessed in connection with the review of the reports required by the Guide and in connection with the review of other documents to be submitted to STUK in accordance with the YVL Guides.

Information and design bases relating to protection against internal and external hazards and layout design is presented in several documents to be submitted to STUK, for example, in the Preliminary and Final Safety Analysis Reports, system descriptions, conceptual design plans, structural plans and suitability assessments. In addition, the Technical Specifications include conditions regarding internal and external hazards.

In addition to document inspections, STUK participates, to the extent needed, in the overseeing of tests, manufacturing and facility walkdowns.

3 International provisions concerning the scope of the Guide

International guides and requirements essential for the Guide are presented in the references of the Guide.

Based on the international comparison conducted in connection with the Fukushima reports, it was assessed that the Guide covers the international requirements. For example, the IAEA’s requirements and guides discuss several phenomena that can be practically ruled out at the facility sites in Finland, such as landslides, soil instability, dam failures, volcanoes and, with regard to earthquakes, active fault zones and the effect of soil and sediments on the interaction between the ground and the structures.

In 2012, VTT made an estimate of the fulfilment of the IAEA Safety Requirements for STUK. According to the estimate, Guide YVL B.7 has no significant deviations from international requirements. In the content of the Guide or the corresponding IAEA requirements, there have not been any significant changes in principle after the assessment that would have an impact on the conclusions.

The IAEA's guide SSG-38 "Construction for Nuclear Installations" gives instructions for taking into account other nuclear facilities at the facility site. Chapters 3 and 5 of Guide YVL B.7 cover those instructions of guide SSG-38.

WENRA has renewed its reference requirements based on, for example, the experiences from the Fukushima accident and prepared instructions concerning external hazards. Guide YVL B.7 covers the requirements concerning internal and external hazards in the revised WENRA reference requirements within the scope of application. (WENRA Reactor Safety Reference Levels, Western European Nuclear Regulators' Association, Reactor Harmonization Working Group, January 2014.)

The requirements concerning seismic classification are presented in Guide YVL B.2 "Safety classification of systems, structures and components in nuclear facilities".

Guide YVL B.7 and the WENRA reference levels related to external hazards and the instructions specifying them have the difference in principle that Guide YVL B.7 concerns new nuclear facilities whereas the WENRA reference requirements concern facilities in operation. The WENRA instructions discuss so-called "cliff edge" situations and related analyses. The purpose of "cliff edge" analyses is to ensure that exceeding the facility's design bases does not lead to uncontrollable consequences. Examining the exceedance of the design basis comes into question especially in connection with events caused by natural phenomena, because it is often impossible to specify the highest physically possible value for natural phenomena, and the design basis has to be specified based on a statistical analysis of observation series as a value corresponding to the exceedance probability. The starting point of Guide YVL B.7 is that the design bases of a new nuclear facility shall be specified as sufficient and they are complemented with requirements concerning DEC C situations. It is appropriate to design a nuclear facility to be robust so that "cliff edge" phenomena do not occur.

Requirements concerning the assessment of internal and external events exceeding the design basis and the improvements considered necessary based on it are presented in Guide YVL A.7. Although the analyses in question are performed in connection with the PRA, the effects of the exceedance of the design bases are assessed mostly with the same methods as in deterministic safety analyses. The PRA and the related analyses of internal and external hazards shall be regularly updated throughout the life cycle of the facility.

4 Impacts of the Tepco Fukushima Dai-ichi accident

Requirement 302 of Chapter 3.1 "Layout design of the site area" requires generally that the layout design shall take into account the possibility of simultaneous accidents at several facility units. Requirement 303 requires that rare meteorological conditions, floods and other rare external conditions as well as radiation conditions during an accident shall be taken into account in traffic and access arrangements at the site area. In addition, the site area layout design shall take into account the accessibility of buildings and structures in the event of fires and accidents.

Chapter 3.2 "Protection of the nuclear facility against internal hazards" presents requirements concerning the separation between safety divisions intended to prevent the spread of hazards from one safety division to another.

According to requirement 408 of Chapter 4 “Earthquakes”, earthquakes stronger than the design basis earthquake shall be taken into account as design extension conditions (DEC C) in accordance with Guide YVL B.1. This corresponds to the “cliff edge” analysis occurring in international requirements updated since the Fukushima accident. The analysis may also be carried out using seismic fragility curves prepared for the PRA and HCLPF values.

Because of the events at Fukushima and Kashiwazaki-Kariwa and other observed cases where the design requirements for earthquake resistance have been exceeded, requirement 409 has been added to the Guide, requiring periodic assessment of the source information and methods used in determining the design basis earthquake. If necessary, the design basis earthquake shall be updated in connection with periodic safety assessments.

According to the Guide, other external conditions and events exceptional in Finnish conditions that exceed the actual design basis shall also be considered design extension conditions (requirement 506).

Experiences from the Fukushima accident have also been taken into account in the update of WENRA reference levels. The consistency between the WENRA reference levels for external hazards and the requirements of Guide YVL B.7 have been covered above in Chapter 3 “International provisions concerning the scope of the Guide”.

Experiences from the Fukushima accident have brought relatively few new viewpoints to the principles that were already followed in Finland before the accident.

5 Needs for changes taken into account in the update

The needs for changes due to changes made to international and national laws/regulations and the change proposals made in connection with the preparation of the YVL Guide implementation decisions (SYLVI) together with others recorded in STUK’s change proposal database have been considered when updating the requirements.

Most of the changes have been made to clarify requirements, decrease ambiguity and improve the outline of the Guide. The most significant changes concerning the factual content are included in the requirements concerning the selection of damping coefficients used in dynamic structural analyses carried out for seismic design. The changes made during the update do not change the required safety level.

In addition, the possibilities to reduce the so-called administrative burden have been considered. The Guide mainly consists of technical requirements concerning the determination of the design basis and design solutions. During the update, hardly any requirements were found that would have enabled the administrative burden of the licensee to be essentially reduced. The delivery method of the plan and report mentioned in requirement 542 has been changed into submission for information.

5.1 Detailed changes

The following is a chapter-specific list of changes made to the Guide, excluding changes made solely because of typing or grammar errors.

5.1.1 Chapter 1 Introduction

The quotes from and references to upper-level provisions have been updated.

Certain items related to external hazards in the WENRA reference levels published in 2014 (RL T5.3) have been added to the introduction as general good design principles (requirement 108).

5.1.2 Chapter 2 Scope of application

From requirement 204 concerning the application of the Guide to a nuclear facility being decommissioned, the phrase “in accordance with a separate decision” has been removed as unnecessary.

Requirement 208 has been supplemented with a mention of matters relating to protection against internal and external hazards discussed in Guide YVL A.11 in view of security arrangements.

The definition of a system important to safety has been specified (requirement 211).

5.1.3 Chapter 3 Layout design of the nuclear facility

In requirement 309, the expression “phenomena simultaneously endangering redundant and diverse systems” has been replaced by the expression “phenomena simultaneously endangering different grid connections”, because the different grid connections referred to in the requirement are not actually redundant.

Possible sources of electromagnetic interference have been added to requirement 311.

Requirement 317 has been divided so that leakage monitoring and drainage are addressed in different requirements.

The wording of requirement 319 has been changed so that it is clearly a reference to other YVL Guides and not a requirement. For Guides YVL D.3 and D.4, the requirements concerning the handling and storage of nuclear fuel have been mentioned in addition to the requirements concerning nuclear waste management.

Requirement 320 has been removed as vague. It required that when there were discrepancies between requirements concerning the different technical domains, their order of importance should be assessed from the perspective of nuclear and radiation safety.

Requirement 333 concerning the avoidance of doors, hatches and penetrations between safety divisions and other rooms has been supplemented with a requirement for the justification of the functional need for these doors, hatches and penetrations.

The reference to Guide YVL B.1, which does not directly discuss the matter referred to, has been removed from requirement 324. Requirement 326 has been divided into two requirements so that the section concerning underground facilities is under a separate requirement number 326a. A reference to Guide YVL E.4 regarding the consequences of pipe breaks has been added to requirement 327.

The sentence concerning the avoidance of penetrations between safety divisions below ground level has been removed from requirement 329. Although the matter is very important in parts of buildings below ground level, it is clearly included in the general requirement 322 and there is no need to repeat it.

The reference to requirement 335 has been removed from requirement 336, and the purpose of the reference has been written into the requirement.

The extensive requirement 343 concerning the 3D model has been divided into four requirements. The description of the 3D computer model has been changed to describe the objectives of the model from the point of view of authorities, and the details have been transferred to the presentation memorandum. A separate requirement 345a has been added regarding the update of the model. The 3D computer model has been added to requirement 346, and the documents referred to have been specified by referring to the requirement numbers. The separate requirement 348 for keeping the documents and the 3D model up to date has been added, because it is not clear whether the 3D model in particular can be considered to be included in the scope of the requirement on keeping the safety analysis report up to date.

Sub-headings 3.5.2 and 3.5.3 have been specified to cover the construction stage and the operation stage in addition to the licence applications.

5.1.4 Chapter 4 Earthquakes

Subchapter 4.1 has been specified, and the order of requirements has been changed to be more consistent. The aim has been to write the sections concerning the factual content and administrative procedures as separate requirements.

The section concerning the submission of the design procedure has been moved from requirement 410 to requirement 452.

The analysis and assessment of the durability of systems, structures and components in seismic classes S1 and S2A and their design against external vibrations have been further specified. Requirement 418 has been included in requirements 410a, 416a and 416b. The need for sensitivity analyses is removed when the sufficiency of the analyses is clearly assessed against the corresponding acceleration, speed and transfer amplitude requirements and when the application instructions in 416c and 416d are followed.

In requirement 422 concerning the combination of loads, the term “approved standard” has been replaced by referring to requirement specifications in which the matter is presented more comprehensively.

Instead of design strengths, requirement 423 discusses partial safety coefficient of materials, which brings deformation capacity into the assessment as well as design strengths. The reference to RakMK has been removed because standard SFS-EN 1990 and the national appendix included in it provide sufficient instructions for this. The sentence “A dynamic load includes inertial forces generated within a structure and the components supported by it.” has been removed from requirement 423 because these matters have been discussed in the references mentioned in the updated requirement 416 and requirement 410a.

It has been added to requirement 424 that the information mentioned in it shall be presented in the design procedure in accordance with requirement 410.

The section concerning the submission of the report on equipment aggregates has been moved from requirement 437 to requirement 456.

The section requiring the assessment of the shutdown after an earthquake with PRA has been removed from requirement 438 because the matter is included in the seismic PRA required in Guide YVL A.7. The reference to the IAEA guide SSG-9, which is unnecessary in this context, has also been removed from the requirement.

In order to meet the WENRA reference level RL T5.5, a new requirement 438a has been added, according to which nuclear power plants shall have instructions describing the inspections and other measures to be carried out after an earthquake, their dependency on the magnitude of the earthquake and the conditions for continued operation.

Requirement 450 has been specified so that the design basis earthquake shall be presented in the Preliminary and Final Safety Analysis Reports. Other clarifications regarding the design basis earthquake may be in subject-specific reports.

5.1.5 Chapter 5 Other hazards external to the nuclear facility

In order to meet the WENRA reference level RL T5.5, new requirements 506a and 507a have been added to Chapter 5, requiring that the nuclear facility have the necessary measurement instruments for monitoring weather phenomena, the sea level and the temperature, and instructions describing the inspections and other measures to be carried out after exceptional weather phenomena and other external events and the conditions for continued operation. Guide YVL C.4 “Assessment of radiation doses to the public in the vicinity of a nuclear facility” discusses the meteorological measurements needed for radiation protection and emergency operations. The meteorological measurement instruments required by requirement 506a may be the same or partly the same as the measurement instruments referred to in Guide YVL C.4, but in this case, it shall be ensured that the measurement instruments are suitable for observing exceptionally severe weather conditions.

Requirement 541 has been supplemented so that the need for a facility walkdown shall be assessed in connection with plant modifications and, if necessary, the facility walkdown shall be carried out.

According to the new requirement 542a, the design bases pertaining to external events shall be presented in the conceptual design plans concerning plant modifications and the pre-inspection documents in addition to the operating licence application documentation.

5.1.6 Section 6 Regulatory oversight by the Radiation and Nuclear Safety Authority

The reference to the example figure of an accepted ground response spectrum in the appendix has been removed from requirement 604, and the appendix has been removed. A figure presenting the ground response spectra approved in the OL3 and FH1 projects has been added to the explanatory memorandum.

Requirement 605 has been removed because it is not necessary to combine the review of the requirements concerning safe shutdown after an earthquake to the review of the facility walkdown report.